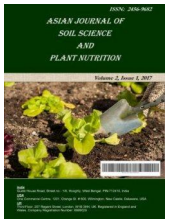

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Response of Cassava (*Manihot esculenta* Crantz) and Sesame (*Sesamum indicum* L.) to Different Levels of NPK Fertilizer Application in Cassava/Sesame Intercrop in Makurdi, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author JAI designed the study, wrote the protocol, the first draft of the manuscript and managed the literature searches. Authors TI and EEA managed the field, collected data and performed the data analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Field experiments was conducted during the 2014 and 2015 growing seasons at the Teaching and Research farm of the Federal University of Agriculture, Makurdi to evaluate the response of cassava and sesame to different rates of fertilizer NPK 20:10:10 application under intercropping. The treatments consisted of factorial combinations of three levels of NPK 20:10:10 (0 kg/ha, 200 kg/ha, 400 kg/ha) and two cropping systems [sole cropping (cassava and sesame) and intercropping (cassava + sesame)] laid out in randomized complete block design (RCBD) with three replications. Sole cropping gave significantly higher plant height at harvest, number of leaves at harvest, number of branches at harvest, number of roots per plant, root diameter and root yield of cassava than intercropping. Fertilizer level at 400kg/ha gave significantly ($P \leq 0.05$) higher plant height at harvest, number of leaves at harvest, number of branches at harvest, number of roots per plant, root diameter and root yield of cassava than 200 and 0 kg/ha NPK 20:10:10 fertilizer respectively. Intercropping gave higher number of days to 50% flowering of sesame than sole

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cropping. However, sole cropping gave significantly higher plant height at harvest, number of leaves at harvest, number of branches at harvest; stem girth, number of capsules per plant, grain yield and 1000-seed weight of sesame than intercropping. Sesame yield and growth parameters increased with increase in NPK fertilizer application. All intercrop combinations had LER values above 1.0 indicating intercrop advantages. Therefore 400kg/ha NPK 20:10:10 should be recommended for cassava/sesame intercrops in Makurdi Location, Nigeria.

Keywords: Cropping system; fertilizer levels; cassava-sesame intercrop; yield advantage.

1. INTRODUCTION

Cassava (*Manihot esculenta* L. Crantz) originated from Central and Southern America and has since then spread to various parts of the world [1]. It is a dicotyledonous plant, belonging to the family *Euphorbiaceae* [2]. It is a perennial woody shrub 2 to 4m in height and is mainly propagated from stem cuttings with an edible root [3]. It is widely grown in most countries in the tropical regions of Africa, Latin America and Asia. Cassava is grown over a range of climates and altitudes and on a wide variety of soils. It is tolerant to drought and is productive in poor soils where other staple crops cannot grow [4]. Its systemic cultivation became generally accepted and integrated into the farming system in Nigeria and based on the area cropped and quantity produced, cassava was the country's most important root crop [5]. In the country, the crop ranked first with an annual production of 34 million metric tonnes, followed by yam, sorghum, millet and rice [6]. The tuber flesh is composed of about 62% water, 35% carbohydrate, 1-2% protein, 0.3% fat, 1-2% fibre and 1% mineral matter [7]. Cassava flour can practically and technically replace wheat flour in processing meal, sweet cookies, meat pies, iced creams, bread, etc. [8]. The leaves have a similar nutritive value as other dark green leaves and are valuable sources of vitamins A, C, iron, calcium and protein [9].

Sesame or benniseed (*Sesamum indicum* L.) is cultivated in almost all tropical and sub-tropical Asian and African countries for its highly nutritious and edible seeds [10]. It is an erect annual herb belonging to the family *Pedaliaceae* which is of nutritional significance for its dual use as leafy vegetable and oilseed [11]. The world hectarage exceeds 6 million tonnes and world output stood at 2.4 million tonnes. In Africa, Nigeria is the second largest producer after Sudan. Sesame oil is of good quality. According to Kamara, the oil is used for cooking, baking, candy making, soaps, lubricant, hair treatment, industrial uses and alternative medicine (in the control of blood pressure, stress and tension). Leaves are used in vegetable soup, seeds are consumed when fried and mixed with sugar in most African countries, while stems are used in making paper, fuel wood and source of potash after burning.

Cassava/sesame intercrop offers great potentials for increased output per unit area which translates into poverty reduction and food security. However, when farmers fail to consider the response of component crops to fertilization, unhealthy competition may arise which is capable of rendering intercropping unproductive. Fertilizer application, depending on the rate and type stimulates faster growth in some crop species than the other. It may hastens or delay rate of physiological activities and development depending on the crop species in question. Knowledge of the positive or negative effect of fertilizer application on the interaction between component crops in cassava/sesame intercrop serve as a base line for decision making on fertilizer practices for improved intercrop production.

A number of studies have been conducted on sole cassava and sole sesame as affected by rate of fertilizer application [12,13,14,15,16,17, 18] but documented scientific information on the response of cassava-sesame intercrop to different rates of NPK fertilizer application is scarce. The study therefore was undertaken to evaluate the response of cassava and sesame to different levels of NPK 20:10:10 fertilizer and cropping systems on the productivity of cassava-sesame intercropping system.

2. MATERIALS AND METHODS

2.1 Study Location

A field experiment was conducted from July to December, during 2014 and 2015 cropping seasons at the Teaching and Research Farm of

the University of Agriculture, Makurdi-Nigeria to evaluate the response of cassava and sesame to different levels of NPK (20:10:10) fertilizer application and cropping systems on the productivity of cassava-sesame intercropping system. The study location falls within the Southern Guinea Savanna Zone of Nigeria with mean rainfall of 1, 250 mm per annum and temperature of 25-30°C. The location is between (Latitude 07°45` - 07 °50`N, Longitude 08°45`- 08°50`E) at an altitude of 98 m above sea level.

2.2 Crop Varieties

Cassava variety 30/70 was sourced from the National Root Crop Research Institute Sub-station Otobi, Benue state. While the sesame variety used (Ex-Sudan) was sourced from National Cereal centre sub-station Yandev, Benue state. The variety of both crops show good adaptation to the local environment and are popularly grown by farmers in the locality.

2.3 Soil Sampling and Analysis

Ten core samples of soil were collected from different parts of the experimental field from adepth of 0-30 cm and bulked into a composite sample and used for the determination of the physical and chemical properties of the soil (Table 1) before planting. The soil of the experimental site was classified as Dystric Ustropept (USDA) (Fagbemi and Akamigbo, 1986).

2.4 Experimental Design, Experimental Area and Treatments

The field experiment consisted of two factors: cropping system at two levels (sole cassava, sesame and intercropped cassava/sesame) and NPK 20:10:10 fertilizer at three levels (0 kg/ha, 200 kg/ha and 400 kg/ha). Treatments were laid out in split plot in Randomized complete block design with cropping system assigned to the main plots and fertilizer levels at sub plots replicated three times. The experimental area was 800.0m^2 and consisted of 27 subplots. Each treatment plot had an area of 24.0m^2 consisted of 5 ridges spaced 1m apart.

2.5 Cultural Practices

The experimental field was manually cleared and ridged using a native hoe. Cassava stem and sesame seeds were planted manually on the same day on the 28th July in 2014 and 16th July, 2015 in both seasons. Cassava stem cuttings measuring 30cm in length were planted by the crest of each ridge at a spacing of 50cm intra-row, representing a plant population of 20,000 plants/ha. Sesame seeds were planted at 5cm intra-row spacing. Sesame was thinned to three seeds per stand 2 weeks after planting (2 WAP), giving a plant population density of 300,000 plants/ha. The fertilizer rates were applied three weeks after planting (3WAP). Three manual weeding were done at 3, 8 and 12 WAP using traditional hoe. Sesame was sprayed with 'Best'® (Cypermithrin 10% EC) at a dose of 60 ml in 10 litres of water for the control of insect pest.

Table 1. Physico-chemical properties of the surface soil (0-30cm) at the experimental site in Makurdi before planting

Parameter	Values	
	2014	2015
Sand (%)	77.36	75.10
Silt (%)	9.64	11.20
Clay (%)	13.00	13.70
Textural class	Sandy loam	Sandy loam
pH (H_2O)	6.29	6.40
pH (KCl)	5.70	5.61
Organic Carbon (%)	0.50	0.90
Organic Matter (%)	0.89	1.56
Total Nitrogen (%)	0.05	0.08
Available Phosphorus (ppm)	5.20	2.90
Ca^{2+} (Cmol kg^{-1}soil)	4.10	3.77
Mg^{2+} (Cmol kg^{-1}soil)	3.30	1.90
K^+ (Cmol kg^{-1}soil)	0.28	0.35
Na^+ (Cmol kg^{-1}soil)	0.22	0.55
CEC (Cmol kg^{-1}soil)	9.00	6.80
Base Saturation (%)	87.80	97.00

2.6 Harvesting

Cassava was harvested when the leaves were observed to dry, turn yellowish and fallen off, which were signs of senescence and tuber maturity [19] while sesame was harvested when capsules turned yellowish with shedding of leaves [19].

2.7 Data Collection and Statistical Analysis

Data taken for sesame include days to attain 50% flowering, plant height (cm), number of

branches per plant, number of branches per plant, stem girth (cm), number of capsules per plant, grain weight and 1000-seed weight.

Data taken for cassava included plant height (cm), number of branches per plant, number of leaves per plant; others are number of cassava roots per plant, root diameter, and root yield.

All data collected were statistically analyzed using GENSTAT Release (Rothamsted Experimental Station) copy right 2013. Least Significant Difference (LSD) was used for mean separation (P≤ 0.05) following the procedure of [20]. Main treatment effects and the magnitude of interactions were also determined.

2.8 Evaluation of Yield Advantages

The land equivalent ratio (LER) was determined as described by [21] using the formula:

$$\text{LER} = \frac{\text{Intercrop yield of crop A}}{\text{Sole crop yield of A}} + \frac{\text{Intercrop yield of crop B}}{\text{Sole of yield of crop B}}$$

The land equivalent coefficient (LEC) as described by [22] was determined using the formula:

LEC = La x Lb;

Where La: LER of main crop; Lb: LER of intercrop.

The percentage (%) land saved as described by [21] using the formula:

$$\% \text{ Land saved} = 100 - {}^{1}/_{LER} \text{ X } 100$$

The competitive ratio (CR) as described by [23] was determined using the formula:

$$\text{CR} = Lc/Lo$$

Where; Lc: Partial LER for cassava; Lo: Partial LER for sesame.

3. RESULTS AND DISCUSSION

3.1 Growth and Yield of Cassava in a Cassava-sesame Intercrop as Influenced by NPK Fertilizer Application Rates

The main effects of cropping system and fertilizer rates on the growth and yield components of cassava in cassava-sesame intercrop at Makurdi, Nigeria, during 2014 and 2015 cropping seasons is given in Table 2.

Sole cropping significantly (P≤ 0.05) gave higher plant height at harvest, number of leaves at harvest, number of branches at harvest, number of roots per plant, root length, root diameter and root yield of cassava than intercropping in both seasons. This might be due to interplant competition for natural growth resources such as soil nutrients, water, etc. by both intercrop components. It is known that competitive reactions reduce yields in intercropped crop species as compared to mono cropping [24]. [25] reported that sharing of growth resources among components crops under intercropping can limit growth and accumulation of dry matter compared to sole cropping where competition exists. Adeniyan made a similar observation when most of the cowpea cultivars evaluated showed degree of yield decrease under cassava-maize intercropping system compared to sole cowpea.

Cassava growth and yield increased with increase in fertilizer. 400 kg/ha NPK fertilizer gave the highest number of roots, root length, root diameter and root yield. The positive response of growth and yield parameters to the applied NPK fertilizer is attributable to their role in cell multiplication and photosynthesis which gave rise to increase in size and length of the parameters of cassava evaluated. The favour-able response also confirmed the essentiality of NPK in plant growth and development [26]. This result is in harmony with [27] who reported highest significant cassava root yield from NPK fertilizer application rate of 400 kg/ha. The findings also agrees with the work of [14] who reported that higher rates of N (80 kgN/ha) and 120kgP/ha gave optimum yield of cassava in Uyo, South Nigeria. The control plot had the lowest returns suggesting that NPK 20:10:10 fertilizer even at the rate of 200 kg/ha could produce significant returns. [28] stated that fertilizer application at 200 kg/ha (NPK 20:10:10) significantly increased yam yield and productivity of the sole yam minisette cropping system. The interaction effect of cropping systems x fertilizer application significantly (P ≤ 0.05) affect the growth and yield of cassava in cassava-sesame intercrop with sole cropping recording the optimum yield at 400kg/ha application (Table 3).

Table 2. Mean effect of cropping systems x fertilizer rates on cassava growth and yield in Makurdi during 2014 and 2015 cropping seasons

Treatment	Plant height at harvest (cm)		Number of leaves at harvest		Number of branches at harvest		Number of roots per plant		Root length (cm)		Root diameter (cm)		Root yield (t/ha)	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Cropping System														
Intercrop	178.98	181.86	47.34	49.66	3.10	3.28	4.40	4.41	38.80	42.76	14.56	15.41	10.23	12.17
Sole	210.56	201.34	55.90	58.98	3.70	3.93	4.48	4.52	41.60	44.45	16.32	16.62	13.44	14.49
F-LSD (0.05)	4.90	2.41	2.00	1.13	1.02	0.24	0.44	0.43	3.45	1.89	2.12	1.80	0.32	0.18
Fertilizer Rate kg/ha														
0kg/ha	163.23	171.54	34.87	40.43	2.30	2.56	3.51	3.56	33.00	35.23	13.99	14.11	9.00	10.13
200kg/ha	189.00	191.85	49.88	55.95	3.46	3.65	4.78	4.85	38.87	40.10	15.56	16.23	14.11	14.66
400kg/ha	199.43	201.65	55.43	61.91	4.12	4.28	5.23	5.46	44.55	47.33	16.87	17.09	14.88	15.21
F-LSD (0.05)	3.95	5.40	3.55	3.50	1.14	0.52	1.00	0.56	1.57	4.89	1.42	0.99	0.38	0.45

Table 3. Interaction effects of cropping system x fertilizer rate on the growth and yield of cassava in cassava/sesame intercropping system in Makurdi during 2014 and 2015 seasons

Cropping system	Fertilizer rate (kg/ha)	Plant Height at harvest(cm)		Number of leaves per plant at harvest		Number of branches per plant at harvest		Number of roots per plant		Root length (cm)		Root diameter(cm)		Root yield (t/ha)	
		2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Intercropping	**0**	154.96	165.29	37.56	38.02	2.32	2.44	3.25	3.34	32.71	33.90	13.54	14.08	8.67	9.36
	200	179.34	186.12	50.88	52.81	3.19	3.38	4.60	4.64	37.80	37.88	14.87	15.64	13.90	14.08
	400	188.90	194.16	57.76	58.15	3.89	4.03	4.92	5.00	43.62	44.67	15.98	16.50	14.44	14.68
Sole	**0**	170.23	184.06	43.23	45.27	2.66	2.79	3.88	4.02	34.90	36.77	14.11	14.18	11.27	11.38
	200	199.98	203.33	59.32	62.23	4.14	4.20	5.22	5.29	41.44	42.56	16.56	17.41	15.30	15.81
	400	205.34	206.63	68.94	69.43	4.53	4.79	5.68	5.73	52.33	53.93	17.76	18.26	16.13	16.28
F-LSD(0.05)		17.45	18.42	5.12	6.25	NS	NS	0.76	0.55	4.12	3.51	0.88	0.61	3.89	4.36

NS – Not Significant

Table 4. Mean effect of cropping system x fertilizer rates on the growth and yield of intercropped sesame in Makurdi during 2014 and 2015 cropping seasons

Treatment	Days to 50% flowering		Plant height at harvest (cm)		Number of leaves at harvest		Number of branches at harvest		Stem girth (cm)		Number of capsules per plant		1000-Seed weight (g)		Grain yield (t/ha)	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Cropping system																
Intercropping	42.14	42.12	63.16	64.65	50.86	50.93	4.13	4.25	2.72	2.73	50.11	51.28	2.11	2.13	231.10	233.17
Sole	40.67	40.89	69.97	73.53	58.22	60.31	5.63	5.88	3.00	3.06	58.34	59.99	2.38	2.40	278.25	286.57
F-LSD(0.05)	0.42	0.39	1.30	1.26	2.49	2.32	0.20	0.16	0.11	0.09	3.24	3.87	0.10	0.07	12.99	13.32
Fertilizer rate (kg/ha)																
0	43.01	43.11	54.86	55.75	35.12	35.74	2.92	2.95	2.28	2.37	30.44	31.82	1.89	1.91	98.77	100.10
200	41.09	41.22	70.45	71.96	57.10	59.25	5.23	5.35	2.89	2.95	56.55	59.75	2.23	2.27	308.26	310.09
400	40.66	40.78	74.88	75.12	63.19	67.13	5.99	6.07	3.12	3.20	67.21	70.98	2.43	2.48	339.69	342.63
F-LSD(0.05)	0.45	0.41	2.45	2.50	4.79	4.88	0.56	0.52	0.20	0.22	6.10	5.87	0.20	0.18	15.10	15.30

Table 5. Interaction Effects of Cropping Systems tilizer rate on the Growth and Yield of Intercropped Sesame in Makurdi during 2014 and 2015 cropping seasons

Cropping system	Fertilizer rate (kg/ha)	Days to 50% flowering		Plant height at harvest (cm)		Number of leaves at harvest		Number of branches at harvest		Stem girth (cm)		Number of capsules per plant		1000-Seed weight(g)		Grain yield (kg/ha)	
		2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Intercropping	**0**	42.89	43.34	50.88	52.99	33.03	33.70	2.61	2.64	2.30	2.34	29.56	29.95	1.82	1.85	89.12	88.61
	200	41.00	41.84	66.32	68.90	53.23	55.45	4.72	4.79	2.78	2.81	54.98	56.67	2.10	2.17	286.20	287.44
	400	40.97	41.17	71.73	72.07	62.10	63.55	5.38	5.37	3.03	3.01	66.23	67.34	2.31	2.39	318.34	320.62
Sole	**0**	42.11	42.67	58.12	61.28	38.56	39.82	3.49	3.58	2.37	2.39	35.10	35.57	2.00	2.05	120.78	123.27
	200	39.88	40.00	76.45	78.09	64.20	66.84	6.38	6.57	3.20	3.24	63.20	66.13	2.49	2.48	350.23	355.41
	400	39.76	40.00	79.00	81.23	73.69	74.28	7.33	7.49	3.53	3.60	75.79	78.26	2.63	2.66	375.30	381.01
F-LSD (0.05)		0.71	0.67	2.12	2.20	4.54	5.44	0.30	0.27	0.29	0.31	9.89	10.20	0.16	0.15	32.61	33.25

Table 6. Evaluation of yield advantages of cassava-sesame intercrop as influenced by different levels of NPK 20:10:10 fertilizer application in years 2014 and 2015 at Makurdi, Nigeria

Treatments	Sole crop yield				Intercrop yield											
	Cassava		Sesame		Cassava		Sesame		Lc		Ls		LER		%Land saved	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Soles	13.44	14.49	278.25	286.57	-	-	-	-	-	-	-	-	-	-	-	-
0 kg/ha	-	-	-	-	9.00	10.13	98.77	100.10	0.69	0.70	0.35	0.35	1.04	1.05	3.84	4.76
200 kg/ha	-	-	-	-	14.11	14.66	308.26	310.09	1.05	1.01	1.11	1.08	2.16	2.09	53.70	52.15
400 kg/ha	-	-	-	-	14.88	15.21	339.69	342.63	1.11	1.05	1.22	1.20	2.33	2.25	57.08	55.55

Lc – Partial LER for cassava, Ls – Partial LER for Sesame, LER – Land Equivalent Ratio

3.2 Growth and Yield of Sesame in a Cassava-sesame Intercrop as Influenced by NPK Fertilizer Application Rates

The main effects of cropping system and fertilizer rates on the growth and yield components of sesame in cassava-sesame intercrop at Makurdi, Nigeria, during 2014 and 2015 cropping seasons is given in Table 4.

Days to attain 50% flowering for sesame were significantly (P≤0.05) affected by both cropping systems and fertilizer application, longer days were taken to attain 50% flowering for intercropped sesame than sole cropping. The intense overcrowding of the intercrops which might have induced competitive demands on available nutrients and moisture could have been responsible for prolonging days to attain 50 % flowering for intercropped sesame. This finding is in support of [29] who reported longer days to 50% flowering in maize and egusi-melon intercrop than its sole component.

Sole cropping gave significantly higher plant height at harvest, number of leaves at harvest, number of branches at harvest, stem girth, number of capsules per plant, grain yield and 1000-seed weight of sesame than intercropping. The growth and yield reduction in sesame caused by the cassava intercrop was in agreement with the report of other workers [30,31,19]. The implication of this finding is that the nutrient requirements of sesame and cassava in the intercropping system were higher than the nutrient need of the sole crops as [32] and [33] reported that the nutrient demand of the component crops were always higher than for sole crops. Sesame yield and growth parameters increased with increase in NPK fertilizer application. Similar positive responses to NPK fertilizer application have been reported by some researchers [34,33,35]. [36] in their study with straight nitrogen within the range (0-100 kgN/ha) and potassium (0-80 kg K_2O/ha) fertilizers in the humid rainforest zone reported high response of sesame to fertilizer application and concluded that nitrogen alone was very effective in increasing yield. [35] also reported that nitrogen at 90kgN/ha with phosphorus at 90kgP/ha gave the highest yield and yield components of sesame and concluded that application of these rates is recommended for general cultivation in agro-climatic condition of Peshawar valley. The results of the present investigation showed that sesame benefited more from the highest fertilizer rate (400 kg/ha), hence corroborate these reports. The zero NPK treatment gave the least yield of components assessed. Considering that sesame yields produced at fertilizer application rate of 400 kg/ha were significantly (P≤0.05) higher than the yields obtained at application rates of 0 and 200 kg/ha, it is apt to suggest that fertilizer application at the rate of 400 kg/ha be adopted for optimum performance and yield of sesame and cassava intercropping system. The interaction effect of cropping systems x fertilizer application significantly (P ≤ 0.05) affect the growth and yield of sesame in cassava-sesame intercrop with sole cropping recording the optimum yield at 400kg/ha application (Table 5).

3.3 Yield Advantages of Intercropping Cassava and Sesame

Land Equivalent Ratio (LER) and Percentage of Land Saved are as presented in Table 6. The land equivalent ratio (LER) values for all treatments at the 2-way interaction of cropping system x fertilizer application were all above 1.0, indicating yield advantage of the intercropping system (Table 6). Both intercropped mixture showed that the highest LER of 2.33 and 2.25 was recorded when 400kg/ha NPK fertilizer was applied, signifying that it is most advantageous having both crops in intercropping at this interaction level. Okwuowulu had reported that row intercropping of cocoyam with upland rice in Umudike and Otobi enhanced the total yield of mixture components through complimentary yield advantages, resulting in high productivity efficiency. [27] also reported highest significant cassava root yield from NPK fertilizer application rate of 400 kg /ha. The level of treatment also recorded an average of 57.08% and 55.55% of land saved, which could be used for other agricultural purposes. [29] also observed 46.81% to 54.75% of land saved in maize/egusi melon intercrop at 600kg/ha of NPK fertilizer application. Ekwere et al. (2013) also observed 46.81% to 54.75% of land saved in maize/egusi melon intercrop at 600kg/ha of NPK fertilizer application.

4. CONCLUSION

From this work, it can be observe that NPK fertilizer application had significant influence on both growth and yield parameters of cassava-

sesame in intercropping. The LER, and %Land saved in all combinations showed yield advantages but the highest advantage was obtained at the NPK fertilizer rate of 400kg/ha. Based on yield advantage, it can be concluded that in Makurdi, a location in southern guinea savannah agro-ecological zone of Nigeria, cassava and sesame should be intercropped and 400 kg/ha NPK fertilizer 20:10:10 be applied to cassava/sesame intercrop for optimum yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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