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Effects of Planting Spacing on the Growth and Yield of First Crop of Plantain in the High Rainfall Agro-Ecology of South-South Nigeria

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Abstract **– Field experiments were conducted in 2017-2018 at Port Harcourt and Bori to determine the most appropriate planting spacing for optimum growth, yield and quality of plantain (Musa sp) for the zone. Planting spacing (treatments) used were : 1.5m x 1.5 m, 2m x 1,5m, 2m x 2m, 2m x 2.5m, 2m x 3m (control), 2.5m x 3m and 3m x 3m, replicated three times in a randomized complete block design (RCBD). Results showed that flowering in plantain crop was significantly delayed by closer spacing but was earlier with wider spacing. Wider spacing increased plants pseudostem girth, number of green leaves and LAI at flowering. The closest plant spacing (1.5m x 1.5m) produced the tallest plants at flowering, gave the least bunch weight of 11.63 and 13.84 kg/plant and highest total bunch yield of 33.3 and 36.8 t/ha at Port Harcourt and Bori sites respectively. On the other hand the widest planting spacing (3m x 3m) gave the highest bunch weight of 25.78 and 28.13 kg/plant and lowest total bunch yield of 21.8 and 24.3 t/ha, at Port Harcourt and Bori sites respectively. The intermediate planting spacing 2m x 3m and 2m x 2.5m gave higher bunch weight that were similar to the widest planting spacing and also higher bunch yield that were similar to the closest planting spacing at the respective sites. Since they possess high bunch yield in addition to good marketable fruits quality, were acclaimed winners for both domestic and industrial consumption, followed by 2m x 2m planting spacing.**

Keywords **– Plantain, Spacing, Competition, Yield, Port Harcourt and Bori.**

I. Introduction

Plantain (*Musa paradisiaca* L.) is a staple food crop grown in the tropical and subtropical regions (Englberger *et al*., 2006; USDA, 2013). In West and Central African low land, it is of major socioeconomic importance where it significantly contributes to food security and rural development of the people (Akinyemi *et al.*, 2010; Obiefuna *et al.*, 2008). The crop is a next major staple food after rice, wheat and maize (Tripathi *et al.*, 2007). It is an important source of carbohydrate, crude fibre, vitamins, proteins, potassium, phosphorus, iron, sodium, calcium, magnesium, carotenes and ascorbic acid (Awedem *et al*., 2015; El-Khawaga, A.S., 2013) and also contains moderate amounts of thiamine, riboflavin, nicotinic and folic acid and others (Adepoju *et al.*, 2012; Rasheed, 2003). The fruit's waste and leaves also form nutritious fodder for livestock. Studies carried out have shown that plantain and banana waste (fruits, stems and leaves) can be used as fodder to provide energy sources for livestock, and in particular during the dry season when there are feed shortages (Rusdy, 2017: Yitbarek, 2019).

Plantain production is faced with numerous constraints which include soil degradation and infertility (Meya *et al.,* 2020; Osundare *et al.*, 2015), high labour demand for cultivation (Idumah *et al.*, 2016; Kainga and Seiyebo, 2012), inappropriate planting spacing (Nwaiwu *et al*., 2012; Obiefuna *et al.*, 2008), weed competition (Prameela, 2010) and pests and disease invasion (Kumar *et al.*, 2015; Tinzaara and Gold, 2008). To maintain and sustain the increasing demands for plantains as a staple food and industrial material in Nigeria, appropriate technologies must be employed to address such constraints to increase yield and general performance of the crop. One of such strategies is to adopt proper planting spacing to avoid un-necessary competition for soil and atmospheric resources.

Planting spacing is seen as an important factor of crop production and varies with the ultimate aim of such planting, nature and size of planting material, fertility of the soil and growth pattern of the crop (Hauser and Amougou, 2010). Information on planting spacing needs to be explored alongside changes in cropping systems. In plantain production, like most other crops, planting spacing greatly influences growth rate as well as leaves exposure to receive optimum sunlight for photosynthetic activities (Falodun and Ogedegbe, 2016; Gbaraneh, 2018). Close planting although may protect plantations exposed to high wind effect, on the other hand encourages keen competition for both atmospheric resources and soil nutrients (Tetteh *et al.,* 2019). There is the need to know the most appropriate planting spacing for optimum growth, yield and quality in plantain production in each ecosystem.

Different planting distances are being adopted throughout plantain production areas depending on soil fertility level, climatic condition, management techniques and purpose of cultivation (bunch for human consumption or fodder for livestock feeding). Planting spacing ranging from 1.0m x 1.5m through 3m x 4m (6666 to 833 plants ha^{-1}) have been advocated by researchers in different environments for plantain and banana production (Athani *et al.,* 2009; Kumar *et al.,* 2014; Cortazar *et al.,*2017). For whatever planting spacing adopted, the principal motivation is the yield and quality of the produce. Most of the plantains produced in Nigeria are consumed domestically and for this purpose, while aiming at high yield, bunches must be heavy with long and big fingers to be accepted by consumers (Obiefuna *et al.,* 2008; Ayanwale *et al.,* 2016). The objective of this study, in view of the above facts, was to find out the optimum planting spacing to achieve healthier growth and high yield and quality of plantain in a high rainfall agro-ecology of South-south Nigeria.

II. Materials and Methods

Description of the Study Site

The study was carried out simultaneously at the Rivers Institute of Agricultural Research and Training (RIART) Farm, Rivers State University, Port Harcourt and the Agricultural Development Programme (ADP) Farm, Bori, Rivers State. The Port Harcourt site is situated on Latitude 4.5° N and Longitude 7.01° E on an elevation of 18m above sea level while Bori is on Latitude 4.42° N, and Longitude 7.21° E on an elevation of 20m above sea level, all in the rain forest belt of South-south Nigeria. The rainfall pattern of the zone is bimodal, distributed over a 9 months period from March through November, with an annual average of 2500mm and 2450mm for Port Harcourt and Bori respectively. Generally, the relative humidity of the experimental zone remains high all year round with means values of 75-78% in February, increasing to 83-89% in the months of July and September. The mean annual temperatures of Port Harcourt and Bori are 25 - 29^{0}C and 24.6 - 28.6°C, respectively. The soil details are shown in Table 1.

Treatments and Experimental Design

The experiment comprised of seven treatments was laid out in a Randomised Complete Block Design (RCBD) and replicated three times. The treatments details are presented in Table 2. A total land area measuring 1856m^2 (32m x 58m) was allocated to the experiment at each site. This was further subdivided into three blocks, each carrying the seven treatments. Each plot carrying the treatment measured, 6m x 8m (48m^2).

Table 1. Soil properties at soil depth (0-30 cm) at the experimental sites, prior to commencement of experiments in 2016.

Parameters	**Port Harcourt Site**	**Bori Site**
Soil type	Ultisols	Ultisols
Soil aggregate distribution	(loamy sand)	(loamy clay)
Soil physical properties		
Sand	83%	78%
Silt	5%	10%
Clay	11%	12%
Soil Chemical Properties		
Acidity in water (pH)	4.90	4.83
Organic matter (%)	1.20	1.50
Total N (%)	0.08	0.08
Phosphorus (kg ha^{-1})	46.80	31.70
Potassium (kg ha^{-1})	78.00	81.65

Table 2. Treatments and Plant Population per Hectare.

Code	**Treatments: Planting spacing (m)**	**Number of plants $Hectare^{-1}$**
S1*	1.5 x 1.5	4,444
S2	2 x 1.5	3,333
S3	2 x 2	2,500
S4	2 x 2.5	2,000
S5	2 x 3 (control)	1,666
S6	2.5 x 3	1,333
S7	3 x 3	1,111

*S = Planting spacing.

Land Preparation, Planting and Cultural Practices

At Port Harcourt a one-year fallowed land with *Chromoleana odorata, Aspilia Africana*, *Panicum maximum* as dominant vegetative covers was chosen while the Bori site was a two-year fallow land consisted primarily of *Chromoleana odorata, Aspilia Africana*, *Panicum maximum* and some woody species of *Alchornia cordifolia, Dactyladenia barteria* and *Anthonata mycrophilia*. At both sites, the land was manually cleared with machete. The slashed vegetation was allowed to dry and the sticks and woody parts of the dry matter that would obstruct planting operations were removed. There was no burning. The plots were marked out. The planting material consisted of healthy uniform sized sword suckers of the 'False Horn' plantain cv. 'Agbagba'. The planting suckers were organized into homogeneous groups of same size and weight to create uniformity in growth and development of the plantation crop. Planting was done on 7th and 13th June 2017 at Port Harcourt and Bori respectively, in dug holes measuring 0.3 m x 0.3 m x 0.3 m, at the appropriate spacing, according to the design of the trial. Before planting, each of the holes was treated with 15 g of Furadan 5G for control of plantain weevil

(*Cosmopolites sordidus*) and root-knot nematodes (*Meloidogyne spp*) (according to Obiefuna, 1984). Inorganic fertilizer (N = 100; P_2O_5 = 50; K_2O = 210 kg/ha) was applied all P_2O_5 and K_2O and 1/3 N at planting and the remaining 2/3N at four months later to all the plots. Weeding was not timed but manually done as at necessary. Pruning of dead and dried leaves was done every 3 weeks interval and tall plants especially those carrying fruit bunches were supported with bamboo stakes (of the family *Bambuseae*). The stakes were used to prop plants up against wind damage.

Data Collection

Data were collected at two major growth stages for the crop - at flowering and at harvest. Data collected at flowering were, number of days to 50% flowering, plant height, stem girth, number of green leaves plant^{-1}and Leaf area index. At harvest, bunch weight plant^{-1}, number of hands bunch^{-1} number of fruits hand^{-1}, fruit weight, length and circumference of fruits and bunch yield (t/ha) were recorded.

Data Analysis

All data collected were subjected to analysis of variance (ANOVA) in a randomized complete block design using GLM procedure of SAS (2010) to assess treatment effects. The ANOVA was carried out for each site of study and thereafter as a combined analysis over the two sites for bunch weight and yield. The least significant difference (LSD) test at the 5 % probability level was used to compare treatment means.

III. Results

Vegetative Growth of Plantain at Flowering

Planting spacing significantly (P<0.05) influenced flowering dates, plant height, plant girth, number of green leaves per plant and leaf area index (LAI) (Tables 3 and 4.). Flowering date was earlier in widest planting spacing (3m x 3m) with 361and 382 days at Port Harcourt and Bori sites, respectively, while closest spacing (1.5m x 1.5m) had a prolong flowering date of 417.8 and 429.5 days at the respective sites. The number of days dropped gradually with increasing planting spacing at both sites.

Closest plant spacing (1.5m x 1.5m) produced the tallest plants of 255.5 and 283.2 cm as against 226.6 and 231.1 cm recorded in the widest planting spacing (3m x 3m) at Port Harcourt and Bori, respectively. Plant height of treatment 1.5m x 1.5m was not significantly higher than treatments 2m x 2m and 2m x 1.5m. Plant height decreased progressively with increasing planting spacing. Nevertheless, plant height of the widest plant spacing (3m x 3m) was the shortest and did not differ significantly from all other treatments except 2m x 2m, 2m x1.5m and 1.5m x 1.5m. Plant girth, number of leaves at flowering and leaf area index (LAI) were also significantly (P<0.05) influenced by planting spacing. The widest spacing of 3m x 3m produced the largest stem girth of 73.4 and 76.9 cm, largest number of leaves of 11.6 and 12.1 per plant and LAI of 5.42 and 5.82 at Port Harcourt and Bori sites, respectively. All these attributes, stem girth, number of green leaves per plant and leaf area index (LAI) decreased linearly with decrease in planting spacing.

Bunch Yield and Yield Components

Yield characteristics of plantain were significantly (p<0.05) influenced by planting spacing (Tables 5 and 6). The closest planting spacing (1.5m x 1.5m) significantly (p<0.05) delayed bunch maturity to 498.2 and 481.1 DAP at Port Harcourt and Bori sites, but did not differ statistically from planting spacing 2m x 1.5m, 2m x 2m and 2m x 2.5m. Generally number of days taking to maturity decreased progressively with increase in planting spacing to 418.6 and 399.1 DAP for widest spacing (3m x 3m) at Port Harcourt and Bori, respectively. The control treatment (2m x 3m) produced matured bunches at 441.8 and 424.6 DAP at Port Harcourt and Bori, respectively and differed significantly from all further reduced planting spacing except 2m x 2m and 2m x 2.5m. The control did not differ significantly from other wider planting spacing of 3m x 3m and 2.5m x 3m at both sites.

Table 3. Effects of Planting Spacing on Plantain Growth Characteristics in the Soils of Port Harcourt.

Planting spacing (m)	Plants Hectare^{-1}	Date to 50% flowering	Plant height (cm)	Stem girth (cm)	Number of green Leaves	Leaf area index (LAI)
1.5 x 1.5	4,444	417.8	255.5	54.5	9.4	2.82
2 x 1.5	3,333	419.1	248.1	57.3	9.6	3.13
2 x 2	2500	411.2	251.5	64.5	10.6	3.68
2 x 2.5	2,000	406.8	244.4	67.1	11.5	4.14
2 x 3	1666	391.2	240.8	70.3	11.7	4.98
2.5 x 3	1333	378.6	236.2	71.4	12.2	5.23
3 x 3	1111	361.2	226.6	73.4	12.6	5.42
$LSD_{(0.05)}$		23.13	9.10	7.64	1.32	1.100

Table 4. Effects of Planting Spacing on Plantain Growth Characteristics in The Soils Of Bori.

Planting spacing (m)	Plants Hectare^{-1}	Date to 50% flowering	Plant height (cm)	Stem girth (cm)	Number of green Leaves	Leaf area index (LAI)
1.5 x 1.5	4,444	429.5	273.2	54.2	10.3	3.13
2 x 1.5	3,333	422.4	270.8	58.6	10.7	3.43
2 x 2	2500	411.6	260.7	66.8	11.3	3.85
2 x 2.5	2,000	396.1	254.3	69.4	12.3	4.62
2 x 3	1666	390.2	252.2	72.8	12.2	5.22
2.5 x 3	1333	384.5	248.8	73.7	12.6	5.74
3 x 3	1111	382.3	231.1	76.9	13.1	5.82
$LSD_{(0.05)}$		19.94	19.80	8.79	1.06	1.163

Bunch weight/plant was significantly ($p<0.05$) influenced by planting spacing (Fig. 1(A)). The widest spacing (3m x 3m) gave the highest bunch weight of 25.78 and 28.13kg at Port Harcourt and Bori, respectively which were not significantly higher than the weight recorded by spacing 2.5m x 3m, 2m x 3m and 2m x 2.5m. The closest planting spacing (1.5m x 1.5m) produced the least bunch weight/plant of 11.63 and 13.84kg, that did not differ significantly from weight recorded for planting spacing 2m x 1.5m and 2m x 2m at the respective sites. Similarly, fruit length, circumference and average fruit weight were significantly influenced by the respective planting spacing (Tables 5 and 6) such that planting spacing 3m x 3m gave the longest fruit of 25.5 and 26.3cm, largest circumference of fruits (15.7 and 17.8cm) and average fruit weight of 243.7 and 296.3g, at Port Harcourt and Bori, respectively as against the closest plant spacing (1.5m x 1.5m) producing the least fruit length of 15.8

and 16.8cm, circumference (10.2 and 11.3cm) and average fruit weight of 112.4 and 124.1g at the respective sites. Result showed that the variables, number of hands/bunch and number of fruits/hand, did not differ statistically among the different planting spacing.

Bunch yield was significantly ($p<0.05$) affected by the different planting spacing adopted (Fig. 1(B)). The closest planting spacing (1.5m x 1.5m) gave the highest bunch yield of 33.3 and 36.8 t/ha at Port Harcourt and Bori respectively as against the least yield of 21.8 and 24.3 t/ha (yield reduction of 35 and 34%) recorded by the widest spacing (3m x 3m) at the respective sites. The yield of the closest spacing was not significantly higher than those of spacing 2m x 1.5m, 2m x 2m, 2m x 2.5m and 2m x 3m. The pulp: peel ratio of the fruit was highest and lowest with the widest and closest planting spacing respectively at both sites (Table 7), indicating that pulp content of the fruit was maximum in wider planting spacing than the closer spacing. Domestic demand for the bunches was highest for those of planting spacing 3m x 3m, 2.5m x 3m, 2m x 3m and 2m x 2.5m. Spacing 2m x 2m had a medium acceptability while 2m x 1.5m and 1.5m x 1.5m had very poor demand due to the nature of the fruits.

The combined analysis (Table 7) shows that the percentage reduction in bunch weight (kg) over the widest spacing (3m x 3m) ranged from 10.2% in spacing 2.5m x 3m to 58.5% in the closest spacing (1.5m x 1.5m). Similarly, the percentage reduction in bunch yield (t/ha) over the closest spacing (1.5m x 1.5m) ranged from 1.6% in spacing 2m x 1.5m to 33.3% in the widest spacing (3m x 3m). Fig. 2 a, b and c show the relationship between planting spacing and some attributes of yield. Fruit length, fruit circumference and average fruit weight showed positive linear relationship with planting spacing, indicating the positive contribution of planting spacing at enhancing bunch yield of plantain.

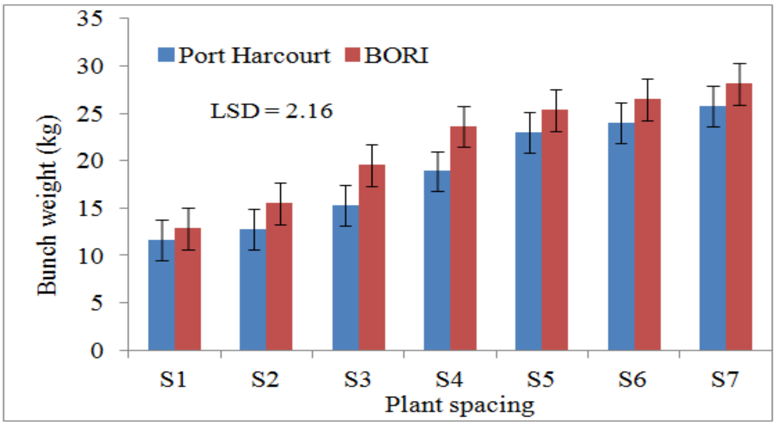
Table 5. Effect of planting spacing on yield attributes of plantain grown at port Harcourt.

Plant Spacing (m)	Plants hectare^{-1}	Number of days to harvest	Number of plants harvested (%)	Number of hands bunch^{-1}	Number of fruits hand^{-1}	Fruit length (cm)	Fruit Circum-ference (cm)	Fruit weight (g)
1.5 x 1.5	4444	498.2	78.1	6.9	11.3	15.8	10.2	112.4
2 x 1.5	3333	484.1	85.3	7.1	11.3	17.3	10.6	122.6
2 x 2	2500	472.4	90.1	7.1	11.3	19.1	11.2	147.2
2 x 2.5	2000	453.6	93.4	7.2	11.3	22.8	12.8	189.5
2 x 3	1666	441.8	95.6	7.2	11.3	24.6	13.3	207.3
2.5 x 3	1333	428.6	96.4	7.3	11.3	25.2	13.9	218.8
3 x 3	1111	418.6	98.8	7.3	11.4	25.5	15.7	243.7
$LSD_{(0.05)}$		31.14	7.69	0.67	0.04	4.26	1.32	53.42

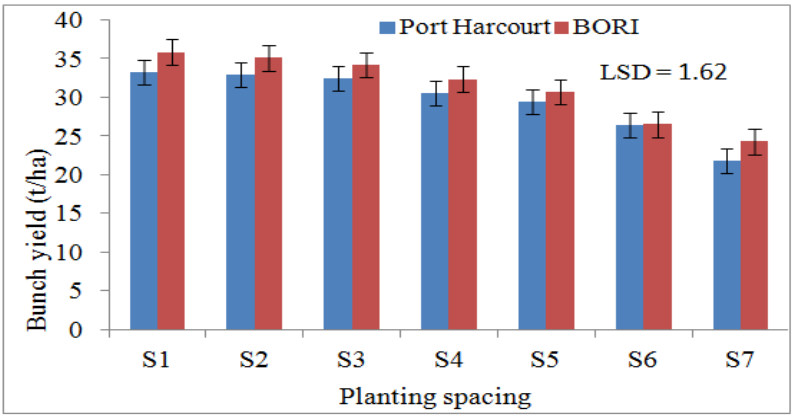
Table 6. Effect of planting spacing on yield attributes of plantain grown at Bori.

Plant Spacing (m)	Plants hectare^{-1}	Number of days to harvest	Number of plants harvested (%)	Number of hands bunch^{-1}	Number of fruits hand^{-1}	Fruit length (cm)	Fruit Circum-ference (cm)	Fruit weight (g)
1.5 x 1.5	4444	481.1	10.8	7.1	11.8	16.8	11.3	124.1
2 x 1.5	3333	473.4	10.2	7.1	11.8	17.6	11.7	148.2
2 x 2	2500	454.6	7.8	7.1	11.8	22.8	12.0	162.1

Plant Spacing (m)	Plants hectare^{-1}	Number of days to harvest	Number of plants harvested (%)	Number of hands bunch^{-1}	Number of fruits hand^{-1}	Fruit length (cm)	Fruit Circum-ference (cm)	Fruit weight (g)
2 x 2.5	2000	441.8	7.6	7.2	11.8	23.8	12.8	201.4
2 x 3	1666	424.6	3.6	7.2	11.8	24.6	13.1	260.3
2.5 x 3	1333	412.6	3.1	7.3	11.8	25.2	15.1	278.1
3 x 3	1111	399.1	2.4	7.3	11.9	26.3	17.8	296.3
$LSD_{(0.05)}$		32.54	3.67	0.34	0.04	4.26	1.54	72.53

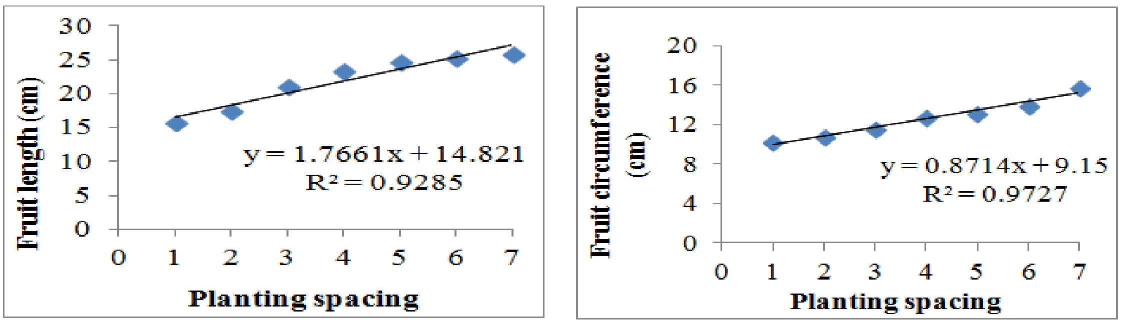


(a)

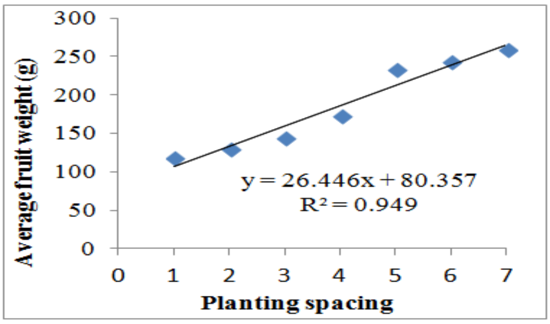


(b)

Fig. 1. (A) Average bunch weight (B) Total bunch yield: of plantain as influenced by planting spacing at Port Harcourt and Bori sites S1 (1.5m x 1.5m), S2 (2m x 1.5m), S3 (2m x 2m), S4 (2m x 2.5m), S5 (2m x 3m), S6 (2.5m x 3m), S7 (3m x 3m).



(a) (b)



(c)

Fig. 2. Relationship between total bunch yield and (a) fruit length, (b) fruit circumference and (c) average fruit weight of plantain as influenced by planting spacing at Port Harcourt and Bori sites.

Table 7. Effect of plant spacing on pulp and peel percentage and domestic consumer's acceptability (Bunch Weight and Marketable Fingers) of plantain grown at port harcourt and Bori.

Planting Spacing (m)	Plants Hectare^{-1}	Port Harcourt Site			Bori Sites		
		% Pulp	% Peel	Domestic consumer's acceptability	% Pulp	% Peel	Domestic consumer's acceptability
1.5 x 1.5	4,444	65.7	34.3	1	66.7	33.3	1
2 x 1.5	3,333	66.1	33.9	1	66.9	33.1	2
2 x 2	2500	68.2	31.8	3	65.2	34.8	3
2 x 2.5	2,000	69.2	30.8	5	67.4	32.6	5
2 x 3	1666	71.3	28.7	5	70.7	29.3	5
2.5 x 3	1333	73.4	26.6	5	75.4	24.6	5
3 x 3	1111	75.2	24.7	5	76.7	23.3	5
$LSD_{(0.05)}$		6.51	6.54	2.1	11.09	11.09	1.8

Table 8. Combined (CUM) analysis of Bunch Weight (Kg/Plant) and total yield (t/ha) of plantain as influenced by planting spacing at port harcourt and Bori.

Planting Spacing (m)	Plants Hectare^{-1}	COM Bunch wt (kg)	% reduction over widest spacing	COM Bunch yield (t/ha)	% reduction over closest spacing
1.5 x 1.5	4,444	12.24	58.5	34.55	-----
2 x 1.5	3,333	14.18	49.6	34.00	1.6
2 x 2	2500	17.41	41.6	33.35	3.5
2 x 2.5	2,000	21.26	26.2	31.45	9.0
2 x 3	1666	24.18	17.4	30.55	11.6
2.5 x 3	1333	25.24	10.2	26.45	23.4
3 x 3	1111	26.96	------	23.05	33.3

Planting Spacing (m)	Plants Hectare^{-1}	COM Bunch wt (kg)	% reduction over widest spacing	COM Bunch yield (t/ha)	% reduction over closest spacing
$LSD_{(0.05)}$		6.041		4.526	

IV. Discussions

Growth Attributes

The range of significant differences in most growth parameters observed between closest and widest planting spacing (1.5m x 1.5m and 3m x 3m) indicated that optimum planting spacing is critical at enhancing growth attributes of plantain. In closer spacing, population per unit area was high. There could have been a severe competition between the plants for soil nutrients and water and atmospheric resources such as sunlight for photosynthetic activities (Violet *et al.*, 2020; Gbaraneh *et al.*, 2018). Plants were taller with small stem girth and less number of functional green leaves. On the other hand, wider spaced plants significantly produced shorter plants with many healthier (green) leaves and large stem girth than the closer spaced plants. It could be established from these results that in plant spacing studies, plant stem girth and height tend to be inversely proportional to each other. The observation is in harmony with that of Benson (2013), that densities greater than 2,000 plants ha^{-1} had an adverse effect on growth and development as a consequence of root superposition and leaf overlapping. This suggests that plants spaced wider enough enjoyed unlimited supply of environmental resources for growth and developments. These confirm earlier reports of Lanza *et al.*, (2017); Kumar *et al.*, (2014); Obiefuna *et al.*, (2008) on the influence of planting spacing on plantain production. Gbaraneh *et al.*, (2004) had reported that competition for space, light and soil nutrients are common phenomenon in crop production system. There could have been serious overlapping of leaves from adjacent plants in closer spacing subjecting the plants to struggling for sunlight hence, tall and slim plant stems thrived in closer spacing than wider planting spacing (Athani *et al.*, 2009). The number of leaves produced before or at flowering is an indication of the healthy functionality of the plantain plants. In wider planting spacing, competition for resources of growth was not limiting hence photosynthesis was optimal.

Wider spacing had positive effect on leaf area than closer spacing. The decreasing leaf area index (LAI) experienced in closer spacing could be attributed to high plant density per unit area, causing overlapping of leaves and leading to low absorption of sunlight by individual plant for photosynthesis, resulting to poor surface development of leaves. These results are in agreement with those obtained by Athani et al. (2009) who observed that wider spacing had a positive effect on leaf area (m2) due to a larger number of leaves with bigger sizes. El-Khawaga, (2013) similarly observed significant decreasing of leaf area with decreasing planting spacing which was attributed to high plant density per unit area leading to excessive interception of sunlight, gradually responsible for decreasing the leaf area. Benson (2013) had also stated that densities greater than 2,000 plants ha-1 had an adverse effect on growth and development of plantain plants as a consequence of root superposition and leaf overlapping.

It is hereby established from our studies that wider spacing have a positive effect on all vegetative growth parameters except plant height which was negatively affected.

Bunch Yield

Yield of Crop being highly polygenic and complex in nature, is usually determined through various vegetativ-

-e and reproductive parameters. The length, circumference and weight of fruits showed strong positive correlation with wider planting spacing, a result that could be linked to the likely effect of a higher incidence of solar radiation per unit of leaf area and unlimited supply of soil nutrients. It could therefore be established, based on the results, that shading might negatively or positively influence fruit development in plantain, depending on the intensity. Number of hands/bunch and number of fruits/hand were not significantly influenced by the respective planting spacing adopted. Violet *et al.,* (2020) working on Musa AAA Simmonds, similarly reported non significant effect of planting arrangement or planting density on number of hands and number of fingers. Such non-effect on number of hands/bunch and number of fruit/hand could be attributed to genetic factors.

The higher bunch weight observed in wider spacing could possibly be attributed to the large size and heavy weight of the fruits contained in the bunch. On the contrary, closer spacing produced significantly low bunch weight due to the small size and low weight of the fruits. These considerations are consistent with reports of Kumar *et al.,*(2013); Sarrwy *et al*., (2012) and Smith *et al.,* (2010), who stated that an increase in planting density linearly reduces bunch weight. Similarly, Gogoi *et al.* (2015) observed that bunch weight reduction under increasing planting densities was due to a lower solar radiation interception, a situation which according to Thippesha *et al*., (2008) affected the photosynthetic processes and eventual translocation of assimilates.

Bunch yield per hectare was significantly higher in closer spacing than wider planting spacing; a situation attributed to high plant population, resulting to an augmented number of bunches per unit area. This result is in line with the findings of Cortazar *et al.,* (2017) and Athani *et al.,* (2009) working on banana, that closer spacing significantly increased yield per hectare as a result of the high population per unit area, while on the other hand wider spacing significantly produced higher bunch weight. Oluwafemi (2013) and Lanza *et al*. (2017) working independently had also recorded yield increments under increased planting densities than in reduced density in studies carried out in Ado-Ekiti, Nigeria and Brazil, respectively.

Although the total yield per hectare was significantly higher with closer spacing (1.5m x 1.5m), the individual bunch weight and size of fruits significantly decreased progressively to an unacceptable size to the domestic consumers, bearing in mind that most of the plantain produced in Nigeria is consumed locally (Akinyemi *et al.,* 2010). The pulp: peel ratio of the fruit was highest and lowest with the widest and closest planting spacing respectively at both sites (Table 7), indicating that pulp content of the fruit was maximum in wider planting spacing than the closer spacing, a phenomenon that could be attributed to photosynthetic production and eventual relocation of assimilates to the fruits. Domestic demand for the bunches was highest for those of wider planting spacing 3m x 3m, 2.5m x 3m, 2m x 3m and 2m x 2.5m because of the large fruit sizes and weight and general bunch weight. Spacing 2m x 2m had a medium acceptability while 2m x 1.5m and 1.5m x 1.5m had very poor demand due to the poor nature of the fruits.

For whatever planting spacing adopted, the principal motivation is always high yield and good and acceptable quality of produce. Most of the plantains produced in Nigeria are consumed domestically and for this purpose, while aiming at high yield, bunches must be heavy with long and big fingers to be accepted by consumers (Obiefuna *et al.,* 2008; Ayanwale *et al.,* 2016). The intermediate planting spacing 2m x 3m (control treatment) and 2.5m x 3m possess the characteristics of closer spacing (high yield/ha) as well as the attributes of wider planting spacing (high bunch weight) and would therefore command the acceptance of both the domestic and in-

-dustrial consumers.

V. Conclusion

The huge advantage of closer planting spacing, which is synonymous with high population density, is the potential to increase yields significantly, which is proper as industrial input but for domestic consumption, wider spacing with heavy bunch weight is advantageous.

Early bunch shooting and minimum number of days to harvest of the crop was recorded with wider planting spacing as against long delay experienced with closer planting spacing at all sites, indicating that more crop circles could be achieved within a specified time lag with wider spacing than closer spacing.

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