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The effect of plant density on growth and yield of 'NsukkaYellow' aromatic pepper (*Capsicum annuum* L.)

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Nsukka yellow pepper is an important aromatic pepper that is highly valued for heat, spice and flavour in Eastern Nigeria. The study was initiated to investigate the effects of different plant population densities on the morphological and fruiting characteristics of Nsukka yellow pepper cultivar. Eight treatment combinations giving rise to different population densities were used. The data on the number of leaves, number of branches, canopy diameter, plant height, number of fruits and fruit weight were collected at different days after planting (DAP) covering the periods of growth, flowering and fruiting. The results of the study showed that the different morphological parameters in addition to the number of fruits and fruit weight were significantly affected by plant population densities. The number of leaves was highest in T1 at 129 DAP and least in T2 at 66 DAP. The number of branches ranged from 0.27 to 3.47 and 55.1 to 97.9 at 66 and 129 DAP, respectively. The canopy diameter ranged from 9.24 to 19.82 cm recorded at 66 DAP and 41.18 to 73.66 cm recorded at 129 DAP, while the least plant height (6.33 cm) was recorded in T7 and the highest (56.01 cm) in T1 at 66 and 129 DAP, respectively. The highest fruit number and fruit weight per plant were obtained at plant densities of 20689.66 plants/ha (T1) and 31034.48/ha (T3) under plant spacing of 75 × 60 and 45 × 60 cm, respectively. The highest weight of fruits per hectare was obtained at the highest population density of 77586.21 plants/ha (T8). Farmers aiming at the selling point of single fruits are encouraged to use low population densities which is achieved by higher plant spacing but cumulative yield per hectare was higher at high population density under low plant spacing.

Key words: Aroma, Nsukka, pepper, plant spacing, population density, spice.

INTRODUCTION

Indigenous vegetable production is an important component of the subsistence farming system generally practiced in West Africa (Maga et al., 2012). In Nigeria, pepper is regarded as the third in importance among the cultivated vegetable crops after onions and tomatoes (Uzo, 1984; Ado, 1998; Romain, 2001). It plays a vital role in the nutritional balance of the rural and urban dwellers by supplying vitamins and minerals in their diets (Leung et al., 1968; Uguru, 1999). The varieties of pepper produced in Nigeria include Bird peppers-atawere

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(*Capsicum frutescens*), Cayenne pepper or red pepper-sombo (*C. frutescens*), Atarado (*Capsicum annuum*), Tatase (*C. annuum*) and also Nsukka yellow pepper (*C. annuum*) (Olufolaji and Denton, 2000; Adetula and Olakojo, 2006).

Nsukka yellow pepper, a variety of *C. annuum*, is a popular crop, and is considered among the principal vegetable crops grown in the derived savannah agro-ecology for its fruits which are characterized by unique aroma, hotness due to the capsaicin content, nutritional values, adaptability to the existing cropping systems and potentials for wealth creation (Nwankiti, 1981; Uguru, 2000; Abu and Uguru, 2005). Asogwa (2006) noted that the distinctive aroma of Nsukka yellow pepper enhances its acceptability in the market. Consequently, it attracts higher price than other pepper types in the local and urban markets. Similarly, Ajayi and Eneje (1998) reported that the distinctive aroma of the cultivar makes it very much cherished in the diets of several homes and eateries. Nsukka yellow pepper is not widely cultivated in most states in the country, this may be because of its tendency to lose its pungency, aroma and colouring in other areas (Uguru, 1999). Nsukka agricultural zone is generally considered to be the home of Nsukka yellow pepper (maga et al., 2012). For many years, the inhabitants of Nsukka agricultural zone have been engaged in the cultivation of Nsukka yellow pepper (*C. annuum* L.) for its fruits which are characterized by unique aroma and yellow colour. It is peculiar to Nsukka hence it is called 'Nsukka Yellow Pepper'. Although, it is also cultivated in some parts of Kogi State which is also in derived ecological zone as Nsukka.

Ekwu and Okporie (2002) suggested that the best spacing for the plant is 30 × 60 cm while 150 kgN/ha was sufficient for the growth of Nsukka yellow pepper in Abakiliki. Meanwhile, Aliyu et al. (1990) and Indalsingh and Antomie (2006) reported that reducing the intra-row spacing of two pepper varieties from 50 to 40 cm significantly decreased plant height, number of fruits and diameter of fruits, while total fruits yield per hectare was conversely increased. Continuous flowering starts 60 to 90 days after sowing. Flowers open three hours after sunrise and are open for 1 to 3 days. In the bud stage, the stigma is receptive, but the pollen is not yet mature; under normal circumstances 40 to 50% of the flowers set fruits. Fruits begin to mature 4 to 5 weeks after flowering. The peak harvest period is 4 to 7 months after sowing (Govindarajan, 1985). Flowering is a vital physiological process in crop existence and assurance for reproduction (Marcelis et al., 2005). Time of flowering is particularly of great importance in annual crops, because it is a component of the adaptation of a cultivar to an environment. It also determines fruit set and crop yield (Ishiyaku et al., 2005; Ferrara et al., 2011). Plant growth and development, especially flowering, is dependent on the interaction of many complex processes which are influenced by both genetic and environmental factors (Uarrota, 2010).

Nsukka yellow aromatic pepper is grown widely in derived savannah agro-ecology for its cherished aroma and as a major cash crop, especially among women farmers. The aim of this study was to assess the effect of plant population densities on the morphological and fruiting attributes of Nsukka yellow pepper (*C. annuum*) cultivar.

MATERIALS AND METHODS

The experiment was conducted in the new botanical garden, Department of Plant Science and Biotechnology, University of Nigeria, Nsukka. The dry seeds of Nsukka yellow pepper were raised in nursery baskets in the old botanical garden in a cured nursery mixture of 3:2:1 top soil, poultry manure and river sand, respectively. The seedlings were transplanted to the field after four weeks. A field experiment, laid out in randomized complete block design (RCBD) of three replications was used to determine the effect of pepper plant population densities on the growth and fruit characteristics of Nsukka yellow pepper genotype. The plot size was 2 × 2.9 m (5.8 m^2).

Eight population densities of pepper were tested and the inter and intra row spacing are as shown on Table 1. Plates 1 and 2 show Nsukka yellow pepper plants at 77586.21 (T8) and 31034.48 (T3) plants/ha population densities. The study was done under rain-fed conditions and poultry manure was applied broadcast at 34.48 t/ha. The manure was manually hoed in and allowed to decompose for five days before transplanting. The seedlings were transplanted to the field at appropriate spacings.

Data were collected on the following parameters by numerical count, number of leaves, number of branches and number of fruits per plant. Others as canopy diameter and plant height were by metrical measurement, while fruit weight was by the use of weighing balance. All the quantitative data collected were subjected to multivariate analysis of variance following the procedure outlined for RCBD format in Obi (2002). The means were separated using least significance difference (LSD) at P ≤ 0.05 only when the F-value is significant.

RESULTS

The results of the number of leaves showed significant differences among treatments at different days after planting (DAP). At early growth stages of 66 and 73 DAP, T5 and T6 had significantly the highest number of leaves, however, at 80 DAP, T6 had the highest number of leaves which did not differ significantly from that of T5. At full fruiting stage (129 DAP), the widest spaced plant (T1) with low plant density had significantly the highest number of leaves of 789.3 per plant. This was followed by T2 which had a value of 722.6 per plant (Table 2).

T6 had significantly the highest number of branches per plant at 66, 73 and 101 DAP. Number of branches per plant at 129 DAP ranged from 52.2 to 107.7 in different population densities. At fruiting stage (129 DAP), the lower plant densities with wider spacing (T1) had the highest number of branches (Table 3).

The canopy diameter, measured in centimetres, across different plant densities ranged from 9.24 to 19.82, 14.61

Table 1. Plant spacing and population densities per plot and per hectare, respectively.

Treatment	Plant spacing (cm)	Plant population density/plot (5.8 m^2)	Plant population density/ha (10,000 m^2)
T1	75 × 60	12	20689.66
T2	55 × 60	15	25862.07
T3	45 × 60	18	31034.48
T4	35 × 60	21	36206.9
T5	55 × 30	25	43103.45
T6	45 × 30	30	51724.14
T7	35 × 30	35	60344.83
T8	15 × 60	45	77586.21

Plate 1. Nsukka yellow pepper at 77586.21 plants/ha (15 × 60 cm spacing) at fruiting (green stage).

Plate 2. Nsukka yellow pepper at 31034 plants/ha (45 × 60 cm spacing) at fruiting (green stage).

Table 2. Effect of different plant population densities on number of leaves per plant (NL/P) at different days after planting (DAP).

Plant population	NL/P at 66 DAP	NL/P at 73 DAP	NL/P at 80 DAP	NL/P at 101 DAP	NL/P at 129 DAP
T1	7.87^{cd} ± 0.62	16.20^{c} ± 1.48	36.06^{bc} ± 2.52	194.9^{c} ± 3.25	789.3^{a} ± 26.3
T2	5.60^{d} ± 0.49	11.87^{c} ± 1.11	29.73^{dc} ± 3.42	187.1^{d} ± 9.16	722.6^{c} ± 9.29
T3	8.47^{c} ± 0.60	15.60^{c} ± 1.23	32.93^{bc} ± 2.11	168.4^{cd} ± 3.81	674.1^{c} ± 10.4
T4	6.27^{cd} ± 0.65	11.87^{c} ± 1.51	23.13^{d} ± 3.196	151.2^{e} ± 2.51	493.9^{e} ± 17.1
T5	22.80^{a} ± 1.25	36.40^{a} ± 1.77	52.40^{a} ± 3.22	274.1^{a} ± 12.35	515.9^{d} ± 14.8
T6	20.73^{a} ± 0.93	34.20^{a} ± 1.37	57.27^{a} ± 2.82	272.6^{b} ±12.38	592.3^{d} ± 23.2
T7	18.73^{b} ± 0.56	27.60^{b} ± 1.27	39.87^{b} ± 1.95	227.0^{c} ± 12.84	393.0^{f} ± 14.8
T8	8.47^{c} ± 0.99	14.67^{c} ± 1.85	28.33^{dc} ± 3.52	122.2^{e} ± 6.998	338.8^{g} ± 9.97
F-LSD (P=0.05)	2.33	4.12	8.18	30.82	79.81

Values are mean ± SE.

Table 3. Effect of different plant population densities on number of branches per plant (NB/P) at different days after planting.

Plant population	NB/P at 66 DAP	NB/P at 73 DAP	NB/P at 80 DAP	NB/P at 101 DAP	NB/P at 129 DAP
T1	0.87^{c} ± 0.22	2.27^{c} ± 0.37	4.53^{c} ± 0.496	30.00^{bc} ± 1.82	97.9^{a} ± 5.13
T2	0.40^{c} ± 0.16	1.67^{c} ± 0.37	3.93^{cd} ± 0.54	26.87^{d} ± 1.33	92.5^{a} ± 3.30
T3	0.80^{c} ± 0.2	2.07^{c} ± 0.27	3.80^{cd} ± 0.42	22.73^{d} ± 1.04	84.5^{c} ± 3.54
T4	0.27^{c} ± 0.12	1.20^{c} ± 0.31	2.67^{d} ± 0.53	28.60^{cd} ± 2.89	73.0^{d} ± 5.93
T5	2.20^{b} ± 0.2	5.40^{b} ± 0.39	10.47^{b} ± 0.49	34.87^{b} ± 1.6	55.1^{d} ± 3.62
T6	3.47^{a} ± 0.4	8.13^{a} ± 0.496	13.67^{a} ± 0.80	40.33^{a} ± 2.13	66.3^{d} ± 4.42
T7	2.47^{b} ± 0.26	4.67^{b} ± 0.41	9.87^{b} ± 0.43	35.20^{ab} ± 1.31	57.2^{d} ± 3.67
T8	1.00^{c} ± 0.26	1.80^{c} ± 0.38	3.20^{c} ± 0.61	21.00^{d} ± 2.31	63.4^{d} ± 3.15
F-LSD (P=0.05)	0.69	1.06	1.54	5.59	12.46

Values are mean ± SE.

Table 4. Effect of different plant population densities on canopy diameter (CD) (cm) at different days after planting.

Plant population densities	CD at 66 DAP	CD at 73 DAP	CD at 80 DAP	CD at 101 DAP	CD at 129 DAP
T1	11.90^{cd} ± 0.56	17.36^{c} ± 0.63	23.61^{cd} ± 0.797	44.08^{ab} ± 1.09	73.66^{a} ± 1.24
T2	9.24^{f} ±0.81	14.61^{d} ± 1.00	20.68^{de} ± 1.24	46.85^{bc} ± 1.55	68.01^{b} ± 1.50
T3	11.36^{cde} ± 0.53	16.89^{cd} ± 0.53	22.52^{cde} ± 0.798	43.60^{ab} ± 0.75	67.34^{b} ± 1.54
T4	9.77^{ef} ± 0.98	15.29^{cd} ± 1.297	20.06^{e} ± 1.32	40.52^{d} ± 1.61	52.19^{d} ± 0.98
T5	17.40^{b} ± 0.48	23.23^{b} ± 0.42	30.52^{b} ± 0.83	42.85^{ab} ± 1.21	53.24^{d} ±1.64
T6	19.82^{a} ± 0.53	27.07^{a} ± 0.62	38.41^{a} ± 1.46	47.34^{a} ± 1.39	59.13^{c} ± 1.34
T7	16.76^{b} ± 0.46	22.30^{b} ± 0.50	28.60^{b} ± 0.79	42.13^{c} ± 0.83	52.74^{d} ± 1.08
T8	10.21^{ef} ±0.85	15.52^{de} ± 1.14	20.19^{e} ± 1.11	30.13^{e} ± 1.14	41.18^{e} ± 1.01
F-LSD (P=0.05)	1.82	2.38	2.94	4.16	4.98

Values are mean ± SE.

to 27.07, 20.19 to 38.41, 30.13 to 47.34 and 41.18 to 73.66 at 66, 73, 80, 101, and 129 DAP, respectively (Table 4). T6 had significantly the widest canopy diameter (19.82 cm) at the peak of vegetative growth (63 DAP) and also 27.07, 38.41 and 47.34 cm at 73, 80 and 101 DAP, respectively. At 129 DAP, full fruiting stage, the plant population of 12 plants/plot (T1) had the highest canopy diameter of 73.66 cm (Table 4).

The results of plant height at different growth stages of Nsukka yellow pepper showed variations at different plant spacing. Plant height ranged from 6.33 to 9.2 cm at 66 DAP. Plant density treatment (T6) had significantly the highest value for plant height at 73, 80 and 101 DAP. At 129 DAP which is the peak of fruiting T1, had the tallest plant which measured 56.01 cm (Table 5).

The number of fruits/plant showed significant variation across the treatments (Figure 1). The range of values was 39.3 to 136 fruits/plant in the different plant densities.

Table 5. Effect of different plant population densities on plant height (PH) (cm) at different days after planting.

Plant population densities	PH at 66 DAP	PH at 73 DAP	PH at 80 DAP	PH at 101 DAP	PH at 129 DAP
T1	$9.29^{a} \pm 0.39$	$11.89^{ab} \pm 0.395$	$14.99^{b} \pm 0.61$	$29.75^{d} \pm 0.53$	$56.01^{a} \pm 1.22$
T2	$7.07^{de} \pm 0.41$	$9.01^{e} \pm 0.499$	$12.09^{cd} \pm 0.66$	$21.85^{f} \pm 1.36$	$48.55^{c} \pm 0.96$
T3	$8.91^{ab} \pm 0.41$	$11.24^{abc} \pm 0.43$	$14.47^{b} \pm 0.45$	$27.16^{e} \pm 0.76$	$46.23^{c} \pm 0.87$
T4	$7.48^{cde} \pm 0.499$	$9.60^{de} \pm 0.67$	$11.63^{d} \pm 0.95$	$24.61^{f} \pm 1.55$	$42.06^{d} \pm 1.23$
T5	$6.35^{e} \pm 0.17$	$10.59^{bcd} \pm 0.30$	$18.49^{a} \pm 0.56$	$33.69^{b} \pm 0.88$	$44.91^{c} \pm 1.08$
T6	$7.99^{bcd} \pm 0.189$	$12.20^{a} \pm 0.21$	$17.33^{a} \pm 0.33$	$42.29^{a} \pm 1.01$	$50.55^{b} \pm 1.76$
T7	$6.33^{e} \pm 0.197$	$10.40^{bcd} \pm 0.35$	$13.75^{b} \pm 0.52$	$31.69^{de} \pm 0.93$	$39.42^{d} \pm 0.897$
T8	$8.65^{abc} \pm 0.74$	$10.78^{abcd} \pm 0.85$	$13.74^{bc} \pm 1.09$	$19.65^{f} \pm 0.75$	$37.73^{d} \pm 0.93$
F-LSD (P=0.05)	1.13	1.33	1.85	4.08	4.68

Values are mean ± SE.

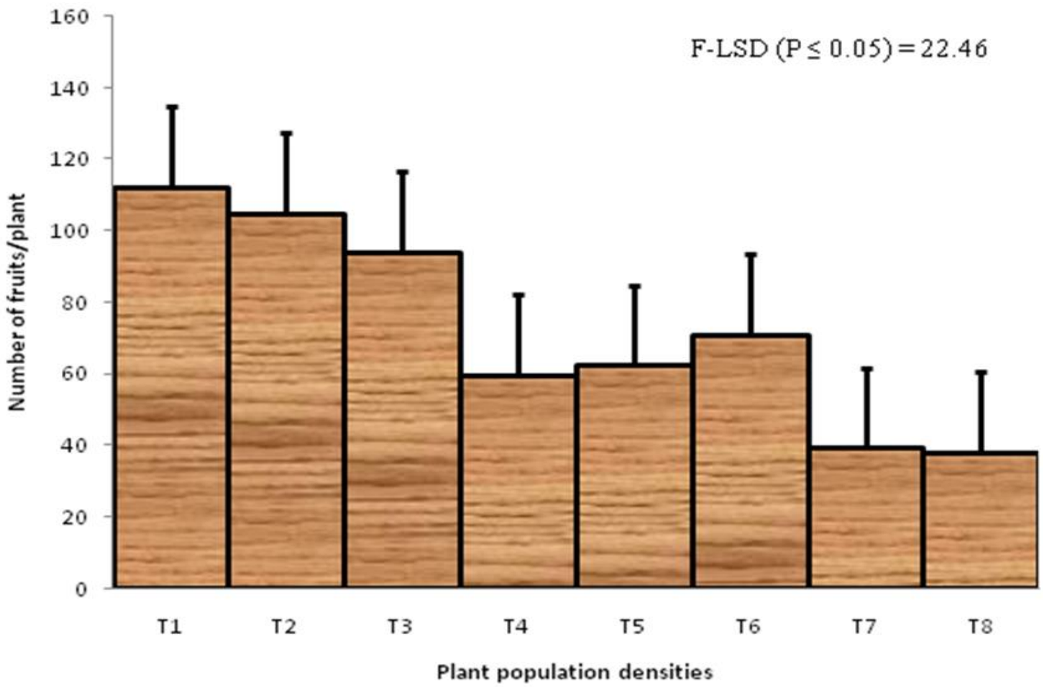

Figure 1. Effect of plant population density on number of fruits per plant.

The lowest plant population densities (T1) had the highest number of fruits/plant after three harvests. T1, T2 and T3 did not differ significantly in their number of fruits per plant. The least number of fruits per plant (39.3 and 38.1 fruits) was observed in T7 and T8, respectively, which did not vary significantly from each other.

The weight of fruits per plant was found to be highest in T3 population density. Fruits weight/plant was higher at low population densities (Figure 2). The three lowest population densities T1 to T3 had significantly the highest number of fruits per plant. The same treatments had significantly the highest values in fruit weight per plant. In considering the weight of fruit per plot, the higher plant population densities had more weight than those with low population (Figure 3). Equally, the estimated fruit weight in tonnes per hectare based on plant density of 77586.21 in 15 × 60 cm gave the highest fruit weight of 5.78 T/ha (Figure 4).

DISCUSSION

Pepper plants in this study behaved differently in the growth and fruiting attributes based on the plant densities. Plant population has been considered a major factor that determines the degree of competition between plants based on the observations on maize (Abuzar et al., 2011). So the observed variations in the growth and yield

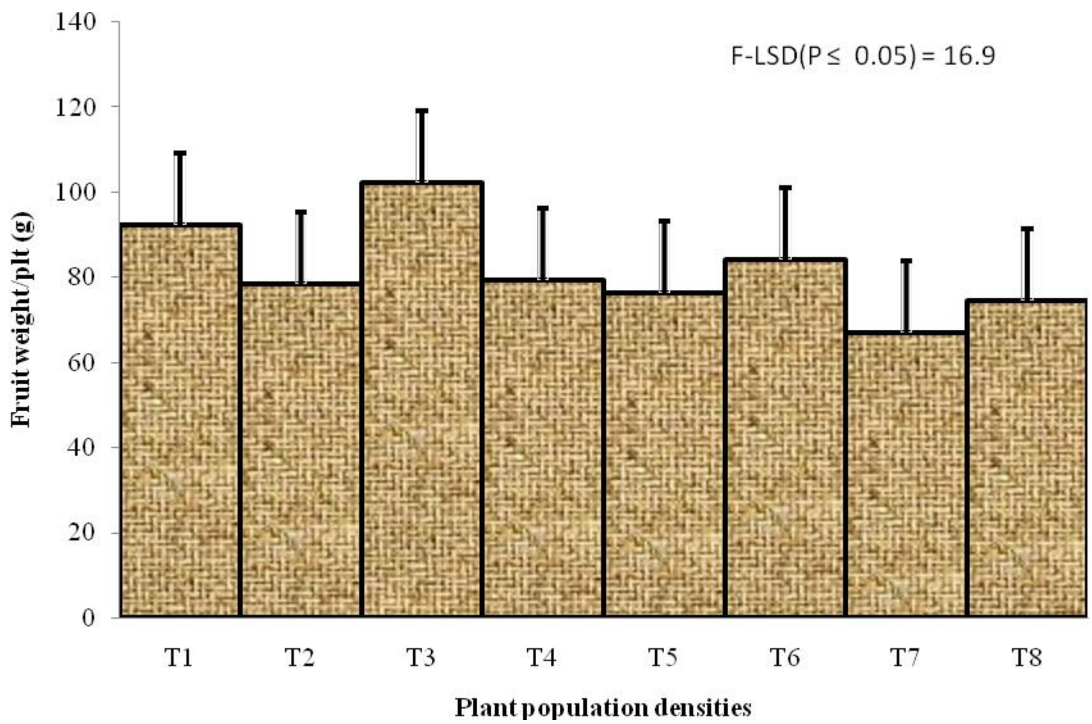

Figure 2. Effect of plant population density on fruit weight per plant.

characteristics of *C. annuum* L. var. Nsukka yellow could be attributed to the agronomic practice adopted which in this case are the plant population densities in the different plots. Nasto et al. (2009) also noted that modern vegetable production practices emphasize the need to use optimum plant population attained with appropriate spacing and plant arrangements. Adequate plant spacing could help farmers in maximizing yield (Ahmed, 1981; Stofella and Bryan, 1988; Adams et al., 2001).

The observed large canopy diameter (CD) in low population density could be an indication of numerous branches and leaves. It is a pointer that the wider the spacing, the higher the canopy diameter. This could equally be translated to higher yield if plant population is adequate. Plants with larger canopy diameter may also be pertinent in the metabolic activities of the plant by providing numerous leaves for photosynthetic activity as also was suggested by Aluko et al. (2014). It was observed that higher plant densities had lower number of leaves, branches and less canopy diameter, which was similar to the reports of Johnson and William (1997) and Islam et al. (2011). This may be due to competition among plants. Plants under high population compete for space, assimilates and sunshine. At the fruiting stage, plants with lower population densities were still more vigorous than those of higher population densities which may be, due to availability of space, assimilates and other micro-environmental components like air movements. It should also be noted that poultry manure was applied broad cast on equal measures per plot according to the suggestion by Echezona and Nganwuchu (2006). Therefore, plants with lower densities had more available nutrients which invariably were translated to higher vigor.

Higher number of leaves/plant is an indication of higher photosynthetic efficiency since the leaves are the major sites of photosynthesis in green plants. Therefore, it is expected that the high number of leaves/plant recorded at T1 will enhance high assimilate production which will promote growth, development and yield in that population. Number of leaves/plant increased as plant densities/hectare decreased from 77586.21 to 20689.66, similar to the observations of Aliyu et al. (1990).

The tallest and most profusely branched plants and those with the highest number of leaves were recorded in 75 × 60 cm plant spacing with 20689.66 plant density per hectare. This may be attributed to wider spacing between plants. Plant height increased as plant spacing increased from 15 × 60 cm to 75 × 60 cm. This was also reported by Nagdy et al. (1979) who observed that varying plant spacing and rates of nitrogen application increased plant height, number of branches and leaves on pepper plants. Increase in plant height may enhance the emergence of more branches, leaves and consequently increase the canopy diameter; it equally, could contribute in exposing the plants to higher sun intensity. The fruit weight per plant was highest at wider spacing with low plant population. This may suggest that there were less

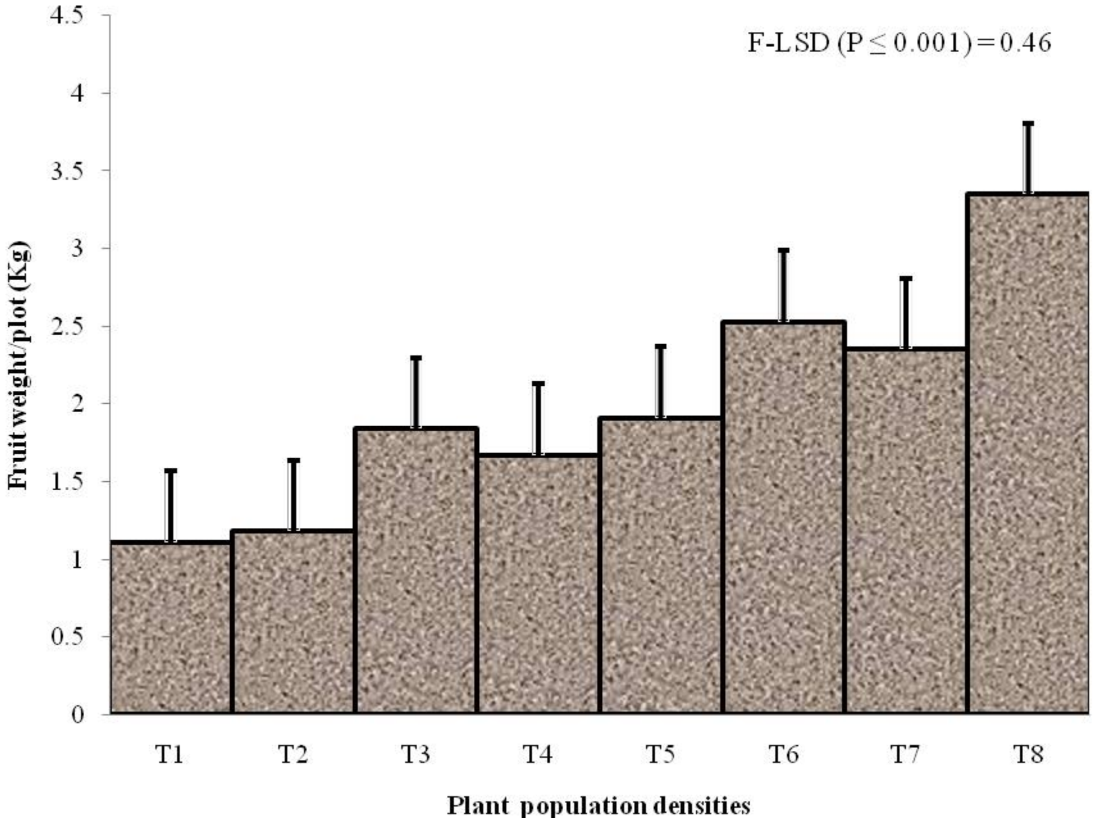

Figure 3. Effect of plant population density per plot on fruit weight.

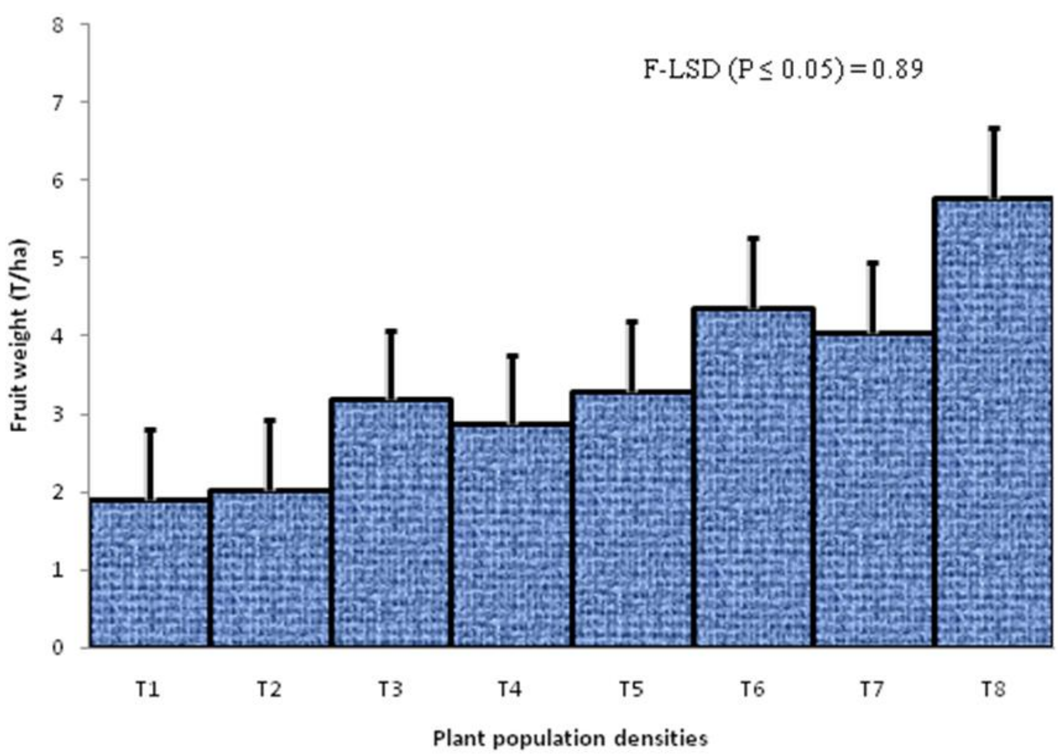

Figure 4. Effect of plant population density per hecter on fruit weight.

competition for nutrient and space among plants. Similar observation was made among Okra cultivars by Ekwu and Nwokwu (2012). Even though plants in low population densities, had higher values in most vegetative characters, which had been reported to have higher correlation with number of fruits and fruit yield (Abu et al., 2013), their cumulative yield were low based on lower plant population. The higher population densities due to competition for space and assimilate could not produce fruits as those with low population in both number and weight on single plant stand basis but on cumulative basis higher populations produced more number of fruits. This result contradicts the report on Okra, where widest plant spacing consistently gave least values in all vegetative parameters (Amjad et al., 2001). Number of fruits/plant and fruit weight per plant were more at the widest spacing. This also agrees with the reports of Ekwu and Nwokwu (2012).

Russo (2003), Nasto et al. (2009) and Khasmakhi-Sabet et al. (2009) had observed that the highest fruit yield of pepper was obtained when grown at the higher population densities. Therefore, the result is of interest to the farmer because it could be deceptive making conclusions based on fruit weight per plant which was recorded in wider spacing of 45 × 60 cm and plant population of 31034.48 per hectare. The spacing that gave the highest plant population per hectare equally had the highest fruit weight per hectare.

In conclusion, higher plant population density of 77586 plants per hectare (15 × 60 cm) gave the highest yield and within the scope of this work could be recommended for the cultivation of Nsukka yellow pepper. Higher population is of advantage to the farmer since the fruits of Nsukka yellow pepper are not sold based on single fruit weight basis but on fruit weight per basket in both local and urban markets. This could also translate to higher income for the farmer.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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