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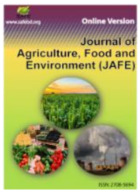

Original Article

Improving growth, yield and quality of cherry tomato (*Solanum lycopersicum* var. *cerasiforme*) using staking and mixed fertilization

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ABSTRACT

An experiment was conducted at the Horticulture Farm and Postgraduate Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period from September 2019 to March 2020 to study the effects of staking and mixed fertilization for improving growth, yield and quality of cherry tomato cv. Binatomato 10. The two-factor experiment consisted of two types of staking viz. S_1 = Single, S_2 = Trellis type and five doses of mixed fertilizers viz. T_0: Control, T_1: 25% of mixed fertilizers (cowdung, mustard oil cake (MOC), urea, TSP and MoP @ 4000, 125, 100, 87.5, and 75 kg/ha, respectively), T_2: 50% of mixed fertilizers (cowdung, MOC, urea, TSP and MoP @ 6000, 250, 200, 175, and 150 kg/ha, respectively), T_3: 75% of mixed fertilizers (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively) and T_4: 100% of mixed fertilizers (cowdung, MOC, urea, TSP and MP @ 12000, 500, 400, 350, and 300 kg/ha, respectively). The experiment was laid out in randomized complete block design with three replications. Staking and mixed fertilization had significant effects on all the parameters under study. Trellis type staking along with combined application of cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively (S_2T_3) gave the highest plant height (134.93 cm), number of leaves (46.87), flowers (384.32) and fruits per plant (312.31), individual fruit weight (11.68 g), fruit length (3.68 cm) and diameter (2.67 cm), yield per hectare (64.24 t), and TSS (8.69%).

Introduction

Cherry tomato (*Solanum lycopersicum* var. *cerasiforme*) belongs to the family Solanaceae, is an important vegetable crop in the world. It is a common form of table tomato that and is regarded as a genetic intermediate between wild-type tomatoes and home garden tomatoes (Nesbitt and Tanksley, 2002). Cherry tomato is round in shape; similar to a cherry juicy and meaty berry, bigger than 1.5 cm in diameter (Silva and Giordano, 2000). Various colours of cherry tomato such as red, black, green, bi-color, white, stripped, yellow-orange, pink and their unique size makes them more attractive. Different colorful cherry tomatoes are found like. Plants of cherry tomato produce large clusters of the one-inch round tomatoes on vigorous, tall, indeterminate plants that are easy to grow and can be grown in the greenhouse or outdoors in a sunny spot. Cherry tomatoes have a long postharvest shelf life of 10-14 days at room temperature (Khan and Rashid, 2021; Estiaque *et al.*, 2021).

Cherry tomato production is estimated to be over 47000 million tons globally (FAO, 2018). It has become more popular all over the world in light of its ideal attributes, for example, great source of vitamin A and C, sugars, taste and low calories and fruit set even at high temperature (Prema *et al.*, 2011). Cherry tomato (also called salad tomato) is consumed more as a fruit rather than as a vegetable and preferred to eat fresh or in salad, though they also lend themselves to being flash grilled or roasted. Though cherry tomato has become popular as a cash crop in some Asian countries however it is still new crop in Bangladesh (Islam *et al.*, 2012). Due to its higher yield and two-three times higher market value compared to other tomato varieties, cherry tomato causes great interest from greenhouse producers in Bangladesh (Saha and Rashid, 2020; Soares *et al.*, 2005). Cherry tomato has significant nutritional and health benefits. It is a source of calories, protein, fatty acids, vitamin (A, B_6, B_9, C and K) and different minerals (calcium, copper, iron, magnesium, phosphorus and zinc). Beside all these vitamins and minerals, cherry tomatoes are known for being rich in carotenoids, lycopene and phenolic compounds, which may help reduce the risk of certain cancer and inflammation. It has an excellent consumer acceptance due to its high sweetness (Preczenhak *et al.*, 2014) among other organoleptic characteristics superior to the traditional tomato fruits (Pinheiro, 2016). Some varieties i.e., Black cherry tomatoes are good source for providing disease resistance and adaptability to fruit set even at high temperature (Prema *et al.*, 2011). So, growing cherry tomato could be a profitable activity for Bangladeshi farmers. However, its production depends on pre-harvesting factors like optimum fertilizer doses, planting models, irrigation, staking, etc.

In cherry tomato production, staking plants plays an important role in aspect of higher yields and good quality produce. It is proved through different experiments that staking is an asset for best result in tomato production. Staking helps in increasing fruit yield reduces the proportion of unmarketable fruit and facilitates chemical spraying and harvesting (Kader and Morris, 1976). Among the various staking techniques, vertical staking produces high number and quality fruits of cherry tomato and avoids fruits rot (Khan and Rashid, 2021). It improves aeration, decreases fungal disease assaults, and ensures that the foliage is exposed to light for optimum photosynthesis. According to Ariyarathne (1989) recommended staking because it protects vegetables from animals, diseases and also provides good quality vegetables. Akoroda *et al*. (1990) and Trenbath (1976) supported the idea of staking because it facilitates harvesting of vegetables and pods and exposes the leaves for effective light reception. Cherry tomatoes grown on staked plants are larger and ripen earlier than those grown on sprawling plants. Good air circulation around the leaves and fruits of upright tomato plants lessens diseases problems and fruit held in high are free dirt and slug bites. On the other hand, staking practice may also give the uniform sized fruit, easy harvesting of fruits and conveniences in intercultural operations without damage to the fruits and less infestation of insects and diseases as well as increase the yield of cherry tomato (Santos *et al*., 1999).

The main way of increasing production of any crop depends on soil condition and improved production technology. In conventional agriculture, heavy doses of inorganic fertilizers are often used to improve the yield of cherry tomato to meet out the increasing higher demand. Inorganic fertilizers have high nutrient contents and are rapidly taken up by plants. However, the use of excess fertilizer can result in a number of problems, such as nutrient loss, surface water and groundwater contamination, soil acidification or basification, reductions in useful microbial communities, and increased sensitivity to harmful insects and causes health hazard. On the other hand, the use of organic manures improves texture, structure, humus, color, aeration, water holding capacity and microbial activity of soil. The application of organic leachate from cowdung, vermi-compost and mustard oil cake results in higher growth, yield and quality of cherry tomato. They supply essential macro and micronutrients, many vitamins, essential amino acids, growth promoting factors like IAA, GA and beneficial microorganisms (Palekar, 2006). A good soil has an organic matter content of more than 3%, but in our country soil of most regions have less than 1.5%. Some soils even have less than 1% organic matter (BARC, 2012). In Bangladesh, productivity of soils is declining due to depletion of organic matter caused by high cropping intensity. Application of organic manure in the cultivation is, therefore, important for ensuring satisfactory production of cherry tomato (Wu *et al.*, 2022). Mixed application of organic and inorganic fertilizers increased the yield of tomato, cabbage, okra (Islam *et al.*, 2017). 75% recommended inorganic fertilizer along with 20t cowdung contributed in highest yield of tomato (Mamun *et al*., 2019). Moreover, due to lack of knowledge and problem of preservation of organic manure, our farmers are habituated in use of inorganic fertilizers more readily compared to organic one. Hence, balanced application of mixed fertilizers and suitable staking can increase the production and quality of cherry tomato and lower the cost of production. However, very limited research has been conducted on the effect of vertical staking and mixed fertilizers on the growth, yield and quality of cherry tomato under Bangladesh condition. Keeping above points in view, present investigation has been undertaken to improve the growth, yield and quality of cherry tomato using staking and mixed fertilization.

Materials and Methods

Experimental site

The experiment was executed at the Horticulture Farm and Postgraduate Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh to evaluate the effect of staking and mixed fertilization on improving growth, yield and quality of cherry tomato during the period from September 2019 to March 2020. The climate of the experimental area was subtropical in nature, which was characterized by high temperature, heavy rainfall, high humidity and relatively long day during the months of April to September and low rainfall associated with moderately low temperature, low humidity and short day during the rest of the year. The experimental site was medium high land belonging to the Old Brahmaputra Floodplain under the Agro-Ecological Zone 9 having non-calcareous dark gray floodplain soil (UNDP and FAO, 1988). The soil of the experimental plot was silty loam in texture and neutral (pH 7.0) in reaction, which is suitable for cherry tomato production.

Plant materials

Binatomato 10 as cherry tomato variety was used in this experiment. The seeds were collected from the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. These seeds were sown in the seedbed for raising seedlings.

Seedbed preparation, seed sowing and raising of seedlings

A seedbed was prepared on September 16, 2019 for raising seedlings of cherry tomato, which comprised an area of 3 sq. meters. First of all, the soil was ploughed and converted into loose friable and dried masses to obtain good tilth. Weeds, stubbles and dead roots were removed from the seedbed. Cowdung was applied to the prepared seedbed at the rate of 10 t/ha. The soil was amended by Seven 50 WP at 5 kg/ha to protect the young plants from the attack of different insects such as mole crickets, ants and cutworms. Cherry tomato seeds were treated by Vitavax-200 @ 5 g/kg seeds to protect them from various seed borne diseases such as leaf spot, blight, anthracnose, etc. One gram seed of cherry tomato was sown on 21 September 2019 in seedbeds and after sowing, seeds were covered with light soil. Sowing was done by using broadcasting method and covered with a fine layer of soil followed by light watering. After that the beds were covered with banana leaf to maintain required temperature and moisture. The banana leaves were removed immediately after emergence of seed sprouting. The emergence of seedlings took place within 5 to 6 days after sowing. Light watering and weeding were done when necessary. No manures or chemical fertilizers were applied for raising of seedlings. Seedlings were not attacked by any kind of insects or diseases.

Experimental treatments and design

The two-factor experiment consisted of two types of staking viz. S_1 = Single, S_2 = Trellis type and five doses of mixed fertilizers viz. T_0: Control, T_1: 25% of mixed fertilizers (cowdung, mustard oil cake (MOC), urea, TSP and MoP @ 4000, 125, 100, 87.5, and 75 kg/ha, respectively), T_2: 50% of mixed fertilizers (cowdung, MOC, urea, TSP and MoP @ 6000, 250, 200, 175, and 150 kg/ha, respectively), T_3: 75% of mixed fertilizers (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively) and T_4: 100% of mixed fertilizers (cowdung, MOC, urea, TSP and MP @ 12000, 500, 400, 350, and 300 kg/ha, respectively). The experiment was laid out in randomized complete block design with three replications. The experimental plot was first divided into three blocks, each of which was then subdivided into 10 plots. There were 10 (2 x 5) treatment combinations and thus 30 unit plots (3 × 10) in total. The size of each unit plot was 1.25 m x 1.0 m. A distance of 50 cm between the plots and 100 cm between the blocks were maintained.

Land preparation

The land of the experimental field was first opened on September 25, 2019 with the help of a power tiller. Then it was exposed to the sunlight for 7 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed to obtain good tilth. Leveling was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubbles were removed from the field. The experimental field was partitioned onto the unit plots in accordance with the experimental design.

Application of organic and inorganic fertilizers

The entire quantity of cowdung and mustard oil cake were applied in each unit plot according to their treatments at 21 days before planting of seedlings and incorporated into the soil carefully. Urea was applied in each plot according to their treatments in three equal installments at 30 days after transplanting (DAT), 45 DAT and 60 DAT. 50% of TSP and MP as a basal dose and the rest of them were applied in two equal installments according to their treatments in each plot at 30 DAT and 45 DAT.

Transplanting of seedlings

35 days old, healthy and uniform seedlings were uprooted separately from the seedbed so as to minimize damage to the roots. Six seedlings in two rows maintaining a spacing of 50 cm × 30 cm was transplanted in one experimental plot in the afternoon of 26 October 2019. Each unit plot was 1.25 m x 1.0 m in size, which consisted of 6 plants. The spacing between plots and blocks were 50 cm and 100 cm, respectively. Light irrigation was given immediately after transplanting by using a watering can.

Intercultural operations

Very few seedlings have been damaged after transplanting and new seedlings from the same stock replaced these. Weeding was done as and when necessary throughout the growth period to keep the crop free from weeds, for better soil aeration, to lessen nutrition competition between crops and weeds and to break the crust. It also helped in soil moisture conservation. After 15 days of transplanting when the plants were well established staking was provided using bamboo sticks to keep the plants erect and around 1.5 m high single and trellising type staking were constructed in each plot according to the treatment combinations for proper growth, development and fruiting of cherry tomatoes. Several irrigations were given throughout the growing season. Besides this irrigation was done after every application of fertilizers. Nitro 505 EC was applied at the rate of 2 ml/L as preventive measure against insect pests on November 7, 2019. The insecticide was applied next time at 10 days interval during early vegetative stage. Precautionary measures against diseases like damping off, wilt, fruit rot and late blight of tomato was taken by spraying Trichoderma at the rate of 2 ml/10 L, Topral 52.5 WP at the rate of 10 g/3L and Deconil 500 SC at the rate of 1.5 ml/L respectively during the early vegetative stage. Fruits were harvested at full maturity. Harvesting was started on January 26, 2020 and continued up to March 2020. Tomato fruits were harvested in the morning. The collected fruits were carried in gunny bags and then they were kept in the laboratory for data collection and chemical analysis. Proper care was taken while harvesting and handling the collected fruit samples to avoid any mechanical injuries.

Data collection

Data were recorded at 10 days intervals starting from 15 days after transplanting (DAT) up to 55 DAT and at harvest from sample plants of each plot under each treatment and replications on the parameters *viz*., plant height (cm), number of leaves per plant, days of first flowering, number of flower cluster per plant, number of flowers per cluster, number of flowers per plant, number of fruit cluster per plant, number of fruits per cluster and per plant, fruit length and diameter (cm), individual fruit weight (g), fruit yield per plant (kg) and per hectare (t), and total soluble solids (TSS) content (% brix). The plant height was measured from the sample plants in cm from the ground level to the tip of the longest stem. Plant height was recorded at 10 days interval starting from 15 days of transplanting to observe the growth rate of plants. Lastly, the plant height was recorded at 55 DAT. The number of leaves of sample plants was counted at 10 days interval from 15 DAT to 55 DAT and the average number of leaves produced per plant was recorded. Date of first flowering was recorded, and the number of the days required for first flowering was calculated. The number of flower clusters was counted from the plants periodically, and average number of flower clusters produced per plant was recorded. Number of flowers was recorded from the each plant throughout the flowering period. It was calculated as follows: Number of flowers per cluster =Total number of flowers in plant/Total number of flower cluster in plant. Total number of flower was counted from the plants and then recorded until last flowering. The number of fruit clusters was counted from the plants periodically, and average number of fruit clusters produced per plant was recorded. The number of fruits per cluster was recorded as follows: Number of fruit per cluster= Total number of fruits in plant/Total number of fruits cluster in plant. The number of fruits per plant was counted from the each plant periodically and the number of fruit produced per plant was recorded. The length of cherry tomato fruit was measured from the neck of the fruit to bottom of the selected marketable fruits from each treatment with a slide calipers and their average was calculated in centimeter. The diameter of cherry tomato fruit was measured at the middle portion of selected marketable fruits from each treatment with a slide calipers and their average was calculated in centimeter. The mature fruits were harvested and weight of fruits was measured by using measuring balance. The total weight of fruit per plant was calculated by adding the weight of all the fruits collected from each treatment after final harvest and then fruit yield was recorded in kg. Fruit yield of cherry tomato per plant was converted into fruit yield in ton per hectare. Fruit yield (t/ha) = Fruit yield per plant (kg) × total no. of plants of 1 ha land/1000. Total soluble solids (TSS) content of cherry tomato was determined from fruit juice by using a hand refractometer (Model N-1, Atago, Japan). Before measurement, the refractometer was calibrated with distilled water to give a zero reading. One or two drops of the filtrate were placed on the prism glass of the refractometer to obtain the TSS reading. The reading was multiplied by dilution factor to obtain an original TSS of the pulp tissues. Since differences in sample temperature could affect the TSS measurement, temperature corrections were made by using the methods described by Ranganna (1994). Pictorial views of various growth stages of cherry tomato are shown in plate 1.


1a. Seedbed


1b. Seedling stage


1c.Vegetative growth stage


1d. Flowering stage


1e. Fruiting stage


1f. Harvested cherry tomatoes

Plate 1. Pictorial views of various growth stages of cherry tomato, 1a. Seedbed, 1b. Seedling stage, 1c. Vegetative growth stage, 1d. Flowering stage, 1e. Fruiting stage, and 1f. Harvested cherry tomatoes.

Statistical analysis

The data on recorded parameters were statistically analyzed using MSTATC computer programme. The means of all the treatments were calculated and analysis of variance (ANOVA) for each of the characters under study was performed by F test. The significance of difference between the pairs of means was separated by LSD test at 1% and 5% levels of probability (Gomez and Gomez, 1984).

Results and Discussion

Effects of staking

Staking had significant effects on all the parameters under study except fruit length of cherry tomato (Figure 1-2,5 & Table 1). Results revealed that trellis type staking (S_2) recorded the higher plant height (112.07 cm) and number of leaves per plant (35.19) at 55 DAT in comparison to the plant height (106.31 cm) and number of leaves per plant (32.85) from single staking (S_1) (Figure 1-2). Trellis type staking plants provided the best output in terms of vegetative growth and development. Trellis type staking was good for plant growth. Trellis type staking provided strong and more support for growth, on the other hand single gave less support for growth that's why the trellis type plants gave the best output in terms of vegetative growth and development.

Minimum days required for first flowering was observed in trellis type staking (55.88 days) and the maximum days (57.41 days) were required by the plants in single staking (Table 1). It was also found that trellis type staking produced greater number of flower cluster per plant (36.89), number of flower per cluster (6.41), number of flower per plant (247.34), number of fruit cluster per plant (30.49), number of fruit per cluster (6.54) and number of fruit per plant (207.30) in comparison to single staking (30.92, 5.82, 188.12, 27.91, 6.10 and 176.95, respectively) (Table 1). Diver and Chandiposha discuss the reasons why trellising staking provided better results than single staking from the research works. Diver *et al.* (1999) noted that single pole staking is associated with more damages on foliage thereby reducing the photosynthetic area of the plant which produces food, forcing premature abscission of flowers, leaving only the fruits the plant is able to support.

In both staking systems (single and trellis type), length of individual fruit was recorded as 3.24 cm (Table 2). Higher fruit diameter (2.54 cm), individual fruit weight (9.13 g), fruit yield per plant (0.91 kg) and per hectare (43.73 t) was recorded from trellis type staking compared to single staking (2.47 cm, 8.63 g, 0.82 kg and 39.17 t, respectively) (Table 2 & Figure 5). Chandiposha *et al.* (2015) showed that single pole staking had the least number of fruits per cluster than the trellising staking and this may be attributed to limited exposure of flowers to sunlight due to lack of proper structural support from staking. It was also had been added that the caging trellising method resulted in an increased number of fruits per plant, highest marketable yield and lowest unmarketable yield.

Trellis type staking plants gave the highest yield. Trellising provided strong and more support for bearing fruits on the other hand single staking gave less support for bearing fruits that's why the trellis type staked plants gave the highest yield. The results of present experiment were also in agreement with the observation of Srinivasan *et al.* (1999) and Ignatov (1975). Srinivasan (1999) observed that staked plants of tomato were significantly taller than non-staked plants and the staked plants produced higher yield compare to non-staked plants. Adpawar *et al.* (2000) found that apart from plant height and nodal distance, staking with double wire gave the best results for quality and yield-contributing characters of tomato. Moreover, trellising staking provides more protection from inspect pest attack. Trellising staking facilitates the environmental factors' activities to the plants better than single staking i.e., proper light exposure to the leaves, air movement, humidity and temperature control. Results also showed that the higher TSS of cherry tomato (7.81%) was found in trellis type staking (S_2) than the TSS of cherry tomato (7.71%) of single staking (S_1) plants (Table 1).

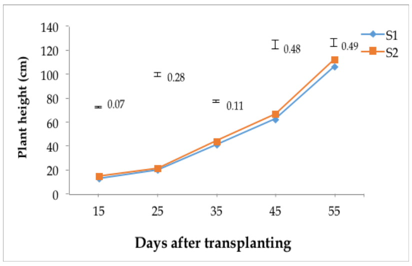

Figure 1. Effects of staking on plant height at different DAT. Vertical bars represent LSD at 5% level of significance. Here, S_1 = Single staking and S_2 = Trellis type.

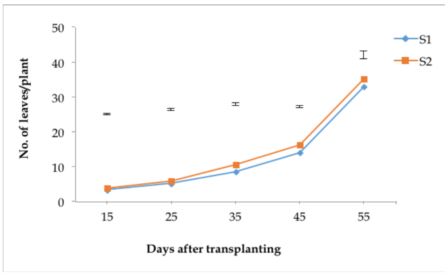

Figure 2. Effects of staking on number of leaves per plant at different DAT of cherry tomato. Vertical bars represent LSD at 5% level of significance. Here, S_1 = Single staking and S_2 = Trellis type.

Table 1. Effects of different staking on flowering, fruiting and yield characteristics of cherry tomato.

Staking	Days to first flowering	No. of flower cluster per plant	No. of flower per cluster	No. of flower per plant	No. of fruit cluster per plant	No. of fruit per cluster	No. of fruit per plant	Fruit length (cm)	Fruit diameter (cm)	Individual fruit weight (g)	Fruit yield per plant (kg)	Total soluble solids (%brix)
S_1	57.41	30.92	5.82	188.12	27.91	6.10	176.95	3.24	2.47	8.63	0.82	7.71
S_2	55.88	36.89	6.41	247.34	30.49	6.54	207.30	3.24	2.54	9.13	0.91	7.81
$LSD_{0.05}$	0.19	0.19	0.36	15.75	0.31	0.03	5.91	0.02	0.02	0.23	0.02	0.04
$LSD_{0.01}$	0.26	0.26	0.50	21.57	0.43	0.05	8.10	0.03	0.03	0.31	0.03	0.06
Level of significance	**	**	**	**	**	**	**	NS	**	**	**	**

** = Significant at 1% level of probability, S_1 = Single staking, S_2 = Trellis type staking

Effects of mixed fertilization

Mixed fertilizers had also significant influences on all the parameters under study (Figure 3-4,6 & Table 2). The highest plant height (130.79 cm) and number of leaves per plant (46.17) at 55 DAT were recorded from fertilizer dose T_3 = 75% of mixed application of fertilizers (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively), whereas the lowest plant height (82.61 cm) and number of leaves per plant (19.83) were obtained from control (T_0) (Figure 3-4). Earliest days to first flowering (52.57 days) was observed from fertilizer dose T_3 = 75% of mixed application of fertilizers (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively) followed by days to first flowering (54.83 days) with application of fertilizer dose T_4 = 100% of mixed application of fertilizers (cowdung, MOC, urea, TSP and MoP @ 12000, 500, 400, 350, and 300 kg/ha, respectively), whereas the late flowering (59.73 days) was observed from control (T_0) (Table 2).

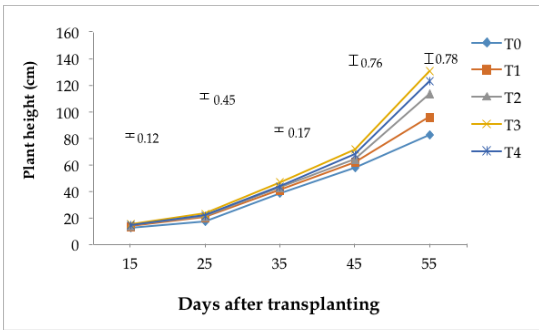

Figure 3. Effects of mixed fertilizers on plant height at different DAT of cherry tomato. Vertical bars represent LSD at 5% level of significance. Here, T_0 = Control, T_1 = 25 % (cowdung, MOC, urea, TSP and MoP @ 4000, 125, 100, 87.5, and 75 kg/ha, respectively), T_2 = 50 % (cowdung, MOC, urea, TSP and MoP @ 6000, 250, 200, 175, and 150 kg/ha, respectively), T_3 = 75 % (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively) and T_4 = 100 % (cowdung, MOC, urea, TSP and MoP @ 12000, 500, 400, 350, and 300 kg/ha, respectively).

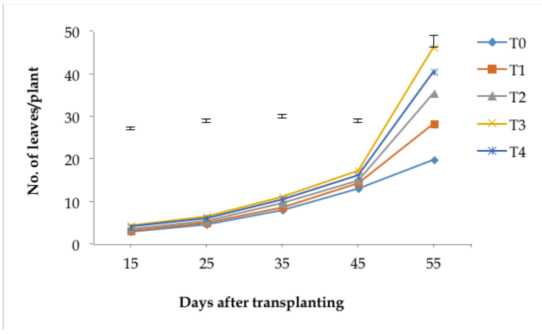

Figure 4. Effects of mixed fertilizers on number of leaves per plant at different DAT of cherry tomato. Vertical bars represent LSD at 5% level of significance. Here, T_0 = Control, T_1 = 25 % (cowdung, MOC, urea, TSP and MoP @ 4000, 125, 100, 87.5, and 75 kg/ha, respectively), T_2 = 50 % (cowdung, MOC, urea, TSP and MoP @ 6000, 250, 200, 175, and 150 kg/ha, respectively), T_3 = 75 % (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively) and T_4 = 100 % (cowdung, MOC, urea, TSP and MoP @ 12000, 500, 400, 350, and 300 kg/ha, respectively).

The maximum number of flower cluster per plant (42.23), number of flower per cluster (7.82) and per plant (332.21), number of fruit cluster per plant (38.47), fruit per cluster (7.55) and per plant (290.74), fruit length (3.66 cm) and diameter (2.64 cm), individual fruit weight (11.53 g), fruit yield per plant (1.26 kg) and per hectare (60.59 t), respectively, were recorded from fertilizer dose T_3 = 75% of mixed application of fertilizers (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively), whereas the minimum number of flower cluster per plant (22.67), number of flower per cluster (3.88) and per plant (88.27), number of fruit cluster per plant (14.83), number of fruit per cluster (5.17) and per plant (76.74), fruit length (2.59 cm) and diameter (2.38 cm), individual fruit weight (5.82 g), fruit yield per plant (0.40 kg) and per hectare (18.96 t), respectively, were obtained from control (T_0) (Table 2 & Figure 6). Highest number of flower clusters per plant (24.40), flowers per cluster (7.04), and flowers per plant (183.38) were found at 20t cowdung + 75% recommended inorganic fertilizer per ha were found in an experiment conducted by Mamun *et al.* in 2019. Availability of plant growth influencing substances such as hormones and humates produced by microorganisms due to organic manuring, probably contributed to increased flowering and number of flowers (Arancon *et al.*, 2008). Mamun *et al.* (2019) found that maximum number of fruit clusters per plant (7.12), and fruits per cluster (3.26) had been recorded from 20t cowdung + 75% recommended inorganic fertilizer per ha application.

Table 2. Effects of mixed fertilizers on flowering, fruiting and yield characteristics of cherry tomato.

Mixed fertilizer	Days to first flowering	No. of flower cluster per plant	No. of flower per cluster	No. of flower per plant	No. of fruit cluster per plant	No. of fruit per cluster	No. of fruit per plant	Fruit length (cm)	Fruit diameter (cm)	Individual fruit weight (g)	Fruit yield per plant (kg)	Total soluble solids (%brix)
T_0	59.73	22.67	3.88	88.27	14.83	5.17	76.74	2.59	2.38	5.82	0.40	6.67
T_1	58.90	31.23	5.24	163.39	25.00	5.41	135.53	3.16	2.44	7.00	0.70	7.43
T_2	57.20	35.27	6.20	218.92	30.33	6.57	199.53	3.25	2.48	9.36	0.89	7.93
T_3	52.57	42.23	7.82	332.21	38.47	7.55	290.74	3.66	2.64	11.53	1.26	8.66
T_4	54.83	38.13	7.44	285.88	37.37	6.90	258.10	3.57	2.59	10.69	1.07	8.12
$LSD_{0.05}$	0.30	0.30	0.57	24.90	0.50	0.05	9.35	0.04	0.04	0.36	0.04	0.07
$LSD_{0.01}$	0.42	0.41	0.78	34.11	0.68	0.07	12.81	0.05	0.05	0.49	0.05	0.09
Level of significance	**	**	**	**	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability. T_0 = Control, T_1 = 25 % (cowdung, MOC, urea, TSP and MoP @ 4000, 125, 100, 87.5, and 75 kg/ha, respectively), T_2 = 50 % (cowdung, MOC, urea, TSP and MoP @ 6000, 250, 200, 175, and 150 kg/ha, respectively), T_3 = 75 % (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively), T_4 = 100 % (cowdung, MOC, urea, TSP and MoP @ 12000, 500, 400, 350, and 300 kg/ha, respectively).

Maximum photosynthetic activity and accumulation of number of fruits might be due to increased number of flowers which might have formed into fruits due to adequate availability of major and minor nutrients during its growth and development (Laxmi *et al.*, 2015). The increase in yield per hectare might be due to the availability of nutrients that increased flower and fruit attributes like number per plant, size, weight and minimum number of fruits and yield in Control (T_0) might be due to non-availability of nutrients during its development (Laxmi *et al.*, 2015). Combined application of organic manures reduces the C:N ratio which helps to increase the number and weight of fruit (Nagavallemma *et al.*, 2004). Wu *et al.* (2022) showed in an experiment that organic-inorganic fertilizer treatment was 25% cow manure and 75% inorganic fertilizer, which significantly increased tomato yield by 245% and application of 100% cow manure significantly increased soil pH, nitrogen and carbon from the full fruiting period to the end-fruiting period, but did not achieve good tomato quality and yield.

The highest total soluble solids content (8.66%) was recorded by the application of fertilizer dose of T_3 = 75% of mixed application of fertilizers (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively) followed by total soluble solids (8.12%) with the application of fertilizer dose of T_4 = 100% of mixed application of fertilizers (cowdung, MOC, urea, TSP and MoP @ 12000, 500, 400, 350, and 300 kg/ha, respectively), whereas the lowest total soluble solids (6.67%) was recorded by the application of control dose of fertilizers (T_0) (Table 2). Wu *et al.* (2022) showed that total soluble solids concentration had been increased by 9.2% with the application of 25% cow manure and 75% inorganic fertilizers. Only application of organic fertilizer or inorganic fertilizer cannot perform a better yield of tomato. But their combined effect helps in better growth and yield of tomato (Mamun *et al.*, 2019).

In most of the parameters, application of fertilizer dose T_4 = 100% of mixed fertilizers (cowdung, mustard oil cake, urea, TSP and MoP @ 12000, 500, 400, 350, and 300 kg/ha, respectively), was found to be the second treatment to give highest output. Application of 100% of mixed fertilizers was meant to be best to give highest output in terms of growth and yield of cherry tomato but it did not come out as it was meant to. This result is supported by Wu *et al.* (2022). In their experiment they showed that application of 100% cow manure significantly increased soil pH, nitrogen and carbon from the full fruiting period to the end-fruiting period, but did not achieve good tomato quality and yield. 100% inorganic fertilizer application could increase tomato yield by 72.9%, but the soil quality was remarkably degraded. Yield first increased and then remained same or declined with further increases of N fertilizer (Greenwood *et al.*, 1980). From the above discussion it was evident that among staking types trellising is the better than single staking and 75% of mixed organic-inorganic fertilizers was better than any other fertilizer treatment.

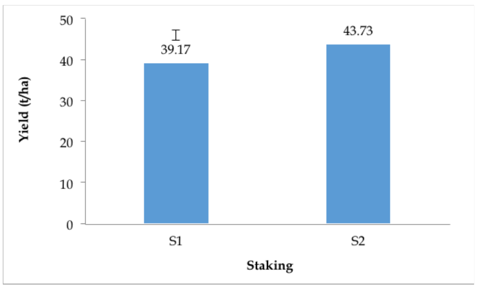

Figure 5. Effects of different staking on fruit yield per hectare of cherry tomato. The vertical bar represents LSD at 5% level of significance. Here, S_1 = Single staking, and S_2 = Trellis type staking.

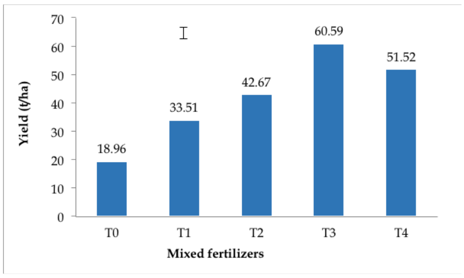

Figure 6. Effects of mixed fertilizers on fruit yield per hectare of cherry tomato. Vertical bars represent LSD at 5% level of significance. Here, T_0 = Control, T_1 = 25 % (cowdung, MOC, urea, TSP and MoP @ 4000, 125, 100, 87.5, and 75 kg/ha, respectively), T_2 = 50 % (cowdung, MOC, urea, TSP and MoP @ 6000, 250, 200, 175, and 150 kg/ha, respectively), T_3 = 75 % (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively) and T_4 = 100 % (cowdung, MOC, urea, TSP and MoP @ 12000, 500, 400, 350, and 300 kg/ha, respectively).

Combined effects of staking and mixed fertilization

The combined effects of staking and mixed fertilizers had significant influence on all the parameters under study (Table 4, Figure 7). It was observed that the highest plant height (134.93 cm) and number of leaves per plant (46.87) were found with treatment (S_2T_3), trellis type staking and fertilizer dose of T_3 = 75% of mixed application of fertilizers (Cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively), whereas the lowest plant height (81.41 cm) and number of leaves per plant (18.87) were recorded in treatment (S_1T_0), single staking and control application of fertilizers (Table 3). Pictorial views of cherry tomato showing different combined effects of staking and mixed fertilizers on fruit length and diameter are shown in plate 2.

Table 3. Combined effects of staking and mixed fertilizers on plant height and number of leaves per plant at different days after transplanting (DAT) of cherry tomato.

Treatment combination	Plant height (cm) at different DAT					No. of leaves per plant at different DAT				
	15	25	35	45	55	15	25	35	45	55
S_1T_0	11.53	16.85	37.59	56.52	81.41	2.60	4.20	7.07	11.53	18.87
S_1T_1	12.55	19.28	38.82	59.71	93.99	2.93	4.67	7.80	13.13	27.20
S_1T_2	13.38	20.43	41.61	62.21	110.92	3.13	4.93	8.13	13.87	33.67
S_1T_3	14.35	22.13	45.01	69.30	126.65	3.93	6.07	10.07	16.27	45.47
S_1T_4	13.83	20.91	41.83	65.10	118.59	3.73	5.53	9.27	14.93	39.07
S_2T_0	13.30	17.39	39.93	59.65	83.81	3.07	4.93	8.80	14.67	20.80
S_2T_1	14.25	21.47	42.73	64.11	97.93	3.47	5.33	9.60	15.40	29.33
S_2T_2	14.65	21.79	44.55	65.79	116.40	3.87	5.93	10.93	16.07	37.13
S_2T_3	15.68	24.21	48.32	74.33	134.93	4.67	6.80	12.13	18.33	46.87
S_2T_4	15.27	22.59	45.23	70.19	127.27	4.27	6.47	11.67	17.13	41.80
$LSD_{0.05}$	0.16	0.64	0.24	1.07	1.11	0.12	0.16	0.20	0.17	0.65
$LSD_{0.01}$	0.22	0.87	0.33	1.47	1.51	0.17	0.22	0.27	0.23	0.89
Level of significance	**	**	**	*	**	**	*	**	**	**

**, * = Significant at 1 and 5% levels of probability, respectively. S_1 = Single staking, S_2 = Trellis type staking, T_0 = Control, T_1 = 25 % (cowdung, MOC, urea, TSP and MoP @ 4000, 125, 100, 87.5, and 75 kg/ha, respectively), T_2 = 50 % (cowdung, MOC, urea, TSP and MoP @ 6000, 250, 200, 175, and 150 kg/ha, respectively), T_3 = 75 % (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively), T_4 = 100 % (cowdung, MOC, urea, TSP and MoP @ 12000, 500, 400, 350, and 300 kg/ha, respectively).

Plate 2. Pictorial views of cherry tomato showing different combined effects of staking and mixed fertilizers on fruit length and diameter.

From the combined effects, it was observed that the earliest flowering (51.33 days) results came with the treatment combination (S_2T_3), trellis type staking and fertilizer dose of T_3 = 75% of mixed application of fertilizers (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively), followed by days to first flowering (53.80 days) with treatment combination (S_1T_3) single staking and fertilizer dose of T_3 = 75% of mixed application of fertilizers (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively), whereas late flowering (60.00 days) was found in treatment combination (S_1T_0), single staking and control application of fertilizers (Table 4). It was observed that the maximum number of flower cluster per plant (45.07), number of flower per cluster (8.53) and per plant (384.32), number of fruit cluster per plant (39.53), number of fruit per cluster (7.90) and per plant (312.31), fruit length (3.68 cm) and diameter (2.67 cm), individual fruit weight (11.68 g), fruit yield per plant (1.34 kg) and per hectare (64.24 t), and total soluble solids content (8.69%) were found from the treatment combination (S_2T_3), trellis type staking and fertilizer dose of T_3 = 75% of mixed application of fertilizers (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively), whereas the minimum number of flower cluster per plant (18.53), number of flower per cluster (3.87) and per plant (71.59), number of fruit cluster per plant (13.87), number of fruit per cluster (5.03) and per plant (69.75), fruit length (2.56 cm) and diameter (2.37 cm), individual fruit weight (5.81 g), fruit yield per plant (0.37 kg) and per hectare (17.84 t), and total soluble solids content (6.56%) were found from the treatment combination (S_1T_0), single staking and control dose of fertilizers (Table 4 & Figure 7).

Table 4. Combined effects of staking and mixed fertilizers on flowering and fruiting characters of cherry tomato.

Treatment combinations	Days to first flowering	No. of flower cluster per plant	No. of flower per cluster	No. of flower per plant	No. of fruit cluster per plant	No. of fruit per cluster	No. of fruit per plant	Fruit length (cm)	Fruit diameter (cm)	Individual fruit weight (g)	Fruit yield per plant (kg)	Total soluble solids (%brix)
S_1T_0	60.00	18.53	3.87	71.59	13.87	5.03	69.75	2.62	2.37	5.81	0.37	6.56
S_1T_1	58.93	28.53	5.40	154.13	23.47	5.27	123.63	3.14	2.39	6.92	0.69	7.33
S_1T_2	58.60	32.67	6.10	199.11	28.47	6.37	181.22	3.27	2.42	8.74	0.84	7.90
S_1T_3	53.80	39.40	7.10	280.10	37.40	7.20	269.16	3.63	2.61	11.38	1.19	8.63
S_1T_4	55.73	35.47	6.65	235.69	36.33	6.63	241.01	3.54	2.56	10.32	1.00	8.13
S_2T_0	59.47	26.80	3.90	104.95	15.80	5.30	83.73	2.56	2.39	5.83	0.42	6.78
S_2T_1	58.87	33.93	5.09	172.65	26.53	5.55	147.42	3.17	2.49	7.09	0.71	7.53
S_2T_2	55.80	37.87	6.30	238.73	32.20	6.77	217.83	3.23	2.54	9.98	0.94	7.96
S_2T_3	51.33	45.07	8.53	384.32	39.53	7.90	312.31	3.68	2.67	11.68	1.34	8.69
S_2T_4	53.93	40.80	8.23	336.06	38.40	7.17	275.20	3.59	2.62	11.07	1.15	8.11
$LSD_{0.05}$	0.43	0.42	0.81	35.22	0.70	0.08	13.22	0.05	0.05	0.51	0.05	0.09
$LSD_{0.01}$	0.59	0.58	1.11	48.24	0.96	0.11	18.11	0.07	0.07	0.70	0.07	0.13
Level of significance	**	**	**	**	**	**	*	*	*	**	**	**

**, * = Significant at 1 and 5% levels of probability, respectively. S_1 = Single staking, S_2 = Trellis type staking, T_0 = Control, T_1 = 25 % (cowdung, MOC, urea, TSP and MoP @ 4000, 125, 100, 87.5, and 75 kg/ha, respectively), T_2 = 50 % (cowdung, MOC, urea, TSP and MoP @ 6000, 250, 200, 175, and 150 kg/ha, respectively), T_3 = 75 % (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively), T_4 = 100 % (cowdung, MOC, urea, TSP and MoP @ 12000, 500, 400, 350, and 300 kg/ha, respectively).

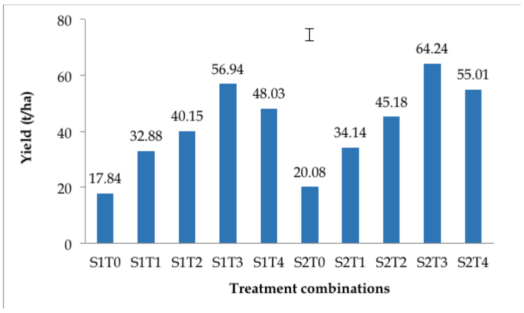

Figure 7. Combined effects of different staking and mixed fertilizers on fruit yield of cherry tomato. The vertical bar represents LSD at 5% level of significance. Here, S_1 = Single staking, and S_2 = Trellis type staking, T_0 = Control, T_1 = 25 % (cowdung, MOC, urea, TSP and MoP @ 4000, 125, 100, 87.5, and 75 kg/ha, respectively), T_2 = 50 % (cowdung, mustard oil cake, urea, TSP and MoP @ 6000, 250, 200, 175, and 150 kg/ha, respectively), T_3 = 75 % (cowdung, MOC, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively) and T_4 = 100 % (cowdung, mustard oil cake, urea, TSP and MoP @ 12000, 500, 400, 350, and 300 kg/ha, respectively).

Conclusion

Results revealed that trellis type staking was found to be most effective for the production of high yield of cherry tomato. Between different fertilizer doses, 75% of mixed fertilizer (cowdung, mustard oil cake, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively) was the best in respect of yield of cherry tomato. Therefore, it can be concluded that trellis type staking along with 75% of mixed fertilizers (cowdung, mustard oil cake, urea, TSP and MoP @ 9000, 375, 300, 262.5, and 225 kg/ha, respectively) was found to be better in respect of growth, yield and quality of cherry tomato.

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