DOI: 10.1515/cerce-2017-0015
Available online: www.uaiasi.ro/CERCET_AGROMOLD/
Print ISSN 0379-5837; Electronic ISSN 2067-1865

Original Article

Cercetări Agronomice în Moldova
Vol. L , No. 2 (170) / 2017: 57-72

EFFECTS OF NEEM SEED CAKE AND NPK FERTILIZER ON THE GROWTH AND YIELD OF SESAME (*SESAMUM INDICUM* L.)

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Received: Feb. 16, 2017. Revised: Apr. 29, 2017. Accepted: May 12, 2017. Published online: June 30, 2017

ABSTRACT. Soils of the southern Guinea savannah zone of Nigeria are low in organic matter content, inherently infertile due to intensive weathering and leaching caused by high temperature and rainfall. A field experiment was conducted at the Teaching and Research Farm of the University of Ilorin, during the 2013 and 2014 cropping seasons, to determine the effect of neem seed cake and NPK fertilizer on the performance of sesame crop (Ex Sudan cv). Treatments consisted of three levels of NPK fertilizer 20:10:10, applied at 0, 100 and 200 kg ha^{-1} and neem seed cake (NSC), applied at 0, 1, 2, 3 and 4 t ha^{-1}. The experiment was laid out in a 3 x 5 factorial arrangement replicated thrice. Data were collected on soil parameters (some physical and chemical properties), plant growth parameters (plant height, number of leaves and leaf area) and yield components (number of capsules per plant, weight of seeds per plant and weight of seeds per hectare). The result of the study indicated that using the highest level of application of NPK fertilizer, neem seed cake and their combinations significantly (p<0.05) increased the growth of sesame plants, in the 2 years of study. However, the 100 kg ha^{-1} of NPK and 3 tha^{-1} and their combinations gave the highest yield and yield components of sesame during the period of study. The result of the study revealed that using high levels of NPK, neem seed cake and their combinations favoured vegetative growth at the expense of seed formation. Farmers are therefore encouraged to use organic and inorganic fertilizer moderately to prevent excessive vegetative growth of sesame.

Keywords: sesame; inorganic and organic fertilizers; vegetative growth; yield.

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INTRODUCTION

Sesame (*Sesamum indicum* L.), also known as beniseed in West Africa, sim-sim in East Africa, is an oil producing crop belonging to the Pedaliaceae family, grown in both tropical and sub-tropical regions of Africa, Asia and Latin America (Haruna, 2011) and to some extent in Russia for edible oil and animal feed (Tunde-Akintunde and Akintunde, 2007). In Nigeria, sesame is cultivated in the savanna zone, where it is regarded as a crop with high economic potentials, both as raw material for industry and reliable foreign exchange earner (Alegbejo *et al.,* 2003). Hence attention has been focused on the crop, and this has resulted in an increase in area of production (Umar *et al.,*2014). In addition, the demand for its seeds has made it the third largest export commodity crop after oil and cocoa (*Theobroma cacao*), in terms of foreign exchange earned in Nigeria (FAO, 2012; Umar *et al*., 2014). Sesame oil is a raw material used in the production of paints, soaps, cosmetics, perfumes, insecticides, canned sardine and canned beef, as well as for pharmaceutical and ethno botanical uses (RMRDC, 2004; Haruna and Abimiku, 2012). It is a good source of minerals and vitamins, such as calcium and phosphorous and the seed cake after oil extraction is an excellent high-protein feed for poultry and livestock (Malik *et al*., 2003). Moreover, the addition of sesame to high lysine meal of soybean (*Glycine max*) produces a well-balanced animal feed (Ram *et al.*, 1990).

The practice in Nigeria of soil fertility restoration is the use of bush fallow system, but due to the reduction in fallow period from seven to two years, this method is no longer sustainable and the use of animal manure, compost, crop by-products and green manure has become important (Vanlauwe *et al.,* 2002). Soils will be mined by repeated cropping without the addition of organic or inorganic inputs (Waddington, 2003).

The use of neem seed cake, which is a form of organic manure, has become imperative. Neem *(Azadirachta indica)* seed cake (residue of neem seed after oil extraction), when added to the soil, not only improves the soil with organic matter, but also lowers nitrogen losses by inhibiting nitrification. It increases the yield of crops on the long term, an excellent soil conditioner and has no negative effect on the environment (Lokanadhan *et al.,* 2012). The seed cake also contains nitrogen (2 - 5%), phosphorus (0.5 - 1.0%), potassium (1 - 2%), calcium (0.5 - 3%) and magnesium (0.3 -1%) (Radwanksi and Wickens, 1981). Neem seed cake, as a form of organic manure on decomposition, promotes an increase in soil microbial communities and this in turn will affect the growth and yield of crops. The combined use of neem seed cake, that is a form of organic manure, and a inorganic fertilizer will increase nutrient use efficiency and reduce environmental stress (Bationo, 2008). Neem seed cake mixed with urea fertilizer significantly improves efficiency of fertilizer utilization in crop production by gradual release of nitrogen to crops thereby increasing the fertility of the soil (Ketkar, 1983). In addition, combined application of organic and inorganic fertilizer has lasting effects on nutrients and physical properties of soil than when either source is used alone (Bationo, 2008).

Sesame is an important crop, among rural farmers, who practice low input agriculture, which often results in low yield. In Nigeria, sesame is cultivated by smallholder farmers (USAID, 2002) and the area under cultivation has remained very low, due to absence of high yielding varieties and poor cultural practices used by peasant farmers. There is a need forintegrated use of neem seed cake, a form of organic manure, which is made up of both macro and micro nutrients and also has the ability of releasing nutrients slowly, and inorganic fertilizer, which on the other hand has concentrated nutrients, that are released very fast, which will help to bridge this yield gap. The objective of this study was, therefore, to evaluate the effects of neem seed cake (NSC) and NPK fertilizer on the growth and yield of sesame.

MATERIALS AND METHODS

Site description

The study was conducted during the 2013 and 2014 cropping seasons, at the Teaching and Research Farm of the University of Ilorin, Ilorin, Nigeria (8^o48'N, 4^o58'E and 307 m above sea level) in a southern Guinea savannah zone of Nigeria. The site was a 2 years fallow land, that had been cropped to maize (*Zea mays*) and cassava (*Manihot esculenta*) for 2 years, prior to the establishment of the experiment. Physico-chemical properties of the soil before and after cropping are summarized in *Table 1*.

Meteorological data for the 2 years of study were obtained from the Lower Niger River Basin Development Authority, Ilorin, and are presented in *Table 2*.

Experimental design

The experimental design was a randomized complete block, fitted into a 3 x 5 factorial scheme, which consisted of three levels of NPK fertilizer 20:10:10 (0, 100 and 200 kg/ha) and five levels of neem seed cake (0, 1, 2, 3 and 4 t/ha), replicated thrice.

Table 1 - Soil properties of the experimental site before and after cropping in 2013 and 2014

Year	Soil pH	Percent (%)			ppm	cmol/kg			
		Org. C	Org. Matter	Total N	P	K	C	Mg	Na
2013a	6.1	0.53	0.92	0.04	4.5	0.30	4.0	1.0	0.2
2013b	6.2	1.02	1.76	0.14	5.6	0.35	6.0	1.5	0.4
2014	6.2	0.80	1.38	0.11	4.3	0.29	4.3	1.2	0.3

a. Before initial cropping; b. End of first year cropping

Table 2 - Meteorological data in 2013 and 2014

Months	Rainfall (mm)		Temperature (°C) 2013		Temperature (°C) 2014		Relative humidity (%)	
	2013	2014	Min.	Max	Min.	Max	2013	2014
January	0.5	6.3	19.4	34.2	20.6	34.5	81	81
February	39.2	34.2	22.7	34.8	20.7	35.3	81	82
March	39.0	71.0	24.2	35.6	23.8	34.8	81	81
April	181.8	321.4	23.6	32.3	22.5	32.7	81	81
May	81.8	163.8	22.7	31.5	22.7	39.6	81	81
June	132.9	154.4	20.9	34.2	21.9	30.4	80	81
July	107.3	82.1	21.8	28.0	21.9	29.6	80	81
August	17.7	94.9	21.4	27.8	21.3	27.5	80	80
September	202.5	391.6	21.5	29.2	21.2	28.5	80	80
October	154.3	259.4	21.7	31.0	21.7	31.6	80	81
November	0.0	0.0	23.4	31.5	22.7	32.5	83	81
December	11.4	0.0	19.4	33.5	19.4	33.2	82	82
Mean	80.8	131.6	21.9	32.0	21.7	32.5	81	81

Land preparation and planting

The land was ploughed and harrowed before mapping out was done. The experiment comprised of 15 treatments, which were replicated thrice. The size of each plot was 2 m x 5 m, with 1 m alleyway between the plots and replicates. NSC was applied to the soil one week before sesame seeds (cv Ex Sudan) were sown by drilling and the plants were later thinned at a spacing of 20 x 50 cm. Weed control and fertilizer application. Weed control was carried out by hoe weeding at 3 and 6 weeks after planting (WAP) and NPK 20:10:10 fertilizer was applied at 3 WAP, using the side band placement method.

Data collection

Data collected on growth and yield indicators during the study include:

Growth indicators

The plant height of the five-tagged plants was assessed by measuring the stem from the base of the plant to the terminal point using a measuring tape. The number of leaves of the five-tagged plants was visually assessed by counting the green leaves, while the leaf area was assessed by using the dry weight method as described by Rhoads and Bloodworth (1964).

Yield and yield components

The yield and yield components of sesame assessed were: number of capsules per plant, seed weight per plant and total yield per ha. Number of capsules per plant and this was determined by counting the number of capsules per plant at harvesting. The seed weight per plant was determined by harvesting all the capsules in the five-tagged plants, sun dried and shelled to get the mean yield per plant. The yield per hectare was extrapolated from the seed weight per plant.

Data analysis

The data collected were subjected to analysis of variance (ANOVA) using Genstat 12 statistical package and their means were separated by using the least significant difference (LSD), at 5% probability level, based on the work of Steele and Torrie (1980).

RESULTS AND DISCUSSION

Soil analysis

The results of the soil analysis presented in *Table 1* indicated that the soil of the experimental site was slightly acidic, throughout the experimental period, and very low in most of the plant nutrients evaluated, except potassium, implying low fertility status. There was, however, an improvement after the first year's cropping, which may be attributed to the residual effect of the NSC application. The organic matter content was low at the onset of the experiment, but at the end of the first cropping season it was moderate and low at the end of the second cropping season, hence poor nutrient status. Salako (2003) had reported that the southern Guinea savannah zone of Nigeria has fragile top soil, which contains large proportion of sand and low level of organic matter. Jones and Wild (1975) had also asserted that the soils of the southern Guinea savannah are inherently low in fertility, cation exchange and water holding capacities, due to low organic matter content. Garuba and Oyinlola (2014) and Varalakshmi *et al.* (2007) asserted that the use of organic and inorganic fertilizers improved the organic carbon, available N, P and K status of the soil in groundnut (*Arachis hypogaea*) and finger millet (*Eleusine coracana*). Eifediyi *et al.* (2016) also reported that the use of mulch (a form of organic manure) and NPK fertilizer improved the growth and yield of sesame in a southern Guinea savannah zone of Nigeria. Gaur *et al.* (1992) had posited that neem seed cake is a rich source of nutrients, which increases the carbon content and improves soil physical properties, it is quick acting, provides slow and steady nourishment, thereby increasing the yield of crops.

Meteorological data

The month of September experienced the highest rainfall, while the months of November, December and January experienced the lowest rainfall during the 2 years of study. This fluctuation in rainfall and temperature has adverse effect on crop growth and development and often brings about variation in crop yield in different seasons. Sivakumar *et al.* (2005) and IPCC (2007) had reported that the major cause for yield fluctuations in agriculture across the world is related to weather and climatic effects, such as erratic rainfall, which severely affects agriculture, especially in developing countries, where irrigation facilities are not available and crop cultivation is rain fed.

Growth indicators

Plant height

The data on the plant height as affected by neem seed cake and NPK fertilizer at 4, 6 and 8 WAP in 2013 and 2014 are presented in *Table 3*.

The result shows that at the three sampling periods, there were significant ($p<0.05$) differences observed between the treated plots and the control, following NPK fertilizer and neem seed cake application. The tallest plants were observed with combined application of NPK fertilizer and the NSC amendment. The combined application ensured all round nutrient availability to the crop; the inorganic components were readily available and hence absorbed for early crop growth and development, while the organic components of the NSC was released slowly after mineralization thereby making nutrients available for the development of the crop. This report is in agreement with the findings of Eifediyi *et al.* (2016), who observed that the application of mulches (a form of organic manure) and NPK fertilizer improved the plant height of sesame in Ilorin, Nigeria. The observation was also in line with the findings of Bonsu *et al.* (2003), who reported that an increase in the level of fertilizer application also resulted in an increase in the growth parameters of sesame. Narkhede *et al.* (2001) reported that the application of castor oil seed cake at 1 t/ha and 50 kg of N was found to be the most effective strategy to maximize the productivity of sesame. Jaishankar and Wahab (2005) reported that the application of NPK fertilizer and vermicompost at 5 t/ha gave the highest growth and yield components of sesame. The availability of nutrients to the crop and their subsequent absorption of the assimilates, which were translocated to the different parts of the plant, might be responsible for the increased growth observed in the experiment.This may be attributed to better availability and uptake of essential nutrients present in the NPK fertilizer and the neem seed cake, which were readily available to the plants for absorption.

Number of leaves

Data on the number of leaves of sesame as affected by neem seed cake and NPK fertilizer in 2013 and 2014 are presented in *Table 4*. The result shows that at the three sampling periods of 4, 6 and 8 WAP, applying neem seed cake at the rate of 4 t/ha produced the highest number of leaves, which was significantly different ($p<0.05$) from the other rates and the control. The application of 200 kg/ha of NPK fertilizer at 4 and 8 WAP produced the highest number of leaves, but no significant difference was observed. At 6 WAP, applying 200 kg/ha of NPK fertilizer produced the highest number of leaves, which was significantly different ($p<0.05$) from the other rates. The combination of NPK fertilizer at 200 kg ha^{-1} and NSC at 4 t ha^{-1} produced the highest number of leaves across the three periods of sampling, but there was significant ($p<0.05$) interactions only at 6 WAP. The improved soil fertility was enough for assimilate production and hence increase in the number of leaves produced.

Table 3 - Effects of NPK fertilizer and neem seed on the plant height (cm) of sesame at 4, 6 and 8 weeks after planting (WAP) in 2013 and 2014

	NPK (kg/ha)	Neem seed cake (NSC) (t/ha) 2013						Neem seed cake (NSC) (t/ha) 2014					
		0	1	2	3	4	Mean	0	1	2	3	4	Mean
4WAP	0	10.67	15.7	19.37	23.6	29.8	19.83	13.7	21.17	26.57	31.37	40.43	26.67
	100	10.77	15.97	20.73	25.58	30.57	20.78	14.43	23.17	28.7	34.26	40.67	28.23
	200	12.03	16.7	21.1	26.23	32.2	21.65	16.17	25.9	32.8	36.83	44.4	31.23
	Mean	11.13	16.12	20.4	25.23	30.86		14.74	23.41	29.36	34.21	41.83	
	LSD (0.05)	NPK 1.62	NSC 2.09	NPK x NSC 3.71				NPK 4.60	NSC 5.24	NPK x NSC 9.84			
6WAP	0	21.6	44.7	64.2	72.8	79.9	56.64	30.9	69	85.4	105.1	114.8	81.04
	100	22.6	48.2	64.5	77.7	86.8	59.96	31.4	72.5	90.4	105.9	118.2	83.68
	200	24.7	50.2	73	8.3	99.5	67.14	39.6	77.2	94.4	112.5	124.2	89.58
	Mean	22.8	47.7	67.2	79.4	88.7		34	72.9	90.1	107.8	119.1	
	LSD (0.05)	NPK 5.49	NSC 6.71	NPK x NSC 12.2				NPK 8.50	NSC 9.70	NPK x NSC 18.2			
8WAP	0	40.8	83.4	96.9	114.5	130.7	93.26	38.73	84.77	94.47	118.49	140	95.2
	100	41.2	84.7	109.4	126.2	136.4	99.58	43.87	86.1	113.81	120.49	139	101
	200	46.1	96.5	113.2	127.2	137	104	46.62	99.11	119.99	129.09	141	107
	Mean	42.1	88.2	106.5	122.6	134.7		43.07	89.99	109.42	122.69	140	
	LSD (0.05)	NPK 7.51	NSC 8.92	NPK x NSC 16.4				NPK 171	NSC 512	NPK x NSC 2.619			

Table 4 - Effects of NPK fertilizer and NSC on the number of leaves of sesame at 4, 6, and 8 weeks after planting in 2013 and 2014

	NPK (kg/ha)	Neem seed cake (t/ha) 2013						Neem seed cake (t/ha) 2014					
		0	1	2	3	4	Mean	0	1	2	3	4	Mean
4WAP	0	9.63	17.63	22.13	26.83	29.77	21.2	13.13	21.33	26.07	30.32	35.33	25.22
	100	10.57	19.07	22.67	25.2	27.67	21.03	15.07	21.87	26.97	34.0	40.43	27.67
	200	10.93	17.07	22.7	25.1	30.53	21.17	13.73	22.8	27.73	35.2	41.87	28.27
	Mean	10.38	17.92	22.33	25.71	29.35		13.93	22	26.92	33.14	39.21	
	LSD (0.05)	NPK 1.57	NSC 2.03	NPK x NSC 3.60				NPK 1.79	NSC 2.31	NPK x NSC 4.10			
6WAP	0	23.09	40.3	49.3	56.5	69.3	47.8	20.63	38.72	46.43	58.57	69.1	46.7
	100	23.1	48	70.8	85.5	97.9	65	26.35	41.32	69.33	92.07	93.55	64.53
	200	25.2	53	74.7	91.3	90	68.6	27.85	56.79	81.61	96.12	101	72.66
	Mean	24	47.1	69.9	77.8	88.7		24.95	45.61	65.79	82.25	87.9	
	LSD (0.05)	NPK 4.14	NSC 8.26	NPK x NSC 12.40				NPK 0.782	NSC 1.010	NPK x NSC 1.749			
8WAP	0	44.3	73.3	78.5	87.3	100.5	76.8	37.3	63.3	75.3	83.5	96.5	71.2
	100	40	83.5	95.8	105.2	121.9	89.3	31	67.1	90.4	102.9	119.9	82.2
	200	41	78.8	94.8	113.4	128.1	91.2	32.1	69.5	85.3	107.7	119.5	82.8
	Mean	41.8	78.5	89.7	102.2	116.8		33.5	66.6	83.7	98	111.9	
	LSD (0.05)	NPK ns	NSC 21.85	NPK x NSC 38.62				NPK ns	NSC 17.68	NPK x NSC 31.37			

Table 5 - Effects of NPK fertilizer and neem seed cake on the leaf area (cm^2) per plant of sesame in 2013 and 2014

	NPK (kg/ha)	Neem seed cake (t/ha) 2013						Neem seed cake (t/ha) 2014					
		0	1	2	3	4	Mean	0	1	2	3	4	Mean
4WAP	0	20.38	36.44	39.77	44.14	48.48	37.84	21.22	25.10	27.40	28.22	30.4	26.45
	100	27.24	35.43	38.00	41.87	47.32	37.97	22.83	31.90	30.80	29.42	27.80	28.54
	200	28.91	35.53	38.79	41.84	46.06	38.11	24.49	28.50	31.20	29.42	33.60	30.17
	Mean	27.84	35.73	38.85	42.62	47.28		22.85	27.10	29.30	30.7	32.0	
	LSD (0.05)	NPK 1.24	NSC 1.48	NPK x NSC 2.72				NPK 1.369	NSC 1.769	NPK x NSC ns			
6WAP	0	30.25	38.82	45.80	50.27	52.36	43.50	33.42	37.30	39.00	41.38	43.24	38.85
	100	31.95	42.49	46.33	51.48	54.31	45.30	34.59	38.50	40.70	42.40	43.49	39.95
	200	32.19	42.98	47.01	52.60	55.77	46.11	35.12	45.20	46.70	46.69	48.92	50.26
	Mean	31.46	41.43	46.38	51.12	54.15		34.38	40.40	42.10	44.20	45.66	
	LSD (0.05)	NPK 1.30	NSC 1.67	NPK x NSC 2.97				NPK 2.789	NSC 3.600	NPK x NSC ns			
8WAP	0	**32.84**	48.82	51.43	54.94	57.35	49.08	32.64	46.28	50.25	54.50	57.98	48.33
	100	33.30	48.94	52.01	56.78	60.44	50.29	32.38	46.91	50.53	54.81	58.94	48.71
	200	34.55	50.05	53.23	59.16	61.36	51.67	33.20	49.05	51.28	57.82	60.12	49.65
	Mean	33.56	49.27	52.22	56.96	59.71		32.74	47.41	50.71	55.71	59.01	
	LSD (0.05)	NPK 1.45	NSC 1.93	NPK x NSC 3.38				NPK 1.37	NSC 1.78	NPK x NSC 3.15			

Table 6 - Effects of NPK fertilizer and neem seed cake on the yield and yield components of sesame in 2013 and 2014

	NPK (kg/ha)	Neem seed cake (t/ha) 2013						Neem seed cake (t/ha) 2014					
		0	1	2	3	4	Mean	0	1	2	3	4	Mean
Number capsules/ plant	0	24.77	41.13	48.17	58.8	54.17	45.41	18.23	31.93	39.3	51.07	44.60	37.03
	100	27.03	42.27	49.6	61.4	55.94	47.25	21.1	32.27	39.4	51.37	44.67	37.76
	200	28.23	42.33	49.7	62.13	56.03	47.68	22.8	35.4	42.07	53.93	48.80	40.58
	Mean	26.68	41.91	49.16	60.78	55.38		20.71	33.2	40.27	52.12	45.99	
	LSD (0.05)	NPK 1.95	NSC 2.53	NPK x NSC 4.48				NPK 1.74	NSC 2.24	NPK x NSC 3.98			
Seed wt/ plant (g)	0	1.04	2.7	4.97	7.27	6.12	4.31	1.09	2.95	4.52	7.36	6.25	4.44
	100	1.24	3.35	4.64	7.51	6.49	4.65	1.29	3.41	4.68	7.46	6.55	4.68
	200	1.26	3.5	4.78	7.57	5.95	4.62	1.39	3.66	4.93	7.52	6.90	4.88
	Mean	1.18	3.19	4.61	7.45	6.19		1.26	3.34	4.71	7.44	6.57	
	LSD (0.05)	NPK 5.49	NSC 6.71	NPK x NSC 12.2				NPK 8.50	NSC 9.70	NPK x NSC 18.2			
Seed wt/ha (kg)	0	104.33	270.33	439.67	727	612	430.67	109.33	295.33	452.33	736	624.67	443.53
	100	123.67	335	464	751.33	649	464.6	129.33	341	468	745.67	655.33	467.87
	200	126.33	350.33	478	756.67	592.67	460.8	139.0	365.67	493.33	751.67	690	487.93
	Mean	118.11	318.56	460.56	745	617.89		125.89	334	471.22	744.44	656.67	
	LSD (0.05)	NPK 4.56	NSC 5.89	NPK x NSC 10.19				NPK 2.54	NSC 3.280	NPK x NSC 5.681			

The leaves are the pivot in photosynthetic processes which means more food was produced for translocation to different parts of the plants. This report is in line with the findings of Fathy and Mohammed (2009), who stated that vegetative production in plants increases with increased fertilizer level. Eifediyi *et al.* (2016) also observed an increase in the number of leaves of sesame when inorganic fertilizer and mulch was used in a southern Guinea savannah zone of Nigeria and disagreed with the findings of Langham and Wiermeers (2006), who argued that response of sesame to fertilizer application was highest at the least level of fertilizer application.

Leaf area

Data on the leaf area of sesame in 2013 and 2014 is presented in *Table 5*. At the three sampling periods in 2013, using NPK at the rate of 200 kg/ha produced the largest leaf area, which was significantly different ($p<0.05$) from the control. Also, using the NSC at the rate of 4 t/ha produced the largest leaf area, which was significantly different ($p<0.05$) from the control. There was also a significant ($p<0.05$) NPK and NSC interaction. A similar trend of the observations in 2013 was recorded in 2014. There was a significant NPK fertilizer ($p<0.05$) and significant NSC ($p<0.05$) at the three sampling periods, but no significant interaction at 4 and 6WAP, except at 8WAP. The leaf area produced by the plant is a reflection of the nutrient provision by the NPK fertilizer and NSC and their combinations after mineralization of the NSC and NPK fertilizer, which improved the physical properties of the soil. The leaf area produced by the combined application may have helped the plants to intercept and convert sunlight energy for assimilate production; thus, intercepting light more efficiently (Caliskan *et al.*, 2004), because nutrients were available for the plant, which were utilized for assimilate production and were later translocated to other parts of the plant. This is in agreement with the findings of Ayotamuno *et al.* (2007), who attributed the increase in leaf area due to fertilizer application, to a peculiar consumptive nutrient use in the soil, due to nitrogen availability for absorption by the crop. This may have been responsible for the vegetative growth experienced by the sesame plant. The response of sesame to higher rate of application to leaf area maybe an indication that the nutrient absorbed by the plants was utilized for cell multiplication, amino acid synthesis and energy formation that acted as structural compounds of chloroplast and essential component in photosynthesis (Ng'etich *et al.*, 2013). In addition, the low leaf area experienced in the control may be attributed to nutrient deficiency, which has been reported to reduce leaf area, hence reduced surface light interception for photosynthesis (Cechin and Fumis, 2004).

Yield and yield components

The data on the yield and yield components of sesame in 2013 and 2014 are presented in *Table 6*. The increase in the NSC application led to an increase in the number of capsules per plant up to 3 t/ha and decreased at 4 t/ha. The application of 3 t/ha produced the highest number of capsules, which were significantly ($p<0.05$) different from the other treatments. In the same vein, an increase in NPK fertilizer application led to an increase in the number of capsules up to the 100 kg ha^{-1} and decreased at 200 kg ha^{-1} treated plots in 2013, but in 2014, the 200 kg ha^{-1} treated plot produced the highest number of capsules, which was significantly different ($p<0.05$) from the control. There was also a significant NSC and NPK fertilizer interaction ($p<0.05$). Study carried out at Varanasi, Ultra Pradesh, India, by Jadhav *et al.* (1992) showed that there was no significant effect on the number of capsules per plant with the application of fertilizer. This disagrees with this research, which showed significant response of sesame capsules to increase in the rate of fertilizer application.

Seed weight per plant

The results of the seed weight per plant presented in *Table 6* showed an increase in the seed weight per plant with increasing rates of NSC and NPK fertilizer application. This finding is in agreement with the findings of Duhoon *et al. (*2004), who stated that seed weight per capsule varied by no more than ± 4% from the overall means as fertilizer increases. From the result, it appears that the number of capsules per plant increased due to the increased rate of fertilizer application up to certain level, but excess application of nitrogen enhanced the vegetative growth, instead of pod formation as reported by Pathak *et al. (*2002). Moreover, seed weight and plant height has been reported to have direct effect on sesame yield in Nigeria (Ogunremi and Ogunbodede, 1986).

Seed weight per hectare

The results of effects of NSC and NPK fertilizer on seed weight per hectare of sesame in 2013 and 2014 are presented in *Table 6*. The seed weight increased significantly ($p<0.05$) with increase in the rate of NSC application up to the 3 t/ha and declined at the 4 t/ha. Similarly, the seed weight also increased significantly ($p<0.05$) with increase in NPK fertilizer application with the highest recorded at 100 kg ha^{-1} in 2013 and in 2014 the highest seed weight was recorded at the 200 kg ha^{-1}, but not significantly different from the 100 kg ha^{-1} applied plot. This is in line with the works of Ojikpong *et al.* (2007) and Haruna *et al.* (2011), who all observed that yield increased with increased level of fertilizer application. The higher rates of neem seed cake and inorganic fertilizer produced the highest number of capsules per plant and seed yield per plant. This can be adduced to better availability and uptake of the nutrients, which might have led to the balanced C/N ratio and increased plant metabolism (Emura and Hosoya, 1979). Neem seed cake contains 2-5% nitrogen, 0.5 – 1% phosphorus, 1-2% K, 0.3 – 1% Mg 0.5 – 3% Ca (Radwanksi and Wickens, 1981). The incorporation of neem seed cake has the tendency of increasing the micronutrient content of the soil as most organic manures.

CONCLUSION

The poor fertility status of the soil thereby justifies the need for amendment, in the form of NPK fertilizer and neem seed cake, to improve soil fertility, growth and yield of crops. The neem seed cake has an organic matter content, which has the ability to improve the physical characteristics of the soil, leading to improved water and nutrient holding capacities of the soil that probably aided crop growth and seed yield. The result of this trial indicated that the area is inherently low in soil fertility; froth with rapid organic matter depletion because of high temperature, bush burning and fast rate of decomposition and fast rate of weathering. Moreover, the neem seed cake, which was used for the study, increased the organic matter content of the soil. However, higher rates of nutrient application favoured vegetative growth at the detriment of seed formation. It is recommended that moderate application of fertilizer should be encouraged to forestall vegetative growth at the expense of seed formation. In addition, the application of neem seed cake alone and in combination with reduced rates of NPK fertilizer improved soil properties and significantly increased the growth and yield components of sesame.

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