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Effect of planting density on growth, development and yield of Tomato (*Solanum lycopersicum* L.)

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Abstract

A field experiment was carried out to investigate the influence of planting density on the growth, development, and yield of tomatoes during the Rabi season 2019-2020. Plant height, number of primary branches, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, individual fruit weight, fruit yield per plant, total yield, marketable yield, and unmarketable yield were recorded. Results showed that maximum plant height and unmarketable yield were recorded at 40,000 plants ha^{-1}. However, number of primary branches, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, individual fruit weight, and fruit yield per plant were higher at 25,000 plants ha^{-1}. Moreover, the maximum total yield and marketable yield were recorded at 28,571 plants ha^{-1} and the minimum at 40,000 plants ha^{-1}. Therefore, our present study recommended cultivating tomato crops at 28,571 plants ha^{-1} to obtain a higher yield.

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Introduction

Tomato (*Solanum lycopersicum* L.) belongs to Solanaceae family is an economically important vegetable widely grown for human consumption because of its diverse nutrient compounds *i.e.*, ascorbic acid, β-carotene, niacin, riboflavin, thiamine, and phenolic compounds as well as some minerals like potassium, magnesium, iron, phosphorus, and sodium (Alam *et al.*, 2019; Huda *et al.*, 2020; Hossain *et al.*, 2019). Tomato is not only consumed as salad or curry but is also used as sauce, soup, ketchup, and puree (Hossain *et al.*, 2019).

Globally tomato is the most widely grown vegetable crop after potato, whereas, 5,051,983 hectares of land were under the cultivation of tomato in 2020 with a total production of 186,821,216 metric tons (FAOSTAT, 2022). In Bangladesh, tomato is cultivated as the second most important vegetable crop after potato and devoted 70,460 acres of land for tomato cultivation with a total yield of 4,15,494 metric tons in 2019-2020 (BBS, 2021).

However, the production and quality of tomatoes are affected by various factors and the planting density is one of the vital factors which remarkably reduced the yield of this crop due to improper planting density. Appropriate planting density can improve the fruits quality as well as yield of tomatoes for both fresh market and processed tomatoes (Tuan and Mao, 2015). Therefore, the present study was aimed to determine the effects of planting density on the growth, development, and yield of tomato and to identify the appropriate planting density for better tomato production.

Materials and methods

Description of the study area

The study was carried out at Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI), Hathazari, Chattogram, Bangladesh in Rabi season 2019-2020. The experiment was conducted at 22.18°N latitudes and 91.89°E longitudes with an average altitude of 20 m above the sea level. The experimental area was Chittagong Coastal Plains which was under the Agroecological Zone 23 which comprised low hills and valleys. The soils are moderately fine textured and the pH is about 6.5.

Experimental design and treatments

Tomato variety "BARI tomato-2" was used as the plant material in this experiment. This study was executed in a Randomized Complete Block Design (RCBD) using 4 planting densities (P_1: 40,000 plants ha^{-1}; P_2: 33,333 plants ha^{-1}; P_3: 28,571 plants ha^{-1}; P_4: 25,000 plants ha^{-1}) as treatments with four replications where plot size was 7m × 3m.

Management of the experiment

Land was prepared properly by ploughing and laddering as per requirement and 10 ton/ha cow dung was added into the soil during final land preparation. After land preparation, 32 days aged seedlings of tomato were transplanted on 1 December 2019. The applied fertilizer doses were 260, 180, 90, and 120kg/ha of Urea, TSP, MP, and Gypsum, respectively. During final land preparation, all fertilizers at full dose along with a half dose of urea were incorporated into the soil. From the remaining urea, half urea was applied at 20-25 days of transplanting after weeding and the rest of the remaining urea was used before flowering. Before applying every dose of urea, the field was irrigated. Weeding and other intercultural operations were done according to the requirements.

Data collection

The plant growth, development, and yield-related traits were recorded from randomly selected five plants from the middle two rows of all plots. Data were collected on plant height (cm), number of primary branches, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, individual fruit weight (g), fruit yield per plant (kg), total yield (ton/ha), marketable yield (ton/ha), and unmarketable yield (ton/ha) and the mean of all characters was calculated.

Data analysis

The collected data were statistically analyzed by SAS 9.2 software. Duncan Multiple Rang Test was used to compare between means at 0.05 level of significance and the mean separation was done by using LSD at 0.05 level of significance. Fig. s were prepared from means and standard errors to simplify interpretation.

Results and discussion

The statistical analysis indicated that planting density was significantly affected the measured agronomic characters and yield components of tomato except for plant height (cm) and number of flowers per cluster which showed a non-significant relationship at ($P≤0.05$).

Plant height

Results showed that planting density did not significantly affect the plant height ($P≤0.05$), although the highest planting density (40,000 plants ha^{-1}) treatment had the highest plant height (109.73 cm) and gradually reduced with the decrease of planting density and the lowest plant height (89.68 cm) was recorded at lowest planting density (25,000 plants ha^{-1}) treatments (Fig. 1A). This finding indicates that plant height was the highest at high planting density where plants grow vertically as plants got less space to spread. A similar trend was observed by Hamid *et al.,* 2010; Hussen *et al.,* 2013; Law-Ogbomo and Egharevba, 2009; Nganga, 2017; Zakher, 2017; Papadopoulos and Ormrod, 1991; Tuan and Mao, 2015.

Number of Primary Branches

The number of primary branches per plant showed significant differences due to planting density treatments (Fig. 1B). The highest (9.75) and lowest (6.05) number of primary branches per plant were recorded at 25,000 plants ha^{-1} and 40,000 plants ha^{-1}, respectively. This might be due to less competition for light, space, nutrients, and water among the plants at plots with low planting density which increased vegetative growth, particularly, more primary branches compared to high planting density. These results are agreed with the findings of Guade, 2017; Nganga, 2017; Rashid *et al.,* 2016; Shanmukhi *et al.,* 2017 and are opposite to the results of Hamid *et al.,* 2010.

Number of flowers per cluster

Planting density exhibited non-significant differences at ($P≤0.05$) for the number of flowers per cluster shown in Fig. 1C. But the highest number of flowers per cluster were observed at 25,000 plants ha^{-1} and gradually decreased with the increase of planting density and the minimum number of flowers per cluster were obtained from 40,000 plants ha^{-1}. These findings agreed with the results observed by Prodhan *et al.,* 2014; Shanmukhi *et al.,* 2018.

Number of fruits per cluster

For the number of fruits per cluster, the results in Fig. 1D showed that there were significant differences among treatments. In terms, the maximum number of fruits per cluster with a value of 4.65 was achieved at 25,000 plants ha^{-1}, whereas the minimum number of fruits per cluster was obtained at 40,000 plants ha^{-1} with a value of 2.95. It seems that the number of fruits per cluster lowered at higher planting density which is disagreed with the finding of Nganga, 2017.

Number of fruits per plant

The number of fruits per plant had a significant relationship among the treatment means (Fig. 1E). In the present study, number of fruits per plant was from 16.70 to 22.975, in which the minimum number of fruits per plant with the value of 16.70 was observed at 40,000 plants ha^{-1}, followed by 20.375 at 33,333 plants ha^{-1} and 21.30 at 33,333 plants ha^{-1}, whereas the maximum number of fruits per plant was recorded at 25,000 plants ha^{-1}. It might be due to the highest number of primary branches per plant, number of flowers per cluster, and higher number of fruits per cluster in the lowest planting density. A similar result was found by Hamid *et al.,* 2010; Law-Ogbomo and Egharevba, 2009; Maboko and Du Plooy, 2018; Maboko *et al.,* 2017; Prodhan *et al.,* 2014, while the opposite result was recorded by Shanmukhi *et al.,* 2017.

Individual fruit weight (g)

The results summarized in Fig. 1F indicated that planting density treatments significantly affected the individual fruit weight. In term, the highest individual fruit weight was recorded at 25,000 plants ha^{-1} with the value of 91.625 g and the lowest individual fruit weight was obtained from 40,000 plants ha^{-1}. Individual fruit weight decreased as planting density increased, which complies with the finding of Law-Ogbomo and Egharevba, 2009; Rashid *et al.,* 2016; Prodhan *et al.,* 2014; Tuan and Mao, 2015 and opposite to the results of Hamid *et al.,* 2010.

Fruit yield per plant (kg)

The highly significant differences were recorded in fruit yield per plant due to planting density treatments (Fig. 2G). The maximum fruit yield per plant (2.097kg) was observed at 25,000 plants ha^{-1}, whereas the minimum fruit yield per plant (1.016kg) was obtained from 40,000 plants ha^{-1}. Moreover, fruit yield per plant was 1.912kg and 1.729kg at 28,571 plants ha^{-1} and 33,333 plants ha^{-1}, respectively. These findings agreed with the results observed by Law-Ogbomo and Egharevba, 2009; Maboko and Du Plooy, 2018; Shanmukhi *et al.,* 2018.

Total yield (ton/ha)

For the total yield, there were significant differences among the treatment means (Fig. 2H). The maximum yield was obtained from 33,333 plants ha^{-1} with values of 63.525 tons per hectare, followed by the total yield of 60.229 ton per hectare and 57.808 ton per hectare at 28,571 plants ha^{-1} and 25,000 plants ha^{-1}, respectively, and the minimum yield was obtained from 40,000 plants ha^{-1} with values of 44.822 ton per hectare. This finding is similar to the result found by Maboko *et al.,* 2017; Rashid *et al.,* 2016; Tuan and Mao, 2015; Law-Ogbomo and Egharevba, 2009; Warner *et al.,* 2002, they reported the highest fruit yield at the lower planting density than the highest planting density but opposite results were found by Hamid *et al.,* 2010 who recorded the highest fruit yield at the highest planting density than the lowest planting density.

Marketable yield (ton/ha)

For marketable yield, the results in Fig. 2I showed that there were significant differences in marketable yield among the treatments. In terms, the maximum marketable yield with the value of 58.647 tons per hectare was recorded at 33,333 plants ha^{-1}, whereas the minimum marketable yield was recorded from 40,000 plants ha^{-1} with the value of 39.398 tons per hectare.

It seems that low planting density gave a higher marketable yield than the high planting density. Moreover, the marketable yield was 56.077 tons per hectare and 53.864 tons per hectare at 28,571 plants ha^{-1} and 25,000 plants ha^{-1}, respectively, which complies with the finding of Law-Ogbomo and Egharevba, 2009; Maboko and Du Plooy, 2018; Maboko *et al.,* 2017; Warner *et al.,* 2002.

Unmarketable yield (ton/ha)

Highly significant effects ($P \leq 0.01$) of planting density were reported for unmarketable yield (Fig. 2J). The maximum unmarketable yield was reported at 40,000 plants ha^{-1} and the value was 5.424 tons per hectare, followed by 4.878 tons per hectare and 4.153 tons per hectare at 33,333 plants ha^{-1} and 28,571 plants ha^{-1}, respectively, and the minimum unmarketable yield was recorded from 25,000 plants ha^{-1}. This finding is similar to the result found by Assefa *et al.,* 2015; Maboko *et al.,* 2017. The unmarketable yield was gradually decreased with the decrease of planting density, high planting density led to phyto-sanitation because of water uptake and lack of adequate ventilation at the bottom of plants compare to low planting density, which facilitated physiological disorders e.g., blossom-end rot, fruit cracks and fruit rot disease (Maboko *et al.,* 2017).

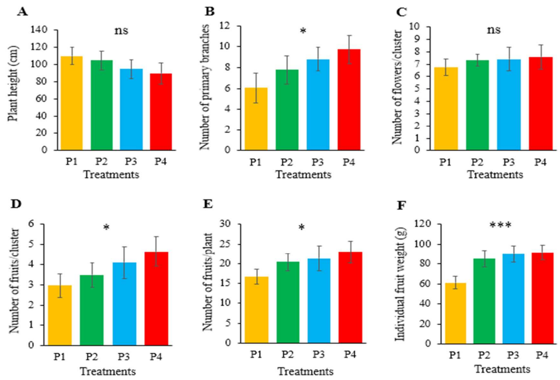

Fig. 1. Effect of planting density on (A) Plant height (cm), (B) Number of primary branches, (C) Number of flowers per cluster, (D) Number of fruits per cluster, (E) Number of fruits per plant, (F) Individual fruit weight (g).

Here, *= significant at P < 0.05, **= significant at P < 0.01, ***= significant at P <0.001, ns = non-significant at P < 0.05.

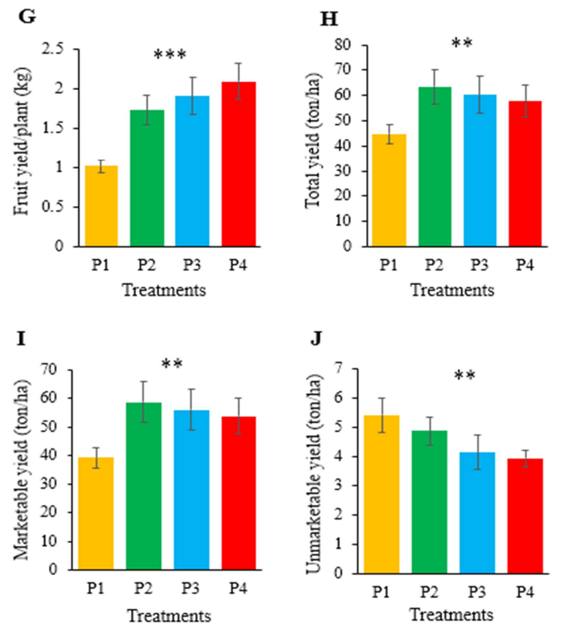

Fig. 2. Effect of planting density on (G) Fruit yield per plant (kg), (H) Total yield (ton/ha), (I) Marketable yield (ton/ha), (J) Unmarketable yield (ton/ha).

Here, *= significant at P < 0.05, **= significant at P < 0.01, ***= significant at P <0.001, ns = non-significant at P < 0.05.

Conclusion and recommendation

From the present study results, number of primary branches, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, individual fruit weight, and fruit yield per plant were higher in low planting density (25,000 plants ha^{-1}) and higher in high planting density (40,000 plants ha^{-1}). Moreover, the maximum total yield and marketable yield were observed at 28,571 plants ha^{-1} and the values are 63.526 and 58.647 tons per hectare, respectively, while, the lowest total yield and marketable yield were observed at 40,000 plants ha^{-1} with the values 44.822 and 39.398 tons per hectare, respectively. Therefore, tomato planting at 28,571 plants ha^{-1} is highly recommended to obtain the maximum marketable fruit yield of tomatoes under field conditions.

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Conflict of interest

Authors have declared that no competing interests exist.

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