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EFFECTS OF DIFFERENT NPK LEVELS ON GROWTH AND SEED YIELD OF SESAME (*SESAMUM INDICUM L*) VARIETIES IN BAUCHI, NIGERIA

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ABSTRACT
Sesame is an important oil seed crop which is cultivated in the tropics and subtropics of the world but farmers in the northern guinea savanna zone of Nigeria seldom apply fertilizers to the crop. Trials were conducted during the 2018 and 2019 rainy seasons at the Research Farm of the Abubakar Tafawa Balewa University (ATBU), Bauchi, to study the effects of different levels of NPK on the growth and seed yield of sesame (*Sesamum indicum* L.) in Bauchi. The experiment was laid out in split plot design consisting of four levels of NPK and 8 varieties of sesame, giving a total of 32 treatment combinations. The varieties were kept in the main plot while NPK levels were assigned to subplots. The parameters assessed include plant height, number of leaves, number of primary branches, number of secondary branches, stem diameter, internode length, dry matter, leaf area, days to 75% flowering and maturity, number of capsules, number of seeds per capsule, number of seeds per locule, one thousand seed weight and seed yield. Results showed significant difference ($p < 0.05$) on growth, yield and yield attributes of sesame in both years. The different grain yield responses were associated with the differences in NPK levels. Sesame seed yield increased linearly from the application of 75 kg NPK ha^{-1}, 100 kg NPK ha^{-1} to 125 kg NPK ha^{-1}.

Key words: *Nutrient; treatment; yield; capsules; locules*
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INTRODUCTION
Throughout history, sesame (*Sesamum indicum* L.) has been regarded as one of the most important oil crops because of its high oil content (50-60%) and high protein content (Kashani *et al.*, 2015). In Nigeria, sesame is a crop with significant economic potential since it provides companies with raw materials and is a steady source of foreign earning (NCRI 2008; Munyua and Okwadi, 2013). One of the oldest oilseed crops grown worldwide is sesame, which belongs to the Pedaliaceae family (Haruna and Usman, 2015). Since sesame cannot thrive in waterlogging conditions, high rainfall is not necessary for sesame growth; instead, adequate drainage is essential (Bedigian, 2003). It is grown in Nigerian Sahel Savannah, Sudan and Northern and Southern Guinea regions. Due to the low yield of the crop and the difficulties associated with sesame harvesting, farmers are deterred from cultivating it, which reduces the overall area of its production (Bezerra *et al*., 2010). Because sesame is regarded as a minor crop and can thrive on soils with little fertility, traditional sesame growers in Nigeria do not use fertilizer. However, studies have shown that sesame planted on soils where fertilizers were administered performed better than those grown on soils where fertilizers where not applied. Low quantities of fertilizer or no fertilizer at all are used by farmers to cultivate this crop under rain-fed conditions. When compared to the potential yield elsewhere in the world, average sesame yield in Nigeria is poor. Nigeria's average yield per hectare is 300 kg, while it is 1,960 kg in Venezuela; 1,083 kg in Saudi Arabia; 517 kg in the Ivory Coast, and 510 kg in Ethiopia (Haruna, 2011).

Sesame seeds are a good source of food, medicine and edible oil. Sesame is known as "the queen of oilseeds" due to its superior nutritional content as well as its therapeutic, cosmetic and culinary properties. The crop is mostly cultivated for its edible seeds, which contain 50–60% oil, 8% protein, 5.8% water, 3.2% crude fibre, 18% carbohydrate and 5.7% ash. The seeds are extremely rich in vitamins and minerals including phosphorus and calcium. Because sesame oil contains unsaturated fatty acids, it is believed to have lowering effects on both plasma cholesterol and coronary heart disease. Sesame's protein and oil contents have an antagonistic relationship; when seed oil concentration rose, protein levels dropped (Dange *et al*., 2008). A sustainable approach to soil nutrient management takes into account the type, amount, timing and application techniques. The right timing and application of fertilizer are believed to be crucial for a high yield. NPK and other inorganic fertilizers are crucial nutrients for plant growth and productivity (Etukudo *et al*., 2015). The nutrients required for optimum sesame development are provided, to some extent, by balanced fertilisation (Etukudo *et al*., 2015).

The low yield coupled with challenges encountered during harvesting of the crop has tended to discourage growers, leading to a reduction in the total area devoted to its cultivation. Among the traditional sesame growers in Nigeria (especially in the Northern region), fertilizer application has not been a common practice because it is considered a minor crop that can perform well even on nutrient-deficient soils (Haruna and Usman, 2015). It has been demonstrated that sesame grown in soils that were fertilised yielded more highly than the one grown in soils without fertilisation (Jakusko and Usman, 2013). Generally, this crop is grown by farmers with low levels of fertilizer under rainfall condition. The application of optimum nutrients at the right time is essential for increasing seed yield. It has become necessary to increase the productivity of sesame by application of inorganic nutrients like NPK which can influence growth and development, flowering, fruit set, seed formation and seed yield. Many trials have been carried out to study the effects of NPK fertilizer on the growth and yield of other crops (Zaghlool *et al*., 2001, 2006; Abo El-Saoud, 2005; Abd El-Dayem *et al*., 2005; Ibrahim and Sharaf El-Deen, 2008; Haruna and Usman, 2015) Khan (2016) reported varying responses of sesame plants to nitrogen fertilizer using four sesame varieties in Pakistan. The variety that produced significantly higher yield was, variety 5.17 compared to varieties Calid, PV and 37-40. The response of ten sesame varieties to nitrogen fertilisation has been reported by Khan (2016), who observed that M 3-1 and Vinayak had the highest yield of 2.76t/ha and 2.65t/ha, respectively.

Nitrogen plays a major role in the synthesis of proteins, nucleic acid, nucleotides, enzymes, alkaloids, vitamins and chlorophyll. It affects flowering and fruit setting in sesame and other crops (Jasimuddin, 2014). Iorlamen *et al*. (2014) and Shirazy *et al.* (2015) reported that nitrogen fertilizer application on soils that where below N critical range of 10-15 kg/ha resulted in good crop growth. Zainab *et a l*. (2016) reported that application of 60 - 150 kg N/ha increased plant height, number of branches per plant and leaf area index of sesame, due to the role of N in enhancing physiological processes (Nahar *et al*., 2008). The net assimilation rate also increased. Zainab *et al.* (2016) reported that the application of N fertilizer up to 80 kg/ha increased the number of branches per plant, dry matter yield, leaf area, number of capsules per plant and seed yield of sesame. The application of N fertilizer at 80 kg N/ha also increased the number of capsules per plant in sesame. The N fertilizer application in the range of 102-120 Kg/ha increased seed yield of sesame. These results indicate that a low N application increased the number of capsules per plant, while a high application increased seed yield (Sultana *et al,* 2011). The high sesame seed yield was due to the increase in seed protein content, that was triggered by increase in N application (Ghosh *et al*., 2004). Babaji *et al*. (2006) and Shehu (2014) reported that the application of N fertilizer in the range of 60-75 Kg/ha resulted in a higher number of capsules per plant. Patra (2001) and Malhi (2014) reported that the application of nitrogen fertilizer at 60 kg/ha increased the oil content of sesame seeds significantly. The low oil seed content of sesame at high N rate was due to interference of carbohydrate metabolism by N application. Saturated carbon skeletons promote enzyme imbalance that affects oil synthesis (Hashem, 2013; Johnson and Russ, 2013). El-Nakhlawy *et al*. (2009) and Hashem (2013) reported that the application of 75-150 kg N/ha increased both oil and protein contents significantly. Earlier findings showed that application of N fertilizer on groundnut increased the seed yield, with no effect on the oil content. It has been reported that the addition of 6 t/ha of finger millet husks into the soil resulted in significantly higher crude protein content when compared with the application of 3 t/ha. The high content of nitrogen in finger millet husk led to a higher quantity of nitrogen in the soil upon decomposition. Ali and Jan (2014) observed that the supply of high levels of inorganic nitrogen fertilizers increased sesame seed protein content. Mina *et al*. (2016) reported that the oil content of sesame increased with increasing

N-application up to 45- 95 kg/ha. This could be due to enhancement of lipid metabolism by phosphorus which increased seed oil yield. Basavaraj *et al*. (2000) reported that the application of NPK fertilizer at 60-75 kg N/ha, 45-75 kg P/ha and 22.5- 40 kg K/ha resulted in high sesame seed yield when compared to the control. Carlson *et al*. (2009) reported that sesame responded less to higher doses of organic fertilizer and concluded that the application of 36 kg N/ha, 9 kg P/ha and 9 kg K/ha was enough to improve sesame seed yields. Haruna (2011) reported that the application of 60 kg N/ha and 13.2 kg P/ha significantly increased sesame seed yields. The application of 60-160 kg N/ha and 30-100 kg P/ha resulted in maximum seed yield (Olowe and Busari, 2000; Ahmad *et al*., 2001; Haggai, 2004; Vaghani *et al*., 2010).

The present study investigated the effects of different levels of NPK application on the growth and seed yield of sesame.

MATERIALS AND METHODS

Experimental Site

The field trials were conducted during the rainy season in 2018 and 2019 at Abubakar Tafawa Balewa University Bauchi Research and Training Farm, Yelwa campus (Latitude10^{o}15`–10$^{o}$30`N and Longitude 9^{o}45`E–10$^{o}$60`E and situated at 690.3 m above sea level) in the Northern Guinea savannah zone of Nigeria.

Source of materials

The varieties ADAW-TING, E8, EX-SUDAN, KENANA- 4, NCRI 01M, NCRI 02M and NCRI 04E were sourced from the National Cereals Research Institute (NCRI), Badeggi, Niger state while the variety NCRI 03L was obtained from Lake Chad Research Institute, Maiduguri, Borno State.

Experimental Design

The experimental design used was split-plot design. The treatments consisted of 8 sesame varieties, namely ADAW-TING, E8, EX-SUDAN, KENANA- 4, NCRI 01M, NCRI 02M, NCRI 03L, NCRI 04E, and four levels of NPK (0, 75,100 and 125 kg NPK/ha), giving a total of 32 treatment combinations. Varieties were assigned to the main plot while NPK levels were placed in the subplots. The treatments were replicated three times.

PHYSICO-CHEMICAL PROPERTIES OF SOIL FROM EXPERIMENTAL SITE

The physico-chemical properties of the soil from the experimental site is presented in Table I. The results showed that the soil pH was slightly acidic. The organic matter was low and the bulk of the soil was sandy. The chemical properties such as total nitrogen content, available phosphorus and exchangeable cations (such as potassium, calcium and magnesium) were very low. The available micronutrients such as zinc was very low during the cropping seasons. These soil nutrients of the study site are below the critical levels for optimum crop growth and yield using soil data rating as suggested by Linsday and Norvell, 1978; FDALR (1990), as follows: organic carbon, 1–1.4 %, total nitrogen, 0.151-0.200 %; available phosphorus, 7.0– 20 mg kg-^{1}; exchangeable potassium, 0.3–0.6 cmol kg-^{1}; exchangeable calcium, 5-10 cmol kg-^{1}; exchangeable magnesium 1-3 cmol kg-^{1} and available zinc 0.6 –1.0 cmol kg-^{1}.The low nutrient status of the experimental site, which is typical of Alfisols, could be attributed to leaching of nutrients from valuable organic matter. This may be why the cultivation of crops is done solely with the application of external inputs such as nitrogenous fertilizer, which can result in the depletion of other important nutrients such as zinc over time. Hassan and Obonaya (2016) reported that soils of the study area were deficient in macro and-micro-nutrients, which are essential for crop growth and development.

Table 1: Physico-chemical properties of soil at experimental site

	2018		2019		
Property	0-15 cm	0-30 cm	0-15 cm	0-30 cm	Reference
Sand	72.40	71.55	73.32	72.55	
Silt	18.56	19.34	17.43	18.62	
Clay	9.04	10.53	8.45	9.76	
Organic C %	0.86	0.67	0.45	0.21	Allison (1965)
Soil PH	5.4	6.3	5.7	6.5	
Available N	0.04	0.02	0.05	0.03	Subbia (1956)
Available phosphorus	5.98	3.41	6.34	4.21	Olsens (1965)
Ca	1.89	1.21	2.02	1.65	Jackson (1973)
Mg	0.65	0.32	0.89	0.21	Jackson (1973)
K	0.18	0.03	0.43	0.32	Olsens (1965)
Na	0.21	0.02	0.31	0.12	Olsens (1965)
Zn	2.86	0.54	2.21	0.76	Olsens (1965)
Cu	1.38	0.87	1.42	0.21	Olsens (1965)
Fe	11.25	6.32	10.62	5.65	Olsens (1965)
Mn	6.63	4.21	5.21	3.87	Olsens (1965)

Table 2: Meteorological data in 2018 and 2019

Month	Rainfall (mm)		Temperature (^{0}C)				Relative humidity (%)	
			2018		2019			
	2018	2019	Minimum	Maximum	Minimum	Maximum	2018	2019
January	0	0	13.3	28.9	21.5	36.3	28	21
February	0	0	19.4	35.4	24.0	36.8	22	18
March	1.2	0	22.9	38.0	26.9	38.6	22	18
April	3.9	71.5	25.4	38.7	27.2	38.6	36	34
May	137.9	92.6	25.2	35.9	24.8	34.3	71	49
June	259.9	288.6	23.3	33.3	23.6	31.0	78	61
July	230.7	494.5	22.6	31.7	23.6	28.7	83	72
August	606.5	690.0	21.8	29.8	23.3	30.3	84	77
September	208.4	274.0	22.3	31.2	22.8	31.2	83	73
October	57.4	307.7	23.6	33.9	22.8	31.0	76	53
November	0	0	20.9	34.6	23.3	35.2	63	31
December	0	0	16.2	30.3	20.1	35.6	48	27
Total	1505.9	2218.9	256.9	401.7	283.9	407.6	694	534
Mean	125.5	184.9	21.4	33.5	23.7	34.0	57.8	44.5

Source: Federal Metrological Station Bauchi, Nigeria.

METEOROLOGICAL DATA

The rainfall data of the study site for 2018 and 2019 are presented in Table 2. The data showed that no precipitation was experienced in the month of February during the two cropping seasons. In both 2018 and 2019, the highest rainfall was recorded in August with values of 302.7 mm and 690 mm, respectively. The highest temperature in 2018 was observed in the month of March while in 2019 the highest temperature was recorded in the month of February.

Cultural Practices

The main plot size was 10m x 13.5m, consisting of four rows, each measuring 3 m x 0.75 m. The experimental field was ploughed, harrowed and ridged at 75 cm apart. The prepared land was marked and sub-divided into the required plots and replications in accordance with the layout of the experiment.

A mixture of one part of sesame seed and two parts of riversand was sown manually at a depth of about 2 cm, by dibbling at an intra-row spacing of 15 cm on ridges spaced 75 cm apart. The seeding were thinned to three plants per stand at two weeks after sowing. Immediately after thinning, NPK fertilizer was applied at different levels of 0, 75, 100 and 125 kg/ha.

The fully matured plants from the net plots (the two inner rows) were harvested manually by carefully cutting the stems at base using a sharp sickle. The harvested plants were placed separately in a sack and allowed to dry before threshing. The fully dried harvest from the net plots was threshed manually by gently beating the sacks with stick to separate the seeds from the capsules. This was followed by winnowing to separate the grains from the chaff.

DATA COLLECTION

Data were collected from 10 randomly tagged plants within each net plot during the plant growth and at harvest. The height of five tagged plants in each plot was measured from the base of the plant to its apex using a metre rule and the means were used for statistical analysis. Number of leaves from each of the five tagged plants in each plot were counted. The number of primary branches per plant on 5 tagged plants in each plot was counted at harvest and recorded. The number of secondary branches was counted for 5 sampled plants in each plot at harvest and the mean was calculated and recorded. Stem diameter and internode length were measured using a metre rule at the third internode. Dry matter per plant was obtained by sampling five plants from each plot at weekly interval, harvested, oven-dried and weighed to determine the shoot dry matter per plant. Leaves from five sampled plants were detached and weighed. These were then oven-dried and weighed again. The leaf area per plant was determined using leaf area-dry weight relationship as was described by Rhoads and Bloodworth (1964). The dry weight of 5 sampled plants from each plot was used to determine crop growth rate (CGR) per plant as suggested by Radford (1967). Days to 75 % flowering and days to 75 % maturity was recorded on the plants in the net plot. The number of capsules per plant was determined by counting the number of capsules on 5 sampled plants in each plot at harvest and dividing by 5. The number of seeds per capsule/locule was determined by counting the number of seeds per capsule/locule in each capsule/locule at harvest in the sampled plants and dividing by the number of sampled plants (Ahmed 2001). Grain yield per hectare was determined from the harvest of each net plot. The harvested plants were threshed and winnowed to obtain clean grains, which were then weighted and converted to yield per hectare. One thousand seed weight was determined by counting 1000 seeds and weighing using the digital weighing balance. Data were subjected to one-way analysis of variance. Means were seperated using the Duncan's new Multiple- Range Test.

RESULTS AND DISCUSSION

Growth characteristics

The variety ADAW-TING was the shortest among the eight sesame varieties studied in this experiment. The variety had the highest number of leaves, leaf area and number of primary branches. The variety EX-SUDAN had the highest stem diameter and internode length when compared with the rest of the varieties (Table 3). Varietal differences with respect to morphology have been reported (Ibrahim and Sharaf El-Deen, 2008; Nahar *et al.*, 2008). The results showed that the second-year experiment performed better than that of the first year (Table 4). This could have be due to the heavy rainfall experienced during the second year. Plant height, number of leaves, leave area, dry weight of stems, stem diameter, number of primary and secondary branches and internode length were significantly increased by NPK application in both 2018 and 2019 (Table 5). The highest plant height, number of leaves per plant and leaf area were observed with 125 kg/ha NPK application at 8 weeks after sowing.

Crop growth rate increased with increasing NPK level (Table 6). Increase in leaf area is of great importance because it is a reflection of the efficiency of photosynthesis and production of assimilates which are used in the formation of capsules. The increase in leaf area with increasing level of NPK fertilizer may be due to

increased cell-division, enlargement, differentiation and expansion of the leaves. Ibraheem (2007), Abo El-Saoud (2005), Wanas (2007 a, b) and Zaghlool *et al*. (2001, 2006) observed that growth hormones increased with increased nutrient availability in wheat and other plants.

The shoot dry matter increased with increasing NPK application up to 125 kg/ha. Increase in dry matter and other parameters may be attributed to the improvement in the physiological processes such as cell-division and differentiation as well as enhancement of growth promoters such as indole-3-acetic acid and gibberellins (Ibraheem, 2007). Also, with increased NPK application, photosynthetic activities are increased and more assimilate is produced and translocated to the sink (seeds), thereby increasing seed yield. The endogenous cytokinins are increased so that more leaves are produced, resulting in increased in photosynthetic area (Arigita *et al*., 2005).

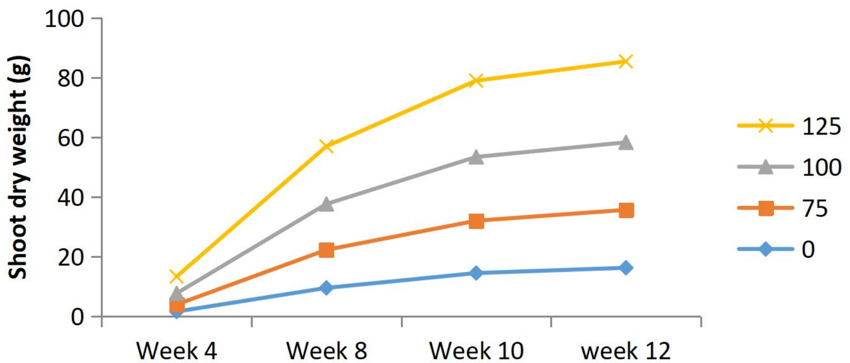

Figure 1. Effects of different levels of NPK fertilizer on shoot dry weight (g) per plant of sesame, using the combined data for 2018 and 2019.

The stimulating effect of NPK fertilizer on flowers and the number of capsules per plant may be due to the important role of these nutrients in enhancing various processes during the reproductive phase. These include flower initiation (flower bud initiation, differentiation and development), delayed flower abscission, increased pollination, fertilisation and development of fruits, increased fruit set and increased translocation of assimilates from the source to the sinks (seeds).

Table 3: Effect of variety on vegetative growth of sesame, using the combined data for 2018 and 2019

Variety	Plant height (cm)	Number of leaves per plant	Stem diameter per plant (cm)	Internode length per plant (cm)	Leaf area per plant (cm^2)	Number of primary branches per plant
ADAW-TING	63.12^{e}	256.08^{a}	1.58^{c}	10.49^{h}	927.67^{a}	22.38^{a}
E8	65.08^{d}	72.03^{e}	1.85^{c}	13.94^{c}	866.27^{e}	10.54^{e}
EX-SUDAN	85.31^{a}	93.23^{b}	3.89^{a}	15.43^{a}	927.94^{a}	12.95^{c}
KENANA-4	74.15^{c}	56.86^{f}	1.43^{d}	11.58^{f}	915.84^{c}	12.67^{c}
NCRI 01M	74.91^{c}	46.10^{g}	2.45^{b}	12.97^{d}	782.89^{g}	15.49^{b}
NCRI 02M	70.41^{e}	81.52^{c}	2.57^{b}	14.64^{b}	920.14^{b}	14.57^{bc}
NCRI 03L	77.41^{b}	43.75^{h}	3.47^{a}	12.38^{e}	882.24^{d}	11.39^{d}

NCRI 04E	76.51^{b}	75.10^{d}	1.98^{c}	11.28^{g}	863.53^{f}	8.94^{f}
SE±	0.16	8.33	0.31	0.03	12.60	2.01

Means followed by the same letter(s) within the same column are not statistically different at 5% level of probability (Ducan's Multiple-Range Test)

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Table 4: Effect of year on vegetative growth of sesame for 2018 and 2019 field experiment in Bauchi, Nigeria

Year	Plant height (cm)	Number of leaves per plant (cm)	Stem diameter per plant (cm)	Internode length per plant (cm)	Leaf area per plant (cm^2)	Number of primary branches per plant (cm)
2018	64.44^{b}	74.94^{a}	2.30^{b}	11.86^{a}	847.47^{b}	11.93^{b}
2019	69.53^{a}	70.936^{b}	2.61^{a}	11.72^{a}	859.55^{a}	12.08^{a}
SE±	0.97	2.10	0.08	0.26	3.60	0.19

Means followed by the same letter(s) within the same column are not statisticantly different at 5% level of probability (Duncan's Multiple-Range Test)

Yield and yield components

The effect of variety on days to 75% flowering and maturity was significant (Table 7). The variety E8 and EX-SUDAN flowered and matured earlier. The flowering period of NCRIBEN 01M and NCRIBEN 03L was similar. The variety ADAW-TING flowered and matured later than the other varieties. The NPK levels affected 75% flowering and maturity. The variety ADAW-TING out- performed the other varieties in the number of capsules per plant. The other varieties were not significantly different. Haruna *et al.* (2014) reported differences in days to flowering and maturity in sesame. The effect of variety on the number of seeds per capsule was significant. The varieties EX-SUDAN and ADAW-TING produced the highest number of seeds per capsule, followed by KENANA- 4. The varieties NCRIBEN 03L and NCRIBEN 04E did not differ significantly in the number of seeds per capsule. Tahir *et al*. (2015) reported the increase in the number of capsules per plant with increasing fertilizer level. The number of seeds per locule was maximum in the varieties KENANA- 4 and ADAW-TING, followed by the variety EX-SUDAN while the number of locules per capsule in the other varieties was similar.

Table 5: Effect of NPK on vegetative growth of sesame, using combined data for 2018 and 2019

NPK(kg/ha)	Plant height (cm)	Number of leaves per plant	Stem Diameter per plant(cm)	Internode length per plant (cm)	Leaf Area per plant (cm^2)	Number of primary branches per plant
0	62.11^{d}	55.43^{d}	1.48^{d}	10.89^{d}	785.39^{d}	11.65^{d}
75	69.32^{c}	63.69^{c}	2.20^{c}	13.45^{c}	848.44^{c}	16.68^{a}
100	76.23^{b}	73.71^{b}	3.34^{a}	15.27^{b}	895.48^{b}	14.79^{b}
125	88.41^{a}	156.73^{a}	2.71^{b}	16.04^{a}	1277.72^{a}	12.58^{c}
SE±	1.06	5.64	0.53	0.15	2.75	2.10

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability (Duncan's Multiple-Range Test)

The varieties differed significantly in 1000-seed weight (Table 8), with the variety E8 having the highest value, followed by EX-SUDAN. Haruna and Usman (2015) reported that the application of NPK at the rate of 65 kg/ha resulted in increased seed yield in the soybean by 9.3 % when compared with the control. The 1000-seed weight differed significantly with increasing NPK level. Olowe and Busari (2000) observed that the application of 60 kgN/ha and 13.2 kg P_2O_5/ha-[1] resulted in the highest number of capsules per plant and seed yield per hectare. Okpara *et al*. (2007) reported that the application of 75 kg N/ha, 26 kg P_2O_5/ha significantly increased the number of seeds per capsule, one thousand-seed weight and seed yield. Babeji *et al*. (2006) reported that there was a significant increase in the number of capsules per plant at 60 kg N/ha. The increase in the number of capsules per plant was accompanied by increasing number of flowers and decreased shedding of flowers and fruits.

Table 6: Crop growth rate at 6 and 10 weeks after sowing of sesame as influenced by NPK levels

NPK (kg/ha)	Week 6	Week 10
0	43.63^{d}	55.67^{d}
75	52.75^{c}	63.98^{c}
100	65.94^{b}	76.34^{b}
125	74.44^{a}	85.36^{a}
SE±	2.53	2.87

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability (Duncan's Multiple-Range Test)

The increased number of capsules per plant with incresing NPK rate up to 125 kg/ha may be attributed to increased number of flower buds, number of flowers and multiple flowers in the axils of lower nodes on the main stem. The type of leaf arrangement has been reported to control the number of flowers formed in the axils and the number of capsules per plant (Weiss, 2000). The highest number of capsules/plant (70.27) was observed at 125 kg/ha, followed by 100 kg/ha (64.27). Maximum seed yield was observed when NPK was applied at the rate of 125 kg/ha while the lowest seed yield was as observed in the control. This could be due to the effect of NPK fertilizer on yield and yield components such as number of capsules per plant and 1000-seed weight. Ahmed *et al.* (2001) reported similar findings. The increased leaf area and crop growth rate with increasing NPK rate may have contributed to the increase in yield and yield components. Similar findings have been reopted by Shehu *et al*. (2010). Haruna and Usman (2015) reported that the early application of NPK at the rate of 65 kg/ha resulted in increased yield in soyabean by 9.3 % when compared with the control. The yield increase was attributed to the increase in the number of capsules per plant.

Table 7: Influence of variety on yield and yield components of sesame, using combined data for 2018 and 2019

Variety	DT75%F	DT75%M	NC plant^{-1}	NSPC	NSPL	1000sw(g)	GY (kg/ha)
ADA-WTING	77.54^{a}	125.47^{a}	64.56^{b}	84.92^{b}	21.23^{b}	3.16^{c}	1055.35^{b}
E8	57.78^{c}	91.52^{f}	30.33^{h}	51.77^{g}	12.94^{g}	2.79^{d}	610.65^{h}
EX-SUDAN	59.48^{b}	100.56^{d}	66.67^{a}	92.55^{a}	23.13^{a}	3.75^{a}	1228.56^{a}
KENANA-4	57.33^{d}	97.83^{e}	58.45^{c}	83.43^{c}	20.85^{c}	3.18^{b}	1020.59^{c}
NCRI01M	52.55^{e}	110.62^{b}	35.73^{e}	59.84^{e}	14.96^{e}	2.31^{e}	1009.83^{e}
NCRIB 02M	59.47^{b}	100.42^{d}	37.85^{d}	66.34^{d}	16.58^{d}	3.06^{c}	935.88^{f}
NCRIBN 031	52.68^{e}	105.47^{c}	31.74^{g}	58.56^{ef}	14.64^{e}	2.31^{e}	1010.8^{d}
NCRIB04E	59.46^{b}	105.47c	33.93^{f}	57.33^{f}	14.33^{f}	1.98^{ef}	809.56^{fg}
SE±	0.43	1.54	2.87	0.56	0.32	0.63	9.78

Means followed by the same letter (s) within the same column are not significantly different at 5% level of probability (Duncan's Multiple-Range Test)

DT75%F = Days to 75% flowering; DT75%M = Days to 75% maturity; NC = number of capsules; NSPC =number of seeds per capsule; NSLP= number of seeds per locule

The 1000-seed weight was also observed to have increased with increasing NPK rate (Table 8). With increased NPK fertiliser, photosynthetic activity was enhanced resulting in high production of assimilates by the source (leaves), which was translocated to the sink (seeds). Similar findings have been reported by Bahera *et al.* (20017), Ibrahim *et al.* (2001), Abd El-dayem *et al.* (2005), Abo El-Saoud (2005), Zaghlool *et al.* (2006), Wanas (2007a,b), Ibraheem (2007), Gurpreet and Nelson (2015) and El-Moawaty (2008). Generally, yield and yield components of sesame were higher in 2019, than in 2018 across the varieties. This could be due to higher rainfall and lower temperature (Table 2). A linear relationship was observed between grain yield and leaf area (Figure 3). As the leaf area increasesd, grain yield also increased.

Table 8: Effect of NPK on yield and yield components of sesame, using combined data for 2018 and 2019

NPK (kg/ha)	(DT75%F)	(DT75%M)	NC plant-[1]	NSPC	NSPL	Seed yield (kg/ha)	1000 sw(g)
0	46.34^{d}	95.48^{d}	32.54^{d}	50.32^{d}	13.44^{d}	806.58^{d}	1.35^{d}
75	47.76^{c}	98.58^{c}	25.78^{c}	59.56^{c}	15.50^{c}	978.65^{c}	1.97^{c}
100	67.45^{a}	115.65^{b}	36.55^{b}	64.27^{b}	19.34^{b}	988.45^{b}	3.81^{b}
125	52.92^{b}	126.77^{a}	40.43^{a}	70.27^{a}	17.65^{a}	1209.76^{a}	4.28^{a}
SE±	0.15	0.87	2.02	0.42	0.23	5.54	0.92

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability (Duncan's Multiple-Range Test)
DT75%F = Days to 75% flowering; DT75%M = Days to 75% maturity; NC = Number of capsules; NSPC Number of seeds per capsule; NSLP= number of seeds per locule

Table 9: Effect of year on yield and yield components of sesame, using combined data for 2018 and 2019

Year	(DT75%F)	(DT75%M)	NC plant-1	NSPC	NSPL	GY(kg/ha)	1000 sw (g)
1	62.17^{a}	99.34^{b}	34.97^{b}	57.32^{b}	14.08^{b}	959.21^{b}	3.66^{a}
2	62.22^{a}	102.83^{a}	40.76^{a}	59.30^{a}	15.36^{a}	1006.1^{a}	2.64^{ab}
SE±	0.57	0.72	0.52	0.71	0.20	8.39	0.07

Means followed by the same letter(s) within the same column are not significantly different at 5% level of probability (Duncan's Multiple-Range Test)
DT75%F = Days to 75% flowering; DT75%M = Days to 75% maturity; NC = Number of capsules; NSPC =Number of seeds per capsule; NSLP= Number of seeds per locule

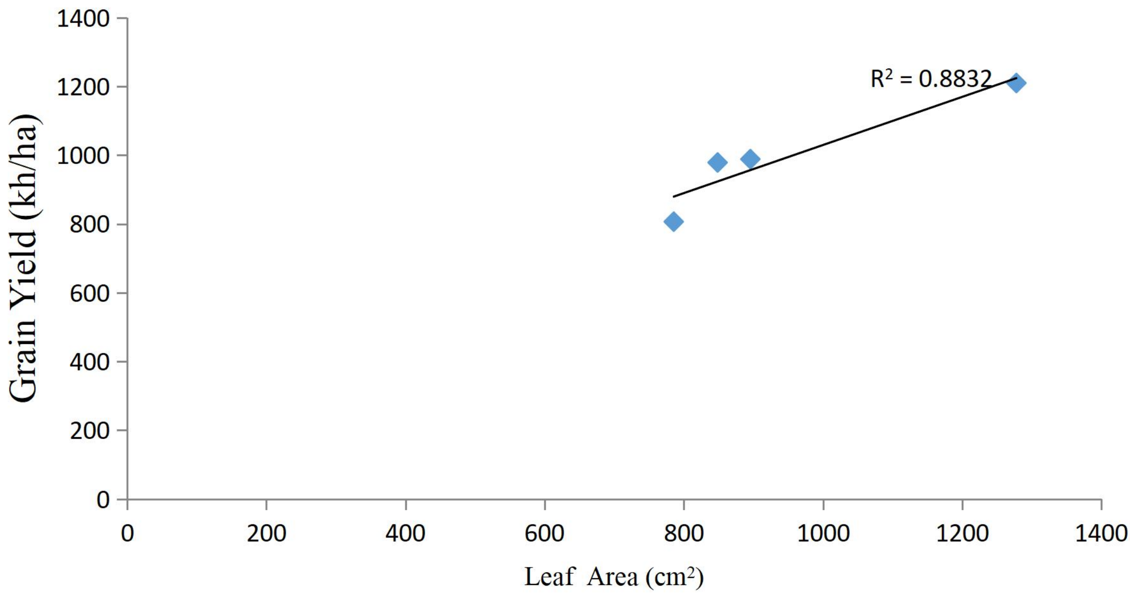

Figure 2: Effects of different levels of NPK on the relationship between leaf area per plant and grain yield of sesame, using combined data for 2018 and 2019.

CONCLUSION

NPK application at the rate of 100 kg/ha and 125 kg/ha resulted in significant increase in growth parameters such as plant height and number of leaves per plant. Maximum seed yield was observed at 125 kg/ha. Sesame varieties responded differently to different levels of NPK application. The varieties EX-SUDAN, KENANA and ADAW-TING showed potentials to be adopted for cultivation in Bauchi using NPK fertiliser at the rate of 125 kg/ha.

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