sciendo DOI: 10.2478/ats-2021-0010 AGRICULTURA TROPICA ET SUBTROPICA, 54 OV, 97–103, 2021

Original Research Article

Agronomic response of soybeans (*Glycine max* (L.) Merrill) to organic soil and foliar fertilisation in a forest savanna transitory location

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Abstract

Organic soybean is presently less than 0.1% of total world production partly because of inappropriate fertiliser regime on degraded tropical soils. Therefore, two field trials were carried out during the late cropping seasons (June–November) of 2017 and 2018 to evaluate the agronomic performance of three soybean varieties: TGx 1448-2E, TGx 1835-10E and TGx 1989-19F as affected by foliar organic fertilisers: Arati Baja, Arati Nawoz, DI Grow, and soil applied organic fertiliser (Aleshinloye Grade B), and the control. The experimental design was Randomised Complete Block Design in a 3 × 5 factorial arrangement with three replications. Data were collected on yield attributes and seed yield of soybeans. Significant varietal difference ($P < 0.05$) in both years was recorded for number and weight of pods and seeds per plant, 100 seed weight, harvest index, and grain yield, except number of seeds per plant in 2018. Fertiliser × Variety interaction effect significantly ($P < 0.05$) affected above-ground plant weight and pod weight per plant in both years. On average, application of organic fertilisers resulted in grain yield (1.30–2.28 t/ha) comparable with Nigeria's (0.97 t/ha) and Africa's (1.37 t/ha) but lower than the world's (2.85 t/ha) average values. The three foliar fertilisers and soil applied organic fertiliser enhanced seed yield of soybeans and are therefore recommended for soybean cultivation in the tropics.

Keywords: foliar application; food security; organic fertiliser; soybean varieties; seed yield; tropics

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is an oilseed crop that is very strategic to global food security because it contains about 40% quality protein, 23% carbohydrate and 20% cholesterol-free oil (Raei et al., 2008; Gutte et al., 2018). At present, soybean is one of the most widely cultivated oilseed crops in the world with 352.6 million tonnes in 94 countries from 123.5 million ha and an average yield of 2,854 kg/ha (world), 1,379 kg/ha (Africa) and 973.3 kg/ha (Nigeria) based on FAOSTAT (2018). Soybean is often referred to as the cheapest source of food protein, hence its relevance to any food security programme aimed at alleviating hunger and malnutrition (Rao and Reddy, 2010). Although the volume of organically produced soybean is less than 0.1% of total world production, the demand for organic soybean has been increasing gradually in the last decade due to increase in soybean products being consumed by human beings and organic soybean meal for livestock feeds (Hartman et al., 2016). However, the lull in organic soybean production in the tropics could be attributed partly to inappropriate fertiliser regime, vagaries of the weather, bulkiness of organic fertilisers, low fertility status of tropical soils, weed infestation, sourcing organic inputs i.e availability and accessibility, poor interactions among researchers, extension workers and farmers and other stakeholders in agriculture (Sodangi et al., 2011; Rusike et al., 2013; Affholder et al., 2013; Onyenali et al., 2020).

In a bid to address the issue of bulkiness of organic fertilisers and cost of transportation, foliar application of liquid organic fertilisers is gradually gaining importance in the world. Research efforts on foliar nutrition of soybeans in the last decade have focussed on the use of synthetic fertilisers in India (Lingaraju et al., 2016; Mangaraj et al., 2017; Dandge et al., 2018) in Iran (Heidarian et al., 2011), in Serbia (Mallarino et al., 2001; Mandic et al., 2015), and in the United States (Moreira et al., 2017; Craft et al., 2019). The few works on organic liquid fertilisers were on the use of compost tea (Nath and Singh, 2011) and different solid and liquid forms of manure in which the combination of farm yard manure and liquid fertiliser enhanced growth and yield of soybeans (Nagar et al., 2016) in India and aerated compost tea in South Korea (Kim et al., 2015). There is no consensus yet on the appropriate time to apply foliar fertilisers on soybeans worldwide. Mannan (2014) had earlier recommended pod filling stage in Bangladesh in a study that compared foliar and soil fertilisation of soybean. Foliar application twice at ten-day intervals during flowering (R2) to beginning pod (R3) was recommended in Serbia (Mandic et al., 2015), at the beginning pod (R3) and 14 days thereafter in the US (Craft et al., 2019), and during the vegetative stage in India in combination with neem based bio-pesticides (Nath and Singh, 2011). Recently, Dandge et al. (2018) reported that at flowering and pod initiation stage, crops require more nutrients for development of reproductive organs along with sufficient moisture and hence the need for foliar application of such nutrients. On average most of the results from these studies have been contradictory in terms of increased productivity and fertility status of the environment under which the studies were carried out. There is a dearth of empirical scientific information on organic foliar nutrition in soybean in tropical Africa. In recent past, some liquid organic fertilisers have been emerging in the market. However, no empirical evidences are available that compared the response of the commercially available liquid fertilisers with the soil applied fertilisers under the same experimental conditions in Africa. Therefore, this study evaluated the effects of three foliar and one soil applied organic fertilisers on grain yield and yield attributes of soybeans in the tropics.

MATERIALS AND METHODS

Description of growth conditions

The experiment was conducted on the Organic Research plot of the Institute of Food Security, Environmental Resources and Agricultural Research, of the Federal University of Agriculture, Abeokuta, Nigeria (7° 13’ 51.17” N and 7° 13’ 53.16” N and longitudes 3° 23’ 49.12” E and 3° 23’ 51.86” E 131.5 m above sea level) during the late cropping seasons (June–November) of 2017 and 2018. Soil samples were randomly taken and analysed to determine the physico-chemical properties of the soil of the experimental sites. On average, the textural class of the soil was loamy sand and contained 0.15 and 0.16 g/kg N, 3.33 and 5.40 mg/kg P and, 0.09 and 0.06 cmol/kg K with a pH of 6.70 and 6.2 in 2017 and 2018, respectively. The weather parameters taken during the late cropping seasons of 2017 and 2018 are presented in Table 1. Total rainfall recorded in 2017 and 2018 was 330.5 and 902.5 mm, respectively. Temperature was not limiting in both years even though 2017 (25.3–30.0 °C) was slightly hotter than 2018 (25.3–28.3 °C).

Table 1. Rainfall distribution (mm), mean monthly temperature (T, oC) and relative humidity (RH, %) during the late cropping seasons of 2017 and 2018

Month	2017 Total rainfall (mm)	No. of rainy days	Mean Temperature (°C)	Relative Humidity (%)	2018 Total rainfall (mm)	No. of rainy days	Mean Temperature (°C)	Relative Humidity (%)
June	111.0	15	27.6	83.5	40.2	10	26.6	76.3
July	156.1	11	30.0	83.5	222.9	17	25.3	80.3
August	90.5	11	25.3	83.7	161.8	8	25.8	77.2
September	50.0	7	26.1	79.2	270.0	15	26.5	74.8
October	92.2	4	27.6	82.4	17.4	12	27.3	73.3
November	45.6	2	27.6	76.1	36.0	4	28.3	68.7
Total	330.5	50	-		902.5	66	-	-

Source of data: Agrometeorology Station, Department of Water Resources Management and Agrometeorology, FUNAAB

Treatment details

The experimental design used was Randomised Complete Block Design (RCBD) in a 3 × 5 factorial arrangement with three (3) replicates. The factors were varieties – TGx 1448-2E (late maturing), TGx 1835-10E (early maturing) and TGx 1989-19F (early maturing) as described by Asafo-Adeji and Adekunle, (2001) and NASC (2013); organic fertilisers – Aleshinloye grade B (soil-applied organic fertiliser), an abattoir waste based compost (1.30% N), DI Grow is a foliar fertiliser made with the acadian seaweed (*Ascophyllum nodosum*) and comes in two containers namely green (2.35% N sprayed during vegetative stage) and red (1.85% N sprayed during reproductive stage), Arati Baja (1.01% N) and Arati Nawoz (2.01% N) and Control (no fertiliser). Arati Baja and Arati Nawoz were applied at the rate of 50 litres per hectare. DI Grow was applied at the rate of 1 litre per hectare. All the foliar organic fertilisers were applied to the plants using Diaphragm Pump Knapsack Sprayer (CP3). Aleshinloye was applied at the rate equivalent to 25 kg N/ha. Arati Baja, Arati Nawoz and DI Grow were applied on the leaves at 3, 6 and 9 weeks after sowing (WAS) whereas Aleshinloye was applied manually to the soil by row placement method at 3 WAS in both years.

Crop husbandry

The experimental field was ploughed twice and disc harrowed once at two weeks later before sowing in both years. Each gross experimental plot consisted of six rows measuring 4 m × 3 m (12 m^2), marked out with a walk-way of 0.6 m between plots and 1 m between replicates. Soybean seeds were sown on August 11, 2017 and June 28, 2018 by drilling method at a spacing of 60 cm × 5 cm. The seedlings were thinned at 3 WAS to one plant per stand. Weeding was carried out manually with hoe at 3, 6 and 9 WAS. The organic foliar fertilisers were applied at 3, 6 and 9 WAS which coincided with vegetative (V3–V4), flowering (R1–R2) and podding (R4-R5) stages, respectively, as described by Fehr and Caviness (1977). Harvesting was carried out when 95 % of the pods had attained physiological maturity as described by Fehr and Caviness (1977).

Data collection

Five plants were tagged randomly with rope within the net plot at 3 WAS for the collection of data on soybeans agronomic traits. Data were collected on plot basis using the growth stages descriptor by Fehr and Caviness (1977). At harvest, yield components such as the number of branches per plant (NBP), number of pods per plant (NPP), number of seeds per plant (NSP), pod weight (g) per plant (PWT) and seed weight (g) per plant (SWT), above ground plant weight, AGPW (g) and 100 seed weight, 100 SWT (g). Seed yield was determined on plot basis after threshing all the pods and later converted to weight per unit land area in kg/ha. Every weight measurement was done using METTLER PJ260 Delta Range Model manufactured by Metler Instrument Ltd., High Wycombe, Switzerland.

Statistical analysis

All data collected were subjected to analysis of variance (ANOVA) to determine the significance of the main effects and interactions between the two factors in both years. The means of significant treatments were separated using the least significant difference method (LSD) at 5% probability level using Genstat 12th edition.

RESULTS

Effects of organic fertiliser application on some seed yield and yield attributes of three soybean varieties in 2017 and 2018.

Organic fertiliser had significant ($P < 0.05$) effect on the measured parameters in both years, except NPP in 2018 (Table 2). Soil applied organic fertiliser resulted in ($P < 0.05$) higher number of pods and seeds per plant relative to the control in 2017. Varietal effect was significant ($P < 0.05$) on NBP, NPP, NSP and PLTN in both years, except NBR and NSP in 2018. Fertiliser × variety effect was not significant on yield attributes in both years (Table 2). Application of organic fertilisers increased ($P < 0.05$) 100 seed weight, above ground plant weight, pod and seed weight in both years, except 100 SWT in 2017 (Table 3). The soil applied organic fertiliser resulted in significantly ($P < 0.05$) higher above-ground plant weight, pod and seed weight in 2017 and higher pod weight in 2018 compared to the foliar organic fertiliser treatments and control. Varietal effect significantly ($P < 0.05$) affected all the yield attributes in Table 3 in both years. Varieties TGx 1835-10E and TGx 1989-19F recorded higher ($P < 0.05$) 100 SWT, AGPW, PWT and SWT in 2017 and SWT in 2018 as compared to TGx 1448-2E. Fertiliser × Variety effect was significant ($P < 0.05$) on all the yield attributes except 100 SWT in both years and SWT in 2018 (Table 3). Soil application of Aleshinloye to TGx 1835-10E resulted in the highest AGPW in 2017. However, in 2018 TGx 1989-19F grown on Aleshinloye treated plots accumulated significantly ($P < 0.05$) higher AGPW than all other treatments, except TGx 1448-2E that was sprayed with DI Grow (Figure 1). Application of all the organic fertilisers to the three varieties resulted in significantly ($P < 0.05$) higher pod weight per plant with varieties TGx 1835-10E and TGx 1989-19F recording

Table 2. Effects of organic fertiliser application on number of branches, pods and seeds per plant, and pod length (cm) of three soybean varieties in 2017 and 2018

Treatment	Yield attributes 2017 NBP	NPP	PLTN (cm)	NSP	2018 NBP	NPP	PLTN (cm)	NSP
Fertiliser (F)								
Arati Baja	4.94	56.84	3.89	100.62	4.38	74.67	4.01	138.40
AratiNawoz	4.51	47.88	4.04	76.60	4.33	74.33	3.89	128.67
D I Grow	5.56	57.07	4.21	99.16	5.00	75.44	3.87	127.56
Aleshinloye	4.96	66.13	3.86	113.71	4.78	92.38	3.74	138.91
Control	3.57	33.53	3.34	48.32	3.37	55.27	3.34	81.78
LSD 5%	0.91	16.71	0.37	40.89	0.85	ns	0.27	40.86
Variety (V)								
TGx 1448-2E	4.25	45.69	3.67	51.75	4.44	81.64	3.48	123.25
TGX 1835-10E	5.28	46.93	4.11	87.97	4.53	58.13	3.97	118.51
TGx 1989-19F	4.59	64.25	3.88	123.33	4.15	83.48	3.86	127.43
LSD 5%	0.71	12.94	0.28	31.67	ns	19.57	0.21	ns
Fertiliser ×Variety	ns	ns	ns	ns	ns	ns	ns	ns

ns – not significant, NBP – Number of Branches per Plant, NPP – Number of Pods per Plant, PLTN – Pod Length, NSP – Number of Seeds per Plant

Table 3. Effects of organic fertiliser application on 100 seed weight (g), above-ground plant weight (g), pod weight (g), seed weight (g) and seed yield (t/ha) of three soybean varieties in 2017 and 2018

Treatment	2017 100SWT (g)	AGPW (g)	PWT (g)	SWT (g)	SYD (t/ha)	2018 100SWT (g)	AGPW (g)	PWT (g)	SWT (g)	SYD (t/ha)
Fertiliser (F)										
Arati Baja	9.21	22.16	13.58	9.47	1.79	12.52	26.44	20.56	12.76	1.91
AratiNawoz	9.66	18.70	12.50	8.90	1.30	12.90	26.28	19.61	12.56	2.03
D I Grow	9.57	20.88	14.07	8.74	2.11	12.92	32.71	19.70	13.30	1.99
Aleshinloye	9.47	26.77	18.87	11.83	1.72	13.59	31.31	22.29	15.19	2.28
Control	7.79	12.26	6.54	3.58	0.71	9.83	24.61	16.39	10.36	1.55
LSD 5%	0.93	2.65	1.67	1.61	0.88	1.32	2.48	1.73	1.94	0.17
Variety (V)										
TGx 1448-2E	8.17	11.70	5.79	3.92	0.79	11.25	29.31	18.03	11.01	1.74
TGX 1835-10E	9.40	24.00	16.61	10.93	1.72	11.92	24.47	19.80	13.93	2.09
TGx 1989-19F	9.85	24.76	16.94	10.65	2.07	13.89	31.04	21.30	13.55	2.03
LSD 5%	0.72	2.05	1.29	1.25	0.62	1.02	1.92	1.34	1.50	0.13
Fertiliser × Variety	ns	*	*	*	ns	ns	*	*	ns	*

ns – not significant, 100SWT – 100 Seed Weight, AGPW- Above Ground Plant Weight, PWT- Pod Weight, SWT – Seed Weight, SYD – Seed yield

the highest values relative to the control in both years (Fig. 2). Organic fertilisers significantly ($P < 0.05$) enhanced seed yield (SYD) in both years relative to the control, except seed yield when Arati Nawoz was applied in 2017 (Table 3). The two early maturing varieties significantly ($P < 0.05$) out yielded the late maturing variety (TGx 1448-2E) in both years.

DISCUSSION

According to Doss and Thurlow (1974) and Olowe and Alofe (1991), the final plant height of soybeans is a function of the genetic composition of the variety. Application of solid and liquid forms of organic manures have been reported to impact positively on growth parameters like number of branches per plant, number and pods and seeds per plant (Nagar et al. 2016; Gutte et al., 2018; Mangaraj et al., 2017; Onyenali et al., 2020). The major seed yield attributes of soybeans that contribute significantly to seed yield are number of seeds and pods per plant, and weight of seeds per plant (Pandey and Torrie 1973; Olowe and Adebimpe, 2009; Onyenali et al., 2020). These traits were significantly ($P < 0.05$) enhanced by the application of soil and

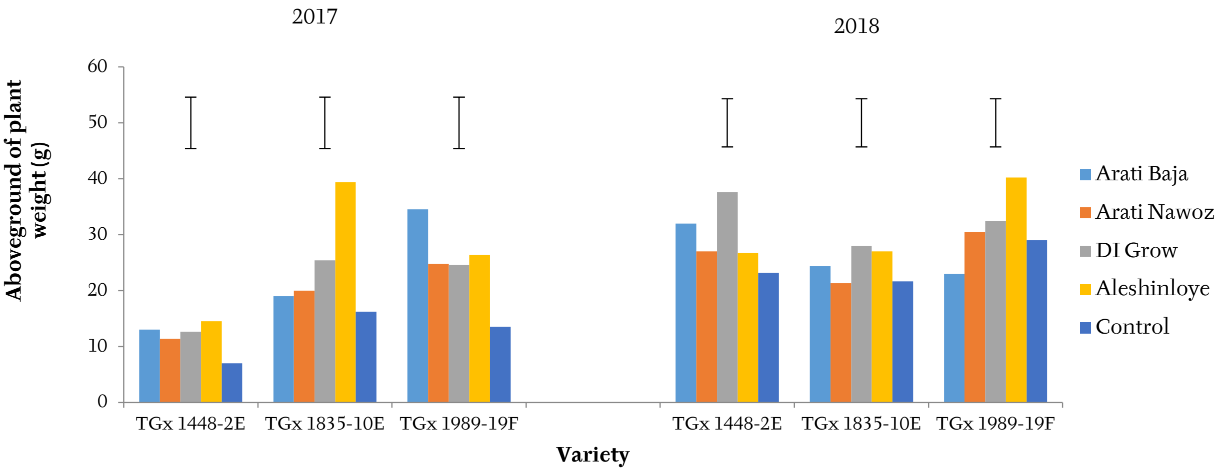

Figure 1. Interaction effect of V×F on above ground plant weight of soybean varieties in 2017 and 2018

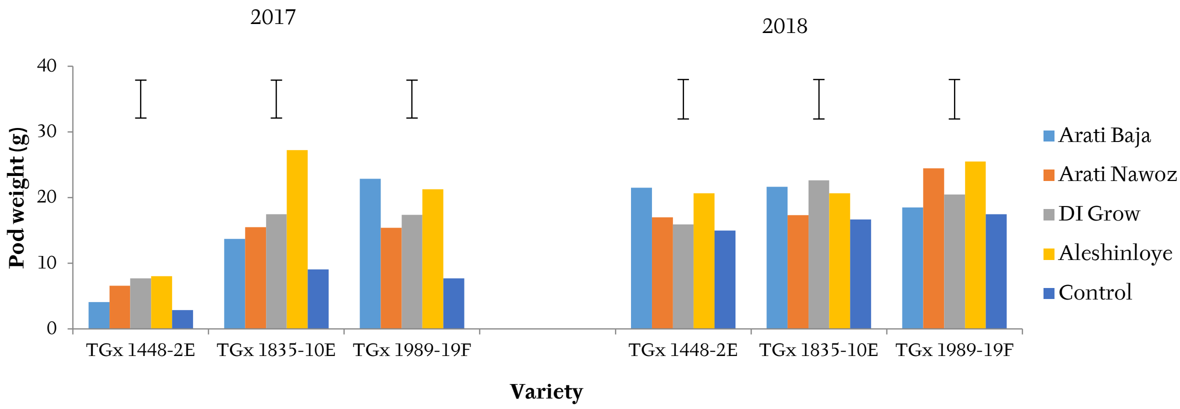

Figure 2. Interaction effect of V×F on pod weight of soybean varieties in 2017 and 2018

foliar organic fertilisers relative to the control in our study, except number of pods per plant in 2018. This trend could be attributed to supply and availability of nutrients required for partitioning of assimilates to the plant parts of soybeans. Similar results have been reported by Devi et al. (2013) in India and in northern Ghana (Ezekiel-Adewoyin et al., 2017). On average, the two early maturing varieties, especially TGx 1989-19F recorded higher number of seeds and pods per plant, pod and seed weight in both years. Although foliar and soil applied organic fertilisers resulted in comparable number of pods and seeds per plant in our study, it has been reported in literature that foliar spraying of fertilisers at flowering and podding stages increased these traits due to better absorption of macro and micronutrients applied and their effect on the stamens and pollens (Heidarian et al., 2011; Seifi Nadergholi et al., 2011; Mannan, 2014). Organic fertiliser application enhanced above-ground plant weight in both years. However, it has been reported that oftentimes, accumulation of dry matter in soybeans does not translate to high grain yield (Olowe and Adebimpe, 2009). This was evident in TGx 1989-19F that accumulated the highest amount of above-ground plant weight (24.76 g) and produced the highest seed yield (2.07 ton/ha) in 2017 as against TGx 1835-10E (2.09 ton/ha) with the smallest above-ground plant weight (24.47 g).

On average seed yield was significantly ($P < 0.05$) increased by organic fertiliser application relative to control in both years. It has been reported that temperature and moisture must not be limiting at reproductive stage (R3-R6) of soybean because it can upset photosynthesis and remobilization of photosynthates, and consequently reduce grain yield (McWilliams et al. 1999). Mean seed yield recorded across organic fertiliser treatments (1.30–2.11 ton/ha in 2017 and 1.55–2.28 ton/ha in 2018) compared favourably with Nigerian (0.97 ton/ha) and African (1.37 ton/ha) but slightly lower than the world's 2.85 ton/ha (FAOSTAT 2018). The comparatively medium to high seed yields recorded in 2017 relative to the control when moisture was slightly limiting from fertilised treatments confirmed earlier reports that organic plots usually produce greater yield than conventional plots during dry years because of the inherent advantage of better water holding capacity of under organic production system relative to the conventional system (Posner et al. 2008; Olowe and Adejuyigbe 2020). The highest seed yield (2.10 ton/ha) recorded on soybeans sprayed with DI Grow fertiliser during the relatively hot 2017 could be attributed to ability of foliar fertilisation to reduce negative impact of limited moisture on seed yield in summer months as suggested by Mandic et al. (2015). Our results corroborated very recent findings of yield performance in the range of 2.45–2.78 ton/ha of soybean under a five year organic crop rotation system (Olowe and Adejuyigbe, 2020). On average, soybean seed yield from organic plots (1.3–2.28 ton/ha) was superior to the current Nigerian average (0.97 ton/ha), African (1.37 ton/ha) but slightly lower than the world's 2.85 ton/ha.

CONCLUSION

From this study, it may be concluded that organic production of soybeans in the humid tropics using foliar or soil applied organic fertilisers is a worthwhile enterprise irrespective of the prevailing weather conditions. Soil applied organic fertiliser impacted more than the foliar fertilisers on the agronomic traits of the three test soybean varieties, especially during wetter growth conditions in 2018. It is therefore, recommended that the three foliar organic fertilisers: Arati Baja, Arati Nawoz and DI Grow applied at 3, 6 and 9 WAS, and soil applied Aleshinloye Grade B fertiliser at 3 WAS can be applied for sustainable soybean production of preferably early maturing soybean varieties in the tropics.

CONFLICT OF INTEREST

The authors declared no conflicts of interest with respect to research, authorship and publication of this article.

ETHICAL COMPLIANCE

The authors have followed the ethical standards in conducting the research and preparing the manuscript.

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Received: August 20, 2020
Accepted after revisions: May 17, 2021