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African Journal of Plant Science

Full Length Research Paper

Improvement of the kola tree cuttings root (*Cola nitida*) in nursery by removing the terminal bud of the semi-lignified plagiotropic cuttings

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The influence of the terminal bud treatment and genotype on the cutting of plagiotropic semi-lignified kola tree cuttings was studied with the aim of vegetative propagation. Two dressing modes cuttings (B1: Presence of terminal bud and B2: Absence of terminal bud) were tested on three genotypes (D9L20A3, 315 and 323) in a split-plot design with the genotype in the large plot and the cutting dressing mode in the small plot. The experimental unit consists of twenty cuttings. Six months after transplanting, no significant difference of cutting dressing mode on the survival rate was noted. The survival rate was 76.1±11.7% with terminal bud and 70±12.17% without terminal bud for an overall mean of 73.06±12.1%. However, it appears that the way in which kola plant cuttings are dressed, including the removal of the apical bud from semi-lignified plagiotropic cutting, boosts root development and growth despite the predisposition of some kola plant genotypes to rooting (genotype 315). The cuttings dressing method including terminal bud suppression favours root formation at the cuttings, taproot length growth, fresh and dry root biomass compared to cuttings with a terminal bud.

Key words: *Cola nitida*, cuttings, genotype, terminal bud.

INTRODUCTION

Despite its economic importance, kola nut production in Côte d'Ivoire faces several difficulties. Indeed, the kola nut has a slow germination and the seedlings enter into production late (5 to 6 years after planting). In order to

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shorten the time of entry into production, the cutting of the kola tree has been initiated. Unfortunately, in the nursery, the survival rate of the plants is low for the species and the growth of plants from cuttings is very slow. It is necessary to wait 12 to 18 months to obtain plants suitable for transplanting in the field. In addition, the root quality of these plants is poor. It is therefore necessary to propose methods to improve the survival rate of cuttings, to accelerate the growth and root development of kola plants from cuttings. Previous research on several tropical tree species, including kola tree, has indicated a wide range of factors such as genotype, substrate type, leaf area, length of cuttings and rhizogenic substances; which influence the rooting of cuttings (Paluku et al., 2018) in the nursery. These factors also include apical dominance (Charrier, 1969). This apical dominance is the control exerted by the apical portions of the shoot over the outgrowth of the lateral buds and also over root. The classical explanations for correlative inhibition have focused on hormone/nutrient hypotheses (Cline, 1991). The terminal bud is one of the seats of production of high concentration of hormone such as auxin (Normanly, 2010). The auxin hormone and its polar movement, originating in young shoot organs like terminal bud (Aloni et al., 2003, 2006), play a crucial role in many aspects of root growth, development and differentiation. Auxin regulates the development of the primary and lateral roots (Blilou et al., 2005; Raven et al., 2005). The aim of our study is to improve kola rooting system of plant from cutting by suppression of terminal bud. Could this elimination of the terminal bud on the cuttings, contrary to current practices, promote the root development of the cuttings in kola and improve survival rates in the nursery? In the present study, this aspect will be tested in order to propose a method of dressing the cuttings and an optimal method of cuttings of the kola under tunnel.

MATERIALS AND METHODS

Study site and characteristics

Experiments were conducted in April 2019 at Centre National de Recherche Agronomique (CNRA) Man Station, located in the Tonkpi Region, West of Côte d'Ivoire western (7° 19,130'N; 8° 19,452'W). This six-month trial ended in October 2019. Rainfall in the Man area is monomodal. The dry season generally runs from October to March and the rainy season from April to September. The site received an average annual rainfall in 2018 of 1632 mm. The temperature in 2019 ranged from 23 to 27°C.

Plant

The improved kola variety of Centre National de Recherche Agronomique (CNRA) was used for the experiment. 360 kola cuttings of tree genotype were used for experiment. We took 120 cuttings per genotype. These three genotypes were identified by the following codes D9L20A3, 315 and 323. These genotypes were selected on the basis of their productivity.

Technical material

The technical equipment used for this study consists of pruning shears for taking and dressing the cuttings and a decameter for measuring the circumference and height of the cuttings. White plastic bags, hermetically sealed with a stapler and stored in glacial containers were used to preserve the cuttings during transport. The growing medium used for this trial was topsoil (black soil). Bags measuring 30 cm high by 15 cm in diameter were used for transplanting the cuttings. IVORY × 80% WP Fungicide (a.i.: Maneb, Manufacturer: ARYSTA Lifescience) was used for preventive treatment as soon as the cuttings were transplanted.

The method of cuttings used was tunnel cutting (Koko et al., 2011). The reinforcement of the tunnel to shelter the pots (bags) containing the cutting was made of 2.4 m arches connected by bamboo slats. The tunnel was covered with 100 µ thick and 2.6 m wide transparent plastic sheeting, which was veneered on the ground at the sides and ends with stones and bamboo. The tunnels were placed under a nursery shelter which consists of a 2 m high palm frame that allows about 50% of the total light to pass through (Figure 1).

Description of the experiment

Experimental design

The experimental design used was a factorial block arranged in a split-plot with two factors and three replicates. One factor was the terminal bud treatment. Cutting were either with presence or absence of terminal bud (Figure 2). The other factor was the genotype with three modalities (D9L20A3; 315; 323). The genotype was in the large plot and terminal bud treatment in the small plot. A total of six treatments were studied in this trial. Twenty pots each containing one cutting of the same genotype was used per treatment. A total of 120 cuttings from the same genotype were used for this experiment (40 cuttings/genotype/replicate). A total number of 360 cuttings were used for the three genotypes.

Preparation of materials and setting of cuttings

In each tunnel, the pots were filled with previously homogenised topsoil. Three hundred and sixty cuttings from 3 genotypes (120 cuttings/genotype) were taken early in the morning from semi-lignified plagiotropic twigs. The size of the cuttings ranged from 10 to 12 cm. They have 4 leaves cut in half. Cuttings were set about 3 cm deep in the pots.

Conduct of the experiment

The arrangement of the pots and the phytosanitary treatment were carried out one day before the cuttings were tunnelled. For the phytosanitary treatment, the fungicide IVORY 80% WP (a.m. maneb, Manufacturer: ARYSTA Lifescience) was used (70 g of fungicide in 2 L of water applied in the pots). Cuttings were watered in the morning every 2 days with approximately 100 ml/pot. For the measurement of growth parameters, on the 20 pots of each treatment, the number of live plants was recorded at six months. The number of life cuttings at the time of data collection was used to estimate survival. Root development (root length and number of roots), number of new leaves, height of the seedling and aerial and root biomass were assessed after six months. A cutting was considered to have rooted if it had a root of at least 1 cm (Atangana et al., 2006). A rooted cutting was assessed for number of roots by counting, whereas root lengths were measured using a ruler. Dry biomass was assessed using an electronic scale after air drying for two weeks.

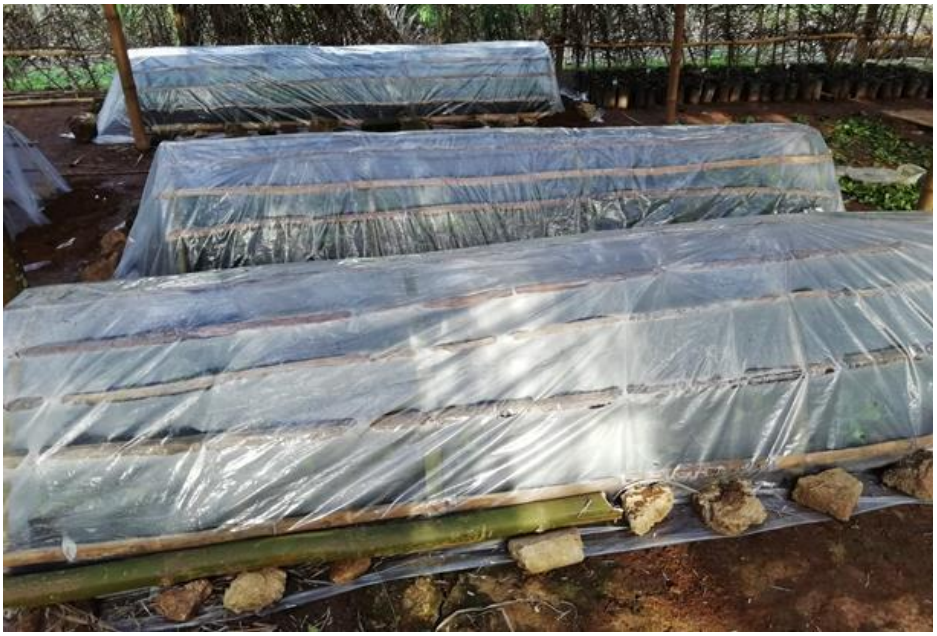

Figure 1. Cutting under tunnel.

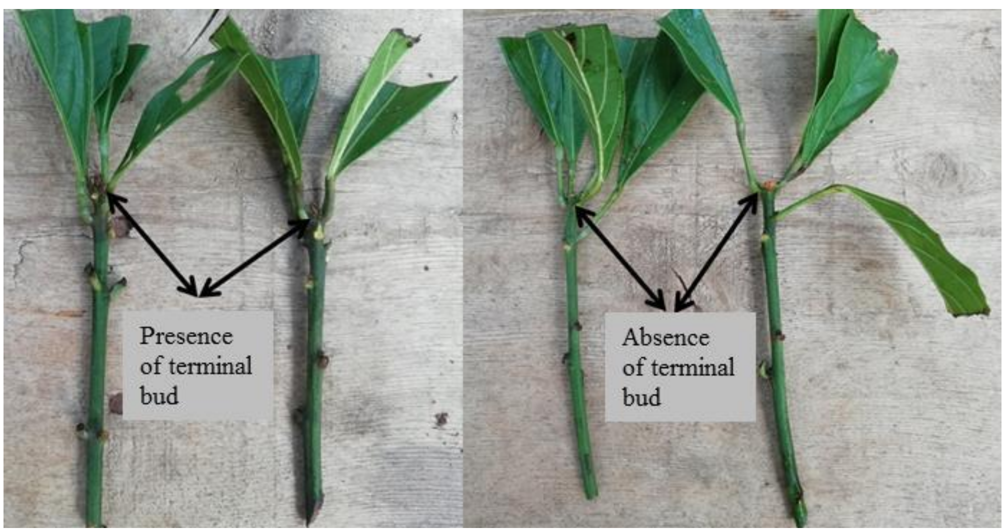

Figure 2. Semi-lignified plagiotropic kola tree cuttings with "Presence" or "Absence" of terminal buds.

Statistical analyses of the data

For the parameters examined, a comparison of the means between the different factors and the different treatments was carried out using the analysis of variance (ANOVA). When a significant difference is observed between treatments for a given factor, the ANOVA is supplemented by post-hoc tests, in particular the Newman-Keuls test, to identify significant differences between the means at the 5% threshold. For all these tests, the STATISTICA 7.1 software was used. The survival rate (SR) was calculated according to the following formula:

Survival rate = 100 × (number of live plants/initial number of plants)

RESULTS

Impact of terminal bud suppression and genotype on cutting survival rate

The ANOVA of the factors "Terminal bud treatment: Presence or Absence of the terminal bud" and "Genotype" on the survival rate of cuttings showed no significant effect of the two factors (Table 1). The survival rate of kola cuttings (Table 2) for the three genotypes (D9L20A3, 315, 323) ranged from 51.7 % to 86.7%. The

Table 1. ANOVA of "Terminal bud treatment" and "Genotype" factors on survival rate.

Factor	F	p
T. Bud T.	1.77	0.207
Genotype	1.507	0.26
Bud × Genotype	0.507	0.61

S.s: Sum of squares; D. f: Degree of freedom; M.s: Mean square; F: Fischer; p: Probability. T. Bud T.: Terminal bud treatment (Presence or Absence of the terminal bud).

Table 2. Cuttings survival rate depending on the treatment of the terminal bud.

Terminal bud treatment	Survival rate per genotype			
	D9L20A3	315	323	Overall average
Presence of the terminal bud	86.7±2.7	80±4.7	61.7±16.57	76.1±11.7
Absence of terminal bud	83.3±6.8	75±11.8	51.7±8.9	70±12.17
Overall average	85±5.2	77.5±9.06	56.7±13.6	73.06±12.1

Table 3. ANOVA of the "Terminal bud treatment" and "Genotype" factors on kola aerial development.

Variable	Factor	F	p
Collar diameter	T. Bud T.	0.750	0.39
	Genotype	2.145	0.128
	T. Bud T. × Genotype	0.812	0.449
News leaves number	T. Bud T.	5.180	***0.027***
	Genotype	1.121	0.334
	T. Bud T. × Genotype	0.668	0.517
Plant height	T. Bud T.	0.968	0.33
	Genotype	1.557	0.221
	T. Bud T. × Genotype	0.195	0.823

F: Fischer; p: Probability. T. Bud T.: Terminal bud treatment (Presence or Absence of the terminal bud).

mean survival rate was 73.06±12.1% for all clones in this trial.

Impact of terminal bud removal and genotype type on the development of the aerial system of the kola cuttings (diameter, height and number of new leaves)

The impact of terminal bud removal and genotype type on the development of kola cuttings aerial system including collar diameter, height and number of new leaves was assessed through an analysis of variance (Table 3). In this study, terminal bud removal had a significant effect (p=0.027) only on the number of new leaves formed. In fact, cuttings with no terminal bud produced more leaves than kola tree cuttings whose terminal bud remained intact with respectively 2.56 and 1.41 new leaves produced on average (Figure 3).

Impact of terminal bud removal and genotype type on the development of the kola root system

Kola cuttings root development was strongly affected by the removal or not of the terminal bud during tunnel cutting (Table 4 and Figure 4). Parameters such as the average number of rooted cuttings (p=0.009) and the average number of cuttings with callus (p=0.01) was

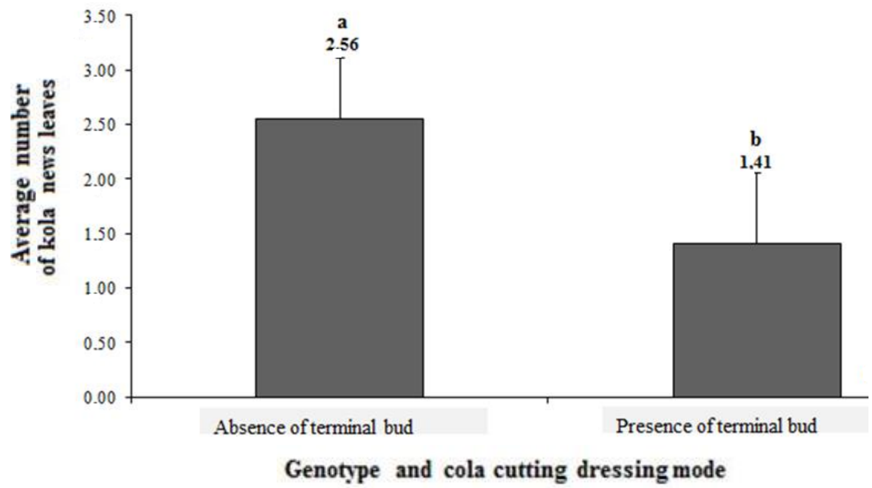

Figure 3. Impact of the terminal bud treatment on the production of kola new leaves.

Table 4. Analysis of variance of the factors "Cuttings dressing mode" and "Genotype" on the root development of cola cuttings.

Variable	Factor	F	p
Average length of the taproot	T. Bud T.	6.96	***0.011***
	Genotype	3.52	***0.037***
	T. Bud T. × Genotype	0.59	0.558
Average number of rooted cuttings	T. Bud T.	7.36	***0.009***
	Genotype	2.54	0.089
	T. Bud T. × Genotype	0.00	1.00
Average number of cuttings with callus	T. Bud T.	7.36	***0.01***
	Genotype	2.54	0.09
	T. Bud T. × Genotype	0.00	1.00
Average number of roots per cutting	T. Bud T.	5.69	***0.02***
	Genotype	3.46	***0.04***
	T. Bud T. × Genotype	0.46	0.63

F: Fischer; p: Probability. T. Bud T.: Terminal bud treatment (Presence or Absence of the terminal bud).

affected. The terminal bud treatment including terminal bud removal favours rooting of cuttings (0.81±0.13 versus 0.48±0.16) (Table 5). Conversely, callus formation is preponderant in cuttings that have preserved their terminal bud (0.52±0.16 versus 0.18±0.13). For parameters such as mean taproot length (p=0.011; p=0.037) and mean number of roots per cutting (p=0.02; p=0.04), an effect of both factors was noted. The removal of the terminal bud stimulates the growth of the taproot (15.15±3.62 versus 7.81±3.32). However, it should be noted that genotype 315 is predisposed to the production of long taproot (16.1±3.06 cm after six months). As for the average number of roots produced per cutting, it was the same observation. The absence of terminal bud would increase root production (p=0.02); however, the genotype's aptitude for root production should not be minimized (p=0.04). Genotype 315 has the highest average number of roots produced per cutting after six months of cutting (1.94±0.47).

Impact of terminal bud treatment and genotype on dry aerial and root biomass of kola

Fresh root biomass and dry root biomass were the two parameters significantly impacted by terminal bud

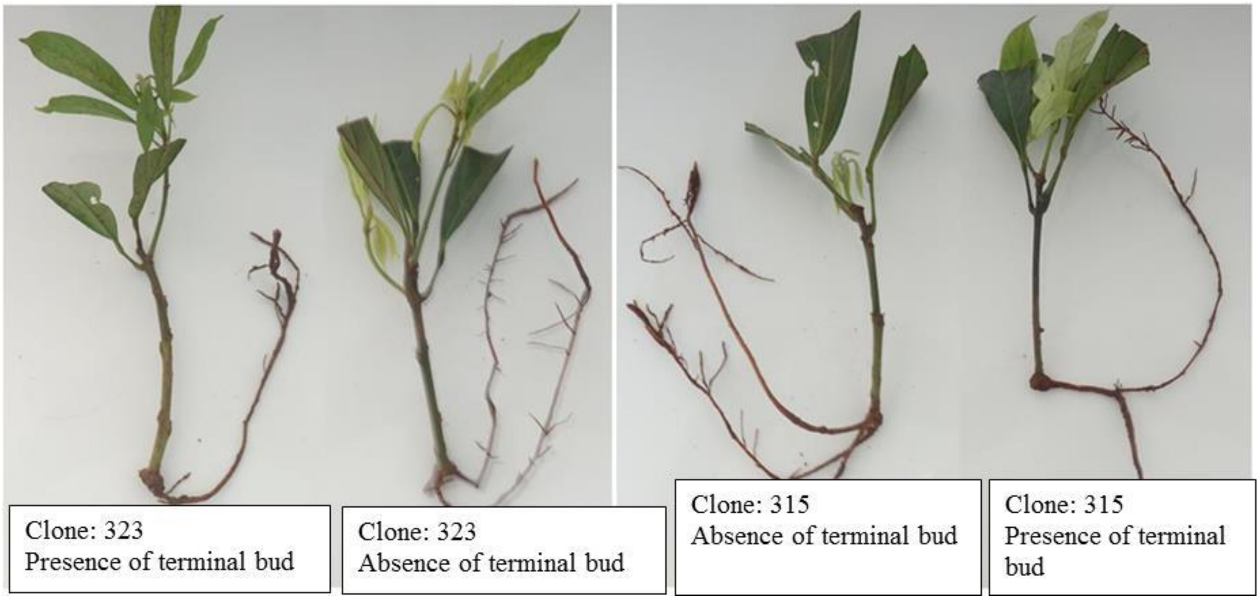

Figure 4. Impact of terminal bud treatment on the kola root system.

Table 5. Kola cuttings root system data analysis.

Genotype and terminal bud treatment	Taproot average length (cm)
D9L20A3	7.0611±3.04[b]
315	16.1±3.06[a]
323	11.29±4.19[ab]
Absence of the terminal bud	15.15±3.62[a]
Presence of the terminal bud	7.81±3.32[b]
	Rooted cuttings average number
D9L20A3	0.5±0.16[a]
315	0.83±0.12[a]
323	0.61±0.16[a]
Absence of the terminal bud	0.81±0.13[a]
Presence of the terminal bud	0.48±0.16[b]
	Cuttings with callus average number
D9L20A3	0.5±0.16[a]
315	0.17±0.12[a]
323	0.39±0.16[a]
Absence of the terminal bud	0.18±0.13[b]
Presence of the terminal bud	0.52±0.16[a]
	Roots average number
D9L20A3	0.94±0.34[b]
315	1.94±0.47[a]
323	1.17±0.37[ab]
Absence of the terminal bud	1.74±0.45[a]
Presence of the terminal bud	0.96±0.35[b]

*On the same column data with the same letters are not significantly different at the 5% threshold (Newman-Keuls test). F: Fischer; p: Probability. T. Bud T.: Terminal bud treatment (Presence or Absence of the terminal bud).

Table 6. ANOVA of "Terminal bud treatment" and "Genotype" factors on the biomass of kola cuttings.

Variable	Factor	F	p
Total fresh biomass	T. Bud T.	1.24	0.27
	Genotype	1.79	0.177
	T. Bud T. × Genotype	0.55	0.58
Fresh root biomass	T. Bud T.	4.11	***0.04***
	Genotype	2.83	0.07
	T. Bud T. × Genotype	1.23	0.3
Fresh aerial biomass	T. Bud T.	0.65	0.42
	Genotype	1.63	0.20
	T. Bud T. × Genotype	0.74	0.48
Total dry biomass	T. Bud T.	0.57	0.45
	Genotype	1.51	0.23
	T. Bud T. × Genotype	1.81	0.17
Dry root biomass	T. Bud T.	4.48	***0.039***
	Genotype	2.93	0.06
	T. Bud T. × Genotype	1.19	0.31
Aerial dry biomass	T. Bud T.	0.008	0.92
	Genotype	1.38	0.26
	T. Bud T. × Genotype	2.83	0.06

*On the same column data with the same letters are not significantly different at the 5% threshold (Newman-Keuls test). F: Fischer; p: Probability. T. Bud T.: Terminal bud treatment (Presence or Absence of the terminal bud).

Table 7. ANOVA of root biomass.

Factor	Fresh root biomass (g)	Dry root biomass (g)
D9L20A3	0.313 ± 0.15^{a}	0.19 ± 0.09^{a}
315	0.708 ± 0.18^{a}	0.45 ± 0.11^{a}
323	0.44 ± 0.17^{a}	0.29 ± 0.11^{a}
Absence of the terminal bud	0.63 ± 0.19^{a}	0.4 ± 0.12^{a}
Presence of the terminal bud	0.35 ± 0.15^{b}	0.22 ± 0.09^{b}

*On the same column data with the same letters are not significantly different at the 5% threshold.

removal (p=0.04 and p=0.039, respectively) (Table 6). Data analysis of kola cuttings root biomass (Table 7) revealed that fresh (0.63±0.19 g) and dry (0.4±0.12 g) root biomass was significantly greater in the case of terminal bud removal of cuttings than fresh (0.35±0.15 g) and dry (0.22±0.09 g) kola cutting biomass with terminal buds.

DISCUSSION

The survival rate of kola cuttings for the three genotypes (D9L20A3, 315 and 323) ranged from 51.7% to 86.7%. The survival rate was 76.1±11.7% with terminal bud and 70±12.17% without terminal bud for an overall mean of 73.06±12.1% regardless of the clone used. This survival rate is higher than the first rate of about 41% previously obtained by Séry et al. (2019) for dry season tunnel cutting of kola. This difference is the result of several factors including the rainy season period (April to October) favourable to cuttings as opposed to the dry season (Ricez, 2008) and the ability of clones (D9L20A3, 315 and 323) to tunnel cuttings (Séry et al., 2019; Koko et al., 2011). In this trial, the impact of terminal bud and genotype suppression could not be demonstrated on the survival rate but on the development of the aerial system of kola cuttings; in particular on the number of new leaves formed, root development and dry root biomass. Indeed, cuttings with no terminal bud produced more leaves than kola cuttings with an intact terminal bud. The same applies to the root development of kola cuttings, which is strongly affected by the removal or not of the terminal bud during tunnel cutting of the kola tree. The apical bud and young leaves are the site of production of high concentration of phytohormone such as auxin (Indole Acetic Acid) (Normanly, 2010) then it is transported by the cellular route by diffusion or using membrane proteins (Kramer and Bennett, 2006) or via phloem vessels (Davies, 2010) to reach the places of function in all parts of the plant including the root system. This hormone controls apical dominance. It inhibits the development of axillary buds, stems and roots at high concentrations. As a result, the suppression of the terminal bud reduces the concentration of auxin in these organs and removes the inhibition exerted by it (William-G Hopkins, 2003). Root elongation is particularly sensitive to auxin (Gaspar et al., 2003; Pacurar et al., 2014). At very low concentrations (10^{-8} M or even less), it causes growth of excised or intact roots. The way in which cuttings are dressed, including the removal of the terminal bud thus favours the rooting of cuttings (Charrier, 1969). This hypothesis is supported by the fact that in cuttings that have preserved their terminal bud there is late root production with a preponderance of cuttings with callus. This is probably due to high concentrations of auxins produced by the apical bud.

For parameters such as the average length of the taproot and the average number of roots per cutting, in addition to the effect of apical bud suppression, the effect of genotype was also noted. In fact, some genotypes were found to be predisposed to root production, notably clone 315. Root formation is a complex physiological process that is influenced by various endogenous and exogenous factors such as the genetic composition of mother plants, thus of the genotype, their physiological state, and several other environmental factors (Makouanzi et al., 2014). Fresh root biomass and dry root biomass were therefore positively impacted by the removal of the terminal bud.

CONFLICT OF INTERESTS

The authors have declared any conflict of interests.

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Effects of organic and inorganic fertilizers on sweet potato production in Iwo, Nigeria

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Sweet potato (*Ipomea batatas*) is one of the most important horticultural crops for human consumption and livestock feed. All parts of the plant are found useful to human consumption, animal feed, and industrial uses. Fertilizer applications have been shown to improve vegetative and storage parameters could be enhanced, but inorganic fertilizers are not always readily available, or are too expensive for prevalently subsistent farmers in Nigeria. This study aimed to compare the performance characteristics of four potato varieties using two fertilizers from inorganic and organic sources using morphological characteristics of the plants. The experiment was carried out in the field and laid out as randomized complete block design with three replications. Two treatments that is, inorganic and organic fertilizers with three levels for each treatment were used. The yield and other morphological characteristics were measured. The results showed that Iwo 1 (variety 3) produced the highest number of tubers (16.67 and 16.69; 16.67 and 16.33) with both inorganic and organic fertilizers and levels, respectively. Iwo 1 (variety 3) also produced the biggest tuber weight (4.57 and 4.60 kg; 3.97 and 3.88 kg) with both inorganic and organic fertilizers and levels, respectively. The results showed significantly (P≤0.05) similar levels of performance of organic fertilizers when juxtaposed with inorganic fertilizer applications, suggesting that in the absence of inorganic fertilizers either due to cost and or availability, organic fertilizers which are relatively more available to the farmer could be used to obtain similar yield levels. Given the bulky nature of the fertilizers as suggested by the quantity used in this experiment, further research will need to be done to determine the best rate for organic fertilizer application.

Key words: Fertilizers, improvement, productivity, sweet potato.

INTRODUCTION

According to the CIP (2018), the sweet potato is the 6th most important crop in the world. In 2019, Nigeria was the third highest producer of the crop in the world, producing over four million tonnes (FAOSTAT, 2019). It is an important horticultural crop in Nigeria whose storage roots are used for both animals and human beings and as a source of income. The crop occupies a vital place in the diet regime of people in Nigeria (Ejechi et al., 2020). Sweet potato is an important crop for food security in some of the world's poorest nations (Yared et al., 2014) and the fresh storage roots are also sold in the market for income generation. All the plant parts of sweet potato and

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its culls are used for food, feed, or for industrial uses (Claessens et al., 2008). Sweet potato adapts to many environmental conditions and is of short life cycle when compared with other tropical tuber crops (Horton, 1988).

The importance of sweet potato is increasing in Nigeria's farming and food systems because it is easy to plant, matures easily and has enormous industrial and economic potentials (Chukwu, 1999). According to the survey conducted in six States in Nigeria by Egeonu and Akoroda (2010), the different forms of sweet potato utilization are boiling and eating with stew/palm oil, slicing and frying, roasting, boiling and eating as snack; boiling and pounding alone or with boiled yam/garri for eating with soup; cooking alone or with another crop to make pottage; slicing and sun-drying for milling into flour; feeding of vines and leaves to livestock; small tuberous roots as livestock feed; made into fufu like cassava; fresh leaves and young shoots consumed as vegetable. In most parts of the Kenya, the storage roots are boiled and eaten, or chipped, dried and milled into flour which is then used to prepare snacks and baby weaning foods (Hagenimana et al., 2001).

Sweet potato supplies vital nutrients such as carbohydrates, proteins, minerals, and vitamins (Stathers et al., 2005). Its storage roots provide 25-30% as carbohydrates and 2.5-7.5% as protein of its dry weight, respectively. It also provides 200-300 mg 100 g^{-1} of potassium (K), 0.8 mg 100 g^{-1} of iron (Fe), 11 mg 100 g^{-1} of calcium (Ca) and 20-30 mg 100 g^{-1} of vitamin C of its dry matter (Çalifikan et al., 2007) as well as copper, zinc and manganese, vitamin B2, B6 and E, while the orange fleshed storage roots provide pro-vitamin A. It can also be used as starch, natural colorants, and fermented products. Wine, ethanol, lactic acid, acetone, and butanol are used as fermented products of sweet potato (Winarno, 1982; Clark, 1988; Duvernaya et al., 2013).

Several researches have been carried out with the use of commercial nitrogen - phosphorus - potassium (NPK) fertilizers and farmyard manure, suggesting that a mix of the two is most efficient (Negassa et al., 2001; Balemi, 2012). However, estimates of typical use of fertilizer (of any kind) by farmers growing sweet potato are largely speculative. Maduakor (1991) noted that actual fertilizer use in Nigeria pales in comparison to the estimated requirements for optimum food production. This position is buttressed by an experiment in Imo State, Nigeria, which showed that despite relatively unfertile soils and high population density, some of the primary root crops (cassava, yam, and cocoyam) were grown with minimal fertilizer in most areas (Goldman, 1996). One of the reasons for this observation is the limited availability of inorganic fertilizer at the time farmers need them; this unavailability is sometimes due to poor transportation systems, and the high cost needed to acquire the fertilizers (Liverpool-Tasie et al., 2016).

Although the tuber yield of the sweet potato plant in marginal soils is relatively high (Uwah et al., 2013), for optimum yield, production of the crop is better on soils which have the required nutrients for proper growth of the plant. NPK (15:15:15) was used for this experiment. The application rate of 300 kg NPK/ha is considered beneficial in the savanna zones of Nigeria (Mukhtar et al., 2010), but as earlier mentioned, farmers will not always have access to the required inorganic fertilizer needs. This was considered in deciding what inorganic fertilizer treatment levels to use for this experiment. Organic fertilizer sources can offer themselves as alternatives to the predicament of farmers in Nigeria because of their relative availability (on-farm sources), and significantly lesser cost. Although they are touted for their many advantages which help to improve soil and soil microorganism health, they are not without their own challenges including bulkiness and non-standardization of the fertilizer content. Regardless, they still present themselves as possible alternatives especially for small scale subsistence farmers who form the bulk of farmers in Nigeria. Given their typically non-standardized nature, it is imperative to compare the performance of the crop under their cultivation with the much more standardized inorganic fertilizer if farmers are to consider them as a substitute for the more popular inorganic fertilizer.

The objective of this study was therefore to evaluate the performance of organic and inorganic fertilizers based on agronomic and morphological characteristics of four potato varieties in Iwo, Nigeria. This information can help farmers the major nutrient requirements (N-P-K) of the sweet potato in regard to growth and productivity using organic and inorganic fertilizers.

MATERIALS AND METHODS

Experimental site and planting materials

This experiment was carried out on sweet potato at Bowen University Teaching and Research Farm Iwo, Osun State, Nigeria. Bowen University is located on latitude 7°62ˈ N and longitude and 4°19ˈ E. The altitude is 210 m above sea level. The soil is well drained, light to moderate textured and sandy loam in nature.Two introduced and two local varieties were used in the present study. The two introduced varieties called Mother's delight and King J were respectively designated as V1 and V2 and the local varieties known as Iwo 1 and Iwo 2 are called V3 and V4, respectively. V1 is the orange fleshed varieties while V2 was cream fleshed sweet potato variety. Mother's delight and King J were obtained from a Commercial Agricultural Center located in Abuja. This Commercial Agricultural Center sells the vine of sweet potato in order to promote the production of orange fleshed sweet potato across the country because it is rich in vitamin C.

Planting and experimental layout

Planting of 30 cm long vine cuttings was carried out on each ridge of 2 m long on 21 July 2016. Each vine cutting was inserted at a slant at a spacing of 30 cm within the rows and 90 cm between rows. The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replicates (block). Each block had

Table 1. Effect of fertilizers on vine length (cm).

Variety	Inorganic fertilizer			Organic fertilizer		
	Control	150 kg/ha	300 kg/ha	Control	18 tonnes/ha	36 tonnes/ha
Mother's delight	20^{aC}	26.61^{bC}	25.88^{bC}	20.94^{aC}	27.06^{bC}	32.56^{bB}
King J	40.78^{aA}	43.22^{aA}	42.28^{aA}	38^{aA}	37.28^{aA}	45.78^{bA}
Iwo 1	32.44^{aB}	32.11^{aB}	33.33^{aB}	32^{aA}	38.33^{bA}	36.44^{bB}
Iwo 2	24^{aC}	32.22^{bB}	33.06^{bB}	27.42^{aB}	32.56^{bB}	33.67^{bB}

Different small letters in the same row for each treatment and capital letters in the column for varieties show significant difference at P<0.05 and P<0.001 probability level, respectively. Treatment 1 was NPK and L1= 150 kg/ha and L2=300 kg/ha. Treatment 2 was organic fertilizer: L1 =60 g and L2 =120 g. Varieties are V1= Mother's delight; V2= King J; V3=Iwo 1 and V4 = Iwo 2.

Table 2. Effect of fertilizers on petiole length (cm).

Variety	Inorganic fertilizer			Organic fertilizer		
	Control	150 kg/ha	300 kg/ha	Control	18 tonnes/ha	36 tonnes/ha
Mother's delight	13.39^{bC}	16.30^{aC}	18.63^{aB}	13.03^{bB}	16.08^{aB}	17.56^{aC}
King J	19.12^{cA}	25.44^{bA}	28.54^{aA}	19^{cA}	23.80^{bA}	28.57^{aA}
Iwo 1	15.93^{bB}	18.21^{aB}	17.00^{abB}	15.59^{bB}	16.22^{bB}	23.93^{aB}
Iwo 2	12.88^{bC}	15.41^{aC}	14.53^{aC}	13.04^{aB}	13.49^{aB}	14.71^{aD}

Different small letters in the same row for each treatment and capital letters in the column for varieties show significant difference at P<0.01 and P<0.001 probability level, respectively. Treatment 1 was NPK and L1= 150 kg/ha and L2=300 kg/ha. Treatment 2 was organic fertilizer: L1 =60 g and L2 =120 g. Varieties are V1= Mother's delight; V2= King J; V3=Iwo 1 and V4 = Iwo 2.

a size of 24 × 2 m and a total of 156 plants were planted in each block.

Fertilizer treatment

Two types of fertilizers were applied. Treatment 1 was NPK and treatment 2 was organic manure. As is standard practice, the fertilizer treatments were applied two and four weeks after planting. Three levels of each treatment including the control were considered while the other two levels were designated as level 1 and level 2. For NPK, 150 and 300 kg/ha were used as level 1 and level 2, respectively. While for the organic fertilizer: one (60 g – equivalent to 18 tonnes/ha) and two handfuls (120 g – equivalent to 36 tonnes/ha) of composted manure purchased from a compost farmer in Iwo were used as level 1 and 2, respectively. The organic manure (compost) was applied per plant.

Data collection

Growth and reproductive parameters were measured. Vine length (cm): The length of two most vigorous vines was taken using a measuring tape. The length was taken from the base of the plant vine to the tip of the vine. The vines were straightened to get accurate reading. Petiole length (cm): This was taken by measuring the stalk of the leaf from the base of the leaf to the point of attachment to the stem. Leaf length was measured from the tip of the leaf to the base or bottom of the leaf. Leaf breadth (cm) was the measurement of the width of the leaf. The widest part of the bottom was measured from side to side. Internode length (cm) was obtained by measuring the distance between the nodes of the vines. Fresh weight of the tubers harvested were taken with a weighing balance.

Statistical analysis

The data collected were subjected to an analysis of variance to determine the differences among the varieties and treatments used. Means separation was performed by Tukey's test.

RESULTS

Data presented in Table 1 show the effect of organic and inorganic fertilizers on vine length. The longest vine was recorded in V2 fertilized with 60 g of manure while the shortest was recorded with V1 without any treatment (control). Effect of fertilizers on petiole length is presented in Table 2. Significant differences between the control and the fertilizer treatments were observed. However, there was no significant difference between 150 kg per ha and 300 kg NPK per ha, but slight difference was observed as 300 kg/ha treatment showed higher average values when compared to the treatment with 150 kg/ha. 60 and 120 g of organic fertilizer showed the same the trend as 120 g treatment showed higher average values when compared to the treatment with 60 g. King J (variety 2) had the longest petiole (25.44 and 28.54 cm; 23.80 and 28.57 cm) with both treatments and levels, respectively.

Data presented in Table 3 show the effect of organic and inorganic fertilizers on internode length. There were no significant differences between the control and the fertilizer treatments. Although slight differences were observed between 150 kg per ha and 300 kg NPK per ha,

Table 3. Effect of organic and inorganic fertilizers on internode length (cm).

Variety	Inorganic fertilizer			Organic fertilizer		
	Control	150 kg/ha	300 kg/ha	Control	18 tonnes/ha	36 tonnes/ha
Mother's delight	3.17^{aA}	3.29^{aA}	5.53^{aA}	4.22^{aA}	4.46^{aA}	4.80^{aA}
King J	3.64^{aA}	4.32^{aA}	5.64^{aA}	4.36^{aA}	4.02^{aA}	4.67^{aA}
Iwo 1	3.67^{aA}	4.21^{aA}	4.47^{aAB}	3.22^{aA}	4.49^{aA}	3.48^{aA}
Iwo 2	3.48^{aA}	3.93^{aA}	3.06^{aB}	3.74^{aA}	4.26^{aA}	3.72^{aA}

Different small letters in the same row for each treatment and capital letters in the column for varieties show significant difference at P<0.05. Treatment 1 was NPK and L1= 150 kg/ha and L2=300 kg/ha. Treatment 2 was organic fertilizer: L1 =60 g and L2 =120 g. Varieties are V1= Mother's delight; V2= King J; V3=Iwo 1 and V4 = Iwo 2.

Table 4. Effect of organic and inorganic fertilizer on leaf breadth (mean ± SD cm).

Variety	Inorganic fertilizer			Organic fertilizer		
	Control	150kg/ha	300kg/ha	Control	18 tonnes/ha	36 tonnes/ha
Mother's delight	$7.57±1.08^{aB}$	$8.58±1.57^{aB}$	$9.58±2.31^{aA}$	$7.10±2.42^{aB}$	$9.83±1.29^{aA}$	$8.50±1.77^{aB}$
King J	$10.16±1.85^{aA}$	$12.11±2.47^{aA}$	$11.7±0.91^{aA}$	$10.1±0.74^{aA}$	$11.2±0.67^{aA}$	$11±0.75^{aA}$
Iwo 1	$10.19±0.77^{aA}$	$10.27±0.32^{aA}$	$10.50±0.6^{aA}$	$9.09±0.9^{bAB}$	$10.23±0.9^{bA}$	$13.34±1.7^{aA}$
Iwo 2	$8.90±2.37^{bB}$	$10.4±2.15^{abA}$	$11.39±1.4^{aA}$	$7.94±0.9^{bB}$	$9.38±0.3^{baA}$	$10.23±1.3^{aB}$

Different small letters in the same row for each treatment and capital letters in the column for varieties show significant difference at P<0.001. Treatment 1 was NPK and L1= 150 kg/ha and L2=300 kg/ha. Treatment 2 was organic fertilizer: L1 =60 g and L2 =120 g. Varieties are V1= Mother's delight; V2= King J; V3=Iwo 1 and V4 = Iwo 2.

Table 5. Effect of organic and inorganic fertilizers on leaf length (cm).

Variety	Inorganic fertilizer			Organic fertilizer		
	Control	150 kg/ha	300 kg/ha	Control	18 tonnes/ha	36 tonnes/ha
Mother's delight	7^{bC}	9^{abB}	11.18^{aB}	7.68^{aB}	10.86^{aB}	10.33^{aB}
King J	12.44^{aA}	14^{aA}	14.28^{aA}	$13. 31^{aA}$	13.28^{aA}	13.47^{aA}
Iwo 1	12.38^{aA}	13.89^{aA}	13.44^{aA}	11.88^{aA}	13.20^{aA}	14.34^{aA}
Iwo 2	10^{bB}	10.66^{abB}	12.23^{aAB}	9.27^{aB}	10.61^{aB}	11.29^{aAB}

Different small letters in the same row for each treatment and capital letters in the column for varieties show significant difference at P<0.001. Treatment 1 was NPK and L1= 150 kg/ha and L2=300 kg/ha. Treatment 2 was organic fertilizer: L1 =60 g and L2 =120 g. Varieties are V1= Mother's delight; V2= King J; V3=Iwo 1 and V4 = Iwo 2.

as 300 kg/ha treatment showed higher average values when compared to the treatment with 150 kg/ha. King J (variety 2) had the longest internode (4.32 and 5.64 cm) for treatment 1 across both levels. Mother's delight (variety 1) had the longest internode (4.46 and 4.80 cm) for treatment 2 across both levels.

Table 4 shows the effect of organic and inorganic fertilizer on leaf breadth. There were no significant differences between the control and the fertilizer treatments for varieties 1 and 2 for both treatments 1 and 2. Significant differences were however between the control and fertilizer treatment 2 for variety 3 and between the control and the fertilizer levels for variety 4. King J (variety 2) had the widest leaf breadth (12.11 and 11.70 cm) for treatment 1 across both levels and King J (variety 2) also had the widest leaf breadth (11.2 cm) for treatment 2, level 1 while Iwo 1 (variety 3) had the widest leaf breadth (13.34 cm) for treatment 2, level 2.

Effect of inorganic and organic fertilizers on leaf length is presented in Table 5. The results showed that there were significant differences between the control and the fertilizer treatments. Only slight difference was observed between 150 kg per ha and 300 kg NPK per ha as 300 kg/ha treatment showed higher average values when compared to the treatment with 150 kg/ha. Similar results were recorded between 60 and 120 g of organic fertilizer as 120 g treatment showed higher average values when compared to the treatment with 60 g. King J (variety 2) had the longest leaves (14 and 14.28 cm; 13.28 and 13.47cm) with both treatments and levels, respectively.

Table 6. Effect of organic and inorganic fertilizer on number of tubers.

Variety	Inorganic fertilizer			Organic fertilizer		
	Control	150 kg/ha	300 kg/ha	Control	18 tonnes/ha	36 tonnes/ha
Mother's delight	8.33^{bAB}	9.33^{abC}	11.33^{aB}	6^{aD}	12.33^{aB}	8^{aC}
King J	6.67^{bB}	10^{abC}	13^{aB}	9^{aC}	11.67^{aB}	13^{aB}
Iwo 1	10.33^{bA}	16.67^{aA}	16.69^{aA}	15.33^{aA}	16.67^{aA}	16.33^{aA}
Iwo 2	6.33^{cB}	13^{bB}	16.33^{aA}	13^{aB}	12^{aB}	14.67^{aAB}

Different small letters in the same row for each treatment and capital letters in the column for varieties show significant difference at P<0.05. Treatment 1 was NPK and L1= 150 kg/ha and L2=300 kg/ha. Treatment 2 was organic fertilizer: L1 =60 g and L2 =120 g. Varieties are V1= Mother's delight; V2= King J; V3=Iwo 1 and V4 = Iwo 2.

Table 7. Effect of organic and inorganic fertilizer on tuber weight (kg).

Variety	Inorganic fertilizer			Organic fertilizer		
	Control	150 kg/ha	300 kg/ha	Control	18 tonnes/ha	36 tonnes/ha
Mother's delight	0.40^{bB}	1.43^{abB}	3.43^{aA}	0.33^{aB}	1.30^{aB}	0.53^{aB}
King J	2.43^{aA}	2.46^{aB}	3.37^{aA}	1.73^{aB}	2.40^{aAB}	3.03^{aA}
Iwo 1	3^{aA}	4.57^{aA}	4.60^{aA}	2.83^{aA}	3.97^{aA}	3.88^{aA}
Iwo 2	1.37^{bAB}	1.80^{abB}	4.30^{aA}	2.10^{aAB}	2^{aB}	3.13^{aA}

Different small letters in the same row for each treatment and capital letters in the column for varieties show significant difference at P<0.05. Treatment 1 was NPK and L1= 150 kg/ha and L2=300 kg/ha. Treatment 2 was organic fertilizer: L1 =60 g and L2 =120 g. Varieties are V1= Mother's delight; V2= King J; V3=Iwo 1 and V4 = Iwo 2.

The effect of organic and inorganic fertilizer on number of tubers is shown in Table 6. Significant differences between the control and the fertilizer treatments were observed for treatment 1. But, there was no significant difference between 150 kg per ha and 300 kg NPK per ha except for variety 4, although, slight difference was observed as 300 kg/ha treatment showed higher average values when compared to the treatment with 150 kg/ha. Iwo 1 (variety 3) produced the highest number of tubers (16.67 and 16.69; 16.67 and 16.33) with both treatments and levels, respectively.

Data recorded in Table 7 demonstrates the effect of organic and inorganic fertilizer on tuber weight. The tuber weight was taken as the average weight of tubers in a plot. Significant differences between the control and the fertilizer treatments were observed but, there was no significant difference between 150 kg per ha and 300 kg NPK per ha, although, slight difference was observed as 300 kg/ha treatment showed higher average values when compared to the treatment with 150 kg/ha. Iwo 1 (variety 3) produced the biggest tuber weight (4.57 and 4.60 kg; 3.97 and 3.88 kg) with both treatments and levels, respectively.

DISCUSSION

Plant productivity is impinged by many factors especially nutrients availability in the soil and soil biota. The depletion in essential soil nutrients nowadays call for fertilizer application to enhance crop yield so as to fight against food insecurity and alleviate poverty in Africa. The cost of inorganic fertilizers is becoming more and more unaffordable to farmers in smallholder agriculture systems. Making use of the available natural resources for organic fertilizer production is of paramount importance in reducing the cost of soil mineral input and replenishing soil fertility and maximizing crop productivity. Many researchers have reported about the importance of organic fertilizers due to the fact that organic fertilizers improve soil chemical, physical and biological properties, soil fertility, water holding capacity, cation and anion exchange capacity, permeability, porosity and texture (Hafifah et al., 2016; Novianantya et al., 2017). Organic fertilizers have the above advantages over the inorganic fertilizers. Thus, the purpose of this study was to compare the strength and performance of inorganic and organic fertilizers during sweet potato growth and development so as to recommend the cheaper organic fertilizers to farmers for their crop production. The decomposition of organic fertilizers such as manure, compost and bio-fertilizers help to amend the soil through the release of organic material needed by plants for its growth and development and high productivity. But the application of manure during crop development may not significantly improve crop productivity due to its slow release type of nutrients to the soil when compared to the inorganic fertilizers. Rishirnmuhirwa and Roose (1998) showed that the decrease in agronomic performance from organic fertilizers could be explained by the slow process of manure decomposition. Nutrients from organic matter are progressively released through mineralization and their action is much slower.

The application of fertilizers whether inorganic or organic resulted in an increase in petiole length, an increase in internode length, an increase in number of tubers and an increase in weight of sweet potato tubers. The longest petiole was recorded in plants receiving 120 g of organic fertilizer. King J variety however provides the best option for longer petioles. The longest internodes were obtained with King J variety using inorganic fertilizer at 300 kg/ha while Mother's delight variety recorded the longest internodes when using organic fertilizer at 120 g. Our results are similar to those of Amara et al. (2015) and Nduwayezu et al. (2005) who reported that application of farmyard manure and solid organic fertilizers increased the vegetative growth of potato through the soil improvement. Atekan and Surahman (2005) reported that application of *Gliricidia* prunings (*Gliricidia sepium*) into acid mineral soils enhanced soil chemical properties due to the increase in the total base cations (Ca, Mg, and K).

An increase in the measure of fertilizers whether inorganic or organic resulted in mixed results for leaf breadth. This suggests that it may be appropriate to use anywhere between 150 kg/ha and 300 kg/ha of inorganic fertilizer to have wider leaf breadth or between 60 to 120 g of organic fertilizer. The use of organic fertilizer and Iwo 1 variety provide the best option for wider leaf breadth. Similar results were reported by Adeyeye et al. (2016) who indicated that numbers of leaves were significant in all the treatments using organic and inorganic fertilizer.

An increase in the measure of fertilizers whether inorganic or organic resulted in an increase in the number of tubers. Our results are consistent with those of Sidiky et al. (2019) demonstrated that fertilizers improved all the agronomic parameters of sweet potato compared to the control treatment during two years of experiment. Similar results were also reported by Okpara et al. (2004) showed that the species of green manure used improved the yield of successively cultivated sweet potato. Okpara et al. (2004), also in a study on infertile soil in Nigeria, found that green manure with mucuna (*Mucuna pruriens*) provided a root yield similar to the yield obtained mineral NPK fertilizer and a higher yield than those under other green manure species. In the present study, the highest number of tubers were obtained with 300 kg/ha of inorganic fertilizer. Iwo 1 (a local variety) provides the best option for more tubers. This is likely due to its acclimatization to the region. It is quite interesting to note that the number of tubers produced by 150kg/ha of inorganic fertilizer and 60g of organic fertilizer yielded averagely the same number of tubers. Also, for organic fertilizer considering the Iwo 1 variety, 120 g yielded less tubers than 60 g. These are contrary to those of Balemi (2012) who reported that the application of any of the cattle manure at 10, 20 and 30 t ha^{-1} alone improved the total tuber yield only over the absolute control but could not significantly increase the total tuber yield over the standard control indicating that unless it is combined with inorganic fertilizers, farmyard (cattle) manure alone cannot considerably enhance tuber yield. An increase in the measure of inorganic fertilizer resulted in an increase in yield. This suggests that to have greater yield, there is a need to use preferably between 150 to 300 kg/ha of inorganic fertilizer. For organic fertilizer, smaller portion of fertilizer resulted in increased yield. To use organic fertilizer, 60 g is preferable. Iwo 1 variety provides the best option for increased yield. Novianantya et al. (2017) reported that the application of compost and biofertilizer increase the weight of sweet potato tuber and starch content of sweet potato tubers because the application of compost mixture and biofertilizer supplied the essential nutrients to plants during the growth and development stages. Similarly, Sidhu et al. (2007) demonstrated that there was 29% yield increase due to the application of 50 t ha^{-1} in potato over FYM untreated control. According to Pahlevi et al. (2016), potassium is an important macronutrient which contribute to the expansion of tuber during development and which participates in the process of translocation of phyto-assimilates from the source (mature leaves) to the storage section (sweet potato tuber). Djalil and Dasril dan Pardiansyah (2004) also reported that the amendment of soil with organic matter sources of potassium can increase the production of sweet potato tubers.

Conclusion

This study suggests to us that smallholder farmers can successfully use organic fertilizers to produce their sweet potato crops at relatively comparable levels when inorganic fertilizers are either too expensive or unavailable altogether. The application of fertilizers whether inorganic or organic resulted in an increase in petiole length, an increase in internode length, an increase in number of tubers and an increase in weight of sweet potato tubers. Iwo 1 (variety 3) produced the highest number of tubers (16.67 and 16.69; 16.67 and 16.33) with both treatments and levels, respectively. Iwo 1 (variety 3) also produced the biggest tuber weight (4.57 and 4.60 kg; 3.97and 3.88 kg) with both treatments and levels, respectively.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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