AGRONOMIC PERFORMANCE OF SUNFLOWER (*HELIANTHUS ANNUUS* L.) IN AN ORGANIC CROP ROTATION SYSTEM IN THE HUMID TROPICS

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ABSTRACT

The demand for organic sunflower seeds is very high in the international market. Sunflower is a rustic plant that is cultivated under different production systems across several agro-ecological zones in the world. A locally adapted and late maturing sunflower variety ('Funtua') was sown after soybean, sesame and maize between 2008 and 2012 to assess its agronomic performance under continuous, rotational and conventional cropping systems in the forest – savanna transition zone. The field trials were carried out during the late cropping season (June – Nov.) in a randomized complete block design and replicated four times. Data were collected on plant height at maturity, seed yield and yield attributes of sunflower each year. Varying results were obtained on the effects of cropping systems on the agronomic parameters measured across the years. However, cropping system significantly (*P<0.05; F-test*) affected seed yield of sunflower in 2009, 2011 and 2012. 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 rotational cropping (1262.0 kg.ha^{-1})systems in 2009. Thereafter, as the system stabilized, the rotational cropping system recorded higher seed yield than the continuous and conventional cropping systems in 2010, 2011 and 2012. The difference was significant (*P<0.05*) in 2012 with the rotational cropping system producing seed yield higher by 7.3 and 31.3% than the conventional and continuous cropping systems, respectively. Adoption of rotational cropping system is hereby recommended for sustainable organic crop production system in the humid tropics.

Key words: crop rotation, sesame, sunflower, yield, yield characters

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is an oilseed crop that has a very wide range of adaptation ability, low labour requirement for its cultivation and also very suitable for mechanization (Ozer *et al.,* 2004; Kaemeini *et al.,* 2009). Consequently, sunflower can be described as a suitable crop for crop rotation scheme in the tropics where water and not temperature is the major growth limiting factor. It also exhibits erect growth habit, comparable resistance to lodging, short duration, limited ground cover and has easily harvestable heads (Robinson, 1984; Kamal and Bano, 2009). Sunflower is grown principally for its seed that contains oil (36–52%) and protein (28–32%) as reported by Rosa *et al.* (2009). According to NSA (2016), the world's average yield and total land area statistics of sunflower increased appreciably by 11.3% and 9.3% between 2007/2008 and 2012/2013, respectively.

Crop rotation is a planned order (sequence) of specific crops from different genus, species, subspecies or varieties on the same field over a given period of time (Helm, 1993). The advantages of crop rotation include: prevention of soil depletion; improvement of soil fertility, internal resource utilization; reduction of soil erosion, reliance on synthetic chemicals, allelopathic or phytotoxic effects and environmental impact; control of diseases and pest infestation; enhancement of workload distribution and distribution of economic risks (Helm, 1993). According to Kamal and Bano (2009), over 200 natural allelopathic compounds have been discovered and isolated from different cultivars of sunflower. However, the responses of crops that follow sunflower in a sequence of as companion crops vary (Farooq *et al*., 2011; Nikneshan *et al*., 2011). It was recently reported that the α-pinene in essential oil of sunflower head is very critical to the inhibitory effect of head extract (Kaya *et al.,* 2013). Consequently, it was suggested that removing the head of sunflower could be beneficial for alleviating the allelopathic effect. Unfortunately, this crop is rarely cultivated in rotation with other crops in the tropics. Therefore, in a bid to develop a production package for some staple and commercial food crops with high export potentials a crop rotation scheme was initiated consisting of four component crops with export potentials (soybean, sunflower, sesame and maize) in 2008. The objective of the study was to evaluate the performance of the component crops in rotation relative to continuous and conventional cropping systems.

MATERIALS AND METHODS

The mean monthly rainfall data during the late copping season of 2008 – 2009 are presented in Table 1. 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 (October) which coincided with grain filling. The crop rotation scheme involved four component crops (soybean, sesame, sunflower and maize as shown in Table 2) and the study was carried out at the Organic plot of the Teaching and Research Farm of the University of Agriculture, Abeokuta (7° 15’ N, 3° 25’ E, altitude 140 m.a.s.l). The soil of the experimental field is oxic Paleudulf (Adetunji, 1991). The test variety of sunflower was Funtua (a local adapted and late maturing variety). 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 row spacing adopted for sunflower under the three cropping systems was 60 x 30 cm and each plot measured 6.5m by 6.0m (39m^2). Sowing of sunflower seeds 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) were applied on the conventional plots at sowing and 4 weeks after sowing (WAS), respectively. Manual weeding was done on all plots at 3 and 6 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. 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 was done at physiological maturity (R8) as described by Schneiter and Milner (1981). Five randomly selected plants per plot were tagged from the net plot for plant height measurement and yield attribute analysis. Data were collected on plant height at physiological maturity, head weight and diameter, number and weight of seeds per head and seed yield on plot basis. 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).

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 three years, except when yield values were pooled and the continuous was at par with rotational system (Table 8).

DISCUSSION

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 and 791.2 mm and these values compared favorably with the rainfall amount (500 – 750 mm) reported to be adequate for optimum performance of sunflower (Weiss, 2000). Year 2008 with the smallest amount of rainfall (328.0 mm) also recorded the lowest seed yield (540.8 kg/ha). This could be attributed to the low rainfall in October (84.5 mm) which coincided with the grain filling period. The rotational and conventional cropping systems recorded grain yields above 1,000 kg/ha between 2009 and 2012, except conventional cropping system in 2010 and 2011. These yield values must have been enhanced by the rainfall in the months of September and October, and the availability of nutrients supplied through fertilizer application and they compared favorably with Nigerian (1000 kg/ha), African (812 kg/ha) averages (Olowe *et al.,* 2013) and world average (1520 kg/ha) according to USDA (2012), and the more recent forecast (1410 kg/ha) for 2012/2013 by NSA (2016). The consistently higher seed yield recorded under rotational cropping system in 2010, 2011 and 2012 could be due to the gradual stabilization of the system following application of organic fertilizers and rotation of soybean and sesame as preceding crops to sunflower.

The main agronomic traits that critically contribute to seed yield of sunflower include number of heads per hectare, weight of seeds per head and number of seeds per head (Robinson, 1978). However, in our study, the pooled mean revealed that cropping system significantly affected grain yield with the conventional and rotational cropping systems recording higher values for weight and number of seeds per head relative to sunflower under continuous copping system. Furthermore, the relatively lower values for plant height, number and weight of seeds per head, head weight and diameter on sunflower under continuous cropping system could also be attributed to depleted nutrients in the soil and accumulation of pest and disease organisms following continuous cropping of sunflower for the fourth year on the same plot. However, no serious disease or pest problem was recorded during our study.

CONCLUSION

Based on the pooled results of this study, the agronomic performance of sunflower that received organic fertilizer under rotational cropping system confirmed the huge potential for sunflower being a crop with high adaptability and low labour requirement as a viable component in organic crop rotation system in the tropics.

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Table 1: 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 2: 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 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 $P \leq 0.001$ 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	**2008**	**2009**	**2010**	**2011**	**2012**	**Mean**

systems						
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 $\leq$ 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 $\leq$ 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 $\leq$ 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 $\leq$ 0.001 and 0.05, respectively, ns – non-significant