EFFECT OF PLANT SPACING AND NPK 15-15-15 FERTILIZER RATES ON THE GROWTH AND YIELD OF SWEET POTATO (*Ipomea batatas* LAM) IN KASHERE, GOMBE STATE

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Abstract: A field experiment was conducted to determine the effect of plant spacing and NPK 15-15-15 fertilizer rates on the growth and yield of sweet potato (*Ipomea batatas* Lam.) at the Teaching and Research Farm of Federal University of Kashere, Gombe State during the 2019 and 2020 wet seasons. The trial consisted of five plant spacing (30 x 30, 30 x 45, 30 x 60, 30 x 75 and 30 x 90 cm) and five NPK 15-15-15 fertilizer rates (0, 90, 120, 150 and 200 kg ha^{-1}). The treatments were laid out in a randomized complete block design (RCBD), replicated three times. Results from the combined analysis indicated that vine length, number of vines, number of leaves, tuber weight and tuber yield significantly differed due to spacing and NPK 15-15-15 fertilizer rates. However, there was no significant difference (P>0.05) among the treatment means on leaf area plant^{-1} tuber length and tuber diameter due to plant spacing and NPK 15-15-15 fertilizer rates. There was no significant interaction between spacing and NPK 15-15-15 fertilizer. It can be concluded that spacing 30 × 30 cm was found to produce higher growth attributes over the rest of the treatments, while spacing 30 × 90 produced higher yield attributes over the rest of the treatments. Application of 200 kg ha^{-1} of NPK 15-15-15 fertilizer was found to produce higher growth yield attributes over the rest of the treatments.

Keywords: Sweet potato, NPK fertilizer, Plant-spacing, plant growth, crop yield

Introduction

Sweet potato (*Ipomea batatas* L) is a dicotyledonous plant that belongs to the family *Convolvulaceae* (Agim, 2000). The crop is grown in many countries globally but production primarily occurs in tropical and subtropical areas where it is an important staple food in the diet of many people (Amjad and Anjum, 2001). Sweet potato is one of the most important root and tuber crops in sub-Saharan Africa with both domestic and industrial uses and its nutritional value far exceed that of yam, cocoyam and cassava (Shiiel *et al.*, 1997). Potato is used for varieties of purposes and as vegetable for cooking at home. It is likely that less than 50% of potato grown worldwide is consumed fresh and the rest processed into potato food product and food ingredient for cattle, pigs, and chicken (Anikwe, 2000). In Nigeria it is prepared into potato chips. More so, the starch from potato is widely used by pharmaceutical, textile, wood and paper industries as adhesive agent (Ashgar *et al.*, 2006).

Plant population is an important factors in contributing to higher yield of sweet potato (Mohammed, 1984). Optimum plant spacing is also another important aspect of crop production; wider plant spacing not only leads to excessive vegetative growth but also accelerates the evaporative losses of water from the bare ground (Rashid and Shakar, 1986). On the other hand, the struggle for existence increases with increasing plant population because of severe competition for light, water and nutrients (Rashid and Shakar, 1986). The spacing of a crop may be varied according to climatic condition, soil fertility and cultivar adaptation to a particular region. Under wider spacing, the plants are more vigorous in terms of leaf size, which might be due to less competition for light, nutrients and moisture as compared to closer spacing (Rai *et al*., 2003). Among the various cultural practices, proper spacing and application of different doses of fertilizer at appropriate time are of great importance especially for semi-arid conditions. It is well documented that growth and yield of plants are greatly influenced by a wide range of spacing and nutrient supply. An approach involving chemical fertilizers, organic manures and bio-fertilizers to bridge the gap between nutrient demand and supply will boost crop production (Siyang and Arora, 1978).

Ashrafu *et al.* (2013) reported that sweet potato yield ha^{-1} in Nigeria has declined. However, the low yield could be attributed to poor field management by the farmers. Soil fertilization is one of the main factors in increasing the yield of plants. It affects the accumulation, mineralization and humification of fertilizer added to the soil and determines plant production potential (Loginow *et al*., 1991; Bijisma and Lamber, 2000). The amount of fertilizers introduced into the soil, including mineral fertilizers affects the amount of mineral nitrogen available to the plants and the organic carbon content of the soil (Chatterjee and Som, 1991). Mineral fertilization improves light, soil physical properties and water. Fertilization not only increases crop yield but also alter its quality and results in higher buildup of nutrients (Vos, 1999). Crop yield and mineral fertilizer efficacy depend on the content of available phosphorous, potassium and nitrogen in the soil (Strimumari and Ockerman, 1990). It has been found that nutrients present in fertilizers are more effective than the equivalent amount of these nutrients present in farmyard manure. Therefore mineral fertilizer efficacy for potatoes was noticeably higher than that of organic fertilizer (Sheil *et al.*, 1997). Depending on fertilizer forms, rates and nutrient ratios, the content of dry matter, starch, protein and other substance may either increase or decrease.

Researchers also show that the crop requires as much of 169 kg ha^{-1} of P_2O_5 with increasing phosphorous requirements (Rai*et al.*, 2003). Pervez *et al.* (2004) said 180 kg ha^{-1} should be used to dress potato. However 168 kg ha^{-1} fertilizer could be used to maintain long term soil fertility. Soil fertility makes crop grow faster and also improve healthy soil.NPK 15-15-15 fertilizer should be applied at the rate of 250 kg ha^{-1} and this must be done before and after planting before flowers emerge (Rai *et al.*, 2003).

According to Mohammed (1984), most of the farmers usually do not apply any fertilizer or just apply a small amount of urea or organic manures of unspecified quantity. This may be one of the reasons that yields obtained by local farmers are lower than yields obtained elsewhere. Josji and Patil (1992) reported that potato crop has strict requirements for a balanced fertilization without which growth and development of the crop are poor; yield and quality of tubers are also diminished.

Among macro nutrients required by the crop nitrogen is found to be the most limiting in soils (Joshi, 1987). Availability of nitrogen is of prime importance for growing plants. It is one of the major and indispensable constituents of protein, nucleic acid and integral part of chlorophyll molecules which are responsible for photosynthesis. Phosphorus is also an indispensable constituents of nucleic acid, phosphor lipids and several enzymes. Potassium imparts increased vigour and disease resistance to plants. It also regulates water loss from the plants by maintaining a balance between metabolism, respiration and transpiration. As with other root crops, sweet potato has high requirements for potassium relative to nitrogen. However, due to unavailability of straight K fertilizer in the market, wood ash could be an alternative and cheaper source of K that is available. The K_2O concentration in the wood ash was analyzed and discovered to be about 3%. Thus, ash could be an important source of potassium for sweet potato production (Tsuno and Fujise, 1965).

In Nigeria, the mixed farming system with livestock rearing is an integral part of crop production. The availability of large quantity of farmyard manure being rich in organic matter can be used for supplementing nutrients. The organic manure not only provides nutrient to the plants but also improves the soil texture by binding effect to soil aggregates. Organic manure increases CEC, water holding capacity and phosphate availability of the soil. Besides improving the fertilizer use efficiency and microbial population of soil; it reduces nitrogen loss due to slow release of nutrients. A number of factors are responsible for successful cultivation of sweet potato. Among these is the judicious application of fertilizers especially N, P and K with different spacing. Keeping these facts in view, a field experiment was conducted with the objective to study the effect of plant spacing and NPK 15-15-15 fertility rates on the growth and yield of sweet potato.

Materials and Methods

A field trial was conducted during the 2019 and 2020 cropping season at the Teaching and Research Farm of the Federal University of Kashere, located at latitude $9^0$46'N, longitude 10^0 57' E and at an altitude of 431 m above the mean sea level. Soil samples from the study area were taken randomly to a depth of 0-30 cm using tubular auger. The samples were mixed thoroughly in a container after which a representative sample was scooped out from the bulk and analyzed to determine the initial soil fertility levels. The pH was measured in water (1:2.5 soil: water) and also in 0.01M $CaCl_2$ using a cyber scan 20 pH meter. The soil organic carbon was determined through the wet oxidation method (Walkely and Black, 1965). The total nitrogen was determined by micro kjeldahl digestion distillation method (Bremmer, 1965). While available phosphorous was determined by Bray 1 method (Bray and Kurtz, 1945). The exchangeable cations (Ca, Mg, K and Na) and the cation exchange capacity (CEC) were determined using standard procedures as described by Agbenin (1995).

The trial consisted of five plant spacing (30 x 30, 30 x 45, 30 x 60, 30 x 75 and 30 x 90 cm) and five NPK 15-15-15 fertilizer rates (0, 90, 120, 150 and 200 kg ha^{-1}). The treatments were laid out in a randomized complete block design (RCBD), replicated three times. The experimental field was thoroughly and cross-ploughed with the help of mould board plough and cross-harrowing was done with a tractor, the soil was made to a fine tilth. Plots of 2.40 × 2.25 m size were prepared, with paths and channels prepared according to the layout of the experiment.

Rooted vine cuttings of sweet potato were treated with 0.02% Thiram to check the infection of damping off before planting on prepared beds at 3.5 cm depth. Regular watering was applied from time to time. The vines were ready for transplanting within six weeks after sowing. Transplanting of the seedlings was carried out as per treatments *viz.* 30 × 30 cm, 45 × 30 cm, 60 × 30 cm, 75 × 30 cm and 90 x 30 cm.

The vine cuttings were cut for transplanting from the nursery beds when they have attained six to eight well developed leaves and a good root system. To replace the unsuccessful or dead vines, gap filling was done in the early period to maintain plant population. To protect the plants from termites, chloropyriphos 20 EC at 0.75 kg ha^{-1} was applied to entire field immediately after transplanting. To check pest infestation malathion 50EC (0.05%) was sprayed at interval of 20 and 45 days after transplanting and up to a week before maturity of the crop. To reduce the attack of rodents, zinc phosphate tablets were kept inside the soil in the experimental plots.

Five plants were randomly selected from each plot and tagged. All the following observations were recorded from these plants: vine length of sweet potato was measured using a measuring tape from bottom to terminal bud of five randomly selected plants and averaged to give vine length $plant^{-1}$. Number of vines $plant^{-1}$ was obtained by physical counting of vines from five randomly selected plants and averaged to give number of vines $plant^{-1}$. Number of leaves $plant^{-1}$ was obtained by physical counting of leaves from five randomly selected plants and averaged to give number of leaves $plant^{-1}$. Leaf area of five randomly selected plants of each plot were obtained at 45 days after planting using a leaf area meter and the area averaged to give leaf area (cm^2) $plant^{-1}$.

Weight of tubers was taken from the five randomly selected plants after removing soil from the tubers. The length of tubers of five randomly selected plants was measured using a measuring tape and averaged to give tuber length $plant^{-1}$. The diameter of tubers from the base portion of the tuber was measured with vernier calipers and averaged to give tuber diameter $plant^{-1}$. The tuber yield $plot^{-1}$ (kg) was obtained by weighing the tubers in each plot using a weighing balance and the weight recorded. Tuber yield ha^{-1} was obtained by converting total tuber yield $plot^{-1}$. Data collected was analyzed using analysis of variance (ANOVA). Means were compared using the least significant difference at 5% level of probability.

Results and Discussion

Soil physical and chemical analysis used for the experiment

From the soil physical analysis as shown in Table 1 the soil contains a higher proportion of sand and clay, low sit and low organic carbon. The chemical analysis (Table 1) also shows low pH, the total nitrogen was low, low available phosphorus, low available potassium, low available calcium, low available sodium, low available magnesium and low cation exchange capacity as reported by Anon (2005). The physico-chemical characteristic of the soil of the study area may have contributed to the good performance of the crop.

Table 1: Physico-chemical characteristics of soils of the experimental site

Soil composition	Soil depth 0 – 30 cm	
	2019	**2020**
Particle size (g/kg)		
Clay	21.72	22.44
Silt	18.28	19.42
Sand	60.00	58.14
Textural class	Sandy clay	Sandy clay
Chemical properties		
pH in water	5.6	7.4
pH in 0.1 ml CalCl2	6.1	6.6
Organic Carbon g/kg	1.22	0.63
Available P (mg/kg)	6.25	6.32
Total Nitrogen	0.14	0.09
Exchangeable cations (c mol/kg)		
Ca	2.63	2.67
Mg	1.40	0.79
K	0.31	0.26
Na	0.70	0.17
CEC	6.50	9.47

Table 2: Effects of spacing and NPK (15-15-15) fertilizer on growth attributes of sweet potato in Kashere during the 2019 and 2020 wet seasons combined analysis

Treatments	Vine Length (cm)	No. of Leaves plant^{-1}	No. of Vines plant^{-1}	Leaf area(cm^2)
Spacing				
30 x 30 cm = S_1	157.35	18.47	17.12	126.42
30 x 45 cm = S_2	154.28	14.26	14.26	132.88
30 x 60 cm = S_3	151.32	11.38	13.37	133.34
30 x 75 cm = S_4	147.28	9.46	11.68	136.10
30 x 90 cm = S_5	137.23	6.32	09.24	141.57
LSD	4.24	2.67	2.12	NS
NPK (15-15-15) Fertilizer (kg) ha^{-1}				
0	134.45	10.11	8.88	124.32
90	146.36	11.57	10.46	131.18
120	153.16	12.54	12.25	133.24
150	154.36	14.33	14.23	136.30
200	158.45	16.87	16.28	141.37
LSD	4.33	2.66	2.10	NS
Interaction S x NPK	NS	NS	NS	NS

Effect of spacing and NPK 15-15-15-fertilizer application on growth attributes

Significant difference ($P<0.05$) among the treatment means due to plant spacing and NPK 15-15-15-fertilizer application on vine length was observed as shown in Table 2. The result indicated that S_1 produced longer vine length (157.35 cm), which was followed by S_2 (154.28 cm), followed by S_3 (151.32 cm), followed by S_4 (147.28 cm) and lastly S_5 produced the shortest vine length (137.23 cm). Similarly, in the application of the different rates of NPK 15-15-15-fertilizer, NPK at 0 kg ha^{-1} produced the shortest vine length (134.45 cm), followed by NPK 15-15-15 fertilizer at 90 kg ha^{-1} (146.36 cm), followed by NPK 15-15-15 fertilizer at 120 kg ha^{-1} (153.16 cm) followed by NPK 15-15-15 fertilizer at 150 kg ha^{-1} (154.36 cm) and NPK 15-15-15 fertilizer at 200 kg ha^{-1} produced the longest vine length (158.45 cm).

There was also significant difference ($P<0.05$) on number of vines among the treatment means due to plant spacing and NPK 15-15-15-fertilizer application (Table 2). S_1 produced more number of vines plant^{-1} (8.47), which was followed by S_2 (7.26), followed by S_3 (6.37), followed by S_4 (5.68) and lastly S_5 produced the fewest number of vines plant^{-1} (4.24). Similarly NPK at 0 kg ha^{-1} produced the fewest number of vines plant^{-1} (4.44), followed by NPK 15-15-15 fertilizer at 90 kg ha^{-1} (5.46), followed by NPK 15-15-15 fertilizer at 120 kg ha^{-1} (6.25), followed by NPK 15-15-15 fertilizer at 150 kg ha^{-1} (7.23) and NPK 15-15-15 fertilizer at 200 kg ha^{-1} produced the highest number of vines plant^{-1} (8.28).

Number of leaves was observed to be significant difference ($P<0.05$) among the treatment means due to plant spacing and NPK 15-15-15-fertilizer application as shown in Table 2. S_1 produced more number of leaves plant^{-1} (18.47), which was followed by S_2 (14.26), followed by S_3 (11.38), followed by S_4 (9.46) and lastly S_5 produced the fewest number of leaves plant^{-1} (6.32). Similarly, NPK at 0 kg ha^{-1} produced the fewest number of leaves plant^{-1} (10.11), followed by NPK 15-15-15 fertilizer at 90 kg ha^{-1} (10.57), followed by NPK 15-15-15 fertilizer at 120 kg ha^{-1} (12.54), followed by NPK 15-15-15 fertilizer at 150 kg ha^{-1} (14.33) and NPK 15-15-15 fertilizer at 200 kg ha^{-1} produced the highest number of leaves plant^{-1} (16.87).

However, there was no significant difference ($P>0.05$) among the treatment means on leaf area plant^{-1} due to plant spacing and NPK 15-15-15 fertilizer rates. There was no significant interaction between spacing and by NPK 15-15-15 fertilizer application on all growth attributes.

The results of the present study indicated that spacing significantly affected growth parameters. The data showed that application of 30 × 30 cm spacing gave maximum increase in vine length, number of vines plant^{-1} and number of leaves plant^{-1}. Ideally, wider spacing helps the individual plants to utilize more water, nutrient, light and air in contrast to closer spacing, where the plants population unit^{-1} area are higher. Higher competition among closer crops are expected to result into poor growth as reported by Joshi (1987); Sounda *et al*. (1989). However the result of this present work shows that 30 × 30 cm spacing was optimum for the growth of the crop.

The application of 200 kg of NPK 15-15-15 fertilizer resulted in increased vine length; number of vines plant^{-1} and number of leaves plant^{-1}, the control of no NPK 15-15-15 fertilizer applied did not enhance growth of the crop. This further shows the importance of these nutrient in crop growth and development and that when these elements are in deficit, the growth is restricted; this could be responsible for the low vegetative growth in the control.

Effect of spacing and NPK 15-15-15-fertilizer application on yield attributes

The differences observed among the treatment means due to plant spacing and NPK 15-15-15-fertilizer application on tuber length and tuber diameter was not significant ($P<0.05$) as shown in Table 3. However, significant difference was observed on tuber weight as shown in Table 3. S_1 produced a lesser tuber weight plant^{-1} (291.15 gm), which was followed by S_2 (347.11 gm), followed by S_3 (356.61 gm), followed by S_4 (363.40 gm) and lastly S_5 produced the heaviest tuber weight plant^{-1} (394.73 gm). Similarly, NPK at 0 kg ha^{-1} produced the least tuber weight plant^{-1} (303.53 gm), followed by NPK 15-15-15 fertilizer at 90 kg ha^{-1} (323.62 gm), followed by NPK 15-15-15 fertilizer at 120 kg ha^{-1} (331.36 gm), followed by NPK 15-15-15 fertilizer at 150 kg ha^{-1} (341.16 gm) and NPK 15-15-15 fertilizer at 200 kg ha^{-1} produced the heaviest tuber weight plant^{-1} (343.80 gm). There was no significant interaction between spacing and by NPK 15-15-15 fertilizer application on these yields attributes.

Table 3: Effects of spacing and NPK (15-15-15) fertilizer on yield attributes of sweet potato in Kashere, during the 2019 and 2020 wet seasons combined analysis.

Treatments	Tuber length (cm)	Tuber diameter (cm)	Tuber Weight (gm)
Spacing			
30 x 30 cm = S_1	13.51	7.11	291.15
30 x 45 cm = S_2	11.71	8.79	347.11
30 x 60 cm = S_3	10.29	9.07	356.61
30 x 75 cm = S_4	10.27	10.11	363.40
30 x 90 cm = S_5	10.17	10.31	394.73
LSD	NS	NS	4.34
NPK (15-15-15) Fertilizer (kg) ha^{-1}			
0	8.28	8.11	303.53
90	9.20	8.57	323.62
120	10.19	8.72	331.36
150	11.13	8.87	341.16
200	14..30	10.12	353.20
LSD	NS	NS	4.32
Interaction S x NPK	NS	NS	NS

Table 4: Effect of Spacing and NPK (15-15-15) Fertilizer Rates on Tuber Yield Plot^{-1} and ha^{-1} in Kashere, during the 2019 and 2020 wet Season combined analysis

Treatments	Tuber Yield (kg) Plot^{-1}	Tuber Yield (tons) ha^{-1}
Spacing		
30 x 30 cm = S_1	5.88	116.87
30 x 45 cm = S_2	9.34	188.35
30 x 60 cm = S_3	11.32	228.47
30 x 75 cm = S_4	12.11	238.77
30 x 90 cm = S_5	7.56	110.00
LSD	0.17	3.71
NPK (15-15-15) Fertilizer (kg) ha^{-1}		
0	5.90	118.34
90	9.12	200.87
120	10.11	216.34
150	10.87	220.86
200	11.34	226.12
LSD	0.16	3.68
Interaction S x NPK	NS	NS

Tuber yield

Significant difference ($P<0.05$) among the treatment means due to plant spacing and NPK 15-15-15-fertilizer application was observed on tuber yield plot^{-1} as shown in Table 4. S_1 produced a lower tuber yield plot^{-1} (5.88 kg), which was followed by S_2 (9.34 kg), followed by S_3 (11.32 kg), followed by S_4 (12.11 kg) and lastly S_5 produced the highest tuber yield plot^{-1} (13.12 kg). Similarly, NPK at 0 kg plot^{-1} produced the lowest tuber yield plant^{-1} (5.90 kg), followed by NPK 15-15-15 fertilizer at 90 kg plot^{-1} (9.12 kg), followed by NPK 15-15-15 fertilizer at 120 kg ha^{-1} (10.11 kg), followed by NPK 15-15-15 fertilizer at 150 kg plot^{-1} (10.87 kg) and NPK 15-15-15 fertilizer at 200 kg plot^{-1} produced the heaviest tuber weight plot^{-1} (12.34 kg).

Similarly, there was a significant difference ($P<0.05$) among the treatment means due to plant spacing on tuber yield ha^{-1}. S_1 produced the lowest tuber yield ha^{-1} (116.87 tons), which was followed by S_2 (188.35 tons), followed by S_3 (228.47 tons), followed by S_4 (238.47 tons) and lastly S_5 produced the highest tuber yield ha^{-1} (249.48 tons). It was also indicated in Table 4 that there was a significant difference ($P<0.05$) among the treatment means on tuber yield ha^{-1} due to NPK 15-15-15-fertilizer. NPK at 0 kg ha^{-1} produced the lowest tuber yield ha^{-1} (111.34 tons), followed by NPK 15-15-15 fertilizer at 90 kg ha^{-1} (200.87 tons), followed by NPK 15-15-15 fertilizer at 120 kg ha^{-1} (216.34 tons), followed by NPK 15-15-15 fertilizer at 150 kg ha^{-1} (220.86 tons) and NPK 15-15-15 fertilizer at 200 kg ha^{-1} produced the heaviest tuber yield ha^{-1} (226.68 tons). There was no significant interaction between spacing and by NPK 15-15-15 fertilizer application on the yield of the tubers.

The results indicated that wider spacing (90 × 30 cm) gave significantly higher tuber weight and yield over narrow spacing of 45 × 30 cm, 60 × 30 cm, 75 x 30 cm. This may be due to the fact that higher spacing promotes crop growth and development. Competition was also reduced among the crops. Plants grown under wider spacing took more nutrients and the rate of photosynthesis was higher than plants under narrow spacing. Therefore, whenever plants are grown under narrow spacing, there would be higher competition for space, light, nutrients and water and so could not perform very well due to the less land area available plant^{-1} (Amjad and Anjum, 2001). This finding is in conformity with the results of Pervez *et al.* (2004) who reported that due to reduced competition for essential soil nutrients and sunlight higher spacing promotes the accumulation of photo assimilates, resulting into yield increases. Norman (1992) observed that higher plant density unit^{-1} area increases the competition for essential growth factors among individual plants which do not attain their normal size and yield increases. Muck (1980) reported that carrot yield increased when plant density increased with closer spacing.

The supply of nitrogen and other nutrients by NPK 15-15-15 fertilizer resulted in increased tuber weight and yield. The control of no NPK 15-15-15 fertilizer applied did not enhance growth and yield of the crop. However, 200 kg ha^{-1} of NPK 15-15-15 fertilizer significantly increased both growth and yield of potato. The findings are in accordance with the results obtained by Joshi and Patil (1992), Chatterjee and Som (1991) and Asghar *et al*. (2006) who reported that increases in yield might be due to sustained availability of nutrients throughout the growing phase and also the enhancement of photo assimilates produced to the sink *i.e.* tuber.

Conclusion

It can be concluded that spacing 30 × 30 cm was found to produce higher growth attributes over the rest of the treatments, while spacing 30 × 90 produced higher yield attributes over the rest of the treatments. Application of 200 kg ha^{-1} of NPK 15-15-15 fertilizer was found to produce higher growth yield attributes over the rest of the treatments.

Conflict of Interest

The authors declare that there is no conflict of interest related to this work.

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