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EFFECTS OF CANOPY ARCHITECTURE AND PLANTING DENSITY MANAGEMENT ON YIELD AND QUALITY ATTRIBUTES OF LITCHI (*LITCHI CHINENSIS* SONN.)

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Abstract

Development of the effective canopy architechture management for optimum light interception, and planting density on significant yield and fruit quality of Litchi cv. Shahi was investigated. The litchi cv. Shahi, planted in square system at 2 × 2, 3 × 3, 4 × 4, 5 × 5, 6 × 6 and 8 × 8 m (control), showed average light interception higher in the upper part of the canopy. Flowering and yield attributes (number of panicles, panicle length, number of flowers and fruit yield/plant) were obtained maximum in wider spaced trees (8x8 m) while fruit yield kg/plant was recorded maximum in 6x6 m in square system of planting. Fruits harvested from 8x8 m trees were superior in fruit quality (fruit length, weight, diameter, total soluble solids, organoleptic score, TSS: Acidity). Biochemical parameters and leaf nutrient content (total phenol, N, P, K and total chlorophyll, total sugar) were recorded maximum in 8x8 m. Hence, 8x8 m planting space can be recommended to the farmers for better yield.

Introduction

Canopy architecture of Litchi (*Litchi chinensis* Sonn.) is one of the most important subtropical, evergreen fruit tree belonging to Sapindaceae allocates the distribution and interception of light in the canopy. Reasonable shaping and pruning can improve tree structure; increase land use, location and light intensity; and laid the foundation for gaining early fruits, great harvests, health and longevity. Naturally, the plant grows vigorously and fruiting area gradually shifts to the upper peripheral region which makes it difficult for fruits to harvest. Besides producing less quality fruits, the shade cast by vigorous trees lowers the harnessing efficiency of interception of light under and above canopy for photosynthesis. Canopy management in litchi improves the ability of sunlight to penetrate the tree, enhances the colour of fruit and improves quality. Pruning resulted in increased photosynthetic efficiency of litchi plants due to improved light penetration inside the trees. The litchi is one of the least adaptable of tropical and subtropical fruit crops, which flowers and fruits satisfactorily only under consistent favorable climatic conditions and dry winter. Canopy architecture of a tree is dependent on its flushing behavior, carbohydrate budgeting, plant spacing and planting system. A well-designed canopy structure is essential to control tree growth pattern, tree formation and maintain high quality fruit production. Well-formed canopies permit better aeration and sunlight exposure to foliage and fruits, improve the biochemical, photosynthetic efficiency, fruit bud differentiation, ripening and fruit quality and reduce microclimate buildup for pests and disease. Canopy management techniques that maximize light interception and distribution in orchard trees would therefore be expected to improve CO_2 fixation and fruit yields in litchi. Dense litchi orchards with poor productivity due to poor light mixing lead to limited flower development (Kumar 2015). The distribution of light nitrogen and leaf in the middle of a tree is often a good indication of potential photosynthesis. Interaction effect

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of light, temperature, partial pressure of CO_2, water vapour and leaf water status influences photosynthesis by affecting the opening and closing of the stomata or leaf chemistry. To increase litchi production and optimize fruit quality, it is very important to choose the correct training system and optimum plant spacing to obtain good light interception and photosynthetic radiation (Hampson *et al*. 2002). Novel architectures that enhance light interception and distribution into the canopy have been developed, ensuring early cropping, high yield, improved cropping efficiency, and fruit quality (Long *et al*. 2005, Whiting *et al.* 2005). Thus the present study was aimed to study effects of canopy architecture and planting density management on yield and quality attributes of litchi (*Litchi chinensis* Sonn.).

Materials and Methods

The present investigation was carried out at the ICAR- National Research Centre on Litchi, Muzaffarpur (Bihar) during the year 2018-19 and 2019-2020 on twelve to fifteen-year-old litchi plants cv. Shahi. Litchi plants planted under different spacing in the square system. The experimental field was sandy loam in texture, alkaline in reaction with low to medium in fertility status with high organic matters with a balanced ratio of nitrogen, phosphorous, potash, and carbon. The experiment was laid out in Completely Randomized Block Design with 6 treatment combinations (2 × 2, 3 × 3, 4 × 4 , 5 × 5 , 6 × 6 and 8 × 8 m) were replicated four times in the square system of planting in litchi. The planting spacing at 8x8m was used as control. This spacing is the common and conventional system so comparisons with new planting densities become effective and informative for the present experiment. The light interception were recorded thrice in a day i.e. at 2 to 3 hrs before solar noon (8.00-10.00 am), at solar noon (12.00-1.00 pm) and 2 to 3 hrs after solar noon (4.00-5.00 pm) on completely cloudy, overcast days and on clear sunny days. To estimate light interception, the observations were recorded from three spots centre (near the trunk), mid canopy (area having thick foliage cover) and periphery (outside the canopy). The reference of absolute light intensity was measured from the open area at the time of respective observation. Light interception per tree was estimated by calculating the value of each below canopy reading the percentage subtracted from the above canopy readings (transmission), and then by subtracting the average percentage transmission of all 90 sensor reading from 100% (total incident light). Leaf nutrient contents were estimated according to the guidelines described by Singh *et al.* (2007). The total phenol content was determined as suggested by Lal *et al.* (2018). The numbers of panicles per branch were counted and the length of panicles measured by using scale (cm) in April during both the years. Total number of fruits from each experimental tree was counted in the month of April- May before harvest and the average was worked out. Fruit diameter of randomly collected 10 fruits per replication was measured at the widest positions by digital vernier callipers and average fruit width was expressed in millimeter. From each replication, 10 fruits plant^{-1} were randomly taken and weight (g) was recorded on a digital balance. The mean weight (g) was computed by dividing the total weight of the fruits with the number of fruits. Fruit length of randomly collected samples having ten fruits per replication was measured at the longest positions by digital vernier's calliper and average fruit length was expressed in millimeter. Fruit yield (kg) per plant was computed by multiplying the total number of fruits retained on each plant with the mean fruit weight at the time of harvest. Total soluble solids (TSS) were determined using a Fisher hand refractometer at 20°C and results were expressed as °Brix. Titratable acidity was determined by the titration method with 0.1 N NaOH up to pH 8.1, using 2 g of homogenized pulp in 100 mL distilled water. The result was expressed as percentage of citric acid. Organoleptic score in terms of general appearance, taste and flavor were recorded by panel of five judges on the basis of Hedonic scale 1-9 described by Reddy (2012). The two years data at all stages were analyzed as per methods suggested by Gomez and Gomez (1984). Data were subjected to analysis of variance. Significance was tested by the 'F' value at a 5 per cent level of probability. Critical difference (CD) values were calculated wherever the F test was found to be significant.

Results and Discussion

Planting densities and canopy management in Litchi significantly influenced the light interception in the below and upper parts of canopy under square system of planting (Table 1). Light interception showed that the mean light interception below canopy was significantly higher (75.18%) in the wider spaced plants (8x8m) and lowest interception (46.45%) in close spaced plants (2 × 2 m) whereas light interception by the upper part of canopy was found higher in treatment 8x8m (93.31%) whereas, lowest light interception in treatment 2 x 2m (83.07%) under different planting densities. It might be due to larger tree volume and more spreading branches in the wider spaced trees. It indicates that there was the highest sunlight utilization per unit area in wider spacing plantings. The upper part of the tree canopy intercepted maximum radiation relative to the middle and lower canopy parts. The similar results were reported by Singh and Dhaliwal (2007). Different planting densities in Litchi significantly affected on tissue nutrient content in both the years under square system of planting of litchi (Table 2). Average nitrogen (N) content was found to be higher (1.56%) in wider spacing (8 × 8 m) among different densities whereas the minimum nitrogen (N) content (1.23%) was recorded in close spaced plants (2 × 2 m). It might be due to the dilution effect of vegetative growth. The highest phosphorus (P) content was found in 8x8m (0.25%) whereas the lowest phosphorus content (0.12%) was recorded in the spacing 2 × 2 m. Increasing foliar phosphorus (P) content found in less dense plants it might be due to wider spacing responsible for higher uptake and translocation of nutrient from soil to aerial part of the plants. Average mean potassium content was recorded maximum in wider spacing (8 × 8 m) in both the years while lowest mean potassium content was recorded in 2 × 2 m in square system of planting.

Table 1. Effect of planting density on Light interception below canopy.

Treatments	Light interception below canopy (%)	Light interception above canopy (%)
2×2 m	46.45	83.07
3×3 m	56.70	86.89
4×4 m	68.69	87.59
5×5 m	72.16	88.66
6×6 m	73.82	91.75
8x8 m (Control)	75.18	93.31
CD (P= 0.05)	2.638	1.812
SE(m)	0.867	0.596

Pramanick *et al.* (2006) pointed out that maximum leaf nutrient content (K) accumulation was observed in case of apple tree under wider density, whereas the minimum level was recorded at a less planting density. The total leaf phenol content was found to be significantly higher in spacing of 8 × 8 m (82.25 mg GAE/g) among square system of planting while minimum was recorded under dense planting systems. It indicates that total phenol content of leaf increased in wider spacing. Chlorophyll content of litchi was significantly more at the spacing of 8x8m (9.31 mg/g) among different planting densities whereas the lowest mean chlorophyll content was observed at the spacing of 2 × 2 m (3.73 mg/g). Less chlorophyll content in close spacing may be due to comparatively less radiation penetration in the inner parts of tree canopy which might have adversely affected the rate of photosynthesis and in turn the fruit quality. Maximum total chlorophyll (2.02 mg/g) contents were found in plants under square planting system than other system of plantings (Raj *et al.* 2017). Total sugar in litchi significantly varied among planting densities under square system of plantings. The maximum total sugar was observed in treatment 8 × 8 m (15.10%) whereas minimum total sugar was recorded in 3 × 3 m (13.60%). The higher amount of sugars in the wider spacing might be due to more vigour and healthy trees which could synthesize more photosynthates and supply the same to the developing fruits as a major sink. Similar results were also obtained by earlier workers Kundu (2007) and Singh *et al.* (2010).

Table 2. Effect of planting density on leaf contents.

Treatment	Nitrogen (%)	Phosphorus %	Potash %	Total phenol (mg GAE/g)	Total chlorophyll content (mg/100g)	Total sugar (%)
2×2 m	1.23	0.12	1.10	42.26	3.73	13.66
3×3 m	1.30	0.13	1.16	42.60	4.24	13.60
4×4 m	1.35	0.17	1.20	50.84	5.35	14.07
5×5 m	1.41	0.21	1.24	54.90	6.95	14.17
6×6 m	1.50	0.22	1.28	66.40	7.76	14.89
8x8 m (Control)	1.56	0.25	1.34	82.25	9.31	15.10
CD (P= 0.05)	0.058	0.041	0.04	1.036	0.502	0.265
SE(m)	0.019	0.014	0.013	0.34	0.165	0.087

Different planting density and proper canopy management under Square System had significant influence on number of panicles per branch in litchi (Table 3). Maximum number of panicles per branch (19.02) was recorded in wider spacing 8x8 m (control). Further minimum numbers of panicles (5.62) were recorded in the treatment (2x2 m) in square system of planting. Maximum panicle length (32.73 cm) was recorded in treatment 8x8 m while lowest panicle length (19.79 cm) was recorded in treatment (2 × 2 m). The highest increased in panicle length was recorded in 4 × 4 m (12.57%) and lowest in 2 × 2 m (3.01%). It may be due to apportioned spaced provided to the plants and maximum interception of light at the spacing of 8x8m. Maximum numbers of flowers per panicle (113.62) were recorded in control (8x8 m) among different planting density while minimum numbers of flowers (36.77) were recorded in treatment (2x2 m) under square system. This may be due to greater photosynthetic activity, because of exposure of more number of leaves to intercept light, that distribution of proper sunlight within the canopy at wider spacing. This result is in accordance with the finding of Pandey *et al.* (2015) as recorded maximum number of flowers in wider spacing. These findings are in confirmatory with the findings of Dalal *et al.* 2013 in mandarin.

Pal *et al.* (2016) observed that the maximum number of flower bud emergence was recorded with the spacing 2.0 x 1.5 m, whereas, minimum was recorded with the plant spacing 1.0 x 1.0 m. Average fruit yield were recorded maximum (46.79 kg/plant) in the treatment (8x8 m) while minimum fruit yield (3.51 kg/plant) were observed in treatment (2 × 2 m) under square system of planting. This might be due to the fact that under wide spaces the plant has relatively high vegetation, a high proportion of leafy fruit. Trees with bigger vegetative dimension normally give larger number of fruit per tree (Dalal *et al.* 2013). The different planting densities under square system had significant influence on fruit weight of litchi. It was found maximum in treatment 8x8 m (22.04 g) whereas, it was lowest in 2 × 2 m (19.34 g) under square system of planting. Maximum fruit weight in wider spacing may 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. Hosomi *et al.* (2013) reported reduced size and weight of fruit under closer spacing in fig. There are studies in which fruit quality was maintained, suffered little (Nath *et al.* 2007) or considerable changes. Fruit length was significantly influenced by different planting density. The maximum fruit length was recorded in 8x8 m whereas minimum fruit length was recorded in 2 × 2 m in square system of plantings in litchi.

Table 3. Effect of planting density on yield and quality attributes.

Treatments	No. of panicles/ branch	Panicle length (cm)	number of flowers/ panicle	fruit yield (kg/ plant)	Fruit weight (g)	Fruit length (mm)	Fruit diam. (mm)	Total soluble solid (^{0}B)	Acidity (%)	TSS/ Acidity	Organo-leptic score
2×2 m	5.62	19.79	36.77	3.51	19.34	32.76	23.51	18.17	0.44	45.46	6.67
3×3 m	5.76	20.23	42.69	5.89	19.42	32.82	23.41	19.37	0.43	45.82	6.51
4×4 m	7.46	23.49	58.79	13.14	19.63	32.86	23.72	19.42	0.40	47.79	7.00
5×5 m	7.74	25.25	79.50	20.18	20.45	33.09	23.89	19.98	0.41	49.61	7.39
6×6 m	12.14	29.91	89.01	39.30	21.79	33.66	24.22	20.29	0.37	59.35	8.06
8x8 m (Control)	19.02	32.73	113.62	46.79	22.04	34.95	27.79	20.40	0.33	64.96	8.45
CD (P= 0.05)	0.644	0.813	2.079	0.521	0.549	0.462	0.646	0.673	0.046	0.277	0.174
SE(m)	0.212	0.267	0.684	0.171	0.181	0.152	0.212	0.221	0.015	0.091	0.054

Fruit diameter was significantly influenced by different planting densities under square system of plantings. The maximum fruit diameter was found in treatment 8x8 m (27.79 mm) while minimum fruit diameter was recorded in 2x2 m (923.41 mm). Decrease in fruit diameter with increase in plant density is reported by Sousa *et al.* (2012). Total soluble solids of litchi were significantly influence among different planting densities. The maximum total soluble solids were recorded in 8 × 8 m (20.40 ^{0}B) whereas minimum total soluble solids were found in 2 x 2 m (18.17 ^{0}B). The highest TSS under wider spacing may be due to better light penetration which increases more photosynthetic activities and resulted into conversion of higher photosynthate which ultimately improve the fruit quality (Pandey *et al.* 2015). The maximum fruit acidity was observed in close planting 2 × 2 m (0.44%) whereas; minimum acidity was recorded in wider planting 8x8 m (0.33%). 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 effects on fruit quality (Policarpo *et al.* 2006). Total soluble solid: acidity was found maximum in wider planting 8 x 8 m (64.96) whereas, it was lowest in 2 × 2 m (45.46). Different planting densities and canopy management had significant influence organoleptic score of litchi fruit. Maximum organoleptic score of fruit (8.45) were recorded in control (8 x 8 m) among different planting density while minimum organoleptic score (6.51) were recorded in 3 x 3 m. Kundu (2007) also reported organoleptic score was higher under wider spacing.

It may be concluded that a square system of planting at a spacing of 8x8m was able to produce a better yield of 46.79 kg/plant over spacing of 6x6 m yielding 46.79 kg/plant. Therefore for Litchi cv. Shahi, the square system with spacing of 8x8m can be recommended for farmers to obtain higher yield. High planting density enhanced competition for nutrients, light and space, and that this competition enhanced soils from continuous plantations compared to wider spacing.

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