Indian Journal of Agricultural Sciences **89** (3): 489–93, March 2019/Article
https://doi.org/10.56093/ijas.v89i3.87594

Effect of planting density on growth, yield and quality of strawberry (*Fragaria* × *ananassa*) cv. Camarosa

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Received: 08 October 2015; Accepted: 09 October 2018

ABSTRACT

An investigation was carried out at experimental field, Department of Horticulture, Aromatic and Medicinal Plants, Mizoram University to study the effect of planting density on growth, yield and quality of strawberry (*Fragaria* × *ananassaa* Duch.) cv. Camarosa. The experiment comprises of a number of planting densities, viz. T_1: 50 × 40 cm, T_2 : 40 × 40 cm, T_3 : 40 × 30 cm, T_4 : 30 × 30 cm, T_5: 30 × 25 cm, T_6 : 25 × 25 cm, T_7 : 25 × 20 cm and T_8 : 20 × 20 cm. Among the different planting density, the maximum growth in terms of plant height (26.85 cm), E-W (37.83 cm) and N-S spread (39.58 cm), number of leaves (34.45), leaf area (213.92 cm^2) and crowns/plant (8.11) were observed in the widest spacing, i.e. 50 × 40 cm. This treatment also exhibit superiority in yield attributing characters like berry set percentage (81.17), berry weight (21.73 g), berry diameter (36.06 mm), berry length (43.73 mm), number of berries/plant (21.05) and total biomass (964.64 g). The quality parameters of the fruit like TSS (8.94 °Brix), titratable acidity (0.812%), TSS: acid ratio (11.03), total sugars (8.50%), reducing (4.78%) ascorbic acid (67.67/mg/100g) and anthocyanin content (38.53 mg/100g) were also found superior in this spacing. The overall assessment of the present study concluded that a spacing 50 × 40cm is the most efficient planting denstity for improving growth, yield and quality in Camarosa strawberry under Mizoram conditions.

Key words: Growth, Planting density, Quality, Strawberry, Yield

The strawberry (*Fragaria* × *ananassa* Duch.), is one of the most delicious, nutritive and refreshing fruits throughout the sub-tropical and temperate regions of the world. The modern cultivated strawberry is a hybrid of *Fragaria virginiana* (meadow strawberry) and *Fragaria chiloensis* (Chilean strawberry) (Bowling 2000). Botanically, an octoploid (2n = 56) is a dicotyledonous, perennial low-growing herb grown in most arable regions of the world and is enjoyed by millions of people in all kinds of climates (Hazarika *et al*. 2016). It is amongst the few fruit crops which give quicker and very high returns per unit area on the capital investment, as the crop is ready for harvest within six months of planting (Kumar *et al.* 2012). Among the fruits, it is one of the most popular, delicate in flavour, rich in vitamins and minerals (Singh and Singh 2009). The fruits are also good sources of natural antioxidants including carotenoides, vitamins, phenols, flavonoides, dietary glutathionine and endogenous metabolites (Hazarika *et al*. 2015). Antioxidants in strawberries include vitamin C and phenolic compounds such as phenolic acids and flavonoids. These antioxidants can delay or inhibit the oxidation of lipids or other molecules by inhibiting oxidizing chain reactions and providing protection against harmful free radicals, and have been associated with lower incidence and mortality rates of cancer and heart disease in addition to a number of other health benefits (Wang 2014). In addition, the presence of ellagic acid prevents many diseases and has made strawberry a more valuable fruit (Hazarika *et al*. 2017).

Among the various factors which contribute to the growth and yield of strawberry, plant density is an important aspect of crop production. It plays an important role in achieving high productivity per unit area. It's basic function is to confine the exploitation zone of the plant with regard to light, water and nutrients so that the highest total yield potential can be reached in the smallest possible area (Singh 2005). However, due to lack of suitable planting density, high percentage of undersized, unmarketable fruit and incidence of pest and diseases have been noticed which bottleneck for obtaining good returns.

Being bestowed with a wide range of agro-climatic conditions, north-eastern hill region of India offers immense

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potentiality for growing strawberry (Singh *et al.* 2008). The rich fertile soil and well distributed rainfall favours the cultivation of strawberry in this region. But till today, no research work has been carried out in this remote part of India to study the effect of planting density on strawberry. Therefore, keeping this in view all the above background information and research gaps, the present study was conducted to analyze the effect of planting density on strawberry production in Mizoram condition.

MATERIALS AND METHODS

The present investigation was conducted at research orchard, Mizoram University, Aizawl, India during 2014-15. The soil of the experimental plot is sandy loam; the available N, P and K were 278.28 kg/ha, 32.54 Kg/ha and 128.53 Kg/ha with 0.68% organic carbon and the soil was acidic in reaction with soil pH 4.97. The experiment was laid out in a Randomized Block Design (RBD) with 8 treatments and 3 replications. Required quantity of FYM @ 20 t/ha was applied before transplanting of strawberry runners in the respective plots as per scheduled treatments. The recommended dose of P_2O_5 and K_2O @ 80 kg and 100 kg/ha in the form of single super phosphate and muriate of potash were applied at the time of field preparation. The recommended N @120 kg/ha, in the form of urea was applied in two split doses, half after one month of planting and the second half after flowering.

The various treatments comprising of eight different planting density were as follows: T_1: 50 × 40 cm, T_2: 40 × 40 cm, T_3 : 40 × 30 cm, T_4 : 30 × 30 cm, T_5: 30 × 25 cm, T_6 : 25 × 25 cm, T_7 : 25 × 20 cm and T_8 : 20 × 20 cm. The experiment was laid out in Randomized Block Design (RBD) with 3 replications. There were total 24 plots and, each accommodating 12 number of plants with 0.50 m distance between each plot. The total size of the experimental plot was 44.21 m^2. Standard methods were followed to take the observations on various growth and yield characters. Plant growth characters of five plants from the middle of each plot were selected randomly for observation and tagged for subsequent record. The leaf area was recorded with Li-Cor 3100 leaf area meter and expressed in square centimeter (cm^2). Twenty berries from each treatment were randomly selected to record the data on physico-chemical characters. The total soluble solids were determined with Zeiss Hand Brix Refractometer (0-32 °B). The titratable acidity, sugars and ascorbic acid were determined by method as suggested in AOAC (1995). The data obtained from different observations during field experimentation and laboratory analysis were subjected to Fisher's method of analysis of variance (ANOVA) by following completely randomized design. Significance and non-significance of the variance due to different treatments were determined by calculating the respective 'F' value and comparing with the appropriate value of 'F' at 5% probability level (Panse and Sukhatme 1985). By comparing different treatments among themselves critical difference were calculated at 5% probability level.

RESULTS AND DISCUSSION

Plant growth characters

Growth characters like plant height, plant spread, number of leaves, leaf area, number of crowns, number of runners, days to first flowering, duration of flowering, days to first fruiting, duration of fruiting, etc. were significantly influenced by different plant density.

The maximum plant height (26.85 cm), was recorded in treatment T_1 and lowest was recorded in T_8 (17.90 cm). The maximum height in low density plants might be due to the fact that wider spacing provided better space for the root distribution. It also indicated a shift in the most favourable environment in root growth consists of optimal moisture availability. This lead to increase root activities which might have been resulted in better nutrient uptake, subsequently better dry matter formation and gas exchange which helps in better plant height of the plants as compared to the closer spacing. These results are also supported by Sonkar *et al.* (2012) and Tariq *et al*. (2013) in strawberry.

From the perusal of data presented in Table 1, it is evident that, maximum E-W (37.83 cm) and N-S spread

Table 1 Effect of plant density on growth characteristics of strawberry cv. Camarosa

Treatment	Plant height (cm)	E-W spread (cm)	N-S spread (cm)	Leaves/ plant	Leaf area/ plant (cm^2)	Crowns/ plant	Runners/ plant	Days to first flowering (Days)	Duration of flowering (Days)	Days to first fruiting (Days)	Duration of fruiting (Days)
T_1	26.85	37.83	39.58	34.45	213.92	8.11	5.67	48.33	133.06	55.00	74.42
T_2	26.42	36.33	39.00	33.12	197.74	7.89	4.56	49.00	126.56	58.33	69.10
T_3	25.62	36.17	36.92	33.00	178.55	7.67	4.45	56.00	125.99	62.67	68.97
T_4	24.87	34.93	34.80	28.33	167.44	6.78	4.33	57.33	123.07	65.33	67.23
T_5	24.81	34.92	34.17	27.22	128.14	6.33	4.11	60.00	121.30	67.67	66.27
T_6	23.35	33.29	33.73	25.44	121.32	5.89	3.89	60.67	115.10	70.00	64.90
T_7	23.44	32.50	32.10	19.11	97.01	5.22	3.44	68.00	114.67	74.33	62.13
T_8	17.90	25.42	26.00	18.00	78.25	4.67	2.33	69.00	108.94	76.33	57.42
CD (P=0.05)	1.97	2.82	4.76	1.76	33.61	1.12	0.57	5.54	5.18	3.39	4.20

(39.58 cm) was recorded in T_1 and the lowest (25.42 cm and 26.00 cm) was recorded in T_8. Due to reduced interplant competition for resources by the wider spaced plants accounted for the higher canopy spread. The lower plant spread in closer spaced plants might be due to more competition for light among plants grown at higher plant density. Our study is in close conformity with the findings of Paranjpe *et al.* (2008).

The number of leaves also showed decreasing trend with increasing plant population. Among all the spacing, the maximum leaf number was recorded in T_1 (34.45) and lowest was in T_8 (18.00). The increase in leaf number in lower plant density might be due to less interplant competition in soil moisture, nutrient and light intensity at flowering and fruiting stages as compared to closer spacing with higher plant density (Ogendo *et al* 2008).

Leaf is the main site of photosynthetic activity and hence the estimation of leaf area is very important in the growth analysis of crop plants. The leaf area also showed significant variation among different spacing. The maximum of leaf area (213.92 cm^2) was recorded in T_1 while, the lowest (78.25 cm^2) was recorded in T_8. Increase in leaf area in wider spacing may be due to less competition for moisture and sunlight and hence leaf emergence reduced under very close planting owing to lower temperature inside the canopy since temperature had significant influence on leaf emergence. This might have helped in production of higher leaf area by producing wider leaves in wider spacing and narrow leaves in closer spacing. Similar results were also obtained by Sonkar *et al.* (2012).

The highest no. of crowns/plant (8.11) was recorded in wider spacing (T_1), while the lowest was recorded in low density plants with a value of 4.67, but it was statistically *at par* with T_7 (5.22). The plants grown under the higher densities produced fewer crowns and leaves as reported by Tarara (2000) and Tariq *et al.* (2013).

Among the treatments, T_1 recorded the highest no. of runners/plant (5.67) which was significantly superior to all other treatments, while the lowest was recorded in T_8 (2.33). The higher number of runners in wider spacing might be due to reduced interplant competition for soil resources. In addition, high light intensity which reportedly favours runner production could have been received under the wider spaced plants (Ogendo *et al.* 2008) and Bielinski (2013) in strawberry.

Days to flowering and fruiting, were significantly influenced by plant spacing. Among the different treatments, T_1 recorded the minimum days to first flowering (48.33 days) which was significantly lower than rest of the treatments except T_2 (49.00 days) with which it was statistically *at par*. The maximum days to first flowering was recorded in T_8 (69.00 days), Similarly, the maximum duration of flowering was recorded in T_1 (133.06 days), while, the minimum was recorded in T_1 (108.94 days). While, the significantly lowest days to first fruiting was recorded in T_1 (55.00 days), which was significantly lower than rest of the treatments except T_2 (58.33 days), with which it was statistically *at par*. The maximum days to first fruiting was recorded in T_8 (76.33 days), which was significantly higher than rest of the treatments except T_7 (74.33 days), with which it was statistically *at par*. Likewise, the maximum duration of fruiting was recorded in T_1 (74.42 days) which was significantly higher than rest of the treatments. Treatment T_8 recorded the minimum duration of fruiting (57.42 days) which was significantly lower than rest of the treatments. The early flowering and fruiting in wider spaced plants might be due to the fact that in wider spacing, more leaf surfaces exposed to light, which increased the metabolism of the plant causing early physiological maturity, flowering and subsequently fruiting. The maximum days to flowering and fruiting in closer spaced plants might be due to more interplant competition that is accepted by Niels (2009). Delayed shooting due to closer spacing was also reported by Sarrwy *et al.* (2012).

Yield attributing characters and yield

Different plant spacing has positive effect on berry set per cent of the strawberry. Among different spacing, the maximum berry set (81.17%) was recorded in T_1. Higher berry setting in plant under wider spacing might be due to greater photosynthetic activity, because of exposure of more number of leaves to sunlight, availability of poor sunlight to the lower leaves of the plant at closer spacing which on the contrast becomes a limiting factor and adversely affects the flowering and fruiting. Research finding is in close conformity with the findings of Tariq *et al.* (2013) in strawberry.

It is also evident from the data given in Table 2 that the maximum berry length (43.73 mm), diameter (36.06 mm) and weight (21.73 g) were obtained at widest spacing. At wider spacing, more space is available for uptake of all the nutrients to the fruits where they acted as sink for storing the nutrient and finally translocated to fruits which are the source of sink. These absorbed nutrients might have been utilized by the fruits as a result of which there was increase in size and weight of fruit. In addition, in wider spacing, more leaf surface is exposed to sunlight and indirectly greater amount of assimilates accumulated in the various organs of the plant leading to increased berry weight. The low fruit weight in close spaced plants might be due to less per cent radiation interception on per tree basis in closely spaced trees which led to severe competition for metabolites and caused reduction in fruit weight. Although, the closer spacing accommodate more number of plants as compared to wider spacing, but it results in overlapping of leaves (shelf shading) to their adjacent plants and intermingled of roots that increased competition for the available resources (water, light and nutrients). Similar result for fruit weight was obtained by Paranjpe *et al.* (2008) and Ahmad (2009).

The wider spacing produced more number of berries per plant and it decreased as the spacing decreases. In wider spaced plants, due to sufficient availability of natural resources, i.e. space, light, moisture and nutrients results in more carbohydrate reserves resulted better fruit number. In

Table 2 Effect of plant densities on yield attributing characters and yield of strawberry cv. Camarosa

Treatment	Berry set (%)	Berry length (mm)	Berry diameter (mm)	Berry weight (g)	Berries/plant	Total biomass (g)	Yield (q/ha)	B: C ratio
T_1	81.17	43.73	36.06	21.73	21.08	964.64	209.97	3.61
T_2	79.53	42.65	35.63	20.96	18.67	833.08	240.18	3.29
T_3	78.20	41.68	33.49	20.75	17.75	791.12	284.69	3.26
T_4	77.84	39.00	33.32	18.61	15.70	699.53	303.07	2.92
T_5	76.91	38.64	32.57	18.11	13.77	594.34	309.63	2.62
T_6	76.40	38.54	32.01	16.89	13.08	391.67	325.56	2.38
T_7	74.97	37.79	31.73	16.05	11.83	334.11	337.47	1.97
T_8	70.30	35.19	30.50	14.17	11.33	172.08	361.03	1.33
CD (P=0.05)	2.96	3.34	2.49	2.96	2.87	41.62	11.56	

addition, in wider spaced plants, due to larger plant spread with more leaf area, number of flower/plant, and per cent berry set augmented the fruit number. Study is in close conformity with the findings of Paranjpe *et al.* (2008), who also reported increase in no. of berries with the decrease in plant densities.

Observations pertaining to yield/h were found to be varied significantly. among all the treatments, the closest spaced treatment, i.e. T_8 recorded highest yield (361.03 q/ha) which was significantly higher than all other treatments while, the lowest yield of 209.97 q/ha was recorded in widest spacing, i.e. T_1. The highest yield/h in high density plants might be due to accommodation of higher number of plants per unit area. Similar results on increased yield with closer spacing have also been reported by Paranjpe *et al.* (2008), Ogendo *et al.* (2008), Ram *et al.* (2009), Sonkar *et al.* (2012) in strawberry.

The difference among the various treatments in total biomass of the plants was also found significant. Among all the treatments, the highest total biomass (964.64 g) was recorded in T_1, while, T_8 recorded the lowest value (172.08 g). The highest biomass at low plant density might be due to less interplant competition for light, nutrient and moisture which ultimately improved aeration for forming greater root system, promoted shoot nutrition uptake, and increased yield of strawberry plants (Du *et al.* 2007 and Tehranifar *et al.* 2007). Among the treatments, the highest cost benefit ratio of 1: 3.61 was recorded in T_1 followed by 1: 3.29 in T_2 as compared to the lowest of 1:1.33 in higher plant density.

Physico-chemical characteristics of fruits

An inquisition of data presented in Table 3 revealed that different plant densities have significant role on physico-chemical characteristics of the berries.

The maximum TSS (8.96%), total sugars (8.50%), reducing sugar (4.78%), ascorbic acid (67.67 mg/100g), TSS: acid ratio (11.03) and lowest titrable acidity (0.812%) was recorded in T_1 and lowest value in all the parameters and maximum acidity was recorded in T_8. Possibly at wider spacing due to higher photosynthesis and availability of metabolites because of higher interception of PAR by individual plant might have improved fruit quality (Mehta *et al.* 2006, Verma *et al.* 2009).

The higher ascorbic acid in the low density planting might be due to more light exposure and greater accumulation of photosynthates in the low density plants which might have contributed to an increase in ascorbic acid content in berry. Higher acidity in higher plant population may be due to shade effect where sugar conversion from organic acid is hampered due to lack of sufficient light. The result was in consonance with Tripathi *et al.* (2000) who reported that the ascorbic acid and acidity was found higher in wider spacing.

Further, under high planting density besides the changes in the quantity and quality of intercepted light, the partitioning of assimilates between vegetative and reproductive shoots may be responsible for the higher TSS

Table 3 Effect of plant densities on Quality parameters of strawberry cv. Camarosa

Treatment	TSS (°Brix)	Acidity (%)	TSS: acid ratio	Total sugars (%)	Reducing sugar (%)	Non-reducing sugar (%)	Ascorbic acid (mg/100 g)	Anthocyanin (mg/100g)
T_1	8.94	0.812	11.03	8.50	4.78	3.97	67.67	38.53
T_2	8.78	0.819	10.72	8.39	4.61	4.01	65.56	37.74
T_3	8.69	0.825	10.53	8.45	4.55	4.13	63.11	36.48
T_4	8.34	0.830	10.05	8.21	4.44	3.99	60.33	35.21
T_5	8.25	0.834	9.90	7.97	4.40	3.79	60.11	35.17
T_6	8.19	0.836	9.81	8.00	4.35	3.87	58.89	33.87
T_7	7.84	0.841	9.32	7.66	4.15	3.71	57.11	30.19
T_8	7.80	0.848	9.20	7.48	4.05	3.63	55.33	28.08
CD (P=0.05)	0.44	0.017	0.54	0.45	0.26	NS	2.95	2.98

(Policarpo *et al.* 2006). The result was in consonance with Sonkar *et al.* (2012) who reported that the TSS was found higher in wider spacing.

The higher TSS: acid ratio was obtained in low density plants or wider plant spacing. Similar result was obtained by Kundu (2007) who reported that TSS: acid ratio of fruits were higher in the fruits from the plants under wider spacing.

Moreover, higher reducing, and total sugar in the wider spacing may be due to less conversion of sugar from starch. The present study gets ample support from the work of Seyyedi *et al*. (2010) who also recorded higher total sugar with wider plant spacing.

Different treatments indicated significant to highly significant difference in anthocyanin content of the fruits (Table 3). The maximum anthocyanin content (38.53 mg/100g), was recorded in wider spacing (T_1), while lowest was recorded in closer spacing (28.08 mg/100g).

Conclusion

From the results of present investigation, it can be concluded that, among the various planting densities of strawberry, a spacing of 50 × 40 cm is the best for improving growth, yield and quality in 'Camarosa' strawberry.

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