Optimizing plant spacing, fertilizer and herbicide application for crop performance and weed control in sweet potato (*Ipomoea batatas* (L.) Lam

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Abstracts
Trials was conducted to evaluate the efficacy of fertilizer rates, spacing and weed control methods on weed control and performance of sweet potato at Lafia and Agyragu-tofa, Nasarawa State. The experimental design was a split plot design in Randomize Complete Block with three replications. These comprised of two NPK (30 and 60 kg/ha) and untreated control (0 kg/ha) (No fertilizer), two plant spacing (35 and 40 cm within the rows) and two herbicide application [Pre-plant S-metolachlor, Post emergence fluazifop-P-butyl, Hand-weeding at 3 and 6 WAP and a weedy check (control)], Generally, vine length number of vine per plants vine dry weight and tuber yield ha^{-1} significantly increased with increase in fertilizer rate. Higher increased were recorded in plots treated with 60 kg ha^{-1}rate of the fertilizer throughout the period of observation. Spacing had no effect on vine length, number of vine per plants and yields per hectare of sweet potato but these increased with wider spacing. While in the weed control treatments, hoe-weeded check recorded the highest growth parameters; the minimum was obtained with the weedy check. These results suggested that the application of 60 kg ha^{-1} of inorganic fertilizer and weed control using preplant S-metolachlor (0.803 kgai ha^{-1}) and post emergence fluazifop-P-butyl (0.30 kgai ha^{-1}) has potential to be utilized in sweet potato production.

Keywords: Fertilizer rates, Spacing, Weed control methods, Sweet potato, S- metalachlor Fluazifop-P-Butyl.

Introduction

Sweet potato is a primary source of carbohydrates and food security crop in much of the Pacific and sub-Saharan Africa (McGregor *et al*., 2016, Low *et al.,* 2017). In Nigeria, sweet potato ranks fourth among root and tuber crops after cassava, yam and cocoyam (Okonkwo *et al*., 2009). The annual production in Nigeria is estimated to be about at 3.46 million tons per year; with an average yield of 9.8 tons/ha and a total land area of 204.7 million hectares as reported by Udemezue, (2019).

Sweet potato yield, quality, and value can be negatively threatened by weeds and soil nutrient depletion (Barkley *et al.,* 2016; Coleman *et al.,* 2016; Darko *et al.,* 2020). Although several weed management strategies such as tillage, hand hoeing, mulching, spacing, hand-weeding and herbicides are practice in sweet potato production (Hoyt and Monks, 1996; Aladesanwa and Adigun, 2008; Takim *et al.,* 2020). There is no selective post-emergence herbicide registered for broadleaf weed control in sweet potato in Nigeria; therefore, most farmers rely on pre-emergence herbicides. Several pre-emergence herbicides such as linuron, metolachlor, clomazone and metribuzine are used (Harrison and Jackson, 2011; Meyers *et al.,* 2013; Beam *et al*., 2018).

In Nasarawa state, most farmers apply little or no fertilizers to roots and tuber crops, including sweet potato with the belief that the crop is adapted to poor soils. The dearth of planting material has also been reported in the study area. The ideal spacing of any crop is determined resource allocation, size of machinery for planting, weeding between the rows and cost of planting (Kemble, 1997); Seem *et al.,* 2009). However, optimum in-row plant spacing may differ depending on the soil nutrients and resource utilization to regulate inter-plant competition as well as weed-crop competition. Henceforth, optimizing plant density, fertilizer and herbicide management strategies in crop ecosystems would be the surest way to attain eco-friendly agriculture in order to curb the rising demand for food and future risks due to climate change and Covid-19 pandemic. Therefore, the objective was to determine plant spacing, fertilizer rates and herbicides growth and yield parameters and weed control in sweet potato.

Materials and Methods

The study was conducted at Teaching and Research Farm Faculty of Agriculture Shabu-Lafia Campus of Nasarawa State University Keffi (N 8°33' 49" longitude E 8°33'1"W), with an altitude of 168.47m and Agyaragu Koro, with (8°31' 26" N; 8° 39'58"W) with an altitude of 189.1m in the southern agro-ecological zone of Nasarawa State.

The experimental design was a split plot design in Randomize Complete Block with three replications. These comprising two plant spacing (35 and 40 cm within the rows) and 75 cm inter rows, giving planting densities of 21,428 and 18,750 plants per hectare, respectively), two NPK (30 and 60 kg/ha) and untreated control (0 kg/ha) (No fertilizer), and two herbicide application [Pre-plant S-metolachlor (Dual Magnum; Syngenta), Post emergence fluazifop-P-butyl, Hand-weeding at 3 and 6 WAP and a weedy check (control)], giving 24 treatment combinations. The plant spacing and NPK fertilizer rates was laid to the main plots and herbicides was randomized to the subplots.

Field preparation included slashing, ploughing and harrowing with a tractor and then prepared into ridges using hoes and garden lines. Each plot measured 4 × 4 m with 1 m space between rows and 1 m within rows. The length of a ridge was 4 m; giving 12 plants per ridge. Vines were multiplied for eight weeks and vine cuttings were 30 cm long containing 4 or 5 nodes. Vines of white variety (O' henry) of sweet potato were used.

Statistical analyses were performed using Genstat. The differences between the means were determined using least significant difference (LSD) at $P < 0.05$ probability.

Results and Discussion

The vine length differed significantly at 4, 6, 8, 10 and 12 weeks after sowing (WAS) with respect to fertilizer application and weed control methods (Table 1). Generally, the application of 60 kg $ha^{-1}$of NPK fertilizer produced the longer vine length throughout the period of observation which was longer at Lafia that at Agyragu Tofa. Similarly, in the weed control methods, the weedy check recorded significantly shorter vine length of sweet potato throughout the period of observation when compared to all other weed control treatments (Table 1). At 6 WAS, the maximum was obtained with plots that was hoe-weeded at 3 and 6

WAS which did not diferred significantly with plots treated PRE application of S-metolachlor POE of fluozifop-butyl at the rate of 0.803 and 0.30kg a.i./ha, respectively. Although, at 10 and 12 WAS, it was observed that plots that received PRE application of S-metolachlor at the rate of 0.803 kg a.i./ha recorded the longest vine length compared to all other treatments. This might be attributed to plants recovery from chlorosis/necrosis injury within the first 3 to 4 weeks that were slower in growth as a result of the initial injury due to the application of the herbicides. These findings corroborated with Beam *et al.* (2018), who reported that the application of S-metolachlor and linuron caused stunting of the plants within the first 3 weeks after transplanting (WAT). The spacing did not differed significantly; however, the 40x75cm spacing produced longer vine length compared with the 30x75cm spacing. The placing spacing most likely affects change in resource allocation. Somda and Kays (1990) found that decreasing spacing resulted in less branching of stems and fewer leaves per plant. These decreases were especially noticeable when in-row plant spacing was decreased from 45 to 30 cm.

Table 1: Effect of Fertilizer rate, Spacing and Weed Control Methods on vine length

Treatment	Vine length (WAP)									
	Lafia					Agyragu-Tofa				
	4	6	8	10	12	4	6	8	10	12
Fertilizer rates kg/ha (F)										
0	40.94	56.29	72.16	87.23	101.87	36.00	52.10	66.60	83.82	97.65
30	46.54	65.13	84.47	101.41	119.27	44.33	60.79	77.00	93.15	109.65
60	50.45	72.55	94.65	114.00	131.65	50.38	68.51	88.70	104.92	123.99
LSD	1.574		3.271	2.920	3.825	6.880	0.874	8.28	4.851	8.345
Spacing (S)										
Narrow	45.63	64.62	83.49	100.64	118.21	41.66	60.39	78.9	94.85	111.67
Wide	46.33	64.70	84.03	101.12	116.98	45.52	60.54	75.9	93.07	109.18
LSD	1.008	0.719	3.295	3.224	2.717	2.444	2.543	4.24	2.382	2.460
Weed control methods (W)										
S-metolachlor	47.35	65.80	85.89	103.10	119.25	44.87	60.58	79.7	96.68	114.31
Fluazifop-butyl	46.25	64.88	84.04	101.36	118.75	44.03	61.97	78.6	94.56	109.86
HW 3 and 6 WAP	47.50	69.33	89.51	107.81	126.59	46.98	62.07	80.0	96.55	114.31
Weedy check	42.81	58.62	75.59	91.26	105.79	38.48	51.26	71.5	88.07	102.72
LSD	1.521		2.080	3.205	3.816	3.728	1.978	5.58	3.144	3.469
CV%	2.0	2.7	2.8	2.6	3.3	4.4	1.4	7.2	3.1	5.0
Interaction										
F x W	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
F x S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
W x S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F x W x S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS – Not significant; ** - Significance at 5 % level of probability

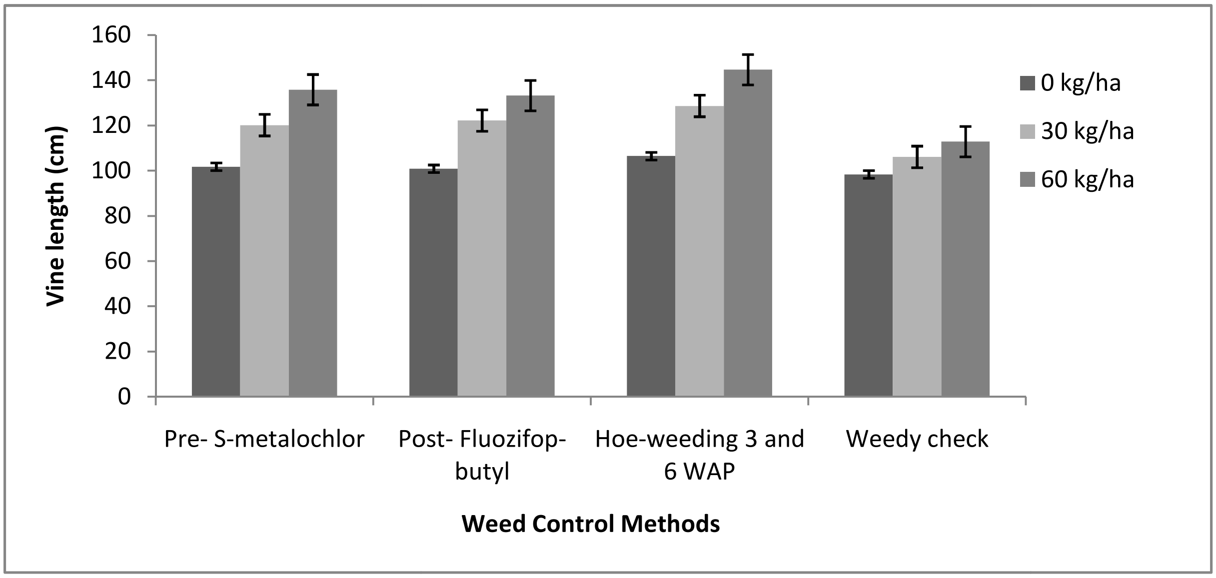

Figure 1: Effect of Interaction between Fertilizer rate and Weed Control Methods on Vine Length at Agyragu-tofa

The interaction for fertilizer application rate and weed control methods was significant for sweet potato vine length at 12 WAS in Lafia. The longest vine length was recorded in plots that received 60 kg ha^{-1} of NPK and hoe-weeded at 3 and 6 WAP (Figure 1). This was followed by the plots that were applied PRE S-metolachlor at the rate of 0.803kg a.i. ha^{-1} which did not differed significantly with the POE fluazifop-P-butyl. The shorter vine length was recorded in the control plots.

Table 2: Effect of fertilizer rate, Spacing and Weed Control Methods on Number of vine per plant

Treatment	Vine per plant (VPP) (WAP)									
	Lafia					Agyragu-Tofa				
	4	6	8	10	12	4	6	8	10	12
Fertilizer rates (F)										
0	1.65	1.80	1.94	1.93	1.85	1.49	1.88	2.00	1.70	1.43
30	2.53	2.75	2.91	3.03	2.95	2.83	3.41	3.80	3.53	2.82
60	3.65	4.06	4.31	4.47	4.52	3.97	4.92	5.79	5.52	4.95
SE±	0.091	0.099	0.082	0.079	0.044	0.072	0.224	0.160	0.620	0.190
LSD	0.252	0.276	0.228	0.218	0.121	0.201	0.621	0.443	0.471	0.528
Spacing (S)										
Narrow	2.47	2.75	2.90	3.04	2.98	2.73	3.22	3.62	3.38	3.00
Wide	2.75	2.99	3.20	3.25	3.23	2.79	3.59	4.11	3.78	3.13
SE±	0.071	0.08	0.073	0.073	0.083	0.085	0.129	0.900	0.127	0.095
LSD	0.146	0.165	0.152	0.151	0.172	0.176	0.267	0.186	0.263	0.196
Weed control methods (W)										
S-metalochlor	3.21	3.46	3.61	3.59	3.59	3.01	3.64	3.56	4.07	4.30
Fluozifop-P-butyl	2.13	2.38	2.62	2.79	2.68	3.04	3.66	3.24	3.78	4.08
HW 3 and 6 WAP	3.44	3.88	4.16	4.44	4.47	3.17	4.29	3.97	4.48	4.76
Weedy check	1.66	1.77	1.81	1.74	1.68	1.82	2.02	1.49	1.99	2.32
SE±	0.089	0.103	0.112	0.119	0.115	0.131	0.180	0.127	0.180	0.201
LSD	0.186	0.217	0.360	0.250	0.242	0.276	0.377	0.267	0.378	0.422
CV%	4.6	3.4	3.3	4.0	3.5	5.4	5.8	4.9	3.7	4.6
Interaction										
F x W	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F x S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
W x S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F x W x S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS – Not significant; ** - Significance at 5 % level of probability

Number of vine/plant differed significantly among the various treatments (Table 2). At both locations, the application of 60 kg ha^{-1} of NPK fertilizer produced the highest number of vines/plant compared to other treatments. Similarly, the 40x75cm spacing recorded the highest of 2 – 4 vines/plant as against 2 – 3 vines observed in the 39x75cm. As spacing increased, the number of vine increased as did their number per plant. Wees *et al.* (2015) reported that the plants at 40x75cmspacing appeared to have thicker stems than those at 30x75cm spacing. These trends were observed in both locations. In the weed control methods, even though there was a significant difference in number of vine per plant, the weedy check had less number of vines when compared with all plots that received PREPLANT application of S-metolachlor, POST fluazifop-P-butyl and hoe-weeded at 3 and 6 WAP. The higher number of vines was recorded on plots that were hoe-weeded at 3 and 6 WAP. However, the crop injury and yield reduction associated with the early season PREPLANT and POST applications of S-metolachlor and fluazifop-P-butyl are of some concern that caused the decreased. Beam *et al.* (2018) reported that injury and yield reduction to sweet potato from the application of linuron followed by S-metolachlor.

Table 3: Effect of fertilizer rate, Spacing and Weed Control Methods on Weed Density, Weed Dry Weight, Vine Dry Weight and Tuber Yield

Treatment	Lafia					Agyragu		
	Weed density		Weed dry matter	Vine dry matter	Yield/ha	Weed density		Weed dry matter
	14 DAA	28 DAA			(tons)	14 DAA	28 DAA	
	No m^{-1}		(tons ha^{-1})	(tons ha^{-1})		No m^{-1}		(tons ha^{-1})
Fertilizer rates kg ha^{-1} (F)								
0	5.54	5.08	2.04	3.30	5.08	5.96	6.88	1.02
30	4.83	5.98	2.20	5.03	6.18	5.00	6.46	1.57
60	5.62	5.88	2.25	6.66	6.78	6.38	7.08	2.02
LSD	1.946	1.342	0.111	0.261	0.526	1.572	1.711	0.177
Spacing (S)								
Narrow	5.81	5.03	2.04	4.86	5.89	5.44	7.25	1.47
Wide	4.86	6.25	2.30	5.14	6.14	6.11	6.36	1.60
LSD	0.184	1.438	0.236	0.161	0.257	1.195	1.215	0.165
Weed control methods (W)								
S-metalochlor	4.97	3.94	0.84	5.89	6.42	5.06	6.06	0.84
Fluozifop-P-butyl	6.28	6.11	1.55	4.60	6.39	6.28	8.00	1.42
HW 3 and 6 WAP	3.33	3.67	0.91	6.13	7.79	4.89	4.11	0.83
Weedy check	6.18	8.83	5.36	3.38	3.48	6.89	9.06	3.04
LSD	1.470	1.617	0.303	0.332	0.396	1.157	2.043	0.240
CV%	10.2	14.6	4.5	3.4	0.7	11.5	17.3	4.4
Interaction								
F x W	NS	NS	NS	NS	NS	NS	NS	NS
F x S	NS	NS	NS	NS	NS	NS	NS	NS
W x S	NS	NS	NS	NS	NS	NS	NS	NS
F x W x S	NS	NS	**	NS	NS	NS	NS	NS

NS – Not significant; ** - Significance at 5 % level of probability

Weed densities were higher at Agyragu-tofa than they were at Lafia (Table 3). The application of 60 kg ha^{-1} gave rise to higher weed densities compared to plots that did not received fertilizer which did not differed significant with the plots treated with 30 kg ha^{-1} of NPK fertilizer. This is an indication that the weeds equally benefitted from the applied fertilizer (Okpara *et al*., 2009). In terms of spacing, there was no significant difference between the 30x75cm and 40x75cm spacing on weed density except at 14 days after application at Lafia. The highest weed densities were observed on the 49x 75cm spacing compared to the 30x75cm spacing. This might be attributed to the canopy of the plant to smoother the under growing weeds. The weedy checks had more weed densities compared with all other weed control treatments. The weed dry weight was significantly influenced by weed control treatments (Table 3). At both location, only the plots sprayed with S-metolachlor, fluazifop-P-butyl and hoe-weeded at 3 and 6 WAP produced lower weed dry weight compared to season-long weedy check.. On an average, weed dry weight treated plots were 1g/m^2 compared with 5g/m^2 for weedy check.

Fertilizer significantly affected the yield of sweet potato, where increases in yield were achieved in 30kg and 60kg ha^{-1} applied plots in both locations. Tuber yields at Agyragu-tofa were considerably lower than those at Lafia because of high weed density. The highest was obtained at Lafia with the application of 60 kg ha^{-1}, which had yields of 6.78 tons ha^{-1} compared with 5.54 tons ha^{-1} at Agyragu-tofa - an increase of 18 %. Spacing did not differed significantly at both locations. However, the 40x75cm spacing produced higher yield when compared with the 30x75cm spacing. The 40x75cm resulted in more and heavier storage roots and higher overall yields. A report by Arancibia *et al.* (2014) found little or no impact of in-row or between row spacing on yield sweet potato cultivars. The yield varied significantly due to weed control treatments (Table 3). All the treatments resulted in significantly higher yield than weedy check, and the hoe-weeded 3 and 6 WAP performed excellent in terms of yield (ranging from 6.40 to 7.79 tons ha^{-1} at Lafia and Agyragu-tofa, respectively) which was statistically different to that obtained from the application of S-metolachlor and fluazifop-P-butyl at both locations. Similar trends of observations were recorded with the dry weight of sweet potato vines.

Table 4: Effect of Interaction between Fertilizer rate and Weed Control Methods on Vine Length at Lafia

Weed control methods	Fertilizer rates kg ha^{-1}	Spacing	
		Narrow	Wide
		Weed dry matter (tons ha^{-1})	
Pre S-metalochlor	0	0.20	0.60
Post- Fluazifop-butyl		1.63	1.40
Hoe-weeding 3 and 6 WAP		0.47	1.00
Weedy check		4.60	6.40
Pre S-metalochlor	30	0.87	1.07
Post- Fluazifop-butyl		1.40	1.53
Hoe-weeding 3 and 6 WAP		0.47	1.10
Weedy check		6.27	4.93
Pre S-metalochlor	60	1.17	1.13
Post- Fluazifop-butyl		1.73	1.60
Hoe-weeding 3 and 6 WAP		1.30	1.13
Weedy check		4.27	5.67
$LSD_{0.05}$		0.719	

The interaction for fertilizer application rate, spacing and weed control method was significant ($P \leq 0.05$) for weed dry matter at Lafia (Table 4). The application of fertilizer to sweet potato within the narrow and wide in-row spacing (35 and 40 cm) using the weed control methods gave significantly higher weed dry weight at the weedy check plots than all other combination of treatments. The highest weed dry weight (6.40 tons ha^{-1}) was obtained in the weedy check without fertilizer application to sweet potato in the 40x75cm spacing treated plots which differed significantly with all other combination of treatments except with plots that received 60 kg ha^{-1} under the same treatment combinations.30x75cm with the application of Pre-plant S-metolachlor without fertilizer application had significantly ($P \leq 0.05$) lowest weed dry weight (0.20 tons ha^{-1}) compared to other treatment combinations. These results suggest that the application of 60 kg ha^{-1} of inorganic fertilizer and weed control using preplant S-metolachlor (0.803 kgai ha^{-1}) and post emergence fluazifop-P-butyl (0.30 kgai ha^{-1}) has potential to be utilized in sweet potato. Additionally, future research should also focus on designing effective weed management programs in sweet potato production system with the use of S-metolachlor and fluazifop-P-butyl in combination with other herbicides.

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