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Effect of high density planting systems on growth of mango (*Mangifera indica* L.) var. Amrapali

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Abstract
The present field experiment entitled "Effect of high density planting systems on growth of mango (*Mangifera indica* L) var. Amrapali" was carried out at the horticulture farm of Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj during the year 2023 to study the performance of different varieties for vegetative growth, reproductive growth, fruit physical parameters, yield parameters, quality of fruits and organoleptic parameters under high density planting. The experiment comprised of five treatments with six replications in randomized block design. The result revealed that, Amrapali mango plants recorded the maximum plant height (2.32 m), number of tertiary leaves per plant (24.99), spread of plant (N-S) and E-W (216.58 and 206.63 cm), Stem girth (6.86 cm), total number of panicle per plant at initial flowering (9.73), length of panicle (40.22 cm), width of panicle (28.20cm), fruit set (7.66%), fruit weight (386 g), fruit length (13.38 cm), fruit width (7.92 cm), number of fruits per plant (48.10), yield per plant (747.78 g), yield per plant (10.15 kg), and number of fruits yield per ha (16.91 t) were recorded in plants in the treatment T6. The quality parameters mango plants TSS (16.23 °B), reducing sugar (6.22), non-reducing sugar (15.92) were recorded in plants in the treatment T_6. The maximum cost of cultivation (Rs.), gross return, net return and benefit cost ratio was recorded in the Treatment T6 with cost of cultivation Rs.71970, Gross return Rs. 338200 and Net Return Rs 266230 and Benefit cost ratio Rs 3.70. The application of T6 (R.D.F + F.Y.M) was found to best in terms of growth parameter, quality and found the best treatment on basis off economics of mango.

Keywords: FYM, cocopeat, vermicompost, amarpali

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 an 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.

Mango (*Mangifera indica* L.) is one of the most economically important fruit crops globally, prized for its delicious flavour, nutritional value, and significant contribution to agricultural economies. Among the various cultivars, 'Amrapali' stands out for its superior taste, attractive appearance, and adaptability to different agro-climatic conditions. In recent years, optimizing cultivation practices to enhance mango productivity and quality has become imperative, particularly with the increasing demand and competitive market dynamics.

Traditional mango orchard management typically involves wide spacing between trees, allowing ample room for growth and development. However, this conventional approach may not always be the most efficient in terms of land utilization and resource allocation. High-density planting (HDP) systems offer a promising alternative by maximizing orchard productivity through closer spacing of trees, thereby potentially increasing yield per unit area while optimizing resource use efficiency.

The 'Amrapali' mango variety, known for its compact growth habit and relatively small canopy size compared to other cultivars, presents an intriguing opportunity for evaluation under high-density planting systems. The adoption of HDP could potentially influence various aspects of mango growth and development, including tree architecture, canopy management, fruit yield, quality attributes, and overall orchard management practices.

This thesis aims to investigate the effect of high-density planting systems on the growth parameters of 'Amrapali' mango. By conducting empirical research and comparative analysis, this study seeks to elucidate how different planting densities influence vegetative growth, flowering patterns, fruiting behavior, nutritional status, and water and nutrient utilization efficiency of 'Amrapali' mango trees. Moreover, the economic feasibility and sustainability implications of adopting HDP for 'Amrapali' mango cultivation will be critically assessed.

Through a comprehensive examination of agronomic practices, physiological responses, and yield outcomes, this research endeavors to provide valuable insights into optimizing mango orchard management strategies. The findings are expected to contribute not only to academic knowledge but also to practical recommendations for mango growers, extension services, and policymakers aiming to enhance productivity and profitability in mango cultivation, particularly with the 'Amrapali' variety.

Benefit of Amarpali Mango

Mangos contain antioxidants like quercetin, fisetin, isoquercitrin, astragalin, gallic acid, and methyl gallate. All of these things protect our bodies from breast cancer, colon cancer, prostate cancer, and leukaemia. Mangoes have a lot of vitamin C, fibre, and pectin, which makes them a great fruit for lowering your cholesterol level. Mangoes are also good for you because they clean your skin from the inside out. It gets rid of pores and makes your skin shine. So, eat mangoes to have beautiful skin.

Since mangoes are high in tartaric and malic acid and have a small amount of citric acid, they help keep the alkaline reserve of our bodies stable. Mango has a lot of vitamins and essential nutrients, so eating one mango makes you feel fuller. Also, because it is full of fibre, it helps the digestive system work better and burns extra calories. In turn, this helps people lose weight. Mangoes also have a lot of vitamin A, which makes them a great fruit to help your eyesight. It also keeps eyes from going blind at night and getting dry. Mangos have enzymes that help break down the protein in the body. Mangoes are full of fibre, which helps digestion and keeps many stomach diseases at bay.

Materials and Methods

The present investigation was carried out in the department of Horticulture, Sam Higginbottom Institute of Agriculture, Technology and Sciences which is located in Prayagraj and it is situated in the south-east part of Uttar Pradesh 2023- 24 India. Prayagraj falls under agroclimate zone IV which is named as "middle Gangetic plains" the site of experiment is located at 25.57º N latitude 81.51º E longitude and 98 meter above the sea level the temperature falls down as low as 4-5ºc during winter, the average rainfall in this area is around 798.900 mm annually with maximum concentration during July to September with few showers and drizzles in winter also.

Randomized Block Design was used to set up the experiment, and six treatments were reproduced three times. The six treatments consist of T_0 Control (soil), T_1 cocopeat, T_2 FYM, T_3 RDF (20 t/ha.), T_4 Cocopeat + FYM, T_5 Cocopeat +RDF, T_6 FYM + RDF. Effect of potting media were applied at the time of seed sowing and observations were recorded on Germination percentage, Number of leaves, Plant height, Leaf length and stem Diameter.

Treatment	Treatment Composition
T_0	Control
T_1	cocopeat
T_2	FYM
T_3	RDF (20 t/ha.)
T_4	Cocopeat + FYM
T_5	Cocopeat +RDF
T_6	FYM + RDF

Observations Recorded

The following observations were recorded and average was computed at growing successive stages.

Vegetative Growth parameters

The different growth parameters were measured at 90 days interval from each replication of each treatment and average was calculated.

Plant height (m)

Plant height was measured from ground level to the tip of the plant with the help of measuring tape at three months interval and expressed in meter.

Stem girth (cm): Plants were marked with paint at collar region above the ground and girth was measured by using verniar calipers and expressed in centimeters.

Plant spread (cm): The plant spread was measured by taking horizontal distance from one end of the canopy to the other end in both directions *viz.*, North-South and East-West with the help of measuring tape and it was expressed in centimeters.

Number of tertiary branches

The number of tertiary branches was recorded by counting the branches developed on secondary branches.

Reproductive parameters

The following reproductive parameters were recorded from flower emergence to fruit setting.

Total number of panicles per plant

The number of panicles per plant was recorded by counting panicles physically at initial stage of flowering, 50 per cent of flowering and completion of flowering of plants.

Length of panicle (cm)

Randomly the length of panicle at full growth stage was measured at anthesis from the shoot apex to that of panicle apex and an average values was expressed in centimeter (cm).

Width of panicle (cm)

The width of the panicle was measured at the widest part of panicle at anthesis stage with the help of meter scale and expressed in centimeters.

Organoleptic evaluation

The ripe mango fruits of five varieties were subjected to organoleptic evaluation. The Organoleptic characters like Fruit colour, taste, aroma and over all acceptability was evaluated by a panel of judges consisting of teachers and post- graduate students of Department of Horticulture, on a nine point hedonic scale using the score card. The mean score given by panelists were used for statistical analysis (Ranganna, 2003).

Economics of Cultivation

Cost of cultivation (Rs ha^{-1})

The cost of the inputs hat was prevailing at the time of their use was considered to work out the cost of cultivation which is given in rupees per hectare.

Gross Income (Rs.)

Gross income was calculated based on the prevailing market price for the produce.

Net income (Rs)

The net income per hectare was calculated on the basis of income and cost of cultivation per hectare as follows:

Net income = gross income - cost of cultivation

Benefit to cost ratio

The benefit to cost ratio was worked out by using the following formula:

$$\text{Benefit : cost ratio} = \frac{\text{Net income (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

Result and Discussion

It is evident from the Table 4.1 that the plant height was found significant among the treatments. There was a continuous increment in growth up to 6 months after pruning in all the treatments.

The interpretation of data for plant height revealed significant difference among the treatments at different months after pruning. Maximum plant height after pruning, at 3 months after pruning (MAP) and 6 MAP was recorded in T_6 (1.83 m, 2.06 m and 2.32 m respectively) which is followed by T_5 (1.81 m, 2.03 m and 2.27 m respectively) and T_3 (1.77 m, 1.96 m and 2.16 m respectively) and they are *on par* with each other. The minimum plant height after pruning, 3 MAP and 6 MAP was recorded in T_0 (1.25 m, 1.40 m and 1.55 m respectively).

Plant height is increased by the mixing of FYM and cocopeat. These are rich in essential nutrients like nitrogen, phosphorus, and potassium, which are crucial for the growth of mango plants and helps in improves soil structure, increasing its ability to retain water and nutrients and enhances microbial activity in the soil, promoting better nutrient availability and uptake by the plant.

Table 1: Effect of high density planting systems on plant height (m) of mango

Treatments	Plant height (m)		
	After pruning	3 MAP	6 MAP
T_0	1.25	1.4	1.55
T_1	1.4	1.55	1.71
T_2	1.59	1.76	1.95
T_3	1.77	1.96	2.16
T_4	1.64	1.87	2.04
T_5	1.81	2.03	2.27
T_6	1.83	2.06	2.32
Ftest	S	S	S
SEm±	0.08	0.09	0.11
CD @ 5%	0.03	0.03	0.04
CV (%)	1.61	1.86	1.31

It is evident from the Table 4.2 that the stem girth was found statistically significant among the variety of mango.

Mango trees treated with FYM and RDF are better equipped to withstand environmental stresses such as drought or fluctuations in nutrient availability. This stress resilience supports consistent growth rates, including the development of thicker stems in high-density planting conditions.

The data recorded for stem girth at different months after pruning differed significantly. Maximum stem girth at after pruning, 3 MAP and 6 MAP was recorded in T_6 (5.72 cm, 6.27 cm and 6.86 cm respectively) which was followed by T_5 (5.61 cm, 6.09 cm and 6.63 cm respectively) and T_3 (5.41 cm, 5.87 cm and 6.32 cm respectively) and they are *on par* with each other. The minimum stem girth after pruning, 3 MAP and 6 MAP was recorded in T_0 (3.56 cm, 3.92 cm and 4.02 cm respectively).

Table 2: Effect of high density planting systems on stem girth (cm) of mango

Treatments	Stem girth (cm)		
	After pruning	3 MAP	6 MAP
T_0	3.56	3.92	4.02
T_1	4.11	4.48	4.86
T_2	4.76	5.19	5.59
T_3	5.41	5.87	6.32
T_4	5.05	5.45	5.93
T_5	5.61	6.09	6.63
T_6	5.72	6.27	6.86
Ftest	S	S	S
SEm±	0.3	0.33	0.38
CD @ 5%	0.11	0.11	0.13
CV (%)	1.49	2.26	1.66

The data pertaining to number of tertiary branches per plant among the variety is presented in Table 4.3 and are found statistically significant.

The number of tertiary branches per plant was recorded significantly maximum in T_6 (24.99) followed by T_5

(20.61). The minimum number of tertiary branches was recorded in T_0 (10.05).

By optimizing soil conditions and nutrient availability, the combination of Cocopeat and RDF supports the overall health and productivity of mango trees in HDP. This includes the development of tertiary branches, which are critical for fruit production and canopy development.

Table 3: Effect of high density planting systems on tertiary branches of mango

Treatments	Number of tertiary branches
T_0	10.05
T_1	11.33
T_2	17
T_3	17.5
T_4	17.05
T_5	20.61
T_6	24.99
Ftest	S
SEm±	1.94
CD @ 5%	0.68
CV (%)	1.26

The maximum plant spread in North-South direction after pruning was recorded in T_6 (169.69 cm) which is *on par* with T_5 (165.39 cm), T_3 (165.02 cm) and T_4 (150.45 cm). The minimum North-South plant spread was recorded in T_0 (127.30 cm).

North-South plant spread was recorded maximum at 3 MAP in T_6 (189.39 cm) which is *on par* with T_3 (188.20 cm), T_5 (187.32 cm) and T_4 (169.25 cm). However, minimum North-South plant spread was recorded in T_0 (132.12 cm).

The variety T_3 (219.80 cm) recorded maximum North-South plant spread at 6 MAP which is *on par* with T_6 (216.58 cm), T_5 (213.36 cm) and T_4 (191.77 cm). The minimum North-South plant spread was recorded in T_0 (155.75 cm).

Table 4: Effect of high density planting systems on plant spread N-S (cm) of mango

Treatments	Plant Spread (cm) North - South		
	After pruning	3 MAP	6 MAP
T_0	127.23	132.12	155.75
T_1	137.5	154.75	175.36
T_2	140.25	160.24	175.61
T_3	165.02	188.2	219.8
T_4	150.45	169.25	191.77
T_5	165.39	189.39	213.36
T_6	169.69	187.32	216.58
Ftest	S	S	S
SEm±	6.2	8.11	9.37
CD @ 5%	2.17	2.84	3.28
CV (%)	10.88	12.71	12.88

The data presented in Table 4.5 reveled that, maximum plant spread after pruning in East-West direction was recorded in T_6 (167.46 cm) which was *on par* with T_5 (166.50 cm), T_3 (156.42 cm) and T_4 (151.69 cm). The minimum East-West plant spread was recorded in T_0 (102.45 cm).

The East-West plant spread was recorded maximum in T_6 (187.55 cm) at 3 MAP which is *on par* with T_5 (186.29 cm), T_3 (179.56cm) and T_4 (169.73). The minimum East-West plant spread was recorded in T_0 (112.65 cm).

The variety T_3 (210.12 cm) recorded maximum East-West plant spread at 6 MAP which is *on par* with T_5 (208.03 cm), T_6 (206.63 cm) and T_4 (189.50 cm). The minimum East-West plant spread was recorded in T_0 (135.95 cm).

Table 5: Effect of high density planting systems on plant spread E-W (cm) of mango

Treatments	Plant spread (cm) East - West		
	After pruning	3 MAP	6 MAP
T_0	102.45	112.65	135.95
T_1	112.03	129.39	147.89
T_2	135.9	145.75	169.55
T_3	156.42	179.56	210.12
T_4	151.69	169.73	189.5
T_5	166.5	186.29	208.03
T_6	167.46	187.55	206.63
Ftest	S	S	S
SEm±	9.82	11.23	11.51
CD @ 5%	3.44	3.93	4.03
CV (%)	18.32	18.72	16.82

It is evident from the Table 4.6 that the total number of panicles per plant was found statistically significant among the treatments.

At initial flowering the number of panicles per plant was recorded maximum in T_6 (9.73) followed by T_5 (8.37) which is *on par* with T_3. The minimum number of panicles per plant was recorded in T_0 (5.50).

At 50 per cent flowering the number of panicles per plant was recorded maximum in T_6 (42.63) which is *on par* with T_6 (40.47). The minimum number of panicles per panicle (32.33) was recorded in T_0.

Table 6: Effect of high density planting systems on flowering parameter of mango

Treatments	Total number of panicles per plant	
	At initial flowering	At 50% flowering
T_0	5.5	32.33
T_1	6.2	33.95
T_2	6.42	35.67
T_3	7.4	38.5
T_4	6.8	36.85
T_5	8.37	40.47
T_6	9.73	42.63
Ftest	S	S
SEm±	1	2.52
CD @ 5%	0.35	0.88
CV (%)	3.31	6.59

The observations on breadth of the panicle among the variety was found to be statistically significant and presented in Table 4.7.

The breadth of panicle was recorded maximum in T_6 (28.20 cm) followed by T_4 (25.17 cm) and the minimum breadth of panicle was recorded in T_3 (20.03 cm).

Table 7: Effect of high density planting systems on length of panicle and width of panicle (cm) of mango

Treatments	Length of panicle (cm)	Width of panicle (cm)
T_0	34.13	24.89
T_1	40.22	23.22
T_2	38.76	21.78
T_3	31.76	20.03
T_4	36.55	25.17
T_5	34.73	23
T_6	35.02	28.2
Ftest	S	S
SEm±	1.09	1
CD @ 5%	0.38	0.35
CV (%)	8.02	3.09

The economics of different treatment *viz.* cost of cultivation of mango (Rs/ha), net return (Rs/ha) and benefit cost ratio has been worked out and presented in the table 4.19. The maximum net return of mango was obtained Rs. 266230 with T_6 and maximum cost benefit ratio was recorded 3.70 with T_6. However, the minimum cost benefit ratio was recorded 2.08 with T_0 (control).

Table 8: Economics of mango

Notation	Fruit yield(t)	Selling rate (Rs./q)	Gross return (Rs.)	Cost of cultivation	Net return (Rs.)	B/C ratio
T_0	9.28	2000	185600	60170	125430	2.08
T_1	9.6	2000	191900	60470	131430	2.17
T_2	10.91	2000	218200	65670	152530	2.32
T_3	13.91	2000	278200	71370	206830	2.9
T_4	11.68	2000	233500	72520	160980	2.22
T_5	15.07	2000	301400	70770	230630	3.26
T_6	16.91	2000	338200	71970	266230	3.7

Mango cultivation, particularly for the *Amrapali* variety, involves several costs associated with land preparation, planting, maintenance, and harvesting. These costs can vary depending on factors such as location, soil type, and management practices. For both traditional and high-density planting systems, the major costs include:

- **Land Preparation**: This involves clearing, plowing, and preparing the land for planting, which can be a significant cost depending on the size of the farm and the type of soil.
- **Planting Material**: The cost of purchasing grafted seedlings or budded plants for planting is another substantial expense, especially for high-density systems where a larger number of trees per hectare are required.
- **Fertilization and Irrigation**: Regular application of fertilizers and water is essential for the healthy growth of mango trees. While drip irrigation is often more efficient, the initial setup and maintenance costs can be higher compared to traditional irrigation methods.
- **Labor**: Labor costs, including for activities such as planting, pruning, irrigation management, fertilization, and pest control, are significant in both systems but may be higher in high-density systems due to the need for more frequent care and management.
- **Pest and Disease Control**: Mango orchards require regular pest and disease management. In high-density systems, the close spacing of trees can lead to higher susceptibility to pests and diseases, increasing the frequency of spraying and pest control measures.
- **Pruning and Canopy Management**: Intensive pruning and canopy management are necessary in high-density systems to ensure proper light penetration and to avoid overcrowding, which can increase labor costs.

The economics of mango cultivation, particularly in high-density systems, presents both opportunities and challenges. High-density planting can lead to increased yields per hectare, early fruiting, and potentially higher profits in the long run. However, careful management of tree growth, nutrition, and water is essential to ensure fruit quality and maximize profitability. For *Amrapali* mango, the system's success largely depends on balancing the higher initial costs and labor requirements with the increased yield and market opportunities. The long-term economic viability of high-density systems in mango farming will ultimately depend on effective management practices and market conditions.

Conclusion

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

On the basis above findings it is be concluded that use of organic resources and RDF drastically enhance of high density planting systems, the plant height, number of branches per plant, fruit parameter, yield parameter and quality parameter, stem diameter of mango fruit plants respectively. From the above experimental finding, the application of T6 (R.D.F + F.Y.M) was found to best in terms of growth parameter and found the best treatment on basis off economics of mango. The B:N ratio was the 3.70 with the treatment T6.

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