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Impact of Plant density on physiological growth and yield of tomato varieties in Rain-Forest Agro-Ecological zone of Nigeria

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Abstract
Optimal plant density can be achieved by establishing appropriate distances both between and within the rows of plants.Understanding the proper planting pattern and spacing is very important to increase yield and to decrease interference with weeds. Therefore, this study determined the influence of plant density on physiological growth and yield of tomato varieties. Field trail was carried out in 2017 and 2018 to determine the appropriate densities that will give optimum tomato yield. The trial was laid in a randomize complete block design (RCBD) with a split plot arrangement and replicated three times. Tomato varieties were the main plot while plant density was the sub plots. Data collected included plant growth parameters and yield component. All data were analyzed using the analysis of variance (ANOVA) and significant means were separated by the least significant difference at 5% probability level ($LSD_{0.05}$). Ibadan local within the density of 53,333 plants/ha gave the highest yield. Significant differences among the two varieties for a number of factors confirmed their different genetic background. The growth and yield attribute were affected by the two treatments; variety and plant density. In conclusive, Ibadan local and Roma VF planted at 53,333 plants/ha is recommended for optimum production.
***Key words**: Plant density, Roma VF, Ibadan local, Yield component, Solanum lycopersicum*

Introduction

Tomato belongs to the family of solanaceae and the genus *lycopersicon* (Vander *et al.,* 2004).Tomato is a very important vegetable cultivated and consumed in most parts of the world, from home gardens and greenhouses to large commercial farms due to its wider adaptability to various agro-climatic conditions (Agyeman *et al*., 2014).Increase in tomato productivity is attained only when tomato is grown using improved varieties and agro techniques. Tomato yield could be increased substantially through improved agronomic techniques like population density (Nguyen *et al*., 2015). Plant population is a production factor which affects light interception by plant canopy (Board, 2001). Ogundare *et al*. (2015) reported the declines in plant height with reduced in plant population and the stem girth of plants that receive more light usually tend to have slower elongation rates. Tiago *et al*. (2014) reported 0.50 m spacing in tomato resulted in greater increases in both total fruit mass and normal fruit mass. Tiago *et al*. (2014) also emphasized that, plant density management influences the balance between vegetative and reproductive growth of the tomato plant, as it affects the penetration of solar radiation inside the canopy and thus photosynthesis. Increasing density causes a reduction in leaf area per plant and increased shading, while fresh fruit tomato mass decreases with increasing plant density Tiago *et al*. (2014). Roy *et al*. (2000) working on spacing of tomato in Bihar, India obtained greater yields with higher plant

population. They further found that decreases in spacing resulted in a reduction of fruit weight and number of fruits/plant, this was related to the report by Murphy *et al.*, 1996 stating that proper planting pattern and spacing is very important to increase yield and to decrease interference with weeds on competition within the corn. Optimal plant density can be achieved by establishing appropriate distances both between and within the rows of plants (Victor *et al*., 2014; Ozer, 2003). Essentially, plant density plays a crucial role as it determines the yield and yield related properties which in turn translate to economic returns. The aim of this study was to determine the plant density that will give optimum yield for tomato varieties commonly grown in south-western Nigeria.

Materials and Methods

Description of study area:

The field trial was carried out in early raining season of 2017 and 2018 at the vegetable research field of the National Horticultural Research Institute (NIHORT), Ibadan (Latitude 7° 22' N and Longitude 3° 50' Eat an altitude of 234m above sea level), Oyo state in the forest agro-ecological zone of Nigeria. The experimental site had been under continuous cultivation for many years.

Experimental design:

The plots were laid out in a randomized complete block design (RCBD) in a split-plot arrangement and replicated three times. Tomato varieties were the main plot (Roma VF and Ibadan local) while plant population was the subplot (17,777 plants/ha, 26,666 plants/ha and 53,333 plants/ha). Topsoil for the nursery was handled and sterilized by heating to 100^0C in a metal drum and was allowed to cool. The sterilized soil was filled into nursery trays after which seeds of tomato were sown. Regular watering and monitoring were carried out in the nursery. The land was ploughed and left for two weeks to allow buried weeds to decay and reploughed followed by harrowing. Tomato seedlings were transplanted at 5 weeks after sowing at different spacing of 75 cm x 75 cm, 75 cm x 50 cm and 75 cm x 25 cm giving rise to 17,777 plants/ha,26,666 plants/ha and 53,333 plants/ha respectively. The plot size was 3 m x 3 m, the alley of 0.5 m within plots and 1.0 m between replicates. Uniform fertilizer rate of 90 kg N ha^{-1}, 45 kg P_2ha^{-1} and 45 kg K_2O $ha^1$was applied in two split doses at 5 and 7 WAS (Week after Sowing) as recommend by Oyinlola and Jinadu (2012). Weeds were controlled manually, using traditional hoe at 3, 5 and 7 weeks after transplanting. Cypermethrin was applied at 0.4 L/ha was used to control insect pest at 7WAS and also 1 liter of NIHORT lyptol was mixed with 5litre of water and was applied at 6 and 9WAS to control diseases. The following data were collected from randomly sampled tagged plants per plot; plant height, number of leaves, leaf area, stem girth (cm), fruit diameter, number of fruit/plant, fruit yield (ton/ha), average fruit weight. Growth indices were estimated from the primary growth data. These indices include the leaf area index (LAI), leaf area ratio (LAR), relative growth rate (RGR), crop growth rate (CGR) and unit leaf rate or net assimilation rate (NAR). These were estimated using the classical equations as presented by Hunt (1978).

Statistical Analysis

All data collected were subjected to the analysis of variance (ANOVA) using Gen-Stat Discovery Edition 4 (2013). Significant means were separated using the least significant difference (LSD) at five percent level of probability ($p \leq 0.05$).

Results

Experimental soil

The results of soil analysis showed that the textural class of the soil of the experimental site is sandy loamy. The pH of the experimental soil ranged between 5.90 to 5.30 in 2017 and 2018 as presented in Table 1.The result during the early cropping season showed that there were significant varietal differences in term of plant height of the two tomato varieties used in 2017 and 2018 respectively.

Main effect on Plant Height

Roma VF had highest plant height of 35.90 and 33.83cm which was significantly higher than Ibadan local that gave 32.27and 31.16cm as shown in Table2. Plant density had significant influenced on the plant height (Table 2).Plot with 53,333 plants/ha had significantly higher plant height of 37.59 and 36.55cm in 2017 and 2018 respectively (Table 2).

Main effect on Number of Leaves

The number of leaves of tomato evaluated had no significantly effect on the tomato varieties. Roma VF and Ibadan local had the same value in 2017 while Ibadan local gave significantly higher number of leaf in 2018(Table2). Tomato transplanted at 26,666 plants/ha had significantly higher number of leaves in both years. Plots with 26,666 plants/ha had the highest number of leaf in 2017 and 2018 respectively (Table2).

Main effect on Leaf area

Leaf area of tomato variety was significantly different among the two varieties (Table2). Roma VF had significantly higher leaf area (12.2cm^2) than Ibadan local in 2017 while planting in the year 2018; Ibadan local gave significantly higher leaf area (17.84cm^2) than Roma VF. Plant density was significantly affected by the leaf area. Tomato transplanted at 17,777 plants/ha gave significantly higher leaf area of 13.89cm^{2}in 2017 while tomato transplanted at 26,666 plants/ha gave significantly higher leaf area of 17.73cm^2(Table 2).

Main effect on Stem girth

The result showed no significant varietal difference on the stem girth of the tomato varieties. Roma VF had the highest stem girth of 2.83cm although not significantly different from stem girth obtained from Ibadan local in 2017 while Ibadan local gave significantly higher stem girth of 3.23cm in 2018. Plant density (PD) had no significant effect on stem girth in 2017 while in 2018 was significantly different. The highest stem girth (2.89cm) was obtained from tomato transplanted at 17,777plants/ha in 2017 while significantly higher stem girth of 3.24cm was gotten from 26,666 plants/ha in 2018 (Table 2).

Interactive effect on plant height

Interaction of varietal x plant density had significant effect on plant height in 2018 although no significantly differ in 2017. Roma VF planted at 53,333 plants/ha gave the tallest plant (39.44 and 38.86cm) in 2017 and 2018 respectively (Table3). Roma VF within the higher plant density that recorded the tallest plant.

Interactive effect on number of leaves and leaf area

Roma VF transplanted at 26,666 plants/ha gave significantly higher number of leaves (22.36 and 28.98) than other treatment obtained in 2017 and 2018 respectively. In contrary, Roma VF planted at 17,777 plants/ha gave significantly higher leaf area in 2017 while Ibadan local planted at 26,666 plants/ha gave significantly higher leaf area in 2018.

Interactive effect on stem girth

Ibadan local transplanted at 17,777 plants/ha had significantly higher stem girth of 3.04cm in 2017 while Ibadan local planted at 26,666 plants/ha gave significantly higher stem girth (3.49cm) in 2018(Table3). The significant higher stem girth gotten at 17, 777 plants/ha and 26,666 plants/ha could be probably because of spacing between the plants.

Main effect on yield component

There was significant varietal effect on the entire yield component except average fruit weight which had no significant effect between the varieties at both years. Ibadan local gave significantly higher yield component although average fruit weight obtained was not significantly different from that of Roma VF in 2017and 2018 respectively. In 2017, number of fruit/plants increases at the population of 26,666 and 53,333 plants/ha although not significantly different among all the plant population observed while significantly higher number of fruit/plants was gotten from 26,666plants/ha in 2018. Average fruit weight increases at the increase in plant population per ha in both years. Tomato transplanted at 53,333 plants/ha gave significantly higher average fruit weight compared to tomato transplanted at 26,666 plants/ha while tomato transplanted at 17,777 plants/ha gave significantly lower average fruit weight in 2017 and 2018 respectively. Similarly, significant higher yield was obtained from tomato transplanted at 53,333 plants/ha while tomato transplanted at the population of 17,777 plants/ha gave significantly lower yield (Table 4). The significant increase in fruit weight and fruit yield at 53,333 plants/ha could be associated with highest number of plant which produced more fruit in 2017 and 2018 respectively.

Interactive effect on yield component

There were significant differences observed among the interaction of varieties x plant density in the entire yield component (Table5). The significant higher number of fruit/plant was obtained from Ibadan local within the plant density of 26,666 plants/ha in both years while average fruit weight and fruit yield was significantly higher when Ibadan local was transplanted at 53,333 plants/ha in 2017 and 2018 respectively (Table5).

Table 1: Physical and chemical properties of pre- cropping soil of experimental sites

Soil properties	2017	2018
pH	5.90	5.30
Organic carbon(g/kg)	4.51	3.45
Total Nitrogen(g/kg)	0.65	0.50
Available phosphorus(mg/kg)	8.85	4.60
Exchangeable cation (cmol/kg)		
Na^{2+}	0.22	0.37
Ca^{2+}	0.25	0.24
Mg^{2+}	2.78	3.32
K^{2+}	0.56	0.63
Exchangeable acid	0.26	0.25
Effective cation exchangeable capacity	4.07	4.81
Particle size distribution (g/kg)		
Sand	878	865
Silt	12	11
Clay	110	124
Textural class	Sandy loamy	Sandy loamy

Table 2: Main effects of transplanting age and plant density on growth parameter of tomato varieties

	2017				**2018**			
					10WAS			
Treatment	**Plant height (cm)**	**Number of leaf**	**Leaf area (cm^2)**	**Stem girth (cm)**	**Plant height (cm)**	**Number of leaf**	**Leaf area (cm^2)**	**Stem girth (cm)**
Variety (V)								
Roma VF	35.9	16	12.20	2.83	33.83	24	15.49	2.88
Ibadan local	32.27	16	9.75	2.82	31.16	25	17.84	3.23
$L.S.D._{0.05}$	2.35	NS	1.27	NS	0.53	0.79	0.11	0.01
Plant density(P)								
17,777 plants/ha	30.15	16	13.89	2.89	28.38	25	16.85	3.08
26,666 plants/ha	34.51	20	8.99	2.83	32.55	27	17.73	3.24
53,333 plants/ha	37.59	13	10.05	2.76	36.55	22	15.42	2.85
$L.S.D._{0.05}$	1.48	1.27	0.83	NS	0.45	0.31	0.14	0.01

V X P	NS	*	*	NS	*	*	*	*	

LSD.$_{0.05}$: Least Significant Difference at 5% probability, NS: Not Significant, Significant: *, WAS: weeks after sowing

Table 3: Interactive effects of tomato varieties and plant density on growth parameter

		2017				2018			
					10WAS				
Variety	**Plant density (Plants/ha)**	**Plant height (cm)**	**Number of leaf**	**Leaf area (cm^2)**	**Stem girth (cm)**	**Plant height (cm)**	**Number of leaf**	**Leaf area (cm^2)**	**Stem girth (cm)**
Roma VF	17,777	32.71	11.68	18.71	2.74	28.65	23.57	16.18	2.81
	26,666	35.57	22.36	9.82	2.89	33.99	28.98	16.26	2.98
	53,333	39.44	13.14	8.06	2.87	38.86	19.74	14.02	2.83
Ibadan local	17,777	27.60	20.03	9.06	3.04	28.11	25.67	17.52	3.34
	26,666	33.45	16.77	8.17	2.77	31.12	24.65	19.20	3.49
	53,333	35.75	12.02	12.03	2.65	34.24	24.94	16.81	2.86
L.S.D.$_{0.05}$		2.11	2.72	1.17	0.45	0.58	0.60	0.17	0.01
Sig.		NS	**	**	NS	**	**	**	**

LSD.$_{0.05}$: Least Significant Difference at 5% probability, NS.: Not Significant, Significant: ** , WAS: weeks after sowing

Table 4: Main effects of transplanting age and plant density on yield component of tomato varieties

	2017			2018		
Treatment	Number of fruit/plant	Average fruit weight	Fruit yield (ton/ha)	Number of fruit/plant	Average fruit weight	Fruit yield (ton/ha)
Variety (V)						
Roma VF	2.41	55.2	4.7	2.56	125.2	8.76
Ibadan local	3.93	66.7	9.78	2.93	129.5	11.59
L.S.D.$_{0.05}$	1.28	NS	1.91	0.16	NS	0.79
Plant density(P)						
17,777 plants/ha	2.94	52.4	2.84	2.67	110.5	5.05
26,666 plants/ha	3.28	58.6	5.58	3.00	126	8.14
53,333 plants/ha	3.28	71.8	13.3	2.56	145.4	17.34
L.S.D.$_{0.05}$	NS	8.65	1.09	0.30	18.51	1.01
V X P	**	**	**	*	*	*

Table 5: Interactive effects of transplanting age and plant density on yield component of tomato varieties

		2017			2018		
Variety	**Plant density (Plants/ha)**	Number of fruit/plant	Average fruit weight	Fruit yield (ton/ha)	Number of fruit/plant	Average fruit weight	Fruit yield (ton/ha)
RomaVF							
	17,777	2.67	61.2	2.87	2.56	125.2	5.5
	26,666	2	45.9	2.83	2.22	150.5	6.14
	53,333	2.56	58.6	8.39	2.89	99.8	14.64
Ibadan local	17,777	3.22	43.7	2.80	2.78	95.9	4.59
	26,666	4.56	71.4	8.33	3.78	101.6	10.13
	53,333	4	85	18.21	2.22	191	20.04
L.S.D.$_{0.05}$		0.98	33	1.63	0.35	24.69	1.22
Sig.		**	**	**	**	**	**

Discussion

The pH of the experimental soil ranged between 5.90 to 5.30 in 2017 and 2018. Tomato plants require nutrients for growth and development, including nitrogen, phosphorus, and potassium, but plant growth and production will vary depending on soil pH. Tomato transplanted at 26,666 plants/ha had significantly higher number of leaves in both years. Plots with 26,666 plants/ha had the highest number of leaf (20 and 27) in 2017 and 2018 respectively. Roma VF within the higher

plant density that recorded the tallest plant may be due to Roma VF that exhibits wild survival tendency to grow fast (Nasto *et al*., 2009) at higher plant density (53,333 plants/ha) which they compete for light and air (Seid *et al*., 2013).The result of the study for this character in stem girth was in agreement with the findings of Monirul *et al*., (2011) in sweet pepper, which expressed gradual decreased with decreasing plant spacing. Stem girth determines the dimensional attainment of a plant during the growing period. Ibadan local being a desirable trait commonly grown in south western Nigeria as described by Olosunde *et al*., (2018), could be due to the desirable trait in Ibadan local variety with good performance. This agreed with the report of Adebooye *et al.,* (2006) that gave the highest fruit diameter and fruit yield in Ibadan local. Shobo *et al*., (2016) also gave similar report on significant increase on yield component of tomato.
This result is in agreement with Nasto *et al*., (2009) who reported progressive increase in the number of fruits plant, fruit yield/ ha in pepper as planting density increases.

Conclusion

Base on general observation and the result of this study, significant differences among the two varieties for a number of factors confirmed their different genetic background. The growth and yield attribute were affected by the two treatments; variety and plant density. In conclusion, Ibadan local and Roma VF planted at the density of 53,333 plants/ha is recommended for optimum yield for tomato varieties commonly grown in south-western Nigeria.

The study discovered 53,333 plants/ha can be beneficial for farmers' cultivation in the study area. This study will help the researcher to uncover the critical areas of plant density in tomato cultivation that many researchers were not able to explore. Thus, a new theory on plant density among the tomato varieties, and possibly other combinations, may be arrived at.

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