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Growth and Yield of Irrigated Sweet Potato (*Ipomoea batatas* (L.) Lam.) As Influenced by Intra-Row Spacing and Potassium

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Abstract: Field study was conducted in 2003/2004 and 2004/2005 dry seasons at the Usmanu Danfodiyo University Teaching and Research Fadama Farm, Sokoto to study the effects of intra-row spacing and potassium on growth and yield of sweet potato. Treatments consisted of factorial combinations of five levels of potassium (0, 50, 100, 150 and 200 kg K ha^{-1}) and four intra-row spacings (20, 30, 40 and 50 cm) laid out in a Randomized Complete Block Design (RCBD) replicated three times. Results showed significant effect of intra-row spacing on all parameters measured. Close intra-row spacing (20 cm) produced tubers of comparatively lower weight, while wide intra-row spacing (50 cm) resulted in significantly bigger tubers. Yield increased with every increment in plant population and was highest at closest intra-row spacing (20 cm). Application of potassium had no significant effect on all the growth parameters under study but significantly increased marketable tuber and fresh tuber yield. Thus, 40 cm intra-row spacing (Due high proportion of marketable tuber) and 50 bags of 100 kg of ash/ha is recommended for use under irrigated condition in the Sokoto Fadama.

Key words: Sweet potato, potassium, intra-row spacing, Fadama

Introduction

Sweet potato (*Ipomoea batatas* (L.) Lam.) belongs to the family Convolvulaceae and has historically played an important role in the quest for food and the struggle for human survival in several countries (Hossain, 1985). It originated in Central America and North Western South America and spread to other parts of the world. It is a warm-season crop and grows best in abundant sunshine, temperatures above 24°C, sandy loam soil and a well-distributed rainfall of 850-900mm per annum. It matures in of 3-9 months duration or longer depending on the variety (Peru, 2003).

Peru (2003) reported 133 million tons of sweet potatoes produced globally per year. Asia with 125 million tons of annual production is the world's largest sweet potato producing region, China with 117 million tons accounts for 90% of worldwide sweet potato production. In contrast, African farmers produce only about 7 million tons of sweet potatoes annually.

In spite of its importance as food and vegetable, very little attention has been paid for improvement in cultural practices (Sarkar, 1985). Sweet potato yields in Africa (5 t ha^{-1}) are low due to poor crop management as compared to Asia (16 t ha^{-1}) and South America (10 t ha^{-1}) (Onwueme and Sinha, 1991). In Nigeria 4.876 t ha^{-1} was the national average and 32 t ha^{-1} is the experimental figure living yield gap of 19t and 146 percent possible improvement (FAOSTAT, 2005).

Plant population is one of the most important factors contributing to high yield of sweet potato (Sarkar, 1985). Farooque *et al*. (1983) and Tallyrand (1981) reported that increase in sweet potato plant population increased total yield per unit area. However, Baker (1981) reported that intra-row spacing had no effect on total root yield or yield of marketable tuber. Thus, proper spacing of sweet

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potato is still a controversial factor among the growers. According to Mohammed (1982), most farmers usually do not apply any fertilizer or just apply a small amount of urea or organic manure of unspecified quantity. This may be one of the reasons why yields obtained by local farmers are lower than yields obtained elsewhere. Patricia and Bansal (1999) reported that potato crop has strict requirement for a balanced fertilization management, without which growth and development of the crop are poor and both yield and quality of tubers are diminished.

As with most root crops, sweet potato has a high requirement for potassium relative to nitrogen. According to Tsuno and Fujise (1965) K is important to the development of tubers because high concentration in leaves (above 4%) promote translocation of photosynthate from leaves to the tuber. The soils in Sokoto Fadama are low in K content therefore the need to study the response to K fertilizer. However due to unavailability of straight K fertilizer in the market, wood ash could be an alternative and cheap 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. Therefore an experiment was setup to study the effect of intra-row spacing and wood ash on the growth and yield of sweet potato in the Sokoto Fadama (Inland valley).

Materials and Methods

Field trials were conducted during 2003/2004 and 2004/2005 dry seasons at the Usmanu Danfodio University Fadama (Inland valley) Teaching and Research farm, Kwalkwalawa Village Sokoto, Sokoto is located (latitude 13°01" N; longitude 5°15" E) at an altitude of about 350 m Above Sea Level (ASL) in the Sudan Savanna agro-ecological zone of Nigeria with a mean annual rainfall of about 752 mm (Kowal and Knabe, 1972). The area is characterized by long dry season with cool air during harmattan (November-February), dry air during hot season from march-may followed by short rainy season. The relative humidity ranged from 15-20% in the dry season and 60-70% during the wet season (Davis, 1982) (Fig. 1). Composite soil samples from 0-30 cm layer were taken at random at different location at the experimental site before planting. The sample was analysis using analytical procedures by Black *et al*. (1965). The soil at the experimental site was loamy sand in texture and was low in total N, exchangeable cat ions, CEC, K, Ca, mg, Bulk density, very low in available P and low to medium in OC (Table 1).

Treatments consisted of factorial combinations of five levels of potassium (0, 50, 100, 150 and 200 kg ha^{-1}) and four intra-row spacings (20, 30, 40 and 50 cm) laid out in a Randomized Complete Block Design (RCBD) replicated three times.

The land was ploughed harrowed and four ridges of 4 m long spaced at 75 cm apart were constructed. Ex-Fateka a common local variety was purchased from nearby farm and harvested for planting into the experimental site. Plant-to-plant spacing within the ridges was maintained as per the treatment. Two vines sets of 30 cm length were planted per hill. Fifty percent of the vine was inserted into the soil at acute angle to the ground. Two vines were planted because it is difficult to get epical portion that can cover the experimental area. Two week after transplanting the crop was thinned to one vine (plant) per stand 40 kg N and 45 kg P ha^{-1} was applied. Nitrogen was applied in form of urea and phosphorous in form of SSP while potassium was applied in form of wood ash (3.0% K) as per the treatments. Half of N, all P and K were applied at land preparation and the remaining half of N was applied 4 weeks after planting. Irrigation was done as and when necessary.

Weeds control was carried out manually using a hoe at the interval of two weeks. In 2003/04 season there was out break of grasshoppers (*Zonocherus variagatus*) that was controlled by spraying Karate® (at the rate of 100 mL/15 L of water) three times at interval of 10 days. Stem rot or *Fusarium wilt* (*Fusarium oxysporum*) infestation was also recorded was controlled by up rooting and burning of infested plant.

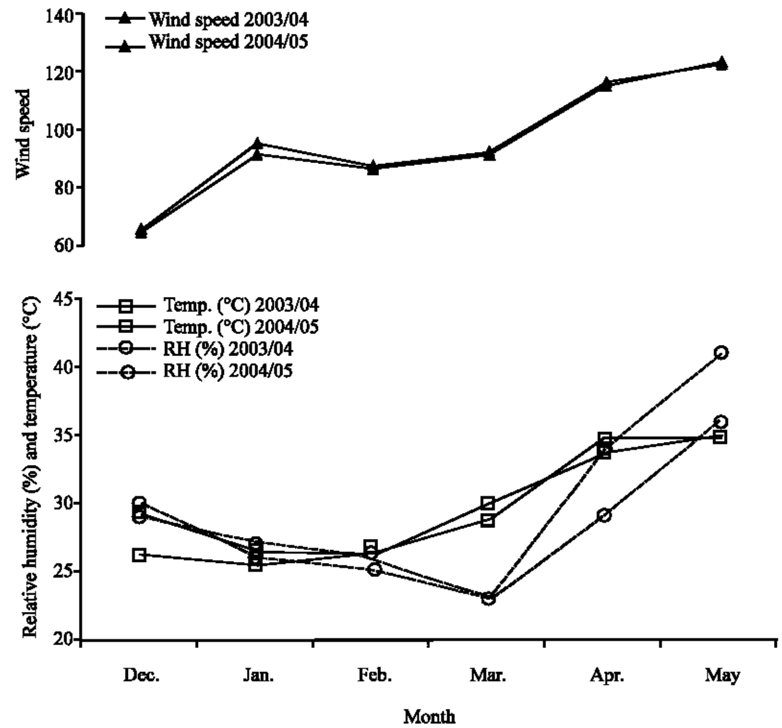

Fig. 1: Temperature, relative humidity and wind speed at the experimental site in 2003/04 and 2004/05 dry season

Table 1: Physico-chemical properties of the soil at the experimental site in 2003/2004 and 2004/2005 dry seasons

Physico-chemical characteristics	2003/04	2004/05
Chemical Characteristics		
pH (H_2O)	5.770	5.800
pH ($CaCl_2$)	4.960	5.000
Organic-C. (g kg^{-1})	0.036	0.364
Nitrogen (g kg^{-1})	0.028	0.031
Phosphorus (mg kg^{-1})	0.590	0.560
Potassium (cmol kg^{-1})	1.770	2.740
Na (cmol kg^{-1})	1.680	1.700
Ca (cmol kg^{-1})	0.150	0.180
Mg (cmol kg^{-1})	0.830	0.650
CEC (cmol kg^{-1})	14.600	19.200
Physical properties		
Sand (g kg^{-1})	700	704
Silt (g kg^{-1})	218	194
Clay (g kg^{-1})	82	102
Textural class	Sandy loam	Sandy loam
BD (g/cm^3)	1.400	1.500

Data collected on growth and yield parameters were subjected to analysis of variance (ANOVA) procedure using the SAS® (1999) system. Significant differences in the treatment were separated using Least Significant Difference test (LSD).

Results and Discussion

Leaf Area Index (LAI)

LAI (Ratio of leaf area to soil area occupied) at 3, 6, 9, 12 and 15 WAP was significantly ($p<0.01$) influenced by intra-row spacing. Higher LAI was recorded with 20 cm than with 30, 40 and 60 cm at all sampling dates (0.77, 1.30, 3.71, 5.38 and 3.46 at 3, 6, 9, 12 and 15 WAP, respectively (Table 2). This is as a result of higher number of plants per unit land area at close intra-row spacing. Tsuno and Fujise (1965) and Chapman and Cowling (1965) observed that a maximum rate of dry matter accumulation in sweet potato is achieved at LAI of 3.24. LAI steadily Increases from 9 and 12 week after planting and declined at 15 weeks due to leaf senescence.

Potassium fertilizer has no effect on LAI (Table 2). This could be as a result of leaching and fixation of K in sandy soil, Brady (1974) and Brady and Ray (2002) reported that fertilizer applied sandy soils on which crops such as vegetables or tobacco are grown might suffer serious losses by leaching. The result of the finding is in agreement with that of Bourke (1985), who reported that a higher rate of K fertilization had no effect on the LAI, but not in conformity with that of Anguria *et al*. (1998) who reported that fertilizer application significantly increased LAI of sweet potato in Uganda.

Crop Growth Rate (CGR)

The dry matter accumulation rate per unit of land area (CGR) was significantly ($p<0.01$) influenced by intra-row spacing (Table 2). Significant higher CGR was recorded with 20 cm intra-row spacing at 3 and 6 WAP than other intra-row spacing. At 9, 12 and 15 WAP higher CGR was recorded with 50 cm intra-row spacing than with 20, 30 and 40 cm spacing. This could be as a result of very high LAI at close spacing, which result to mutual shading of leaves (Table 2), competition for nutrients, water and radiation. The finding is synonymous with that of Warne (1951) who reported that an increase in plant density of glove beet, decreased growth and highest growth was produced in wider plant spacing. The decline in growth at 12 and 15 WAP was due to rapid leaf senescence experienced over time with advancing age in sweet potato plant.

Potassium fertilizer had no significant effect on sweet potato growth (Table 2). this could be as a result of leaching of K from the soil and this make very large proportion of K relatively unavailable to plants. This finding is in agreement with that of Amoah (2001) in Ghana, who reported that potassium fertilizer had no significant effect on growth and yield of sweet potato.

Marketable Tuber

Intra-row spacing had significant effect ($p<0.01$) on the marketable tubers with 20 and 30 cm (6.06, 6.81 t ha^{-1}, respectively) intra-row spacing yielding higher tuber than 40 and 50 cm (5.33, 5.5 t ha^{-1}, respectively) (Table 3). Close spacing (20 and 30 cm) significantly differ from the wide intra-row spacing (40 and 50 cm) with higher number of marketable tuber which is due to more number of pants/unit area, Wide intra-row spacing (40 and 50 cm) produced bigger marketable tubers with more proportion of marketable tuber (Table 3); this could be as a result of efficient utilization of light, nutrients space and water due low or no competition, Ariyo *et al*. (1991) observed that yield per unit area is more a function of the number of plants involved than the potentials of individual plants. And Enus and Razzague (1977) who reported that tuber yield decreased with increase spacing.

K fertilizer had significant effect on the marketable tuber yield with 150 and 200 kg K ha^{-1} significantly out yielding the other K rates (50, 100 and 200) with 6.66 and 6.44 t ha^{-1}; this could be as a result deficient of K in the soil (Table 3). This finding is in line with those of Hameet (1984), Jackson and Thomas (1960) and Nicholaides *et al*. (1981).

Non-marketable Tuber

Close intra-row spacing produced the highest number of non-marketable tubers, while wide intra-row spacing resulted in minimum number of non-marketable tubers (Table 3). This could be due to inefficient utilization of water, light, space and nutrients in densely populated plants in close spacing. The finding is the same with that of Farooque *et al*. (1983), Sarkar (1985) and Bianco (1975) who reported decrease in tuber weight per plant with increase in plant density.

Potassium had no significant effect on number of non-marketable tuber; this could be as a result of loss of K by leaching and fixation reaction.

Table 2: Leaf Area Index (LAI) and Crop Growth Rate (CGR) as affected by spacing and potassium in 2004 and 2005 combined

	Leaf Area Index (LAI)					Crop Growth Rate (g/m²/day) (CGR)				
Treatments	3 WAP	6 WAP	9 WAP	12 WAP	15 WAP	3 WAP	6 WAP	9 WAP	12 WAP	15 WAP
Intra-row spacing (cm)										
20	0.770a	1.300a	3.710a	5.380a	3.460a	1.000	2.350a	2.600c	2.910c	2.520d
30	0.550b	0.940b	2.930b	4.040b	2.870b	0.970	1.990c	3.020b	3.400b	2.860c
40	0.390c	0.830bc	2.380c	3.300c	2.500c	0.980	2.300b	3.330a	3.750a	3.230b
50	0.260c	0.660c	1.930	2.950d	2.480d	0.800	1.570d	3.300a	3.850a	3.640a
SE±	0.029	0.0512	0.095	0.001	0.001	0.053	0.001	0.021	0.001	0.042
Significance	**	**	**	**	**	Ns	**	**	**	**
Potassium (K) rate (kg ha^{-1})										
0	0.490	0.930	2.750	3.800	2.900	1.010	2.040	3.180	3.630	2.220
50	0.500	0.940	2.760	3.840	2.920	1.120	2.040	3.190	3.640	2.190
100	0.490	0.940	2.770	3.840	2.910	1.130	2.050	3.190	3.630	2.190
150	0.500	0.930	2.780	3.850	2.910	1.100	2.070	3.220	3.640	2.200
200	0.490	0.940	2.770	3.850	2.900	1.110	0.187	3.200	3.600	2.210
SE±	0.006	0.025	0.001	0.001	0.002	0.005	0.006	0.002	0.060	0.001
Significance	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Interaction										
S×K	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

Means in column followed by same letter(s) are not significantly different using Least Significance Difference test (LSD) at 5 and 1% level of significance using LSD. Ns = Not significant; * Significant at 5% level; ** Significant at 1% level

Table 3: Marketable, non-marketable and fresh tuber yield (t ha^{-1}) as influenced by spacing and potassium in the two years combined

Treatments	Marketable tuber (t ha^{-1})	Non marketable tuber	Proportion of marketable tuber (t ha^{-1})	Fresh tuber yield (t ha^{-1})
Intra-row spacing (cm) (S)				
20	6.06a	7.91a	43.50	13.90a
30	6.81a	7.09a	49.52	13.75a
40	5.33b	3.58b	60.00	08.91b
50	5.50b	3.31b	62.00	08.81b
SE±	0.149	0.630	-	0.581
Significance	**	**	-	*
Potassium (K) rate (kg ha^{-1})				
0	3.92b	7.050	-	10.97b
50	4.54b	6.800	-	11.34b
100	4.89b	6.610	-	11.50ab
150	6.66a	6.270	-	12.93a
200	6.44a	5.640	-	12.74a
SE±	0.446	0.053	-	0.994
Significance	*	Ns	-	*
Interaction				
S×K	Ns	Ns	-	*

Means in a column followed by same letter(s) are not significantly different at 5 and 1% level of significance using LSD. ns = not significant; * Significant at 5%; ** Significant at 1%

Fresh Tuber Yield

Fresh tuber yield was significantly ($p<0.05$) influenced by intra-row spacing (Table 3). Closer spacing (20 and 30 cm) yielded significantly higher fresh tuber yield (13.9 t ha^{-1} with 20 cm, 13.7 t ha^{-1} with 30 cm) than 40 and 50 cm spacing (8.81 and 8.91 t ha^{-1}, respectively). Yield increased with every increase in plant population, this was because large number of plants per unit area was in closer intra-row spacing (20 and 30 cm). Even though the tuber weight per plant was lower at closer intra-row spacing, the higher plant population compensated the total yield. The results were very similar to those of Farooque *et al*. (1983), Talleyrand (1981) and Sarker (1985) who obtained higher yields at closer spacing; Ariyo *et al*. (1991) who observed that yield per unit area is more a function of the number of plants involved than the potentials of individual plants but the finding is not in harmony with that of Baker (1981) who observed insignificant effect with intra-row spacing.

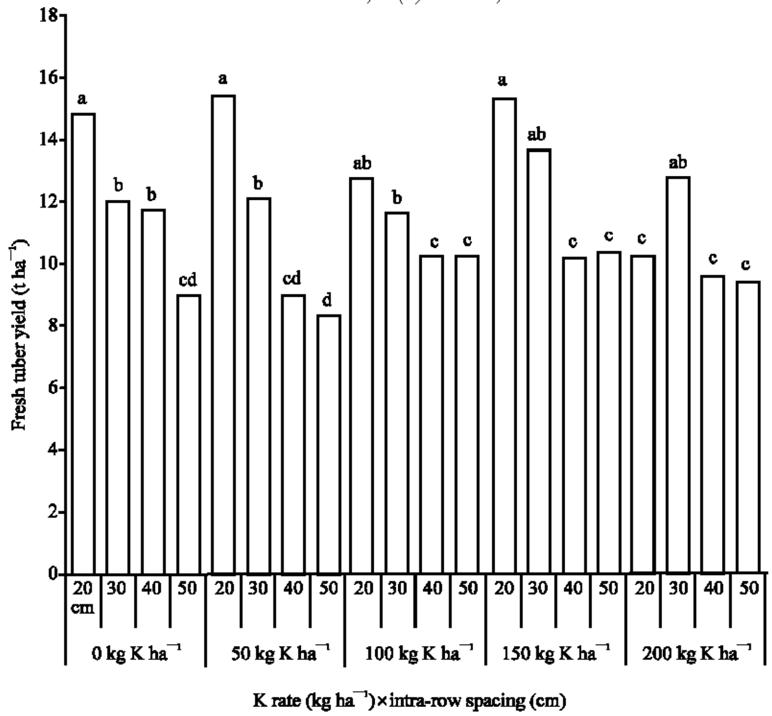

Fig. 2: Fresh tuber yield as influenced by intra-row spacing potassium interaction in the two years combined Bars with same letter(s) are not significantly different using DMRT at 5% level

K fertilizer had significant effect on the fresh tuber yield of sweet potato. Significant higher fresh tuber yield was recorded with 150 and 200 kg K ha^{-1} than with 0, 50 and 100 kg K ha^{-1} (Table 3).

There was significant effect of interaction between intra-row spacing and K fertilizer on fresh tuber yield of sweet potato. Bars in Fig. 2 showed that at all K rates 20 cm intra-row spacing yielded significantly higher fresh tuber yield than other spacing (Fig. 2).

Conclusions

Though the closer intra-row spacing (20 and 30 cm) produced the highest yield from the results, considering the economic viewpoint as well, 40 cm intra-row spacing is the optimum intra-row spacing for sweet potato in the area because it gave the highest proportion of marketable yield (60%) compared to 43.5 and 49.5% marketable tuber yield, respectively from 20 and 30 cm intra-row spacing. Also more planting materials, labour and other resources that do not results to appreciable marketable yield are required at closer intra-row spacing (20 and 30 cm) and 50 bags of 100 kg of ash (150 kg K ha^{-1}) seems most practical and profitable in sweet potato, as it has increased the marketable yield tremendously without deteriorating the quantity of tubers, hence it can be safely recommended for use in those places where climatic and soil conditions are similar to Sokoto *Fadama*.

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