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Foliar fertilization of organic sunflower, enhanced yield components and seed yield in the humid tropics

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Abstract: In a two year experiment carried out on the organic research plots of the Institute of Food Security, Environmental Resources and Agricultural Research, Nigeria. Two liquid organic fertilizers (ARATI NAWOZ {2.01% N} and ARATI BAJA {1.01% N}) and control were applied to four sunflower varieties (SAMSUN 1, SAMSUN 2, SAMSUN 3 and SAMSUN 4) during the late cropping season (July – Nov.) of 2016 and 2017 to evaluate their agronomic response. The experiment was laid out in a randomized complete block design using a 4 × 3 factorial arrangement in three replicates. Data were collected on plant height at maturity, head diameter and weight, weight and number of seeds per head, 100 seed weight and seed yield. The varietal effect was significant ($P < 0.05$) on head diameter and weight, and number and weight of seeds per head, and seed yield in 2016. However, during the markedly dry 2017, the varietal effect was not significant for any trait measured. Foliar application of ARATI NAWOZ significantly ($P < 0.05$) increased height at maturity, the weight of seeds and head per plant and seed yield relative to the control in both years. Significant Variety × Fertilizer interaction effect was also recorded on the height at maturity, head diameter and weight, and seed yield in 2016. SAMSUN 4 (975.6 kg/ha) produced significantly ($P < 0.05$) higher seed yield than SAMSUN 1 (789.82 kg/ha) and SAMSUN 2 (778.54 kg/ha) in 2016. The efficacy of the application of both fertilizers was on par for most traits in both years. On

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average, the application of organic fertilizers resulted in a 15.76 and 69.02% increase in seed yield relative to the control in 2016 and 2017, respectively. ARATI NAWOZ and ARATI BAJA appeared promising for sunflower production in the humid tropics.

Keywords: foliar application; humid tropics; organic liquid fertilizer; organic sunflower; seed yield.

Introduction

Sunflower (*Helianthus annuus* L.) is at present the third (53.48 million metric tonnes) most widely cultivated oilseed crop in the world after soybeans (337.48 million metric tonnes) and rapeseed (68.02 million metric tonnes) as reported by Shabandeh (2020). According to Rosa et al. (2009), the crop is grown mainly for its seed that contains oil (36–52%) and protein (28–32%). Furthermore, sunflower oil is premium oil with light colour and is widely used in the diets of heart patients because it contains high (90%) unsaturated fatty acid concentration (Flagella et al. 2002; Qahar et al. 2010). Between 2009 and 2018, the land area, yield and production statistics of sunflower increased by 8.72, 30.76 and 36.80% (world) and 15.00, 11.70 and 24.9% (Africa), respectively (FAOSTAT 2019). Despite the average yield of sunflower in the world (1948.20 kg/ha) and Africa (1137.30 kg/ha) as of 2017, the potential productivity of sunflower can still be improved using appropriate agronomic practices. The global low productivity of sunflower could be attributed to insufficient supply of nutrients, non-adoption of appropriate crop rotation scheme, poor weed management practices, cultivation under rainfed conditions with sub-optimal crop stand, imbalanced nutrition, declining soil fertility attributable to mono-cropping of cereals, crop residue removal and limited fertilizer availability and continuous use of inorganic fertilizers that result in deterioration of soil health and productivity (Gebremedhin et al. 2015a; Krishnaprabu 2015). Unfortunately, the total land area under organic sunflower in the world is about 0.06% of the total land dedicated to sunflower production (Willer and Lernoud 2019). This is against the backdrop that organic crops and crop-based foods contain up to 60% higher key antioxidants than conventionally grown crops (Branski et al. 2014). Organic agriculture is still emerging in tropical Africa, particularly in sub-Saharan Africa (Olowe 2018). However, the potential of growing sunflower has been confirmed in the humid tropics either as sole (Olowe 2005; Olowe et al. 2013; Osundiya et al. 2014) or intercrop with soybean (Olowe and Adebimpe 2009), sesame (Olowe and Adeyemo 2009), groundnut and cowpea (Olowe et al. 2006), cassava and sesame (Adekunle et al. 2014), and in crop rotation

(Olowe and Adejuyigbe 2020). Nevertheless, about 256 million people with 239 million of them resident in sub-Saharan Africa (SSA) are hungry in Africa (FAO 2019). According to Khojely et al. (2018), the SSA occupies about 600 million hectares of arable land out of which <10.0% are under cultivation, thus making the region the largest underutilized land reserve in the world. Consequently, the marginal available arable land and low fertility status of the soils have made the SSA a food-insecure region (Olowe 2018; Smalling et al. 1997; Zerihun and Haile 2017). There is therefore the need to identify resilient staples that are nutritious and adaptable to a wide range of agroecological zones in the tropics where they can be easily cultivated and thereby improve the livelihoods of the populace. Sunflower, being a rustic, photo and thermo-insensitive, short duration, the deep-rooted, drought-resistant, wide adaptable crop is a good candidate that can be used to ameliorate the challenges of resource-constrained farmers in the tropics (Bochalya et al. 2018). Unfortunately, sunflower production of the countries in sub-Saharan Africa is not significant even though the weather is conducive for sunflower production, except the United Republic of Tanzania which occupies number eight (8) among the top 10 producing countries in the world (Shahbandeh 2020).

Different attempts have been made by scientists to improve the fertility status of soils under sunflower such as the application of a combination of organic and inorganic fertilizers in Iran (Gorttappeh et al. 2000) in Pakistan (Munir et al. 2007), in Iraq (Yaseen et al. 2016), in India (Elankavi 2017; Elayaraja et al. 2019; Krishnaprabu 2015; Ramesh 2017) and Egypt (Morsy et al. 2018). Some scientists combined nitrogen fertilizers and foliar fertilization in Pakistan (El-Kady et al. 2010; Haseeb and Maqbool 2015), macro and micronutrients in Pakistan (Kaleri et al. 2019; Shehzad et al. 2016), in Ethiopia (Gebremedhin et al. 2015b) and more recently foliar fertilization and growth regulators in India (Bochalya et al. 2018), micronutrients and biostimulants in China (Tian et al. 2015), sole plant regulators in Slovakia (Ernst et al. 2016), boron in Iraq (Al-Amery et al. 2011) and urea (Oad et al. 2018) nitrogen and boron (Shehzad et al. 2016) in Pakistan. In recent time, scientists have devoted concerted efforts to foliar fertilization of sunflower because foliar fertilization has many advantages such as improved nutrient efficiency uptake by plants, lower environmental pollution, promotion of root absorption through improved root growth and increased nutrient uptake, reduced leaching of nutrients and minimization of groundwater pollution (Bochalya et al. 2018; Kuepper 2003) and better utilization of some nutrients like zinc since some soil properties like high pH, lime of heavy texture do not favour root absorption (Dange et al. 2018). Such recent efforts on foliar fertilization include the use of humic substances (Thakur et al. 2013) and aqueous seaweed sprays (Suganthi and Sujatha 2014) in India and seaweed extracts (Osman and Salem 2011), bio-fertilizer, seaweed and elemental sulphur (Hababshy and Bishara 2013) and compost rates and ascorbic acid (Osman et al. 2014) in Egypt. On average most of these studies reported significant enhancement of sunflower productivity following the use of single or combined nutrient sources. However, there are limited studies on the efficacy of locally produced and sole applied organic foliar fertilizers on sunflower in the humid tropics. Organic agriculture is all about minimizing the use of external inputs by substituting them with efficient nutrient management (Neves et al. 2008). Therefore, this study was conducted to evaluate the agronomic performance of four sunflower varieties as influenced by the application of two commercial organic foliar fertilizers.

Materials and methods

Growth conditions

The two-year field experiments were carried out on the organic research plots of the Institute of Food Security, Environmental Resources and Agricultural Research, Nigeria (located between latitudes 7° 13′ 51.17″ N and 7° 13′ 53.16″ N and longitudes 3° 23′ 49.12″ E and 3° 23′ 51.86″ E on altitude 131.5 m above sea level) during the late cropping seasons of 2016 and 2017 on a loamy sand soil. The rainfall distribution in this area is bimodal having two peaks in July and September with a dry spell in August (August break). However, the two peaks were recorded in September and October in 2016 and July and October in 2017. The irregular distribution could be attributed to the climate change effect over the years. During the period of experimentation, total rainfall of 480.0 and 357.1 mm was recorded in 2016 and 2017, respectively. Table 1 shows rainfall distribution, mean monthly temperature and relative humidity during the period of experimentation in both years. The year 2016 was 25.6% wetter than 2017 during the experiment. Furthermore, the number of rainy days was 23 in 2016 as against 11 in 2017 during the two critical months (September and

Table 1: Rainfall distribution (mm), mean monthly temperature (T, °C) and relative humidity (RH, %) during the late cropping seasons of 2016 and 2017.

Growth week	July		August		September		October		November	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
I	3.7	50.5	0.0	36.2	75.5	8.0	73.2	5.4	5.9	7.1
II	11.3	6.4	10.2	6.5	36.3	21.8	25.7	86.8	0.0	0.0
III	24.1	20.4	28.2	5.1	52.5	0.0	48.0	0.0	0.0	38.5
IV	26.1	78.8	25.2	42.7	64.7	20.0	8.5	0.0	0.0	0.0
Total rainfall	65.2	156.1	63.6	90.5	229.0	50.0	155.4	92.2	5.9	45.6
Rainy days	7	11	8	11	14	7	9	4	1	2
Mean T °C	26.3	30.0	25.7	25.3	26.9	26.1	27.6	27.6	28.1	27.6
RH, %	72.7	73.8	72.8	77.4	68.9	69.1	65.3	72.8	65.3	64.2

Total rainfall (IV week of July – Nov.): 480.0 mm (2016) and 357.1 mm (2017).

October) of growth and development of sunflower. Mean monthly temperature ranged between 25.3 and 30.0 °C during the period of experimentation and it was adequate for the growth and development of sunflower since it is slightly above the recommended mean daily range of 20–25 °C for sunflower (Weiss 2000). Relative humidity ranged between 65.3 and 73.8% during the wettest months in both years. Based on the ratings of Anonymous (1989), the soils of the experimental sites were moderate in total nitrogen (1.60–1.77 g/kg) and total organic matter (2.84–2.87%), and low to medium in available phosphorus (3.33–17.98 mg/kg), and very low in exchangeable potassium (0.09–0.61 cmol/kg) in both years (Table 2).

Experimental design and measurements

The experimental design was a 4 × 3 factorial arrangement laid out in randomized complete block design and replicated three times. The factors were variety (four recently released oil type varieties): SAMSUN-1 (early maturing, drought-tolerant, very high in antioxidants and high in Vit. E), SAMSUN-2 (medium maturing, drought-tolerant and high in Vit. E), SAMSUN-3 (late maturing, large-seeded, drought-tolerant and high in antioxidants) and SAMSUN-4 (early maturing, drought-tolerant, contains excellent antioxidants, rich in Vit. A and E and good for intercropping) as described by NASC (2013) and organic commercial foliar fertilizer application: ARATI NAWOZ {2.01% N, 1.05% K_2O and 1.84% P_2O_5} and ARATI BAJA {1.01% N, 2.15% K_2O and 1.64% P_2O_5} at 21 days after sowing, DAS (V2-V3 vegetative stage) and 42 DAS (beginning flowering R1-R2) and control. Both liquid fertilizers also contain micronutrients, plant hormones, enzymes and organic acids (Table 3). Application rates of the foliar fertilizers (50 L per hectare) were based on labelled recommendations. The sunflower growth stages were measured based on growth descriptors by Schneiter and Miller (1981). Each experimental plot measured 4 × 1.8 m (7.2 m^2) and consisted of

Table 2: Pre-planting physical and chemical characteristics of the soil of experimental fields.

Soil properties	2016	2017
Physical properties		
Sand ($g\ kg^{-1}$)	812.0	845.00
Clay ($g\ kg^{-1}$)	74.0	110.00
Silt ($g\ kg^{-1}$)	114.0	45.00
Textural class	Loamy sand	Loamy sand
Chemical properties		
pH in H_2O	6.3	6.70
Total nitrogen ($g\ kg^{-1}$)	1.77	1.60
Available P (mg/kg)	17.98	3.33
Total organic matter (%)	2.84	2.87
Exchangeable bases (cmol/kg)		
Na	0.18	0.93
K	0.61	0.09
Ca	3.04	7.01
Mg	2.59	0.95

Table 3: Composition of Arati Baja and Arati Nawoz commercial organic fertilizers.

Parameter	Units	Arati Baja Value	Nawoz Value
Nitrogen (N)	g/kg	10.10	20.10
Potassium (K_2O)	g/kg	21.50	10.50
Phosphorus (P_2O_5)	g/kg	16.40	18.40
Magnesium (Mg)	mg/kg	58.91	34.55
Sulphur (S)	mg/kg	3.00	10.18
Calcium (Ca)	mg/kg	40.51	8.52
Boron (B)	mg/kg	0.23	0.19
Manganese (Mn)	mg/kg	28.90	2.60
Zinc (Zn)	mg/kg	1.20	1.40
Chloride (Cl)	mg/kg	0.45	0.26
Molybdenum (Mo)	mg/kg	0.09	0.08
Iron (Fe)	mg/kg	26.10	26.30

four rows with a distance of 60 cm between the rows and plots within a replicate. The replicates were separated with a distance of 1 m between them.

Crop husbandry

For land preparation, the experimental site was ploughed twice and harrowed once each year. Three seeds of the sunflower varieties were sown per hole at a spacing of 60 × 30 cm giving 56,000 plants/ha as recommended by Ogunremi (2000). The preceding crops were maize and soybeans in 2016 and 2017, respectively. Sowing was done on August 7, 2016, and August 2, 2017, during the late cropping seasons followed by thinning to one plant per stand at 14 days after sowing DAS. Weeds were controlled manually at 21 and 42 DAS and no herbicides were sprayed to simulate the growing conditions of the resource-constrained farmers under the organic production system. The crop was grown under rainfed conditions. After the first weeding at 21 DAS, five randomly selected plants were tagged in the two middle rows for plant height and yield attributes measurement at maturity.

Data collection

Plant height was measured at physiological maturity (R9 – when the bracts of the head had turned brown) as described by Schneiter and Miller (1981). At harvest, the earlier tagged five plants in the net plots were destructively sampled for determination of some head characteristics such as head diameter (cm), head weight (g), number and weight (g) of seeds per head and 100 seed weight (g). For seed yield in kg/ha, the heads of all the plants were harvested on a plot basis and threshed before weighing the seeds. A sensitive weighing balance – METTLER PJ360 Delta Range Model manufactured by Mettler Instrument Ltd, High Wycombe, Switzerland was used to weigh the dry weights of the heads and seeds (achenes) on a plot basis.

Data analysis

All data collected were subjected to analysis of variance using a fixed model to test the main effects and interaction between the two factors of variety and fertilizer regime (*F*-tests) for the two experiments (years) separately using the MSTATC package (Freed et al. 1989) and where effects were statistically significant ($P < 0.05$, *F*-test), treatment means were separated using the least significant difference method (LSD) at 5% probability level.

Results

Effect of foliar application of organic fertilizers on plant height of sunflower varieties at maturity (R9)

Application of two types of foliar organic fertilizers significantly ($P \leq 0.05$; *F*-test) increased plant height of sunflower at maturity relative to the control (Table 4). Plants that were sprayed with Arati Nawoz were significantly ($P < 0.05$), taller than those sprayed with ARAT BAJA and the control during the wetter the year 2016. However, in 2017, sunflower plants sprayed with Arati Baja and Arati Nawoz were on par and significantly ($P \leq 0.05$) taller than plants on the control plots. There was no significant difference among the four sunflower varieties at maturity. Although, SAMSUN 1 plants were taller than all the other varieties in 2016. The interaction effect of Variety × Fertilizer Application was significant ($P \leq 0.05$; *F*-test) for plant height at maturity in 2016 only (Table 4).

Effect of foliar organic fertilizer application on seed yield and some yield components of sunflower

Data on head diameter, head weight, number and weight of seeds per head, 100 seed weight and seed yield of four sunflower varieties as influenced by foliar application of two organic fertilizers in 2016 are presented in Table 5. The four test sunflower varieties were significantly ($P \leq 0.05$; *F*-test) different from each other for head diameter, head weight, number and weight of seeds per head and seed yield in 2016. SAMSUN 2 variety recorded significantly ($P \leq 0.05$) higher values for these traits than the other three varieties, except seed yield. Foliar application of organic fertilizers significantly ($P < 0.05$; *F*-test) affected sunflower head diameter, head weight, the weight of seeds per head, 100 seed weight and seed yield relative to the control. Sunflower plants sprayed with Arati Nawoz produced significantly ($P \leq 0.05$) higher weight of

Table 4: Plant height (cm) of sunflower at maturity (R9) as affected by foliar organic fertilizer application and sunflower varieties in 2016 and 2017.

Treatment	Plant height (cm) at maturity (R9)	
	2016	2017
Variety (V)		
SAMSUN 1	157.9	142.6
SAMSUN 2	152.5	143.6
SAMSUN 3	144.5	144.1
SAMSUN 4	150.7	142.4
LSD (5%)	ns	ns
Fertilizer application (FA)		
Control	144.5	135.2
ARATI NAWOZ	158.3	145.9
ARATI BAJA	151.4	148.3
LSD (5%)	4.71	6.47
Interaction		
V × FA	**	ns

ns – not significant, ** – significant at 1% probability level.

seeds per head than the plants grown on control plots and 100 seed weight than those sprayed with Arati Baja and on control plots. Sunflower plants that were sprayed with Arati Nawoz were similar to those sprayed with Arati Baja for head diameter, head weight per plant and seed yield. The application of foliar fertilizers had no significant effect on the number of seeds per head in 2016 (Table 5).

There was no significant varietal difference among the four test varieties of sunflower during the relatively dry 2017 four head diameter, head weight, number and weight of seeds per head, 100 seed weight and seed yield (Table 6). Similarly, the Variety Fertilizer Application interaction effect was not significant for any of the traits. However, foliar application of organic fertilizers significantly ($P \leq 0.05$; F-test) enhanced head diameter and weight, number and weight of seeds per head, and seed yield relative to the control. Sunflower plants that were sprayed with Arati Nawoz produced heads with a diameter on par with the control in 2017 (Table 6).

The interaction effect of variety × fertilizer application on plant height, seed yield and some yield attributes of sunflower

The mean values of plant height at R9, head diameter, head weight and seed yield of sunflower as influenced by V × FA interaction effect are presented in Table 7. On

Table 5: Sunflower seed yield and some yield attributes as affected by foliar organic fertilizer application and sunflower varieties in 2016.

Treatment	HD (cm)	HDWT (g)	NSPHD	WTSHD (g)	100 SWT (g)	Seed yield (kg/ha)
Variety (V)						
SAMSUN 1	11.8	36.7	375.9	18.8	5.3	789.82
SAMSUN 2	13.1	45.6	511.7	24.7	5.8	778.54
SAMSUN 3	11.5	32.8	349.0	17.2	5.0	897.57
SAMSUN 4	10.4	26.9	336.4	14.0	4.6	975.60
LSD 5%	0.72	6.07	75.09	4.06	ns	146.58
Fertilizer application (FA)						
Control	11.1	30.3	360.2	15.8	4.9	800.25
ARATI NAWOZ	12.3	40.9	394.5	21.1	5.8	976.88
ARATI BAJA	11.7	35.3	425.1	19.1	4.7	875.93
LSD 5%	0.62	5.25	ns	3.51	0.72	126.94
Interaction						
V × FA	*	*	ns	ns	ns	**

ns – not significant; *, ** – significant at 5 and 1% probability levels, respectively; HD – head diameter; HDWT – head weight; NSPHD – number of seeds per head; WTSHD – weight of seeds per head; SWT – seed weight.

Table 6: Sunflower seed yield and some yield attributes as affected by foliar organic fertilizer application and sunflower varieties in 2017.

Treatment	HD (cm)	HDWT (g)	NSPHD	WTSHD (g)	100 SWT (g)	Seed yield (kg/ha)
Variety (V)						
SAMSUN 1	7.1	21.7	277.6	10.8	3.8	572.29
SAMSUN 2	7.2	21.9	256.1	11.4	4.0	608.32
SAMSUN 3	7.3	20.5	337.0	14.0	3.7	743.17
SAMSUN 4	6.9	20.8	311.7	13.8	3.6	603.61
LSD 5%	ns	ns	ns	ns	ns	ns
Fertilizer application (FA)						
Control	6.6	16.8	227.5	8.6	3.5	432.73
ARATI NAWOZ	7.1	22.0	305.4	14.6	4.0	731.62
ARATI BAJA	7.7	24.9	353.8	14.2	3.9	731.19
LSD 5%	0.68	5.00	53.44	3.50	ns	166.47
Interaction						
V × FA	ns	ns	ns	ns	ns	ns

ns – not significant; *, ** – significant at 5 and 1% probability levels, respectively; HD – head diameter; HDWT – head weight; NSPHD – number of seeds per head; WTSHD – weight of seeds per head; SWT – seed weight.

Table 7: Interaction effect of Variety × Fertilizer Application on plant height, head diameter, head weight and seed yield (kg/ha) of sunflower in 2016.

Fertilizer application	Varieties	Plant height at R9 (cm)	Head diameter (cm)	Head weight (g)	Seed yield (kg/ha)
Control	SAMSUN 1	159.9	12.0	38.2	770.06
Control	SAMSUN 2	146.6	12.3	40.9	714.94
Control	SAMSUN 3	120.2	9.8	20.6	521.30
Control	SAMSUN 4	151.1	10.0	21.8	907.03
ARATI NAWOZ	SAMSUN 1	168.7	12.4	41.4	968.52
ARATI NAWOZ	SAMSUN 2	160.5	14.2	56.3	919.45
ARATI NAWOZ	SAMSUN 3	153.0	12.1	36.9	1167.71
ARATI NAWOZ	SAMSUN 4	150.9	10.9	28.9	851.85
ARATI BAJA	SAMSUN 1	145.0	11.0	30.4	630.86
ARATI BAJA	SAMSUN 2	150.2	12.7	39.6	701.23
ARATI BAJA	SAMSUN 3	160.3	12.4	40.9	1003.71
ARATI BAJA	SAMSUN 4	150.1	10.5	30.1	1167.91
LSD 5%		13.82	1.25	10.56	53.897

R9 – harvest maturity.

average, the application of Arati Nawoz resulted in comparatively taller plants relative to the plants sprayed with Arati Baja and those on the control plots. Plants of SAMSUN 1 sprayed with Arati Nawoz were significantly ($P \le 0.05$) taller than their counterparts sprayed with Arati Baja. A similar trend was recorded for head diameter and weight in 2016 for SAMSUN 1. However, this trend did not translate to high seed yield values for SAMSUN 2 since only SAMSUN 3 (1167.71 kg/ha) sprayed with Arati Nawoz and SAMSUN 3 (1003.71 kg/ha) and SAMSUN 4 (1167.91 kg/ha) sprayed with Arati Baja produced seed yield above a tonne during the more the favourable year 2016 (Table 7).

Discussion

The output of any crop production enterprise largely depends on the availability of all the required nutrients by the crop in the soil in balanced quantities and forms (Chen 2006). In a bid to improve the production output of crops, foliar fertilization is now being used to improve the efficiency and rapidity of the utilization of nutrients required by plants for maximum growth and yield (Bochalya et al. 2018). Unfortunately, there is no consensus on the appropriate time to apply foliar fertilizers to sunflower in literature. For example, in recent time, foliar boron application was done at beginning of R2 (Al-Amery et al. 2011) and nanosilver, organic fertilizer and salicylic acid at 65 DAS (Yaseen et al. 2016) in Iraq. Application of foliar nitrogen fertilizers at R1-R2 (Haseeb and Maqbool 2015) and foliar urea at 35, 60 and 85 DAS (Oad et al. 2018) was carried out in Pakistan and integrated use of organic and inorganic sources of nutrients (Elankavi 2017; Krishnaprabu 2015) at 40 and 60 DAS, different sources of vermicompost and inorganic fertilizer at 40 and 60 DAS (Ramesh, 2017) in India. In Egypt, foliar urea was applied on 30 and 45 DAS (El-Kady et al. 2010), seaweed extracts at 20, 40 and 70 DAS (Osman and Salem 2011) and ascorbic acid at 20, 35 and 50 DAS (Osman et al. 2014). Whereas, foliar application treatments were imposed at 15, 30, 45 and 60 DAS of sunflower in Ethiopia (Gebremedhin et al. 2015b). On average, enhanced productivity of the sunflower sequel to the application of the various treatments was reported by the investigators. In our study, we applied the liquid organic fertilizers at the vegetative stage (V3–V4) and beginning flowering (R1–R2). This was informed by the recommendation of Anonymous (2020) that nitrogen applied just before floret initiation affects the final number of seeds per head, while later applications before anthesis (R5) tend to influence single seed weight and that plants require more nutrients for the development of reproductive organs along with adequate moisture in the soil (Dandge et al. 2018). The prevailing weather conditions were more clement for sunflower cultivation in 2016 with 480 mm of rainfall as against 357.1 mm in 2017. This trend contributed to the higher values recorded for all the agronomic traits measured in 2016 than 2017 and could be attributed to the fact that foliar fertilization often reduces the negative impact of dry weather conditions on crop grain yield since it provides nutrients for immediate uptake by plants (Mandic et al. 2015). On average, application of the two foliar organic fertilizers significantly ($P \leq 0.05$; F-test) and moderately increased plant height of sunflower at maturity over the control with Arati Nawoz and Arati Baja enhancing plant height by about 8.7% relative to the control plants in 2016 and 2017. This is consistent with earlier findings that nitrogen as a major macronutrient contributes significantly to the vegetative development of plants when applied through organic or inorganic sources through increased uptake (El-Kady et al. 2010; Haseeb and Maqbool 2015; Munir et al. 2007; Thakur et al. 2013). According to Khan (2001) and Machikowa and Saetang (2008), the number of seeds per head, head diameter, 100 seed weight and plant height showed the highest positive direct effect on sunflower seed yield. The increase of head diameter, head weight, the weight of seeds per head, 100 seed weight and seed yield of sunflower over the control treatments in both years following foliar feeding could be attributed to the ready availability of nutrients required for the development of structural and functional components of plants during the vegetative and reproductive stages of sunflower development, activation of various digestive supporting enzymes related to chemical processes and chlorophyll synthesis enzymes (Abdel-Aziz and El-Shafe 2005; Adam and Iwona

2018; Haseeb and Maqbool 2015; Yasin et al. 2013). An increase in seed weight following the application of organic fertilizers in both years of experimentation could be attributed to enhanced partitioning of assimilates locked up in the vegetative parts of sunflower (Nanja Reddy et al. 2003) and an increase in photosynthetic area and metabolic substances stored in the seeds (El-Kady et al. 2010; Gandahi and Oad 2005). Furthermore, humic acid contained in the liquid fertilizers is capable of inducing hormonal effect on respiratory catalytic activity, cell permeability and increased nutrient uptake by the plants (Thakur et al., 2013). The significant effect of V × FA on plant height, head diameter, head weight and seed yield in 2016 suggests that these factors are dependent on each other in affecting the traits. Variety SAMSUN 2 exhibited comparatively higher head diameter and head weight when sprayed with Arati Nawoz under wet conditions than the other three test varieties. The overall seed yield performance of the four sunflower varieties as affected by foliar feeding ranged between 875.93 and 976.88 kg/ha in 2016 and 731.19–731.62 kg/ha in 2017 and was much lower than the African (1137.30 kg/ha), lower than the Nigerian (1000 kg/ha) average values (Olowe et al. 2013) and much lower than the world (1948.20 kg/ha) as reported by FAOSTAT (2019). The below-par performance of the four varieties under rainfed conditions in 2017 could be attributed to markedly low rainfall distribution in October that coincided with the peak reproductive stage. Nevertheless, the average seed yield of the varieties was significantly at par relative to the control and the values were still superior to 517.0 kg/ha reported as average sunflower yield in India by Bochalya et al. (2018). Very recent studies on the potential of organic sunflower production using foliar fertilization (Biofertilizer Alga 300) in Bulgaria demonstrated high hybrid seed yield >2.0 ton/ha during the favourable year and about 1.45 ton/ha under drought (Panayotova 2019).

Conclusion

The results of this two consecutive year study indicate that the four sunflower varieties can be successfully cultivated under an organic production system using ecologically clean and locally produced commercial foliar organic fertilizers. The average efficacy of Arati Nawoz and Arati Baja on sunflower agronomic traits was similar when compared with the control irrespective of the prevailing edaphoclimatic conditions during the late cropping seasons of both years. Organic foliar fertilizer (Arati Nawoz) application significantly increased the weight of seeds and head per plant, and seed yield in both years. Similarly, the application of Arati Baja significantly enhanced head diameter and weight, and seed yield relative to the control during the dry 2017. Consequently, it is recommended that Arati Nawoz and

Arati Baja be adopted for organic production of the four sunflower varieties in the humid tropics. However, future studies that will evaluate more frequency of application are needed.

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