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ORIGINAL RESEARCH

Influence of fertilizer types and placement methods on the yield of white yam *Dioscorea rotundata*

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Abstract

Purpose: Yam cultivation in soils of low fertility has been a major cause of yield decline in Nigeria. The inadequacies associated with either inorganic or organic fertilizer in the aspects of crop growth and productivity necessitated the introduction of organomineral fertilizers. However, information on the appropriate placement method for sustainable cultivation is still limited. Hence, fertilizer type and placement method were evaluated on white yam yield.

Method: *Dioscorea rotundata* (Tdr 219) performance under different fertilizer types [NPK, 15-15-15 and organomineral fertilizer (OMF) at 30 kg N/ha], and different methods of placement (Side/spot and Ring/circular placements) were evaluated.

Results: The average tuber length, circumference, number of ware tubers, and yam tuber weights were higher under NPK treatment, while the number of tubers was higher in OMF treatment. All parameters observed were increased by ring fertilizer placement method compared to side placement. The interaction of fertilizer type and method of placement indicated that under OMF, the ring placement produced comparatively higher tuber weight (13390.0 kg/ha) than side placement (13166.6 kg/ha). However under NPK fertilizer, side placements enhanced tuber weight (15173.3 kg/ha) compared with ring placement (15076.6 kg/ha). The residual cropping revealed that the highest and significant tuber weight was observed in OMF fertilizer with ring placement compared to the other treatments.

Conclusion: Side placement was appropriate for NPK fertilizer, however, applying organomineral fertilizer at 2000 kg/ha with ring placement was recommended for the cultivation of yam in low fertility soils.

Keywords: *Dioscorea rotundata*, Inorganic fertilizer, Organomineral fertilizer, Fertilizer placement, Tuber weight, Yam crop

Introduction

Yam (*Dioscorea spp*.) is an annual crop with high economic and social values for the people in West Africa (Nweke et al. 1991) as wild edible tuber. Nigeria is the world's largest yam producer and the fifth most harvested crop in the country, after cassava, maize, sorghum and cowpeas. In Nigeria, the annual production of yam is about 47530 million kg (FAOSTAT 2019). However, yam production has reduced from 8240.2 kg/ha in 2018 to 8016.3 kg/ha in 2019. Among the various identified problems confronting yam production in Nigeria, the most prevalent is its cultivation on

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low or moderately fertile soil (Udemezue and Nnabuife 2017).

The soils in Nigeria are inherently low in fertility due to the original parent rock composition from which the soil was formed and undesirable human activities (Akamigbo 2000; Bationo et al. 2006). Therefore, the soils are not fertile enough to support crop growth adequately to express their growth and yield potentials fully (Frossard et al. 2017). Hence, the cultivation of marginal land for crop production has necessitated the application of fertilizer to enhance crop yield (Udemezue and Nnabuife 2017; Hammed et al. 2019). The application of different types of fertilizers to improve soil nutrient status and increase yield of yam has been reported by various authors (Ogbedeh et al. 2007; Akom et al. 2015; Tiama et al. 2018). The use of NPK fertilizer at 400 kg/ha had been reported by Ogbedeh et al. (2007), while Asieku et al. (2015) evaluated 300 kg/ha to be appropriate for the production of yam. However, the utilization of inorganic fertilizer for yam production has received setbacks among farmers (Tiama et al. 2018). Studies have revealed inadequacies in applying inorganic fertilizer to boost yam cultivation by resource-limited farmers in the country (Udemezue and Nnabuife 2017). Yams grow with inorganic fertilizer application have no good organoleptic quality and were more susceptible to pathological deterioration during storage than those grown without fertilizer (Ogbedeh et al. 2007; Tiama et al. 2018). Nevertheless, some farmers (who have access to inorganic fertilizer and without the intention of storage) still use it for production. On the contrary, several studies have shown the advantages of organic fertilizers over inorganic fertilizers (Ogbedeh et al. 2007; Adebayo et al. 2017; Tiama et al. 2018; Bhatti et al. 2021). For instance, the application of organic fertilizer in the form of oil palm bunch ash + poultry manure at 10 t/ha was recommended for optimum cultivation of yam with better quality (Agbede et al. 2013). However, the application of organic fertilizer is challenged with having enough quantity to meet the recommended rate. The limitations of inorganic and organic fertilizers have led to the use of organomineral fertilizers. Previous studies have elucidated the advantage of organomineral fertilization in yam production. Oshunsanya and Akinrinola (2013) reported the application of commercially produced pacesetter organomineral fertilizer at 3000 kg/ha, while Asieku et al. (2015) recommended 2000 kg poultry manure + 150 kg NPK 15-15-15 per ha for yam. Consequently, for maximum utilization of applied nutrients to crop by resource-limited farmers, there is a need for appropriate fertilizer placement for enhanced nutrient use efficiency to improve crop yield.

Fertilizer placement method is an integral part of an efficient crop management strategy. According to Nkebiwe et al. (2016), plant nutrient acquisition in the soil is strongly improved by proper fertilizer placement method. The appropriate fertilizer placement method influences the subsequent availability of nutrients in an adequate amount for higher crop yield with minimal nutrient loss in runoff or leaching from the root zone (Reetz 2016). Hence, fertilizer placement method directly influences the achieved yield. Consequently, for optimum yield, appropriate method of placement is very critical most importantly when the farmers have limited access to fertilizer. The application of fertilizers can be achieved in several ways depending on the fertilizer and soil types.

The assessment of the appropriate fertilizer placement method for yam cultivation is therefore necessary for enhancing production by resource-limited farmers who constitute the larger percentage of yam farmers in the country. Consequently, a field study was carried out to evaluate yam performance under different methods of placement for inorganic and organomineral fertilizers.

Materials and methods

Experimental site and soil characteristics

The location of the study was at the Ayepe On-farm Research Project site (7° 17' 29.83" N and 4° 16' 31.88" E), of the Department of Agronomy, University of Ibadan, situated in Isokan LGA, Osun State, Nigeria (Fig. 1). This location is in the low land semi-deciduous forest of the humid zone with average annual precipitation of 1461.8 mm and average number of days with precipitation is 116.3, (Weatherbase 2022). The mean minimum and maximum annual temperatures were 21.1 °C and 31.4 °C, respectively, while the annual mean solar radiation was 18.1 cal. Cm/day. In addition, the average relative humidity at 09:00 GMT ranged from 77.2 to 82.4%. The annual mean evaporation and cloud coverage were 4.44 mm and seven Oktas, respectively (NiMet 2022). Under the Köppen-Geiger classification system, the climate in the region was tropical savannah (Aw) as shown in Fig. 2 (Beck et al. 2018). The soil is an Alfisol with loamy sand texture derived from Apomu soil series of basement complex. Using standard procedures for soil analysis as described by IITA (1982), Hydrometer method was used to determine the soil texture, while soil pH was determined in 1:1 soil-water suspension using HI2209-01 BenchtoppH meter by Hanna Instruments. The total nitrogen was determined using the Kjheldal method and organic carbon using Walkley-Black method. In addition, available phosphorus was determined using sodium bicarbonate method; exchangeable cations (Na, K, Ca and Mg) with ammonium acetate and Cation Exchange Capacity(CEC) were determined by saturating the samples with sodium acetate.Exchangeable acidity was determined by Mclean (1982) method using 1M KCI as the extracting solution and titrated with 0.01M NaOH as outlined by IITA (1982). The physical and chemical properties of the used soil are shown in Table 1.

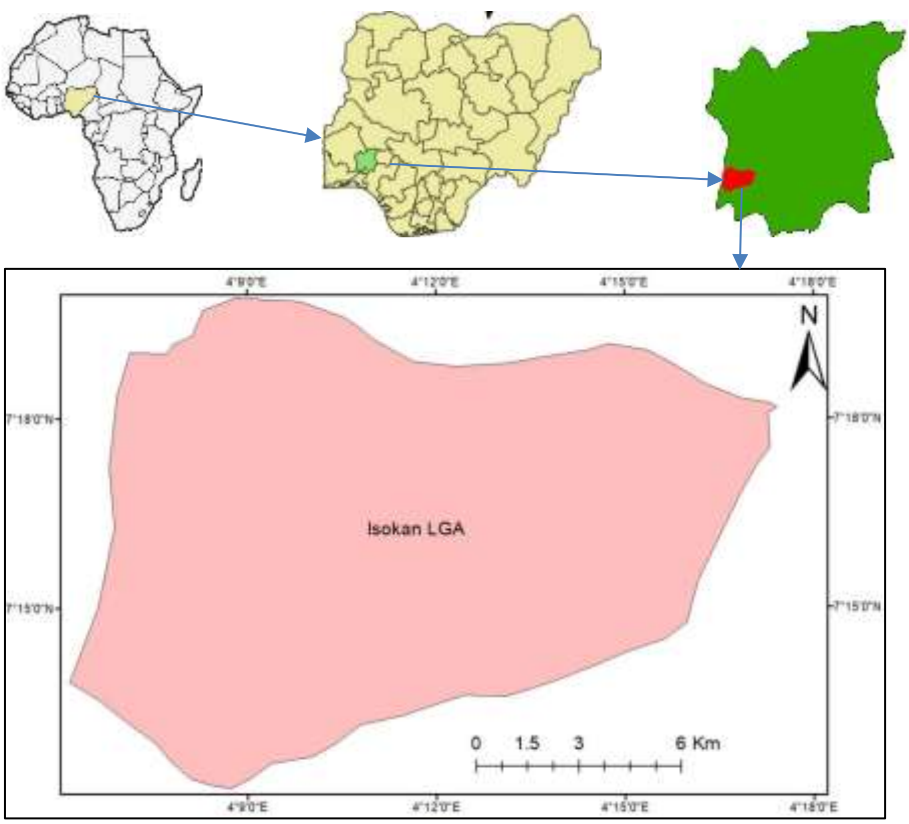

Fig. 1 Map of Africa and Nigeria showing Isokan LGA in Osun State

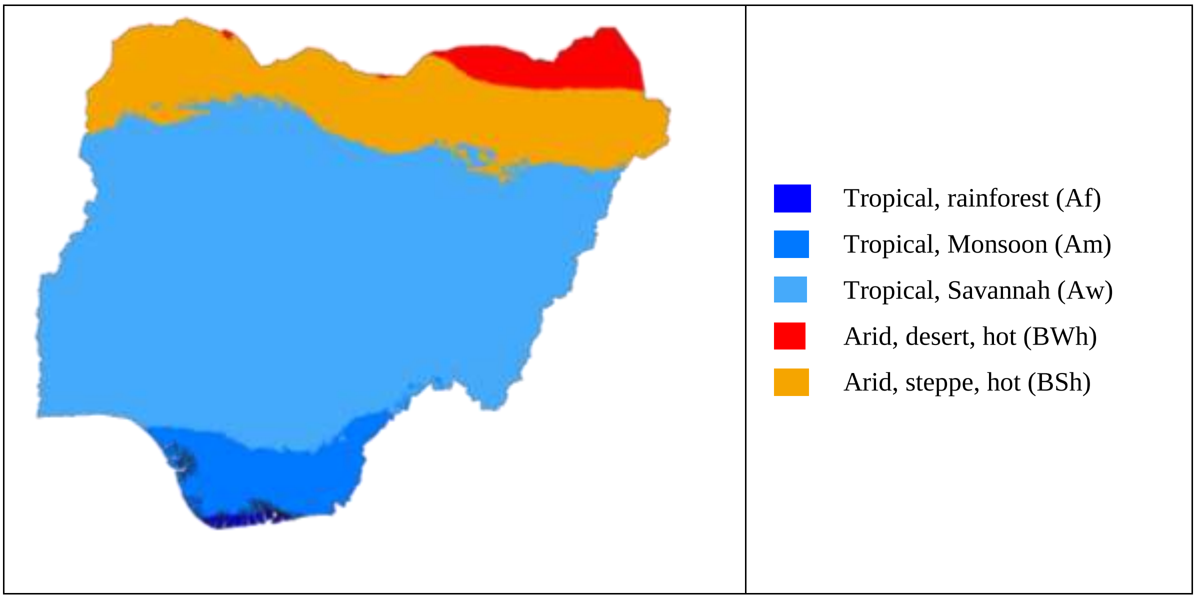

Fig. 2 Koppen-Geiger climate classification map for Nigeria. Source: Beck et al. (2018)

Table 1 The chemical and physical properties of the soil used for the study

Soil parameters	Concentrations in soil
pH (H_2O)	6.4
Exchangeable acidity	0.08
Organic carbon (g/ha)	4.06
N (g/ha)	0.56
P (mg/ha)	7.30
Exchangeable Bases (cmol/kg)	
Ca	3.95
K	0.21
Mg	0.37
Na	0.39
% Base Saturation	92
ECEC (cmol/kg)	5.02
Sand(g/ha)	848
Silt(g/ha)	92
Clay(g/ha)	60
Soil texture	loamy Sand

Organomineral fertilizers analysis

Sample (0.2 g) of the organomineral fertilizer used in this study was weighed and subjected to digestion at 360˚C using tecator digestion block and tubes for four hours using 10 ml concentrated H_2SO_4, one tablet of selenium and sodium sulphate was added. Total N was determined from the digest by steam distillation method (IITA 1982).

The soil organic carbon was determined using the Walkley-Black chromic acid wet oxidation method using a 1 N $K_2Cr_2O_7$ solution (Ciavatta et al. 1989). The P concentration was determined by the vanado-molybdate yellow colorimetric method using spectro-photometer (Olsen et al. 1954). The K was determined with the flame photometer (model FP-640, Ningbo Hinotek Technology, China) (Olsen et al. 1954), while Ca, Mg, Mn, Fe, and Cu were determined with atomic absorption spectrophotometer (model 210, Buck Scientific, USA).

The chemical properties of fertilizers used are shown in Table 2.

Table 2 The chemical composition of the applied organomineral fertilizer

Parameters	Values
Organic C (%)	36.1
Nitrogen (%)	1.73
C -N ratio	20.9
Phosphorus (%)	0.23
Potassium (%)	1.01
Calcium (%)	0.64
Magnesium (%)	0.23

Experimental design and setup

The experiment consists of three treatments designed in the randomized complete block with three replicates as an incomplete factorial experiment including fertilizer types (organomineral fertilizer and NPK 15-15-15 fertilizer), placement methods (Side/spot placement and Ring/circular placement) and control. The plot size used in the experiment was 5 m x 5 m and the mounds constructed were about 50-60 cm high. There were 25 mounds per treatment at spacing of 1 m x 1 m within the plot. The plots and replications were separated by 1.5 m and 2 m, respectively. The experiments were carried out in two consecutive seasons (April - December 2018 and 2019). The trials were set up at the onset of the rainy season (late planting). The site was slashed and the residues were removed without burning. Soil samples were taken randomly from the field at depths of 0 - 30 cm using a soil auger before mound construction.

Field cultivation and management

The yam setts (*Dioscorea rotundata* cultivar TDr 219-4) planted was obtained from IITA, Ibadan station. Nigeria.Fertilizers (NPK 15-15-15 at 200 kg/ha and organomineral fertilizer at 2000 kg/ha, i.e., approximately 30 kg N/ha of each) were applied two months after planting according to the respective method of placement (side/spot and ring/circular application methods) and ensuring almost even distribution along the groove. The time of application ensures the period of complete emergence of the yam setts. The fertilizers were placed 15 cm away from the base of the vine and about 5 cm deep. The grooves were covered immediately after application.

Staking was done before sprouting and trailing operations were carried out continuously by trailing the sprouted vines properly to the artificial supports (stakes) in the field. Trailing was also done when side shoots were produced.

Weeds in the plots were controlled at 6 weeks after planting manually through hoe weeding and subsequently, when necessary, throughout the experiment.

The yams were harvested when the vines were completely dried-up and after which the measurements were taken. These include tuber length (using the ruler) and tuber circumference (determined with the use of tape measure), number of tubers/plot, number of ware tubers/plot (yam tubers greater than one kilogram are group as ware tubers) and tuber weight/plot (using Camry dial spring scale model NS). The values of the parameters obtained from the two cropping seasons were extrapolated to kilogram per hectare and reported as averages.

Statistical analysis

The SAS software version 9.4 was used to analyse the results. Two-way ANOVA followed by the Least Significant Difference (LSD) test was used to determine significant differences between mean values for fertilizer types, method of placement, and their interactions. Differences were considered significant at the level ($p < 0.05$).

Results and discussion

The production capacity of any crop is largely influenced by the soil quality, comprising mainly the soil physical and chemical properties. The physical properties of the soil used in the study indicated that the soil was higher in sand content and its textural classification was loamy sand, making it more likely susceptible to nutrient loss. Similar soils are such that are mostly cultivated by farmers in this locality as a result of the lack of more suitable land for yam cultivation. Under low fertility soil conditions, crops like yam respond dramatically to fertilizer treatment. (Diby et al. 2011).

First cropping season

Fertilizer type effect

Fertilizer applications did not significantly influence average length of tuber in the first cropping (Table 3). The values ranged from 24.27 - 26.61 cm in the control and NPK treatments, respectively. The application of fertilizer did not significantly increase the average tuber circumference. However, the lowest value was observed in the control, while the values observed from OMF and NPK treatments were similar. The application of OMF produced a significantly higher number of tubers per hectare compared to the control (Fig. 3), but the value was not significantly different from NPK. The number of ware tubers produced per hectare was not significantly different among the treatments, but the application of NPK produced the highest number of ware tubers. Applying NPK and OMF increased ware tubers by 79.16% and 41.67%, respectively, than the control. Fertilizer application significantly improved the weight of tubers per hectare (Fig. 4). The application of NPK had significantly higher tubers weight than OMF treatment, and also had a significantly higher weight of tubers compared to the control. Fertilizers are applied to the soil to supply or supplement nutrients that are considered inadequate or insufficient for achieving optimum levels of crop production. The low nutrient status as revealed in the soil analysis ensured adequate yam response to the OMF and NPK fertilizer treatments as compared to the control. These responses were evident in the yield and yield parameters assessed. The production of yams with relatively large sizes (increase in length, circumference and numbers of ware tubers) is of economic importance to the farmers, in that it commands a better price in the market and is also a good source of cut sets for planting (Aighewi et al. 2015). The application of fertilizer did not sufficiently improve the length, circumference and number of ware yam tubers produced; rather, it relatively enhanced their performances. This result supports earlier reports that yam tuber sizes improved with the applications of different fertilizers compared to the no fertilizer application treatments (Diby et al. 2011; Ayeni et al. 2017). The favourable response of sizes of yam tubers to fertilizer application supported the findings of Ayeni et al. (2017), inorganic and organomineral fertilizers improved the sizes of yam tubers. The improvement must have been achieved through the availability of nutrients supplied to the yam crop, which enhances cell multiplication in the tuber during tuberization, thereby increasing the length and girth/circumference of the tuber. This finding is in support of Ayeni et al. (2017) whose report asserted fertilizer application enhances yam tuber sizes, with better improvement in the organomineral fertilizer compared to the inorganic treatment. The improvement in yam tuber sizes by NPK application over OMF may be associated with the more readily supply of N in the NPK fertilizer relative to OMF application, despite the higher N content (4.6 kg N h^{-1}). The N content in the NPK fertilizer was more compared to OMF fertilizer. According to Diby et al. (2009), O'Sullivan (2010) and Rezaei et al. (2016) the ready supply of N improves crop development which enhances the size of tubers. Furthermore, the increase in N application has been reported to improve moisture content of yam, which in turn increases yam tuber size as observed in the NPK treated yam compared to the OMF. This increase in yam tuber sizes resulting from N supply from the inorganic NPK fertilizer treatment may likely make the yam tubers susceptible to fungal attack and quick deterioration as compared to yam tubers harvested from the OMF treated plants (Tiama et al. 2018). Despite the increase in yam tuber sizes resulting from the NPK fertilizer application, it was not significantly differentt fromthe OMF treated plants. This can be attributed to the improvement in soil's physical condition and the supply of more essential nutrients in the OMF beyond NPK (Audu and Samuel 2015: Smith et al. 2020).

The observed results reflect the advantage of OMF treatment over the application of inorganic NPK fertilizer concerning the number of tubers produced. Asieku et al. (2015) has also been reported the increase in the number of tubers resulting from the combined application of organic and inorganic fertilizers over sole inorganic fertilizer. In their report, the combination of poultry manure and NPK fertilizer gave a higher number of yam tubers compared to their sole application.

Yield in yam is a function of the yield components observed. The trends observed in the length, circumference and number of ware yam were similar to the final yield. Yam tuber yields significantly increased with NPK fertilizer and OMF treatments. The application of NPK in improving tuber yield in yam was not in support of the report, that OMF application improved yam tuber yield compared to NPK fertilizer. The better tuber yields from yam treated with NPK fertilizer over organic fertilizer was reported by Eze and Orkwor (2010). However, most reports indicated that compounded organomineral fertilizers produced higher tuber yields than inorganic NPK fertilizers (Agbede et al. 2013; Ayeni et al. 2017). The observed difference between the yields from NPK fertilizer treatment may be inconsequential concerning the tuber dry matter yield.

Table 3 Effects Fertilizers effects on the yield components of white yam in the first cropping

	Average length of tuber (cm)	Average circumference of tuber (cm)	Number of ware tubers/ha
Control	24.27	20.64	1600.00
OMF	24.63	23.37	2266.67
NPK 15-15-15	26.61	23.55	2866.67
LSD	ns	ns	Ns

OMF = Organomineral fertilizer; LSD = Least significant difference at 5% probability; ns = Not significant. Data mentioned as Mean±SD or SE.

Fertilizer placement effects

The method of placement had no significant effect on the average length of the tuber (Table 4). The interactions of fertilizer type and placement indicated significant differences among treatments. The average length of tubers harvested from NPK treatment with ring placement was sufficiently higher compared to tubers harvested from OMF fertilizer with side placement, while the average length of tuber observed from the other treatments was not significantly different. The fertilizer placement had no significant effect on the average circumference of the tuber. The influence of fertilizer placement did not differ for the number of tubers per hectare (Fig. 3). The ring method of fertilizer placement had 17% more ware tubers than side fertilizer placement with no significant difference among treatments. Ring fertilizer placement produced 8.96% higher tubers weight compared to side placement (Fig. 4).

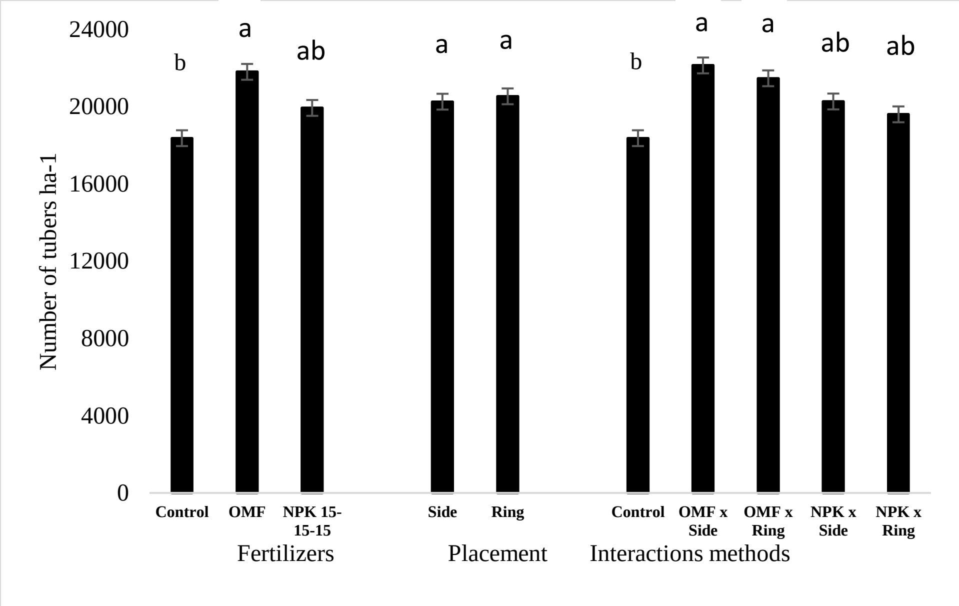

Fig. 3 Influences of fertilizers types, placement methods and their interactions on numbers of tubers in the first cropping season

OMF = organomineral fertilizer; Bars sharing the same letters are not significantly different (p = 0.05, LSD test).

Table 4 Fertilizer placement effects on the yield components of white yam in the first cropping

	Average length of tuber (cm)	Average circumference of tuber (cm)	Number of ware tubers/ha
Side	24.50	22.06	2222.22
Ring	26.63	24.15	2600.00
LSD	ns	ns	ns

OMF = Organomineral fertilizer; LSD = Least significant difference at 5% probability; ns = Not significant. Data mentioned as Mean±SD or SE.

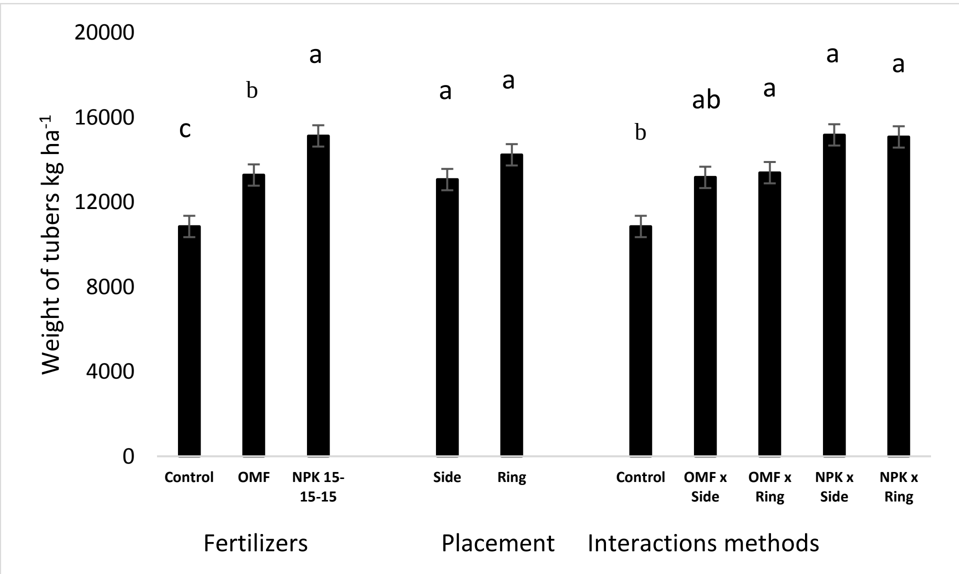

Fig. 4 Influences of fertilizers, placement methods and their interactions on weight of tubers in the first cropping season

OMF = organomineral fertilizer; Bars sharing the same letters are not significantly different (p = 0.05, LSD test).

Interactions of fertilizer and placement methods

The interactions of fertilizer and placement method indicated significant differences among treatments (Table 5). The average length of tubers harvested from NPK treatment with ring placement was sufficiently higher compared to the harvested tubers from OMF fertilizer with side placement, while the average length of tubers observed from the other treatments was not significantly different from each other. Furthermore, OMF with ring placement produced a comparatively higher average length of tuber compared to the OMF with side method of fertilizer placement. Likewise, the interactions of fertilizers and their placement method did not have significant influence on the average circumference of tuber. The application of OMF with ring placement produced yam tubers with the highest average circumference of tuber, while the lowest was observed in the control. Comparatively, OMF with ring placement produced tubers with higher average circumference compared to the OMF with side fertilizer placement. The combined effects of fertilizers and the placement method on the number of tubers per hectare showed that OMF placed by the side or in the ring significantly differed from the control (Fig. 3). The application of NPK, either by the side or in the ring, was not significantly different from the number of tubers per hectare produced in the control. Comparatively, side fertilizer placement produced 3.4% more tubers per hectare compared to the ring fertilizer placement under NPK application. The interaction of fertilizers and placement methods indicated no significant difference among treatments. However, NPK with side fertilizer placement produced the highest number of ware tubers, while control had the lowest value. Under OMF application, treatment with ring fertilizer placement produced 61.53% more ware tubers compared to the side fertilizer placement. The treatments involving the interactions of NPK with side and ring fertilizer placements and OMF with ring placement of fertilizer produced significantly higher tuber weight compared to the control (Fig. 4). However, plants treated with OMF and side placement of fertilizer were not significantly different from the other treatments. Under OMF, the ring placement of fertilizer produced comparatively higher tuber weight than side placement, while under NPK fertilizers, side placements enhanced tuber weight more than ring placement. The choice of fertilizer types and their methods or techniques of placement is a cultural practice that can increase or reduce (when not properly considered) crop yield. Proper fertilizer placement encourages the development of the root system in mass, volume and number of rootlets in the soil to utilize the available reserves of nutrients, subsequently increasing yield (Nkebiwe et al. 2016). The methods of placement directly affect the achieved yields in the NPK fertilizer and OMF treatments. With respect to fertilizer types and placement method, ring method of fertilizer placement produced yam tubers with better sizes, number of tubers and yield compared to the side placement. These differences could be attributed to the ability of the crop root to easily assess the nutrients from the applied OMF when evenly spread around the crop compared to when the OMF was placed in a localized form. According to the reports of Audu and Samuel (2015) and Smith et al. (2020), one of the attributes of OMF over inorganic fertilizer is the ability to retain nutrients and release them slowly. Hence, the ring placement tended to improve the accessibility of the crop root to the nutrient more than the side (considered localized) placement. Although the ring placement may tend to encourage weed growth, when applied at the appropriate time in crop growth, it gives the crop an edge over the weeds (Kirkland and Beckie 1998). Furthermore, the side OMF placement may delay nutrient supply to the plant at the early stage of growth and development. According to Latha et al. (2004), the concentration of nutrients in yam plant parts between three and five months after planting (early stages of growth) significantly increased tuber production. Therefore, a delay in nutrient supply will reduce tuber production. With respect to NPK fertilizer placements, side placement tended to produce higher tuber yield compared to ring placement as observed in this study. Although this was similar to Nwinyi and Enwezor (1985) findings, their choice recommendation was based on the cost of application. This method of placement confines the fertilizer to a small area, hence, making it available to fewer roots. The reduction in yield from the ring placement can be ascribed to the resulting effect of thinly applying inorganic fertilizer to crops on the field, thereby exposing each granule to full soil contact, which maximizes the opportunity for P fixation, which is essential for good yam tuber yield (Latha et al. 2004). Consequently, the nutrients (such as P and K) reaching the plant roots through diffusion are appreciably reduced from the acquisition of the plant root. This is very important in that it limits the ability of the plant to explore the surrounding soil microsphere for nutrient acquisition. Similarly, the thin application of NPK fertilizer is likely to expose the N applied to loss through leaching since the nutrient is mobile and the soil is low in soil organic carbon (Lal 2015). Furthermore, according to Hgaza et al. (2011), the yam rooting system is confined to the mound for the first 100 days after planting and can later be found at the furrow of the mound. The time of fertilizer application indicated that the yam root system would be concentrated on the mound. At this stage, the root system will be minimal in volume to intercept a large amount of the leached nutrient N from the inorganic NPK fertilizer. Hence, the escape or leached nutrients beyond the reach of the plant root may end up favouring weed development. Consequently increasing input due to increase in labour cost required for weeding operation and further encourages the weed's competitive ability for sunlight, moisture and nutrients over the crop.

Table 5 The interaction effects of fertilizer types and placement methods on the yield components of white yam in the first cropping

	Average length of tuber (cm)	Average circumference of tuber (cm)	Number of ware tubers/ha
Control	24.27ab	20.64	1600.00
OMF x Side	23.25b	21.85	1733.33
OMF x Ring	26.00ab	24.88	2800.00
NPK x Side	25.97ab	23.68	3333.33
NPK x Ring	27.25a	23.43	2400.00
LSD	3.51	ns	ns

OMF = Organomineral fertilizer; LSD = Least significant difference at 5% probability; ns = Not significant. Data mentioned as Mean±SD or SE.

Second cropping season

Fertilizer type effect

In the second cropping, the average length of tubers was not significantly different among the treatments but was highest in the treatment of NPK, while the least was observed in the control (Table 6). The Average circumference of the tuber and size of the tuberswere not significantly increased by fertilizer application. The number of tubers/ha was not significantly enhanced by fertilizer application (Fig. 5). Fertilizer application or their placement method had no significant effect on the size of tubers produced in the second cropping of yam (Fig. 6). The application of fertilizer significantly enhances yam tuber weight in the second cropping. The applications of OMF and NPK increased yam tuber weight by 22.27 and 20.16% respectively to the control. The second cropping indicated that the application of OMF proved to increase yam tuber better than the application of NPK fertilizer. This result was affirmed by Ayeni et al. (2017) and Eze and Orkwor (2010) report that the application of OMF increased yam tuber yield compared to the application of inorganic fertilizer in the second cultivation of yam. The ability of OMF in enhancing second cropping than NPK fertilizer application is suggested to be due to the organic matter content of the OMF, which helps to increase the low soil organic carbon as indicated in the soil properties. The reduction in yield from NPK fertilizer treatment reflects the impact of organic matter that has been depleted from the soil over the previous growing season. Tan et al. (2005) reported that the level of organic depletion in a year is serious in the tropics such that annual replenishment is necessary to maintain yield. According to Diby et al. (2009) and Lal (2015), increasing the SOC pool through the application of fertilizer containing organic matter enhances soil structural stability, activity and species diversity of soil biota (micro, meso, and macro), as well as soil fertility thereby increasing crop yield. The application of OMF is likely to have fulfilled these qualities, hence increasing the tuber yield in the second cropping.

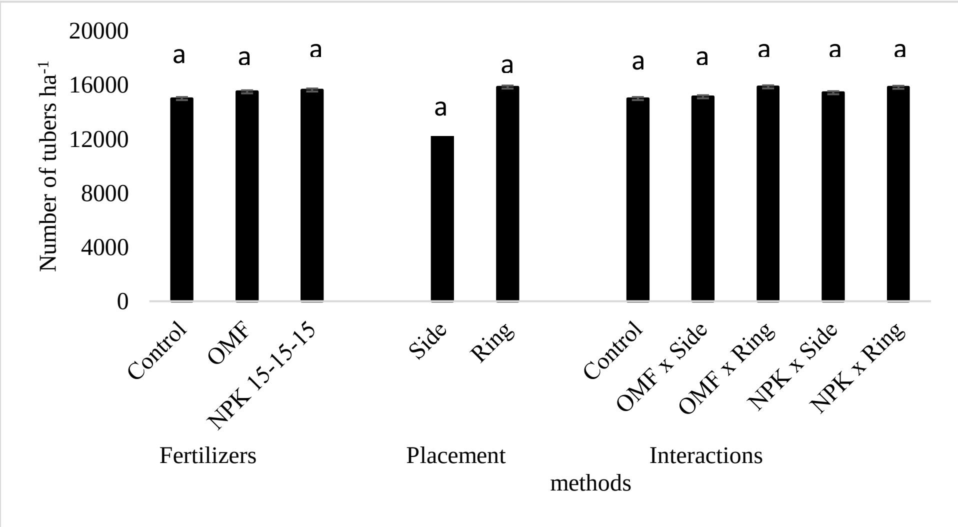

Fig. 5 Influences of fertilizers, placement methods and their interactions on numbers of tubers in the second cropping season

OMF = organomineral fertilizer; Bars sharing the same letters are not significantly different (p = 0.05, LSD test).

Table 6 Responses of yam yield components to fertilizer types in the second cropping

	Average length of tuber (cm)	Average circumference of tuber (cm)	Size of tubers (kg/tuber)
Control	19.86	18.71	0.461076
OMF	21.49	19.67	0.498452
NPK 151515	21.50	19.52	0.505201
LSD	ns	ns	ns

OMF = Organomineral fertilizer; LSD = Least significant difference at 5% probability; ns = Not significant. Data mentioned as Mean±SD or SE.

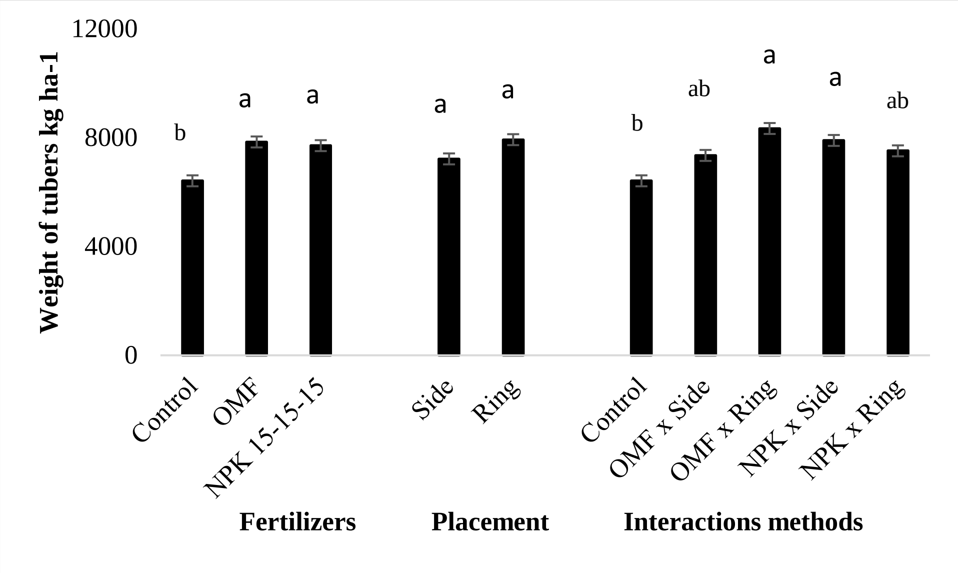

Fig. 6 Influences of fertilizers, placement methods and their interactions on weight of tubers in the second cropping season

OMF = organomineral fertilizer; Bars sharing the same letters are not significantly different (p = 0.05, LSD test).

The method of fertilizer placement had no significant influence on the average length of tubers harvested (Table 7). The average circumference of tuber was not significantly influenced by fertilizer application or method of its placement.However, OMF and ring placement gave tuber with relatively more circumference of tuber than the other treatments. Likewise, the method of fertilizer placement had no significant impact on the number of tubers; however, ring placement enhanced the number of yam tubers by 4.35% compared to side placement (Fig. 5). Fertilizer application or their method of application had no significant effect on the size of tubers produced in the second cropping of yam (Fig. 6). Ring placement of fertilizer improved yam tuber weight by 9.79% compared to side placement of fertilizer, however, the values did not differ significantly.

Table 7 Fertilizer placement effects on the yield components of white yam in the second cropping

	Average length of tuber (cm)	Average circumference of tuber (cm)	Size of tubers (kg/tuber)
Side	20.62	19.23	0.481787
Ring	21.99	19.71	0.511510
LSD	ns	ns	ns

OMF = Organomineral fertilizer; LSD = Least significant difference at 5% probability; ns = Not significant. Data mentioned as Mean±SD or SE.

The average length of tubers was not significantly affected by the interactions between fertilizers and placement methods (Table 8). The application of OMF and NPK applied in ring and side, respectively led to longer average length of tuber than the control. Similarly, the combined effects of fertilizers and placement method had no significant influence on the average circumference of tubers. Furthermore, ring placement of OMF and NPK fertilizers produced a higher number of tubers compared to their respective side placements (Fig. 5). However, no significant difference was observed among the treatment combinations. Also, the interactions between fertilizer and placement method indicated that plants treated with OMF placed in the ring gave the highest tuber sizes followed by NPK fertilizer placed by the side (Fig. 6). The values observed were not significantly different from each other. The effect of fertilizer placement on second cropping indicated a similar trend in all parameters observed. Under OMF application, ring placement showed better yield and yield components than the side placement. The reason could be ascribed to the fact that during mound reconstruction, the ring placed OMF will be more incorporated into the soil, while the side placed OMF will be exposed to the soil surface. Hence, the chances of nutrients left over from the previous cropping being lost from side placement under OMF application were high. With respect to NPK fertilizer application, ring placement caused a reduction in yam tuber yield compared to side fertilizer placement. The possible reason could be associated with the loss of nutrients as a result of thinly distributing the fertilizer around the mound thereby causing N loss and P fixation. Similarly, the weed increase resulting from nutrient loss beyond the reach of plant root may serve as a nutrient trap (Kirkland and Beckie 1998). When decomposed it serves as a means of nutrient recycle, or else the performance observed from the second cropping from NPK with the ring placement would not have produced such an appreciable tuber derived from the ring method of fertilizer placement.

Table 8 Yield components of white yam as influenced by the interaction effects of fertilizer types and placement methods in the second cropping

	Average length of tuber (cm)	Average circumference of tuber (cm)	Size of tubers (kg/tuber)
Control	19.86	18.71	0.461076
OMF x Side	19.83	19.44	0.454091
OMF x Ring	23.14	19.91	0.542812
NPK x Side	22.15	19.53	0.530195
NPK x Ring	20.84	19.51	0.480207
LSD	ns	ns	ns

OMF = Organomineral fertilizer; LSD = Least significant difference at 5% probability; ns = Not significant. Data mentioned as Mean±SD or SE.

The application of OMF with ring placement and NPK with side placement significantly enhanced yam tuber weight compared to OMF with side placement and the control (Fig. 6). However, OMF with side placement and NPK with ring placement were not significantly different from the control but produced 14.55% and 17.18% higher tuber weights than the control. Comparatively, the total average yield reduction of 55.45% was observed between the first and second cropping. The yield differences of 59.07% and 50.96% were observed under OMF and NPK respectively between the first and second cropping compared to 59.12% that was observed under the control treatment. Under methods of placement, the differences between the first and second cropping resulting from side and ring placement were 53.8% and 55.7% respectively. For fertilizer and methods of placement interactions, second cropping resulted in 55.81%, 62.27%, 52.39%

and 69.28% yield reduction for OMF with side placement, OMF with ring placement, NPK with side placement and NPK with ring placement, respectively. The general performance in the yields of yam tuber indicated a wide yield gap between the two growing seasons. The control had the lowest yield gap. Hgaza et al. (2010) and Ayeni et al. (2017) reported similar observations. The reason was attributed to the cultivation of yam on soil low in initial nutrient status. Consequently, the difference in the nutrient status of the first cropping and second cropping will not be so much to cause an appreciable yield difference. The application of OMF produced yam tubers with a relatively lower yield difference compared to NPK fertilizer in the second cropping. This observation was also reported by Hgaza et al. (2010) and Ayeni et al. (2017). This must be the effect of the attributes of OMF over inorganic and organic fertilizers.In other words, it improves soil qualities, thereby making it more sustainable than NPK fertilizer application.

Conclusion

The cultivation of yam using organomineral fertilizer and NPK fertilizer increased yam tuber yield significantly compared to the control. The application of NPK produced the highest tuber yield of 15125.00 kg/ha, while the highest number of tubers (21800) was produced with the application of organomineral fertilizer. Ring method of fertilizer placement produced the highest tuber sizes, number of tubers and tuber yield as compared to side placement under organomineral fertilizer application. Increased tuber sizes, number of tubers and tuber yield was observed with side placement of NPK fertilizer compared to the ring placement. Similar trends of results were observed in the second cropping, except that the highest yields of yam were observed under organomineral fertilizer application. The ring method of placement for organomineral fertilizer application is recommended.

Compliance with ethical standards

Conflict of interest: The authors declare that there are no conflicts of interest associated with this study.

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