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Agronomic Performance of Soybean (*Glycine max* (L.) Merrill) and Sunflower (*Helianthus annuus* L.) under Crop Rotation in the Humid Tropics

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Abstract: Crop rotation is a veritable strategy to achieve one of the principles of agroecology aimed at enhancing recycling of biomass, optimizing nutrient availability and balancing nutrient flow. Consequently, a five year study was carried out between 2008 and 2012 to determine the agronomic performance of soybean, sunflower, sesame and maize in the forest – savanna transition zone of Nigeria. Three cropping systems: continuous, organic rotational and conventional systems were evaluated in a randomized complete block design (RCBD) with four replicates. The two key crops reported herein are soybean and sunflower. Data were collected on plant height, seed yield and yield attributes of sunflower and soybeans. All data collected were subjected to analysis of variance and means of significant treatment were separated using the least significant difference method. Average head diameter and weight of sunflower were significantly ($p<0.05$) affected by cropping system in 2009. The conventional cropping system only significantly ($p<0.05$) produced seed yield (1642.6 $kg.ha^{-1}$) higher than the continuous (778.0 $kg.ha^{-1}$) and organic rotational cropping (1262.0 $kg.ha^{-1}$) systems in 2009. Thereafter, as the system stabilized, the organic rotation cropping system recorded higher seed yield than the continuous and conventional cropping systems in 2010, 2011 and 2012. Soybean grown under organic rotation cropping system produced significantly ($p<0.05$) higher number of branches, seeds and pods per plant than the soybean under continuous and conventional cropping systems in 2012. On average, grain yield of soybeans under organic rotational cropping system (2,445.0 – 2,758.3 kg/ha) was superior to the continuous and conventional systems (1,343.8 – 2556.3 kg/ha) as the system stabilized from 2010 – 2012. Therefore, adoption of organic rotational cropping system with the inclusion of soybean as a component crop is recommended for sustainable organic crop production system in the humid tropics.

Key words: agroecology; crop rotation; cropping systems; oilseeds; organic

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1. Introduction

Crop rotation is undoubtedly an age long agricultural practice with recognized yield advantages, well distributed economic risks, workload, improved nitrogen management, reduced land and water pollution, long term improvement of soil quality and productivity, reduced pest, weed and disease infestation, climate change mitigation and high yield (Slavikova 2018). The scheme perfectly applies some of the basic principles of agroecology such as enhancement of recycling of biomass, optimizing nutrient availability and balancing nutrient flow, species and genetic biodiversity, enhancement of soil quality and biotic activity amongst others (Alteri and Nicholls 2005; Third World Network, 2015). Soybean (*Glycine max* (L.) Merrill) is a grain legume crop grown mainly for its seeds which contain about 30 – 40% high quality protein and 18 – 20% edible vegetable oil (Weiss 2000). Sunflower is grown principally for its seed that contains oil (36–52%) and protein (28–32%) as reported by Rosa et al. (2009). The inclusion of soybean in a crop rotation system is very crucial because it provides the soil with nitrogen through nitrogen fixation, reduces soil erosion, improves soil structure and increases soil organic matter content apart from the economic yield (seeds) it provides for the farmer (Peel 2010). Sunflower is a crop that is quite rustic and it exhibits erect growth habit, comparable resistance to lodging, limited ground cover and has easily harvestable heads (Robinson 1984). These attributes readily qualify sunflower as a good crop for intercropping with other arable crops and a component crop in rotation scheme. Sunflower and soybeans have been successfully grown in association with other crops under conventional system such as sesame and castor in India (Aladakatti et al. 2011), corn in the United States (Petterson and Varvel 1989; Crookston et al., 1991; Meese et al. 1991) and under organic, and conventional systems in Italy (Mazzoncini et al. 2006) and both crops in Nigeria (Olowe and Adebimpe 2009) and corn (Olowe et al. 2003). Unfortunately, crop rotation is seldom practiced by most resource-constrained farmers in tropical Africa because it requires special management or additional planning skills to effectively plan and execute, and it has been described in review as one of the agroecological practices that are poorly integrated into actual agriculture worldwide (Wezel et al. 2014). Therefore, there is the need to generate scientific information that can assist in developing appropriate recommendation package for some crops (soybean, sunflower, sesame and maize) of economic importance in an organic crop rotation system. A study was carried out between 2008 and 2012 to evaluate the agronomic performance of the component crops under organic crop rotation relative to continuous and conventional cropping systems.

2. Materials and Methods

Study site

The five year study was carried out between 2008 and 2012 on the organic agriculture research plots of the Organic Agriculture Project in Tertiary Institutions in Nigeria (OAPTIN) located on the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta (9º 15´ N, 3º 25´ E, altitude 140 m.a.s.l). The component crops in the experiment were soybean, sunflower, sesame and maize (Table 1). The crops were grown in the late cropping season (July – November) each year.

Growth conditions

The soil of the experimental field was oxic Paleudulf (Adetunji 1991). The mean monthly rainfall data during the late copping season of 2008 – 2009 are presented in Table 2. Year 2010 was the wettest year (791.2 mm) during the late cropping season and 2008 was the driest (328 mm). Although, the highest rainfall (288.1 mm) was recorded in 2011 during the most critical month for sunflower and soybean (October) which coincided with grain filling period.

Experimental design and treatments

The experimental design was randomized complete block design (RCBD) with four replicates. Treatments evaluated were continuous, rotational and conventional cropping systems. The plots of the conventional cropping system were located about 15 m away from the organic plots to avoid commingling. The test variety of sunflower was Funtua (a local adapted and late maturing variety) and for soybean TGx 1448-2E, an improved late maturing variety resistant to pod shattering (Asafo-Adeji and Adekunle 2001).

Crop husbandry

The row spacing adopted for sunflower and soybean under the three cropping systems were 60 x 30 cm and 60 x 5 cm, respectively. Each plot measured 6.5m by 6.0m (39 m^2). Sowing of the seeds of the four component crops was done on August 15, 2008, July 2, 2009, August 15, 2010, July 18, 2011 and July 20, 2012 based on the onset of rains in the late cropping season. No herbicides or inorganic fertilizers were applied on the continuous and rotation plots. However, pre-emergence herbicides (Galex and Gramoxone) and fertilizer combination (60 kgN/ha, 56 kg P_2O_5/ha and 100 kgK_2O/ha) on sunflower plots and the conventional soybean plots received the same pre-emergence herbicide (galex + gramoxone) as sunflower and inorganic fertilizer (30 kg N ha^{-1}, 56 kg P_2O_5 ha^{-1} and 100 kg K_2O ha^{-1}) at 4 weeks after sowing (WAS), respectively. Manual weeding was done on all plots at 4 and 8 WAS. The organic fertilizer (Aleshinloye Fertilizer (Grade B) contained 1.2%N, 76 ppm P, 13.75 cmol K, 10.28 cmol Na) was applied at the rate of 25 tonnes/ha to the continuous and rotational cropping systems plots at 4 WAS for sunflower and half the rate for soybean. This rate was equivalent to 60 kg N ha/ha of the inorganic fertilizer recommended for sunflower in the transition zone (Olowe et al. 2005). Application of organic fertilizer commenced in 2009 a year after the rotation scheme took off. Harvesting of sunflower heads was done at physiological maturity (R8) as described by Schneiter and Miller (1981) and soybeans at R8 (harvest maturity) according to Fehr and Caviness (1977).

Data collection

On yearly basis, five randomly selected plants per plot were tagged from the net plot for both crops at 4 WAS and for sunflower data on plant height measurement and yield attributes (head weight and diameter, number and weight of seeds per head and seed yield) were taken. While for soybean data were collected on some yield attributes: number of branches, pods and seeds per plant, weight of pods and seeds per plant, and grain yield.

Data analysis

All data collected were subjected to analysis of variance and means of significant treatment were separated using the least significant difference method as described by Steel and Torrie (1984).

3. Results

Effect of cropping systems on plant height, seed yield and yield attributes of sunflower

Cropping system only significantly ($P \leq 0.05$; F-test) affected plant height in 2012 with sunflower plants on rotational and conventional plots significantly taller than plants on under continuous cropping system (Table 3). However, the pooled mean indicated that the plant height of sunflower under the conventional and rotational cropping systems were at par. Average head diameter and weight of sunflower were significantly ($P \leq 0.05$; F-test) affected by cropping system in 2009 and when pooled, and the plants under continuous cropping system recorded significantly lower head diameter and weight than those under rotational and conventional cropping systems (Table 4 and 5). Weight of seeds per head was significantly ($P \leq 0.05$; F-test) affected by cropping system in 2009, 2012 and when pooled (Table 6). Similarly, the effect of cropping system was only significant ($P \leq 0.05$; F-test) for number of seeds per head in 2009 and when pooled (Table 7). However, sunflower seed yield was significantly ($P \leq 0.05$; F-test) affected by cropping system in 2009, 2011, 2012 and when pooled. Sunflower under continuous cropping system produced lower (significant at $P \leq 0.05$) seed yield than the plants under rotational and conventional cropping systems during the 2009, 2011 and 2012, except when yield values were pooled and the continuous was at par with rotational system (Table 8).

Effect of cropping systems on some yield attributes of soybean in 2012 and grain yield in 2008 – 2012

Number of seeds, pods and branches per plant were significantly ($P \leq 0.05$; F-test) affected by cropping system in 2012. The rotational cropping system resulted in significantly ($P \leq 0.05$) higher number of branches, seeds and pods per plant relative to the continuous and conventional systems (Table 9). However, weight of pods and seeds per plant were not significantly affected by cropping systems in 2012. Significant effect of cropping system on grain yield was recorded in 2009, 2011, 2012 and when pooled. Soybean plants under conventional cropping system produced significantly (($P \leq 0.05$) higher grain yield in 2009 than those under continuous and rotational cropping systems. However, grain yield of plants under rotational cropping system was higher than the yield of plants on plots of conventional cropping system in 2011 and 2012 (Table 9).

4. Discussion

Based on weather data during the five year study, rainfall distribution which is the main growth limiting factor in tropical agriculture varied markedly during the five year period of experimentation. The total rainfall during the late cropping season of 2008 – 2012 ranged between 328.0 to 791.2 mm and these values compared favorably with the rainfall amount (500 – 750 mm) reported to be adequate for sunflower and soybean (Weiss 2000). The seed filling period of sunflower and soybean coincided with late September/October when about 52.7% of the total rainfall fell during the entire period of experimentation. Cropping system had no significant effect on four head characters (head weight, weight of seeds per head, head diameter and number of seeds per head) measured. Although, sunflower plants under conventional and rotational cropping systems recorded consistently higher values for these characters than the sunflower under continuous cropping. This observation could be attributed to the nutrients applied to the conventional and rotational treatments which must have enhanced growth and development of the sunflower plants. The relatively lower values for these traits on sunflower under continuous cropping system could also be attributed to depleted nutrients in the soil following continuous cropping of sunflower for the fourth year on the same plot. Similar results were reported for soybean and corn under monoculture system (Crookston et al. 1991). The seed yield of sunflower under continuous cropping system (584.7 kg/ha) was significantly lower than the seed yield of sunflower under rotational cropping system (1384.6 kg/ha) only. The seed yield of the sunflower under rotational cropping system was higher than the Nigerian (1000 kg/ha) and African (1,123.0 kg/ha) averages, respectively and lower than the recent world average of 1,803.9 kg/ha (FAO 2018). It has been reported that the actual benefits of rotation become apparent after a long time when the system begins to stabilize (TWN 2015). As such, grain yields of component crops in the system may not be statistically different on conventional and rotational plots as recorded in our study for sunflower during the five years, except 2009 when the rotation was just two years.

On average, the grain yield of soybeans under the conventional and rotational cropping systems were at par and superior to the continuous cropping system. The superior performance of the organic rotational cropping system confirmed earlier findings that yields from organic plots are usually higher than yields from conventional plots in drought years because of better water holding capacity of soils under organic system than the conventional soils and at par in normal years (Pimentel et al. 2005; Posner et al. 2008; TWN 2015) and also superior to the continuous cropping system as reported by Pedersen and Lauer (2002). In 2012, the significantly ($p<0.05$, F-test) higher grain yield produced under rotational cropping system could be attributed to significantly ($p<0.05$, F-test) higher number of branches, seeds and pods per plant relative to the soybeans under continuous and conventional cropping systems. On average over five years, the grain yields of soybeans on conventional and organic rotational plots were not significantly different. This corroborated earlier report of TWN (2015). Thus, our findings confirmed the huge potential of crop rotation in the management of soil fertility under organic production systems in the tropics because the grain yield values (623.0 – 2758.3 kg ha^{-1}) recorded compared favorably with the African (1,379 kg ha^{-1}) and world (2,854 kg ha^{-1}) averages (FAO 2018).

5. Conclusion

The agronomic performance of sunflower and soybeans that received organic fertilizer under rotational cropping system demonstrated the potential for the crops as viable component crops in organic crop rotation system. For maintenance of sustainable organic crop rotation system, soybean should be included in the scheme as a legume in the humid tropics.

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Table 1: Crop rotation scheme involving soybean, sesame, sunflower and maize (2008 -2012)

2008	2009	2010	2011	2012
Sunflower	Sesame	Maize	Soybean	sunflower
Sesame	Soybean	Sunflower	Maize	Sesame
Maize	Sunflower	Soybean	Sesame	Maize
Soybean	Maize	Sesame	Sunflower	Soybean

Table 2: Mean monthly rainfall (mm) during the late cropping season (July – November) of 2008 - 2012

Year	July	August	September	October	November	Total
2008	299.2	106.7	136.8	84.5	0.0	328.0
2009	160.0	162.1	151.6	180.1	64.6	718.3
2010	322.9	266.6	257.6	172.3	94.7	791.2
2011	349.5	88.7	204.1	288.1	3.6	584.5
2012	155.4	36.3	181.4	184.7	49.6	607.4

Table 3: Effect of cropping systems on plant height (cm) of sunflower during the late cropping season (July – Nov.) in 2008 - 2012

Cropping systems	2008	2009	2010	2011	2012	Mean
Continuous	-	184.7	125.8	206.1	218.0	183.7
Rotational	208.0	209.0	224.3	255.8	235.0	226.4
Conventional	192.0	206.4	216.7	243.7	237.8	219.3
LSD 5%	ns	ns	ns	ns	10.19	32.32

Notes: **, * Significant at P $\leq$ 0.001 and 0.05, respectively, ns – non-significant

Table 4: Effect of cropping systems on head diameter (cm) of sunflower during the late cropping season (July – Nov.) in 2008 – 2012

Cropping systems	2008	2009	2010	2011	2012	Mean
Continuous	-	9.6	9.1	14.1	17.1	12.5
Rotational	9.8	12.1	10.5	16.2	18.0	13.3
Conventional	8.6	12.8	11.3	16.4	18.1	13.4
LSD 5%	ns	2.17	ns	ns	ns	0.69

Notes: **, * Significant at P < 0.001 and 0.05, respectively, ns – non-significant

Table 5: Effect of cropping systems on head weight (g) of sunflower during the late cropping season (July – Nov.) in 2008 – 2012

Cropping systems	2008	2009	2010	2011	2012	Mean
Continuous	-	32.4	39.9	28.5	112.5	53.3
Rotational	60.3	58.0	57.2	41.3	123.5	68.1
Conventional	43.4	68.0	79.1	41.6	122.5	70.9
LSD 5%	ns	26.50	ns	ns	ns	13.36

Notes: **, * Significant at P < 0.001 and 0.05, respectively, ns – non-significant

Table 6: Effect of cropping systems on seed weight (g) of sunflower during the late cropping season (July – Nov.) in 2008 – 2012

Cropping systems	2008	2009	2010	2011	2012	Mean
Continuous	-	20.2	21.9	19.7	41.3	25.8
Rotational	21.5	33.1	31.9	37.9	57.7	36.4
Conventional	28.3	42.2	35.1	36.2	53.4	39.1
LSD 5%	ns	9.53	ns	ns	3.02	9.93

Notes: **, * Significant at P < 0.001 and 0.05, respectively, ns – non-significant

Table 7: Effect of cropping systems on number of seeds per head of sunflower during the late cropping season (July – Nov.) in 2008 – 2012

Cropping systems	2008	2009	2010	2011	2012	Mean
Continuous	-	319.0	580.0	385.0	580.5	466.0
Rotational	540.8	680.0	853.0	547.0	607.0	645.4
Conventional	664.9	715.0	659.7	520.0	591.5	630.2
LSD 5%	ns	257.2	ns	ns	ns	57.44

Notes: **, * Significant at P < 0.001 and 0.05, respectively, ns – non-significant

Table 8: Effect of cropping systems on seed yield (kg/ha) of sunflower during the late cropping season (July – Nov.) in 2008 – 2012

Cropping systems	2008	2009	2010	2011	2012	Mean
Continuous	-	778.0	1000.0	584.7	981.1	835.9
Rotational	540.8	1262.0	1150.0	1348.5	1428.2	906.0
Conventional	664.9	1642.6	750.0	808.9	1324.0	1038.0
LSD 5%	ns	366.75	ns	579.8	75.23	145.0

Notes: **, * Significant at P < 0.001 and 0.05, respectively, ns – non-significant

Table 9: Grain yield (2008 – 2012) and some yield attributes of soybeans (2012) under three cropping systems

Cropping System	Number per plant			Weight per plant (g)		Grain yield ($kg.ha^{-1}$)					
	branches	seeds	pods	pods	seeds	2008	2009	2010	2011	2012	Mean
Continuous	2.9	156.8	78.5	21.3	11.8	1822.4	623.0	1343.8	1269.3	1893.3	1390.4
Rotational	4.9	317.3	132.8	34.0	19.5	1822.4	1029.0	2758.3	2445.0	2711.7	2153.3
Conventional	3.2	163.9	75.7	25.0	13.8	2004.0	1771.5	2556.3	1733.0	1913.2	1995.6
LSD (0.05)	0.59	74.03	22.16	ns	ns	ns	481.1	ns	415.60	556.12	511.79

ns – not significant