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PRODUCTIVITY OF LIVING STONE POTATO *(Plectranthus esculentus L.)* AS INFLUENCED BY ROW SPACING AND NUTRIENT SOURCES IN BILLIRI, GOMBE STATE, NIGERIA.

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ABSTRACT

Field experiments were carried out for two years during the rainy seasons of 2015 and 2016 to study the productivity of Living stone potato as influenced by intra row spacing and fertilizer type at Tangji village in Billiri Local Government Area of Gombe State, Nigeria. Three different intra row spacing: 15, 20 and 25 cm and four nutrient sources (fertilizer types); cow dung, poultry droppings, sheep/goat manure, mineral fertilizer (NPK 15:15:15 and Urea 46 % N) and control were used for the study. The treatments were combined and laid in a randomized complete block design with three replications. The use of 25 cm intra row spacing produced significantly ($P \leq 0.05$) taller plants, higher number of leaves, more branches, net assimilation rate, leaf area index and relative crop growth rate. However, application of 20 cm intra row, had higher significant influence on yield parameters such as number of roots per plant, tuber length, number of tuber and tuber yield except in tuber weight where 25 cm intra row spacing was significantly ($P \leq 0.05$) superior. The use of different fertilizer types was also observed to be significantly different on growth and yield parameters. Application of mineral fertilizer (NPK 15:15:15 and Urea 46 % N) was consistently and significantly ($P \leq 0.05$) superior in all the growth and yield parameters except on tuber yield where the use of sheep / goat manure was at par with mineral fertilizer. Growing Living Stone potato in 2016 rainy season was significantly ($P \leq 0.05$) superior on both growth and yield parameters than when the crop was cultivated in 2015. Living stone potato farmers could therefore be advised to grow the crop at a row spacing of 20 cm with the application of mineral fertilizer (N.P.K. 15;15;15 and Urea 46 % N) or sheep/goat manure for optimum yield.

Keywords: Living Stone Potato, Row Spacing, Nutrient Sources and productivity

INTRODUCTION

Living Stone potato (*Plectranthus esculentus L.*) is a dicotyledonous annual crop belonging to the family *laminecea*. The crop is called 'rizga' in hausa land, pomme detare de'Afica, 'Nvat' in talig, 'sinia' in birom and 'fur' in tangal (Kyesmu, 1994). Although Living Stone potato is indigenous to southern tropical Africa (Ade, 1998), the crop is grown in many places in Nigeria and around the world. It is mainly grown due to its high carbohydrate and protein content, and was ranked moderately high among tuber crops like Irish potato and yam. However, despite its nutritive potential, it is classified among the lesser known and under exploited species of crops in Africa (KEW, 2012). The tuber taste similar to Irish potato and trifoliate yam and can also be eaten as a main starchy staple in combination with legumes, rice and vegetables. It can also be prepared in India and African cuisines as boiled, baked or fried (Schipper, 2000; Wulueng and Abdulsalam 2000). Some workers reported that the tuber can be used to make aromatic alcoholic beverages (Schipper, 2000; Phngpanya *et al*., 2013) while the leaves sometimes may also be eaten as pot-herbs (PROTA, 2013). Compared to other tuberous staple in Nigeria, tubers of Living Stone potato are rich in protein, vitamin and minerals. One hundred grammes of raw tubers contain water (76%), carbohydrate (21%), protein (1.4%), fibre (0.7%), fat (0.2%) and ash (1.0%) among other important nutrients (PROTA, 2013).

The application of organic manure to the soil plays an important role in the chemical, physical and biological properties of the soil. The applications of organic manure decreases the bulk density of the soil while it increases the moisture content of the soil, water holding capacity of the soil, , permeability (infiltration rate), soil structure and soil porosity (Nagar 2016). The chemical properties of the soil like P^H, EC, total organic carbon, total phosphorus, total potassium and C/N can be increased by the type and level of the application of organic manure to the soil (Sharma 2012). The biological properties of the soil can be improved by the addition of organic manure to increase microbial activity, leading to release of nutrients for plant adsorption.

With Nigeria's colloquial growth in population and which is in an increasing rate, the country cannot afford to rely on tuber

crops like Irish potato which is limited to few areas of the nation due to weather conditions. Therefore, diversifying into other crops like Living Stone potato that has wide suitable environmental conditions for its growth could be useful for its tubers as food in Nigeria. Little work has been carried out on Living Stone potato, the crop belongs to the same botanical family with Irish potato. Spacing for planting need to be ascertained to determine the right plant population if optimum production is to be achieved. The uses of appropriate spacing have been observed to adversely influence crop yield positively as reported by (Bello, 2015). As much as possible all edible wild crop of all types need to be rapidly domesticated and brought into cultivation to meet the food and medicinal needs of the country and the world's rapidly increasing populaces. Therefore, all measures particularly cultural practice, needed to achieve this, must be explored, for example, through evaluation of crop nutrition sources and appropriate spacing (Ifenkwe, 2000). This study provides vital information on how small holder farmers can improve productivity of Living stone potato through agronomic practices like the appropriate plant population and the use of different fertilizer types. In the light of the above, the study was carried out to determine the influence of row spacing and nutrient sources on productivity of Living stone potato.

MATERIALS AND METHODS

Field experiments were conducted between June and October 2015 and 2016 at Tangji village **Latitude:** 9° 51' 31.79" N **Longitude:** 11° 13' 18.60" E of Billiri Local Government, Gombe State to study the productivity of Living Stone potato as influenced by intra row spacing and fertilizer type. A variety of Living stone potato (Ex-Br) was obtained from the Agricultural Development Programme in Billiri Local Government. The variety is indigenous to the locality and has been grown in the area for decades.

The soil of the experimental fields was of sandy loam texture (Table 1). The pH (5.60) in 2015 and (5.85) in 2016 indicated that the soil was acidic in reaction. Total organic carbon (%) was 4.01 in 2015 and 4.15 in 2016. Total nitrogen was 1.14 in 2015 which was far less than 2.15 in 2016. Available P (kg^{-1}) of the experimental soil was lesser in 2015 (58.61) compared to 2016 (59.66). Exchangeable Ca (Cmol k_g^{-1}) of 1.29 in 2015 and 1.18 in 2016 was also observed.

Four nutrient sources: poultry droppings, cow-dung, sheep/ goat manure, mineral fertilizer (NPK 15:15:15 / Urea 46%) and control were used in the study. Poultry dropping, Cow-dung and Sheep/goat manure were collected from a poultry farm where the birds were kept under battery cage system, cattle pen (where the herd were kept but allowed to go on open grazing) and goat pen (where sheep/goats were raised under semi-intensive system respectively and the manures were allowed to undergo partial decomposition for five months following the recommendation of Bello (2015) before it was used for the research. Mineral fertilizer (NPK 15:15:15 / urea 46 %) was bought from the open market. Two factors: intra row spacings (15 cm, 20 cm, 25 cm) and different fertilizer types (poultry dropping, cow dung, sheep/goat manure, mineral fertilizer (NPK 15:15:15 / Urea 46%) as well as control) were used in this experiment. The three intra row spacings and the five fertilizer types were combined to form fifteen factorial treatments fitted into a randomized complete block design (RCBD) with three replications. Prior to land preparation, soil samples were randomly taken from 0-15 cm depth using a soil auger, bulked and sub-sampled for routine soil analysis. Each year, land was harrowed in early July before the plots of 9 m^2 were laid out with 1 m between plots and 0.5 m between blocks. There were three blocks with 15 plots each within a block. This gave a total number of 45 plots for the study. Planting tubers of 3-4cm in length were kept for 3-4 months after harvest to sprout, the pre-sprouted were incubated where they were kept locally in a clay pots and covered with sacks to aid sprouting at room temperature. The sprouted tubers were sown at a depth of 3 – 5cm with the tuber buds positioned upward. Sowing was then carried out based on the spacings following the different treatments of 15, 20 and 25cm intra row x75cm inter row spacing. All the organic sources; poultry dropping, cow dung and sheep/goat manure were applied during land preparation and incorporated well into the soil. Sowing was then carried out a week after the incorporation of the different nutrient sources. The four (4) different nutrient source were applied at the rate of 3 tones/ha as recommended by Bello (2015). Application of NPK 15:15:15 and Urea 46% on the other hand, was carried out at the rate of 80kg N, 40kg P and 40 kg K following the fertilizer recommendation of Irish potato as reported by Vos (1999). The first application was carried out at 2 weeks after sowing (WAS) while the remaining N – dose of 40kg N was applied as top dress in the form of Urea at 8 WAS. After sowing, weeding was then carried out twice at 4 and 8WAS, manually with hand hoe to obtain weed free plots and to avoid weed-crop competition.

The parameters assessed at 10 WAS were plant height (PH) (cm), number of leaves per plant (NOLP), number of branches per plant (NOBP), net assimilation (NAR), leaf area (LA), leaf area index (LAI), relative growth rate (RGR), crop growth rate (CGR), number of roots per plant (NORP), number of tuber per plant (NOTP), tuber length (TL) (cm), tuber weight (TW) (kg) and tuber yield (TY) (kg / ha). All parameters were obtained on the basis of ten randomly selected plants from each net plot before the mean was computed and recorded. The method used to determine the leaf area is the use of milimeter graph method where the leaf is drown of the graph paper and the number of box is counted and calculated to obtain the leaf area. The unit for the leaf area is cm^2. Data for Relative Growth Rate (RGR) and Crop Growth Rate (CGR); were obtained by harvesting a few stands outside the net plot but within the gross plot then oven dried to obtain the date. Data collected for both experiments were combined and subjected to one way analysis of variance (ANOVA) using Statistical Analysis System (SAS)

Version 9.1 (2002). The means were separated with the Least Significant Difference (LSD) method described by Steel and Torrie (1960).

RESULTS

Effect of Intra Row Spacing on Growth Parameters of Living Stone Potatoes

Table 2 shows that all the growth parameters measured at 10 WAS, differed significantly with intra row spacing. Among the different intra row spacing, the adoption of 25cm intra row spacing produced significantly ($P \leq 0.05$) taller plants, followed by 20 cm intra row spacing. Application of 25 cm intra row spacing had significantly ($P \leq 0.05$) more leaves than the other spacings used. In the same vein, intra row spacing of 25cm was highly significant ($P \leq 0.05$) in terms of number of branches than the other treatments applied. Higher NAR was observed at 25cm intra row spacing than the other treatments used. The intra row spacing of 25cm produced significantly ($P \leq 0.05$) higher leaf area, followed by spacing of 15cm, then, 20cm. Like LA, higher LAI was observed on 25cm intra row spacing when compared with the other spacings considered. CGR shows same order of significant difference ($P \leq 0.05$) as observed in NAR, LA, and LAI.

Effect of Nutrient Sources on Growth Parameters of Living Stone Potatoes

Nutrient sources significantly influenced all the growth parameters. Considering the different nutrient sources applied, mineral fertilizer; (NPK 15:15:15 and Urea 46%) had significantly ($P \leq 0.05$) taller plants than all the other nutrient sources used. The adoption of control and cow dung however, had shorter plants among all the treatments considered. Mineral fertilizer produced significantly ($P \leq 0.05$) more leaves than all the other nutrient sources used, it was followed by cow dung and poultry dropping which were not statistically different from each other, then followed by sheep/goat manure and control which were at par with one another. Application of mineral fertilizer produced significantly higher number of branches than sheep/goat manure and poultry dropping while the least number were observed in cow dung and control which were statistically similar. The order for net assimilation rate was mineral fertilizer > sheep/goat manure > poultry dropping > cow dung > control at ($P \leq 0.05$). Mineral fertilizer was observed to produce significantly ($P \leq 0.05$) larger leaves than the other treatments applied. Sheep/goat manure also produced larger leaves when compared with cow dung and poultry droppings. Control plots on the other hand, had smaller leaves among all the treatments used. The order for Leave area index was statistically similar when compared with leaf area. The performance of mineral fertilizer on crop growth rate was statistically similar with that of Sheep/goat manure but greater than that of poultry droppings, cow dung and control in a descending order. All growth parameters exhibited same character in regard to season performance; the 2016 growing season was superior in all the parameter than 2015 under intra row spacing of 20 cm.

Intra Row Spacing × Nutrient Sources Interaction on Growth Parameters

Tables 4, 5 and 6 show the interaction between spacing and nutrient sources on plant height, number of leaf and Leave area respectively. Taller plants (8WAS), higher number of leaves (10 WAS) as well as higher leaf area (10 WAS) were observed to be significantly higher with intra row spacing of 20cm and mineral fertilizer. Table 7 shows the interaction between spacing and nutrient sources on number of branches per plant. Higher numbers of branches were observed with application of mineral fertilizer, sheep/goat manure and poultry dropping at 15, 20 and 25 cm intra row spacing. Control (untreated) had the least performance at 15 cm, 20 cm and 25 cm intra row spacing. Table 8 shows the interaction between spacing and nutrient sources on net assimilation rate. 20 cm intra row spacing had higher net assimilation rate in its interaction with mineral fertilizer when compared to other nutrient sources. The performance of 20 cm intra row spacing was consistence with other nutrient sources with 15 cm spacing having the least performance except the control where the order was 15 cm, 25 cm and 20 cm. Holding spacing constant the order of performance of the nutrient sources was mineral fertilizer > sheep/goat > poultry dropping > cow dung > control. Table 9 shows the interaction between intra row spacing and nutrient sources on leaf area index. The performance of the interaction between 20 cm and mineral fertilizer significantly differ than others, in all cases, the 20 cm spacing performed better with all the nutrients sources. Table 10 shows the interaction between intra row spacing and nutrient sources on crop growth rate (m^2 / d^2). 20 cm intra row spacing interaction with mineral fertilizer was superiorly significant ($P \leq 0.05$) on CGR throughout the different nutrient sources used. The same holds for 15 cm and 25 cm.

Table 1: Physicochemical properties of the soil collected before the commencement of each study at the experimental site in 2015 and 2016 rainy seasons.

Soil property	2015	2016
P^H (H_20)	5.60	5.85
Organic carbon (%)	4.01	4.15
Total Nitrogen (gk_g^{-1})	1.14	`2.15
Available P (k_g^{-1})	58.61	59.66
Exchangeable K (Cmol k_g^{-1})	0.29	0.25
Exchangeable Ca(Cmol k_g^{-1})	1.29	1.18
Exchangeable mg (Cmol k_g^{-1})	0.65	0.70
Exchangeable Na (Cmol k_g^{-1})	3.34	3.35
Sand (%)	70.50	71.00
Clay (%)	8.50	7.00
Silt (%)	21.00	22.00
Textural class	Sandy Loam	Sandy Loam

Table 2: Influence of row spacing and nutrient sources on growth parameters of Living Stone Potato at 10 weeks after sowing (WAS)

Treatment	PH (cm)	NOLP	NOBP	NAR	LA (cm^2)	LAI	CGR		
Intra row spacing (S) (cm)									
15	20.01c		12.59c	12.80c	2.51bc	3.98b	2.81b	2.25b	
20	25.30b		15.50b	13.91b	2.98b	3.55c	2.51c	2.10bc	
25	29.60a		18.13a	14.21a	3.91a	4.72a	3.10a	3.52a	
Level of significance	*		*	*	*	*	*	*	
SE(±)	1.841		1.710	0.190	0.031	0.003	0.001	0.040	
Nutrient sources (N)									
Cow dung		23.12c		19.67b	14.11c	5.03c	4.66b	2.70b	3.28c
Poultry droppings	24.52c		18.68bc	13.20bc	5.01cd	4.62c	2.60bc	3.30b	
Sheep/goat manure	28.61b		17.86c	13.51b	5.42b	4.97ab	2.81b	4.15a	
Mineral fertilizer	35.78a		23.52a	14.01a	6.01a	5.09a	3.10a	4.15a	
Control (Untreated)	25.21d		11.86c	12.51c	4.21d	3.62d	2.15d	3.00d	
Level of significance	*		*	*	*	*	*	*	
SE(±)	1.021		0.150	0.261	0.041	0.121	0.001	0.051	
Season (Y)									
2015	25.21b		18.92b	12.61b	5.01b	3.99b	2.70b	3.69b	
2016	34.10a		22.51a	14.61a	6.25a	5.03a	3.17a	4.99a	
Level of significance	*		*	*	*	*	*	*	
SE(±)	0.432		0.213	0.299	0.011	0.101	0.001	0.011	
Interaction									
SXN	**		**	**	**	**	**	**	
SXY	**		**	**	**	**	**	**	
NXY	**		**	**	**	**	**	**	

Means followed by different letter/s within a treatment group are significantly different following DMRT.
WAS: Weeks after sowing
* = Significant at 5% ($P \leq 0.05$), ** = Significant at 1% ($P \leq 0.01$)

Table3.the mean of combine analysis across years on the influence of row spacing and fertilizer type on yield parameters of Living Stone potatoes at harvest grown during the 2015 and 2016 raining seasons in Billiri, Gombe State , Nigeria

Treatment	No. of roots per plant	tuber length (cm)	tuber weight (g)	number of tubers/plant	tuber yield (Kg/ha)
Intra row spacing(S) (cm)					
15	25.01c	4.81b	36.35c	19.17bc	1453.8c
20	36.21a	5.51a	45.98b	21.72a	1677.7a
25	30.31b	4.01b	66.65a	19.95b	1364.0b
Level of significance	*	*	*	*	*
SE(±)	1.050	0.140	0.050	0.510	45.200
Fertilizer types (N)					
Cow dung	35.41b	5.42b	43.01bc	20.19c	1718.6b
Poultry dropping	32.31c	5.53ab	42.64c	21.72bc	1359.8c
Sheep/goat manure	34.62bc	5.01c	44.79b	24.95b	2330.8a
Mineral fertilizer	40.52a	6.40a	50.79a	28.01a	2430.8a
Control (Untreated)	30.81d	4.91d	31.50d	19.19d	5223.3d
Level of significance	*	*	*	*	*
SE(±)	1.180	0.141	1.181	0.390	65.600
Season(Y)					
2015	33.21b	5.00b	45.23b	23.23b	1127.82b
2016	42.55a	6.61a	51.21a	28.51a	2432.12a
Level of significance	*	*	*	*	*
SE(±)	1.101	1.212	1.321	0.121	50.210
Interaction					
SXN	**	**	**	**	**
SXY	**	**	**	**	**
NXY	**	**	**	**	**

Means followed by different letter/s within a treatment group are significantly different following DMRT.
WAS: Weeks after sowing. * = Significant at 5% ($P \leq 0.05$), ** = Significant at 1% ($P \leq 0.05$)

Table 4: Interaction between intra row spacing and nutrient sources on plant height per plant of Living Stone potato grown during the 2015 and 2016 rainy seasons in Billiri, Gombe State.

	Intra row spacing (cm)		
Nutrient sources	15	20	25
Cow dung	12.3	10.2	13.2
Poultry dropping	14.2	12.4	11.2
Sheep/goat manure 11.2	11.6	12.5	
NPK / Urea	14.2	13.6	14.5
Control	10.2	11.2	11.8
LSD	0.90	0.80	0.90

Table 5: Interaction between intra row spacing and nutrient sources on number of leaves per plant of Living Stone potato grown during the 2015 and 2016 rainy seasons in Billiri, Gombe State.

	Intra row spacing (cm)		
Nutrient sources	15	20	25
Cow dung	12.2	15.8	13.9
Poultry dropping	13.8	16.9	16.8
Sheep/goat manure 12.9	17.2	16.1	
NPK / Urea	16.6	19.9	18.2
Control	10.1	12.2	11.1
LSD	0.10	0.10	0.20

Table 6: Interaction between intra row spacing and nutrient sources on leaf area of Living Stone potato grown during the 2015 and 2016 rainy seasons in Billiri, Gombe State.

	Intra row spacing (cm)		
Nutrient sources	15	20	25
Cow dung	2.9	2.5	2.4
Poultry dropping	3.1	3.0	2.8
Sheep/goat manure 2.3	2.9	3.0	
NPK / Urea	4.2	4.9	3.9
Control	2.2	2.1	2.0
LSD	0.10	0.10	0.10

Table 7: Interaction between intra row spacing and nutrient sources on number of branches per plant of Living Stone potato grown during the 2015 and 2016 rainy seasons in Billiri, Gombe State.

	Intra row spacing (cm)		
Nutrient sources	15	20	25
Cow dung	10.1	11.2	10.9
Poultry dropping	11.1	11.9	10.0
Sheep/goat manure 10.9	11.8	11.2	
NPK / Urea	12.9	13.2	13.2
Control	9.8	9.9	10.1
LSD	0.20	0.10	0.10

Table 8: Interaction between intra row spacing and nutrient sources on net assimilation rate of Living Stone potato grown during the 2015 and 2016 rainy seasons in Billiri, Gombe State.

	Intra row spacing (cm)		
Nutrient sources	15	20	25
Cow dung	2.9	2.8	2.4
Poultry dropping	2.9	3.0	2.8
Sheep/goat manure 2.8	3.2	3.1	
NPK / Urea	3.5	4.0	3.9
Control	2.0	2.1	2.3
LSD	0.001	0.001	0.001

Table 9: Interaction between intra row spacing and nutrient sources on leaf area index of Living Stone potato grown during the 2015 and 2016 rainy seasons in Billiri, Gombe State.

	Intra row spacing (cm)		
Nutrient sources	15	20	25
Cow dung	2.6	2.7	3.1
Poultry dropping	2.5	2.8	3.5
Sheep/goat manure 3.2	3.5	3.8	
NPK / Urea	3.9	4.0	4.2
Control	2.0	2.2	2.5
LSD	0.10	0.10	0.10

Table 10: Interaction between intra row spacing and nutrient sources on crop growth of Living Stone potato grown during the 2015 and 2016 rainy seasons in Billiri, Gombe State.

	Intra row spacing (cm)		
Nutrient sources	15	20	25
Cow dung	3.0	3.8	3.2
Poultry dropping	3.4	3.9	3.4
Sheep/goat manure 3.1	3.6	3.2	
NPK / Urea	4.1	4.9	5.0
Control	2.0	2.5	2.6
LSD	0.01	0.01	0.01

Table 11: Interaction between intra row spacing and nutrient sources on number of roots per plant of Living Stone potato grown during the 2015 and 2016 rainy seasons in Billiri, Gombe State.

	Intra row spacing (cm)		
Nutrient sources	15	20	25
Cow dung	25.0	31.2	35.2
Poultry dropping	28.2	32.5	36.1
Sheep/goat manure 33.1	36.5	38.0	
NPK / Urea	35.2	38.2	42.2
Control	26.1	30.2	33.9
LSD	1.14	1.19	1.12

Table 12: Interaction between intra row spacing and nutrient sources on tuber length of Living Stone potato grown during the 2015 and 2016 rainy seasons in Billiri, Gombe State.

	Intra row spacing (cm)		
Nutrient sources	15	20	25
Cow dung	5.3	5.7	6.4
Poultry dropping	5.5	5.9	6.6
Sheep/goat manure 5.8	6.2	6.8	
NPK / Urea	6.3	6.6	7.8
Control	5.2	5.4	6.2
LSD	0.11	0.14	0.19

Table 13: Interaction between intra row spacing and nutrient sources on tuber weight (g) of Living Stone potato grown during the 2015 and 2016 rainy seasons in Billiri, Gombe State.

	Intra row spacing (cm)		
Nutrient sources	15	20	25
Cow dung	40.0	41.8	56.9
Poultry dropping	43.8	45.2	55.9
Sheep/goat manure 45.9	47.2	51.0	
NPK / Urea	59.0	60.2	64.2
Control	36.3	39.9	40.2
LSD	1.00	1.09	1.90

Table 14: Interaction between intra row spacing and nutrient sources on number of tubers per plant of Living Stone potato grown during the 2015 and 2016 rainy seasons in Billiri, Gombe State.

	Intra row spacing (cm)		
Nutrient sources	15	20	25
Cow dung	19.2	20.6	19.9
Poultry dropping	20.9	21.2	20.5
Sheep/goat manure 18.9	19.1	18.2	
NPK / Urea	22.2	25.9	30.1
Control	16.2	17.0	17.2
LSD	0.01	0.00	0.01

Table 15: Interaction between intra row spacing and nutrient sources on tuber yield of Living Stone potato grown during the 2015 and 2016 rainy seasons in Billiri, Gombe State.

	Intra row spacing (cm)		
Nutrient sources	15	20	25
Cow dung	1453.8	1552.1	1678.3
Poultry dropping	1621.4	1728.4	1621.6
Sheep/goat manure	1577.8	1792.8	2200.2
NPK / Urea	1911.9	2342.5	2600.2
Control	1321.2	1432.6	1521.4
LSD	39.21	30.00	40.81

Effect of Intra Row Spacing on Yield Parameters of Living Stone Potatoes

The mean of combined analysis on the performance of Living Stone Potato as influenced by row spacing on all the yield parameter is presented in table 3. On number of roots per plant; the results indicated significant differences among row spacing. At the different row spacing, the use of 20 cm spacing had significantly ($P \leq 0.05$) higher number of roots than the other treatments used. The use of 15 cm intra row spacing on the other hand, had least roots among the treatments considered. On tuber length; row spacing of 20 cm produced significantly ($P \leq 0.05$) longer tubers than the other treatments used. On tuber weight-spacing of 25 cm intra row produced significantly ($P \leq 0.05$) heavier tubers than the other treatments used. It was followed by 20 cm and then 15 cm intra row spacing. On number of tubers per plant - the use of 20 cm spacing produced significantly ($P \leq 0.05$) more tubers than the other treatments evaluated. The order of performance was 20 cm > 25 cm > 15 cm. On tuber yield - intra row spacing of 20 cm produced significantly ($P \leq 0.05$) higher tuber yield than the other treatments used. The order of performance of the intra row spacing on tuber yield was the same with the performance of number of tuber per plant.

Effect of Nutrient Sources on Yield Parameters of Living Stone Potatoes

The mean of combined analysis on the performance of Living Stone Potato as influenced by nutrient sources on all the yield parameter is also presented in table 3. On number of roots per plant; the results indicated significant differences among nutrient sources. At the different fertilizer types, application of mineral fertilizer had significantly ($P \leq 0.05$) more roots than the other fertilizer types with cow dung being second to mineral fertilizer in terms of number of roots while control (Untreated) had the least. On tuber length - considering the different nutrient sources used, application of mineral fertilizer had significantly ($P \leq 0.05$) longer tubers than the other nutrient sources applied, with poultry manure being statistically similar with mineral fertilizer. It was followed by cow dung and then sheep/goat manure. The control had shorter tubers than the other treatments evaluated. On tuber weight - considering the different nutrient sources applied, mineral fertilizers had significantly ($P \leq 0.05$) higher tuber weight than all the other nutrient sources, followed by cow dung, poultry droppings and sheep/goat manure. Control plots on the other hand, had lighter tubers among all the treatments considered. On number of tubers per plant - at the different nutrient sources evaluated, application of mineral fertilizer had significantly ($P \leq 0.05$) higher number of tubers than all the other fertilizer types used. Followed by sheep/goat manure, poultry droppings and cow dung which were statically similar and the control plots however, had least number of tubers among all nutrients of the treatments considered. On tuber yield - at the different nutrient sources evaluated, application of sheep/goat manure and mineral fertilizer which are statically similar had significantly ($P \leq 0.05$) higher tuber yield than the other treatment applied, followed by cow dung and poultry droppings. Control (Untreated) plots on the other hand, produced the least tuber yield among all the other treatments studied.

Intra Row Spacing × Nutrient Sources Interaction on Yield Parameters

The interaction between intra row spacing and nutrient sources is presented in Table 11. Holding row spacing constant and varying nutrient sources, number of root per plant differed significantly in all cases. Generally, mineral fertilizer produced more number of root per plant compared to all other treatment. However, with 20 cm row spacing, sheep/goat manure is at par with mineral fertilizer. Irrespective of the different nutrient used, control plots consistently produced fewer roots than all other treatment applied. On the on hand, when nutrient sources is held constant and row spacing is altered. Number of root per plant still differed significant with mineral fertilizer. In this case 20 cm row spacing produced more number of roots per plant and 15 cm row spacing produced the least. Table 12 presents interaction between intra row spacing and nutrient sources on tuber length. 20 cm row spacing differed statistically from other row spacing with regard to all the nutrient sources. 25 cm also differed statistically from 15 cm row spacing with regard to all the nutrient sources except mineral fertilizer and control where 15 cm row spacing performed better statistically than 25 cm row spacing. Table 13 presents interaction between intra row spacing and nutrient sources on tuber weight. 20 cm row spacing produced heavier tubers statistically than the other spacing used with regard to all nutrient sources except for control where the order of statistical difference was 15 cm, 20 cm and 25 cm. Table 14 presents interaction between intra row spacing and nutrient sources on the number of tuber per plant. 20 cm row spacing produced higher number of tubers statistically than 20 cm and 25 cm respectively. Table 15 presents interaction between intra row spacing and nutrient sources on tuber yield. 20 cm intra row spacing had higher tuber yield statistically than other spacing with regard to all the nutrient sources. 15 cm row spacing in turn shows higher tuber yield statistically than 25 cm intra row spacing with regard to all nutrients sources except in cow dung where 25 cm row spacing shows higher tuber yield than 15 cm row spacing. The interaction between intra row spacing and season hold same for all the yield parameters, 2016 growing season was superior in all the yield parameter than 2015 under intra row spacing of 20 cm.

DISCUSSION

Effect of Intra Row Spacing on Growth

The experiment unveiled the superiority of 25 cm intra row spacing of growing Living Stone Potato over other intra row spacing (20 cm and 15 cm) in all the growth assessed (plant height, number of leaves per plant, number of branch per plant, net assimilation rate, leaf area, leaf area index and crop grow rate). This might be an indication that wider spacing in Living stone potato is best for its growth. For plant height, this could

be as a result of optimum utilization of sunlight, water and nutrients for photosynthetic activities at these spacing as backed by Baker (2000) in Irish potato. The present investigation is in agreement with the earlier report of Bello (2002) who showed that wider spacing in potato could lead to higher plant growth with adequate partitioning of assimilates within the plant. Assimilates partitioned on stem elongation may probably lead to production of leaves. Gebre (2001), Zamil (2010) and Raemaekers (2001) also reported that wider spacing produces healthier plants in Irish potato than closer spacing because of less competition for nutrients. The significantly ($P \leq 0.05$) higher number of leaves produced when 25 cm intra row spacing was used as against 15 and 20 cm, may be due to less competition among plants at wider spacing. Berler (2000) also reported that closer spacing such as spacing of 15 cm could lead to mutual shading which can affect crop yield in Irish potato. NRC (2000) also reported that closer spacing like 15cm produces less number of leaves while wider spacing, producing higher number of leaves. Dense plant population generally leads to ineffectiveness in utilization of photosynthetic assimilate and other resources needed by plant due to competition among plants which may be due to mutual shading.

The higher number of branches observed at the introduction of 25 cm intra row spacing as against 15 cm and 20 cm could be that wider spacing tends to produce higher number of branches due to its ability to absorb available resources such as moisture, nutrient and sunlight. This could be as a result of wider spacing leading to the production of many of branches as reported by Aliyu (2012). This assertion is in agreement with the findings of KEW (2012) who reported that, wider spacing in Irish potato producing higher number of branches which may lead to high yield in Irish potato. The significantly ($P \leq 0.05$) higher assimilation rate observed at 25 cm row spacing could be as a result of the wider spacing used where the plant were also to take up more nutrients for higher photosynthetic assimilation. The present work corroborates with the report of Gagro (2000) that; with a wider spacing in Irish potato, net assimilation rate is increased, there by leading to effective photosynthetic efficiency and final yield of the crop. The higher crop growth rate observed when 25 cm intra row spacing was used as against 15 and 20 cm, could also be due to the wider spacing used, leading to higher photosynthetic activity of the crop. This work is in agreement with the findings of James (2006) who reported that, wider spacing in Irish potato increases crop growth rate. On the other hand, 15 cm intra row spacing with cluster of plants, might have affected crop growth rate leading to low yield. The present study is in conforms to the work of NRC (2012) which reported that, with wider spacing, the rate of crop growth tend to increase due to adequate spacings for optimum physiological activities and crop yield. The gain in LAI from 6 WAS through to 8 WAS could also be an indication that optimum LAI in Living stone potato could be obtained due to its vegetative stage of growth. Although not many literatures have been obtained on the crop, LAI of 3.20 could be reported as optimum for Living stone potato considering the size of the plant when compared to Irish potato. However, more work is needed in this area to fully establish the exact LAI value of the crop through appropriate plant population. The present finding confirms the report of Bala (2005) and Caldiz (2000) that, wider spacing in Irish potato, increases leaf area index up to the stage when the plant fully matured. LAI in Irish potato ranges from 3.5- 6.0 depending on the cultivar, and it can be recorded from 6 WAS – 10 WAS beyond 10 WAS it begins to decline due to natural senesces (Caldiz, 2000).

Effect of Nutrient Sources on Growth

The experiment showed the superior performance of mineral fertilizers over the organic nutrient sources and control in all the growth parameters, this might not be unconnected with the readily mineralized elements in chemical fertilizer as the nutrients are released faster to the crop for growth. The present finding is in line with the earlier reports of Shakaway *et al*., (1976) and Jones (1984) who showed that growth is faster under mineral fertilizer than under organic manure due to faster release of minerals in Irish potato. Application of NPK at the early stage of growth and the use of top dress application of Urea at later stages shows tremendous increase in plant height of the crop as well as other growth parameters. Makare (1992), Abgede *et al*., (2006) and Fagam and Wilson (2009) reported similar results that application of chemical fertilizers leads to faster vegetative growth in Irish potato. It was reported also that increase in plant height and plant vegetative growth occurs with increase in the rate of NPK application. Organic nutrient sources on the other hand, had lower effects on vegetative growth, due to possibly slow release of nutrient by organic sources (Bello, 2015). The performance of Sheep/goat manual was almost consistent across the growth parameters measured. It has been reported that sheep/goat manure is believed to contain a high percentage of available nitrogen or nitrate which is necessary for plant growth (Valadez, 1992). Ifenkwe *et al.*, (1992) reported that organic manures are slow release fertilizers, releasing their nutrient over an extended period of time to ensure efficient plant growth. At 10WAS mineralization was probably at its peak which makes it more suitable for plant growth such as living stone potato. Poultry droppings were similar to cow dung in plant height, net assimilation rate and leaf area index. This infers that, at 10 WAS, there is probably slow release of these organic source of nutrient.

Effect of Intra Row Spacing on Yield

20 cm intra row spacing was observed to be superior in all the yield parameters measured except in tuber weight where 25 cm spacing weigh heavier tubers. This observation might be due to the moderates spacing required by the plant for utilization of resources for growth. It is believed that at close spacing say 20 cm which translates to optimum plant population coupled with appropriate development of photosynthetic apparatus at early vegetative stage translates to increase in number of roots and tuber yield, the plant will be at its best in the utilization of moisture and nutrients for photosynthesis and dry matter

partitioning. This present investigation agrees with the report of Baker (2000) who stated that wider spacing increases root number there by leading to optimum uptake of available nutrients in the soil. Woods (2004) also reported the same trend in Irish potato that at moderate spacing, high number of roots could be obtained mostly due to the competitive nature of the plants in terms of nutrient uptake. The heavier tubers observed under 25 cm intra row spacing as against 20 and 15cm, could be attributed to wider spacing recorded leading to the production of heavier tubers. This is similar with the findings of Lasisi (2000) who reported that, higher tuber weight in Irish potato under wider spacing leads to heavier tubers. Closer spacing on the other hand, led to the production of tiny tubers in Irish potato due to mutual shading and competition on recourses.

Effect of Nutrient Sources on Yield

Under the different nutrient sources, the significant ($P \leq 0.05$) performance of mineral fertilizer over the other organic sources and control may not be unrelated with the results obtained for other parameters observed earlier. This could be due to the quick release of N. P and K from the compound fertilizer which is essential for root growth and tuberization. The faster releasing attribute of mineral fertilizer might have led to higher production of roots on the plants. In the report Jahun (1995) and Kaltungo (1995) lend support to the present study that mineral fertilizer application increases root number, root initiation and growth. This is clear from the results recorded with the application of poultry manure and control plots where shorter tubers were obtained, but this might have enhanced biological, chemical and physical properties of the soil. Addition of organic sourced nutrients could have caused reduction in soil bulk density, increase soil aeration, water holding capacity which enhanced crop growth and culminated in enhanced performance obtained yield characters. The performance of Sheep/goat manual on the tuber weight, number of tuber and tuber yield was superior to cow dung, poultry droppings and control. This could be attributed to the consistent but gradual release of nutrient giving the dry and hard nature of the manure which is still much needed for tuber yield.

Intra Row Spacing × Nutrient Sources Interaction

The observed highly significant intra row spacing × nutrient sources interaction for all parameters measured has practical implications. This could be that panting living stone potatoes at 25 cm intra row spacing enhanced vigorous root growth which made the crop to absorb nutrients made available from mineral fertilizer for enhanced growth and subsequent improvement in yield and yield components. This finding is in agreement with the findings of Bello (2015) who reported that wider spacing and readily available mineral nutrient leads to vegetative growth in plants.

Interaction between spacing, nutrient sources and season on growth and yield parameters measured of living stone potato grown during 2015 and 2016 rainy season in Billiri, Gombe state at 10 weeks after sowing was highly significant. The higher performance observed in 2016 rainy season over that of 2015 could be as a result of the residual nutrient effect. It may also be attributed to higher rainfall recorded in 2016 enabling the crop to utilize nutrients properly through decomposition of the nutrients under optimum moisture supply, adapting to the environmental factors with improved soil conditions. This accession is supported by the work of Ainedu (2010) who reported that with improved cultural practices and left over nutrients in the soil in the previous season, crop yield tends to increase leading to higher performance in the parameter measured.

CONCLUSION

The application of 25cm intra row spacing clearly outperformed the other spacings in growth parameters while 20cm intra row outperformed the other spacings in yield parameters except in tuber weight. Similarly, the application of mineral fertilizer N.P.K. 15:15:15 with Urea 46%N and sheep/goat manure at 3tonnes/ha seems more promising on tuber yield. The 2016

RECOMMENDATIONS

Intra row spacing of 20cm with the application of mineral fertilizer NPK 15:15:15 and Urea 46%N) at the Irish potato recommended rate of 80kg N, 40kg P and 40kg K. or the application of sheep/goat manure at the rate of 3tonnes/ha should be applied by Living Stone potato farmers in the study area.

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