Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2020; 9(1): 229-234
Received: 13-11-2019
Accepted: 15-12-2019

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Effect of high density planting systems on growth, yield and quality of mango (*Mangifera indica* L) cv. Amrapali after rejuvenation

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Abstract
Mango trees grown under high density planting system show a gradual decline in yield after 10-11 years due to overcrowding of canopies. It results in poor utilization of available resources and ultimately low productivity and profitability. So, to maximize the yield per unit area an experiment was conducted on an old senile, rejuvenated high density orchard during the year 2011-12 under experimental area of BAU, Sabour with objective to find out the effect of high density planting systems on growth, yield and quality of mango cv. Amrapali The five different plant densities, *viz*. T_1- square system, T_2 -hedge row system, T_3 -double hedgerow system, T4 -paired planting and T_5 -cluster planting system were taken as treatment. Among them paired planting system performed best in respect to yield (8.21kg/tree.).Thus, rejuvenation of high density planting of Amrapali mango orchard improves the growth yield and quality of plants by modifying the canopy architecture and canopy microclimate.

Keywords: High density planting, mango, rejuvenation, micro-climate, yield, quality

Introduction
Mango (*Mangifera indica* L.) belongs to family Anacardiaceae and originated in Indo- Burma region. Due to its acceptability it is patronized by all people, rich and poor alike.The sweet fragrance, beautiful colour delicious taste and rich nutritional value have given this a superior place in national and international markets. Mango occupies a important place amongst the fruit crops grown in India, because of its great utility and it is known as the king of fruits in India. But its productivity is very low due to several factors. One of the reasons for the low productivity of mango in India is traditional planting *i.e.* 10- 12m distance. The high density planting in mango is recommended to make the maximum use of land and to achieve higher yields per unit area. Mango is a tree which is spreading in nature. If it is planted in high density and are not pruned selectively, then after 11-12 years of fruiting, the yield declines due to overcrowding - of branches and poor light penetration. As a result, leaf sprout is decreased, photosynthetic activity remains low and high incidence of pests and diseases occur due to high relative humidity inside the canopy (Lal *et al.* 2007) [1]. It results in poor utilization of available resources and ultimately low productivity and profitability. Previously several studies have been conducted on pruning in the mango tree in relation to growth, fruit set and yield in pruned trees (Schaffer *et al.*,1989; Lal *et al*., 2000; Mohan *et al.*; 2001; Shinde *et al.*; 2002; Shaban *et al.*; 2009; Sharma *et al.*; 2006) [2, 3, 4, 5, 6, 7]. But earlier studies received only little attention. However, beyond the routine information there is an increasing interest among the researchers to know the effect of high density planting and pruning on plant growth, yield and quality of mango trees after rejuvenation. Hence, the present investigation was carried out to find out the effect of high density planting systems on growth, yield and quality of Amrapali mango tree after rejuvenation.

Materials and methods
The field experiment was conducted in the permanent experimental site of the Bihar Agricultural College, Sabour, Bihar Agricultural University, Sabour, Bhagalpur, India (25º15'40"North 87º2'42"East, Elevation 46 m). The experiment was conducted during 2012-13 on old and senile mango orchard of cv. Amrapali, planted in different planting systems. The climate of this place is tropical to subtropical of slightly semi-arid in nature and is characterized by very dry summer, moderate rainfall and very cold winter. December and January are usually the coldest months when the mean temperature normally falls as low as 21 ^{0}C, whereas; May and June are the hottest months, having the maximum average

temperature of 38.6 ^{0}C. The normal rainfall is about 1207 mm (10 year average) which is unimodel type mostly precipitating during middle of June to Middle of October during cropping season, the maximum and minimum temperature were recorded in between 37.6 ^{0}C and 21.20 ^{o}C, respectively. During the study period, average temperature was ranged from 9.2 ^{0}C to 21.2 ^{0}C during winter and 30.8 ^{0}C - 37.6 ^{0}C during summer with annual rainfall 72.56 mm and 80.8% relative humidity. Flowering normally takes place in spring season, commencing from February to March. Fruit harvest peaks in 1st week of August.

The Experiment was carried out on rejuvenated plant planted in 1992 at Bihar Agricultural College Sabour, and become overcrowded and unproductive during advancement of plant. Hence, rejuvenation pruning was practiced in July, 2009 with the help of mechanized pruner from uniform height of 1.5 meters. Thinning was done during 2010 and 2011 as per recommended practices. All the trees were maintained under uniform cultural practices during the course of investigation. The experiment was laid out in Randomized block design with five treatments and five replications. In the treatments there were 5 plantings system having different plant densities *viz*. T_1- square system (1600 plants/ha and 9 plants/plot), T_2- hedge row system (2670 plants/ha and 15 plants/plot), T_3- double hedge row system (3556 plants/ha and 20 plants/plot), T_4- paired planting (2133 plants/ha and 12 plants/plot), and T_5- cluster planting (2844 plants/ha and 16 plants/plot). Normal planting distance of 2.5m x 2.5 m apart and half normal distance of 1.25 m x 1.25 m apart were followed in this trial. Normal planting distances was maintained in square system of planting. In hedge row system, distance between plant and plant and row to row was maintained 1.25 m and 2.5 m respectively. While in double hedge row system, 2 rows of hedge were planted at half normal distance. In case of paired planting, pairs of 2 plants at the distance of 1.25 m x 1.25m were maintained. Cluster planting system accommodated cluster of 4 plants 1.25 m x 1.25 m apart.Net area under each plot was 56.25 m^2 and total experimental area was 2406 m^2 i.e.0.141 ha.

Observation recorded

1. Growth characters

(a) Shoot length

Newly emerged shoots on individual branch, in all directions, *i.e.* East, West, North and South was tagged. The observations on shoot length were recorded at six months. It was calculated and expressed in per cent increase.

(b) Primary shoots girth

The diameter of the primary shoot was taken at six month intervals at the time of first and final observation of the experiment and expressed in per cent increase.

(c)Trunk girth

The diameter of the trunk above the ground was taken at the start and end of the experiment and mentioned as per cent increase.

(d) Canopy volume

To calculate the canopy volume, plant height was measured by measuring stick and canopy spread in both directions by measuring tape. The canopy volume was calculated by the formula derived by Samaddar and Chakrabarti (1988) [8] as given under:

Volume of canopy = 4/3 π r2 h (m3)

Where, r = diameter/2

H = Plant height (m)

The canopy diameter was calculated from the average of five readings in the following manner

1. Spread of canopy (North to South)
2. Spread of canopy (East to West)
3. Plant height.

2. Flowering and fruiting characters

(a) Time of full bloom

The time of full bloom period was counted from the panicle emergence to more than 50 percent flower bloomed in the panicle and it was expressed in days.

(b) Number of panicles per - plant

The total number of panicles was counted in individual tree.

(c) Panicle length

The average of five tagged panicles was measured by measuring scale from the apex of panicle to base of panicle.

(d) Number of fruits per panicle at maturity

The number of fruits per panicle was counted on each shoot at the time of full maturity of the fruit.

(e) Number of fruits per tree

Number of fruits on each tree was counted and their means was calculated.

(f) Fruit yield

To observe the fruit yield per plant, the fruit weight was multiplied by number of fruit per pant and it was expressed in kg per plant.

3. Micro-climate

(a) Light penetrance

Light penetrance was recorded at 0-1 m from crotch in North-South and East-West direction by the use of portable digital lux meter.

(b) Canopy temperature

It was recorded from the middle of the canopy by using infrared thermometer Euro lab 550 and calculated in degrees celsius.

(c) Canopy relative humidity

The canopy RH (%) was recorded in middle of canopy by using Humidity Dew Point Meter H.D-3008.

4. Physical parameters of fruits

(a) Fruit weight

Weight of five matured ripe fruits was recorded by weighing the samples on an open pan balance. Average weight of a fruit was calculated and expressed in grams.

(b) Fruit size

Fruit size in terms of length from the apex to base of fruit - and maximum breadth was measured by vernier calipers and expressed in terms of centimeters.

(c) Volume of fruit

The data on the fruit volume was recorded by water displacement method. Fruit volume was expressed in terms of cubic centimeter(cc).

(d) Pulp: stone ratio
This was calculated by the weighing the ripen fruits separately, followed by pulp and stone after peeling of fruit**.**

5. Biochemical parameters of fruits
(a) Total soluble solids (TSS)
It was determined with the help of refracto meter and the value was corrected at 20 ^{0}C with the help of temperature correction chart and expressed in ^{0}Brix (AOAC 1975) [9].

(b) Titrable Acidity
Acidity was determined by titrating a known quantity of blended (homogenized) pulp sample, diluted with distilled water against standard sodium hydroxide solution (1N), using phenolphthalein as indicator. The results obtained were expressed as percentage of citric acid.

(c) Reducing and Total Sugars
The sugar was estimated as per method suggested by Ranganna (1986) [10].

(d) Total carotenoids
The total carotenoids were analyzed by the method given by Roy (1973) [11]. The carotenoids were extracted in a pestle and mortar, containing a mixture of petroleum ether and acetone in a ratio of 3:1. The known volume was made with same petroleum ether and acetone mixture. The total carotenoid in the extract was determined by using spectrophotometer at 450 nm. The results were expressed in terms of total carotenoids (mg g^{-1}).

Statistical analysis
The data generated from the experiment were analyzed by following factorial RBD (Panse and Sukhatme (1984) [12].

Results and Discussion
After one year of rejuvenation, plants under high density planting system was recorded a profuse vegetative growth in all directions. Therefore thinning was done as per recommended practices in second year. The observations were recorded in third year of rejuvenation, which showed quite interesting changes in plant growth and yield.

1. Growth characters
High density planting system after rejuvenation had significant effect on vegetative growth of plants. (Table- 1, 2).

(a) Shoot length (%)
Cluster planting system showed highest percentage increase in shoot length in both direction East-West (21.06) and North-South (21.89) followed by paired panting system and minimum increase in double hedge row panting system.

(b) Primary branch girth (%)
The maximum increase in primary branch girth recorded in square planting system (2.13%) followed by cluster planting system (1.39%) and double hedge row planting system (1.38%), whereas; minimum increase reported in paired planting system (1.22%)

(c) Trunk girth (%)
Maximum increase in trunk girth was reported in cluster planting system (1%) followed by double hedge row panting system (0.85%) and minimum was reported in square panting system (0.65%)

(d) Canopy volume (cm^3)
Non-significant variation was reported among the treatment. Highest volume recorded in square planting system (19.87 cm^3) followed by double hedge row (19.18 cm^3) while lowest canopy volume reported in paired panting system (17.60)
It is known fact that at lower plant density, good growth is recorded due to availability of more space and less competition among the adjacent plants, which helped the individual plant to utilize more water, nutrition, air and light. While in higher plant density, plant canopies overlap/intermingle in to the rows, reducing light incidence on leaves. Consequently, greater part of the canopy contributes little or nothing to the synthesis of carbohydrates necessary for growth. It is evident from the present findings that as the area for each plant was decreased, there was a decrease in length of terminal shoots, trunk girth, primary shoot girth and canopy volume. The present work is in confirmation with findings of Ram & Sirohi 1991[13], and Nath *et al.*, 2007 [14].

Table 1: Effect of high density planting systems on shoot length of Amrapali mango after rejuvenation

Treatments	Shoot length (cm) (At the time of bud break)		Shoot length (cm) (After harvesting)		Percent increase in shoot length	
	North-South	East-West	North-South	East-West	North-South	East -West
T_1	115.32	114.12	136.36	135.16	18.25	18.50
T_2	117.06	101.82	136.78	122.64	16.82	20.53
T_3	117.44	118.64	138.96	142.14	18.23	19.80
T_4	98.36	108.94	122.14	129.3	23.87	18.71
T_5	116.08	106.30	149.44	128.48	21.89	21.06
CD at 5%	3.512	8.734	17.50	8.069	3.538	3.53

Table 2: Effect of high density planting systems on growth of primary branches, trunk girth and canopy volume of Amrapali mango

Treatment	Primary branch girth (cm)		Per cent increase	Trunk girth (cm)		Per cent increase (%)	Canopy volume (cm^3)
	At the time of bud break	At the time of harvesting		At the time of bud break	At the time of harvesting		
T_1	31.841	32.511	2.13	54.848	55.192	0.651	19.87
T_2	30.568	30.978	1.38	54.1928	54.6384	0.856	19.18
T_3	31.938	32.354	1.32	48.462	48.864	0.848	17.96
T_4	32.006	32.39	1.22	55.828	56.244	0.751	17.60
T_5	31.267	31.691	1.39	49.396	49.892	1.000	17.63
CD at 5%	6.552	6.613	0.305	7.0598	6.989	0.155	1.390

2. Flowering and fruiting characters

Rejuvenation of high density mango plants showed significant variation on flowering and fruiting characters of mango cv. Amrapali (Table 3).

(a) Time of full bloom (Days)

The more time was taken for full bloom in double hedge row planting system - T_3 (23.60 days) which was found at par with cluster planting system-T_5 (22.80 days) followed by paired planting system- T_4 (22.60 days) and hedge row planting system- T_2 (22.20 days).The minimum time for full bloom was observed in square planting system -T_1 (21.40 days).The more time was taken for full bloom period recorded highest in double hedge row planting system due to narrow spacing and more number of tree accommodation in per unit area resulted low penetration of light inside the canopy (Sharma *et al.*, 2006 and Singh *et al*; 2010) [15, 16].The increase in plant population per unit area showed delay in flower emergence resulted less flowering with lower fruit set.

(b) Panicle length panicle

The planting system, double hedge row (T_3) performed better in respect of maximum panicle length (27.66 cm) which was found at par with cluster planting system- T_5 (25.92 cm), paired planting system-T4 (25.13 cm) and square planting system- T_1 (24.45 cm) whereas, the minimum panicle length at the time of anthesis was observed in hedge row planting system- T_2 (23.27 cm). The panicle length noted maximum in double hedge row planting system due to lower number of panicles and higher vegetative shoot than reproductive shoot. (Singh *et al;* 2010) [16]

(c) Number of panicles per tree

Highest number of panicles per tree was counted in paired planting system- T_4 (21.62) which was observed at par with double hedge row planting system- T_3 (16.71), followed by hedge row planting system- T_2 (16.25) and square planting system- T_1 (14.77), whereas; the minimum numbers of panicles per tree were obtained in cluster planting system- T_5 (13.76). The highest number of panicles per tree and fruit yield (kg/tree) found in paired planting. It might be due to low canopy volume (Singh *et al.*; 2010) [16]

(d) Number of fruits per panicles at maturity

Paired planting system produced more number of fruits per panicle (3.07 fruits) at the time of fruit maturity which was exhibited at par planting system of hedge row T_2 (2.36), followed by cluster planting system- T_5 (2.35) and double hedge row planting system- T_3 (2.13), whereas; minimum no. of fruits per panicles at fruit maturity stage was - noticed in square planting system0 T_1 (1.97). The paired planting system showed more fruits per panicle due to higher light penetrance inside the canopy (Singh *et al.*; 2010). [16]

(e) Number of fruits per tree

The maximum number of fruits per tree was recorded in paired planting system- T_4 (38.47) which was found at par with the cluster planting system -, T_5 (37.36), -whereas; the minimum number of fruits per tree was seen in double hedge row planting system- T_3 (21.42). Plants grown under lower planting density produced flowers in all quadrants of the canopy, while those grown under increasing planting density (1600, 2670, 3556, 2133, 2844 plants/ha) produced flowers only in the two quadrants of the canopy between the rows, but not into the rows. Consequently, there was reduction in the number of fruits per plant (Nath *et al.*; 2007) [14].

(f) Fruit yield (-kg/tree)

The maximum fruit yield (kg/tree) was produced in paired planting system- T_4 (8.21kg/tree), which was observed at par with cluster planting system- T_5 (7.34 kg/tree-. – The more fruit setting in plants under paired planting system seems to be due to lower canopy volume, greater mobility of nutrients because of exposure of more number of leaves to sun light– whereas the minimum fruit yield was - was recorded in double hedge row planting system- T_3 (3.81 kg/tree). - This was happen due to un-availability of proper sunlight into the inner side of the canopy - at close spacing becomes a limiting factor and it adversely affected the flowering and fruiting and consequently yield. The smaller the area available to plants, the higher the tendency to decrease the number and percentage of flower shoots- and yield (Singh *et al*., 2010) [16]

Table 3: Effect of high density planting systems on flowering characters of Amrapali mango after rejuvenation

Treatments	Time of Full bloom (Days)	Panicle length at anthesis (cm)	Number of panicles per tree	Number of fruits per panicles at maturity	Number of fruits per tree	Fruit yield (kg/tree)
T_1	21.40	24.45	14.77	1.97	34.18	6.90
T_2	22.20	23.27	16.25	2.36	31.3	6.83
T_3	23.60	27.66	16.71	2.13	21.42	3.81
T_4	22.60	25.13	21.62	3.07	38.47	8.21
T_5	22.80	25.92	13.76	2.35	37.36	7.34
CD at 5%	NS*	1.97	2.02	0.25	4.27	0.98

NS = Non-Significant*

3. Micro climate

The microclimate of a tree canopy is the major indicator for the growth of plants and its fruitfulness. A healthy micro-climate of a tree-canopy resulted in healthy shoot for bearing of fruits. In this experiment significant difference were recorded in different planting systems (Table 4.)

(a) Light penetrance (Klux)

The maximum light penetrance (Klux) was observed in square planting system-T_1 (6.92 Klux) in North-South direction whereas; in East-West direction showed maximum light penetrance in square planting system-T_1 (5.25 Klux) due to wider spacing. The minimum light penetrance was noticed in hedge row planting system, T_2 (4.08) due to closed spacing (Singh *et al.*, 2010) [16]

(b) Canopy temperature (^{O}C)

The canopy temperature was found significantly differ among the different treatments. The maximum canopy temperature (38.12 ^{0}C) was recorded in paired planting system-T_4 due to lower canopy volume and it is followed by square planting system, T_1 (37.85 ^{0}C), hedge row planting system-T_2 (37.20

^{0}C) and double hedge row planting system, T_3 (37.15 ^{0}C). The minimum canopy temperature (^{0}C) was recorded in cluster planting system-T_5 (36.60 ^{0}C). (Sharma *et al.*, 2006 [17].

(c) Relative canopy humidity (%)

The relative humidity of canopy was observed maximum under the treatment T_2 (hedge row planting system) and T_3 (double hedge row planting system) with having same footing value of 67.11%., which was found statistically at par with T_5 (cluster planting system) and T_4 (paired planting system) with value 66.97% and 66.70%. The minimum relative humidity of canopy was noted in treatment T_1 (square planting system) with value 66.59%. This might be due to overcrowding of canopies and poor light interception. This observation was confirmed by the findings of sharma *et al.*, 2006 [17].

Table 4: Effect of high density planting systems on micro-climate of Amrapali mango after rejuvenation

Treatment	Light penetrance (Klux)		Canopy temperature (^{0}C)	Canopy relative humidity (%)
	North-South	East-West		
T_1	6.92	5.25	37.85	66.59
T_2	5.79	4.08	37.20	67.11
T_3	5.05	4.11	37.15	67.11
T_4	4.80	4.85	38.12	66.71
T_5	5.55	4.58	36.60	66.97
CD at 5%	0.73	0.48	1.26	1.10

4. Physical parameters of fruits

The data presented in Table-5, clearly indicates that rejuvenation of high density mango plants showed significant differences regarding the physical parameters of fruits except fruit weight.

(a) Fruit weight (g)

The highest fruit weight (218.00 g) was recorded in T_2 (hedge row planting system), it might be due to higher accumulation of carbohydrate because of higher photosynthetic activity in this planting system. It is followed by paired planting system-T_4 (203.60g) and cluster planting system-T_5 (197.40 g). The minimum fruit weight (192.80 g) was observed under the treatment double hedge row planting system (T_3).

(b) Fruit size (cm)

The fruit size was recorded maximum (17.76 cm × 6.11cm) in T_4 (paired planting system), followed by T_5 (cluster planting system), with value of 17.45cm x 6.34cm). While minimum fruit size (10.44 cm x 6.13 cm) was noted in T_3 (double hedge row planting system), It might be due to overcrowding of canopies and poor light interception. The maximum fruit size was recorded in paired planting it might be due to low canopy volume which allow the high penetrance of light resulting in to high assimilation light energy in to carbohydrates. (Singh *et al.*, 2010) [16]

Table 5: Effect of high density planting systems on fruit physical quality parameters of Amrapali mango after rejuvenation

Treatments	Average fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Volume of fruit (cm^3)	Pulp-stone ratio
T_1	202.80	12.66	6.45	201.04	4.70
T_2	218.00	12.78	6.52	207.65	5.59
T_3	191.80	10.44	6.13	178.05	5.86
T_4	203.60	17.76	6.11	180.85	4.15
T_5	197.40	17.45	6.34	162.00	4.70
CD at 5%	28.25	1.29	0.83	15.82	0.57

(c) Fruit volume (CC)

The planting system hedge row (207.65cc) showed highest fruit volume and proved its superiority over rest of the treatments, however, it was followed by square planting system-T_1 (201.04cc), paired planting system-T_4 (180.85 cc) and double hedge row planting system-T_3 (178.05 cc). The minimum fruit volume (162.00 cc) was measured in cluster planting system-T_5, fruit shape, size and volume is related to canopy temperature, paired planting system showed higher canopy temperature due to lower canopy volume. (Singh *et al.*; 2010) [16]

(d) Pulp: stone ratio

Double hedge row planting system-T_3 computed highest pulp: stone ratio (5.86) and proved its superiority over rest of the treatments, and it was followed by hedge row planting system-T_2 (5.59). The minimum pulp: stone ratio (4.15) was noticed in paired planting system-T_4. The double hedge row planting system showed maximum pulp/stone ratio it might be due to low fruiting with higher vegetative growth (Singh *et al;* 2010) [16].

5. Biochemical parameters of fruits

(a) Total Soluble Solid (^{0}Brix)

It is evident from the Table-6 that rejuvenation of high density planting systems showed non-significant effect on T.S.S while maximum total soluble solid was noticed in paired planting system-T_4 (22.8 ^{0}Brix) followed by square planting system-T_1 (22.64 ^{0}Brix) and hedge row panting system-T_5 (22.20 ^{0}Brix) whereas, the planting system double hedge row (T_3) exhibited minimum TSS content (21.72^{0}Brix).

(b) Titrable acidity (%)

Rejuvenation of high density planting systems showed non-significant effect on acidity. This could be due to smaller size of fruit on less spaced trees while maximum titrable acidity was titrated in hedge row planting system (T_2) and cluster planting system with same footing value of 0.23%, whereas; the lowest value (0.20%) was noted under the treatment of square planting system (T_4).

(c) Reducing sugars (%)

High density planting systems had significantly affected the reducing sugars. The maximum reducing sugar (5.07%) estimated under paired planting system-T_4 followed by double hedge row planting system (T_3) with having value of 5.13%. While minimum of 4.47% was reported in hedge row planting system -T_2.

(d) Total sugar (%)

The maximum total sugar of 13.42% was obtained in hedge row planting system (T_2) followed by paired planting system-T_4 with value of 13.06%. The lower value of 11.13% was noticed in double hedge row planting system T_3.

(e) Total carotenoids

The maximum total carotenoids of 18.88 mg was obtained in hedge row planting system (T_2) followed by square planting system (T_1) with having value of 17.54. The lowest value of 16.68 mg was noticed under the planting system double hedge row (T_3).

Similar findings were recorded in 'Amrapali' by Singh *et al.*, 2001 [18]. Increasing planting density did not change significantly most variables related to fruit quality soluble solids (^{0}Brix) and acidity. Therefore in present study, high

density had little influence on fruit quality as reported in other studies with mango (Ram and Sirohi, 1991 and Nath *et al.*, 2007) [13, 14]. But as far as total sugar and carotenoids are concerned, in the present study significant effect was focus among the treatments. Fruits from tree in narrow spacing showed higher value of sugars and carotene. According to Policarpo *et al.*, 2006 [19] under high density planting, due to changes in the quality of intercepted light, the portioning of assimilates between vegetative and reproductive shoots might be responsible for the effects on fruit quality.

Table 6: Effect of high density planting systems on fruit biochemical parameters of Amrapali mango after rejuvenation

Treatment	TSS (^{0}Brix)	Acidity (%)	Reducing sugar (%)	Total sugar (%)	Total carotenoids (mg/100 g^{-1})
T_1	22.64	0.21	4.71	12.31	17.54
T_2	22.2	0.23	4.47	13.42	18.88
T_3	21.72	0.22	5.13	11.13	16.68
T_4	22.84	0.20	5.07	13.06	17.46
T_5	22.20	0.23	4.84	11.50	17.32
CD at 5%	NS*	NS*	0.35	0.66	2.29

NS = Non-Significant*

Conclusion

From the results and discussion made so far it can be inferred that rejuvenation of high density planting of Amrapali mango orchard can improve the growth yield and quality of plants by modifying the canopy architecture and canopy microclimate.

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