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Appropriate Nitrogen and Phosphorus Fertilizer Regime for Sunflower (*Helianthus Annuus* L.) In the Humid Tropics

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Abstract: Two field trials were conducted on the Research Farm of the Institute of Food Security, Environmental Resources and Agricultural Research, Nigeria during the late cropping seasons (Jun.–Nov.) of 2014 and 2015 to evaluate the agronomic performance of four recently released sunflower varieties (SAMSUN-1, SMASUN-2, SAMSUN-3 and SAMSUN-4) to three fertilizer regimes: Control, Split application of 30 kg N + 28 kg P_2O_5 at 21 days after sowing (DAS) and at anthesis and Single application of 60 kg N and 56 kg P_2O_5 at 21DAS. The experiment was laid out in a randomized complete block design using a 3 × 4 factorial arrangement and replicated three times. Data were collected on phenology, plant height, seed yield and yield attributes, and quality. The varietal effect was only significant in 2015 for head weight, a number of achene per head and 100 achene weight. Application of N and P fertilizer either as split or single significantly ($P \le 0.05$; F-test) enhanced plant height at R5 and R9, 100 achene weight, achene weight per head and grain yield in both years. Single application resulted in significantly ($P \le 0.05$) higher grain yield in 2014 than the split and control and was on par with a split. Significant variety × fertilizer regime was recorded for protein content in 2014 and 2015, and oil content in 2015. Therefore, a single application of N and P fertilizers at 21 WAS is recommended for adoption in the humid tropics to enhance seed and oil production of SAMSUN-3 and SAMSUN-4.

Keywords: grain yield, nitrogen (N), phosphorus (P), regime, sunflower

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Introduction

Sunflower (*Helianthus annuus* L.) is one of the major contributors to edible vegetable oil in the world market (Thavaprakash *et al.*, 2002). As of January 2016, the total world area under sunflower was 24.7 m ha with an average yield of 1.67 tonnes per ha (NSA, 2016). The three leading world sunflower producers were Ukraine, Russia and the European Union. However, sunflower grain yield had been static at 1.68 tonnes/ha between 2013/14 and 2014/15 and the area under sunflower cultivation also reduced by 6 % during the same period (National Sunflower Association, 2016). The non-significant increase in grain yield despite the use of different inputs (improved seeds, inorganic and organic fertilizers e.t.c) could be partly attributed to inappropriate use of some of the inputs. Sunflower is not a common oilseed crop in the tropics even though it is a very rustic crop that can produce optimally under diverse agro-ecological conditions. Its production potential had however, been confirmed in the forest-savanna transition zone of the humid tropics (Olowe *et al.*, 2005a; Olowe and Adeyemo, 2009). Commercial fertilizers are usually used to boost the yield output of sunflower. According to Heffer (2013), the global application of fertilizers to oilseed crops was estimated at 19.0 Mt or 11.0 % of the world consumption. The breakdown of this consumption stood at 7.3 %, 14.7 % and 19.8 % of the world's total consumption of nitrogen, phosphorus and potassium fertilizers, respectively. However, it is very important that farmers apply the fertilizers at the appropriate rate and time in order to get the maximum output from the commodity being produced. The utilization of nutrients by sunflower varies depending on the stage of development of the crop. Sunflower utilizes the bulk of applied nitrogen from the beginning of terminal bud appearance i. e. R1 – R2 (Schneiter and Miller, 1981) to end of anthesis (R6), phosphorus from emergence (VE) to R6 and potassium from R1 to ripening (Ustimenko-Bakumovski, 1980). Furthermore, oil accumulation in grains begins from R5.1 and stops just before physiological maturity (R7) as reported by Chervet and Vear (1989); Mantese *et al.* (2006).

Research results have demonstrated increased productivity of sunflower through the application of mineral fertilizers that contain the major plant nutrients (nitrogen, phosphorus and potassium) in balanced quantities (Singh *et al.*, 1977; Ogunremi, 1984, 1986; Nassim *et al.*, 2012a; 2012b) and organic fertilizers (Rasool *et al.*, 2013; Oshudiya *et al.*, 2014). The optimum rates of the major nutrients especially nitrogen vary across different ecological zones such as 90 kg N/ha in the lowland areas of Nigeria (Ogunremi, 2000) and 60 kg N/ha in the derived savanna zone of Nigeria (Olowe *et al.*, 2005a), 80 kg N/ha in India (Faisul-ur-Rasool *et al.*, 2013), 150 kg N/ha at Islamabad, Pakistan (Bakht *et al.*, 2010), and 180 kgN/ha at Faisalabad, Pakistan (Nasim *et al.*, 2012b). It has been reported that appropriate integration of synthetic fertilizers, organic manures and residues is essential for sustaining moderate to high crop yields through the improvement of soil organic matter and fertility (Faisul-ur-Rasool *et al.*, 2013; Sharma *et al.*, 2008). The application of different fertilizers (inorganic and organic) to sunflower either as single or split vary depending on agro-ecology and farming system being practised. From literature, fertilizers have been applied to sunflower at planting (Ogunremi, 1984; Zubriski and Zimmermann, 1974), as basal application before planting (Bahl *et al.*, 1997), basal application of phosphorus and potassium and nitrogen at four weeks after sowing (Ogunremi, 2000), three weeks after planting to coincide with first weeding (Ogunremi, 1984, 1986; Olowe *et al.*, 2005b; Oshundiya *et al.*, 2014) or at advanced vegetative stages (Yousaf *et al.*, 1986). An inverse relationship between protein and oil contents in sunflower seeds have been reported in the literature (Andrianasolo *et al.*, 2014; Diepenbrock *et al.*, 2001). Oil yield is a function of seed yield and oil content of the sunflower variety (Rasool *et. al.*, 2013). An earlier study on the appropriate timing of nitrogen and phosphorus fertilizers to sunflower in the forest-savanna zone revealed that single application at 21 days after sowing was optimal for local and two exotic varieties of sunflower (Olowe *et al.*, 2005b). However, the study did not quantify the effect of the macronutrients on seed quality of sunflower. Hence the need to generate quantifiable agronomic information on the response of recently released sunflower varieties. This study was carried out to evaluate the agronomic response and seed quality of four newly released sunflower varieties (SAMSUN-1, SAMSUN-2, SAMSUN-3 and SAMSUN-4) to single and split application of nitrogen and phosphorus fertilizers in the forest-savanna transition zone of the humid tropics.

Materials and methods

Growth conditions

Two field trials were carried out at the Institute of Food Security Environmental Resources and Agricultural Research (IFSERAR) Farm of the Federal University of Agriculture, Abeokuta (7° 23´ N, 3° 39´ E, altitude 139 m above sea level) in south western Nigeria on a loamy sand soil between June and November, 2014 and 2015. Data on physicochemical properties of the soils of the experimental sites are presented in Table 1. The soils belonged to the loamy sand textural

Table 1: Some physico-chemical characteristics of the soil of experimental fields.

Soil Characteristics	2014	2015
Sand (%)	85.8	85.0
Silt (%)	7.4	7.0
Clay (%)	6.8	8.0
Textural class	loamy sand	loamy sand
pH (H_2O)	6.1	5.9
Carbon level (%)	0.72	0.93
Total N (%)	0.06	0.09
Available P (mg/kg)	7.76	12.74
Exchangeable K (cmol/kg)	0.20	0.24

class and were low in nitrogen, medium in phosphorus and potassium based on the rating of Anon (1989). Some weather data collected during the periods of experimentation in 2014 and 2015 are presented in Table 2. The months of September and October were the two wettest months in both years during the periods of experimentation. The total rainfall recorded during the crucial late vegetative – reproductive period of sunflower (Sept.–Oct.) was 42.5 mm higher in 2014 than 2015. The coolest and hottest months were August (25.3° & 26.3°C) and November (27.5° & 28.6°C) in 2014 and 2015, respectively. Relative humidity was slightly above 70 % during the wettest months (September and October) of both years, except October 2015.

Experimental design and measurements

The trials were a 4 × 3 factorial arrangement laid out in randomized complete block design and replicated three times. The factors were variety: 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) and fertilizer regime: control, split application (30 kg.N/ha + 28 kg.P_2O_5/ha at 21 days after sowing (DAS) and at anthesis, and single application of 60 kg N/ha + 56 kg.P_2O_5/ha at 21 DAS. The varieties are the oil types and have been described by NASC (2013). Each plot measured 4 m × 1.8 m (7.2 m2) and consisted of four rows with a distance of 60 cm between the rows and plots within a replicate.

Table 2: Rainfall distribution (mm), mean monthly temperature (T°C) and relative humidity (RH, %) during a period of experimentation in 2014 and 2015.

Growth	June		July		August		September		October		November	
Week	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**
I	31.8	53.5	28.1	20.6	6.5	0**	10.9	18.7	95.6	49.5	11.9	16.6
II	19.3	12.8	11.8	30.2	2.3	14.4	16.2	3.2	72.9	70.1	5.7	0
III	5.3	39.7	33.2	14.8	40.8	2.1	103.0	102.2	24.8	11.4	0	0
IV	60.1*	58.9	17.6	0	43.1	12.9	30.7	41.0	12.6	28.1	0	0
Total rainfall	116.5	164.9	90.7	65.6	92.7	29.4	160.8	165.1	205.9	159.1	17.6	16.6
Mean T°C	27.5	26.1	26.6	26.6	25.6	26.3	26.3	27.5	26.5	27.1	27.4	28.6
RH, %	64.4	70.8	68.8	73.0	70.4	70.3	71.1	71.9	70.2	69.2	67.3	62.3

* Sowing on June 27, 2014 and ** Sowing on August 7, 2015

Crop husbandry

In each year of experimentation, the site of the experiment was ploughed twice and harrowed once. Three sunflower seeds were sown per hole at a spacing of 60 cm × 30 cm giving 56,000 plants/ha as recommended by Ogunremi (2000). Sowing was done on June 27, 2014, and August 7, 2015, during the late cropping seasons. Thinning to one plant per stand was done at 14 days after sowing (DAS). The sources of fertilizers used in the study were urea fertilizer (46 %N), single superphosphate (18.5 % P_2O_5) and muriate of potash (62 %.K_2O). The recommended rate of 100 kg.K_2O (Ogunremi, 2000) was applied on all the fertilized plots along with N and P fertilizers at 21 DAS. Weeds were controlled manually at 21 and 42 DAS and no herbicides were sprayed in order to simulate the growing conditions of the resource-constrained farmers. After the first weeding at 3 WAS, five randomly selected plants were tagged in the two middle rows for plant height and yield attributes measurement at maturity.

Data collection

Parameters measured on plot basis were a number of days to flowering (R5 – 50 % ray flowers) and physiological maturity (R9 – when the bracts of the head had turned brown) as described by (Schneiter and Miller, 1981). Plant height (cm) using a 2 m ruler was determined on a plot basis at R5 and R9. 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, 100 seed weight (g), Shelling percent (5) and seed yield (kg/ha). 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. The method used for the determination of oil and protein contents were Soxhlet extraction with petroleum ether as the solvent and Kjeldahl block digestion and steam distillation, respectively (Egan *et al.*, 1981)

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.

Analysis of variance (ANOVA) fixed model for the experiment:

$$Y_{ijk} = m + b_{jk} + g_i + f_j + gf_{ij} + e_{ijk}$$

where Y_{ijk} is an observation of the i^{th} variety in the j^{th} fertilizer regime and the k^{th} replicate, m the general mean, b_{jk} the block effect, g_i the fixed variety effect, the fixed fertilizer regime effect,the fixed variety × fertilizer regime interaction effect, and the error.

Results

Effect of nitrogen and phosphorus fertilizer regime on plant height and phenology

Fertilizer regime significantly ($P \leq 0.05$; *F*-test) affected plant height of sunflower at flowering and physiological maturity in 2014 and 2015. Application of N and P fertilizers either as split or single dose significantly ($P \leq 0.05$) increased sunflower plant height at flowering and physiological maturity relative to the control treatment in both years. However, fertilizer regime had no significant effect on a number of days to flowering and physiological maturity of sunflower in both years. Similarly, variety and variety × fertilizer regime effects were not significant on a number of days to flowering and physiological maturity and plant height at R5 and R9 in both years (Table 3).

Effect of nitrogen and phosphorus fertilizer regime on seed yield and yield attributes

Fertilizer regime significantly ($P \leq 0.05$; *F*-test) affected a number of achene per head, achene weight per head, 100 achene weight and seed yield of sunflower in both years and average head diameter and head weight, and shelling per cent of sunflower in 2015 (Tables 4 and 5). A split and single

Table 3: Number of days to flowering (R5) and physiological maturity (R9), and plant height of sunflower as influenced by variety and fertilizer regime in 2014 and 2015.

Treatment	2014				2015			
	Days to		Height (cm) at		Days to		Height (cm) at	
	R5	R9	R5	R9	R5	R9	R5	R9
Variety (V)								
SAMSUN-1	60.7	103.0	99.6	148.6	70.6	109.7	161.6	174.8
SAMSUN-2	60.9	103.2	107.3	147.2	71.1	109.4	148.9	161.8
SAMSUN-3	60.2	103.0	114.2	164.9	71.0	110.1	155.3	173.7
SAMSUN-4	60.3	102.7	106.4	158.9	70.2	110.8	157.2	174.3
LSD 5 %	ns	ns	ns	ns	ns	ns	ns	ns
Fertilizer Regime (FR)								
Control	59.8	102.2	98.6	144.0	71.0	109.9	141.7	156.6
Split	60.9	103.1	115.6	168.9	70.4	109.8	164.8	180.7
Single	60.9	103.5	106.3	151.7	70.7	110.3	160.7	176.2
LSD 5 %	ns	ns	13.31*	20.32*	ns	ns	8.16**	10.79**
Interaction								
V × FR	ns	ns	ns	ns	ns	ns	ns	ns

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

Table 4: Sunflower seed yield and yield attributes as influenced by variety and fertilizer regime in 2014.

Treatment	Head diameter (cm)	Head weight (g)	Achene number per head	Achene weight per head (g)	100 achene weight (g)	Shelling percent (%)	Seed yield (kg/ha)
Variety (V)							
SAMSUN-1	12.4	326.8	442.4	39.4	6.2	16.2	1746.9
SAMSUN-2	11.4	365.5	410.9	34.2	4.9	9.0	1527.4
SAMSUN-3	12.0	347.8	341.9	36.8	4.7	8.7	1652.2
SAMSUN-4	11.1	357.4	423.4	36.3	4.5	10.6	1595.5
LSD 5 %	ns	ns	ns	ns	ns	ns	ns
Fertilizer Regime (FR)							
Control	11.1	296.5	352.4	27.8	3.9	10.3	1246.9
Split	12.3	361.8	411.8	36.7	5.8	10.2	1650.4
Single	11.9	389.9	449.8	45.5	5.6	12.9	1994.2
LSD 5 %	ns	ns	79.19*	9.97**	1.54*	ns	425.94*
Interaction							
V × FR	ns	ns	ns	ns	ns	ns	ns

Notes: **, * Significant at P ≤ 0.001 and 0.05, respectively, ns – non-significant application of N and P fertilizers to sunflower resulted in significantly ($P \leq 0.05$) higher values for the parameters relative to the control treatment, except seed yield in 2014 (Table 4). Fertilizer regime had no significant effect on head diameter, average head weight and shelling per cent of sunflower in 2014. Variety effect was only significant ($P \leq 0.05$; F-test) on average head weight, number of achene per head and 100 achene weight of sunflower in 2015 (Table 5). However, in 2014, variety effect was not significant on any trait measured. Similarly, variety × fertilizer regime effect did not affect seed yield and any yield attribute of sunflower significantly in both years.

Effect of nitrogen and phosphorus fertilizer regime on seed quality and oil yield

The four sunflower test varieties were significantly different ($P \leq 0.05$) for protein and oil contents in both years, except oil content in 2014 (Table 6). The varietal effect was not significant for oil content and oil yield in both years,

Table 5: Sunflower seed yield and yield attributes as influenced by variety and fertilizer regime in 2015.

Treatment	Head diameter (cm)	Head weight (g)	Achene number per head	Achene weight per head (g)	100 achene weight (g)	Shelling percent (%)	Seed yield (kg/ha)
Variety (V)							
SAMSUN-1	8.4	22.3	440.2	10.8	2.5	49.5	506.1
SAMSUN-2	7.8	22.9	413.6	12.0	3.0	50.2	506.7
SAMSUN-3	7.5	16.5	442.5	11.3	3.1	63.9	606.5
SAMSUN-4	6.8	17.1	192.6	8.0	4.2	46.2	599.3
LSD 5 %	ns	4.80*	163.99*	ns	1.19*	ns	ns
Fertilizer Regime (FR)							
Control	6.6	13.5	227.3	6.7	2.8	41.4	361.9
Split	8.5	26.3	463.3	14.2	4.0	60.9	704.9
Single	7.8	19.2	426.0	10.6	2.8	55.1	597.0
LSD 5 %	1.04**	4.16**	142.0**	2.71**	1.04*	13.09*	126.67**
Interaction							
V × FR	ns	ns	ns	ns	ns	ns	ns

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

Table 6: Sunflower seed quality and oil yield as influenced by variety and fertilizer regime in 2014 and 2015.

Treatment	2014			2015		
	Protein Content (%)	Oil Content (%)	Oil yield (kg/ha)	Protein Content(%)	Oil Content (%)	Oil yield (kg/ha)
Variety (V)						
SAMSUN 1	14.4	27.5	474.08	19.2	27.3	137.78
SAMSUN 2	17.2	27.6	416.82	18.7	27.6	137.29
SAMSUN 3	17.3	28.0	454.40	19.7	27.5	165.06
SAMSUN 4	21.8	27.9	440.49	17.0	27.7	163.95
LSD 5 %	0.09	ns	ns	0.24	0.20	ns
Fertilizer Regime (FR)						
Control	15.3	27.2	331.59	18.0	26.6	94.23
Split	21.1	27.8	449.37	18.3	27.8	191.67
Single	16.7	28.4	558.39	19.7	28.3	161.17
LSD 5 %	0.08	0.33	96.930	0.21	0.17	27.960
Interaction						
V × FR	**	*	ns	**	ns	ns

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

except oil content in 2015. However, N and P fertilizer regime significantly ($P \leq 0.05$; *F*-test) increased seed quality and oil yield in both years relative to the control. A single application of N and P fertilizers significantly ($P \leq 0.05$) increased the oil content of sunflower relative to the split regime and control in both years. The split application, however, resulted in significantly ($P \leq 0.05$) higher protein content in 2014 (wetter year) than the single application and control treatments.

The mean values of protein and oil contents of significant ($P \leq 0.05$) interaction between varieties and fertilizer regime in 2014 and protein content in 2015 are presented in Table 7. On average SAMSUN-4 variety that received N and P fertilizer as split or single contained significantly ($P \leq 0.05$) higher protein and oil than the other three varieties in 2014. During the late cropping season of 2015, SAMSUN-3 variety under control treatment recorded significantly ($P \leq 0.05$) higher protein content, whilst SAMSUN-2 and SAMSUN-4 varieties that received a single application of N and P fertilizers also contained comparatively high protein content in their seeds.

Table 7: Effects of variety × fertilizer regime on protein and oil content in 2014 and protein content in 2015.

Variety	Fertilizer Regime	2014 Protein Content (%)	2014 Oil Content (%)	2015 Protein Content (%)
SAMSUN-1	Control	12.8	27.4	19.6
SAMSUN-2	Control	17.8	27.0	16.1
SAMSUN-3	Control	16.4	27.0	23.0
SAMSUN-4	Control	14.3	27.3	13.2
SAMSUN-1	Split	18.6	26.5	19.5
SAMSUN-2	Split	17.4	27.4	19.7
SAMSUN-3	Split	18.5	28.4	17.1
SAMSUN-4	Split	19.6	28.2	16.7
SAMSUN-1	Single	11.8	28.3	18.4
SAMSUN-2	Single	16.6	28.5	20.4
SAMSUN-3	Single	17.1	28.2	18.8
SAMSUN-4	Single	21.3	28.2	21.1
LSD 5 %		0.16	0.66	0.41

Discussion

Adoption of the appropriate fertilizer regime is very crucial for successful sunflower cultivation and the performance of the crop depends largely on the prevailing weather conditions. The late cropping season of 2014 was wetter (610.2 mm) than that of 2015 (370.0 mm). This scenario apparently contributed to the better overall performance of sunflower in 2014 than in 2015. Application of N and P fertilizers either as split or single regime significantly ($P \leq 0.05$; F-test) enhanced plant height of sunflower relative to the control at R5 and R9. The availability of N on the fertilized plots apparently boosted plant growth. No significant variety effect was recorded in 2014 for sunflower on seed yield and yield attributes. All the four new varieties were able to express themselves very well under the wetter growth conditions of 2014 than 2015. In an earlier trial where two exotic varieties (Record and Isaanka) and Funtua (locally adapted variety) were subjected to similar fertilizer regimes, Funtua grew taller than the exotic varieties (Olowe *et al.*, 2005b). However, during the hotter and drier late cropping season of 2015, the varieties were significantly ($P \leq 0.05$; F-test) different for head weight, number of achene per head and 100 achene weight. SAMSUN-1 and SAMSUN-2 recorded significantly ($P \leq 0.05$) higher head weight and a number of achene per head than SAMSUN-4. However, these differences did not translate to significant seed yield among the varieties.

Among the yield attributes evaluated in our study, split and a single application of N and P significantly ($P \leq 0.05$; F-test) enhanced only 100 achene weight relative to the control in 2014. However, in 2015 all the yield attributes were significantly ($P \leq 0.05$; F-test) enhanced by the split and a single application of N and P fertilizers with the split application regime resulting in higher values for most traits. According to earlier reports, application of N up to 60 kg N/ha either as split or single significantly (P ≤ 0.05) increased head diameter, achene weight per head and 100 achene weight (Olowe *et al.*, 2005b) and 112 kg N/ha head diameter (Yousaf *et al.*, 1986).

According to Robinson (1978), the seed yield of sunflower is highly dependent on a number of heads per hectare, the number of seeds (achene) and weight per head. The fertilizer regimes evaluated in our study significantly affected these traits in both years, except a number of heads per hectare which was not calculated in our study. The seed yield values (1246–1994.2 kg/ha) recorded in our study during the wetter and more the favorable year 2014 compared very well 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). However, the imposed fertilizer regimes under drier and hotter 2015 conditions resulted in seed yield values at par with only the African average (812 kg/ha). The seed yield values recorded under split and a single application of N and P fertilizers were at par in both years with the split regime resulting in a slightly higher value in 2015. This trend also corroborated the results of earlier experiments on sunflower (Singh *et al.*, 1977; Ogunremi, 1984, 1986; Olowe *et al.*, 2005b).

Seed quality of sunflower is generally determined by interaction between genetic makeup and environmental factors (time, space and nutritional status of the soil) as reported by Weiss (2000), Radic *et al.* (2009), Olowe *et al.* (2013), Faisul-ur-Rasool *et al.* (2013) and Adrianasolo *et al.* (2014). In our study, the four test varieties of sunflower produced relatively moderate oil content (27.3–28.0 %) compared to the reported global average (25–48 %) for sunflower seeds (Weiss, 2000). A contrary trend was, however, recorded for protein content which ranged between 14.4–21.8 % as against the global average (15–20 %) for sunflower (Weiss, 2000). This trend corroborated the reported inverse relationship between protein and oil in sunflower (Andrainasolo *et al.*, 2014; Diependbrock *et al.*, 2001). Amongst the varieties, SAMSUN-4 contained significantly ($P \leq 0.05$) higher protein than the other three varieties during the wetter 2014 late season and SAMSUN-3 recorded the highest oil content in 2015 (a relatively dry year). Differential performance could be attributed to the genetic makeup of the test varieties. Split application of N and P fertilizers significantly ($P \leq 0.05$) enhanced protein formation only in 2014, while single application significantly ($P \leq 0.05$)

increased oil concentration in both years. The enhanced protein content in 2014 could be attributed to the increased availability of N at anthesis which might have resulted in increased accumulation of protein in the plants and reduction in carbohydrates required for polymerization into fatty acids and consequent reduction in oil content. Similar results have been reported by Ozer *et al.* (2004), Aglave *et al.* (2009) and Rasool *et al.* (2013). Significant variety × fertilizer regime was recorded for protein content in 2014 and 2015, and oil content in 2015. A single application of N and P fertilizers resulted in comparatively high protein and oil content in SAMSUN-4. Whereas, SAMSUN-3 exhibited the potential to produce high protein and oil content under relatively unfavourable conditions such as 2015. These varying results could be attributed to nitrogen-phosphorus interactions, genetics, the disparity in environmental conditions and timing of protein and oil accumulation as suggested by Blumenthal *et al.* (2008), Nassim *et al.* (2012b); Faisul-ur-Rasool *et al.* (2013) and Andrainasolo *et al.* (2014).

On average, the superior performance of the sunflower varieties grown on the fertilized plots over those on the control plots suggests that they had access to the three major macronutrients (N, P and K) and these nutrients apparently contributed to their growth and development on the relatively poor in fertility experimental soils. Lack of significant variety × fertilizer regime interaction effect on the agronomic traits evaluated in this two-year study suggests that the two factors were independent of each other.

Conclusion

The results of this two-year study indicate that the growth, seed yield and quality responses of four newly released sunflower varieties were at par when N and P fertilizers were applied as split or single regime and were superior to plants on the control plots. Consequently, it is recommended that single regime application of fertilizers at three weeks after sowing be adopted in the forest-savanna transition zone of the humid tropics for enhanced SAMSUN-3 and SAMSUN-4 sunflower seed and oil production.

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