

**Investigation on Influence of Planting
Geometry and Canopy Architecture on
Morpho-Physiological, Yield and
Quality Attributes in Litchi cv. Shahi**

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Submitted to

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

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For the Degree of

DOCTOR OF PHILOSOPHY

In

**HORTICULTURE
(FRUIT SCIENCE)**

By

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2020

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This is to certify that the thesis entitled “**Investigation on influence of planting geometry and canopy architecture on morpho-physiological, yield and quality attributes in litchi cv. Shahi**” submitted in partial fulfilment of the requirement for the degree of “**DOCTOR OF PHILOSOPHY in HORTICULTURE (FRUIT SCIENCE)** of the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Ms. Jyoti Singh** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instruction.

All the assistance and help received during the course of investigation has been duly acknowledged by her.

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Publication of Research Paper from Ph.D. thesis work

This is to certify that Ms. Jyoti Singh, Ph.D. scholar of the Department of Horticulture - Fruit science submitted the thesis entitled “Investigation on influence of planting geometry and canopy architecture on morpho-physiological, yield and quality attributes in litchi cv. Shahi” on 16.06.2018 has published the following two research papers (at least one published and one accepted with proof of acceptance) from the research work conducted for Ph.D. thesis.

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LIST OF SYMBOLS

Symbol Abbreviation	Stand for
$^{\circ}\text{B}$: Brix
cv.	: Cultivar
cvs.	: Cultivars
CV	: Coefficient of Variance
Cm	: Centimetre
DMSO	: Dimethyl Sulphoxide
G	: Gram
g^{-1}	: Per gram
GAE	: Gallic acid equivalent
Ha	: Hectare
H_2SO_4	: Sulfuric acid
HCl	: Hydrochloric acid
Mg	: Milligram
ml	: Milliliter
/	: Per
%	: Per cent
NaOH	: Sodium hydroxide
No.	: Number
i.e.	: That is
TSS	: Total soluble solids
dm^{-2}	: Square per decimeter
SD	: Standard Deviation
Na_2CO_3	: Sodium Carbonate
E	: East
N	: Normality
M	: Molarity
viz.	: Namely

INTRODUCTION

Litchi (*Litchi chinensis* Sonn. :Sapindaceae), a subtropical evergreen fruit crops, has specific climatic requirements. Its commercially cultivation is restricted to only a few subtropical countries in the world. Litchi originated in the border region of South China and southeastern Asia. Although it has been distributed to the vast tropical and subtropical areas, it is only commercially grown in about 20 countries, within two narrow strips of the Southern and Northern Hemispheres. The major litchi growing countries are China, Israel, Australia, Thailand, India, Vietnam, South Africa and at higher elevations in Mexico and Central and South America. The top five world litchi producing countries are China, India, Taiwan, Thailand, and Vietnam. India is the second largest producer of litchi in the world after China with an area and production of 92,000 ha and 583,000 tones, respectively during 2016-17 (Anonymous, 2017). Litchi ranks 10th in area and 11th in production among fruit crops in India. It is grown in the states of Bihar, West Bengal, Tripura, Uttarakhand, Jharkhand, Assam and Punjab. Of the total production of litchi in India, 54% is contributed by Bihar. Punjab recorded the highest productivity with 16.14 MT/ ha followed by West Bengal and Bihar (Anonymous, 2015). Over the years, India has recorded above 6% growth in production with modest productivity of around 7 tones per hectare and has potential of doubling it. The Indian and the world litchi markets are expanding fast. Major litchi cultivars in India are China, Culcuttia, Bedana, Late Bedana, Rose Scented and Shahi (Pride of Bihar).

Litchi is considered as the queen of the fruits due to its excellent quality, juicy fruit, excellent sugar and acid blend, characteristic pleasant flavor and for attractive color and nutritional value. The litchi fruit is rich in Calories (63.00-64.00), Thiamine (28 mg), Riboflavin (0.05 mg) & Ascorbic acid (24-60 mg), Protein (0.68-1.0 g), fats (0.3%), carbohydrates (9.4%), minerals (0.7%), fibrous matter (2.25%), calcium (0.21%), phosphorus (0.31%), iron (0.03%) and carotene.

Depending upon variety and climate, the fruits contain 60% juice, 8% rag, 19% seed and 13% peel. The level of TSS is 15.90-20.10⁰ and acid content varies from 0.2 per cent to 0.64 per cent.

Litchi industries are totally rely on the production capacity of orchard.

Lack of proper orchard management such as deciding appropriate spacing based on requirement like high density planting or regular density at initial stage of orchard establishment leads to various kind of production related problems.

Therefore, it is important that trees are managed with scientific tree management system particularly the nutrition and canopy management. Particularly in litchi there are three to fourth recurrent flushes occurs. The shoots grow repeatedly during the growing season provided conditions are favorable for growth (Borchert, 1991), which led to the attainment of vigorous growth over the periods of time. Thus, high density planting couple with canopy management plays an integral role in controlling the size of the trees. This helps reduce the cost of harvesting, which often accounts for more than half the expense of growing the crops. The distribution of chemical sprays to control pests and diseases is also generally better in small trees with open canopies that have been pruned. Pruning removes the apical bud, stimulates the growth of the auxiliary buds and resets the flushing cycle in these tree crops. Besides, it also improves distribution of light through the canopy and promotes the growth of ground covers used to combat soil erosion. For most of the subtropical species, pruning is aimed at producing new shoots at a time which get enough to mature during cool weather in winter after which they are most likely to flower.

High density planting and training systems in subtropical fruit plants has been an important development in recent years leading to increased productivity, higher early yields and better income per unit area. Scientific research has established that high density planting can give more output per unit area within 3 to 4 years of planting as compared to 8 to 10 years in traditional systems. Under these circumstances the high density plantation systems has become extremely significant to increase fruit yield and

productivity (**Goswami et al., 2001**). It depends on maintaining a balance between vegetative growth and fruiting. If the vigor is too low, excessive fruiting results, fruit size decline, biennial bearing increases and trees fail to fill their allotted space soon enough to make the orchard profitable. If the vegetative vigor is excessive then flowering and fruiting are reduced and containment of the tree to the allotted space becomes problematic. The possibilities of high density planting systems in fruit crops have been studied by Das *et al.* (2012), Johnson, *et al.* (2000), Singh, *et al.* (2007), Lal *et al.* (2014), Bal *et al.* (2003), Huang (1997), Furukowa and Monet (1998), Kumawat *et al.* (2014) Balasubramanyan *et al.* (1997) and Kumari *et al.* (2003). Chundawat *et al.* (1992) studies revealed that narrow spacing (6 x 2 m) increased the production per unit area and fruits had significantly higher values for TSS, Vitamine C, sugars and lower values for acidity. Such an increase in production through high plant population per unit area has also been achieved in banana and pineapple. High density orcharding has been standardized in guava (Pandey *et al.*, 1997) citrus fruits (Sharma *et al.*, 1999, Bhullar *et al.*, 1980), Mango (Ram, 1997 and Reddy *et al.*, 1999), cashew nut (Suma *et al.*, 1998) and Papaya (Reddy *et al.*, 1995). However, no such studies seem to have been conducted in litchi. As tree density increases, inter-plant competition is quite obvious which is likely to be reflected in the pattern of plant growth, yielding potential of the tree and fruit quality etc. Dense orchards frequently become uneconomical comparatively earlier than standard orchards because the tree size, although reduced by competition, cannot be controlled sufficiently to prevent light competition, internal shading and barrenness. Although dwarfing root stocks and use of growth retardants are of prime importance for controlling vegetative growth in some species, cultural techniques such as pruning, postharvest topping, orchard design and space provided to plant also have an influence on tree development. Out of these, pruning has emerged as a commercial and alternate method to restrict the growth of the trees in a high density orchard by reducing tree size and improving the fruit quality (Hayden, 1971; Hayden and Emerson, 1973). The current trend toward higher densities in fruit orchards

requires adopting more efficient training systems. To increase fruit crops production and to optimize fruit quality, it is very important to choose the correct training system to obtain light interception and photosynthetic radiation (Hampson et al., 2002). Light interception is extremely important within canopy for maximize formation of fruiting sites with regard to optimum yield/plant. Kappel and Neilson (1993) observed that fruit size of pear positively correlated to light interception within plant canopy. For increased production and productivity high density planting system is foremost important, however successful orcharding under HDP system is possible only adoption of canopy management practices. To reach the goal of an efficient orchard design, canopy modification through various training system is required to attain higher production efficiency than conventional system of planting. This combination tends to increase profitability by improving yield and/or reducing the cost of labour (Robinson, 2008). 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 (Lauri and Claverie, 2005; Long et al., 2005; Whiting, 2005). Hence, it is important to consider tree growth habit in orchard management activities, particularly in regard to pruning, to ensure that proper distribution between vegetative and reproductive output is realized. V-trellis with support system and V-trellis without supporting training systems were developed to increase yield, fruit quality and precocity of production at high planting densities (Bergerman et al., 2012). There are also other management systems derived from a central leader and open centre system etc used in many fruit orchards with high plant densities.

Vegetative growth and fruit yield are functions of light interception and the translation of light energy into chemical energy. Information on the effect of various tree densities and training systems on light interception and growth behavior of different parts of litchi tree, effect of the tree density on compactness, flowering, fruit set, fruit size, yield, fruit quality, maturity pattern, leaf composition, and on overall growth and fruiting potential of litchi are not still well understood. Therefore, the present experiment entitled "Investigation of

influence of planting geometry and canopy architecture on morpho physiological parameters, yield and quality attributes in litchi” was carried out at the National Research Centre on Litchi Muzaffarpur, Bihar with the following objectives:

Objectives

- Assessment of the effect of tree densities and training system on solar energy exploitation, vegetative growth, bud fruitfulness, flowering and fruit yield.
- To study the physiological and biochemical characteristics of fruits at different planting densities and training systems.
- Quantifications of the nutrient composition of leaf in relation to soil condition under different planting densities.

REVIEW AND LITERATURE

Litchi (*Litchi chinensis* Sonn.) is an important subtropical evergreen fruit crop with tremendous export potential and plays a significant role in our national economy. Majority of the litchi trees attain tall, uneven canopy with intermingling branches leading to increase shading, poor interception of light and increase proportion of non-photosynthetic foliage. Litchi plants canopy management, especially canopy architecture management has become a priority for reducing production cost and increasing better yield and quality of fruits. The success of high density planting in perennial crop like litchi depends on successful management of orchard in general canopy architecture management and in particular (Pandey,2105).High density planting are maintained by specialized training and pruning system. Increase planting density in fruit orchard can be achieved not only by the use of dwarfing rootstock but also by the choice of proper training system (Whiting et al, 2005). Planting density and training system are most crucial factor which determines the yield of a litchi orchard. As there is increasing pressure on land for producing more yield in order to fulfill the demand of population, there are practically no scope of increasing the area under fruit crop. Choosing appropriate spacing and planting system are key factors for increasing production and obtain better quality fruits. The review of relevant research work pertaining to effect of planting density and training systems on vegetative, flowerings, fruiting, physicochemical and biochemical parameters compound in litchi has been documented in this chapter under the following heads:

2.1 Growth Characters

- i. Plant spread NS-EW (m)
- ii. Plant height (m)
- iii. Leaf area (cm²)
- iv. Stem girth (cm)
- v. Number of flushes per branch

- vi. Flush length (cm)
- vii. Flush diameter (mm)
- viii. Canopy Diameter (m)
- ix. Canopy Area (m²)
- x. Trunk Cross Sectional area (cm²)

2. 2 Physiological Characters

- I. Photosynthetic rate : ($\mu\text{mol m}^{-2} \text{s}^{-1}$),
- II. Transpiration rate : ($\text{mmol m}^{-2} \text{s}^{-1}$),
- III. Stomatal conductance : ($\text{mol m}^{-2} \text{s}^{-1}$),
- IV. Internal CO₂ concentration ($\mu\text{mol mol}^{-1}$)
- V. Quantum efficiency:
- VI. Carboxylation efficiency: ($\mu\text{mol m}^{-2} \text{s}^{-1} (\mu\text{mol mol}^{-1})^{-1}$,
- VII. Mesophyll efficiency: ($\mu\text{mol mol}^{-1} (\mu\text{mol/m}^{-2}\text{s}^{-1})^{-1}$),
- VIII. Water use efficiency: ($\mu\text{mol mmol}^{-1}$)

Light interception

- I. Light interception upper canopy (%)
- II. Light interception below canopy (%)

Fruit Quality Characters

- I. Acidity: mg/100gm
- II. TSS(⁰Brix)
- III. Total Sugar (%)
- IV. TSS: Acidity Ratio
- V. Organoleptic Score

Flowering and Yield Characters

- I. Number of panicles/branch
- II. Panicle length (cm)
- III. Number of flower per panicle

IV. Fruit weight (g)

V. Fruit length (mm)

VI. Fruit breadth (mm)

VII. Yield per plant (kg).

VIII. Yield (t/ha)

Leaf Nutrient Contents

I. Nitrogen (%)

II. Phosphorus (%)

III. Potassium (%)

IV. Phenolics content (mg GAE/g)

V. Total Chlorophyll (mg/g)

Soil Characters

I. Soil temperature (°C)

II. Soil Moisture (%)

III. Bulk density (g/cm³)

IV. Water holding capacity (%)

Effect of planting densities and training system on Light Interception

Light interception above and below canopy is a fundamental requirement for crop growth and is important for biomass production and plant growth modeling. In photosynthesis and evapo-transpiration, solar radiation is an important parameter. These two phenomena are dependent not only on the intensity of radiation but also on the distribution of intercepted radiation within the canopy (Ismail 2005). Light penetration and light interception are most considering factors under high density planting (Westwood, 1988). Light is the one and only limiting factor in high density planting (G Tzul, 2016). It is the source of energy for photosynthesis, which influence flowering, fruit set and improve fruit quality and color development (Tucker et al., 1994).

Heinicke (1966) and Looney (1968) reported that light intensity decreased rapidly with increasing depth of foliage and lower and central portions of the tree received very low light intensities. **Jackson (1970)** found full light intensity (100%) at the top of round headed apple tree which, then decreased to 34% at a depth of one meter.

Verheij and Verwer (1973), reported that an average of more than 50% of full sunlight occurred at the top periphery of the canopy in apple.

Jackson (1980) the theory of light interception and its relevance to training systems has been extensively studied by several authors. Therefore, a function of absorbed light by the target organ of the tree leads to good quality production.

Mckenzie (1972), Heinicke (1975) and Lespinasse and Delor (1986) recommended the use of relatively natural tree forms that allow light penetration through the canopy by providing many small opening in the foliage such as in the multiple leader, central leader, vertical axis, or slender forms .

Robinson et al. (1991), Kappel and Quamme (1993) and Tustin et al (1993) found that a decreasing ratio of between-to-within-row-spacing (rectangularity) can increase light interception and give more uniform light distribution, resulting in higher yields of good- quality fruits. The principle underlying modern orchard planting systems was to enhance light distribution within tree canopies with an optimized total canopy light interception, by reducing individual tree form and arrangement.

Loreti et al. (1980) observed that sunlight interception by nectarine trees was similar at all planting distances but in peach it was the least in most dense planting owing to poor growth in the lower parts of the canopy.

Wertheim et al. (1986) and Palmer (1988) found that Y-trellis trained trees intercepted about 70% of available PAR (Photo-synthetically Active Radiation) at maturity while the slender spindle system intercepted only 55% of PAR in spite of 30% greater tree density in apple. Similarly **Alekseeva (1986)**

Show that dense plantings impaired the radiation regime in the crown of peach trees which reduced foliation, lowered photosynthetic productivity and finally decreased yield.

Corelli and Sansavini (1989) suggested that the ratio between canopy height, thickness and alley width must be taken into account to ensure adequate light levels inside the canopy. **Chalmers and Vanden (1989)** also pointed that the efficiency of training system may be evaluated in terms of light use that is the capacity to maximize the assimilate distribution into fruit yield.

Jackson (1980), Purohit (1988) and Palmer (1989) found that dry matter production and yield of fruit trees are directly proportional to their light interception behavior. They also reported that a higher tree density leads to increase light interception through a greater leaf area and more even distribution of light. Full-field and multi row training systems intercepted more light than single rows in apple (Jackson 1980). The important of light interception in the canopy in quantity and quality of fruit production.

De-Jong *et al.* (1989) revealed that the difference in yield were related to light interception and results obtained with this system so far were more than satisfactory both in quantity and quality production, precisely on account of the good radiation characteristics within the canopy.

Robinson and Lakso (1989) studied the relationship of tree density, light interception and yield among four apple orchard and found linear relationship between yield and tree density for 3 pyramid shape systems. They also observed that, Y-trellis had greater yield than was predicated for its tree density due to maximum light interception in the tree canopy. Sunlight distribution into the Y-shape tree canopy was 35% higher as compared to central spindle canopy. Mean light interception was almost similar in all the three training systems with values of 74% in the Y-shaped, 71% in the open vase, 69% in the central spindle trees.

Wagenmakers (1991) observed higher light interception and distribution in Y-shaped canopies as compared to vertical systems such as “Central leader” and “Palmette”.

Lakso (1994) reported that in apple total light interception of an orchard can be raised by increasing the density of the canopy (i.e. increasing its LAI without increasing canopy volume), height of the trees (in relation to free alley width) or by increasing the number of trees (of smaller size/ per hectare). Solar energy interception and light distribution within the canopy are strongly related to canopy architecture which influences cropping efficiency, but structure and leaf distribution in fruit trees are primarily affected by training system.

Wunsche et al. (1996) reported that considerable light was lost by the tree due to the extensive and unproductive alleys between rows in case of vertical hedgerow and palmette. Trees trained on spindle system intercepted a higher fraction (60%) of available PAR than palmette tree (52%). They also found that the average amount of radiation intercepted by the canopy at 25cm and 75cm above the soil was higher in spindle as compared to palmette.

Robinson (1997) found that apple trees which were trained to Y-shaped system were 11% and 18% more productive than trees which were trained as slender spindle and palmette respectively.

Tustin et al. (1998) recorded higher total daily photosynthetic photon flux (PPF) within canopies was higher in the wider spaced trees because attenuation of PPF from mid to lower canopy regions was less pronounced than with closely spaced trees under both diffuse and direct light conditions.

Giuliani et al. (1998) reported that Y-trellis system showed a greater capacity for light interception than the delayed vasette and palmette systems. They found that whole canopy photosynthesis was linearly related to the amount of light intercepted by the tree. However, Caruso et al (1998) found that photosynthetic photon flux density decreased significantly from the tree top to the base of central leader trees as compared to Y-shaped tree.

Palmer and Avery (1992) measured light interception on four planting systems of cultivar 'Golden Delicious' and cultivar 'Karmijn de Sonnaville' at tree densities ranging from 2(3,00 to 8333 trees ha⁻¹. For the same trees, light interception increased from 49 to 83%. Yield was closely related to light interception. Trees at the more rectangular arrangement of 2.75 m × 0.8 m intercepted less light than trees at 2.0 m × 1.25 m, despite the latter having a lower tree density.

Grossman and Dejong (1998) conducted an experiment on clingstone peach cv. Ross trained on “Y” training system, perpendicular V (Kac-V), high density perpendicular V (HiD KAC-V), cordon system and open vase system and was observed that cordon and HiD KAC-V system intercepted more light as compared to other training systems.

Giuliani et al (1999) found the effect of tree form on photosynthetic activity of nectarine cv. Stark Redgold which was maximum in the morning in palmette and delayed open crown. Results also indicated that Y-shaped canopy enhanced light interception which leads to higher fruit production.

Giuliani et al. (1998) observed that irrespective of training system viz., Y trellis, sprint palmette and delayed vase whole, canopy photosynthesis of peach trees was linearly related to the amount of light intercepted by the tree.

Robinson (2000) reported that V- systems have very high yield due to high tree densities and high level of light interception at maturity. The openness of the canopy in the center of the V allow light to penetrate in the centre of the canopy and allow less light to fall on the orchard floor. This system also reduced fruit sunburn in high sunlight but have high initial coast.

Wunsche and Lakso (2000) found in apple plant that interception fraction of PAR were curvilinear related to fruit yield and it was maximum at 60% PAR interception.

Barritt (2000) and Wertheim et al. (2001) observed that tall trees can intercept more light and yield as compared to short trees at the same spacing

Lannini et al. (2002) reported on improved yield and quality in peach fruit cv. Cincal 5 when trees were trained to Y system, due to proper distribution of fruits on shoots with optimum exposure of leaves to light.

Nuzzo et al. (2002) studied the effect of two training systems on light interception peach cv. Springcrest and showed that the plants which were trained to transverse “Y” rapidly reached high values of leaf area per unit of ground area (LAI) and better utilized the available solar radiation as compared to delayed vase.

Chenyl et al. (2002) conducted an experiment on apple trees, trained on 5 different training system viz., slender spindle (SS), Geneva Y-trellis (GY), a modified solen (SY), V trellis (LDV) and High density V-trellis (HDV) and found that HDV intercepted more light (73%) as compared to SS (53%) whereas, two Y-shaped training system had 11% to 14% more cumulative yield/ha than the SS.

Singh (2003) studied the light interception behavior in guava cv. Sardar planted at three spacing viz., 6m x 4m, 6m x 5m and 6m x 5m. The interception was recorded highest (65.7%) in plants at widest spacing followed by medium (63.6%) and closest (61.3%) spacing. More than 70 per cent of total light was intercepted in the upper 1/3rd part of the canopy of plants during the actively growing season of the plants.

Singh and Kanwar (2004), reported that trees which were planted at 6m x 1.5m spacing intercepted significantly higher (75.1%) mean total radiation during the year as compared to those planted at 6m x 6m (68.6 %) and 3m x 3m (65.9%) distances. The 6m x 1.5m planted trees intercepted 52.5%, 12.9% and 9.7% of the total irradiances in the upper, middle and lower parts of the tree canopy, respectively. The intercepted irradiance in the 6m x 6m planted trees was 50.4%, 10.9% and 7.3% whereas, 3m x 3m intercepted 49.7%, 9.9% and 6.3% irradiance in the three tree parts mentioned above.

Farina et al. (2005) observed that peach fruit cv. Elegant Lady had more uniform crop load distribution within the canopy in combination with a light

penetration gradient which resulted in greater variability of quality parameters for perpendicular “Y” than “Delayed vase”.

Pratap et al. (2003) and Sharma et al. (2006) obtained that the light penetration was highest in canopy of ‘Amrapali’ (low spreading and dwarf stature) than ‘Mallika’/ ‘Dashehari’. The light penetrance as photosynthetic photon flux increases as one moved away from main trunk (due to exposure of maximum interior canopy to the sun). The light penetration was highest in severely pruned trees and decreased with pruning severity. The better light penetration in the canopy of pruned trees was noticed due to more sieving of light for photons.

Singh (2005) Dhaliwal and Luciano et al. (2007) conducted an experiment to evaluate different training system, spacing and cultivar on the production of peach trees. They observed that central leader and vase training system were suitable for peach cv. Marciel with 10m x 10m spacing.

G. Singh, A.K. Singh, D. Mishra 2007 studied the effect of planting distance on tree growth, yield, fruit quality and light penetration of guava (*Psidium guajava* L.) cv. Allahabad Safeda at 1.5 x 3.0, 3.0 x 3.0, 3.0 x 6.0 and 6.0 x 6.0 m spacing. Photo synthetically active radiation (PAR) was reported less in closely spaced trees than medium and low ones. Overall, better light penetration was reported in the trees planted at 6.0 x 6.0 and 3.0 x 6.0 m than other.

Corelli and Marini (2008) observed that yield per hectare increased less proportionally to tree density. They also concluded that the yield of trees planted at high densities is eventually limited by the amount of light than can be intercepted by the orchard.

Caruso et al. (2008) The important of increased amount of light interception and its uniformity of distribution within the tree canopy in producing higher yield with a larger amount of top quality fruits was obtained in systems like Y, V and Tatura trellis.

Morandi et al. (2008) reported that in red gold nectarine light interception and gas exchanges were linearly related which confirmed that the amount of carbon potential was proportional with light intercepted. Curvilinear relationship was also reported with light interception and fruit quality. The penetration of light into the canopy is related to training system and planting density for a given training system. Guava canopy which was exposed to sun in all directions (NS/EW) received higher PAR which was higher in trees spaced at 1.5m x 3.0m and 3.0m x 3.0m followed by 3.0m x 6.0m and 6.0m x 6.0m.

J.S. Brar, J.S. Bal et al. (2009) conducted research on radiant energy distribution in guava (*Psidium guajava* L.) plants at different spacing and showed that with increase in plant spacing from 6x2 m to 6x4 m, the interception of radiation increased significantly. However, it starts declining with further increase in plant spacing to 6x5m level. In the upper 1/3rd portion of plant canopy, more than 75% radiations were intercepted irrespective of plant spacing followed by 12-16% in middle and 6-9% in the lower 1/3rd parts of plant canopies. In 6x2m and 6x3m spacing there is lower distribution of radiations particularly in middle and lower parts of plants. The plant spacing of 6x4m was found to be best due to maximum absorption of solar radiation for higher fruiting of better quality fruits.

Hoffmann et al. (2012) evaluated the response functions of yield determinants and components to PAR in olive hedgerow trained trees. They found that PAR distribution and leaf density at different positions within the tree affected inflorescence density, fruit set, fruit density, individual fruit dry weight and oil content. They also found that oil production was limited by low solar radiation within the canopy hence, fruit set, individual fruit dry weight and oil content had a linear response to PAR.

Sharma.Y. (2016) investigated the canopy management in peach (*Prunus persica* (L.) Batsch) at two spacing viz., 5m x 2m and 5m x 3m and trained to four training systems viz., Y shaped, Hedge row, Espalier and V trellis. The total radiation interception and penetration in the upper and lower parts of the

Canopy was higher in Espailer and V trellis trained trees. Average radiation interception during the year was higher in the upper part of the canopy as compared to lower canopy part irrespective of spacing and training systems.

Matei et al. (2013) studied the affect of five new peach cultivars viz., Royal Estate, Earlirich, Rubirich, October star and Late luka on four different canopies under different training system viz., Tatura trellis, V system, Sibari Y and Vertical axis and planted at 4.0m x 1.0m and 4.0m x 1.5 m, 4.5m x 1.5m and 4.0m x 1.5m, respectively. They found that Tatura trellis and V system offer the best light interception ratio and a balanced ratio between the tree growth and yield.

Kumawat et al. (2014) reported that maximum light interception above and below canopy ($356 \mu \text{Mol} / \text{m}^2$) recorded under 2.0×2.0 m spacing and minimum under 1.0×1.5 m spacing,

Guo et al. (2015) evaluated grapes performance on two different training system viz., Modified VSP (slope trunk with a vertical shoot positioning training system) and F-MT (Fan training system with multiple trunks). They reported bigger total leaf area per vine, improved light transmittivity and increased PAR level in the fruiting zone in M-VSP.

Ying and co-workers (2016) examined the effect of thinning on efficiency of PAR, fruit quality and yield. They measured solar radiation and leaf air exchange at different canopy levels and by fitting relevant photosynthetic model, vertical distribution characteristics of leaf photosynthetic potential and PAR were analyzed in various levels within canopies in densely planted orchards. Intermediate thinning and pruning significantly improved the radiant environment inside the canopies. PAR distribution within the canopies in the intermediately planted orchard was better than in the densely planted orchards.

Effect of planting densities and training system on Vegetative Growth

Various observations on vegetative growth viz., height, plant spread, leaf area, stem girth, canopy height, canopy area, total cross sectional area were recorded and analyzed by several workers.

Ravishankar et al. (2008) conducted field study on guava to standardize the planting density and its effect on growth parameters such as scion girth, plant height, and growth pattern such as East-West spread, North-South spread, canopy volume and fruit yield of Allahabad Safeda variety. The grafted plants were planted. The studies were conducted in 4 replications comprising 5 planting densities namely 6 x 3; 6 x 4; 6 x 6; 8 x 4 and 8 x 3 m. The results indicated that the scion girth was significantly higher in widely spaced planting density (8 x 4 or 8 x 3 m). The plant spread across East-West directions was significantly higher in 8 x 3 m spacing.

Sharma. Y. (2016) investigated the canopy management in peach (*Prunus persica* (L.) Batsch) at two spacings viz., 5m x 2m and 5m x 3m and trained to four training systems viz., Y shaped, Hedge row, Espalier and V trellis. She observed that vegetative growth in terms of tree girth and spread was higher in V trellis trees whereas Hedge row trees recorded higher tree height, shoot length and canopy volume. Fruits harvested from Espalier and V trellis trained trees were superior in fruit quality (size, weight, colour and total soluble solids) and matured earlier than the Y shaped and Hedge row trees. The 5m x 3m planted trees were found to be better in terms of light interception, vegetative growth, fruit yield and quality as compared to trees planted at 5m x 2m. Foliar nutrient content of peach leaves was not affected significantly by different training systems and spacing.

Sidhu (1992) studied the effect of six different spacings, viz; 2 x 2m, 2 x 4 m, 2 x 6m, 4 x 4 m, 4 x 6m and 6 x 6 m on cv. Allahabad Safeda budded on Sardar rootstock and obtained the maximum tree girth at wider spacing (6x6 m).

Similarly, Rana and Daulta (1997) obtained reduced trunk diameter with the closest spacing in their studies in Peach cv. Flordasun.

According to Srivastava (2017) Planted four apple (*Malus × domestica* Borkh) varieties (Starkrimson, Cooper IV, Red Chief, and Mollies Delicious) at 3 planting densities (1600, 1142 and 952 plants / ha) on semi-dwarf rootstock and showed that TCSA was significantly influenced by the planting density with maximum mean TCSA (82.23 cm²) recorded in S3 (952 plants/ha) and minimum (77.89 cm²) in S1 (1600 plants/ha). The general trend was, lower the planting density, higher the trunk cross sectional area.

Kumawat *et al.* (2014) studied the effect of planting distance on tree growth of guava cv. L- 49 under ultra high density planting system, at different spacing of 2.0 × 2.0, 2.0 × 1.5, 1.5 × 1.5, 2.0 × 1.0 and 1.0 × 1.5 m. Result show that mean maximum gain of shoot (46.7, 67.1 and 76.5 cm, respectively) and (53.7, 77.2 and 90.4 cm, respectively) were recorded under treatment T1 (2.0 × 2.0 m) and minimum recorded under treatment T5 (1 × 1.5 m). Similarly, after two years of planting maximum plant spread E-W (1.19 m) and N-S direction (1.32 m), girth of stem (3.75 cm) and leaf area (97.16 cm²) were recorded at 2.0 × 2.0 m spacing and minimum at 1.0 × 1.5 m spacing.

Biswas *et al.* (1989) carried out a study on papaya cv. Ranchi which was planted at distances of 1.85 × 1.85m (2940 plants per ha), 2x2m (2500 plants per ha) 2.5 × 2.5m (1600 plants per ha) and 3x3, (1111 plants per ha). Plant height was reported to increase with increasing plant density whereas plant spread and diameter decreased with high density.

Pandey *et al.* (1997) observed highest canopy height under single hedge row planting system and minimum under cluster planting system. Average plant spread and volume were obtained under minimum plant density and vice-versa. Difference in stem girth, however, was found to be non-significant for different planting systems.

According to Palmer and Avery (1992) studied leaf area distribution of apple on four planting systems at tree densities ranging from (3,00 to 8333

trees/ha. They found that leaf area index (LAI) varying from 1.4 for 'Golden Delicious' at 2000 trees ha⁻¹ to 3.3 at 8333 trees/ha. Summer pruning reduced the leaf area by 10-30% and light interception by 6-14% (based on the pre-summer pruning level). Leaf dry weight per unit area was closely related to irradiance within the canopy.

Williams et al. (1999) concluded that tree growth of apricot cv. Tiryanthos was higher in spindle bush as compared to Y-shaped system.

Kumar and Singh (2000) conducted a long term trial at Central Horticultural Experiment Station, Ranchi on Allahabad Safeda at four planting spacing-cum- densities, viz. square system (5 x 5 m, 400 trees ha⁻¹), hedge row system (2.5 x 5 x 5 m, 800 trees ha⁻¹), double-hedge row system (5 x 2.5 x 5 m, 530 trees ha⁻¹) and paired planting (2.5 x 2.5 x 2.5 m, 1060 trees ha⁻¹). They revealed that growth characteristics were significantly influenced by planting systems-cum-densities. The girth (37.8, 36.6, 35.3 & 34.4 cm) and volume (20.65, 18.48, 16.36 & 15.09 m³) showed decreasing trend with increasing tree density, while tree height (3.44, 3.52, 3.74 & 4.15 m) increased with increasing tree density.

Reddy et al. (2002) conducted a study to standardize the planting distance in mango (cv. Amrapali) fruits at different spacing combinations viz: 2.5, 5.0 and 7.5m. They recorded highest plant height (2.32 m), tree girth (37.19 cm) in trees planted at the widest spacing (7.5x7.5 m). The lowest plant height (1.97 m) was observed in the 7.5 x 5.0 spacing. Treatment with 2.5 x 2.5 m spacing recorded the lowest tree girth (29.84 cm), and the highest spread in east –west (2.08m), north-south direction (2.10 m) and tree volume (2.54 m³) indicating a positive correlation of spacing with girth spread and tree volume.

Bal and Dhaliwal (2003) studied that the effects of spacing (6x4, 6x5 and 6x6 m) on the growth and yield of 9-year-old guava (cv. Sardar) trees and observed greatest tree height (4.66m), tree spread in the north-west (5.90m) and east-west (6.33m) directions at 6x6 m.

Rufato et al. (2004) found that canopy size in peach was affected by different training system, which decreased in Y-shape as compared to central leader training system.

Lepsis and Blank (2006) concluded that the relationship between cumulative yield and TCSA can be used for yield modeling in fruit crops. The relation between annual yield and TCSA or cumulative yield effectiveness dynamics cannot be exploited for yield modeling.

Dalal and Brar (2012) reported that the canopy volume, leaf area, yield and production efficiency increased gradually with increase in trunk cross sectional area of plant. They also reported that positive and significant correlation between TCSA and yield. However, a positive but non-significant correlation was found between TCSA and growth parameters viz. TSS, leaf N and P content; while acidity content showed a negative correlation.

Singh et al. (2007) studied the effect of planting distance on tree growth, yield, fruit quality and light penetration of guava (*Psidium guajava* L.) cv. Allahabad Safeda were planted at 1.5 × 3.0, 3.0 × 3.0, 3.0 × 6.0 and 6.0 × 6.0 m spacing. They found that tree growth was significantly influenced by different tree densities. The tree height was highest (5.76 m) at the planting distance of 3.0 × 1.5 m (2222 trees ha⁻¹). Similarly, trunk circumference was also higher (0.86 m) at 1.5 × 3.0 m than the planting distance of 6.0 m × 6.0 m. A marked variation was noticed among different tree spacing on canopy spread (NS/EW). The canopy spread was 5.26/5.20 m in NS/EW directions at planting distance of 6.0 × 6.0 m in comparison to 4.46/4.31 m in closely spaced trees (1.5 × 3.0 m). The total yield was highest (79.5 kg tree⁻¹) at the distance of 3.0 × 6.0 m, while it was only 32.60 kg /tree from the planting distance of 1.5 × 3.0 m.

Kiprijanovski et al. (2009) planted Jonagold apple at five different planting distance viz., 4m x 1m, 4m x 1.5m, 4m x 2m, 4m x 2.5m and 4m x 3m and observed that distance between the trees in the row had a significant influence on their vegetative growth, bearing and quality of the fruits. The

biggest crown volume per tree (7.9 m³) was obtained at 4x3 m whereas biggest crown volume per hectare (10.250 m³) was at 4 x1 m.

Pilania et al. (2010) reported that different pruning intensity in meadow orcharding of guava exhibits maximum canopy volume with 25% pruning of previous season growth.

Lukic et al. (2012) was observed that plum cultivars which were grown in the form of open vase canopy had higher canopy volume and were more productive as compared to pyramidal form.

Pratibha et al. (2013) observed that one leaf pair shoot pruning significantly decreased the plant height, plant spread, and stem diameter and plant volume as compared to un-pruned plant under different planting system. They also concluded that maximum annual increase in plant spread, stem diameter and plant volume in unpruned plant. One leaf pair shoot pruning in combination with double-hedgerow system of planting gave minimum annual increase in plant spread, stem diameter and plant volume and was lesser than in treatment combination of un- pruned plant and square planting system.

Kucuker and Ozkan (2014) found that canopy volume was higher in vertical axis system as compared to slender spindle in case of apple.

Choi et al. (2014) evaluated effects of different training systems viz., Y-trellis (YT), T-trellis (TT), and vase-pergola on growth and fruit production of 'Niitaka' pear (*Pyrus pyrifolia* L.) and observed that the trees which were trained to Tatura trellis had lower tree height.

Pandey et al. (2015) standardized the planting density of 7 year old litchi cv. Shahi 8 planting densities i.e. 2x2, 4x4, 4x6, 6x6, 8x4, 8x6, 8x8 and 10x10 m. Among various plant densities, they reported that moderate plant density at 6x6m accommodating 256 plants/ha performed better over other densities. The highest vegetative growth in terms of canopy area (17.95m²), plant volume (53.49 m³) was obtained in 6x6m spacing.

Gaikwad and Chalak *et al.* (2017) studied the effect of spacing on growth, yield and quality of mango variety Kesar and reported highest plant height (7.0m) in the 10 x10 m spacing which was statistically higher than other two spacing. In case of trunk girth, the maximum (98.5cm) was attended in 10 x 10 m spacing, while the plant spread (EW and NS) was significantly higher in 10 x 10m spacing.

According to Raj Amit *et al.* (2017) high density planting systems after rejuvenation did not exert significant differences in leaf area and relative water content of leaf. This might be due to single variety taken in all the planting systems. Plants under cluster planting recorded the highest leaf area (156.68 cm²), which was at par with hedge row planting system (149.24 cm²) and paired planting system (146.24 cm²). The minimum leaf area (137.20 cm²) was recorded in plants under square planting system.

Bhagyashree M, Nagesh Naikl *et al.* (2018) conduct an experiment to find out the effect of plant spacing and nutrients on growth and yield of eight years old guava (*Psidium guajava* L.) cv. Sardar. They revealed that the plant height, stem girth, plant spread for North-South, plant spread for East-West, canopy volume, were significantly higher with the wider spacing of 6 m x 6 m.

Sagar *et al.* (2019) studied the effects of high density planting and pruning seasons on growth and yield of mango (*Mangifera indica* L.) cv. Alphonso and reported the maximum plant height increment (17.66 cm) in D3T2 (5.0 x 5.0 m with previous season growth pruning) whereas, the maximum plant girth (1.87 cm) were recorded in D1T3 (2.5 x 2.5 m with current season growth pruning). The maximum plant spread (East-West) (22.62 cm), plant spread (North- South) (26.04 cm) and canopy volume (0.92 m³) were recorded in the treatment D2T1 (5.0 x 2.5 m in un- pruned plants).

Sidhu (1992) studied the effect of different spacing on the vegetative growth of guava cv. Allahabad Sufeda and obtained maximum tree vigour in terms of tree spread, girth and canopy volume in the widely spaced (6 m²) trees.

Deshmukh et al. (1981) also studied the effect of spacings on nine-year-old Nagpur mandarin trees budded on jambhiri rootstock and recorded greater spread at the wider (6 m²) spacing, with greater height over the tree spread at the narrow spacing (3 m²).

Effect of planting densities and training system on Flowering and Yield Attributing traits

Sharma and Singh (2018) conducted an experiment on trees of Shan-i-Punjab peach were planted at two spacings viz., 5m x 2m and 5m x 3m and trained to four training systems viz., Y shaped, Hedge row, Espalier and V trellis. Maximum mean flower bud density (13.95) was recorded in V trellis trained trees and minimum mean flower bud density was recorded in Hedge row trees. Fruiting characters including fruit set, fruit retention, fruiting pattern was maximum in Espalier trained trees and minimum in Hedge row trees. Maximum fruit drop was found in Hedge row trees and minimum in Espalier trees. Trees planted at 5 X 3 m gave higher flower bud density, fruit set, fruit retention, fruit drop as compared to 5 X 2 m planted trees. It was also reported that upper canopy part carry maximum flower bud density.

Joshi (2017) conducted an experiment to evaluate effect of spacing pruning on yield characteristics of guava. The treatments were consisted of two plant spacing (i.e. 2.0 x 1.0 m and 2.0 x 2.0 m) and three pruning intensities i.e., one fourth, half and three fourth shoot pruning with un-pruned treated as control. Result showed that the emergence of new shoots and flower buds per plant was maximum at wider spacing (2.0 x 2.0 m). The treatment consisted of 2.0 x 2.0 m plant spacing and three fourth shoot pruning was found superior in this regard, significantly higher fruit set (68.42%) was recorded with treatment combination of 2.0 x 2.0 m plant spacing and three fourth shoot pruning, number of fruits and yield per plant increased with increase in plant spacing. Whereas, yield on the basis of per hectare was found higher with closer spacing (2.0 x 1.0 m).

Gordan et al. (2014) concluded that yield per tree in cultivars planted at the distance of 4 x 4 m was higher from 84% ('Max 7') to 171% ('Sunprince') in comparison with trees in the high-density planting planted at 4 x 2 m (1,250 Trees/ ha) and 3.5 x 1 m (2,800 trees/ ha). However, regardless of the lower yields per tree, in the high density system higher yields per hectare were achieved. Lower yield per tree that is obtained in high-density planting is the result of reduced area for the development of the fruit tree.

Lal (2018) investigated the influence of two different planting densities (2.5 m x 2.5 m and 3.0 m x 3.0 m) on yield attributes of four peach/nectarine (Fantasia, Crest Heaven, Red Globe & Gloheaven). The results of study clearly indicated higher number of flowers (428.32), fruit number per plant (257.66), yield (21.84 kg/tree, 35.12 t/ha) were recorded maximum at wider spacing of 3 m x 3 m.

Bhatia et al. (2017) conducted research on effect of different planting time and spacing on growth, yield and quality of strawberry (Fragaria xananassa) cv. Ofra} and obtained the lowest no. of fruits per plant under the closet spacing .The reduced no. of plants under wider spacing undergone less inter or intra plant competition which caused an increased no. of fruits per plants.

Mishriky and Alphonse (1994) stated that the number of fruits per plant decreased with closer plant spacing. Plant spacing had significant effect on yield per hectare. They conclude that the yield of fruits per unit area was inversely related to the plant spacing i.e. the closer the plant spacing the higher yield of fruits per plot and per hectare.

Ughade et al. (2013) reported that the higher yield of fruits was mainly contributed by the higher plant population per unit area in closer spacing.

Kumar and Singh (2000) conducted a long term trial on guava cv. "Allahabad Safeda" under four planting spacing-cum- densities, viz. square system (5 x 5 m, 400 trees ha⁻¹), hedge row system (2.5 x 5 x 5 m, 800 trees/ha), double-hedge row system (5 x 2.5 x 5 m, 530 trees/ha) and paired

planting (2.5 x 2.5 x 2.5 m, 1060 trees/ha). They recorded maximum fruit weight was recorded in lowest density (130.3g) with closer spacing, yield of individual tree showed decreasing trend (20.54, 17.52, 14.87 & 12.62 kg), whereas yield per hectare showed increasing trend (8212, 9065, 11868 & 13697 kg) with increasing tree densities.

Mitra et al. (1984) and Kundu et al. (1993) showed that higher plant density decreased the fruit weight and size but the yield per unit area increased considerably in guava cv. "Allahabad Safeda" planted at 6 x 2 m spacing and managed by hedge-row system. This treatment also produced the highest yield per hectare with better quality fruits. However, per tree yield was reduced as compared to 6 x 6 m spacing.

Kundu (2007) conducted an experiment to find out the effect of high density planting on growth, flowering and fruiting of guava cv. L-49 and concluded that the increase in plant density markedly increased the plant height while the basal girth of the plant and spread of the crown decreased. High density planting delayed the emergence of flowering, shortened the flowering period and reduced the fruit set. An increase in plant density from 278 to 1600 ha⁻¹ was found to decrease the yield from 36.8 kg to 27.9 kg plant⁻¹, reduced the fruit weight from 135.4 g to 125.7 g but increased the yield ha⁻¹ from 102.4 q to 446.5 q ha⁻¹. Close planting decreased the TSS and acid ratio of fruit.

Singh and Dhaliwal (2007) conducted an experiment on the influence of solar radiation interception on the physical characteristics of fruits of guava cv. "Sardar" under 3 different spacing (6 x 4, 6 x 5 and 6 x 6 m) and concluded that trees spaced at 6 x 6 m intercepted significantly higher radiation on per tree basis than 6 x 5 m and 6 x 4 m spaced trees. The upper part of tree canopy intercepted maximum radiation than the middle and lower canopy parts irrespective of planting distances. The size and weight of fruits harvested from the trees spaced at 6 x 6 m were found significantly higher than the trees spaced at 6 x 5 m and 6 x 4 m. However, the specific gravity of the fruits

harvested from 6 x 4 m was found maximum and it decreased with increase in spacing whereas, the fruit yield tree⁻¹ decreased with decrease in spacing.

Arsov et al. (2009) evaluated the influence of four different training systems (slender spindle, Northern Holland spindle, solex and 'V' system) on the productivity of the apple cultivar 'Jonagold'. The planting distance was different and according to the training system. For slender spindle and solex the planting distance was 4 x 1.5 m (1667 trees/ha) and for Northern Holland spindle and 'V' system 4 x 1 m (2500 trees/ha). Their results showed statistically significant differences between location and between different training systems. Concerning the productivity, the tree grown under the slender spindle system has the highest yield, whereas the ones from the 'V'-system had the lowest. Based on per hectare, the Northern Holland spindle system is mostly productive. while the solex system had the lowest yield per ha. The trees on solex training system have the highest yield efficiency and the lowest was observed on slender spindle system. The maximum fruit weight was obtained at slender spindle and solex and minimum in 'V'- system.

Sagar et al. (2019) studied the effects of high density planting and pruning seasons on growth and yield of mango (*Mangifera indica* L.) cv. Alphonso. They obtained maximum number of fruits per plant (54.95) and yield per plant (14.72 kg) was at 7.5 x 5.0 m. Treatment, 2.5 x 2.5 m showed the maximum yield per hectare (14.61 t/ha). Plants spaced at 5.0 x 5.0 m and 7.5 x 5.0 m with pruning showed beneficial results whereas, for get the maximum yield per unit area 2.5 x 2.5 m spacing (high density planting) was found to be effective.

Pandey et al. (2015) conducted an experiment comprising of 8 planting densities i.e. 2x2, 4x4, 4x6, 6x6, 8x4, 8x6, 8x8 and 10x10 m on 7th year old plants of litchi cv. Shahi with an objective to standardize optimum plant density to get higher fruit production per unit area without affecting fruit quality. The highest fruit production to the tune of 18.18 kg/plant, productivity efficiency (0.138) and fruit weight (21.51 g) was obtained in 6x6 m spacing. However, the

closest spacing of 2x2 m showed poor plant vigor, yield/plant and fruit quality except plant height.

Dalal and Sangwan *et al.* (2013) investigated the effect of tree spacing on growth performance, yield parameters and water use efficiency of five and six year- old Kinnow mandarin growing on rough lemon rootstock was studied. Plants were grown at three spacing viz, 6 × 6 m, 6 × 5 m and 6 × 3 m. They found that plant growth parameters were not influenced significantly by different planting densities. However, maximum plant height, plant spread, canopy volume, canopy surface area, canopy foot print and trunk cross sectional area was observed under low density planting (6 m × 6 m) and minimum under high density (6 m × 3 m). Maximum crop load (276.64 fruits/plant) and yield (46.65 kg/tree) on per tree basis was found in low density (6 m × 6 m), while resource distribution was found maximum (2.64 fruits/cm² TCSA) in 6 m × 5 m spacing. The maximum fruit weight (171.83 g), yield (220.99 tonnes/ha) on unit area basis and water use efficiency (24.72 kg/ha/cm) was observed at a spacing of 6 m × 3 m and minimum values in 6 × 6 m spacing. Net profit ranged from Rs. 82,904 to Rs. 1, 33,417/ha in 6 × 6 m and 6 × 3 m spacing respectively. Overall, the closest spacing of 6 × 3 m may be adopted by the Kinnow growers for getting better productivity, WUE and profit per unit area in the initial years of planting, i.e. up to age of six year. Key words: Planting density, Kinnow, canopy, yield, water use efficiency, economics.

Muhammad Azher Nawaz, Waqar Ahmed *et al.* (2017) evaluated the effect of tree spacing on vegetative performance and yield of Kinnow mandarins (*Citrus reticulata* Blanco) at three planting distances D1 (11 × 11 ft), D2 (11 × 22 ft) and D3 (22 × 22 ft). Result revealed that maximum plant height (11.46 ft) was observed in D1 while minimum plant height (8.83 ft) in D3. Maximum numbers of flushes (12.80) were found in D3 and minimum numbers of new flushes (9.25) in D2 while minimum yield was found in D1 (414 fruits). In case of total soluble solids (TSS), highest (11.49) was observed in D3 while minimum TSS (9.92°Brix) was found in D1. For most parameters, D2 outclassed all the

other treatments and proved to be the best planting distance for Kinnow mandarin under agro ecological conditions of the Punjab province of Pakistan.

Kumar et al. (2013) conducted an experiment on two planting densities (3.5 m × 3.5 m and 5 m × 5 m) as main plot and four apricot varieties (CITHApricot-1, CITH-Apricot-2, Harcot and Erani) as sub-plot treatment. Experimental results clearly indicated that maximum trunk cross-sectional area (TCSA) of tree (118.38 cm²), fruit number (2044), fruit weight (56.43 g), fruit size (4.87 cm × 5.06 cm) and yield (118.68 kg/tree), stone weight (3.50 g), stone size (2.59 cm × 2.24 cm), kernel weight (1.13 g) and size (1.66 cm × 1.39 cm), TSS (15.90°Brix) and leaf N,P,K content (1.17, 0.149, 1.69%) were recorded at wider spacing 5 m × 5 m. Whereas, fruit yield per hectare (52.05 t/ha) and acidity (0.71%) was maximum in closer plant spacing (3.5 m × 3.5 m) in main plot treatment. Among variety, maximum Trunk cross-sectional area, fruit weight, size, fruit yield, TSS and leaf NPK content were recorded in CITH-Apricot-1. However, fruit number, stone weight, size, kernel weight, size and acidity were recorded in CITH-Apricot-2. TSS/acid ratio was highest in Harcot.

Kumawat et al. (2014) determine the effect of planting distance on flowering and yield of guava and result showed that maximum flowers plant-1 (88.40), number of fruits plant-1 (17.20), fruit weight (77.50 g), yield plant-1 (1.32 kg) and TSS/acid ratio (33.14) recorded under 2.0 × 2.0 m spacing and minimum under 1.0 × 1.5 m spacing, maximum plant height (1.58 m) and estimated yield (5.72 t ha⁻¹) were recorded under 1.0 × 1.5 m spacing Further, trees spaced at 2.0 × 2.0 m produced better quality fruits as compared to other spacing treatment.

Effect of planting densities and training system on Leaf Nutrient Content

Kumar et al. (2013) found that maximum leaf nitrogen, phosphorous and potassium content (N: 1.17%, P: 0.149%, K: 1.69%) in apricot were recorded in wider spacing as compared to closer spacing.

Dinesh Kumar (2013) conducted an experiment to study the effect of different planting densities and varieties on leaf nutrient status of apricot. The leaf nitrogen, phosphorus and potassium content increased with decrease in

planting density from 816 to 400 plant/ha. Maximum leaf nitrogen, phosphorus and potassium content (N: 1.17, P: 0.149, K: 1.69%) were recorded in wider spacing and minimum in the closer spacing. The wider spacing might be responsible for higher uptake and translocation of nutrient from soil to aerial part of the plants.

Schneider *et al.* (1978) reported that spacing did not affect nitrogen, iron, zinc or copper content of the leaves of apple cv. Red-spur, however, leaves from widest spaced trees had more phosphorus and potassium and closely spaced trees more calcium, magnesium and manganese content.

Barrera and Slowik (1980) found that spacing had no effect on phosphorus and calcium content, however, leaf nitrogen content decreased and potassium iron increased with increasing tree density.

According to Arora *et al.* (1983) higher levels of nitrogen, phosphorus and potassium were recorded from kinnow leaves in closer spacing followed by intermediate and wider spacings, however, the difference could not attain the level of statistical significance.

Olszewski and Mika (1986) found that leaves from triple rows had higher content of phosphorus and potassium and lower content of calcium and magnesium than leaves from single rows in apple cv. Macspur.

Sidhu (1996) also conducted studies in Kinnow mandarin planted at six different spacings i.e. ($7m^2$, $6m^2$, 6×3 m, 6×4 .S, 4×5 m, and $3m^2$) and found maximum leaf nitrogen, phosphorus and potassium content from trees planted at wider spacing ($7m^2$ and $6m^2$).

Hassan *et al.* (2010) reported that apple trees were trained on two different training system viz., Tiller training system and open central leader system. It was found that apple trees which were trained to tiller system recorded more nitrogen and potassium content in leaves as compared to other system. Whereas no significant difference was found in leaf phosphorous content.

Sharma Y. (2016) observes that foliar N concentration was affected significantly by the training systems. Nitrogen level was found to be higher during the year 2014 as compared to 2015. Maximum mean leaf nitrogen (3.99%) was reported in Hedge row trees which was statistically at par with trees trained to Y-shaped system (3.91%). But mean foliar P concentration was not affected significantly by training systems and spacing in peach. However, little variations in foliar P were evident during her studies. In general, foliar P level were found to be higher in 2015 as compared to 2014 irrespective of spacing and training systems. Foliar potassium content was affected significantly training systems. Maximum mean K content was recorded in Hedge row system (2.17 %) and it was significantly higher than foliar K content in the trees trained to other systems.

Hassan *et al.* (2010) found results in agreement with those reported by who found that foliar potassium content was significantly higher in trees trained to tiller training system as compared to central leader system in apple. Spacing also affects K content, significantly. Mean potassium content was found to be more (2.00%) in 5m x 2m spacing planted trees as compared to 5m x 3m planted trees (1.90%).

Kumar *et al.* (2013) found higher foliar K at wider spacing in apricot and apple, respectively.

Sidhu and Kaundal (2005) observed that spacing had no significant effect on K levels in plum and the foliar K levels were well within the optimum range as suggested by Arnold and Crocker (1976).

Singh (2001) also found no significant effect on nitrogen content in the leaves of peach trees planted at different densities.

Kumawat *et al.* (2014) and Kumar *et al.* (2013) found higher leaf N in 5m x 5m planted trees as compared to 3.5m x 3.5m in apricot.

Pramanick et al. (2012) pointed out that maximum leaf nutrient content (K) accumulation was observed in case of apple tree density of 1111, whereas the minimum level was recorded at a planting density of 4444 trees/ha.

Singh et al. (2017) found that spacing also significantly affected the K content. The minimum K content was recorded in leaves taken from plants at 5x2 m spacing (1.23%) and the maximum in leaves taken from plants at 5x5 m spacing (1.28%), the potassium content of leaves increased with decreasing plant density. The potassium content were recorded maximum in leaves taken from plants at wider spacing and the minimum in leaves taken from plants at closer spacing, which might be due to wider spacing responsible for higher uptake and translocation of nutrient from soil to aerial part of the plants.

Raj et al. (2017) studied the effect of high density planting systems on physio-biochemical parameters of mango cv. Amrapali orchard over two consecutive years. High density planting systems showed significant effect on biochemical and nutritional parameters of plants. Among the different planting systems, plants under cluster planting system recorded the highest leaf area (156.68 cm²), and N (1.28%) P (0.20%) and K (0.54%) contents, while the maximum chlorophyll 'a' (1.50 mg g⁻¹), chlorophyll 'b' (0.65 mg g⁻¹) and total chlorophyll (2.02 mg g⁻¹) contents were found in plants under square planting system. The highest total phenol (53.09 mg g⁻¹) content was recorded under paired planting system.

Yakunina and Maslov (1978) studied the effect of tree spacing on chlorophyll content of apple trees and found a decrease in the leaf chlorophyll content with an increase in the density, with the highest in the trees spaced at 7m² and lowest in trees spaced at 7 x 2.5 m.

Rud et al. (1978) investigated the effect of rootstock and spacing on the leaf chlorophyll content of apple cv. Jonathan and found a decreasing trend in the chlorophyll content with diminishing distance between the trees in apples.

Pitushkan (1988) investigated the effects of planting density on the growth and fruiting of apple cultivars in a Super-Intensive Orchard, observed

more pigment accumulation in the leaves of the lower part of the crown regardless of varietal characteristics and planting density.

Effect of planting densities and training system on Fruit Quality

Lal (2018) investigated the influence of two different planting densities (2.5 m × 2.5 m and 3.0 m × 3.0 m) on fruit quality of four peach/nectarine (Fantasia, Crest Heaven, Red Globe & Gloheaven). The results showed that fruit length (54.77 mm), fruit weight (82.88 g), fruit pulp thickness (22.66 mm), TSS (15.34 °B) and TSS/acidity (50.92) were recorded at wider spacing 3 m × 3 m. Whereas, titratable acidity (0.320%) and ascorbic acid content (6.65 mg/100g) was maximum in closer plant spacing (2.5 m × 2.5 m).

Patel et al. (2018) conducted an experiment on “Effect of different levels of planting distance and fertilizers on growth, yield and quality of banana cv. Grand Naine” to evaluate the effect of four different planting distances with three levels of fertigation which was laid out in split plot design with three replications on growth, yield and quality parameters of banana. Growth parameters like plant height and stem girth were found significantly higher with planting distance at 2.0 X 2.0 m two plants per hill (S2). Plants grown under planting distance at 1.2 X 1.2 X 2.0 m pair row (S1) showed significantly higher yield (t/ha) as compared to other planting distance. The maximum numbers of fingers per hand and bunch weight (kg) were found significantly in conventional method of planting at 1.8 X 1.8 m (S4). Quality parameters like TSS and total sugar were found significantly higher at planting distance of 2.0 X 2.0 m with two plants per hill (S2).

Robinson et al. (1991) evaluated the effect of four Orchard Production Systems on fruit quality of apples cv. Empire and Delicious found poor fruit quality in terms of total soluble solids and acids in the close plantation of apple cv. Empire trained to 'Y' trellis due to poor light interception.

Caruso et al. (1999) also studied the effect of planting density on fruit quality of Flordaprince peach and observed the negative effect of plant density on total soluble solids and acids.

Kumar (2013) conducted an experiment to study the effect of different planting densities and varieties on growth, fruit yield, quality and leaf nutrient status of apricot at two planting densities (3.5 m × 3.5 m and 5 m × 5 m) as main plot and four apricot varieties (CITH- Apricot-1, CITH-Apricot-2, Harcot and Erani) as sub-plot treatment were laid out in split plot design with three replication. They found that maximum trunk cross-sectional area (TCSA) of tree (118.38 cm²), fruit number (2044), fruit weight (56.43 g), and fruit size (4.87 cm × 5.06 cm) and yield (118.68 kg/tree), stone weight (3.50 g), stone size (2.59 cm × 2.24 cm), kernel weight (1.13 g) and size (1.66 cm × 1.39 cm), TSS (15.90°Brix) and leaf N,P,K content (1.17, 0.149, 1.69%) were recorded at wider spacing 5 m × 5 m. Whereas, fruit yield per hectare (52.05 t/ha) and acidity (0.71%) was maximum in closer plant spacing (3.5 m × 3.5 m) in main plot treatment. Among variety, maximum Trunk cross-sectional area, fruit weight, size, fruit yield, TSS and leaf NPK content were recorded in CITH-Apricot-1. However, fruit number, stone weight, size and acidity were recorded in CITH-Apricot-2. TSS/acid ratio was highest in Harcot.

Singh et al. (2007) conducted research on trees of guava (*Psidium guajava* L.) cv. Allahabad Safeda at 1.5 × 3.0, 3.0 × 3.0, 3.0 × 6.0 and 6.0 × 6.0 m spacing to determine the effect of planting distance on tree growth, yield, fruit quality and light penetration. The yield of per unit area was more (7.24 kg) at the planting distance of 1.5 × 3.0 m (2222 trees ha⁻¹). Trees spaced at 6.0 × 6.0 m and 3.0 × 6.0 m produced fruits of more weight with better TSS, vitamin C and total sugars. Planting density showed a strong influence on leaf sugar content. The sugar content in outer and inner leaves varied from 0.29 to 0.35, 0.30 to 0.33, 0.26 to 0.35 and 0.38 to 0.38 per cent in the trees planted at 6.0 × 6.0, 3.0 × 6.0, 3.0 × 3.0 and 1.5 × 3.0 m, respectively.

Rana et al. (1998) reported that number of large fruits were higher under Tatura trellis system.

Chenyl et al. (2002) observed no consistent difference in relation fruit size and colour development of apple trees trained on different training system viz., slender spindle, geneva “Y” trellis, modified solen training and V-trellis.

Hampson et al. (2002) showed that planting density had stronger effects on fruit quality, growth and light interception than training systems at the same spacing, underlining the plastic responses of the tree canopy manipulation.

Lannini et al. (2002) reported that ripening and quality parameters of nectarine were found best in Y shape training system as compared to palmette system.

Stanica et al. (2002) reported that Y trellis training system improves the productivity of pear plants and offer the possibility to obtain high quality yields.

Bennewitz et al. (2011) appropriate canopy and crop load management are required to obtain an adequate balance between the yield and fruit size in the fruit crops. (**Thesis of canopy in pear**)

Lu et al. (2003) found that peach cv. Ruipan obtained better light distribution and good fruit quality in slanting central leader system as compared to trees which were trained on Y-system.

Giovannini and Liverani (2005) conducted an experiment on Dwarf peach cv “Valley Red” trees trained to the Palmette, Vase, Y systems and Globe They reported that fruit quality (size, color, soluble solids content and titratable acidity) was not affected by the training system and low fruit quality was largely due to difficulties in optimizing fruit thinning and harvesting associated with the very dense canopy of the dwarf genotype.

Farina (2005) reported that different sized fruits were obtained from trees which were trained to delayed vase, whereas Y shaped trees had distribution throughout the canopy.

Lukic et al. (2012) reported that training system did not affect yield efficiency of stone and fruit weight. 'Cacanska Lepotica', 'Cacanska Rodna' and 'Stanley' plum cultivars grown under improved pyramidal and open vase canopy.

Arsov et al. (2013) found highest value for the fruit weight was obtained at slender spindle and solex whereas 'V'-system had the lowest value for fruit weight in apple cultivar 'Jonagold'.

Cortell and Kennedy (2006), Ristic et al. (2007) and Rahmani et al. (2015) also found that fruits in exposed portion of canopy exhibit higher concentration of sugars as compared with shaded fruits.

Choi et al. (2014) reported that fruit size was found to increase in vase pergola as compared to tatura trellis in asian pear.

According to Smart and Robinson (1991) fruit in exposed portions of the canopy generally exhibit higher concentrations of sugars as compared with shaded fruits.

Singh (2001) observed an increase in sugar content of peach fruits harvested from upper parts of the canopy.

Heinicke (1966) reported that apple fruit in parts of the tree receiving less than 30% of full sunlight had less dry matter and sugar content than those growing in full sunlight.

Bonora et al. (2015) investigated that out of the two training system, fruit ripening heterogeneity was higher in the "palmette" than in "Tatura trellis". It was found that in the palmette, riper were located in the tree upper canopy layer.

Musacchi et al. (2015) reported that training system and tree density had no effect on fruit size distribution in 'Lapins'/'Colt' sweet cherry.

Pandey (2015) reported that physico-chemical parameters of litchi fruits were significantly influenced by planting densities in litchi. However, plant per unit area did not showed any significant response on pulp recovery, seed

weight and ascorbic acid content of the fruit .The highest fruit weight (21.51 g) was recorded in 6x6m spacing and lowest (18.64 g) in 2x2 m spacing. Pulp recovery was ranged from 55.50 to 60.74 % in planting density 2x2 m to 10x10 m spacing. Seed weight ranged from 3.16 to 3.69 g in 8x8 m and 8x4 m spacing. TSS content of the fruit increased with decreasing the plant density, whereas, acidity content showed reverse trend. The highest TSS (20.57 °Brix) was noted in 10x10m spacing which was at par with 8x4 m (19.87 °Brix) and 8x8m (19.46 °Brix) and lowest in 2x2m (17.47 °Brix) and 4x4 m (17.71 °Brix). The acidity varied from 0.58 to 0.75% in 10x10m and 2x2 m spacing. Ascorbic acid content ranged from 19.33 to 24.0 mg in 8x4 m. The highest TSS and lowest acidity under wider spacing may be due to better light penetration which increases the photosynthetic activities for conversion of higher photosynthate which ultimately improve the fruit quality.

Srivastava (2017) planted four apple (*Malus × domestica* Borkh) varieties (Starkrimson, Cooper IV, Red Chief, and Mollies Delicious) at 3 planting densities (1600, 1142 and 952 plants / ha) on semi-dwarf rootstock during 2002-03. Results indicated that largest sized fruit (177.80 g/ fruit) recorded in the S3 (952 tree/ha) and minimum (160.73 g/ fruit) in S1 density (1600 tree/ha). Maximum mean yield and was recorded in Starkrimson and Red Chief and minimum yield in Cooper IV. Density has a detrimental effect on yield; it was maximum in S3 and minimum in S1 density. The fruit weight increases with decrease in plant density, fruit size has negative correlation with number of fruit tree.

Effect of planting densities and training system on Soil Parameters

Adak et al. (2015) observed that compaction in lower depth soils increased the bulk density and lowers porosity across six plantation systems. Water holding capacity was higher in the system where less number of trees was accommodated than 1600 and 800 trees ha⁻¹.

Singha et al. (2016) Based on a study on 20 yrs old Guava HDP system (2200, 1100, 555 and 277 trees ha⁻¹) concluded that medium density systems is best suited from view point of microbial activities.

Tarun Adak (2019) conducted an experiment on analysis of soil and tree productivity under high density planting system in mango cv. Dashehari (*Mangifera indica* L.) and find that higher density plantations showed compaction in deeper depths; hence increased bulk density and lowers porosity. The role of soil compaction in higher density plantation system (>400 trees ha⁻¹) might have decreased the yield.

Effect of planting densities and training system on Physiological traits

Raj et al. (2017) find that rejuvenation of high density mango plants showed significant differences in rates of photosynthesis .The maximum photosynthetic rate (8.36 $\mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$) was recorded in plants of hedge-row planting system, which was at par with cluster planting (8.23 $\mu\text{mol CO}_2\text{m}^{-2}\text{s}^{-1}$), followed by square planting system (7.47 $\mu\text{mol CO}_2\text{m}^{-2}\text{s}^{-1}$) and double-hedge row planting system (7.26 $\mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$). In this study, high density planting systems showed significant effect on photosynthetic rate, stomatal conductance, transpiration rate and internal carbon concentration.

Givnish, (1986), Mendes et al. (2001) Heuvel, (2009), Tingfa Dong et al. (2017) reported that the values of photosynthetic rate were smaller under the high planting density. They found a low photosynthetic level at high densities, with nevertheless a relatively high C_i , suggesting that the stomatal conductance was not the main limitation on photosynthesis (Tuzet et al. 2003). Relative to the stomatal conductance, the mesophyll conductance was more sensitive to changes in the surroundings, such as shading (Niinemets et al. 2006; Warren et al. 2007; Flexas et al. 2007, 2008) and drought (Duan et al. 2009).Leaves of trees in a higher planting density usually suffer from lower light irradiance from the shading of among branches (Warren et al. 2001). In this study, the lower gm in the high planting density was consistent with that found in previous studies (Piel et al. 2002; Niinemets et al. 2006; Flexasetal. 2007; Warren et al. 2007).

At the global scale, the photosynthetic capacity and nutrients in leaves are the core physiological traits (Wright *et al.* 2004). N and P are generally considered the nutrients that most strongly affect photosynthesis in leaves (Boyce *et al.* 2006). Numerous studies have reported that photosynthesis is determined by the N and P concentrations or the N/P ratio in leaves.

MATERIAL AND METHODS

Present study entitled “Investigation on influence of planting geometry and canopy architecture on morpho- physiological parameters, yield and quality attributes in litchi” was carried out at ICAR-NRC on Litchi, Muzaffarpur, Bihar during the year 2018-19 and 2019-20. The experiment were carried out on bearing plantd at different spacing and geometry with the objective of evaluating the morphological growth parameters, yield and quality traits at ICAR-NRC on Litchi, Muzaffarpur. The experimental trees were provided appropriate canopy architecture and management schedule. The detail of the experimental site, climate and methodology of investigation is being presented below.

Location of the Experimental Site

The ICAR-National Research Centre on Litchi is located at Muzaffarpur, Bihar between 26°5'64 “N” latitude and 85°26'64 “E” longitude and an altitude of 210 meters above the mean sea level. The research farm of the centre situated on Muzaffarpur- Pusa state highway near Mushahari is spread over an area of 35ha. Soil type of the site is alluvial with sandy loam texture having calcareous nature with pH ranging from 7.5 - 8.0.

Climate and Weather

The region is characterized by humid subtropical climate with temperature varying from 30°C to 43°C in summer and 5°C to 10°C in winter. The region is characterized by dry and hot summer and cold winter with heavy rainfall during rainy season. The onset of monsoon usually occurs in the second or third week of June and continues in appreciable amount up to mid of September. The meteorological data of the experimental site during the period of investigation are given in Appendix I.

TREATMENTS DETAILS

Experiment I Effect of different Spacing in litchi

Treatment No.	Treatment details(Planting distance in square system)	No. of plant/h	Space allocation per plant (m²)
T1	2x2 m	2500	4
T2	3x3 m	1111	9
T3	4x4 m	625	16
T4	5x5 m	400	25
T5	6x6 m	278	36
T6	8x8 m (Control)	156	64

Experiment II Effect of training systems in litchi

Treatments No.	Treatment details (Planting geometry and Training system)	No. of plants/ha	Space allocation per plant (m²)
T ₁	4 x 3 m (with supporting system)	834	12
T ₂	4 x 3 m (without supporting system)	834	12
T ₃	5 x 3 m (hedge row system)	667	15
T ₄	6 x 4 m (hedge row system)	417	24
T ₅	8 x 4 m (hedge row system)	312	32
T ₆	8x8 m (control)	156	64

Observations to be recorded

The observations on following characters were recorded during the course of study in both the years and pooled analysis was carried out by adopting the procedure Panse and Sukhatme (1985).

1. Vegetative Growth Attributes

Plant Height (m)

Observations on height of the trees were measured from the ground surface to the upper most part of canopy with the help of measuring tape and the data expressed in meter.

Stem girth (cm)

The trunk girth was measured with the help of measuring tape at 30 cm above ground level and mentioned in centimeter.

Plant Spread (m)

The distance between the points to which most of the branches of a tree had grown in the north-south and the east-west directions was marked and measured and mean values were presented in meter (m).

Leaf Area (cm²)

The observations on the leaf area were recorded during last week of April when leaves were fully developed. Twenty fully expanded leaves were collected at random from each direction of the tree and leaf area was measured with the help of Leaf Area Meter (CI-203 Area Meter) and expressed in square centimeter (cm²).

Canopy Diameter (m)

Canopy diameter was derived from following formula,

$$\text{Canopy diameter (m)} = \frac{(E-W)+(N-S)}{2}$$

Where, E-W is canopy spread from East to West (m) and N-S is canopy spread from North to South (m)

Canopy Area (m²)

Canopy area of plant derived was from following formula,

$$\text{Canopy area (m}^2\text{)} = \{[\text{Plant spread (N-S)} + (\text{E-W})/2]^2 \times 0.785\}$$

Number and Extent of Flush Growth

Numbers and extent of flush growth were recorded at 3 stages [Stage I: 1 month after pruning (July- August); Stage II: November and December; Stage III: February] in each experimental years. The number of sprouted shoots/ branch was recorded by counting the number of new shoots. The shoot length was measured on individual branch and presented in absolute value centimeter (cm).

2. Light Interception

The observation on 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 (i.e., transmission), and then by subtracting the average percentage transmission of all 90 sensor reading from 100% (total incident light).

$$\text{Light Interception \%} = \text{La} - \text{Lb}$$

Where, La is Light available in open area (absolute transmission)

Lb is Light available below the canopy

3. Physiological Attributes

The physiological observations were recorded on photosynthesis, transpiration, stomatal conductance, internal CO₂ concentration, relative Humidity, vapour pressure deficit (VPD), photosynthetically active radiation (PAR), using IRGA as per method outlined by (LI 6400, USA) (**Fischer et al., 1998**) measured with the help of Portable Photosynthesis System-I (CIRAS 2, Amesbury, USA version 2.01) between 9.30 to 11.30 am. The stem was connected to a cuvette with a Parkinson leaf chamber whose area was 2 cm². The intact leaf lamina was sealed in the leaf chamber and all the major veins were avoided. These observations were recorded at vegetative and fruit development stages, in four replicates in the fully expanded leaves which were fully exposed, partially exposed and completely shaded in the canopy. The two years data at all stages were analyzed as per methods suggested by Gomez and Gomez (1984).

Derived Physiological Parameters

The water use efficiency, mesophyll efficiency and carboxylation efficiencies were determined as per specification of **Warrier and Vankataraman, 2010**. The quantum efficiency was also determined as per method outlined by **Pandey et al., 2001**.

Water Use Efficiency (WUE) (mol/mol)

The water use efficiency was determined as follows:

$$WUE = \frac{Pn}{E}$$

Where, Pn represents the net photosynthesis and E refers to the transpiration rate.

Mesophyll Efficiency (ME):

The mesophyll efficiency was determined as follows:

$$\mathbf{ME = \frac{i}{Cond}}$$

Where, the C_i refers to the intercellular CO_2 concentration and Cond. refers to the stomatal conductance.

Quantum Efficiency (QE) ($\mu\text{mol m}^{-1} \text{s}^{-1}$) / ($\mu\text{mol mol}^{-1}$)

The quantum use efficiency was determined as follows:

$$\mathbf{QE = \frac{P_n}{Q}}$$

Where, the P_n refers to the net photosynthetic and Q refers to the PAR absorption.

Carboxylation Efficiency (CE):

The carboxylation efficiency was also determined as follows:

$$\mathbf{CE = P_n / C_i}$$

Where, P_n refers to the net photosynthesis and C_i refers to the intercellular CO_2 concentration.

4. LEAF NUTRIENT CONTENTS

1 Analysis of Leaf Nitrogen, phosphorus and potash

(a) Leaf sampling

The middle leaves of 50 to 60 days old current season shoots were sampled for N, P and K analysis. The sample size was thirty leaves per sample. The leaf samples were collected thrice first sampling was done before treatment application i.e. second week of April, Second sampling was done in the month of July and third in the month of October. Sampling was done according to the guidelines described by **Chetri et al., (1999) and Singh et al., (2007)**.

(b) Preparation of leaf sample for nutrient analysis

(i) Washing

The leaves were first properly washed with distilled water followed by 0.1 N solution of HCL. Samples were rinsed three times with de-ionized water to remove any external contamination.

(ii) Drying

Washed leaf samples were kept on blotting paper to soak off the excess water. After that the sample was dried in the oven at 60-70°C for 40-45 hours to get a constant dry weight.

(iii) Grinding and storage

The dried leaf samples were ground in Wiley's Mill to powder form and was passed through a 40 mesh sieve to obtain a finely ground sample. These samples were labeled and stored in air tight glass tubes for analysis. Before analysis, the stored samples were further dried at a temperature of 65°C for 12 hours. These samples were then analyzed for N, P and K content.

(C) Analytical methods

The standard analytical procedures have been used for the estimation of total N, P and K which are given below.

Estimation of Nitrogen

To determine the nitrogen, 0.5g of ground sample was digested with 8-9 ml of concentrated H₂SO₄ along with digestion mixture in Kel plus Nitrogen Estimation System (Pelican Equipment, India). In a digestion tube, 0.5g of powdered sample was taken. Further 4-5 g of the catalyst mixture (50:10:1) consisting of 250 g of K₂SO₄ with 50 g CuSO₄ and 5 g metallic selenium was added in the digestion tube. Digestion tube was heated in the digestion block up to 410°C temperature and the end point of digestion was achieved when samples turn colorless or light green. **Distillation**

The tube containing digested sample was transferred to the distillation apparatus (Pelican Equipment, India). As the distillation begins, the digested sample gets diluted with distilled water and subsequently 40% NaOH was poured into the distillation tube. In a 150 ml capacity conical flask, 10 ml of 4% boric acid was taken and two indicators were used. In distillation apparatus, the digested samples were heated by passing steam. Ammonia liberated due to the addition of alkali gets collected in the flask. The boric acid consisting of ammonia was further utilized for titration.

Titration

The boric acid distillate in a conical flask was titrated with 0.1 N H₂SO₄. The end point of titration was determined with the change of colour from bluish green to permanent pale pink. The percentage of nitrogen was calculated by using formula:

$$\text{Nitrogen (\%)} = \frac{14 (\text{normality of acid}) \times 100}{\text{Sample weight} \times 100}$$

Digestion for the Estimation of Phosphorus and Potassium

To estimate the phosphorus and potassium, 0.5 g of sample along with 8-9 ml of di- acid mixture consisting of nitric acid (HNO₃) and per-chloric acid (HClO₄) in the ratio of 4:1 were taken in the digestion tube. The mixture was allowed to stand overnight and then digested. Initially the temperature was kept low which was increased gradually. The end point of digestion was judged when fumes started emerging out from the digestion tubes and solution became colorless. Tubes were then removed from the digestion unit and were allowed to cool. After cooling, the contents were diluted with double distilled water and filtered. The volume was made up to 100 ml with double distilled water.

Estimation of phosphorus

Phosphorous was estimated by Ammonium-molybedate-vanadate method as described by Chapman and Pratt (1961).

Nitric acid vanadate-molybdate reagent

To develop Nitric acid vanadate –molybdate reagent two beaker of 500 ml capacity and one beaker of 1000 ml capacity were properly washed, dried and autoclaved. In one beaker of 500 ml capacity 25 g of ammonium molybdate was dissolved in distilled water. Separately in another beaker of 500 ml capacity, 1.25 g of ammonium metavanadate was dissolved in 300 ml boiling water and the solution allowed to cool. Added 250 ml concentrated nitric acid in first beaker and solution was allowed to cool at room temperature. Gradually, both the solutions were mixed and final volume was made to one liter with distilled water.

Colour development

In a volumetric flask of 25 ml capacity 5 ml of the digested sample was taken and 1-2 drops in a 25 ml volumetric flask and 1-2 drops of 2,4-Dinitrophenol indicator were added. Then 4 N solution of Na_2CO_3 drop was added till the appearance of yellow colour. Afterwards, 6N solution of HCl was added drop by drop till yellow colour disappeared. Further, 2 ml of 6 N solution of HCl was added additional to get required pH of 4.8 followed by addition of 5 ml of vanadate-molybdate reagent. Volume was made to 25 ml with distilled water and allowed to stand for 30 minutes for colour development.

Phosphorus standard curve and Estimation

Stock solution of 50 ppm was made by using 1000 ppm standard solution of phosphorus. From this 50 ppm solution 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5.0 ml solutions were taken in separate volumetric flasks of 25 ml capacity and colour was developed in the same manner as described above for the test samples. Colour intensity of these standard phosphorous solutions was measured at 470 nm wavelength on a Spectrophotometer (Thermo Fisher) and standard curve was constructed. The colour intensity of test samples was measured and phosphorous concentration was estimated from the standard curve and expressed as per cent phosphorus according to the formula given below:

$$\text{Phosphorus (\%)} = \frac{\text{ppm} \times \text{Total dilution}}{10,000}$$

Potassium Estimation

Potassium content was determined by the Flame Photometer method (AOAC 1990).

Development of standard Potassium curve

From 1000 ppm potassium stock solution, 10 ml solution was taken in a 100 ml capacity volumetric flask and volume was made up with distilled water to make 100 ppm stock solution. Out of this 100 ppm stock solution of potassium 1, 2, 4, 6, 8 and 10 ml solution were taken separately in 100 ml volumetric flasks and volume of each was made up with distilled water to 1, 2, 4, 8 and 10 ppm potassium solution. For determining potassium in the leaf samples, 1 ml of digested sample was taken in volumetric flask of 25 ml and volume was made up with distilled water. The test samples were fed to the atomizer of the Flame Photometer (Elico, India) which had been adjusted with standard K solution and readings were noted. The concentration of K present in the test samples were found from the standard curve and expressed as per cent K according to the formula as given below:

$$\text{Potassium (\%)} = \text{ppm} \times \text{total dilution} / 10,000.$$

2 Analysis of Phenolics Content (mg GAE/g):

The total phenol content was determined by the method given by **Sethi et al. (2013)**. Weighed exactly 200 mg of the sample and ground it with pestle and mortar in 10 ml ethanol (80%). Centrifuged the sample at 10,000 rpm for 10 minutes to homogenate and extracted the supernatant. Pipetted 20 microlitre supernatant in a test tube and make up the volume to 3 ml with distilled water and then added 0.5 ml of 1N of FCR (Folin Ciocalteu reagent). After three minutes, added 2 ml of 20% of Na₂CO₃ solution to each tube. The sample was mixed thoroughly and the absorbance was taken at 750 nm. Standard curve was established using various concentrations of gallic acid and results were

calculated as gallic acid equivalent (GAE). Total Phenolic content was expressed as gallic acid equivalent (mg/100g).

3. Total Chlorophyll

The chlorophyll content was determined by the method of Anderson and Boardman (1964). Fresh leaves were crushed thoroughly with 5 ml of acetone (80%) in a pestle and mortar. The extract was centrifuged for 10 minute at 5000 rpm in centrifuse. The supernatant (I) was retained and the residue crushed again in 3 ml of acetone (80%). The extract was centrifuged again and supernatant (II) was retained. The two supernatants (I and II) were combined and the final volume was made to 10 ml with 80 per cent acetone. The absorbance of the chlorophyll fraction was recorded at 645 nm and 663 nm against 80 per cent acetone as a blank on a by digital spectrophotometer (Model CL 27).

$$\text{Total chlorophyll} = [20.2 (A_{645}) + 8.02 (A_{663})] V / 1000 \times W$$

Where,

V = Total vol. of solution made (ml)

W = Fresh weight of the sample (g)

A =Absorbance at 645 nm and 663 nm wavelength

The chlorophyll content was expressed as mg chlorophyll per g of fresh leaf weight.

5 Soil Parameters

1. Soil Temperature and Moisture

Soil parameters such as temperature and soil moisture was observed with the help of Portable Photosynthesis System-I (PP System USA version 2.01) at 7:30- 8:00 am during December -January. The two years data at all stages were analyzed as per methods suggested by Gomez and Gomez (1984).

2. Bulk Density (gm/ml)

Core method is one of the simple methods of determination of soil bulk density. Drive the samples into vertical soil surface for enough to fill the sampler but not to compress the soil in the confined space. Carefully removed the sampler and its contents. Trimmed the soil extending beyond the sampler with a sharp knife. Transferred the wet soil to a tray and weighed it. Took a portion of the sample in a moisture box, weighed and placed it in an oven at 105°C for about 24 hours and weighed it again. **(Black, 1965)**

Observations and Calculation

Mass of the wet bulk soil sample = M_1 (g)

Mass of moisture box = M_2 (g)

Mass of moisture box + wet soil = M_3 (g)

Mass of moisture box + Oven dry soil = M_4 (g)

Mass of weight soil = $(M_3 - M_2)$

Mass of oven dry soil = $(M_4 - M_2)$

Oven dry mass of bulk soil sample = $(M_4 - M_2) M_1 / (M_3 - M_2)$ or = M_3

Volume of bulk sample/core sampler = $V \text{ cm}^3$ or $\pi r^2 h \text{ cm}^3$

Where, r is the radius and h is the height of the core.

Bulk density = $M_3 / V \text{ g cm}^{-3}$

3. Water Retention (%)

Water retention of soil was measured by oven dry method .Soil sample was dried in at controlled temperature (105–1100C).The water content (w) of soil sample will be equal to the mass of water divided by the mass of solids. **(Piper 1966).**

$$[\text{Water Retention \%} = \frac{M_2 - M_3}{M_3 - M_1} \times 100]$$

Where M_1 =mass of empty container with lid,

M_2 = mass of the container with wet soil and lid

M_3 = mass of the container with dry soil and lid.

Soil Specimen:

As a matter of fact the soil specimen should be representative of the soil mass. The quantity of the specimen taken would depend upon the gradation and the maximum size of the particles. For more than 90% of the particles passing through 425 micron IS sieve, the minimum quantity is 25g.

Procedure:

1. Clean the container, dry it and weight it with lid (M_1).
2. Take the required quantity of the wet specimen in the container and close it with lid. Take the mass (M_2)
3. Place the container with its lid removed in the oven till mass becomes constant (normally for 24 hours).
4. When the soil has dried, remove the container from the oven using tongs. Replace the lid on the container. Cool it in desiccators.
5. Find the mass (M_3) of the container with lid and dry soil sample.

6. FLOWERING AND YIELD

1. Number of flowers per plants

The emergence of flowers were counted on whole plant in April during both the years and mean values were presented for both the years separately.

2. Number and length of panicles per branch

The numbers of panicles per branch were counted on whole plant and the length of panicles measured by using scale (cm) in April during both the years and mean values were presented for both the years separately.

3. Number of fruits per plant

Total number of fruits from each experimental tree was counted in the month of April- May before harvest and the average was worked out.

4 Fruit diameter (mm)

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.

5 Fruit weight (g)

From each replications 10 fruits/plant 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.

6 Fruit length (mm)

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.

7. Yield per plant (kg)

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 and their means were presented during both the years. Total harvest from one tree in each replication was also weighed to confirm the yield (kg/tree).

8. Yield per hectare (t/h)

Fruit yield per hectare was calculated by multiplying yield of one plant with total number of plants per hectare and yield in quintal per hectare was expressed during both the years.

7. FRUIT QUALITY

Total Soluble Solids (^oBrix)

Total soluble solids in the fruits were recorded at room temperature using digital refractometer and were expressed in terms of ^oBrix (Rangana, 1997). Five fruits per replication were taken from each treatment for taking the average value.

Acidity (%)

Fruit juice (10 ml) was taken and volume was made up to 100 ml with distilled water. Then 10 ml of this solution was taken for the purpose of titration with 0.1 N NaOH as per method described by Ranganna (1997) using phenolphthalein as indicator. Titratable acidity of litchi fruits was calculated by using the following formula:

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value} \times \text{Normality of alkali} \times \text{equivalent weight of acid}}{\text{Volume of sample taken} \times \text{volume of sample}} \times 100$$

TSS / Acid Ratio

It was calculated by dividing the total soluble solids with titratable acidity.

Total sugar (%)

Total sugar content of litchi pulp was determined calorimetrically by the anthrone method (Jayaraman, 1981).

Reagents: The following reagents were used for determination of total sugar:

(a) Anthrone reagent: The reagent was prepared by dissolving 2 g of anthrone in one liter of concentrated H₂SO₄.

(b) Standard glucose solution: Standard solution of glucose was prepared by dissolving 10 mg of glucose in 100 ml of distilled water.

Extraction of sugar from litchi pulp: Flesh litchi flesh (4 g) was cut into small pieces and immediately plunged into boiling ethyl alcohol which was allowed to boil for 5 to 10 minutes (5 to 10 ml of alcohol was used per gram of pulp).

The extract was cooled and crushed thoroughly in a mortar with pestle. Then the extract was filtered through two layers of muslin cloth and the ground tissue was reextracted for three minutes in hot alcohol (80%) using 2 to 3 ml of alcohol per gram of tissue. The second extraction ensured complete removal of alcohol soluble substances. The extract was cooled and passed through two layers of muslin cloth. Both of the extracts were filtered through Whatmann no. 41 filter paper. The volume of the extract was evaporated to about 25% (1/4) of the volume over a steam bath and cooled. This reduced volume of extract was transferred to a 100 ml volumetric flask and volume was made up with distilled water.

Procedure: Aliquot of pulp extract (1 ml) was pipette into test tubes and 4 ml of the anthrone reagent was added to each of this solution and mixed well. Glass marbles were placed on top of each test tube to prevent loss of water through evaporation. Then the tubes were placed in a boiling water bath for 10 minutes and then cooled. A reagent blank was prepared by taking 1 ml water and 4 ml anthrone reagent in a tube and treated similarly. The absorbance of blue green solution was measured at 680 nm in a colorimeter. A standard curve of glucose was prepared and the amount of total sugar present in the extract was calculated from the standard curve of glucose. Finally, the percentage of total sugar was determined by using the following formula:

$$\text{Total sugar (g/100 g)} = \frac{\text{Quantity of sugar obtained}}{\text{Weight of Sample}} \times 100$$

Organoleptic score

Organoleptic score in terms of general appearance, taste and flavour were recorded by panel of five judges on the basis of Hedonic scale 1-9 described by Reddy, (2012); Jellink(1985) as following table.

Rating of fruits

1 Extremely desirable - 9

2 Very much desirable - 8

- 3 Moderately desirable - 7
- 4 Slightly desirable - 6
- 5 Neither desirable nor undesirable - 5
- 6 Slightly undesirable - 4
- 7 Moderately undesirable - 3
- 8 Very much undesirable - 2
- 9 Extremely undesirable -1

RESULTS

The results of the field experiment entitled "Investigation on influence of planting geometry and canopy architecture on morpho-physiological, yield and quality attributes of litchi cv. Shahi" was conducted during year 2018-19 and 2019-20 at ICAR-NRC on Litchi, Muzaffarpur (Bihar) are presented in this chapter. The results are presented under different heads and sub-heads.

Morphological Parameters:

Plant Height (m)

The effect of different planting densities in square system on plant height during 2019 and 2020 has been presented in table 4.1.1.1 and figure 1. It is clear from the table that plant height in the first year varied significantly among the treatments. The height among treatments varied between 2.038 m (T₁) to 4.21m (T₆). Critical analysis of data reveals that treatments T₁, T₄, T₅ and T₆ are significantly superior with respect to plant height whereas, T₂ and T₃ were at par during 2019. Almost similar trend was observed during 2020. In the plant height among the treatments varied between 2.23m (T₁) to 4.29m (T₆). During 2020 plant height among various treatments was found significantly different except T₃ and T₄ which were at par.

Pooled analysis of plant height in litchi with various spacing in square system revealed that the plant height varies significantly. However treatment T₂, T₃ and T₄ were at par. The critical analysis of pooled data revealed that although treatment T₂ and T₃ are at par but they vary significantly from T₅ and T₆. Therefore, from this data it is clear that plant height in various treatments is increasing over the years in different proportions.

A perusal of data presented in table 4.1.1.2 and Figure 2 indicates that training system under rectangular planting also affected the plant height significantly which varied among the various treatments during both the years. The maximum plant height was observed in treatment T₆ (4.21m) followed by T₅ (4.14m) whereas, minimum in T₁ (2.33m) followed by T₂ (2.53m) in 2019. While

during 2020, the similar trend with maximum plant height was found in treatment T₆ (4.29m) followed by T₅ (4.16m) whereas, lowest plant height was recorded in treatment T₁ (3.04m) followed by T₂ (3.12m). However treatments T₁ (2.33m), T₂ (2.53m) and T₃ (3.30m), T₄ (3.38m) and T₅ (4.14m), T₆ (4.21m) were *at par* during 2019 and treatments T₁ (3.04m), T₂ (3.12m) and T₃ (3.65m), T₄ (3.52m) and T₅ (4.16m), T₆ (4.29m) were statistically *at par* during 2020

The pooled analysis showed that the maximum plant height was in T₆ (4.25m) followed by T₅ (4.15m)) while minimum was found in treatment T₁ (2.68m) followed by T₂ (2.82m) in case of rectangular planting.

Table 4.1.1.1 Effect of planting density on plant height (m)

Treatments	2019	2020	Pooled
T ₁	2.03	2.23	2.13
T ₂	2.53	2.68	2.61
T ₃	2.70	3.10	2.90
T ₄	2.96	3.25	3.11
T ₅	3.77	3.87	3.82
T ₆	4.21	4.29	4.25
CD at 5%	0.257	0.41	0.307
SE(m)	0.084	0.135	0.101

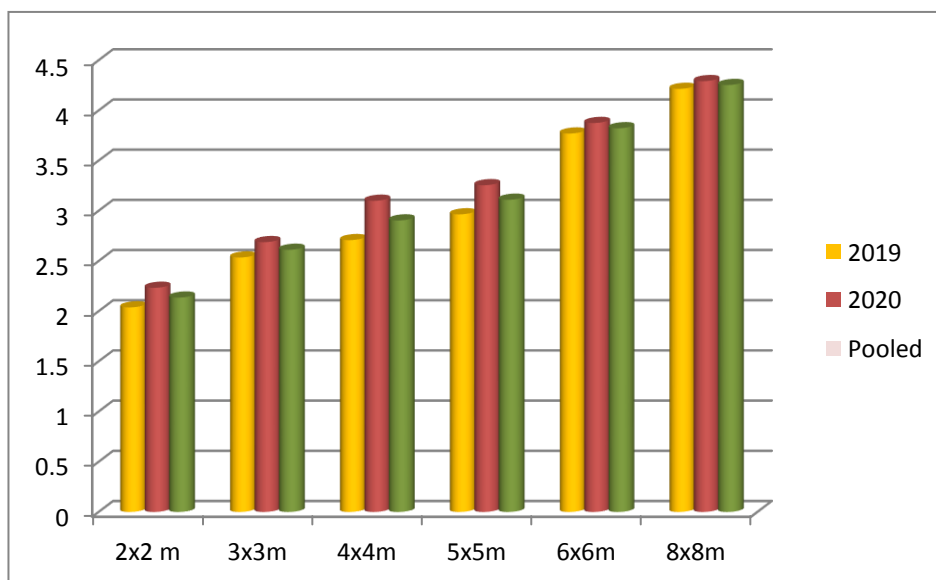


Figure 4.1.1.1 Effect of planting density on plant height (m)

Table 4.1.1.2 Effect of training system on plant height (m)

Treatments	2019	2020	Pooled
T1	2.33	3.04	2.68
T2	2.53	3.12	2.82
T3	3.30	3.65	3.47
T4	3.38	3.67	3.52
T5	4.14	4.16	4.15
T6	4.21	4.29	4.25
CD at 5%	0.465	0.37	0.307
SE(m)	0.153	0.122	0.101

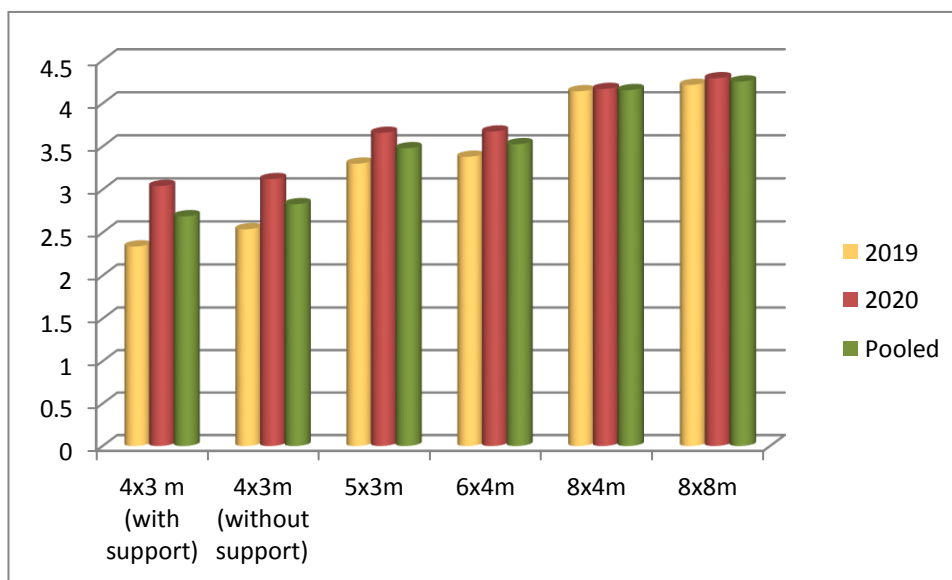


Figure 4.1.1.2 Effect of training system on plant height (m)

4.1.2) Stem Girth (cm):

A perusal of data presented in table 4.1.2.1 and Figure 3 indicates that planting density under square system of planting affected the stem girth significantly which varied among the various treatments during both the years (2019-2020). The maximum stem girth was observed in treatment T₆ (74.96 cm) whereas, minimum in T₁ (26.77 cm), however treatment T₄ (54.26 cm) and T₅ (57.56 cm) were *at par* in 2019. While during 2020, the similar trend with maximum stem girth was found in treatment T₆ (83.38 cm) whereas, lowest stem girth was recorded in treatment T₁ (33.01 cm).

The pooled analysis showed that the maximum stem girth was in T₆ (79.17 cm) while minimum was found in treatment T₁ (29.89 cm) in case of square system of planting.

Different training system under rectangular planting had also affected the stem girth significantly. The observations recorded on stem girth presented in table 4.1.2.2 and graphically depicted in Figure 4. Statistical analysis of data reflected that highly significant difference was observed among different treatments in respect of stem girth. Maximum stem girth was recorded in T₆ during 2019 and 2020 (74.96 cm and 83.38 cm) while minimum stem girth was

found in T₁ (28.77 cm and 34.75 cm). It is also clear that treatments T₁ (28.77cm), T₂(29.46cm) and T₃ (32.44cm) and T₅ (73.15cm), T₆(74.96cm) were *at par* during 2019 whereas treatments T₂ (36.77cm) and T₃ (37.15cm) were at par during 2020.

Based on pooled data it has been found that the plant produced maximum stem girth in control (79.17 cm) followed by T₅ (76.72 cm) whereas, the minimum stem girth was T₁ (31.76 cm). However, treatment T₁ (31.76cm) was *at par* with T₂ (33.11cm) with respect to stem girth in rectangular planting.

Table 4.1.2.1 Effect of planting density on stem girth (cm)

Treatments	2019	2020	Pooled
T1	26.77	33.01	29.89
T2	35.91	42.78	39.34
T3	46.54	53.10	49.82
T4	54.26	62.55	58.40
T5	57.56	66.78	62.17
T6	74.96	83.38	79.17
CD at 5%	4.282	1.157	1.11
SE(m)	1.408	0.381	0.348

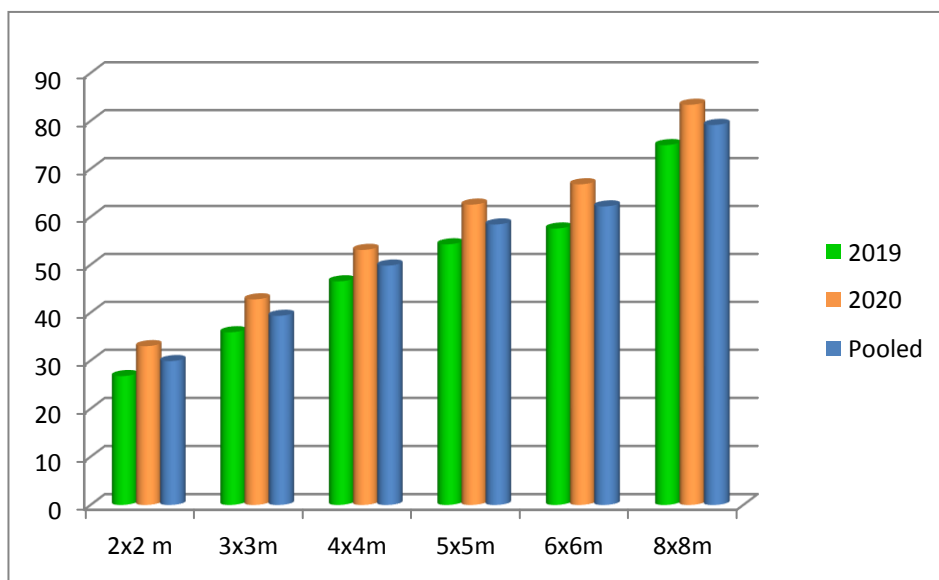


Figure 4.1.2.1 Effect of planting density on stem girth (cm)

Table4. 1.2.2 Effect of training systems on stem girth (cm)

Treatments	2019	2020	Pooled
T1	28.77	34.75	31.76
T2	29.46	36.77	33.11
T3	32.44	37.15	34.79
T4	54.07	62.89	58.48
T5	73.15	80.30	76.72
T6	74.96	83.383	79.17
CD at 5%	3.311	0.97	1.799
SE(m)	1.088	0.319	0.592

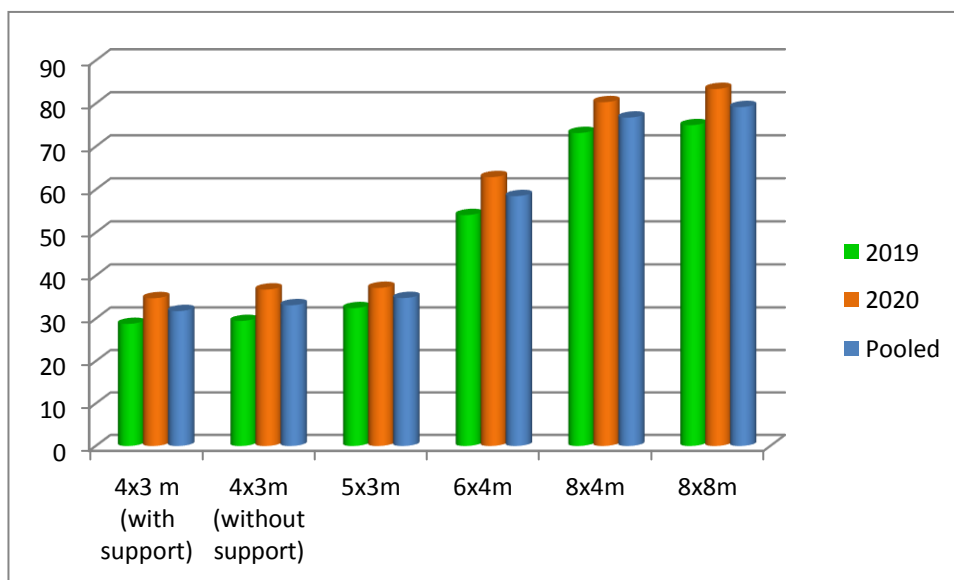


Figure 1.1.2.2. Effect of training system on stem girth (cm)

4.1.3) Plant Spread in East- West Direction (m):

It is evident from table 4.1.3.1 and figure 5 that plant spread in East-West direction during the first year varied significantly among the treatments. The maximum plant spread (East-West) was found in T₆ (5.82m) which was closely followed by treatment T₅ (5.32m) while lowest plant spread (East-West) was reported in treatment T₁ (1.65m) followed by T₂ (2.42m) during 2019. Similarly in 2020, the maximum plant spread (East-West) was recorded in treatment T₆ (6.34m) followed by T₅ (5.89m) whereas, the lowest spread (East-West) was recorded in T₁ (2.07m) which followed by T₂ (2.65m) under square system of planting.

Pooled analysis of East-West plant spread in litchi planted under square system revealed that plant spread among various treatments varies significantly. Minimum plant spread (East-West) was recorded in treatment T₁ (1.96m) whereas, maximum plant spread (East-West) was noticed in treatment T₆ (6.08m) followed by treatment T₅ (5.49m).

In rectangular planting system was affected the plant spread (East-West) significantly as presented in table 4.1.3.2 and depicted in Figure 6. The maximum plant spread (East-West) was found in T₆ (5.82m) while lowest plant

spread was recorded in treatment T₁ (3.42m) followed by T₂ (3.53m) which was *at par* with T₃ (3.54m), T₄ (4.86m) and T₅ (4.88m) during 2019. In 2020, the maximum plant spread (East-West) was recorded in treatment T₆ (6.34m) whereas, the lowest spread (East-West) was recorded in T₂ (3.27m) which was *at par* with T₁ (3.87m). The plant spread in treatment T₄ (4.86m) and T₅ (4.89m) was found *at par* which was also non significant.

A glance of the pooled data indicates that plant spread (East-West) was found minimum in treatment T₂ (3.40m) followed by T₁ (3.64m) and T₃ (3.65m) whereas, the maximum in treatment T₆ (6.08m). The pooled plant spread data are at par among various treatments except T₆ (control) planted at 8x8 m.

Table 4.1.3.1 Effect of planting density on plant spread EW (m)

Treatments	2019	2020	Pooled
T1	1.65	2.07	1.86
T2	2.41	2.69	2.56
T3	3.74	4.01	3.88
T4	4.81	5.06	4.94
T5	5.32	5.88	5.61
T6	5.82	6.34	6.08
CD at 5%	0.226	0.311	0.318
SE(m)	0.074	0.102	0.105

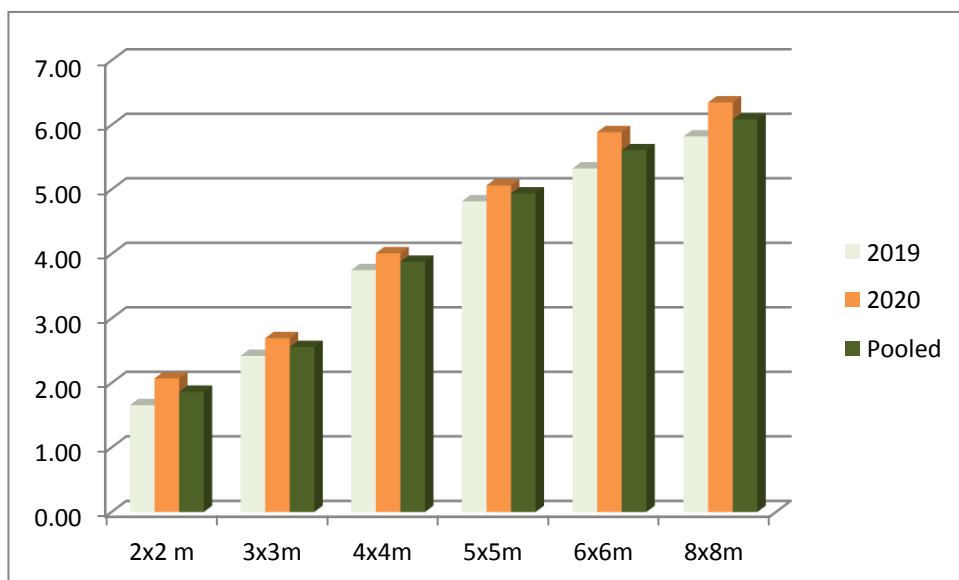


Figure 4.1.3.1 Effect of planting density on plant spread (EW)

Table4.1.3.2 Effect of training system on plant spread EW (m)

Treatments	2019	2020	Pooled
T1	3.42	3.87	3.64
T2	3.53	3.27	3.40
T3	3.54	3.75	3.65
T4	4.86	4.86	4.86
T5	4.89	4.88	4.89
T6	5.82	6.34	6.08
CD at 5%	0.5	0.497	0.318
SE(m)	0.164	0.163	0.105

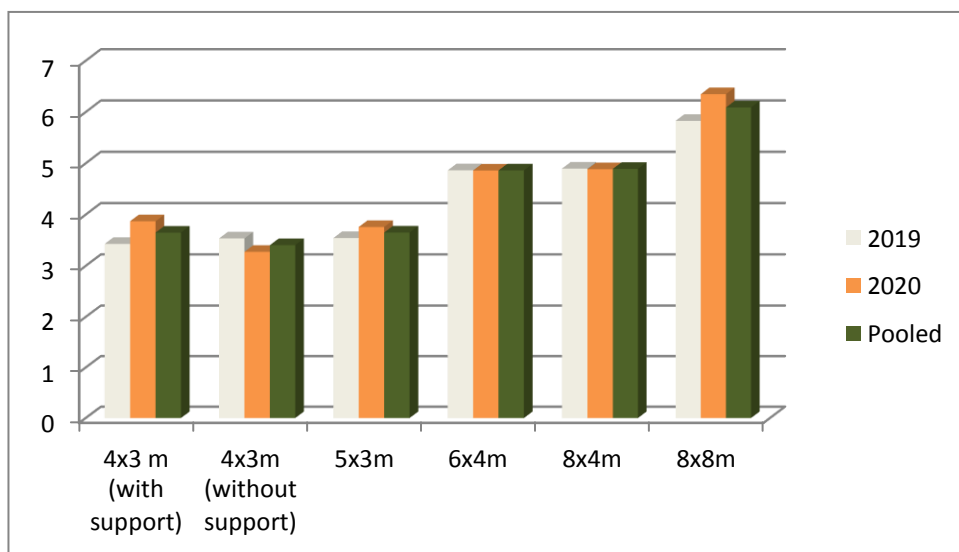


Figure 4.1.3.2 Effect of training system on plant spread (EW)

4.1.4) Plant Spread North- South Direction (m):

The data presented in table 4.1.4.1 showed that planting density under square system had affected the plant spread (North-South). The statistical analysis of the data revealed that the differences among the treatments in respect of plant spread (North-South) was highly significant in both the years as well as in pooled analysis. The maximum plant spread (North-South) was recorded in treatment T₆ in both the years (6.92m, 7.25m respectively) followed by T₅ (5.48m, 5.94m respectively) whereas, the lowest plant spread was observed in treatment T₁ in both the years (2.07m, 2.20m respectively) followed by T₂ (2.54m, 2.77m respectively).

The analysis of pooled data indicated that the maximum plant spread (North-South) under square planting system was in treatment T₆ (7.08m) i.e. 8x8m followed T₅ (4.93m) i.e. 6x6m whereas, minimum North-South plant spread was recorded in T₁ (2.13m) and T₂ (2.65m) which were significant.

Training system also affected the North-South plant spread significantly in both the years where wide space was given under rectangular system of planting. The mean data had been recorded and presented in table 4.1.4.2 with

respect to North-South plant spread. The analyses of variance with respect to this character reveal that the treatment differed with great level of significance in both the years individually as well as in pooled analysis. The maximum spread (North-South) was observed in treatment T₆ (6.91m) whereas, the lowest spread was recorded in treatment T₂ (3.16m) during the first year, while in the second year, though the trend were similar the maximum values were recorded in treatment T₆ (7.25m) whereas, minimum in T₂ (3.91m) which was approx 9.5% in control and 8.0% in 4x3m without support.

The pooled data revealed that maximum spread (North-South) was in control (7.08m) whereas, minimum spread (North-South) was recorded in T₂ (3.53m) followed by T₁ (3.77m).

Table 4.1.4.1 Effect of planting density on plant spread NS (m)

Treatments	2019	2020	Pooled
T1	2.07	2.20	2.14
T2	2.54	2.77	2.66
T3	4.08	3.42	3.75
T4	4.65	4.80	4.73
T5	5.48	5.94	5.71
T6	6.92	7.25	7.09
CD at 5%	0.316	0.482	0.355
SE(m)	0.104	0.158	0.117

Table 4.1.4.2 Effect of training system on plant spread NS (m)

Treatments	2019	2020	Pooled
T1	3.58	3.95	3.77
T2	3.16	3.91	3.53
T3	4.09	4.40	4.25
T4	4.21	5.22	4.72
T5	4.82	5.04	4.93
T6	6.91	7.25	7.08
CD at 5%	0.712	0.255	0.355
SE(m)	0.234	0.084	0.117

Canopy Diameter (m):

A perusal of data presented in table 4.1.5.1 indicates that canopy diameter among different treatments varied significantly during the both years. The canopy diameter was between 2.51m (T₁) to 6.32m (T₆) during first year and between 2.96m (T₁) to 6.75m (T₆) DURING 2020. Critical appraisal of data showed that treatments T₅ (5.91m, 6.30m respectively), T₆ (6.32m, 6.75m respectively) were significantly superior over rest of the treatments with respect to canopy diameter in both the years. The pooled analysis also showed significant increase in canopy diameter under various spacing provided in square system planting.

The data depicted in table 4.1.5.2 canopy diameter under different training system also varied in both the years. The statistical analysis of the data revealed that the differences among the treatments in respect of canopy diameter was found to be highly significant in both the years as well as in pooled analysis. The maximum canopy diameter was recorded in treatment T₆ in both the years (6.23m², 6.75m²) followed by T₅ (6.17 m², 6.48 m²) which

were at par but significantly superior over the rest of the treatments. The lowest canopy diameter was observed in treatment T₂ in both the years (2.99m², 3.73 m²) under rectangular planting at 4x3m apart.

The analysis of pooled data indicated that the maximum canopy diameter was 6.49m² in 8x8m spacing followed by 6.32 m² in 8x4m spacing which were at par in between. Based on approximate 46% and 37.5% less canopy diameter was in T₂ (4x3m) and T₁ (4x3m without support) respectively over 8x4m planting.

Table 4.1.5.1: Effect of planting density on canopy diameter (m)

Treatments	2019	2020	Pooled
T1	2.51	2.96	2.74
T2	2.95	3.27	3.11
T3	4.26	4.64	4.45
T4	4.29	4.94	4.62
T5	5.91	6.30	6.11
T6	6.32	6.75	6.54
CD at 5%	0.433	0.35	0.257
SE(m)	0.142	0.115	0.084

Table 4.1.5.2: Effect of training system on canopy diameter (m)

Treatments	2019	2020	Pooled
T1	3.73	4.18	3.95
T2	2.99	3.73	3.36
T3	3.70	4.24	3.97
T4	4.54	5.49	5.01
T5	6.17	6.48	6.32
T6	6.23	6.75	6.49
CD at 5%	0.406	0.467	0.257
SE(m)	0.133	0.154	0.084

Canopy Area (m²):

The data on canopy area presented in table 4.1.6.1 revealed that canopy area varied significantly among the various treatments under square system of planting during both the years. The canopy area among treatments varied significantly and value range between 4.99 m² (T₁) to 31.70m (T₆). Critical analysis of data indicates that in the first year the canopy area was maximum in treatment T₆ (31.70 m²) followed by T₅ (24.79 m²), T₄ (14.98 m²) and T₃ (11.67 m²) whereas; treatment T₁ with support lowest canopy area 4.99 m² was recorded in treatment T₁. Almost similar trend with respect to canopy area was observed in 2020 where, maximum canopy area was recorded in treatment T₆ (33.12 m²) followed by T₅ (25.11 m²) and the lowest value of calculated canopy area was found in treatment T₁ (5.82 m²) and T₂ (7.36 m²). The canopy area has depicted an increasing trend in various treatment combinations during the period of study which indicates that litchi plants grow at slower rate even after 15 years of planting.

From the pooled data it was observed that maximum canopy area was recorded in treatment T₆ (32.43 m²) whereas, lowest canopy area was noticed in T₁ (5.51 m²).

Data indicates that training system under rectangular planting also affected the canopy area which varied significantly among the various treatments during both the years (Table 4.1.6.2). The maximum canopy area was observed in 8x8m spacing (31.74 m²) whereas, minimum in T₂ (7.08 m²) in 2019. While during 2020, the similar trend with maximum canopy area was found in 8x8m spacing (33.12 m²) whereas, lowest canopy area was recorded in treatment T₂ (9.20 m²).

The pooled analysis of data for canopy area under rectangular system of planting in litchi showed the maximum canopy area was in 8x8m spacing (32.43 m²) while minimum was found in treatment T₂ (8.12 m²).

Table 4.1.6.1 Effect of planting density on canopy area (m²)

Treatments	2019	2020	Pooled
T1	4.99	5.82	5.41
T2	6.85	7.36	7.11
T3	11.67	13.12	12.40
T4	14.98	16.10	15.54
T5	24.79	25.11	24.95
T6	31.70	33.12	32.41
CD at 5%	2.422	1.763	1.551
SE(m)	0.796	0.579	0.51

Table 4.1.6.2 Effect of training system on canopy area (m²)

Treatments	2019	2020	Pooled
T1	10.95	12.26	11.60
T2	7.03	9.20	8.12
T3	10.76	12.36	11.56
T4	28.63	31.40	30.01
T5	15.50	18.28	16.89
T6	31.74	33.12	32.43
CD at 5%	2.986	0.776	1.551
SE(m)	0.982	0.255	0.51

Leaf Area (cm²):

The perusal of data shown in table 4.1.7.1 planting density of litchi not much affected the leaf area significantly for the both years of experiment. The maximum leaf area was recorded in T₆ (35.63 cm²) whereas, lowest leaf area was recorded in T₁ (35.32 cm²) during 2019. Similar trend was found in 2020 where increasing trend of leaf area was observed. Leaf area among various treatments was found significantly different. The maximum leaf area was recorded in control at the spacing of 8x8 m (38.50 cm²) whereas, lowest leaf area was found in T₁ (37.03 cm²) followed by T₂ (37.14 cm²).

In pooled analysis, the maximum leaf area was recorded in T₆ (37.26 cm²). It was clear from table that leaf area was increasing at wider spacing and over the years.

Training system in rectangular system was also not much affected the leaf area significantly table 4.1.7.2. The maximum the leaf area was found in T₆ (35.12 cm²) while lowest the leaf area was reported in treatment T₅ (35.10 cm²) during 2019. In 2020, the maximum the leaf area was recorded in treatment T₆ (39.42 cm²) whereas, the lowest the leaf area was recorded in T₄ (35.91 cm²) A glance of the pooled data indicated that the leaf area was found maximum in treatment T₆ (37.26 cm²) whereas, minimum in treatment T₄ (35.75 cm²) under rectangular system of planting.

Table 4.1.7.1: Effect of planting density on leaf area (cm²)

Treatments	2019	2020	Pooled
T1	35.32	37.03	36.12
T2	35.58	37.14	36.73
T3	35.53	38.56	36.68
T4	35.58	37.36	35.75
T5	35.63	37.84	36.17
T6	35.10	38.50	37.26
CD at 5%	0.513	0.598	0.882
SE(m)	0.179	0.197	0.29

Table 4.1.7.2: Effect of training system on leaf area (cm²)

Treatments	2019	2020	Pooled
T1	35.79	36.45	36.12
T2	36.17	37.30	36.73
T3	36.17	37.19	36.68
T4	35.60	35.91	35.75
T5	35.10	37.24	36.17
T6	35.10	39.42	37.26
CD at 5%	1.091	0.961	0.882
SE(m)	0.389	0.316	0.29

Total number of flushes per branches:

Data on this aspect presented in table 4.1.8.1 show that number of flushes per branch was higher in the year 2020 as compared to 2019 irrespective of planting density during the present studies. Planting density had a significant effect on number of flushes per branch during both the years. Maximum number of flushes was recorded in treatment T₆ (14.29) whereas, minimum number of flushes per branch was recorded in T₁ (3.92) it was closely followed by T₂ (4.10) during 2019. Increasing trend was found in 2020 where, maximum number of number of flushes per branch was noticed in T₆ (14.68) followed by T₅ (11.52) whereas, minimum number of flushes per branch was recorded in treatment T₁ (4.45) followed by T₂ (6.29).

However the pooled analysis showed that total number of flushes per branch with various spacing in square system varied significantly. Maximum number of flushes per branch was found in T₆ (14.49) whereas, minimum number of flushes per branch was recorded in T₁ (4.19) followed by T₂ (5.20) while treatment T₄ (9.77) was statistically at par with T₅ (10.35).

Data further shows that training system in rectangular planting also affected mean total number of flushes per branch significantly (Table 4.1.8.2). The mean total number of flushes per branch among various treatments was varies from 5.15 (T₂) to 14.29 (T₆). Critical appraisal of data shows that mean total number of flushes per branch among various treatments was significantly superior except the treatments T₂ (5.15), T₃ (6.35) and T₅ (12.10), T₆ (14.29) were statistically at par in 2019. During 2020, the minimum mean total number of flushes per branch among treatments was recorded in T₂ (7.02) it was closely followed by T₁ (7.35) while maximum mean total number of flushes per branch was recorded in control at the spacing of 8x8 m (14.68).

Pooled analysis of mean total number of flushes per branch revealed that a total number of flushes per branch vary significantly. Critical analysis of data revealed that maximum total number of flushes per branch was recorded in T₆ (14.49) and minimum total number of flushes per branch recorded in T₂ (6.08).

Table 4.1.8.1: Effect of planting density on number of flushes/branch

Treatments	2019	2020	Pooled
T1	3.92	4.45	4.19
T2	4.10	6.29	5.20
T3	6.60	8.25	7.43
T4	8.65	10.89	9.77
T5	9.16	11.52	10.35
T6	14.29	14.68	14.49
CD at 5%	0.911	0.514	1.2
SE(m)	0.299	0.169	0.395

Table 4.1.8.2: Effect of training system on number of flushes/branch

Treatments	2019	2020	Pooled
T1	5.97	7.35	6.66
T2	5.15	7.02	6.08
T3	6.35	9.15	7.75
T4	9.60	11.56	10.58
T5	12.10	12.60	12.35
T6	14.29	14.68	14.49
CD at 5%	2.316	0.444	1.2
SE(m)	0.761	0.146	0.395

Flush Length (cm):

The data in table 4.1.9.1 clearly depicted that mean flushes length was higher in the year 2020 as compared to 2019 irrespective of planting density in square system of planting during the present studies. Planting density had a significant effect mean flushes length during both the years. The maximum the flush length was found in T₆ (44 cm) while lowest the flush length was reported in treatment T₁ (24.22 cm). The differences among treatments T₁ (24.22cm), T₂ (25.63cm) and treatment T₃ (34.0cm), T₄ (35.24 cm) were statistically *at par* during 2019. In 2020, the maximum the flush length was recorded in treatment T₆ (46.41cm) whereas, the lowest the flush length was recorded in T₁ (26.46 cm) followed by T₂ (27.50 cm).

Pooled data indicated that maximum flush length was found in treatment T₆ (45.21 cm) whereas, minimum in treatment T₁ (25.35 cm) which *at par* with T₂ (26.57 cm) and T₃ (35.08 cm) was at par with treatment T₄ (36.26 cm) under square system of planting.

Data further revealed that training system under rectangular system of planting had affected the flush length significantly presented in table 4.1.9.2. The flush length was significantly varied among the litchi during both the years. The maximum flush length was observed in treatments T₆ (44.00 mm) succeeded by T₅ (41.47 mm) whereas, minimum in treatment T₁ (29.70 mm) in 2019 while treatments T₁, T₂ and T₅, T₆ were statistically at par. While during 2020, the similar trend with maximum flush length was found in treatment T₆ (46.41 mm) followed by T₅ (43.94 mm) whereas, lowest flush length was recorded in treatment T₁ (30.63 mm).

However, the pooled analysis showed the maximum flush length was in treatment T₆ (45.20 mm) followed by T₅ (42.71 mm) while minimum was found in treatment T₁ (30.16 mm). The difference between treatments T₁, T₂ and T₃, T₄ and T₅ were at par under rectangular system of planting.

Table 4.1.9.1: Effect of planting density on average flush length (cm)

Treatments	2019	2020	Pooled
T1	24.22	26.46	25.35
T2	25.63	27.50	26.57
T3	34.05	36.09	35.08
T4	35.24	37.25	36.25
T5	38.59	40.19	39.39
T6	44.00	46.41	45.21
CD at 5%	5.018	0.713	3.553
SE(m)	1.65	0.234	1.168

Table 4.1.9.2: Effect of training system on flush length (cm)

Treatments	2019	2020	Pooled
T1	29.70	30.63	30.16
T2	31.70	33.21	32.45
T3	31.45	33.11	32.28
T4	40.25	42.54	41.39
T5	41.47	43.94	42.71
T6	44.00	46.41	45.20
CD at 5%	7.169	0.695	3.553
SE(m)	2.357	0.229	1.168

Flush Diameter (mm):

Data on this aspect presented in table 4.1.10.1 shows that increasing trend in the diameter of flush was found during both the years. The diameter of flush among treatments varies between 4.38 mm (T1) to 7.60 mm (T6). Critical appraisal of data revealed that treatments T5 (5.54 mm) and T6 (7.60 mm) are significantly superior with respect to diameter of flush, whereas, treatments T1 (4.38 mm), T2 (4.42 mm) and treatments T₃ (5.15 mm), T₄ (5.60 mm) were statistically at par during 2019. In 2020, the maximum diameter of flush among treatment was recorded in T4 (7.95 mm) closely followed by T₆ (7.82 mm) whereas, minimum diameter of flush was recorded in T₁ (7.76 mm).

Pooled analysis of flush diameter in litchi with various spacing in square system revealed that the diameter of flush varies from 6.07 mm (T₁) to 7.71 mm (T₆). Treatments T₁ (6.07 mm) was at par with T₂ (6.80 mm) and T₃ (6.26 mm) which was significantly different with T₄ (6.78 mm), T₅ (7.30 mm) while treatment T₅ was at par with T₆ (7.71 mm)

Data further shows that training system in rectangular planting also affected mean flush diameter significantly (Table 4.1.10.2). The mean flush diameter among various treatments was varies from 4.12 mm (T₃) to 7.60 mm (T₆). Critical appraisal of data shows that mean flush diameter among various treatments was significantly superior except the treatments T₁ (5.15 mm) which was at par with T₂ (4.15 mm) and T₃ (4.12 mm) while T₃ was at par with T₄ (5.28 mm) and T₅ (7.06 mm), T₆ (7.60 mm) were statistically at par in 2019. During 2020, the minimum mean flush diameter among treatments was recorded in T₂ (5.06 mm) it was closely followed by T₃ (5.34 mm) while maximum mean flush diameter was recorded in control (7.82 mm) closely followed by T₅ (7.67 mm). The difference between treatments T₁ (6.12 mm), T₂ (5.06 mm) and T₅ (7.65 mm), T₆ (7.84 mm) were statistically at par.

Pooled analysis of mean flush diameter revealed that a flush diameter vary significantly. Critical analysis of data revealed that maximum flush diameter was recorded in T₆ (7.71 mm) and minimum flush diameter recorded in T₂ (4.61 mm) whereas, treatment T₁ (5.63mm) was at par with T₂ (4.60mm) and T₃ (4.73mm) and treatment T₅ (7.37 mm) was at par with T₆ (7.71 mm).

Table 4.1.10.1 Effect of planting density on flush diameter (mm)

Treatments	2019	2020	Pooled
T1	4.38	7.76	6.07
T2	4.42	9.16	6.80
T3	5.15	7.37	6.26
T4	5.60	7.95	6.78
T5	5.54	7.04	6.30
T6	7.60	7.82	7.71
CD at 5%	0.813	0.268	1.015
SE(m)	0.267	0.088	0.334

Table 4.1.10.2 Effect of training system on flush diameter (mm)

Treatments	2019	2020	Pooled
T1	5.15	6.12	5.64
T2	4.15	5.06	4.61
T3	4.12	5.34	4.74
T4	5.28	6.37	5.83
T5	7.06	7.67	7.37
T6	7.60	7.82	7.71
CD at 5%	1.515	0.739	1.015
SE(m)	0.498	0.243	0.334

Light Interception (%)**4.2.1) Light Interception below canopy (%):**

Data pertaining light interception below part of the canopy are presented in Table 4.2.1.1 and Figure 7. The light intercepted by the below part of canopy was affected significantly due to planting density under square system of planting in litchi. It is clear from table that light interception in the both years varied significantly among the treatments. Data also shows that the radiation intercepted by the below part of canopy among treatment varies between 47.80 % (T₁) to 75.82% (T₅). Critical analysis of data revealed that treatments T₁, T₂ and T₃ are significantly different whereas, treatments T₃, T₄ and T₄, T₅ were at in between but T₆ was vary significantly from T₅ during 2019. Decreasing trend was observed in the second year of experiment (2020). The light interception below canopy among the treatments varies between 45.12% (T₁) to 75.37% (T₆). Critical analysis of data revealed that treatments T₁, T₂, T₃, T₄ and T₆ vary significantly whereas treatments T₄ and T₅ were statistically at par.

Pooled analysis of light interception below canopy among various spacing revealed that light interception varies significantly however treatments

T₄ and T₅ are at par. The highest interception of light below canopy (75.18%) was recorded in control at the spacing of 8x8 m (T₆).

A perusal of data indicates that that training system under rectangular planting also affected the light interception below canopy significantly varied among the various treatments during both the years. The radiation intercepted by the below part of canopy among treatment varies between 54.32 % (T₃) to 74.97% (T₆). Critical analysis of data revealed that all the treatments are significantly different during 2019 (Table 4.2.1.2 and figure 8). Decreasing trend was observed in the second year of experiment (2020). The light interception below canopy among the treatments varies between 51.80% (T₃) to 75.37% (T₆). Critical analysis of data revealed that treatments T₄ (57.15%), T₅ (62.22%) and T₆ (75.37%) vary significantly whereas treatments T₁ (56.52%) was statistically at par with T₂ (54.37%) and T₃ (51.80%).

Data of pooled analysis of light interception below canopy revealed that light interception varies significantly however treatments T₂ (48.90%), T₃ (53.06%) and T₄ (58.27%), T₅ (63.71%) were at par. The highest interception of light below canopy (75.18%) was recorded in control (T₆) whereas, lowest interception was recorded in treatment T₂ (48.90%).

Table 4.2.1.1: Effect of planting density on Light interception below canopy (%)

Treatments	2019	2020	Pooled
T1	47.80	45.12	46.45
T2	57.92	55.47	56.70
T3	70.22	67.17	68.69
T4	72.97	71.35	72.16
T5	75.82	71.82	73.82
T6	74.97	75.37	75.18
CD at 5%	4.747	1.148	2.638
SE(m)	1.561	0.377	0.867

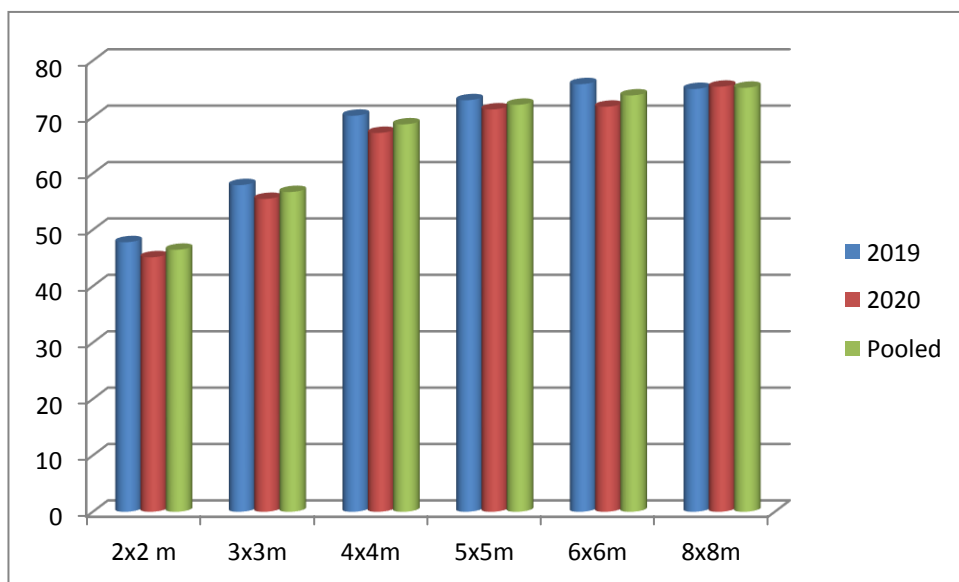


Figure 4.2.1.1 Effect of planting density on light interception below canopy %

Table 4.2.1.2: Effect of training system on light interception below canopy (%)

Treatments	2019	2020	Pooled
T1	59.80	56.52	58.17
T2	56.70	54.37	48.90
T3	54.32	51.80	53.06
T4	59.40	57.15	58.27
T5	65.20	62.22	63.71
T6	74.97	75.37	75.18
CD at 5%	3.22	1.781	7.183
SE(m)	1.059	0.585	2.361

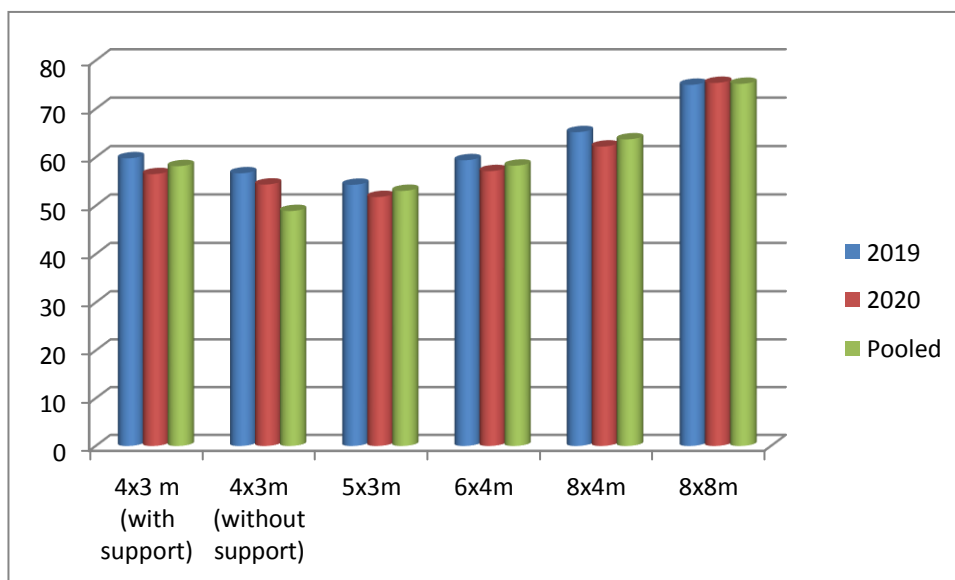


Figure 4.2.1.2 Effect of training system on light interception below canopy

4.2.2) Light Interception upper canopy (%):

The perusal of data in Table 4.2.2.1 and figure 9 reveals that light interception upper part of the canopy was affected significantly due to planting density under square system of planting in litchi. Data (Table) regarding light interception above canopy show that light interception in the years 2019 and 2020 varied significantly among the treatments. The light interception above the canopy varies between 84.52 % (T₁) to 94.02% (T₆). Critical appraisal of data revealed that treatments T₁ was significantly difference by T₂ and T₃ while T₂, T₃ and T₄ are at par but vary significantly with T₅ and T₆ which were statistically at par in between during 2019. Decreasing trend was observed in the second year of experiment (2020) where the light interception above canopy varies between 81.62% (T₁) to 92.60 % (T₆). Critical analysis of data revealed that treatments vary significantly except T₂, T₃ and T₃, T₄ which were statistically at par.

Pooled analysis of light interception above canopy among various spacing showed that light interception varies significantly however treatments T₂, T₃ and T₃, T₄ which are at par. The highest light intercepted above canopy (93.31%) was recorded in wider spacing (T₆).

The data in table 4.2.2.2 and figure 10 showed that training system under rectangular system of planting had also affected the light interception upper canopy. The statistical analysis of the data revealed that the differences among the treatments in respect of light interception above canopy was found to be highly significant in both the years as well as in pooled analysis. The maximum light interception above canopy (94.02%, 92.6%) was recorded in treatment T₆ (control) in both the years (2019, 2020) whereas, the lowest light interception above canopy was observed in treatment T₃ (84.35%) in 2019 and treatment T₂ (82.50%) in 2020. The differences among treatments T₄ (86.4%), T₅ (87.0%) in 2019 and treatments T₂ (82.5%), T₃ (82.7%) and T₄ (83.95%) during 2020 were statistically at par.

The analysis of pooled data indicated that the maximum light interception above canopy was in treatment T₆ (93.31%) whereas, minimum interception was recorded in T₂ (83.75 %) while treatment T₃ (83.52 %) was at par with T₄ (85.18%).

Table 4.2.2.1: Effect of planting density on Light interception upper canopy (%)

Treatments	2019	2020	Pooled
T1	84.52	81.62	83.07
T2	88.25	85.55	86.89
T3	88.80	86.40	87.59
T4	90.05	87.25	88.66
T5	93.62	89.87	91.75
T6	94.02	92.60	93.31
CD at 5%	3.631	0.98	1.812
SE(m)	1.194	0.322	0.596

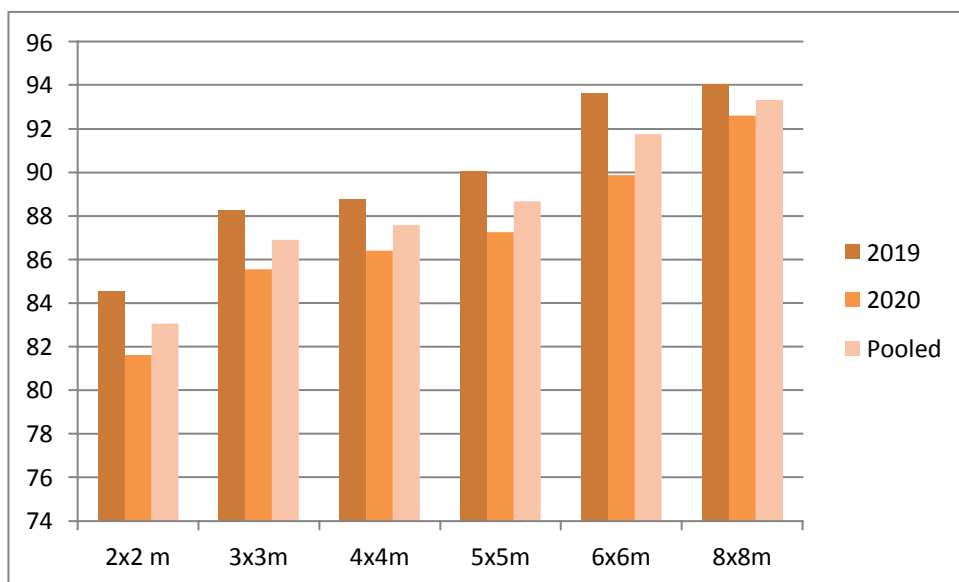


Figure 4.2.2.1 Effect of planting density on light interception upper canopy %

Table 4.2.2.2 Effect of training system on light interception upper canopy (%)

Treatments	2019	2020	Pooled
T1	85.92	84.20	85.06
T2	85.02	82.50	83.75
T3	84.35	82.70	83.52
T4	86.40	83.95	85.18
T5	87.00	84.97	85.98
T6	94.02	92.60	93.31
CD at 5%	3.367	2.335	2.515
SE(m)	1.107	0.768	0.827

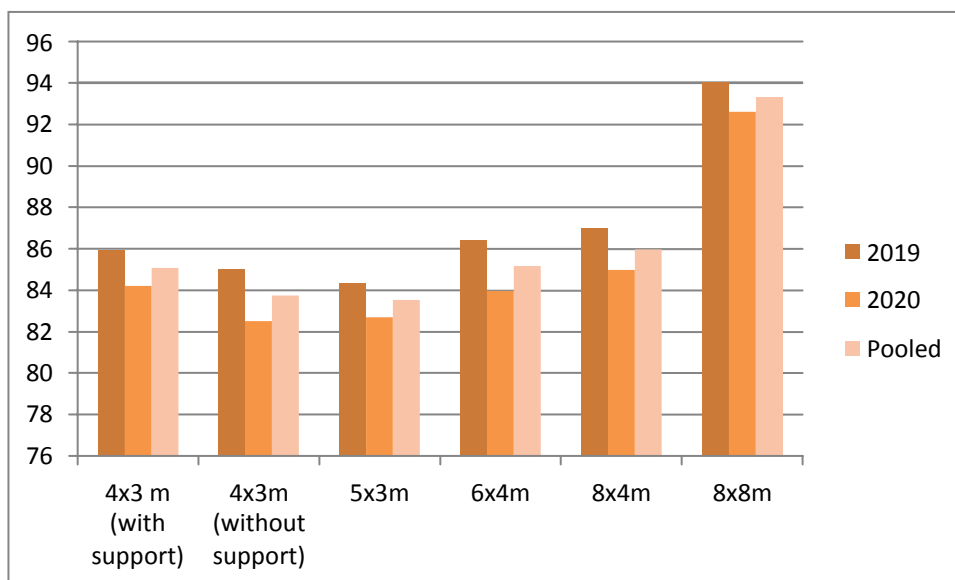


Figure 4.2.2.2 Effect of training system on light interception upper canopy %

4.3.) Physiological parameters:

4.3.1.) Net Photosynthetic Rate ($\mu\text{mol m}^{-2} \text{s}^{-1}$):

Data on net photosynthetic rate under different planting density are given in table 4.3.1.1. Data show that there was significant effect of various planting density in square system on leaf gas exchange parameters. The net photosynthetic rate was found to be varies from different planting densities. The net photosynthetic rate among treatment varies from $1.70 \mu\text{mol m}^{-2} \text{s}^{-1}$ (T_1) to $8.32 \mu\text{mol m}^{-2} \text{s}^{-1}$ (T_6). Critical analysis of data revealed that treatment T_3 ($3.87 \mu\text{mol m}^{-2} \text{s}^{-1}$), T_4 ($4.92 \mu\text{mol m}^{-2} \text{s}^{-1}$), T_5 ($6.35 \mu\text{mol m}^{-2} \text{s}^{-1}$) and T_6 ($8.32 \mu\text{mol m}^{-2} \text{s}^{-1}$) are significantly superior with respect to net photosynthetic rate whereas, treatments T_1 ($1.7 \mu\text{mol m}^{-2} \text{s}^{-1}$) and T_2 ($2.17 \mu\text{mol m}^{-2} \text{s}^{-1}$) were statistically at par during 2019. In 2020, maximum net photosynthetic rate among various treatments was recorded in control ($8.52 \mu\text{mol m}^{-2} \text{s}^{-1}$) followed by T_5 ($6.97 \mu\text{mol m}^{-2} \text{s}^{-1}$). Minimum net photosynthetic rate was recorded in T_1 ($1.84 \mu\text{mol m}^{-2} \text{s}^{-1}$).

From the pooled data it was observed that the maximum net photosynthetic rate was observed in treatment T6 ($8.42 \mu\text{mol m}^{-2} \text{s}^{-1}$) followed by T5 ($6.66 \mu\text{mol m}^{-2} \text{s}^{-1}$) while lowest net photosynthetic rate was recorded in T1 ($1.77 \mu\text{mol m}^{-2} \text{s}^{-1}$) followed by T2 ($2.28 \mu\text{mol m}^{-2} \text{s}^{-1}$). It is clear from data that net photosynthetic rate was found maximum in wider spacing.

Data reveals that different training system had also affected the net photosynthetic rate (Table 4.3.1.2). Data show that there was significant effect of various training system in rectangular system of planting on leaf gas exchange parameters. The net photosynthetic rate among treatment varies from $4.50 \mu\text{mol m}^{-2} \text{s}^{-1}$ (T2) to $8.32 \mu\text{mol m}^{-2} \text{s}^{-1}$ (T6). Critical appraisal of data revealed that differences among treatments T2 ($4.55 \mu\text{mol m}^{-2} \text{s}^{-1}$), T3 ($5.12 \mu\text{mol m}^{-2} \text{s}^{-1}$) and T4 ($5.70 \mu\text{mol m}^{-2} \text{s}^{-1}$) were statistically at par during 2019. Almost similar trend was observed in 2020. The net photosynthetic rate among treatment varies from $4.83 \mu\text{mol m}^{-2} \text{s}^{-1}$ (T2) to 8.52 (T6). Data revealed that differences among treatments T1 ($5.05 \mu\text{mol m}^{-2} \text{s}^{-1}$), T4 ($5.80 \mu\text{mol m}^{-2} \text{s}^{-1}$), T5 ($7.05 \mu\text{mol m}^{-2} \text{s}^{-1}$) and T6 ($8.52 \mu\text{mol m}^{-2} \text{s}^{-1}$) were significantly superior with respect to net photosynthetic rate whereas, treatments T2 ($4.83 \mu\text{mol m}^{-2} \text{s}^{-1}$) and T3 ($5.29 \mu\text{mol m}^{-2} \text{s}^{-1}$) were statistically at par.

From the pooled data it was observed that the maximum net photosynthetic rate among various training systems was significantly superior. Data reveals that maximum net photosynthetic rate was recorded in treatment T6 (8.42) while lowest net photosynthetic rate was recorded in T2 (4.69) followed by T1 (4.94) whereas, differences among treatments T2, T3 and T4 were at par.

Table 4.3.1.1: Effect of planting density on photosynthetic rate ($\mu\text{mol m}^{-2}\text{s}^{-1}$)

Treatments	2019	2020	Pooled
T1	1.70	1.84	1.77
T2	2.17	2.39	2.28
T3	3.87	3.59	3.73
T4	4.92	3.95	4.43
T5	6.35	6.97	6.66
T6	8.32	8.52	8.42
CD at 5%	0.898	0.299	0.448
SE(m)	0.295	0.098	0.147

Table 4.3.1.2: Effect of training system on photosynthetic rate ($\mu\text{mol m}^{-2}\text{s}^{-1}$)

Treatments	2019	2020	Pooled
T1	4.82	5.05	4.94
T2	4.55	4.83	4.69
T3	5.12	5.29	5.20
T4	5.70	5.80	5.75
T5	6.90	7.05	6.97
T6	8.32	8.52	8.42
CD at 5%	0.983	0.798	0.827
SE(m)	0.323	0.262	0.272

Stomatal Conductance(mol m⁻² s⁻¹):

The effect of planting densities in square system on stomatal conductance during 2019 and 2020 has been presented in table 4.3.2.1. Data in this aspect revealed that stomatal conductance were found to be higher in 2020 as compared to 2019 except in control. It is clear from data that stomatal conductance in 2019 varied significantly among the treatments. The stomatal conductance among treatments varies between 14.5 mol m⁻² s⁻¹ (T1) to 62.25 mol m⁻² s⁻¹ (T6). Critical analysis of data revealed that treatments T3 (29.25 mol m⁻² s⁻¹), T4 (38.75 mol m⁻² s⁻¹), T5 (47.75 mol m⁻² s⁻¹) and T6 (62.25 mol m⁻² s⁻¹) are significantly superior with respect to stomatal conductance whereas T1 (14.5 mol m⁻² s⁻¹) and T2 (16 mol m⁻² s⁻¹) were at par during 2019. Almost similar trend was found in 2020 where stomatal conductance among treatments varies between 14.75 mol m⁻² s⁻¹ (T1) to 60.0 mol m⁻² s⁻¹(T6). Critical analysis of data revealed that treatments T3 (30.5 mol m⁻² s⁻¹), T4 (41.5 mol m⁻² s⁻¹), T5 (48.75 mol m⁻² s⁻¹) and T6 (60.00 mol m⁻² s⁻¹) are significantly superior with respect to stomatal conductance whereas T1 (14.75 mol m⁻² s⁻¹) and T2 (16.5 mol m⁻² s⁻¹) were statistically at par.

Pooled analysis of stomatal conductance in litchi revealed that stomatal conductance varies significantly however T1 (14.62 mol m⁻² s⁻¹) and T2 (16.25 mol m⁻² s⁻¹) are at par. Maximum stomatal conductance (61.12 mol m⁻² s⁻¹) among treatments recorded in wider spacing (T6).

The response of various training systems under rectangular planting on stomatal conductance presented in [Table 4.3.2.2]. Data showed that the stomatal conductance was affected significantly in both the years. The stomatal conductance among treatments varies between 19 mol m⁻² s⁻¹ (T2) to 62.25 mol m⁻² s⁻¹ (T6). Critical appraisal of data revealed that treatments T1 (20.75 mol m⁻² s⁻¹), T5 (49.50 mol m⁻² s⁻¹) and T6 (62.25 mol m⁻² s⁻¹) are significantly superior with respect to stomatal conductance whereas T2 (19.0 mol m⁻² s⁻¹), T3 (28.75 mol m⁻² s⁻¹) and T4 (34.0 mol m⁻² s⁻¹) were at par during 2019. Almost similar trend was found in 2020. Stomatal conductance among treatments

varies between 22 mol m⁻² s⁻¹ (T2) to 60.0 mol m⁻² s⁻¹ (T6). Data revealed that treatments T1 (24.75 mol m⁻² s⁻¹), T2 (22.0 mol m⁻² s⁻¹), T3 (30.0 mol m⁻² s⁻¹), T4 (36.0 mol m⁻² s⁻¹), T5 (51.0 mol m⁻² s⁻¹) and T6 (60.00 mol m⁻² s⁻¹) are significantly superior with respect to stomatal conductance.

Pooled analysis of stomatal conductance in litchi revealed that stomatal conductance varies significantly however maximum stomatal conductance was recorded in T6 (61.12 mol m⁻² s⁻¹) whereas, minimum stomatal conductance recorded in T2 (20.50 mol m⁻² s⁻¹).

Table 4.3.2.1: Effect of planting density on stomatal conductance (mol m⁻² s⁻¹),

Treatments	2019	2020	Pooled
T1	14.50	14.75	14.62
T2	16.0	16.50	16.25
T3	29.25	30.50	29.87
T4	38.75	41.50	40.12
T5	47.75	48.75	48.25
T6	62.25	60.00	61.12
CD at 5%	6.658	2.059	3.778
SE(m)	2.189	0.677	1.242

Table 4.3.2.2: Effect of training system on stomatal conductance ($\text{mol m}^{-2} \text{s}^{-1}$),

Treatments	2019	2020	Pooled
T1	20.75	24.75	22.75
T2	19.00	22.00	20.50
T3	28.75	30.00	29.37
T4	34.00	36.00	35.00
T5	49.50	51.00	50.25
T6	62.25	60.00	61.12
CD at 5%	10.366	7.499	8.31
SE(m)	3.408	2.465	2.732

Transpiration Rate ($\text{mmol m}^{-2} \text{s}^{-1}$):

It is evident from the data given in table 4.3.3.1 that mean transpiration rate was significantly more during 2019 as compared to 2020 during the present investigation. Decreasing trend was found in transpiration rate over the years (2019 and 2020). The transpiration rate among treatments varies from 0.275 $\text{mmol m}^{-2} \text{s}^{-1}$ (T1) to 2.475 $\text{mmol m}^{-2} \text{s}^{-1}$ (T6). Critical analysis of data revealed that treatments T3 (1.02 $\text{mmol m}^{-2} \text{s}^{-1}$) and T4 (1.85 $\text{mmol m}^{-2} \text{s}^{-1}$), are significantly superior with respect to transpiration rate whereas treatments T1 (0.275), T2 (0.525) and T5 (2.25), T6 (2.47) were at par during 2019. In 2020 almost similar trend was found where transpiration rate among treatments varies from 0.211 $\text{mmol m}^{-2} \text{s}^{-1}$ (T1) to 2.29 $\text{mmol m}^{-2} \text{s}^{-1}$ (T6). Transpiration rate among treatments was found significantly different except T1, T2 and T2, T3 and T5, T6 which were at par.

Pooled analysis of transpiration rate in litchi revealed that transpiration rate varies significantly however T1 (0.24 $\text{mmol m}^{-2} \text{s}^{-1}$), T2 (0.51 $\text{mmol m}^{-2} \text{s}^{-1}$) and T5 (2.12 $\text{mmol m}^{-2} \text{s}^{-1}$), T6 (2.38 $\text{mmol m}^{-2} \text{s}^{-1}$) are at par. It is clear from

data that maximum transpiration rate ($2.38 \text{ mmol m}^{-2} \text{ s}^{-1}$) among treatments recorded in wider spacing (T6).

The response of various training systems under rectangular planting on transpiration rate presented in [Table 4.3.3.2]. Data showed that the transpiration rate was affected significantly in both the years. Reverse trend was found in transpiration rate in both years of experiment. The transpiration rate among various treatments varies from $0.7 \text{ mmol m}^{-2} \text{ s}^{-1}$ (T1) to $2.4 \text{ mmol m}^{-2} \text{ s}^{-1}$ (T6). Data revealed that transpiration rate among treatments significantly superior whereas differences among treatments T1 ($0.70 \text{ mmol m}^{-2} \text{ s}^{-1}$), T2 ($0.85 \text{ mmol m}^{-2} \text{ s}^{-1}$) and T3 ($1.75 \text{ mmol m}^{-2} \text{ s}^{-1}$), T4 ($1.72 \text{ mmol m}^{-2} \text{ s}^{-1}$) and T5 ($2.17 \text{ mmol m}^{-2} \text{ s}^{-1}$), T6 ($2.47 \text{ mmol m}^{-2} \text{ s}^{-1}$) were at par during 2019. In 2020 almost similar trend was found where transpiration rate among treatments varies from 0.60 (T1) to 2.29 (T6). Transpiration rate among treatments was found significantly different except T1 (0.6), T2 (0.73) and T5 (2.04), T6 (2.29) which were at par.

Pooled analysis of transpiration rate in different training system of litchi revealed that transpiration rate varies significantly except T1 (0.65), T2 (0.79) and T3 (1.6), T4 (1.55) and T5 (2.10), T6 (2.38) are at par.

Table 4.3.3.1: Effect of planting density on transpiration rate ($\text{mmol m}^{-2} \text{ s}^{-1}$),

Treatments	2019	2020	Pooled
T1	0.27	0.21	0.24
T2	0.52	0.50	0.51
T3	1.02	0.94	0.98
T4	1.85	1.61	1.73
T5	2.25	1.99	2.12
T6	2.47	2.29	2.38
CD at 5%	0.362	0.378	0.271
SE(m)	0.119	0.124	0.089

Table 4.3.3.2: Effect of training system on transpiration rate ($\text{mmol m}^{-2} \text{s}^{-1}$),

Treatments	2019	2020	Pooled
T1	0.70	0.60	0.65
T2	0.85	0.73	0.79
T3	1.75	1.50	1.62
T4	1.72	1.37	1.55
T5	2.17	2.04	2.10
T6	2.47	2.29	2.38
CD	0.711	0.343	0.432
SE	0.234	0.113	0.142

Relative Humidity (%):

The effect of planting densities in square system on relative humidity during 2019 and 2020 has been presented in table 4.3.4.1. Data revealed that relative humidity were found to be higher in 2020 as compared to 2019. It is clear from data that relative humidity in 2019 varied significantly among the treatments. Maximum mean relative humidity among various treatments recorded in T1 (58.59%) it was followed by T2 (57.86%) while minimum mean relative humidity was recorded in T6 (46.45%) followed by T5 (49.05%) during 2019. Almost same trend was observed in 2020, relative humidity among treatments varies significantly. Maximum mean relative humidity among various treatments recorded in T1 (59.49%) it was followed by T2 (58.43%) while minimum mean relative humidity was recorded in T6 (46.24%) followed by T5 (49.77%).

Pooled analysis showed that mean relative humidity in various spacing varied significantly. Maximum mean relative humidity (59.04%) was noticed in close spaced plants (T1) while minimum (46.34%) in wider spaced plants (T6).

Mean relative humidity among various training systems under rectangular planting system was found significantly difference presented in table 4.3.4.2. Increasing trend was found in relative humidity in 2019 and 2020. Maximum mean relative humidity among various treatments recorded in T2 (57.74%) it was closely followed by T1 (57.34%). Minimum mean relative humidity was recorded in control (46.45%) followed by T5 (49.32%) during 2019. Similar trend was found in 2020. Relative humidity among treatments varies significantly. Maximum mean relative humidity among various treatments recorded in T1 (58.27%) it was closely followed by T2 (58.16%) while minimum mean relative humidity was recorded in T6 (46.24%).

In pooled analysis mean relative humidity in various training systems varied significantly. Maximum relative humidity was noticed in T2 (57.95%) it was closely followed by T1 (57.80%). Minimum mean relative humidity among various treatments recorded in T6 (46.34%).

Table 4.3.4.1: Effect of planting density on relative humidity (%)

Treatments	2019	2020	Pooled
T1	58.59	59.49	59.04
T2	57.86	58.43	58.14
T3	56.25	56.82	56.54
T4	51.32	51.69	51.50
T5	49.05	49.77	49.41
T6	46.45	46.245	46.34
CD at 5%	2.352	0.991	1.289
SE(m)	0.773	0.326	0.424

Table 4.3.4.2: Effect of training system on Relative Humidity (%)

Treatments	2019	2020	Pooled
T1	57.34	58.27	57.81
T2	57.75	58.17	57.96
T3	52.90	52.95	52.93
T4	50.95	51.54	51.25
T5	49.33	49.44	49.38
T6	46.45	46.25	46.35
CD at 5%	3.09	0.62	1.69
SE(m)	1.02	0.20	0.55

Water Use Efficiency ($\mu\text{mol mol}^{-1}$):

The effect of planting densities on mean water use efficiency during 2019 and 2020 has been presented in table.4.3.5.1. It is evident from the data that water use efficiency were found to be higher in 2020 as compared to 2019. The mean water use efficiency was found to be varies from different planting densities. Maximum mean water use efficiency was recorded in T1 (6.18) and minimum mean water use efficiency was recorded in T4 (2.72) it was closely followed by T5 (2.84) in 2019. Similar trend was found during 2020, where maximum mean water use efficiency was recorded in T1 (6.47) while minimum mean water use efficiency was recorded in T4 (2.98) followed by T5 (3.02).

Pooled analysis showed that mean water use efficiency in various spacing varied significantly. Maximum mean water use efficiency among various treatments recorded in T1 (6.32) while minimum mean water use efficiency was recorded in T4 (2.84) it was closely followed by T5 (2.93).

Training system also had a significant effect on water use efficiency (Table 4.3.5.2). The maximum mean water use efficiency was recorded in T1

(6.94) and it was significantly higher than other treatments it was followed by T2 (5.61). The minimum mean water use efficiency recorded in T3 (2.96) which followed by T5 (3.14) during 2019. Similar trend was observed in 2020. The maximum mean water use efficiency was recorded in T1 (7.06) and it was significantly higher than other treatments. .Minimum mean water use efficiency was recorded in T3 (3.11) followed by T4 (3.44).

In pooled analysis, mean water use efficiency among various treatments in rectangular system varies significantly. Maximum mean water use efficiency was recorded in T1 (7.00) it was significantly higher than other treatments while minimum mean water use efficiency recorded in T3 (3.04).

Table 4.3.5.1:Effect of planting density on Water Use Efficiency($\mu\text{mol mmol}^{-1}$)

Treatments	2019	2020	Pooled
T1	6.19	6.47	6.33
T2	4.14	4.63	4.39
T3	3.86	4.11	3.98
T4	2.72	2.99	2.85
T5	2.84	3.03	2.94
T6	3.43	3.85	3.64
CD at 5%	0.14	0.36	0.19
SE(m)	0.05	0.12	0.06

Table 4.3.5.2: Effect of training system on Water Use Efficiency ($\mu\text{mol mmol}^{-1}$)

Treatments	2019	2020	Pooled
T1	6.95	7.06	7.00
T2	5.62	6.12	5.87
T3	2.96	3.11	3.04
T4	3.54	3.45	3.49
T5	3.15	3.52	3.34
T6	3.43	3.85	3.64
CD at 5%	0.30	0.33	0.21
SE(m)	0.10	0.11	0.07

Internal Carbon dioxide concentration ($\mu\text{mol mol}^{-1}$)

It is apparent from the data presented in table 4.3.6.1 reveal that planting density significantly affected the concentration of internal carbon dioxide during both the years of experiment (2019 and 2020). The internal carbon dioxide concentration was found to be varies from different planting densities. Maximum concentration of internal carbon dioxide in various treatment found in control (382.50) followed by T4 (361.0) and T5 (358.2) while lower concentration of internal carbon dioxide (259.2) was found in closed spaced plants (T1) during 2019. Almost similar and increasing trend was found in 2020 where, maximum concentration of internal carbon dioxide in various treatment found in control (387.5) followed by T4 (361.7) and T5 (360.2) while lower concentration of internal carbon dioxide (260.5) was found in closed spaced plants (T1).

Pooled analysis showed that mean internal carbon dioxide concentration in various spacing varied significantly. Maximum mean internal carbon dioxide concentration among various treatments was recorded in T6 (385.0) and

minimum mean internal carbon dioxide concentration was recorded in T1 (259.87) followed by T2 (274.3).

Data in table 4.3.6.2 revealed that training system under rectangular planting also affected the internal CO₂ concentration significantly. Maximum mean internal CO₂ concentration was recorded in T6 (382.5) followed by T5 (370.5). Minimum internal CO₂ concentration in various treatments recorded in T3 (269.7) during 2019. Almost same trend was observed in 2020. The maximum internal CO₂ concentration among treatments was recorded in T3 (272.1) and minimum internal CO₂ concentration was recorded in control (387.5) followed by T5 (373.17).

Pooled analysis of internal CO₂ concentration among different training system in rectangular planting revealed that the internal CO₂ concentration varied significantly. It is clear that internal CO₂ concentration was maximum in control (385).

Table 4.3.6.1: Effect of planting density on internal CO₂ concentration ($\mu\text{mol mol}^{-1}$)

Treatments	2019	2020	Pooled
T1	259.3	260.5	259.9
T2	273.3	275.5	274.4
T3	283.8	284.8	284.3
T4	361.0	361.8	361.4
T5	358.3	360.3	359.3
T6	382.5	387.5	385.0
CD at 5%	5.2	4.6	3.1
SE(m)	1.7	1.5	1.0

Table 4.3.6.2: Effect of training system on internal CO₂ concentration ($\mu\text{mol mol}^{-1}$)

Treatments	2019	2020	Pooled
T1	351.0	351.6	351.3
T2	347.7	349.6	348.6
T3	269.7	272.1	270.9
T4	365.0	365.9	365.4
T5	370.5	373.1	371.8
T6	382.5	387.5	385.0
CD at 5%	20.315	5.016	10.05
SE(m)	6.679	1.649	3.304

Mesophyll Efficiency ($\mu\text{mol mol}^{-1} (\mu\text{mol/m}^2\text{s}^{-1})^{-1}$):

The effect of planting densities on mean mesophyll efficiency during 2019 and 2020 has been presented in table 4.3.7.1. It is evident from the data that mesophyll efficiency were found to be higher in 2020 as compared to 2019. There was significant effect of various planting density on mesophyll efficiency during both the years. Maximum mean mesophyll efficiency was recorded in T1 (17.82) closely followed by T2 (17.25) while minimum mean mesophyll efficiency was recorded in T6 (6.17) in 2019. Similar trend was found during 2020, where maximum mean mesophyll efficiency was recorded in T1 (18.24) followed by T2 (17.74) while minimum mean mesophyll efficiency was recorded in T6 (6.92) followed by T5 (7.96).

Pooled analysis showed that mean mesophyll efficiency in various spacing varied significantly. Maximum mean mesophyll efficiency among various treatments recorded in T1 (18.03) while minimum mean mesophyll efficiency was recorded in T6 (6.55) followed by T5 (7.79).

Training system also had a significant effect on mean mesophyll efficiency (Table 4.3.7.2). In general foliar P level was found to be higher in 2019 as compared to 2020. In training system the mean mesophyll efficiency among treatment varies from 6.17 (T6) to 18.61 (T2). Critical analysis of data revealed that treatments T1 and T4 are significantly superior with respect to mesophyll efficiency whereas T2, T3 and T4, T5 which were at par during 2019. In 2020, maximum mean mesophyll efficiency was recorded in T2 (19.04). Minimum mean mesophyll efficiency among various treatments was recorded in T6 (6.92).

Pooled analysis of data shows that training system also had a significant effect on mean mesophyll efficiency. Maximum mean mesophyll efficiency was recorded in T2 (18.83) while minimum mean mesophyll efficiency recorded in control (6.55).

Table 4.3.7.1: Effect of planting density on mesophyll efficiency ($\mu\text{mol mol}^{-1} (\mu\text{mol/m}^2\text{s}^{-1})^{-1}$)

Treatments	2019	2020	Pooled
T1	17.825	18.248	18.036
T2	17.255	17.74	17.498
T3	9.553	9.907	9.730
T4	9.345	9.600	9.473
T5	7.623	7.968	7.795
T6	6.178	6.923	6.55
CD at 5%	0.237	0.342	0.17
SE(m)	0.078	0.112	0.056

Table 4.3.7.2: Effect of training system on mesophyll efficiency ($\mu\text{mol mol}^{-1} (\mu\text{mol/m}^2\text{s}^{-1})^{-1}$)

Treatments	2019	2020	Pooled
T1	17.016	17.315	17.166
T2	18.618	19.043	18.830
T3	8.986	9.498	9.242
T4	10.808	11.378	11.093
T5	7.583	8.250	7.916
T6	6.178	6.923	6.550
CD at 5%	0.466	0.266	0.291
SE(m)	0.153	0.088	0.096

Quantum Efficiency ($\mu\text{mol m}^{-2} \text{s}^{-1}/ (\mu\text{molmol}^{-1})$)

Data in table 4.3.8.1 and 4.3.8.2 show planting density (square system) and training system (rectangular system) had no significant effect on the mean quantum efficiency of litchi during the present investigations. The data shows in planting density that mean quantum efficiency was found to be maximum in T5 (0.006) closely followed by T4 (0.005) and T6 (0.005) while minimum quantum efficiency was recorded in T2 (0.003). But, their difference did not attain a level of significance. Similar trend was observed during second year of experiment (2020). Maximum mean quantum efficiency was observed in T5 (0.008) and minimum in T2 (0.003).

Pooled analysis of mean quantum efficiency in litchi revealed that mean quantum efficiency varies non significantly.

Data reveals that training system had also non significant with respect to mean quantum efficiency during 2019 and 2020 (Table 4.3.8.2)

Pooled analysis of mean quantum efficiency in litchi revealed that mean quantum efficiency varies non significantly.

Table 4.3.8.1: Effect of planting density on Quantum Efficiency ($\mu\text{mol m}^{-2} \text{s}^{-1}$) / (μmolmol^{-1})

Treatments	2019	2020	Pooled
T1	0.005	0.006	0.005
T2	0.003	0.003	0.003
T3	0.004	0.006	0.005
T4	0.005	0.007	0.006
T5	0.006	0.008	0.007
T6	0.005	0.006	0.006
CD at 5%	0	0	0
SE(m)	0	0	0

Table 4.3.8.2: Effect of training system on Quantum Efficiency ($\mu\text{mol m}^{-2} \text{s}^{-1}$) / (μmolmol^{-1})

Treatments	2019	2020	Pooled
T1	0.005	0.006	0.005
T2	0.005	0.006	0.005
T3	0.005	0.006	0.005
T4	0.004	0.005	0.005
T5	0.005	0.005	0.005
T6	0.005	0.006	0.006
CD at 5%	0	0	0
SE(m)	0	0	0

Leaf Nutrient

Contents 4.4.1)

Nitrogen (%)

Planting density in square system had no significant effect on leaf nutrient content of litchi. Data in this aspect in table 4.4.1.1 revealed that foliar nitrogen level were found to be higher in 2019 as compared to 2020 irrespective of planting density. Highest nitrogen content was recorded in T6 (1.57%) it was closely followed by T5 (1.52). Lowest nitrogen content was recorded in T1 (1.2%) followed by T2 (1.31%) and T3 (1.36%) during 2019. Similar trend was found in second year of experiment (2020) where highest nitrogen content was recorded in T6 (1.54%) followed by T5 (1.49%) and minimum nitrogen content was recorded in T1 (1.23%) closely followed by T2 (1.29%).

In pooled analysis, maximum nitrogen content (1.56%) among various treatments was recorded in wider spacing (T6) it was closely followed by T5 (1.50%) while minimum nitrogen content (1.23%) was recorded in closed spaced plants (T1). An overall appraisal of Tables shows that nitrogen content was recorded highest in wider spacing (T6) during the both years.

Among training system (rectangular system), nitrogen content of leaves increased non-significantly with increase the plant spacing except T3 (5x3m) where minimum nitrogen content (1.47%) was recorded closely followed by T2 (1.49%) Maximum mean nitrogen content among treatments was recorded in T6(1.57%) it was closely followed by T5 (1.54%) during 2019 . Similar trend was found in second year of experiment (2020). Highest nitrogen content was recorded in T6 (1.54%) followed by T5 (1.52%) and minimum nitrogen content was recorded in T3 (1.43%) while difference among treatments T1 (1.49%) and T2 (1.49%) were at par.(Table 4.4.1.2)

Pooled analysis of data reveals that maximum nitrogen content (1.56%) among various treatments was recorded in wider spacing (T6) it was closely followed by T5 (1.53%) while minimum nitrogen content (1.45%) was recorded in T3.

Table 4.4.1.1: Effect of planting density on Nitrogen (%)

Treatments	2019	2020	Pooled
T1	1.24	1.23	1.23
T2	1.31	1.29	1.30
T3	1.36	1.34	1.35
T4	1.42	1.40	1.41
T5	1.52	1.49	1.50
T6	1.57	1.54	1.56
CD at 5%	0.059	0.067	0.058
SE(m)	0.019	0.022	0.019

Table 4.4.1.2: Effect of training system on Nitrogen%

Treatments	2019	2020	Pooled
T1	1.51	1.49	1.50
T2	1.49	1.49	1.49
T3	1.47	1.43	1.45
T4	1.52	1.49	1.51
T5	1.54	1.52	1.53
T6	1.57	1.54	1.56
CD at 5%	0.034	0.045	0.029
SE(m)	0.011	0.015	0.01

Phosphorus (%)

Data in table 4.4.2.1 show that mean foliar phosphorus concentration was not affected significantly by planting density in litchi during both the years. However little variation in phosphorus were evident during present studies. In general foliar P level was found to be higher in 2019 as compared to 2020. Maximum phosphorus content among treatments was recorded in T6 (0.26%) followed by T5 (0.22%) whereas minimum phosphorus content was recorded in T1 (0.13%) followed by T2 (0.15%) but it did not reach a significant level during 2019. Similar trend was noticed in 2020, where maximum phosphorus content among treatments was recorded in T6 (0.25 %) followed by T5 (0.22 %). Minimum phosphorus content was recorded in T1 (0.12 %) followed by T2 (0.13 %).

In pooled analysis, maximum phosphorus content (0.25%) among various treatments was recorded in wider spacing (T6) it was closely followed by T5 (0.22 %) while minimum phosphorus content (0.12 %) was recorded in closed spaced plants (T1) but did not attain a level of significant. It was clear from data that foliar phosphorus concentration was increasing in wider spacing.

Training system also had a significant effect on total phosphorus content (Table 4.4.2.2). In general foliar P level was found to be higher in 2019 as compared to 2020. In training system the phosphorus content among treatment varies from 0.16% (T1) to 0.26 % (T6) during 2019. In 2020, maximum phosphorus content was recorded in T6 (0.25%). Minimum phosphorus content among various treatments was recorded in T2 (0.16 %) closely followed by T1 (0.16 %).

Pooled analysis of data shows that training system also had a significant effect on total phosphorus content. Maximum concentration of phosphorus was recorded in control (0.25 %) while minimum P% recorded in T2 (0.16 %).

Table 4.4.2.1: Effect of planting density on Phosphorus %

Treatments	2019	2020	Pooled
T1	0.13	0.11	0.12
T2	0.15	0.12	0.13
T3	0.19	0.16	0.17
T4	0.21	0.21	0.21
T5	0.22	0.21	0.22
T6	0.26	0.25	0.25
CD at 5%	0.028	0.065	0.041
SE(m)	0.009	0.021	0.014

Table 4.4.2.2: Effect of training system on Phosphorus %

Treatments	2019	2020	Pooled
T1	0.16	0.16	0.17
T2	0.17	0.16	0.16
T3	0.18	0.18	0.18
T4	0.20	0.20	0.20
T5	0.24	0.22	0.23
T6	0.26	0.25	0.25
CD at 5%	0.03	0.038	0.03
SE(m)	0.01	0.012	0.01

Potassium (%)

The perusal of data in table 4.4.3.1 reveals that foliar potassium content was not affected significantly planting density during the both the years. In general foliar potash level was found to be higher in 2019 as compared to 2020. Planting density did not show significant differences in potassium content in tissues. Maximum potassium content among treatments was recorded in T6 (1.34%) closely followed by T5 (1.30 %) whereas minimum potassium content was recorded in T1 (1.13%) followed by T2 (1.18 %) during 2019. Similar trend was noticed in 2020, where maximum potassium concentration among treatments was recorded in T6 (1.33%) followed by T5 (1.25 %). Minimum potassium content was recorded in T1 (1.07%) followed by T2 (1.14 %).

In pooled analysis, maximum potassium content (1.34%) among various treatments was recorded in wider spacing (T6) it was closely followed by T5 (1.28%) while lower potassium content (1.10%) was recorded in closed spaced plants (T1). An overall appraisal of table 4.4.3.1 shows that total potassium content in wider planted trees was found to be higher as compared to trees planted at closed spaced.

Data in table 4.4.3.2 revealed that training system under rectangular planting also affected the potassium content significantly. Maximum potassium content among treatments was recorded in control (1.34%) it was closely followed by T5 (1.33%) whereas minimum potassium content was recorded in T2 (1.17%) followed by T1 (1.19%) during 2019. Similar trend was noticed in 2020. Maximum potassium concentration among treatments was recorded in control (1.33%) closely followed by T5 (1.32%). Minimum potassium content was recorded in T2 (1.165%) followed by T1 (1.168%).

Pooled analysis of data reveals that maximum potassium content (1.34%) among various treatments was recorded in control (T6) it was closely followed by T5 (1.32%) while lower potassium content (1.17%) was recorded in T2. Total potassium content in wider planted trees was found to be higher as compared to trees planted at closed spaced.

Table 4.4.3.1: Effect of planting density on Potash %

Treatments	2019	2020	Pooled
T1	1.13	1.07	1.10
T2	1.18	1.14	1.16
T3	1.23	1.18	1.20
T4	1.26	1.21	1.24
T5	1.30	1.25	1.28
T6	1.34	1.33	1.34
CD at 5%	0.05	0.046	0.04
SE(m)	0.016	0.015	0.013

Table 4.4.3.2: Effect of training system on Potash%

Treatments	2019	2020	Pooled
T1	1.19	1.16	1.17
T2	1.175	1.16	1.17
T3	1.25	1.23	1.24
T4	1.28	1.25	1.26
T5	1.33	1.32	1.32
T6	1.34	1.338	1.34
CD at 5%	0.041	0.033	0.032
SE(m)	0.013	0.011	0.01

Total Phenol (mg g⁻¹)

The perusal of data in table 4.4.4.1 reveals that total phenols content was affected significantly planting density during the both the years. In general increasing trend was found in total phenols content over the years (2019 and 2020). Total phenol content was estimated highest in T6 (81.15 mg g⁻¹) which differ significantly with T5 (66.00 mg g⁻¹), T4 (54.21 mg g⁻¹) and T3 (49.90 mg g⁻¹) while T1 (41.18 mg g⁻¹) and T2 (41.22 mg g⁻¹) were statistically at par during 2019. Similar trend was noticed in 2020, where total phenol content was estimated highest in T6 (83.35 mg g⁻¹) which differ significantly with T5 (66.79 mg g⁻¹), T4 (55.60 mg g⁻¹) and T3 (51.78 mg g⁻¹) while T1 (43.35 mg g⁻¹) and T2 (43.98 mg g⁻¹) were statistically at par.

In pooled analysis, maximum phenol content (82.25 mg g⁻¹) among various treatments was recorded in wider spacing (T6) which differ significantly with T5 (66.40 mg g⁻¹), T4 (54.90 mg g⁻¹) and T3 (50.83 mg g⁻¹) while T1 (42.26 mg g⁻¹) and T2 (42.60 mg g⁻¹) were at par. It was clear that total phenols content in leaves were increasing with increasing spacing and over the years.

Data in table 4.4.4.2 revealed that training system affected the phenol content significantly. Maximum phenol content among treatments was recorded in control (81.15 mg g⁻¹) whereas minimum phenol content was recorded in T2 (51.45 mg g⁻¹) during 2019. Similar trend was noticed in 2020. Maximum phenol content among treatments was recorded in control (83.35 mg g⁻¹). Minimum phenol content was recorded in T2 (52.42 mg g⁻¹) followed by T1 (53.17 mg g⁻¹).

Pooled analysis of data reveals that phenol content in leaf was significantly different among various treatments. Maximum phenol content (82.25 mg g⁻¹) was recorded in control (T6) while lower phenol content among treatments (51.93 mg g⁻¹) was recorded in T2 followed by T1 (52.41 mg g⁻¹).

Table 4.4.4.1: Effect of planting density on total phenol (mg GAE/g)

Treatments	2019	2020	Pooled
T1	41.18	43.35	42.26
T2	41.22	43.98	42.60
T3	49.90	51.78	50.84
T4	54.21	55.60	54.90
T5	66.00	66.79	66.40
T6	81.15	83.35	82.25
CD at 5%	1.139	1.511	1.036
SE(m)	0.374	0.497	0.34

Table 4.4.4.2: Effect of training system on total phenol (mg GAE/g)

Treatments	2019	2020	Pooled
T1	51.65	53.17	52.41
T2	51.45	52.42	51.93
T3	53.88	55.46	54.67
T4	66.77	67.71	67.24
T5	73.12	75.15	74.14
T6	81.15	83.35	82.25
CD at 5%	1.207	1.614	1.358
SE(m)	0.397	0.531	0.446

Total Chlorophyll Content (mg/g):

Data in table 4.4.5.1 show that mean chlorophyll content was significantly more during 2020 as compared to 2019 during the present investigation. Increasing trend was found in total chlorophyll content over the years (2019 and 2020). The total chlorophyll content among treatment varies from 3.41 (T1) to 9.11 (T6). Critical analysis of data revealed that treatment T1 (3.41) and T2 (3.91) are at par but they vary significantly from T3 (5.19). Similarly T4 (6.68) and T5 (7.30) are at par in between but significantly different from T6 (9.11) during 2019. In second year of experiment chlorophyll content among various treatments was found significantly different. Maximum chlorophyll content was recorded in T6 (9.50) followed by T5 (8.21). Minimum chlorophyll recorded in T1 (4.05) closely followed by T2 (4.47).

Pooled analysis of total chlorophyll content in litchi with various spacing in square system revealed that the chlorophyll content varies significantly where maximum total chlorophyll content among treatment was recorded in T6 (9.3) followed by T5 (7.76). Minimum total chlorophyll content was recorded in T1 (3.73) followed by T2 (4.2).

Chlorophyll content among various training systems under rectangular planting system was found significantly difference. The total chlorophyll content among treatment varies from 4.87 (T2) to 9.11 (T6). Critical analysis of data shows that treatment T1 (5.16) and T2 (4.87) are significantly different but (5.19) treatments T3 (6.72), T4 (7.59), T5 (8.36) and T6 (9.11) were statistically at par in between during 2019. In second year of experiment the chlorophyll content varies from 5.55 (T2) to 9.50 (T6). The chlorophyll content among various treatments was found significantly different except treatment T1 (6.29), T2 (5.55) and T3 (8.09), T4 (8.39) and T5 (9.23), T6 (9.50) were statistically at Par. (Table 4.4.5.2)

Pooled analysis of total chlorophyll content in litchi with various spacing in square system revealed that the chlorophyll content varies significantly where maximum total chlorophyll content among treatment was recorded in T6 (9.31).

Minimum total chlorophyll content was recorded in T2 (5.21). The differences among treatments T3 (7.40), T4 (7.99) and T5 (8.79), T6 (9.31) were at par.

Table 4.4.5.1: Effect of planting density on total chlorophyll content (mg/g)

Treatments	2019	2020	Pooled
T1	3.41	4.05	3.73
T2	3.91	4.57	4.24
T3	5.19	5.51	5.35
T4	6.68	7.23	6.95
T5	7.30	8.21	7.76
T6	9.11	9.50	9.31
CD at 5%	0.955	0.307	0.502
SE(m)	0.314	0.101	0.165

Table 4.4.5.2: Effect of training system on total chlorophyll (mg/g)

Treatments	2019	2020	Pooled
T1	5.16	6.29	5.73
T2	4.87	5.55	5.21
T3	6.72	8.09	7.40
T4	7.59	8.39	7.99
T5	8.36	9.23	8.79
T6	9.11	9.50	9.31
CD at 5%	1.075	0.416	0.628
SE(m)	0.353	0.137	0.206

Flowering and Yield attributing characters
4.5.1) Number of Panicles per branch

Data pertaining numbers of panicles per branch are presented in Table 4.5.1.1. The number of panicles per branch was affected significantly during 2020 as compared to 2019 in all the planting density and training systems during the present studies. The number of panicles per branches among treatment varies between 4.75 (T1) to 18.00 (T6). Critical analysis of data revealed that treatments T1 and T2 are at par but they vary significantly from T3. Similarly T3 and T4 are at par in between but significantly different from T5 and T6 during 2019. Similar and increasing trend was observed in the second year of experiment (2020). The number of panicle per branch among the treatments varies between 6.49 (T1) to 20.05 (T6). Critical analysis of data revealed that treatments T1 and T2 are at par but they vary significantly from T3. Similarly T3 and T4 are at par in between but significantly different from T5 and T6 (control).

Pooled analysis of number of panicles per branches among various spacing in square system revealed that the number of panicle varies significantly however treatment T1, T2 and T3, T4 were statistically at par. It is clear from data that number of panicles in various treatments is increasing over the year. The wider spacing has more number of panicles than high density planting. The highest value (19.02) was recorded in control (T6).

Training system under rectangular system of litchi also affected the number of panicles per branches significantly (Table 4.5.1.2). Number of panicles was higher in the year 2020 as compared to 2019 irrespective of training system during the present studies. The number of panicles per branches among treatment varies between 3.25 (T3) to 18.00 (T6). Critical analysis of data revealed that treatments T2 and T3 are at par but they vary significantly from T1, T4, T5 and T6 during 2019. Similarly in the second year of experiment (2020) minimum number of panicles (3.25) was recorded in T3 and

maximum number of panicles (20.05) recorded in control (T6).

Pooled analysis of number of panicles per branches among various training system in rectangular system revealed that the number of panicle varies significantly however treatment T1, T2 and T2, T3 were statistically at par. It is clear from data that number of panicles in various treatments is increasing over the year.

Table 4.5.1.1: Effect of planting density on number of panicles/branch

Treatments	2019	2020	Pooled
T1	4.75	6.49	5.62
T2	4.80	6.73	5.76
T3	6.77	8.15	7.46
T4	7.17	8.32	7.74
T5	11.00	13.29	12.14
T6	18.00	20.05	19.02
CD at 5%	1.259	0.348	0.644
SE(m)	0.414	0.114	0.212

Table 4.5.1.2: Effect of training system on number of panicles/branch

Treatments	2019	2020	Pooled
T1	7.50	9.80	8.65
T2	5.75	7.74	6.74
T3	3.25	5.55	4.40
T4	8.75	10.21	9.48
T5	15.50	18.32	16.91
T6	18.00	20.05	19.02
CD at 5%	2.203	0.428	1.118
SE(m)	0.724	0.141	0.367

Panicle Length (cm)

The perusal of data presented in table 4.5.2.1 indicates that planting density significantly affected the panicle length during both the years. Data showed that panicle length was higher in the year 2020 as compared to 2019 irrespective of planting densities and training system during the present studies. Planting density had a significant effect on panicle length of litchi tree during both the years. Panicle length among treatment varies from 19.49 cm (T1) to 31.52 cm (T6). Critical analysis of data revealed that treatments T3, T4, T5 and T6 are significantly superior with respect to panicle length whereas, T1 and T2 were at par during 2019. Almost same trend was observed in 2020. The panicle length among treatment varies from 20.08 cm (T1) to 33.93 cm (T6). Panicle length among treatments was found significantly different except T1 and T2 which was at par.

Pooled analysis of panicle length among various spacing in square system revealed that the panicle length varied significantly however treatments T1 and T2 are statistically at par. It is clear that panicle length was increasing in wider spacing. It might be due to higher interception of light and availabilities of natural resources in wider spacing plants than closed planting.

Data also reveal that training system under rectangular planting also affected the panicle length significantly (Table 4.5.2.2). Maximum mean panicle length was recorded in T6 (31.52 cm). Minimum mean panicle length in various treatments recorded in T3 (19.75 cm). The difference in panicle length of treatments T1 (28.5 cm), T2 (23.25 cm) and T4 (25.71 cm), T5 (27.91 cm) and T6 (31.52cm) were statistically at par with each other during 2019. Almost same trend was observed in 2020. The panicle length among treatment varies from 20.24 cm (T3) to 33.93 cm (T6). Panicle length among treatments T4 (26.12 cm), T5 (29.15cm) and T6 (33.98 cm) were found significantly different except T1 (29.19 cm) and T2 (23.92cm) and T3 (20.24 cm) which were statistically at par.

Pooled analysis of panicle length among different training system in rectangular planting revealed that the panicle length varied significantly however treatments T1 (28.84cm), T2 (23.58cm) and T4 (25.92cm), T5 (28.53cm) are statistically at par. It is clear that panicle length was increasing in control.

Table 4.5.2.1: Effect of planting density on panicle length (cm)

Treatments	2019	2020	Pooled
T1	19.49	20.08	19.79
T2	19.93	20.53	20.23
T3	22.10	24.88	23.49
T4	24.44	26.06	25.25
T5	28.93	30.89	29.91
T6	31.52	33.93	32.73
CD at 5%	1.641	0.611	0.813
SE(m)	0.54	0.201	0.267

Table 4.5.2.2: Effect of training system on panicle length (cm)

Treatments	2019	2020	Pooled
T1	28.50	29.19	28.84
T2	23.25	23.92	23.58
T3	19.75	20.24	19.99
T4	25.71	26.12	25.92
T5	27.91	29.15	28.53
T6	31.52	33.93	32.73
CD at 5%	5.092	2.18	3.437
SE(m)	1.674	0.717	1.13

Number of flowers / panicle

The perusal of data in table 4.5.3.1 and figure 11 reveals that mean fruit set was significantly more during 2020 as compared to 2019 in all the planting density and training systems during the present studies. Planting density had a significant effect on total number of flowers per panicle of litchi tree during both the years. The maximum number of flowers per panicle (112.75) was recorded in wider spacing (T6) followed by T5 (88). The minimum number of flowers per panicle was recorded in closed spaced plant (T1) followed by T2 (41.75) and T3 (57.5) during first year of experiment (2019). Similar trend was found in 2020. Total number of flowers per panicle among various treatments was found significantly different. The maximum number of flowers per panicle was recorded in control (114.49) followed by T5 (90.0250 while minimum number of flowers recorded in T1 (37.74) it was followed by T2 (43.64).

In pooled analysis, total number of flowers per panicle among various spacing in square system revealed that number of flowers per panicle varies significantly. Maximum number of flowers was recorded in T6 (113.62) whereas, minimum number of flowers recorded in T1 (36 78) followed by T2 (42.69). An overall appraisal of Table 4.5.3.1 shows that the mean number of flowers per panicle was highest in wider spacing and increasing over the years.

Data in table 4.5.3.2 and figure 12 reveals that training system under rectangular planting also affected the total number of flowers per panicle significantly. Total number of flowers per panicle among treatment varies from 66.25 (T3) to 112.75 (T6). Critical analysis of data revealed that treatments T1 (72.00), T2 (68.75), T3 (66.25) and T6 (112.75) are significantly superior with respect to total number of flowers per panicle whereas, T4 (100.05) and T5 (105.5) were at par during 2019. Almost same trend was found in 2020. Total number of flowers per panicle among treatment varies from 68.24 (T3) to 114.49 (T6). Total number of flowers per panicle among treatments was found significantly different except T1, T2 and T3 which were at par.

Pooled analysis of total number of flowers per panicle among various treatments in rectangular system revealed that the number of flowers per panicle varied significantly however treatments T1 and T2 are statistically at par.

Table 4.5.3.1: Effect of planting density on number of flowers/panicle

Treatments	2019	2020	Pooled
T1	35.81	37.74	36.77
T2	41.75	43.64	42.69
T3	57.50	60.09	58.79
T4	78.75	80.25	79.50
T5	88.00	90.02	89.01
T6	112.75	114.49	113.62
CD at 5%	3.926	0.521	2.079
SE(m)	1.291	0.171	0.684

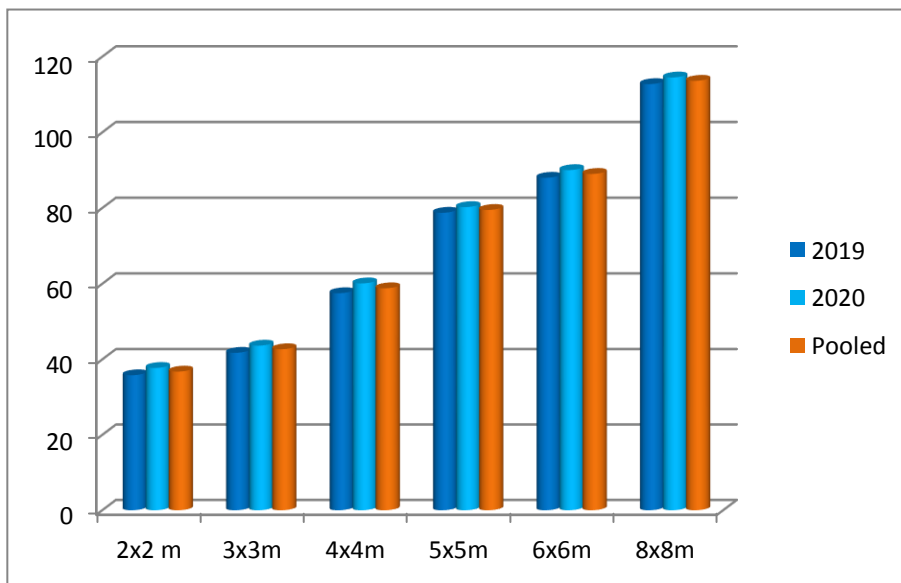


Figure 4.5.3.1 Effect of planting density on number of flowers per panicle

Table 4.5.3.2: Effect of training system on number of flowers/panicle

Treatments	2019	2020	Pooled
T1	72.00	75.42	73.71
T2	68.75	70.53	69.64
T3	66.25	68.24	67.24
T4	100.05	103.41	101.73
T5	105.50	106.27	105.88
T6	112.75	114.49	113.62
CD at 5%	7.009	1.805	3.703
SE(m)	2.304	0.594	1.217

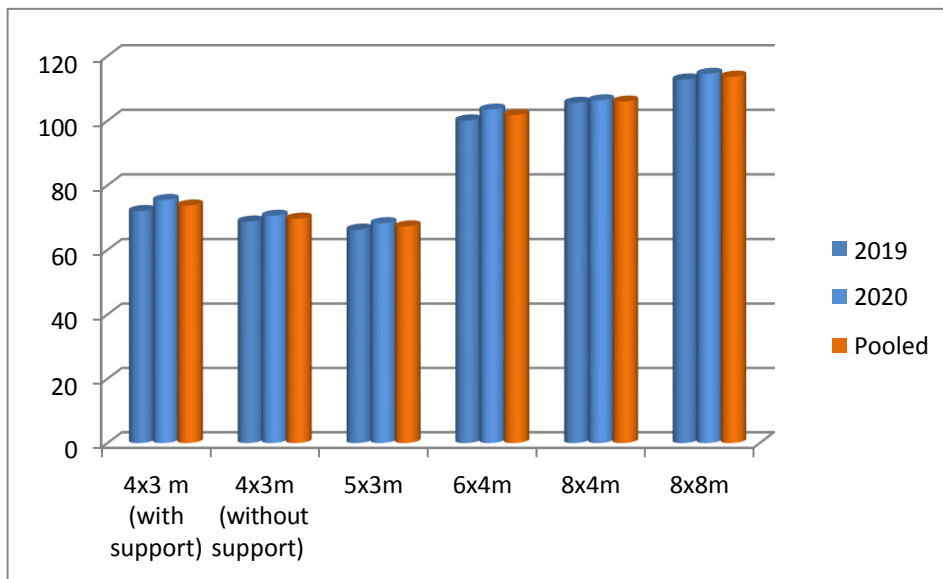


Figure 4.5.3.2 Effect of training system on number of flowers per panicle

Fruit Yield (kg/tree)

The perusal of data presented in table 4.5.4.1 and figure 13 indicates that planting density and training system significantly affected the fruit yield during both the years (2019 and 2020). It is clear from data that spacing affected the productivity significantly. Mean fruit yield/tree was significantly higher during 2019 as compared to 2020. It may be due to adverse environment conditions observed during 2020 as compared to 2019. Maximum fruit yield/tree was recorded in T6 (50.05 kg/tree) and it was significantly higher than other treatments. It was followed by fruit yield of treatment T5 (40.12 kg/tree). Minimum fruit yield was recorded in T1 (3.65 kg/tree) during 2019. Similar trend was found in 2020 where the maximum fruit yield/tree was recorded in T6 (43.52kg/tree) followed by T5 (38.47 kg/tree). Minimum fruit yield was recorded in T1 (3.4 kg/tree) followed by T2 (5.67 kg/tree).

In pooled analysis, fruit yield/tree among various spacing in square system revealed that fruit yield/tree varies significantly. Maximum fruit yield/tree was recorded in wider spacing treatment T6 (46.79 kg/tree) followed by T5 (39.303 kg/tree) while minimum fruit yield/tree recorded in T1 (3.51 kg/tree) followed by T2 (5.89) and T3 (13.14 kg/tree). An overall appraisal of tables

shows that fruit yield/tree was obtained highest in wider spacing than high density. The maximum fruit yield/tree was recorded in control (T6). This may be due to the reason that trees planted at closer spacing had to compete with each other for light, water and nutrients as a result of which yield decreases.

Training system also had a significant effect on fruit yield/tree (Table and figure 14). The maximum mean fruit yield per tree (50.05 kg/tree) was recorded in control (T6) followed by T5 (42.35kg/tree). The minimum mean fruit yield per tree recorded in T2 (8.86kg/tree) which followed by T3 (11.22kg/tree) during 2019. Similar trend was observed in 2020. The maximum fruit yield/tree was recorded in control (43.53kg/tree) and it was significantly higher than other treatments. It was closely followed by T5 (41.47 kg/tree).

Minimum fruit yield was recorded in T2 (6.96 kg/tree) followed by T3 (11.63 kg/tree).

In pooled analysis, fruit yield/tree among various treatments in rectangular system revealed that fruit yield/tree varies significantly. Maximum fruit yield/tree was recorded in wider spacing treatment T6 (46.79 kg/tree) followed by T5 (41.91 kg/tree) while minimum fruit yield/tree recorded in T2 (7.91 kg/tree) followed by T3 (11.42kg/tree) and T1 (15.65 kg/tree).

Table 4.5.4.1: Effect of planting density on fruit yield (kg/plant)

Treatments	2019	2020	Pooled
T1	3.65	3.40	3.51
T2	6.10	5.67	5.89
T3	14.05	12.22	13.14
T4	20.97	19.40	20.18
T5	40.12	38.47	39.30
T6	50.05	43.52	46.79
CD at 5%	1	0.608	0.521
SE(m)	0.329	0.2	0.171

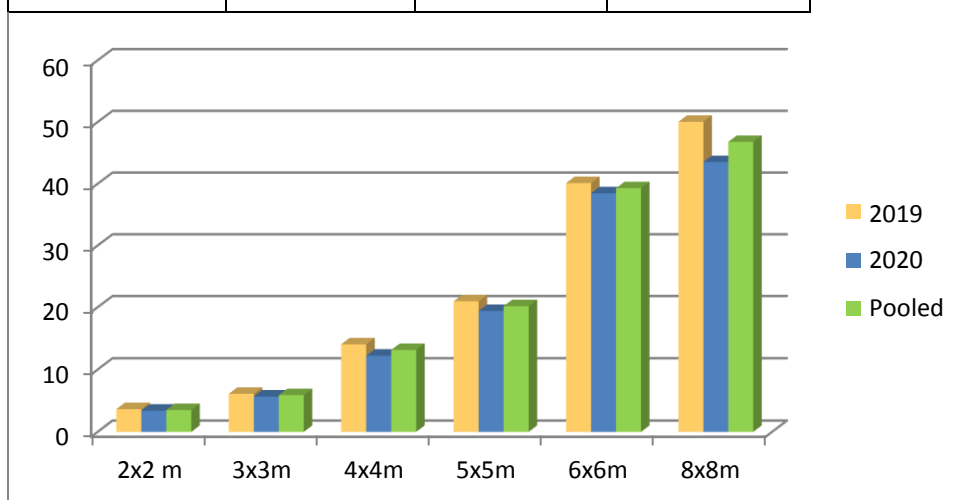


Figure 4.5.4.1 Effect of planting density on fruit yield per plant

Table 4.5.4.2: Effect of training system on fruit yield (kg/plant)

Treatments	2019	2020	Pooled
T1	16.51	14.80	15.65
T2	8.86	6.96	7.91
T3	11.22	11.63	11.42
T4	33.37	31.82	32.59
T5	42.35	41.47	41.91
T6	50.05	43.53	46.79
CD at 5%	3.066	2.872	2.793
SE(m)	1.008	0.944	0.918

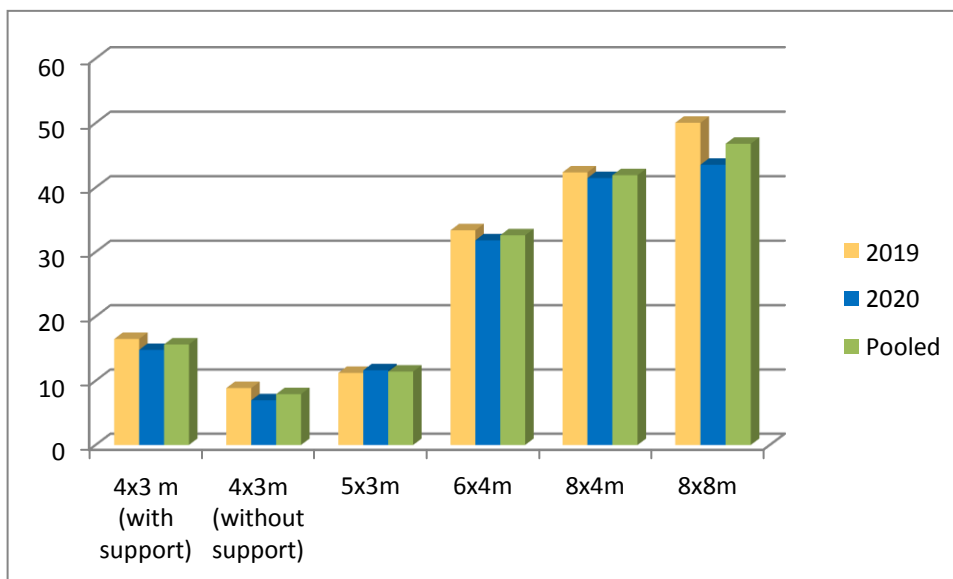


Figure 4.5.4.2 Effect of training system on fruit yield per plant

Fruit Yield (t/ha)

Data in table 4.5.6.1 show that planting density and training system significantly affected the fruit yield on unit area basis. Mean fruit yield per hectare was significantly higher during 2019 as compare to 2020. The fruit yield per hectare among treatment varies from 7.1 t/ha (T2) to 10.13 t/ha (T5). Critical analysis of data revealed that treatment T5 was significantly superior with respect to fruit yield per hectare whereas, treatments T1 (8.26 t/ha), T3 (8.56 t/ha), T4 (8.29 t/ha) and T6 (8.21 t/ha) were non-significant during 2019. In 2020, fruit yield per hectare among treatments varies from 7.03 t/ha (T2) to 10.24 t/ha (T5). Fruit yield per hectare among treatment was found significantly different except T1, T3 and T4 were statistically at par.

In pooled analysis, fruit yield per hectare varies from 7.06 t/ha (T2) to 10.18 t/ha (T5). Pooled analysis of fruit yield per hectare revealed that fruit yield among treatment varied significantly except T1, T3 and T6 were at par. It is clear from data that maximum fruit yield per hectare was recorded in closer spaced plant (T5) as compared with wider spacing (T6).

Training system also had a significant effect on fruit yield per hectare (Table 4.5.6.2). The maximum mean fruit yield per hectare (20.33t/h) was recorded in T5 (8x4 m hedge row system) followed by T4 (15.87t/ha). The minimum mean fruit yield per hectare recorded in T3 (7.47t/ha) which closely followed by T8 (8.21t/ha) during 2019. Almost similar trend was observed in 2020. The maximum fruit yield per hectare was recorded in T5 (17.42t/ha) and it was significantly higher than other treatments. It was followed by T4 (13.42t/ha) whereas minimum fruit yield per hectare was recorded in T3 (7.71t/ha) it was closely followed by T8 (7.79t/ha).

From the pooled data it was observed that fruit yield per hectare varies significantly. Maximum fruit yield/ha was recorded in treatment T5 (18.87t/ha) followed by T4 (14.64t/ha) while minimum fruit yield per hectare recorded in T3 (7.59 t/ha) closely followed by T8 (8.00t/ha).

Table 4.5.6.1: Effect of planting density on fruit yield (t/ha)

Treatments	2019	2020	Pooled
T1	8.26	7.76	8.01
T2	7.10	7.03	7.06
T3	8.56	8.16	8.36
T4	8.29	8.01	8.15
T5	10.13	10.24	10.18
T6	8.21	7.79	8.003
CD at 5%	0.575	1.333	0.778
SE(m)	0.189	0.438	0.256

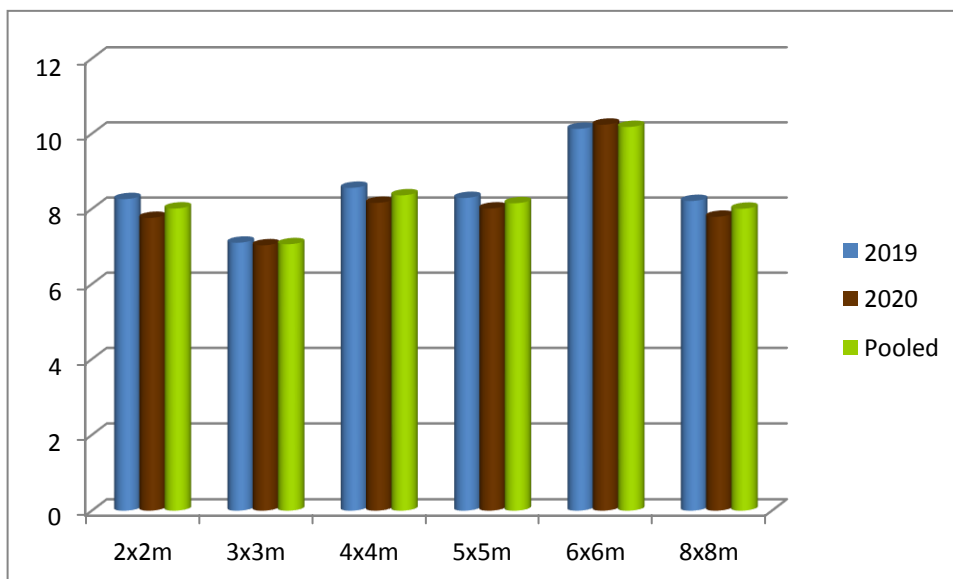


Figure 4.5.6.1 Effect of planting density on fruit yield (t/ha)

Table 4.5.6.2: Effect of training system on fruit yield (t/ha)

Treatments	2019	2020	Pooled
T1	12.88	10.84	11.86
T2	11.67	9.86	10.76
T3	7.47	7.71	7.59
T4	15.87	13.42	14.64
T5	20.33	17.42	18.87
T6	8.21	7.79	8.003
CD at 5%	3.827	3.415	3.552
SE(m)	1.258	1.123	1.168

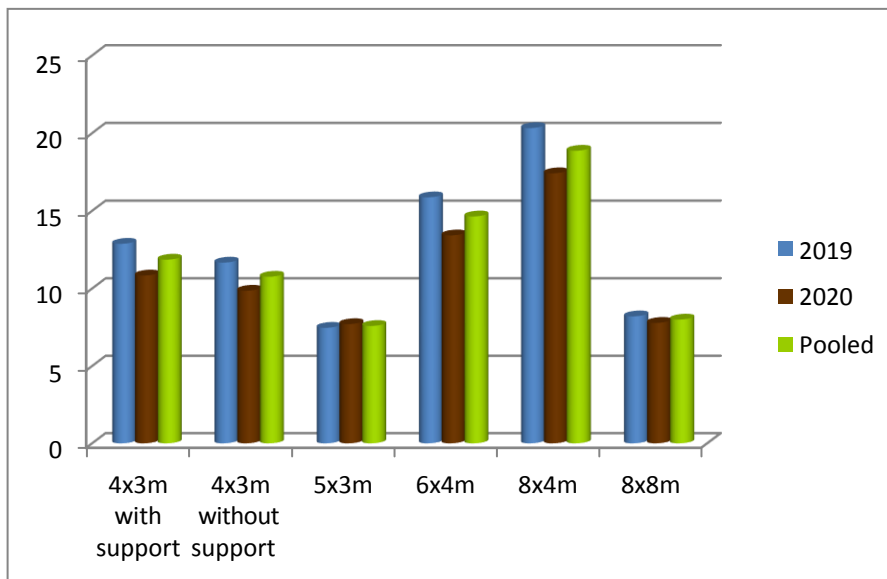


Figure 4.5.6.2 Effect of training system on fruit yield (t/ha)

Fruit Weight (g)

Data on this aspect in table 4.5.7.1 and 4.5.7.2 show that mean fruit weight was significantly more during 2020 as compared to 2019 during the present studies. The perusal of data in table 4.5.7.1 and 4.5.7.2 reveals that mean fruit weight was affected significantly by planting density (square system) and training system (rectangular system) of litchi. Maximum mean fruit weight was recorded in T6 (21.78 g) closely followed by T5 (21.70 g) while minimum mean fruit weight among various treatments recorded in T1 (19.17g) followed by T2 (19.27g) during 2019. Almost same trend was observed in 2020, where maximum mean fruit weight was recorded in T6 (22.31g) followed by T5 (21.88g) and minimum mean fruit weight was recorded in T1 (19.52g) it was closely followed by T2 (19.57g).

In pooled analysis the data revealed that the mean fruit weight among various treatments was varies from 19.34g (T1) to 22.07g (T6). Critical analysis of data revealed that treatments T1 (19.34g), T2 (19.41g) and T3 (19.63g) were at par in between but significantly superior with the treatments T4 (20.45g), T5 (21.79g) and T6 (22.07g) .

Data further reveals that training system in rectangular planting also had a significant effect on mean fruit weight (Table 4.5.7.2). The mean fruit weight among various treatments was varies from 19.99g (T2) to 21.71g (T6). Critical appraisal of data shows that mean fruit weight among various treatments was significantly superior except the treatments T2 (19.99g), T3 (20.06g) and T5 (21.36g) and T6 (21.71g) were statistically at par in 2019. During 2020, the minimum mean fruit weight among treatments was recorded in T2 (20.15g) it was closely followed by T3 (20.38g) and T1 (20.83g) while maximum mean fruit weight was recorded in control (22.38g).

Pooled analysis of mean fruit weight revealed that mean fruit weight varies significantly. Critical analysis of data revealed that treatments T1 (28.57%), T2 (28.21%), T3 (27.02%) was significantly superior but the treatments T1, T2 and T2, T3 were statistically at par.

Table 4.5.7.1: Effect of planting density on fruit weight (g)

Treatments	2019	2020	Pooled
T1	19.17	19.52	19.34
T2	19.27	19.57	19.42
T3	19.51	19.75	19.63
T4	20.18	20.73	20.45
T5	21.70	21.88	21.79
T6	21.77	22.31	22.04
CD at 5%	0.973	0.738	0.549
SE(m)	0.32	0.242	0.181

Table 4.5.7.2: Effect of training system on fruit weight (g)

Treatments	2019	2020	Pooled
T1	20.43	20.83	20.63
T2	19.99	20.15	20.07
T3	20.06	20.38	20.22
T4	21.29	21.90	21.60
T5	21.36	21.89	21.62
T6	21.71	22.31	22.01
CD at 5%	0.817	0.648	0.557
SE(m)	0.269	0.213	0.183

Fruit Length (mm)

Data on this aspect in table 4.5.8.1 and 4.5.8.2 reveal that over the two year of study, planting density and training system had a significant effect on length of litchi fruits. Data shows that mean fruit length was significantly more during 2020 as compared to 2019 during the present studies. Maximum mean fruit length was found in control (34.97 mm) followed by T5 (33.54mm). Minimum mean fruit length among various treatments was found in T1 (32.68mm) it was closely followed by T2 (32.73mm) and T3 (32.77mm) during 2019. Almost same trend was followed by second years of experiment (2020) where maximum mean fruit length was found in control (34.93 mm) followed by T5 (33.79 mm). Minimum mean fruit length among various treatments was found in T1 (32.85 mm) it was closely followed by T2 (32.90 mm) and T3 (32.96 mm).

In pooled analysis of mean fruit length among various treatments varies significantly. Maximum mean fruit length (34.95 mm) was found in wider spacing plant (T6) whereas minimum mean fruit length (323.76 mm, 32.82 mm) was found in close spaced plants (T1 and T2).

Data in table 4.5.8.2 reveal that training system under rectangular planting also affected the mean fruit length significantly. The mean fruit length among various treatments was varies from 32.94 mm (T2) to 34.97 mm (T6). Critical appraisal of data reveals that mean fruit length among various treatments was significantly superior except the differences of treatments T2 (32.94mm) and T3 (32.99mm) were statistically at par in 2019. During 2020, the minimum mean fruit length among treatments was recorded in T3 (33.06mm) it was closely followed by T2 (33.10mm) and T1 (33.1mm) while maximum mean fruit length was recorded in control (34.93mm) it was closely followed by T5 (34.54mm).

In pooled analysis of data revealed that mean fruit length varies significantly. Critical analysis of data revealed that treatments T2 (33.02mm),

T3 (33.03mm), T4 (34.15mm), T5 (34.53mm) and T6 (34.95mm) were statistically at par.

Table 4.5.8.1: Effect of planting density on fruit length (mm)

Treatments	2019	2020	Pooled
T1	32.68	32.85	32.76
T2	32.73	32.90	32.82
T3	32.77	32.96	32.86
T4	32.90	33.28	33.09
T5	33.54	33.79	33.66
T6	34.97	34.93	34.95
CD at 5%	0.905	0.851	0.462
SE(m)	0.298	0.28	0.152

Table 4.5.8.2: Effect of training system on fruit length (mm)

Treatments	2019	2020	Pooled
T1	33.05	33.11	33.08
T2	32.94	33.10	33.02
T3	32.99	33.06	33.03
T4	34.10	34.20	34.15
T5	34.52	34.54	34.53
T6	34.97	34.93	34.95
CD at 5%	0.863	1.229	0.88
SE(m)	0.284	0.404	0.289

Fruit Diameter (mm)

A close observation of the data presented in table 4.5.9.1 and 4.5.9.2 shows that plant planting density and training system had significant effect on fruit diameter in both the years. Data revealed that mean fruit diameter was significantly more during 2020 as compared to 2019 during the present studies. Maximum mean fruit diameter in planting density was recorded in T6 (27.58 mm, 27.99 mm) during 2019 and 2020 respectively. Minimum mean fruit diameter among various treatments was found in T1 (23.35mm) in 2019 and T2 (23.39mm) in 2020.

In pooled analysis of mean fruit diameter among various treatments varies significantly. Maximum mean fruit diameter (27.79 mm) was recorded in T6 whereas, minimum mean fruit diameter (23.41 mm) was found in T2 followed by T1 (23.51 mm).

Data further shows that training system also affected the mean fruit diameter significantly. Maximum mean fruit diameter in various treatments was recorded in T6 (27.58 mm). Minimum mean fruit diameter among various treatments was found in T2 (26.43mm) it was closely followed by T1 (26.57 mm) during 2019. Almost same trend was found in 2020 where maximum mean fruit diameter was found in T6 (27.99 mm) followed by T5 (27.38 mm). Minimum mean fruit diameter among various treatments was found in T2 (26.44 mm) it was closely followed by T1 (26.8 mm).(Table 4.5.9.2)

In pooled analysis of mean fruit diameter among various treatments varies significantly. Maximum mean fruit diameter (27.79 mm) was recorded in T6 whereas, minimum mean fruit diameter (26.44 mm) was found in T2 followed by T1 (26.68 mm).

Table 4.5.9.1: Effect of planting density on fruit diameter (mm)

Treatments	2019	2020	Pooled
T1	23.35	23.66	23.51
T2	23.44	23.39	23.41
T3	23.58	23.87	23.72
T4	23.81	23.96	23.89
T5	24.04	24.41	24.22
T6	27.58	27.99	27.79
CD at 5%	1.043	0.684	0.646
SE(m)	0.343	0.225	0.212

Table 4.5.9.2: Effect of training system on fruit diameter (mm)

Treatments	2019	2020	Pooled
T1	26.57	26.80	26.68
T2	26.43	26.44	26.44
T3	26.89	27.19	27.04
T4	26.98	27.24	27.11
T5	27.17	27.38	27.27
T6	27.58	27.99	27.79
CD at 5%	4.423	3.214	0.44
SE(m)	0.374	0.358	0.323

Quality Traits

Total Soluble Solid (⁰B)

The perusal of data presented in table 4.6.1.1 and 4.6.1.2 clearly indicates that planting density and training system had significant effect on total soluble solids content in both the years. Data revealed that mean total soluble solid was significantly more during 2020 as compared to 2019 during the present studies. Maximum mean total soluble solids in various treatments was recorded in T6 (20.19⁰B) followed by T5 (20.17⁰B). Minimum mean total soluble solids among various treatments was found in T1 (18.15⁰B) followed by T2 (19.15⁰B) and T3 (19.35⁰B) during 2019. Almost same trend was found in 2020 where maximum mean total soluble solids was found in T6 (20.61⁰B) followed by T5 (20.40⁰B). Minimum mean total soluble solids among various treatments was found in T1 (18.2⁰B) it was closely followed by T2 (19.60⁰B) and T3 (19.50⁰B).

In pooled analysis of mean total soluble solids among various treatments varies significantly. Maximum mean total soluble solids (20.40⁰B) were recorded in T6 whereas, a minimum total soluble solid (18.17⁰B) was found in T1 followed by T2 (19.37⁰B).

Data further shows that training system in rectangular planting also affected mean total soluble solids significantly. The mean total soluble solids among various treatments was varies from 19.10⁰B (T2) to 20.19⁰B (T6). Critical appraisal of data shows that mean total soluble solids among various treatments was significantly superior except the treatments T2 (19.10⁰B), T3 (19.41⁰B) and T4 (20.11⁰B), T5 (20.16⁰B) and T6 (20.19⁰B) were statistically at par in 2019. During 2020, the minimum mean total soluble solids among treatments was recorded in T2 (19.21⁰B) it was closely followed by T3 (19.49⁰B) while maximum mean total soluble solids was recorded in control (20.61⁰B) followed by T5 (20.29⁰B).

Pooled analysis of mean total soluble solids revealed that a total soluble solid varies significantly. Critical analysis of data revealed that maximum total

soluble solid was recorded in T6 (20.40⁰B) and minimum total soluble solids recorded in T2 (19.16⁰B).

Table 4.6.1.1: Effect of planting density on total soluble solid (⁰B)

Treatments	2019	2020	Pooled
T1	18.15	18.20	18.17
T2	19.15	19.60	19.37
T3	19.35	19.50	19.42
T4	19.94	20.03	19.98
T5	20.17	20.40	20.29
T6	20.19	20.61	20.40
CD at 5%	1.133	0.703	0.673
SE(m)	0.372	0.231	0.221

Table 4.6.1.2: Effect of training system on total soluble solid (⁰B)

Treatments	2019	2020	Pooled
T1	19.57	19.79	19.68
T2	19.10	19.21	19.16
T3	19.41	19.49	19.45
T4	20.11	20.12	20.12
T5	20.16	20.29	20.22
T6	20.19	20.61	20.40
CD at 5%	0.645	0.587	0.576
SE(m)	0.212	0.193	0.189

Acidity (%)

It is apparent from the data presented in table 4.6.2.1 shows that planting density significantly affected the acidity content of both the years (2019 and 2020). The reverse trend was observed in total acidity content in over the year. Maximum mean acidity content in various treatments was recorded in T1 (0.47%) followed by T2 (0.44%). Minimum mean acidity content among various treatments was found in T6 (0.36%) followed by T5 (0.40%) and T4 (0.41%) during 2019. Almost same trend was found in 2020 where maximum mean acidity content was found in T1 (0.425%) followed by T2 (0.423%). Minimum mean acidity content among various treatments was found in T6 (0.30%) it was closely followed by T5 (0.34%).

In pooled analysis of mean acidity content among various treatments varies significantly. Maximum mean acidity content (0.44%) was recorded in T1 whereas, minimum mean acidity content (0.33%) was found in T6 followed by T5 (0.37%).

Data from table 4.6.2.2 reveals that training system under rectangular planting also affected the mean acidity content significantly. The maximum mean acidity content among treatment recorded in T3 (0.44%) it was followed by T2 (0.41%). The minimum mean acidity content in different training system was recorded in treatment T5 (0.35%) closely followed by T6 (0.36%) and T4 (0.39%) during 2019. Similar trend was found in 2020. Maximum mean acidity content among treatments was recorded in T3 (0.42%). Minimum mean acidity content was recorded in T6 (0.33%) it was closely followed by T5 (0.35%).

In pooled analysis of mean acidity content reveals that acid content among various treatments varies significantly. Maximum mean acidity content (0.43%) was recorded in T3 whereas, minimum mean acidity content (0.35%) was found in T6.

Table 4.6.2.1: Effect of planting density on acidity (%)

Treatments	2019	2020	Pooled
T1	0.47	0.42	0.44
T2	0.44	0.42	0.43
T3	0.42	0.39	0.40
T4	0.41	0.40	0.41
T5	0.40	0.34	0.37
T6	0.36	0.30	0.33
CD at 5%	0.031	0.058	0.046
SE(m)	0.021	0.019	0.015

Table 4.6.2.2: Effect of training system on acidity (%)

Treatments	2019	2020	Pooled
T1	0.36	0.36	0.38
T2	0.41	0.39	0.40
T3	0.44	0.42	0.43
T4	0.39	0.35	0.37
T5	0.35	0.35	0.35
T6	0.36	0.33	0.35
CD at 5%	0.041	0.052	0.038
SE(m)	0.014	0.017	0.013

TSS: Acidity Ratio

The perusal of data presented in table 4.6.3.1 and 4.6.3.2 indicates that planting density and training system significantly affected the TSS: acidity ratio during both the years. Data reveals that TSS: acidity ratio was higher in the year 2020 as compared to 2019. Critical appraisals of data showed that maximum mean TSS: acidity ratio in various treatments was recorded in T6 (62.46) followed by T5 (50.37). Minimum mean TSS: acidity ratio among various treatments was found in T1 (45.38) followed by T3 (45.49) and T2 (45.61) in square system of planting during 2019. Almost same trend was found in 2020 where maximum TSS: acidity ratio was found in control (67.47) followed by T5 (58.34). Minimum TSS: acidity ratio among various treatments was found in T1 (45.54) followed by T2 (46.03).

In pooled analysis of mean TSS: acidity ratio among various treatments varies significantly. Maximum mean TSS: acidity ratio (64.96) were recorded in control whereas, minimum mean TSS: acidity ratio (45.46) was found in T1 followed by T2 (45.82%).

The data further reveal that rectangular system of planting affected the mean TSS: acidity ratio significantly. Critical analysis of data showed that maximum mean TSS: acidity ratio in various treatments was recorded in control (62.46) .Minimum mean TSS: acidity ratio among various treatments was found in T3 (43.65). The difference of T3 was at par with T2 (46.70) and T1 (47.26) in rectangular system of planting during 2019. Similar trend was observed in 2020. Maximum TSS: acidity ratio was found in control (67.47) followed by T5 (57.60). Minimum TSS: acidity ratio among various treatments was found in T3 (46.50) it was at par with T2 (49.73) and T1 (54.73) in between.

Pooled analysis of data reveals that mean TSS: acidity ratio among various treatments varies significantly whereas; treatments T1 (50.99), T2 (48.22) and T3 (19.45) were statistically at par.

Table 4.6.3.1: Effect of planting density on TSS/Acidity

Treatments	2019	2020	Pooled
T1	45.38	45.54	45.46
T2	45.61	46.03	45.82
T3	45.49	50.09	47.79
T4	48.55	50.68	49.61
T5	50.37	68.34	59.35
T6	62.46	67.47	64.96
CD at 5%	0.223	0.465	0.277
SE(m)	0.073	0.153	0.091

Table 4.6.3.2: Effect of training system on TSS/Acidity ratio

Treatments	2019	2020	Pooled
T1	47.26	54.73	50.99
T2	46.70	49.73	48.22
T3	43.65	46.50	45.07
T4	51.47	56.97	54.22
T5	57.40	57.60	57.50
T6	62.46	67.47	64.96
CD at 5%	0.413	0.289	0.273
SE(m)	0.136	0.095	0.09

Total Sugar (%)

Data on this aspect in table 4.6.4.1 and 4.6.4.2 reveals that total sugar content was affected significantly by planting density (square system) and training system (rectangular system) of litchi during the present studies. Total sugar in various treatments was significantly higher during 2020 as compare to 2019. In planting density the total sugar among treatment varies from 13.55% (T1) to 15.07% (T6). Critical analysis of data revealed that treatment T5 (14.86 %) and T6 (15.07 %) was significantly superior with respect to total sugar whereas, treatments T1 (13.55%), T2 (13.57%) and T3 (14.00 %), T4 (14.15%) were statistically at par during 2019. In second year of experiment (2020) same trend was found .Table shows that total sugar among various treatments varies from 13.62 % (T2) to 15.13 % (T6). Data showed that treatment T5 (14.93%) and T6 (15.13 %) was significantly superior with respect to total sugar whereas, treatments T1 (13.77%), T2 (13.62%) and T3 (14.14%), T4 (14.19%) were at par.

In pooled analysis, total sugar among treatment varies from 13.60 (T2) to 15.10% (T6). Pooled analysis of total sugar in litchi revealed that treatments varied significantly except treatments T1 (13.66%), T2 (13.60%) and T3 (14.07%), T4 (14.17%) were at par. An overall appraisal of table 4.6.4.1 shows that total sugar was recorded highest in wider spacing (T6) under square system of planting.

Training system in rectangular planting also had a significant effect on total sugar (Table 4.6.4.2). In training system the total sugar among treatment varies from 13.99% (T2) to 15.07% (T6). Critical appraisal of data revealed that treatment T1(14.06%) was significantly superior with respect to total sugar whereas the differences among treatments T2 (13.99%), T3 (14.00%) T4 (15.0%), T5 (15.06%) and T6 (15.07 %) were statistically at par in 2019. During second year of experiment (2020) same trend was found .Table shows that total sugar among various treatments varies from 14.05 % (T2) to 15.13 % (T6). Data showed that total sugar among various treatments varies significantly

whereas, treatment T1 (14.14%), T2 (14.05%) and T3 (14.09%), T4 (14.07%) and T5 (15.1%) and T6 (15.07 %) were statistically at par.

Pooled analysis of total sugar in litchi revealed that treatments varied significantly except treatments T2 (14.02%), T3 (14.04%) and T4 (15.04%), T5 (15.08%) were at par. An overall appraisal of tables 4.6.4.2 shows that total sugar was recorded highest in T6 (15.10%) under rectangular system of planting.

Table 4.6.4.1: Effect of planting density on total sugar (%)

Treatments	2019	2020	Pooled
T1	13.55	13.77	13.66
T2	13.57	13.62	13.60
T3	14.00	14.14	14.07
T4	14.15	14.19	14.17
T5	14.86	14.93	14.89
T6	15.07	15.13	15.10
CD at 5%	0.34	0.271	0.265
SE(m)	0.112	0.089	0.087

Table 4.6.4.2: Effect of training system on Total sugar (%)

Treatments	2019	2020	Pooled
T1	14.06	14.14	14.10
T2	13.99	14.05	14.02
T3	14.00	14.09	14.04
T4	15.00	15.07	15.04
T5	15.06	15.10	15.08
T6	15.07	15.13	15.10
CD at 5%	0.206	0.371	0.16
SE(m)	0.068	0.122	0.054

Organoleptic score

The perusal of data presented in table 4.6.5.1 and 4.6.5.2 clearly indicates that planting density and training system had significant effect on organoleptic score in both the years. Maximum mean organoleptic score in various treatments was recorded in T₆ (8.35) followed by T₅ (7.87). Minimum mean organoleptic score among various treatments was found in T₂ (6.45) followed by T₁ (6.50) during 2019. Almost same trend was found in 2020 where maximum mean organoleptic score was found in T₆ (8.56) followed by T₅ (8.25) whereas, minimum mean organoleptic score among various treatments was found in T₂ (6.57) it was closely followed by T₁ (6.84).

In pooled analysis of mean organoleptic score among various treatments varies significantly. Maximum mean organoleptic score (8.45) were recorded in T₆ whereas, a minimum organoleptic score (6.51) was found in T₂ under different planting density.

Data in table 4.6.5.2 further shows that training system in rectangular planting also affected mean organoleptic score significantly. The mean organoleptic score among various treatments was varies from 7.15 (T₂) to 8.35 (T₆). Critical appraisal of data shows that mean organoleptic score among various treatments was significantly superior in 2019. During 2020, the minimum mean organoleptic score among treatments was recorded in T₂ (6.57) it was closely followed by T₁ (6.84) while maximum mean organoleptic score was recorded in control (8.56).

Pooled analysis of mean organoleptic score revealed that a organoleptic score varies significantly. Critical analysis of data revealed that maximum organoleptic score was recorded in T₆ (8.45) and minimum organoleptic score recorded in T₂ (6.51).

Table 4.6.5.1: Effect of planting density on organoleptic score

Treatment	2019	2020	Pooled
	Mean	Mean	Mean
1	6.50	6.84	6.67
2	6.45	6.57	6.51
3	6.86	7.14	7.00
4	7.05	7.72	7.39
5	7.87	8.25	8.06
6	8.35	8.56	8.45
C.D.at 5%	0.344	0.485	0.174
SE(m)	0.113	0.16	0.054

Table 4.6.5.2: Effect of training system on organoleptic score

Treatments	2019	2020	Pooled
T1	7.22	7.23	7.23
T2	7.15	7.19	7.17
T3	7.27	7.28	7.28
T4	8.11	8.25	8.18
T5	8.28	8.38	8.33
T6	8.35	8.56	8.45
CD at 5%	0.333	0.301	0.219
SE (m)	0.109	0.099	0.072

Soil Parameters

Soil Temperature ($^{\circ}\text{C}$)

A close examination of data presented in table 4.7.1.1 found no statistical difference in mean soil temperature with respect to planting densities in litchi orchard during both the years but the soil temperature tended to have highest at wider spacing (T6) and minimum soil temperature was recorded in close spaced plants (T1). The mean soil temperature among treatments varies from 14.47°C (T1) to 15.77°C (T6). Critical analysis of data revealed that treatments T1 (14.47°C), T2 (14.55°C), T3 (14.5°C) and T4 (14.85°C), T5 (14.9°C) which were at par during 2019. Almost similar trend was found in 2020 where mean soil temperature among treatments varies from 14.45°C (T1) to 15.7°C (T6). Mean soil temperature among treatments T1 (14.45°C), T2 (14.77°C), T3 (14.63°C) and T4 (15.05°C), T5 (15.25°C) which were at par.

Pooled analysis of mean soil temperature in litchi reveals that mean soil temperature varies significantly. Maximum mean soil temperature among treatments was recorded in T6 (15.7°C) whereas, minimum soil temperature recorded in T1 (14.4°C). It is clear from data that maximum mean soil temperature among treatments recorded in wider spacing (T6).

With respect to different training system in rectangular planting, increment in mean soil temperature during over the years. Mean soil temperature in various treatments reveals that mean soil temperature among treatments varies significantly. From table 4.7.1.2 the maximum mean soil temperature was recorded in T6 (15.77°C) closely followed by T5 (15.70°C). Minimum mean soil temperature among various treatments was recorded in T2 (15.27°C) while treatments T4 (15.57°C) and T5 (15.70°C) were at par during 2019. Similar trend was observed in second year of experiment. The Maximum mean soil temperature was recorded in T6 (15.70°C). Minimum mean soil temperature among various treatments was recorded in T2 (15.36°C) whereas, the difference among treatments T4 (15.42°C) and T5 (15.47°C) were statistically at par.

Pooled analysis of data shows that mean soil temperature in rectangular system of litchi varies significantly. Maximum mean soil temperature among treatments was recorded in T6 (15.73⁰C) whereas, minimum soil temperature recorded in T2 (15.31⁰C). Differences among treatments T3 (15.57⁰C), T4 (15.50⁰C) and T5 (15.58⁰C) were at par.

Table 4.7.1.1: Effect of planting density on soil temperature (⁰C)

Treatments	2019	2020	Pooled
T1	14.47	14.45	14.46
T2	14.55	14.77	14.66
T3	14.50	14.63	14.56
T4	14.85	15.05	14.95
T5	14.92	15.25	15.09
T6	15.77	15.70	15.73
CD at 5%	0.288	0.346	0.226
SE(m)	0.095	0.114	0.074

Table 4.7.1.2: Effect of training system on soil temperature (⁰C)

Treatments	2019	2020	Pooled
T1	15.42	15.43	15.42
T2	15.27	15.36	15.31
T3	15.45	15.70	15.57
T4	15.57	15.42	15.50
T5	15.70	15.47	15.58
T6	15.77	15.70	15.73
CD at 5%	0.323	0.263	0.231
SE(m)	0.106	0.141	0.076

Soil Moisture (%)

The effect of different planting density on soil moisture is presented in table 4.7.2.1. The data shows that soil moisture was slightly affected by planting density during the present studies. It is evident from the data given in table

that soil moisture were found to be slightly higher in 2020 as compared to 2019. The maximum mean soil moisture among various treatments was recorded in T1 (7.32%) it was closely followed by T2 (7.02%). Minimum soil moisture among various treatments was recorded in T6 (4%) followed by T5 (4.7%) during first year of experiment (2019). Similar trend was found in 2020 where, the maximum mean soil moisture among various treatments was recorded in T1 (7.39%) it was closely followed by T2 (7.19%). Minimum soil moisture among various treatments was recorded in T6 (4.2%).

Pooled analysis of mean soil moisture in litchi reveals that mean soil moisture varies significantly. Maximum mean soil temperature among treatments was recorded in T1 (7.36%) closely followed by T2 (7.10%) whereas, minimum soil moisture recorded in T6 (4.14%).

With respect to different training system in rectangular planting mean soil moisture in various varies significantly. Maximum mean soil moisture was recorded in T1 (6.7%) closely followed by T2 (6.6%). Minimum mean soil moisture among various treatments was recorded in T5 (3.9%) during 2019. Similar trend was observed in second year of experiment. The Maximum mean soil moisture was recorded in T1 (6.69%) followed by T2 (6.64%). Minimum mean soil moisture among various treatments was recorded in T5 (4.13%). (Table 4.7.2.2)

Pooled analysis of data shows that mean soil moisture in rectangular system of litchi varies significantly. Maximum mean soil moisture among treatments was recorded in T1 (6.69%) whereas, minimum mean soil moisture recorded in T5 (4.02%).

Table 4.7.2.1: Effect of planting density on soil moisture (%)

Treatments	2019	2020	Pooled
T1	7.32	7.39	7.36
T2	7.02	7.19	7.10
T3	6.57	6.68	6.62
T4	4.87	5.35	5.11
T5	4.70	5.15	4.92
T6	4.00	4.28	4.14
CD at 5%	0.878	0.382	0.558
SE(m)	0.289	0.126	0.184

Table 4.7.2.2: Effect of training system on soil moisture (%)

Treatments	2019	2020	Pooled
T1	6.70	6.69	6.69
T2	6.60	6.64	6.62
T3	5.35	5.53	5.44
T4	4.50	4.83	4.66
T5	3.92	4.13	4.02
T6	4.00	4.28	4.14
CD at 5%	1.261	0.288	0.614
SE(m)	0.415	0.095	0.202

Water Retention (%)

The data on mean water retention of soil in litchi influenced by planting density are presented in table 4.7.3.1. It is clearly indicate that planting density had significant effect on water retention during both the years (2019 and 2020). The water retention among various treatments was varies from 24.41% (T6) to 28.48% (T1). Critical analysis of data revealed that treatments T1 (28.48%), T2 (28.1%), T3 (27.88%) was significantly superior but the treatments T1, T4 and T5, T6 were at par in 2019. During 2020, the maximum water retention among treatments was recorded in T1 (28.67%) closely followed by T2 (28.33%) while minimum water retention was recorded in control (24.71%).

Pooled analysis of mean water retention revealed that mean water retention varies significantly. Critical analysis of data revealed that treatments T1 (28.57%), T2 (28.21%), T3 (27.02%) was significantly superior but the treatments T1, T4 and T5, T6 were statistically at par.

Training system also had a significant effect on mean water retention (Table 4.7.3.2). The water retention among various treatments was varies from 24.41% (T6) to 26.87% (T2). Critical analysis of data revealed that treatments T3 (27.48%), T4 (26.40%) was significantly superior but the treatments T1 (26.85%), T2 (26.87%) and T5 (25.69%) and T6 (24.41%) were at par in 2019. During 2020, the maximum water retention among treatments was recorded in T2 (27.00%) closely followed by T1 (26.93%) while minimum water retention was recorded in control (24.71%). The differences among treatments T1, T2 and T3 were at par.

Pooled analysis of data reveals that mean water retention varies significantly. Critical analysis of data revealed that maximum mean water retention was recorded in treatments T2 (26.94%) closely followed by T1 (26.89%). Minimum mean soil moisture retention was recorded in T6 (24.56%). The differences among the treatments T1, T2 and T5, T6 were statistically at par.

Table 4.7.3.1: Effect of planting density on water holding capacity (%)

Treatments	2019	2020	Pooled
T1	28.48	28.66	28.57
T2	28.10	28.33	28.21
T3	27.88	28.16	28.02
T4	27.46	27.76	27.61
T5	26.90	27.20	27.05
T6	24.41	24.71	24.56
CD at 5%	0.713	0.68	0.692
SE (m)	0.235	0.224	0.227

Table 4.7.3.2: Effect of training system on water holding capacity (%)

Treatments	2019	2020	Pooled
T1	26.85	26.93	26.89
T2	26.87	27.00	26.94
T3	26.48	26.42	26.45
T4	26.40	26.27	26.33
T5	25.69	25.75	25.72
T6	24.41	24.71	24.56
CD at 5%	1.12	1.171	1.134
SE(m)	0.368	0.385	0.373

Bulk Density (g/ml)

The perusal of data in table 4.7.4.1 reveals that bulk density of soil was affected significantly by planting density during the present studies. Maximum mean bulk density (1.097) among various treatments was recorded in control (T6) followed by T5 (1.085) while minimum bulk density was recorded in T1 (1.033) followed by T2 (1.048) during 2019. Almost similar trend was found in 2020 where maximum mean bulk density (1.099) among various treatments was recorded in control (T6) followed by T5 (1.095) while minimum bulk density was recorded in T1 (1.018) followed by T2 (1.059).

Pooled analysis of mean bulk density of soil in litchi revealed that mean bulk density of soil varies significantly. Maximum mean bulk density among treatments was recorded in T6 (1.098) whereas, minimum bulk density was recorded in T1 (1.025). It is clear from data that maximum mean bulk density among treatments recorded in wider spacing (T6).

Training system had also affected the mean soil bulk density significantly. The soil bulk density at lower planting densities was higher and in higher planting density spacing it was significantly lower (Table 4.7.4.2). Maximum mean bulk density (1.097) among various training systems was recorded in control (T6) followed by T5 (1.062) while minimum bulk density was recorded in T2 (1.04) closely followed by T1 (1.042) during 2019. Similar trend was found in 2020. Maximum mean bulk density (1.099) among various treatments was recorded in control (T6). Minimum bulk density was recorded in T2 (1.035).

In pooled analysis of data shows that mean bulk density of soil in rectangular system in litchi revealed that mean bulk density of soil varies significantly. Maximum mean bulk density among treatments was recorded in T6 (1.098) whereas, minimum bulk density was recorded in T2 (1.037).

Table 4.7.4.1: Effect of planting density on bulk density (g/cm³)

Treatments	2019	2020	Pooled
T1	1.033	1.018	1.025
T2	1.048	1.059	1.053
T3	1.05	1.057	1.053
T4	1.075	1.087	1.081
T5	1.085	1.095	1.09
T6	1.097	1.099	1.098
CD at 5%	0.054	0.121	0.031
SE(m)	0.02	0.022	0.02

Table 4.7.4.2: Effect of training system on bulk density (g/cm³)

Treatments	2019	2020	Pooled
T1	1.042	1.045	1.043
T2	1.04	1.035	1.037
T3	1.053	1.055	1.054
T4	1.059	1.056	1.058
T5	1.062	1.059	1.061
T6	1.097	1.099	1.098
CD at 5%	0.018	0.019	0.018
SE(m)	0.006	0.006	0.006

DISCUSSION

Effects of different planting densities and training systems on litchi.

The results of the field experiment entitled “**Effect of different planting densities and training system on litchi cv. Shahi under square and rectangular system of planting**” showed significant variation in morphological, physiological parameters, light interception, flowering attributes, fruits quality, yield and soil parameters. Efforts have been made to discuss the significant findings of the experimental results in this chapter.

: MORPHOLOGICAL PARAMETERS

Plant Height (m)

A significant variation in plant height among the different plant spacing under square system was observed ranging from 2.68 m to 4.25 m in table

Maximum plant height was recorded in planting spacing of 8x8 m (4.25 m) and lowest in the spacing of 2x2 m (2.13 m). During the present study the highest percentage of increase in plant height was recorded in T₃ (14.81%) and lowest in T₆ (1.90 %). Similarly the plant height differed significantly among different training system under rectangular system of planting. The maximum height was found at the spacing of 8x8 m (4.25 m) while lowest in 4x3 m with trellis (2.68 m). The highest increase in plant height during the study period was recorded in T₁ (30.47%) and lowest in T₅ (1.4%) in table 4.1.1.2

The data on plant height among square system and rectangular system showed that the plant height increases with wider spacing .This may be due to vigorous plant growth, less competition for space and nutrients and sufficient availability of space and light (Bhagyashree M, 2018). Similar results were reported by Bal and Dhaliwal (2003) who recorded the higher plant height in 6 m x 6 m spacing than 6 m x 5m and 6 m x 4 m spacing in guava cv. Sardar. Further, Nautiyal (2016) reported that plant height increases in low density plants in guava. Ferree (1987) reported that pyramid hedge row trees planted at 425 trees/ha had maximum height than trellis system trees planted at much

higher densities in apple cv. Golden Delicious. Similar results were also obtained by Mullins and Deyton (1983) in which closer spacing tended to result in smaller trees of apple. Singh *et al.* (2007) pointed out that maximum plant height in closely spaced guava trees (1.5 × 3.0 m). Similar results were found by Mekjell (2005), trees were smallest at the highest density (5000 trees per ha). The present result is also supported by the finding of Dalal *et al.* (2013) in kinnow mandarin that maximum plant height were higher in low density plant.

Stem Girth (cm):

The variation in stem girth among various planting densities under square system ranged from 25.89 cm in treatment T₁ to 79.17 cm in T₆ (8x8 m). The highest increases in stem girth were recorded at the spacing 2x2 m (23.30%) and lowest at 6x6 m (11.23%) in table 4.1.2.1. Similarly the variation in stem girth in different training system differed significantly which ranged from 33.11 cm in treatment T₂ (4x3 m without trellis) to 79.17 cm in treatment T₆ (8x8 m). The highest increases in stem girth were recorded at the spacing 3x3 m (24.81%) and lowest at 6x6 m (9.77%) in table 4.1.2.2.

The data of stem girth under square and rectangular system of planting showed that stem girth among planting densities and training system increased with increasing spacing. It may be due to competition among roots for water, light and nutrients in the closely planted trees. Enhanced stem girth at wider spacing is also justified by greater availability of photosynthates in reserve tissues (Bhagyashree M., 2018). The decrease in tree girth at close spaced plants may be due to availability of lesser amount of photosynthates required by the reserve tissue (Sharma., 2016). This was evident from the lesser chlorophyll in the leaves at 2m x 2m spacing in square system and 4x3 m in rectangular system of planting. Similar results were also found by Mika *et al* (2001) in plum. The results of the present studies are in line with earlier works reported by Ogata *et al* (1989) in apple; Rana and Daulta (1997) and Caruso *et al* (1999) in peach). Singh *et al.* (2007) reported that maximum trunk circumference in closely spaced guava trees (1.5 × 3.0 m).The results are in tune with the

findings of Sidhu *et al.* (1992), Singh and Bal (2002), Bal and Dhaliwal (2003) and Singh *et al.*, (2007). These findings are similar with finding reported by Pramanick *et al* (2012) in which maximum trunk diameter (cm) was recorded in the least dense apple planting and minimum trunk diameter in most dense planting (625 and 444 plants/ha respectively).

Plant Spread in East- West Direction (m):

The plant spread varied significantly among the different planting densities under square system and was noted the maximum value in T₆ (6.08 m) and the minimum in T₁ (1.86 m). The highest increase in plant spread (East-West) were recorded in the treatment T₁ (25.45%) whereas it was lowest in T₄ (5.19%) in table 4.1.3.1. The variation in plant spread among different training system under rectangular planting ranged from 3.40 m (T₂) to 6.08 m (T₆). The highest increase in plant spread were recorded in T₁ (13.15%) and lowest in treatment T₄ (0.2%) in table 4.1.3.2.

The result concluded that under both planting system (square and rectangular system) plant spread in East- West direction increases with increasing plant spacing. Higher canopy spread in wider spacing is attributed to availability of sufficient space and light for canopy spread. The results are in line with the finding of Mitra and Bose (1990) and Singh *et al.*(2007) indicating that increased planting density reduced the interplant spread. This was due to greater availability of nutrients which in turn increased vegetative growth. These findings were confirmed by Dhomane *et al.* (2011) and Reddy *et al.* (2000) in pomegranate and Sureshkumar *et al.* (2011) in custard apple. Mitra *et al.* (2008) also found that plant spread higher in wider spaced plants.

Plant Spread North- South Direction (m):

During the study a significant variation in plant spread in North-South direction was observed among different planting density under square systems. The variation in spread ranged from 2.14 m in treatment T₁ to 7.09 m in T₆. The highest increase in plant spread in North-South direction were recorded in treatment T₂ (9.08%) and it was lowest in T₃ (3.22%) in table 4.1.4.1. Likewise

plant spread (North-South) differed significantly among different training system under rectangular system of planting which ranged from 3.53 m in treatment T₂ (4X3m without support) to 7.08 m (control). The highest increases in spread were recorded in treatment T₄ at the spacing 6x4 m (23.99%) and lowest in T₅ at the spacing 8x4 m (4.56%). The table 4.1.4.2. of plant spread in North- South direction showed that it increases with increasing planting spacing among different planting densities and training system.

Plant spread (N-S) was higher in wider spaced plants due to greater availability of nutrients, higher light interception and less competition for nutrients which in turn increased vegetative growth. These findings are in consonance with the results reported by Dhomane *et al.* (2011), Reddy *et al.* (2000) in pomegranate , Sureshkumar *et al.* (2011) in custard apple and Dalal *et al.* (2012) in kinnow mandarin. Singh *et al.* (2007 b) also pointed out that minimum canopy spread (NS/EW) is found in closely spaced guava trees (1.5 × 3.0 m). The reduction in spread may be due to enhanced competition for substrate at closer spacings. Caruso *et al* (1999) also reported that decline in tree spread with increase in planting density may be due to excess crowding of trees and mutual competition at higher densities. Pfammatter and Evequoz (1983) observed that vegetative growth was more vigorous at wider spacings in apple cv. Golden Delicious. Similar results were also recorded by Dyankov (1998) in peach.

Canopy Diameter (m):

The variation in canopy diameter among various planting densities under square system ranged from 2.83 m² in T₂ (3x3m) to 6.49 m² in T₆ (8x8m). The highest increases in canopy diameter were recorded at 3x3 m (17.92%) and lowest in 6x6m (6.59%). Variation in canopy diameter in different training system differed significantly which ranged from 3.36 m² in treatment T₂ to 6.49 m² in treatment T₆ . The highest increases in canopy diameter were recorded at the spacing 4x3 m without support (24.79%) and lowest in 8x4 m (5.02%).

The data of canopy diameter under square and rectangular system of planting (table 4.1.5.1 and 4.1.5.2) revealed higher vegetative growth in terms of canopy diameter at wider spacing (Pfammatter and Evequoz 1983) except at 2 x 2 m in which higher canopy diameter was recorded than at 3x3 m which they inferred may be due to orientation of plants under square system of planting. The reduction in canopy diameter at closely spaced plants may be due to enhanced competition for substrate. Excess crowding of trees and mutual competition at higher plant densities. Kiprijanovski *et al* (2009) found that Jonagold apple was planted at five different planting distances viz., 4m x 1m, 4m x 1.5m, 4m x 2m, 4m x 2.5m and 4m x 3 m and observed that distance between the trees in the row had a significant influence on their vegetative growth, bearing and quality of the fruits. They found highest canopy size (canopy diameter) under 4m x 3m spacing.

Canopy Area (m²):

Variability was also noticed in canopy area among different spacing in square system of planting which ranged from 5.51 m² in 2x2 m (T₁) to 32.43 m² in 8x8 m (control). The highest increment in canopy area was observed in treatment T₂ (16.63%) while the lowest in T₅ (1.29%).

Canopy area among rectangular system of planting differed significantly which varied from 8.12 m² in treatment T₂ to 32.43 m² in T₆. The highest increases in canopy area was noticed in treatment T₂ at the spacing 4x3 m without support (30.86%) and lowest in T₆ at the spacing of 8x8 m (4.34%) in litchi.

Perusal of data presented in table 4.1.6.1 and 4.1.6.2 shows that canopy area among different planting densities and training system increases with increasing spacing. The least canopy area observed under 2x2 m spacing might be due to the availability of less space and competition between plants for light, water, and nutrition under closer spacing resulting in less increase in basal girth and crown spread. These results are in agreement with the findings of Pandey *et al.* (1997), Prakash *et al.* (2012) and Pratibha *et al.* (2013). The

decreasing trend observed in the canopy area with the increasing plant population might be due to the increase competition among trees for growth and development. Plant in wider spacing had enough space for lateral growth and hence balanced growth (Chundawat *et al.*, 1992 and Nawaz *et al.*, 2007).

Leaf Area (cm²):

During the study, significant variation was observed in leaf area ranged from 36.12 cm² in treatment T₁ (2x2m) to 37.26 cm² in T₆ (8x8 m) among various spacing under square system of planting.

Data presented in table **4.1.7.1** and **4.1.7.2** showed that leaf area among different training system significantly differed. The maximum leaf area was found in T₆ at the spacing of 8x8 m whereas, lowest in T₁ at 4x3 m with support.

The result showed that leaf area was least affected by spacing and training system in square and rectangular system of planting but it was slightly decreasing with increasing plant density (**Kumawat *et al.*, 2014**). These findings are in consonance with finding reported by **Pramanick *et al* (2012)** in which maximum leaf area (cm²) was recorded in the least dense apple planting and minimum leaf area in most dense planting at 444 and 625 plants/ha respectively. These results are in accordance with those reported by **Caruso *et al* (1999)** who also observed that leaf area was not affected by training system in peach. **Palmer (1989) and Palmer *et al* (1992)** observed that higher tree density leads to increased light interception through a greater leaf area and more even distribution of light. Similar results were reported by **Sharma (2016)** that trees planted at 5m x 3m recorded higher mean leaf area of (38.80 cm²) than the 5m x 2m planted trees (38.70 cm²). The competition between plants for light, water and nutrition under closer spacing resulted to less increase in leaf area (Johnson and Robinson, 2000; Policarpo *et al.*, 2006).

Total number of flushes per branches:

The data regarding the total flushes per branch presented in table **4.1.8.1** was found statistically significant among different spacing under square system

of planting. Number of flushes per branch ranged from 4.19 in T₁ (2x2 m) to 14.49 in T₆ (control) in square system of planting. While in different training system the number of flushes per branch ranged from 6.08 in treatment T₂ to 14.49 in T₆ (8x8m) in table 4.1.8.2.

Result indicated that maximum flushes emergence were recorded at the wider spacing among both square and rectangular system of planting. A possible reason for minimum flushes under high density planting may be due the competition among plants for water and soil nutrients (Policarpo *et al.*, 2006), and competition for light (Johnson and Robinson, 2000; Policarpo *et al.*, 2006), owing to overlapping canopies which reduce light incidence on leaves. Consequently a greater part of the canopy contributes little or nothing to the synthesis of carbohydrates necessary for growth. Thus, the competition between plants for light, water and nutrition under closer spacing resulted in less increment in growth of shoot. These finding was similar with Kumawat *et al.*, (2014) in which mean maximum gain of shoot growth were recorded under T₁ (2.0 × 2.0 m) and minimum was recorded under T₅ (1 × 1.5 m. Results similar to present findings are reported earlier by Gaikwad *et al.* (1981), Mitra *et al.* (1984), Kundu *et al.* (1993) in guava, Kumar *et al.* (2010) in apricot and Dalal *et al.* (2012) in kinnow. Nawaz *et al.*, (2007) also observed that maximum numbers of flushes were found in D 3 or 22x22 ft (12.80) followed by D 1 or 11x11ft (12.03) whereas, minimum number of new flushes was found in D 2 22x11 ft (9.25) in mandarin.

Flush Length (cm):

Significantly variation in flush length among different planting density was observed under square system of planting ranging from 24.34 cm in T₁ to 45.20 cm in T₆. The highest increase in flush length was recorded in treatment T₁ at the spacing 2x2m (9.24%) and lowest in T₅ at 6x6m (4.14%). A similar trend was observed among different training system of planting varied significantly which ranged from 30.16 cm to 45.20 cm. The maximum flush length was recorded in T₆ (45.20 cm) and lowest in T₁ (30.16 cm). The highest increase in

flush length were recorded in treatment T₅ at the spacing 8x4m with hedge row system (5.95%) and lowest in T₁ at the spacing 4x3m with trellis(3.13%) in table **5.1.9.1 and 5.1.9.2.**

In close spaced plants there is enhanced competition for substrate and less interception of light within canopy which might affect shoot growth. Similar results were found by **Mika et al. (1981)** in apple. Minimum shoot length recorded in high density planting might apparently be due to restriction of canopy growth. These findings were also reported by **Pramanick et al. (2012)** who reported maximum shoot length (cm) was recorded in the least dense apple planting and minimum shoot length in most dense planting. Further **Sharma (2016)** pointed out that training systems and spacing had a significant effect on shoot length of peach tree during both the years. Maximum mean shoot length was recorded in Hedge row system (47.03 cm) closely followed by Y shaped tree (44.73 cm). Data further shows that spacing also affected shoot length significantly. Trees planted at 5m x 3m recorded (45.53 cm) significantly higher shoot length than 5m x 2m planted trees (43.13 cm). Maximum shoot length was recorded in Hedge row trees (52.81cm) and it was significantly higher than all the training systems. This might be due to comparatively increased radiation penetration in different parts of the canopy than the other systems. On the contrary Jackson and **Palmer (1977)** obtained in apple.

Flush Diameter (mm):

Data pertaining to diameter of flush in different planting densities under square system of planting in litchi presented in table **4.1.10.1**. The maximum flush diameter among different density were recorded in control (7.84 mm) and lowest diameter recorded in treatment T₂ (4.60 mm). Similarly flush diameter among different training system of planting varied significantly which ranged from 4.60 mm to 7.67 mm. The maximum flush diameter was recorded in T₆ (7.84 mm) and lowest in T₂ (5.06 mm) in table 4.1.10.2.

Result showed that diameter of flush was higher in wider spaced plants compared to closely spaced plants. These results are in agreement with the

findings of Johnson and Robinson (2000), Policarpo *et al.* (2006) who reported that under higher planting density plant canopies overlap into the rows, reducing light incidence on leaves. As a result there is inadequate synthesis of carbohydrates by leaf necessary for growth. This might have affected the diameter of flush or newly emerging shoots.

Light Interception (%)

Light Interception below canopy (%):

Data in table 4.2.1.1 regarding light interception show 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 (2x2m) under different planting densities in square system of planting. Among different training systems the maximum mean light interception below canopy (75.18%) was recorded in treatment T₆ (8x8m) and it was lowest (48.90%) in treatment T₂ which was *at par* with T₃ (53.06%) in table 4.2.1.2

From the present investigation, it was clear that light interception % within the canopy (below part of canopy) was higher in wider spaced plants. It may be due to larger tree volume and more spreading branches in the wider spaced trees. Further **Ajitpal Singh** (2003) also pointed out that the trees planted at 6x6 m spacing captured significantly more radiation than the trees spaced at 6x5m and 6x4m on per unit tree basis. The findings are in agreement with that of **Singh (2001)** in Peach cv. Shan- i- Punjab. **Loreti *et al.* (1980)** observed that sunlight interception by nectarine trees was similar at all planting distances but in peach it was the least in most dense planting owing to poor growth in the lower parts of the canopy. The results obtained in the present study are in line with that of **Heinicke (1963)** and **Loony (1968)** who also found rapid decrease in light intensity with increasing depth of plant canopy. **Jackson (1970)** also revealed the similar findings in Apple. However, in Apple it was found that higher tree density leads to increased light interception through greater leaf area and more even distribution of light (**Palmer *et al.*, 1992**). The present findings are in accordance with **Singh *et al.* (2005)** and **Singh and**

Dhaliwal (2007) who also found that, radiation interception by the guava tree increased with increasing planting distance. Similar results found by **Singh and Singh (2007)**.

Light Interception in the upper canopy (%):

Data presented in table 4.2.2.1 shows that the light interception by the upper part of canopy was found higher in treatment T₆ (93.31%) whereas, lowest light interception was recorded in T₁ (83.07%) in different planting densities under square system. Data in table 4.2.2.2 also shows that plants at the spacing of 8x8 m among different training systems capture significantly more light interception in the upper canopy (93.31%) while at the spacing of 5x3 m, they capture less light (83.52%) which was *at par* with 6x4 m (85.18%).

Results indicated that interception of light was the maximum in traditional system (8x8 m) or in wider spaced plants but upper part of canopy intercepted more percent radiation than below canopy. **Ajitpal (2003)** also reported that the trees planted at 6x6 m maximized radiation interceptions than the trees spaced at 6x5m and 6x4m in both the seasons. The upper part of the tree canopy intercepted maximum radiation relative to the middle and lower canopy parts. Similar results were obtained by **Heinicke (1963)**, **Loony (1968)**, **Jackson (1970)** **Singh et al (2005)** and **Singh and Dhaliwal (2007)** who also found rapid decrease in light intensity with increasing depth of plant canopy. Higher tree density leads to increased light interception through greater leaf area and more even distribution of light (**Palmer et al, 1992** and **Singh and Singh, 2007**).

5.3.) Physiological parameters:

5.3.1.) Net Photosynthetic Rate ($\mu\text{mol m}^{-2} \text{s}^{-1}$):

5.3.2.) Stomatal Conductance ($\text{mol m}^{-2} \text{s}^{-1}$):

Planting densities and training systems had significant influence on gas exchange characteristics of litchi leaves. In both the systems highest photosynthetic rate and stomatal conductance were observed in treatment T₆

(8.42 $\mu\text{mol m}^{-2} \text{s}^{-1}$, 61.12 $\text{mol m}^{-2} \text{s}^{-1}$ respectively) and least in T_1 (1.77 $\mu\text{mol m}^{-2} \text{s}^{-1}$, 14.62 $\text{mol m}^{-2} \text{s}^{-1}$) in square system of planting. Whereas in different training systems the maximum mean photosynthetic rate and stomatal conductance were observed in control (8.42 $\mu\text{mol m}^{-2} \text{s}^{-1}$, 61.12 $\text{mol m}^{-2} \text{s}^{-1}$ respectively) and least in treatment T_2 (4.69 $\mu\text{mol m}^{-2} \text{s}^{-1}$, 20.5 $\text{mol m}^{-2} \text{s}^{-1}$ respectively). Results of present investigation indicated that photosynthetic rate and stomatal conductance value (Pn and gs) were higher in low density plants and minimum Pn and gs rate were recorded in high density plants. Increased values for leaf gas exchange (photosynthetic rate and stomatal conductance) are likely to be linked to an increased light incidence reaching the leaves, as reported in other plant species (Givnish, 1986; Mendes *et al.*, 2001; Reynolds and Heuvel, 2009). Similarly Dong *et al.* (2017) reported that the values of photosynthetic rate were smaller under the high planting density. They found a low photosynthetic level at high densities, with nevertheless a relatively high C_i , suggesting that the stomatal conductance was not the main limitation on photosynthesis (Tuzet *et al.* 2003). Relative to the stomatal conductance, the mesophyll conductance was more sensitive to changes in the surroundings, such as shading (Niinemets *et al.* 2006; Warren *et al.* 2007; Flexas *et al.* 2007, 2008) and drought (Duan *et al.* 2009). Leaves of trees in a higher planting density usually suffer from lower light irradiance from the shading of among branches (Warren *et al.* 2001). In this study, the lower gm in the high planting density was consistent with that found in previous studies (Piel *et al.* 2002; Niinemets *et al.* 2006; Flexas *et al.* 2007; Warren *et al.* 2007). At the global scale, the photosynthetic capacity and nutrients in leaves are the core physiological traits (Wright *et al.* 2004). N and P are generally considered the nutrients that most strongly affect photosynthesis in leaves (Boyce *et al.* 2006). Numerous studies have reported that photosynthesis is determined by the N and P concentrations or the N/P ratio in leaves (Loustau *et al.* 1999; Utriainen and Holopainen 2001; Boyce *et al.* 2006; Cernusak *et al.* 2010; Garrish *et al.* 2010).

Transpiration Rate ($\text{mmol m}^{-2} \text{s}^{-1}$):

The rate of transpiration was highest ($2.38 \text{ mmol H}_2\text{O/m}^2/\text{s}$) at the spacing of $8 \times 8 \text{ m}$ (control) among different planting densities and training systems. The minimum rate of transpiration was noticed in treatment T_1 ($0.24 \text{ mmol H}_2\text{O/m}^2/\text{s}$) among different densities while the minimum rate of transpiration rate was recorded in T_1 ($0.65 \text{ mmol H}_2\text{O/m}^2/\text{s}$) under different training systems.

Result indicated that transpiration rate was highest in widely spaced tree. This might be attributed to maximum leaf area and lower water content, which resulted into maximum transpiration of plant. Similarly, in high density planting, the minimum leaf area and higher relative water content caused lowest transpiration from the leaf. However contradictory finding was observed by Singh *et al.* (2013).

Relative Humidity (%):

The influence of planting densities and training systems on relative humidity is presented in table 4.3.4.1. Maximum relative humidity was recorded in treatment T_1 (59.04%) while minimum mean relative humidity was found in T_6 (46.34%) among different planting densities. Data in table 4.3.4.2 reveals that maximum relative humidity was recorded in treatment T_2 (57.95%) and minimum in T_6 (46.34%).

Result indicated that relative humidity was recorded maximum in highly dense plants. It may be due to less penetration of light and less circulation of air in closely spaced plant leading to increase relative humidity.

Water Use Efficiency ($\mu\text{mol mol}^{-1}$):

Data in table 4.3.5.1 and 4.3.5.2 revealed that both planting spacing and training systems had a significant effect on water use efficiency of litchi leaves. Litchi tree planted at $4 \times 3 \text{ m}$ with support recorded maximum mean water use efficiency ($7.00 \mu\text{mol mol}^{-1}$) and tree planted at $5 \times 3 \text{ m}$ recorded minimum water use efficiency ($3.03 \mu\text{mol mol}^{-1}$) among different training systems. In different

planting densities the maximum mean water use efficiency was recorded at the spacing of 2x2 m ($6.32 \mu\text{mol mol}^{-1}$) and lowest in 5x5 m spacing ($2.85 \mu\text{mol mol}^{-1}$).

Results indicated that mean water use efficiency was found maximum in high density plants than wider spaced plant. Higher WUE are often found to maintain lower leaf internal CO_2 concentration. Higher photosynthetic rate and transpiration rate within leaves resulted to lower the value of water use efficiency.

Internal Carbon dioxide concentration ($\mu\text{mol mol}^{-1}$)

The data pertaining to internal CO_2 concentration affected by various planting densities and training systems during both the years. The maximum rate of internal carbon di-oxide was recorded in the treatment T_6 ($385 \mu\text{mol mol}^{-1}$) in both the experiments (square and rectangular system of planting). The lower rate of internal carbon di-oxide was found in the treatment T_1 ($259.87 \mu\text{mol mol}^{-1}$) in different densities whereas, among different training systems the lower rate of internal carbon di-oxide was recorded in T_3 ($270.94 \mu\text{mol mol}^{-1}$) in table 4.3.6.1 and 4.3.6.2.

Data revealed that the internal CO_2 concentration were highest in wider spacing and less in high density planting. The higher internal carbon dioxide concentration in less dense planting may be due to maximum light penetrance within canopy and low relative humidity observed within the tree. This is an essential criterion for carbohydrate metabolism for higher fruit yield/ plant. (Raj *et al.* 2017).

Mesophyll Efficiency ($\mu\text{mol mol}^{-1} (\mu\text{mol/m}^2\text{s}^{-1})^{-1}$):

Both planting spacing and training systems had a significant effect on mesophyll efficiency of litchi. Among different planting densities the maximum mean mesophyll efficiency was recorded at the spacing of 2x2 m (18.03) and lowest in 8x8 m spacing (6.55) in table 4.3.7.1. Litchi tree planted at 4x3 m with support recorded maximum mean mesophyll efficiency (18.83) and tree planted

at 8x8 m recorded minimum mesophyll efficiency (6.55) among different training systems (table 4.3.7.2). From the result it was clear that mesophyll efficiency value was recorded maximum in close spaced plants. This may be due to higher concentration of CO₂ and stomatal conductance resulted lower the value of mesophyll efficiency in wider spacing plants. It limits the rate of photosynthetic rate.

Quantum Efficiency ($\mu\text{mol m}^{-2} \text{s}^{-1}$)/ (μmolmol^{-1})

Quantum efficiency was no significantly influenced by planting densities and training systems of planting as maximum mean quantum efficiency (0.007 $\mu\text{mol m}^{-2} \text{s}^{-1}$)/ (μmolmol^{-1}) was recorded in treatment T₅ whereas, the minimum mean quantum efficiency (0.003 $\mu\text{mol m}^{-2} \text{s}^{-1}$)/ (μmolmol^{-1}) was found in treatment T₂ among different planting density. Among different training systems it was recorded maximum in T₆.

Leaf Nutrient Contents

5.4.1) Nitrogen (%)

Different planting densities under square system and training systems under rectangular system of planting of litchi had significant effect on tissue nutrient content. In this study, highest nitrogen (N) content (1.56%) was recorded in wider spacing (8x8 m) among different densities and training systems. The minimum nitrogen (N) content (1.23%) was recorded in close spaced plants (2x2 m) in different planting densities. While under different training systems the minimum nitrogen (N) content (1.45%) was found in T₃ (5x3 m) in table 4.4.1.1 and 4.4.1.2.

Singh (2003) reported that leaves from 6x6 m planted trees showed more mean N concentration (1.85%) than 6x5m and 6x4m planted trees, which recorded only 1.82% in both the spacing. It may either be due to the dilution effect of vegetative growth or more dry matter accumulation in the leaves as suggested by Schneider and Corell (1956), Arora *et al.* (1983). The nitrogen (N) content differed among the planting systems (Raj *et al* 2017).

Further Pramanick *et al.*(2012) also reported that maximum leaf nutrient content (N) accumulation in apple was observed at tree density of 1111 and minimum level at a planting density of 4444 trees/ha. High density planting systems after rejuvenation had significant effect on tissue nutrient content of mango .Pruning leads to high mobilization of N, P and K nutrients in plants (Singh *et al.*, 2014). On the contradictory finding observed by Raj *et al* 2017 highest nitrogen content was recorded in cluster planting (1.28%), which was at par with double-hedge row planting system (1.22%). The minimum nitrogen (N) content was recorded in square planting (1.04%). Similar finding also observed by Singh *et al.*,(2017).

Phosphorus (%)

The foliar phosphorus (P) content differed significantly among the different densities and training system in litchi. The highest phosphorus (P) content was found in control (0.25%) in both the experiments. The lowest phosphorus content (0.12%) was recorded in the treatment T₁ (2x2 m) in square system whereas, the lowest phosphorus content (0.16%) was found in T₂ (4x3 m without support) in rectangular system.(table 4.4.2.1 and 4.4.2.2.). 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. These results are in line with previous findings of **Kumar *et al.*(2013)** in apricot. Further **Pramanick *et al.*(2012)** also found maximum foliar phosphorus content (P) accumulation in wider spacing in case of apple at tree density of 1111 than at planting density of 4444 trees/ha. Raj *et al.*(2017) reported that the P contents in plants, viz. phosphorus (P) also differed among different planting systems. Similar finding observed by **Singh *et al.* (2017)** that the phosphorus content of leaves increased with decreasing plant density. The phosphorus content were recorded maximum in leaves taken from plants at wider spacing and the minimum in leaves taken from plants at closer spacing.

Potassium (%)

The perusal of data in table 4.4.3.1 and 4.4.3.2 reveals the foliar potassium (K) content was affected significantly by planting densities and training systems during the present studies. The maximum mean potassium (1.34%) content was recorded in wider spacing (8x8m) in both the experiment. The lowest mean potassium (1.10%) content was recorded in 2x2 m in square system and in 4x3 m without support (1.17%) in rectangular system of planting. The maximum leaf nutrient content (K) at low tree density as compared to higher tree density was also reported by Pramanick *et al.*(2012) . **Singh *et al.*** (2017) also found that spacing significantly affected the K content. The minimum K content was recorded in plants at 5x2 m spacing (1.23%) and the maximum in leaves taken from plants at 5x5 m spacing (1.28%) and the potassium content of leaves increased with decreasing plant density. This might be due to wider spacing responsible for higher uptake and translocation of nutrient from soil to aerial part of the plants. These results are in line with previous findings of **Kumar *et al.***(2013) in apricot.

Total Phenol (mg g⁻¹)

The total leaf phenol content varies significantly among different planting density and training systems. The perusal of pooled data indicated that leaf phenol content was maximum in 8x8 m spacing (82.25 mg GAE/g) among both experiments (square and rectangular system of planting). The minimum total leaf phenol content was recorded at the spacing of 2x2 m (42.26 mg GAE/g) in square system whereas, in different training systems under rectangular system of planting, minimum phenol content (51.93 mg GAE/g) was found in the treatment T₂ at the spacing of 4x3 m without support.(table 4.4.4.1 and 4.4.4.2)

The result in table Indicates that total phenol content of leaf increases in wider spacing under different planting density and training systems.

Total Chlorophyll Content (mg/g):

Data in table shows that mean chlorophyll content was significantly more at the spacing of 8x8m (9.31) among different planting densities and training systems during the present investigation. The lowest mean chlorophyll content was observed at the spacing of 2x2 m (3.73) in different planting density under square system while in the second experiment of training systems, the minimum chlorophyll content was recorded in the treatment T₂ at the spacing of 4x3 m without support (5.21).

These results are in agreement with those of Rud *et al* (1978) in apples who also observed a decreasing trend in the leaf chlorophyll content with diminishing distances between the trees. Similar results have also been reported by Yakunina and Maslov (1978) in apple. 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.(Yamini Sharma thesis). Almost similar finding was reported by Raj Amit *et al.*, (2017), the maximum total chlorophyll (2.02 mg g⁻¹) contents were found in plants under square planting system than other system of plantings.

Flowering and Yield attributing characters

5.5.1) Number of Panicles per branch

The result obtained in the present investigation revealed that different planting density and training systems under square and rectangular system of planting significantly influence number of panicles per branch. In both the square system and rectangular system of plantings maximum number of panicles per branch (19.02) was recorded in wider spacing (control) in table 4.5.1.1 and 4.5.1.2. Likewise under training systems minimum number of panicles (4.4) were recorded in the treatment T₃ (5x3 m) while under planting densities minimum number of panicles (5.62) were recorded in the treatment T₁ (2x2 m).

Data in table 4.5.1.1 and 4.5.1.2. indicates that number of panicles per branch increases in wider spacing among both system of planting except treatment T₃ (5x3 m) in different training system in which less panicles were recorded than at 4x3 m. Probably improved photosynthetic efficiency and higher metabolites formation due to elevated light interception by individual tree might have positively influence number of panicles per branches at broader spacing.

Panicle Length (cm)

It is obvious from data presented in the table 4.5.2.1 and 4.5.2.2 indicates that different planting densities and training system had significant effect on panicle length during 2019-2020. Maximum panicle length (32.73 cm) was recorded in treatment T₆ in both experiment while lowest panicle length (19.79 cm) were recorded in treatment T₁ (2x2 m) in square system further lowest length (19.99 cm) in T₃ in rectangular system of planting. The highest increases in panicle length were recorded in T₃ (12.57%) and lowest in T₁ (3.01%) in square system of planting. Further in different training systems, maximum increases in panicle length were recorded in treatment T₆ (7.64%) and lowest in T₄ (1.59%).

Data showed that maximum panicle length was recorded in wider spaced plants under different planting densities and training systems. It may be due to sufficient apportioned spaced provided to the plants and maximum interception of light at the spacing of 8x8m. In different training systems 4x3m (with and without support) intercepted more light than 5x3m spaced plants therefore, there are less accumulation of dry matters and photosynthates within leaves resulted minimum panicle length were recorded in 5x3m under hedge row.

Number of flowers / panicle

The result obtained in the present investigation revealed that different planting densities and training systems had significant influence on number of flowers per panicle. Maximum numbers of flowers per panicle (113.62) were recorded in control (8x8 m) among different planting density and training system in both system of planting while minimum number of flowers (36.77) were

recorded in T₁ (2x2 m) in square system whereas in rectangular system, minimum number of flowers (67.24) were recorded in T₃ (5x3 m).

Data in table 4.5.3.1 and 4.5.3.2 show that number of flowers per panicle in different densities and square system increases with increasing planting spacing. However, under training systems number of flowers were lesser in T₃ (5x3 m) than 4x3m. This may be due to greater photosynthetic activity, because of exposure of more number of leaves to intercept light and distribution of proper sunlight within the canopy (upper and below part of canopy) at wider spacing which positively influence the flowering and fruiting. This result is in accordance with the finding of Pandey *et al.* (2015) who obtained maximum number of flowers were recorded in wider spacing. These finding are in confirmatory with the findings of Dalal *et al.* (2013) in mandarin. The lowest flowering percentage under ultra high density may be due to overcrowding and intermingling of branches and twigs which resulted in less accumulation of carbohydrate reserves and higher source and sink competition as well as low sun light. These results are in agreement with Kumar and Rattanpal, 2010 and Lal *et al.*, 2000 observed in guava crop. Pal and Lal (2015) 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. Similar results also found by Joshi *et al.*(2016) and Joshi (2014).

Fruit Yield (kg/tree)

In present investigation maximum fruit yield per plant (46.79 kg/plant) were recorded in the treatment T₆ (8x8 m) under square system and rectangular system of planting while minimum fruit yield (3.51 kg/plant) were observed in treatment T₁ (2x2 m) under square system and minimum (7.91 kg/plant) in T₂ (4x3 m without support) under rectangular system of planting. (table 4.5.4.1 & 4.5.4.2). The result indicates that fruit yield per plant were higher in less dense plants because under wider spacing plant has comparatively higher vegetation, high leaf fruit ratio. Trees with bigger vegetative dimension normally give larger number of fruit per tree (Dalal *et al.* 2013). A decrease in fruit yield (kg/plant) in

closer spaced plant may be due to increase competition for light, water and nutrients (**Mika et al. 2001**). These results are in agreement with those of **Cepoiu and Muravi (1988)** who reported that wider spacings were helpful in increasing yield due to higher tree volume and reduced competition for metabolites among plants. **Kiprijanovski et al (2009)** found that Jonagold apple was planted at five different planting distances and observed that tree distance within row had a significant influence on their vegetative growth, bearing of the fruits. Further **Gaikwad et al. (2017)** pointed out that the highest number of fruits per tree (347.1) was recorded in spacing 10 X 10m (conventional system). The yield per tree was highest in the spacing 10 X 10m but the yield per hectare was higher (216 MT) in the spacing 5 X 5m. As with vegetative variables, reproductive variables were also negatively affected by planting density. The smaller the canopy area available to plants, the higher the tendency to decrease the number and percentage of lower shoots, and the number and yield of fruit per plant. As a consequence of the higher planting densities was the reduction of the number and percentage of lowering shoots. Plants grown under lower planting density may produce lowers in all quadrants of the canopy.

Fruit Yield (t/ha)

Data in table 4.5.6.1 & 4.5.6.2 was observed that yield per hectare different significantly among different planting densities and training systems. The maximum fruit yield (10.18 t/ha) was found in treatment T₅ (6x6 m) whereas, minimum mean yield (7.06 t/ha) was recorded in T₂ (3x3 m) in square system of planting. Maximum yield (18.87 t/ha) was recorded in treatment T₅ and minimum in T₃ (5x3 m) under different training systems.

A closer spacing accommodates more number of plants per unit area which increases the yield per hectare. **Joglekar et al. (2013)** and **Sousa et al. (2012)** found similar results in mango cv. Tommy Atkins. Higher number of plants/unit area resulted in higher yield/ha, and thereby, more tonnage per unit area. (**Nath et al. 2007**). Similarly **Sagar BS (2019)** reported highest yield per

hectare in the plant spaced at 2.5 x 2.5 m (12.11 t/ha) followed by the spacing of 5.0 x 2.5 m (6.95 t/ha) and the minimum yield per hectare was recorded in 7.5 x 5.0 m (3.41 t/ha) due to maximum number of plants per unit area. Robinson *et al.*(1991), Meland, (1998) reported that the Y-trellis system is an efficient way to increase both early and cumulative yield. This trial showed that the Y-trellis trees were very productive and reached maximum yield in the closest spacing, but the hedgerow system showed almost similar production levels in both apples and sweet cherry. These results concur with many studies (Bunea, 1982; Bargioni *et al*, 1986; Costa *et al*, 1997; Rana *et al*, 1998) in showing that with increase in tree density, yield per tree decreased while the yield per hectare increased. Higher yield per hectare at closer spacing was due to increased number of plants and foliage per hectare.

Fruit Weight (g)

The observation in relation to fruit weight were recorded and presented in table 4.5.7.1 and 4.5.7.2 indicated that fruit weight was found maximum in treatment T₆ (22.04 g) under square and rectangular system of planting whereas, it was lowest in 2x2 m (19.34 g) and treatment 4x3 m without support (20.07 g) in different densities and training systems respectively. The result indicated that fruit weight in both experiment increases in wider spacing except T₂ (4x3 m without support) in rectangular system of planting.

This 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. An increase in fruit weight in widely spaced trees may be due to the fact that this part intercepted maximum radiation which in turn had more efficient photosynthetic activities resulting in higher availability of net photosynthesis which enabled the trees to produce fruits with more weight (Singh, 2001). Hosomi *et al.* (2013) reported reduced size and weight of fruit under closer spacing in fig which could be due to change in lighting conditions which affected photosynthesis rate. Fruit weight was negatively correlated with plant density, it is among the variables that changed more often

due to high planting density (Souza *et al.*, 2012). There are studies in which fruit quality was maintained (Ram & Sirohi, 1991), suffered little (Nath *et al.*, 2007) or considerable changes (Moreira *et al.*, 2007; Singh *et al.*, 2007 Souza *et al.*, 2009). Similar results also reported by Srivastava *et al.* (2010).

Fruit Length (mm)

The maximum fruit length (34.95 mm) was recorded in treatment T₆ (8x8 m) in both experiment (square and rectangular systems). Minimum fruit length was recorded in T₁ (32.76 mm) in square system whereas, in treatment 4x3 m without support (33.02 mm) in rectangular system of plantings in table 5.5.8.1 and 4.5.8.2.

Similar results were reported by Sharma (2016), who observed a significant effect of fruit size. Trees planted at 5m x 3m recorded significantly higher fruit size (5.77 cm length) as compared to 5m x 2m (5.65cm length). McDermott and Sherman (1989) reported that upright and compact canopy interfered with light penetration during critical periods of fruit development resulting in smaller sized fruits. The adverse effects of lower light levels were due to the effects on both cell division and cell size (Jackson and Palmer 1977). Similarly results were also obtained by Gaikwad *et al.* (2017). The significant differences were noticed for the fruit length at the spacing 10X10m recorded highest fruit length then closed spaced plants. Similar results were also reported by Ram & Sirohi, (1991), Nath *et al.* (2007) Moreira *et al.*, (2007), Singh *et al.* (2007), Souza *et al.*, (2009).

Fruit Diameter (mm)

A perusal of data 4.5.9.1 and 4.5.9.2 indicated significant differences in fruit diameter among different planting densities and training systems of litchi. The maximum fruit diameter was found in treatment T₆ (27.79 mm) in both the systems. The minimum fruit diameter was recorded in treatment T₁ (23.41 mm) among different densities. In different training systems under rectangular planting, the minimum diameter was recorded in T₂ (26.44 mm). Lower fruit diameter with increase in plant density is reported by Sousa *et al.* (2012).

Sharma also reported that spacing also affected the fruit size significantly. Trees planted at wider spacing (5x3m) recorded significantly higher fruit size (5.42 cm diameter) as compared to 5m x 2m (5.31cm diameter). McDermott and Sherman (1989) reported that upright and compact canopy interfered with light penetration during critical periods of fruit development resulting in smaller sized fruits. Singh and Dhaliwal.(2007) also found that significantly higher size and weight of fruits harvested from the trees spaced at 6 x 6 m than at 6 x 5 m and 6 x 4 m.

Quality Traits

Total Soluble Solid (⁰B)

Result in table 4.6.1.1 and 4.6.1.2 indicates that total soluble solids of litchi were significantly influence by different planting densities and training systems. The maximum total soluble solids was recorded in treatment T₆ (20.40 ⁰B) in both the system of planting. The minimum total soluble solids was found in treatment T₁ (18.17 ⁰B) in different densities among different training systems. The minimum total soluble solids was found in treatment T₂ (19.16 ⁰B) which were *at par* with T₃ (19.45⁰B). Probably, improved photosynthetic efficiency and higher metabolites formation due to elevated light interception by individual tree might have enhanced fruit quality at broader spacing.

Improved light penetration which increases more photosynthetic activities and conversion of higher photosynthate at wider spacing may ultimately improved fruit TSS. (Pandey *et al.* 2015). Similar result was also obtained by Pramanick *et al* (2012) in which maximum total soluble solids (⁰B) was recorded in the least dense apple planting. Kiprijanovski *et al* (2009) observed a significant influence of inter tree spacing on quality of the fruits and reported maximum TSS (⁰B) at 4m x 3m spaced plant. Mano *et al.* (2011) noted significant differences in fruit quality parameters under closer planting distances in fig. They reported lower TSS at 0.8 m planting distance compared to 2 and 4 m. Similar results were reported by Gaikwad *et al.* (2017). In the spacing of 10x10 m recorded highest TSS (19.62 ⁰Brix). According to Policarpo *et al*

(2006), 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. Mika and Piatkowski (1986) found that lower content of soluble solids in apple fruits which were harvested from closely planted trees. McDermott and Sherman (1989) reported that soluble solids were lower in fruits harvested from closely planted trees due to less interception in low-chill peaches. According to Robinson *et al* (1991) closely planted apple tree of cv. Empire and trained to Y-trellis were poor in fruit quality in terms of total soluble solids and total acids due to poor light interception.

Acidity (%)

The perusal of data in table 4.6.2.1 and 4.6.2.2 reveals that the acidity of fruit significantly varied among planting densities and training systems. The maximum fruit acidity was observed in treatment T₁ (0.44%) whereas, minimum acidity was recorded in T₆ (0.33%) in different planting density. Further in different training system of litchi, the maximum fruit acidity (0.43%) was recorded in T₃ while it was minimum (0.35%) in the treatment T₆.

Pandey *et al.* (2015) reported that the lowest acidity under wider spacing may be due to better light penetration which increases more photosynthetic activities and conversion of higher photosynthate that ultimately improves the fruit quality. According to Policarpo *et al.* (2006), 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. The observations on chemical properties of fruits are in close conformity with the earlier findings of Ram & Sirohi. (1991), Nath *et al.*(2007), Moreira *et al.* (2007), Singh *et al.* (2007), Souza *et al.* (2009). Caruso *et al* (1999) also found that acidity was negatively correlated with plant density in peach cv. Flordaprince. Similar results were also obtained by Wertheim (1985) Robinson *et al.* (1991) in apple.

Total Soluble Solids : Acidity Ratio

The observation in relation to total soluble solid: acidity ratio were recorded and presented in table 4.6.3.1 and 4.6.3.2. A glance of the data indicated that total soluble solid: acidity was found maximum in treatment T₆ (64.96) under square and rectangular system of planting whereas, it was lowest in 2x2 m (45.46) in different planting density and among different training systems, it was lowest in treatment 5x3 m (45.07). Result also indicated that total soluble solid: acidity in both experiment increases in wider spacing except T₃ (5x3 m) in rectangular system of planting. It may be due to availability of proper sunlight to the lower branches of the trees at close spacing becomes a limiting factor and it adversely affects the fruit quality (Heinicke, 1963). 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 effects on fruit quality (Policarpo *et al.*, 2006). Kumawat (2013) reported that, TSS/acid ratio was significantly differed with the planting densities. TSS/acid ratio was maximum at 2.0 x 2.0 m spacing and minimum at 1.0 x 1.5 m spacing.. Similar results were obtained by Kundu (2007) who reported higher in the fruits from the plants under wider spacing in guava. The present results are also supported by the finding of Kumar *et al.* (2010) in apricot; Singh *et al.* (2010) in mango; Singh *et al.* (1980); Gaikwad *et al.* (1981); Bal and Dhaliwal (2003); Singh *et al.* (2007 b) and Bharad *et al.* (2012) in guava.

Total Sugar (%)

The perusal of data in table 4.6.4.1 and 4.6.4.2 reveals that the total sugar significantly varied among planting densities and training systems (square and rectangular system of plantings respectively). The maximum total sugar was observed in treatment T₆ (15.10%) whereas, minimum total sugar was recorded in T₂ (13.60%) in different planting density. Further in different training system of litchi, the maximum total sugar (15.10%) was recorded in T₆ while it was minimum (14.02%) in the treatment T₂ which were *at par* with T₃

(14.04%). Result of the study indicates that sugar content was comparatively higher under wider spacing. This 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 Singh and Bal. (2002) in Sardar guava. Availability of proper sunlight at close spacing becomes a limiting factor and it adversely affects the fruit quality (Heinicke, 1963). Similar result obtained by Policarpo *et al.* (2006) and Kundu. (2007). The present results are also supported by the finding of Kumar *et al.* (2010), Singh *et al.* (2010) in mango, Singh *et al.* (1980), Gaikwad *et al.* (1981), Bal and Dhaliwal (2003), Singh *et al.* (2007) and Bharad *et al.* (2012) in guava.

Organoleptic score

The result obtained in the present investigation revealed that different planting densities and training systems had significant influence organoleptic score of fruit. Maximum organoleptic score of fruit (8.45) were recorded in control (8x8 m) among different planting density and training system (square and rectangular system of planting respectively) while minimum organoleptic score (6.51) were recorded in T₂ (3x3 m) in square system and in rectangular system, minimum organoleptic score (7.17) were recorded in T₂ (4x3 m without support).

Data in table 4.6.5.1 and 4.6.5.2 show that organoleptic score of fruit in different densities and square system increases with increasing planting spacing. Organoleptic score were recorded higher where higher percentage of interception of light observed. Less availability of proper sunlight to the close spacing adversely affects the fruit quality (Heinicke, 1963). Further, it is pointed out by Policarpo *et al.*(2006), Kundu. (2007) organoleptic score recorded higher under wider spacing. The observations on chemical properties of fruits are in close conformity with the earlier findings by Kumar *et al.* (2010) in apricot, Singh *et al.* (2010) in mango, Singh *et al.* (1980), Gaikwad *et al.* (1981), Bal and Dhaliwal (2003), Singh *et al.* (2007 b) and Bharad *et al.* (2012) in guava. The larger tree canopy volume also increased the sink strength which resulted in

better fruit quality. The findings are in agreement with that of Singh (2001) in Peach cv. Shan- i- Punjab

Soil Parameters

Soil Temperature ($^{\circ}\text{C}$)

A detailed study of soil parameters such as soil temperature was analysed in different planting densities and training systems. The maximum soil temperature was recorded in the treatment T_6 (15.73°C) under different densities and training systems. The minimum soil temperature (14.46°C) was recorded in the close spaced plants ($2 \times 2\text{m}$) in different planting densities whereas; among different training systems the minimum soil temperature (15.31°C) was noticed in T_2 ($4 \times 3\text{ m}$ without support).

Soil Moisture (%)

The maximum soil moisture (7.36%) was recorded in close spaced plants ($2 \times 2\text{m}$) whereas; the lowest soil moisture (4.14%) was noticed in wider spaced plants ($8 \times 8\text{m}$) under square system of planting. In different training systems under rectangular system of planting the maximum soil moisture (6.69%) was recorded in the treatment T_1 while lowest in T_6 (4.14%) in table 4.7.2.1 and 4.7.2.2.

Water Retention (%)

The differences in water holding capacity among different planting densities ranged from 24.56% to 28.57% which was maximum in treatment T_1 (28.57%) whereas lowest in T_6 (24.56%). In different training systems the water holding capacity ranged from 24.56% to 26.94%. The maximum WHC was recorded in the treatment T_2 (26.94%) while the lowest in T_6 (24.56%).

Data in table 4.7.3.1 and 4.7.3.2 indicated that water holding capacity among different densities and training systems increases in highly dense plants. It may be due to lower bulk density resulted higher micro pores that hold the moisture in capillary pores and less compaction of soil in close spaced plants.

Bulk Density (g/ml)

Bulk density was significantly influenced by planting densities and training systems of planting as maximum mean bulk density (1.09 g) was recorded in treatment T₆ among both experiments in table 4.7.4.1 and 4.7.4.2. The minimum mean bulk density was found in treatment planting densities whereas; minimum mean bulk density (1.03gm) in different training systems was recorded in T₂. Result indicates that bulk density in different planting density and training system increases with increasing spacing. Adak *et al.* (2017) reported that higher density plantations showed compaction in deeper depths; hence increased bulk density and lowers porosity.

SUMMARY, CONCLUSIONS & SUGGESTIONS FOR FURTHER WORK

The variation in stem girth among various planting densities under square system ranged from 25.89 cm in treatment T₁ to 79.17 cm in T₆ (8x8 m). Variation in stem girth in different training system differed significantly which ranged from 33.11 cm in treatment T₂ (4x3 m without trellis) to 79.17 cm in treatment T₆ (8x8 m). A significant variation in plant height among the different planting spacing under square system was observed ranging from 2.68 m to 4.25 m. Maximum plant height was recorded in planting spacing of 8x8 m (4.25 m) and lowest in the spacing of 2x2 m (2.68 m).

Plant height differed significantly among different training system under rectangular system of planting which ranged from m to m. The maximum height was found at the spacing of 8x8 m (m) while lowest in 4x3 m with trellis (m). The plant spread (East-west direction) varied significantly among the different planting densities under square system and was noted maximum in T₆ (6.08 m) and minimum in T₁ (1.96 m). The variation in plant spread among different training system under rectangular planting ranged from 3.40 m in T₂ to 6.08 m in T₆. A wide variability in plant spread in North-South direction was observed among different planting density under square systems. The variation in spread ranged from 2.13 m in treatment T₁ to 7.08 m in T₆.

Plant spread (North-South direction) differed significantly among different training system under rectangular system of planting which ranged from 3.53 m in treatment T₂ (4x3m without support) to 7.08 m in 8x8 m (control). The variation in canopy diameter among various planting densities under square system ranged from 2.83 m² in treatment T₂ (3x3m) to 6.49 m² in T₆ (8x8m). Variation in canopy diameter in different training system differed significantly which ranged from 3.36 m² in treatment T₂ to 6.49 m² in treatment T₆. A wide variability was noticed in canopy area among different spacing in square system of planting which ranged from 5.51 in 2x2 m (T₁) to 32.43 m in 8x8 m (control).

Canopy area among rectangular system of planting differed significantly

which varied from 8.12 m in treatment T₂ to 32.43 m in T₆. During the study, significant variation was observed in leaf area ranged from 36.12 cm² in treatment T₁ (2x2m) to 37.26 cm² in T₆ (8x8 m) among various spacing under square system of planting. The maximum leaf area was found in treatment T₆ at the spacing of 8x8 m whereas, lowest in treatment T₁ at the spacing of 4x3 m with support in different training systems. Number of flushes per branch ranging from 4.19 in treatment T₁ (2x2 m) to 14.49 in T₆ (control) in square system of planting. While in different training system ranging from 6.08 in treatment T₂ to 14.49 in T₆ (8x8m). Significantly variation was observed in flush length among different planting density under square system of planting ranging from highest in treatment T₆ (45.20 cm) to the lowest in treatment T₁ (24.34 cm).

Flush length among different training system of planting varied significantly which ranged from 30.16 cm to 45.20 cm. The maximum flush length was recorded in T₆ (45.20 cm) and lowest in T₁ (30.16 cm). The maximum flush diameter among different density were recorded in control (7.84 mm) and lowest diameter recorded in treatment T₂ (4.60 mm). Flush diameter among different training system of planting varied significantly which ranged from 4.60 mm to 7.67 mm. The maximum flush diameter was recorded in T₆ (7.84 mm) and lowest in T₂ (5.06 mm).

Mean light interception below part of canopy was significantly higher (75.18%) in the wider spacing of plants (8x8m) and lowest interception (45.45%) in close spaced plants (2x2m) under different planting densities in square system of planting. Among different training systems the maximum mean light interception below canopy (75.18%) was recorded in treatment T₆ (8x8m) and it was lowest (48.90%) in treatment T₂ which was at par with T₃ (53.06%). The upper part of canopy was found higher in treatment T₆ (93.31%) whereas, lowest light interception in treatment T₁ (83.07%) in different planting densities under square system. Plants at the spacing of 8x8 m among different training systems capture significantly more light interception upper canopy (93.31%) while at the spacing 5x3 m capture less light (83.52%).

Highest photosynthetic rate and stomatal conductance were observed in treatment T₆ (8.42, 61.12 respectively) and least in T₁ (1.77, 14.62) in square system of planting. Among different training systems the maximum mean photosynthetic rate and stomatal conductance were observed in control (8.42, 61.12 respectively) and least in treatment T₂ (4.69, 20.5 respectively).

The rate of transpiration rate was found highest (2.38 mmol H₂O/m²/s) at the spacing of 8x8 m (control) among different planting densities and training systems. The minimum rate of transpiration was noticed in treatment T₁ (0.24 mmol H₂O/m²/s) among different densities while the minimum rate of transpiration rate was recorded in T₁ (0.65 mmol H₂O/m²/s) under different training systems.

Maximum relative humidity was recorded in treatment T₁ (59.04%) while minimum mean relative humidity was found in T₆ (46.34%) among different planting densities. Maximum relative humidity was recorded in treatment T₂ (57.95%) and minimum in T₆ (46.34%) under different training systems. Maximum mean quantum efficiency (0.007) was recorded in treatment T₅ whereas, the minimum mean quantum efficiency (0.003) was found in treatment T₂ among different planting density. Among different training systems it was recorded maximum in T₆. 4x3 m with support (T₁) recorded maximum mean mesophyll efficiency (18.83) and tree planted at 8x8 m (T₆) recorded minimum mesophyll efficiency (6.55) among different training systems. Among different planting densities the maximum mean masophyll efficiency was recorded at the spacing of 2x2 m (18.03) and lowest in 8x8 m spacing (6.55).

The maximum rate of internal carbon di-oxide was recorded in the treatment T₆ (385) in square and rectangular system of planting. The lower rate of internal carbon di-oxide was found in the treatment T₁ (259.87) in different densities whereas, among different training systems the lower rate of internal carbon di-oxide was recorded in T₃ (270.94). In different planting densities the maximum mean water use efficiency was recorded at the spacing of 2x2 m (6.32) and lowest in 5x5 m spacing (2.85). 4x3 m with support (T₁) recorded

maximum mean water use efficiency (7.00) and tree planted at 5x3 m (T₃) recorded minimum water use efficiency (3.03) among different training systems.

Highest nitrogen (N) content (1.56%) was recorded in wider spacing (8x8 m) among different densities and training systems. The minimum nitrogen (N) content (1.23%) was recorded in close spaced plants (2x2 m) in different planting densities. The minimum nitrogen (N) content (1.45%) was found in T₃ (5x3 m) in different training systems. The highest phosphorus (P) content was found in control (0.25%) in both the experiments. The lowest phosphorus content (0.12%) was recorded in the treatment T₁ (2x2 m) in square system whereas, the lowest phosphorus content (0.16%) was found in T₂ (4x3 m without support) in rectangular system.

The maximum mean potassium (1.34%) content was recorded in wider spacing (8x8m) in the both experiment. The lowest mean potassium (1.10%) content was recorded in 2x2 m in square system and in 4x3 m without support (1.17%) in rectangular system of planting. Data indicated that leaf phenol content was maximum in the treatment 8x8 m (82.25 mg GAE/g) among both experiments (square and rectangular system of planting). The minimum total leaf phenol content was recorded at the spacing of 2x2 m (42.26 mg GAE/g) in square system whereas, in different training systems under rectangular system of planting, minimum phenol content (51.93 mg GAE/g) was found in the treatment T₂ at the spacing of 4x3 m without support.

Mean chlorophyll content was significantly more at the spacing of 8x8xm (9.31) among different planting densities and training systems during. The lowest mean chlorophyll content was observed at the spacing of 2x2 m (3.73) in different planting density under square system while in the second experiment of training systems, the minimum chlorophyll content was recorded in the treatment T₂ at the spacing of 4x3 m without support (5.21). The maximum number of panicles per branch (19.02) was recorded in wider spacing (control) among the square system and rectangular system of plantings. Further minimum number of panicles (4.4) were recorded in the treatment T₃ (5x3 m) in different training systems while under different planting densities minimum

number of panicles (5.62) were recorded in the treatment T₁ (2x2 m) in square system of planting.

The maximum panicle length (32.73 cm) was recorded in treatment T₆ in both the experiment while lowest panicle length (19.79 cm) were recorded in treatment T₁ (2x2 m) in square system further lowest length (19.99 cm) in T₃ in rectangular system of planting. The maximum number of flowers per panicle (113.62) were recorded in control (8x8 m) among different planting density and training system (square and rectangular system of planting respectively) while minimum number of flowers (36.77) were recorded in T₁ (2x2 m) in square system and in rectangular system, minimum number of flowers (67.24) were recorded in T₃ (5x3 m). Maximum fruit yield per plant (46.79 kg/plant) were recorded in the treatment T₆ (8x8 m) under square system and rectangular system of plantings while minimum fruit yield (3.51 kg/plant) were observed in treatment T₁ (2x2 m) under square system and minimum (7.91 kg/plant) in T₂ (4x3 m without support) under rectangular system of planting.

The maximum fruit yield (10.18 t/ha) was found in treatment T₅ (6x6 m) whereas, minimum mean yield (7.06 t/ha) was recorded in T₂ (3x3 m) in square system of planting. Maximum yield (18.87 t/ha) was recorded in treatment T₅ (8x4m) and minimum in T₃ (5x3 m) under different training systems. Data indicated that fruit weight was found maximum in treatment T₆ (22.04 g) under square and rectangular system of planting whereas, it was lowest in 2x2 m (19.34 g) and treatment 4x3 m without support (20.07 g) in different densities and training systems respectively.

The maximum fruit length (34.95 mm) was recorded in treatment T₆ (8x8 m) in both experiment (square and rectangular systems). Minimum fruit length was recorded in T₁ (32.76 mm) in square system whereas, in treatment 4x3 m without support (33.02 mm) in rectangular system of plantings. The maximum fruit diameter was found in treatment T₆ (27.79 mm) in both the experiments. The minimum fruit diameter was recorded in treatment T₁ (23.41 mm) among different densities. In different training systems under rectangular planting the minimum diameter was recorded in T₂ (26.44 mm).

The maximum total soluble solids was recorded in treatment T₆ (20.40 °B) in both the experiments (square and rectangular system of plantings). The minimum total soluble solids was found in treatment T₁ (18.17 °B) in different densities whereas, among different training systems. The minimum total soluble solids were found in treatment T₂ (19.16 °B). The maximum fruit acidity was observed in treatment T₁ (0.44%) whereas, minimum acidity was recorded in T₆ (0.33%) in different planting density. Further in different training system of litchi, the maximum fruit acidity (0.43%) was recorded in T₃ while it was minimum (0.35%) in the treatment T₆. Total soluble solid: acidity was found maximum in treatment T₆ (64.96) under square and rectangular system of planting whereas, it was lowest in 2x2 m (45.46) in different planting density and among different training systems, it was lowest in treatment 5x3 m (45.07).

The maximum total sugar was observed in treatment T₆ (15.10%) whereas, minimum total sugar was recorded in T₂ (13.60%) in different planting density. Further in different training system of litchi, the maximum total sugar (15.10%) was recorded in T₆ while it was minimum (14.02%) in the treatment T₂ which were at par with T₃ (14.04%). Maximum organoleptic score of fruit (8.45) were recorded in control (8x8 m) among different planting density and training system (square and rectangular system of planting respectively) while minimum organoleptic score (6.51) were recorded in T₂ (3x3 m) in square system and in rectangular system, minimum organoleptic score (7.17) were recorded in T₂ (4x3 m without support).

The maximum soil temperature was recorded in the treatment T₆ (15.73 °C) under different densities and training systems. The minimum soil temperature (14.46 °C) was recorded in the close spaced plants (2x2m) in different planting densities whereas; among different training systems the minimum soil temperature (15.31 °C) was noticed in T₂ (4x3 m without support). The maximum soil moisture (7.36%) was recorded in close spaced plants (2x2m) whereas; the lowest soil moisture (4.14%) was noticed in wider spaced plants (8x8m) under square system of planting. In different training systems

under rectangular system of planting the maximum soil moisture (6.69%) was recorded in the treatment T₁ while lowest in T₆ (4.14%).

Maximum mean bulk density (1.09 g) was recorded in treatment T₆ among both experiments. The minimum mean bulk density was found in treatment planting densities whereas; minimum mean bulk density (1.03gm) in different training systems was recorded in T₂.

The differences in water holding capacity among different planting densities ranged from 24.56% to 28.57% which was maximum in treatment T₁ (28.57%) whereas lowest in T₆ (24.56%). In different training systems the water holding capacity ranged from 24.56% to 26.94%. The maximum WHC was recorded in the treatment T₂ (26.94%) while the lowest in T₆ (24.56%).

Conclusion

To produce better yield and quality in litchi from less land rational use of natural resources is the need of the farmers where planting geometry and planting system plays a crucial role. From the study it was found that rectangular system of plants at spacing of 8x4m occupying 32m² land space was able to produce an yield of 20.33 t/ha. Therefore for Shahi litchi the spacing of 8x4 under hedge row system can be recommended for the farmers for higher yield of 19-20 t/ha against 8.21t/ha in normal square system of planting at 8x8 m.

Suggestion for future work

- Rectangular system of planting should be followed for for litchi cultivation instead of square system of planting.
- If litchi planting done in square system then the planting spacing at 6 x 6 m should be followed.
- If followed the rectangular system of planting then the ideal planting spacing should be 8 x 4 m.
- Canopy architecture management aspect such as training and pruning should be practiced at

specific time for maintain an ideal plant canopy or model.

- For maximum interception of light there should be centre opening up of plants.
- Good agricultural practices should be followed for maximum production.

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APPENDICES

Soil and Weather Parameters (2019)

Centre: Muzaffarpur

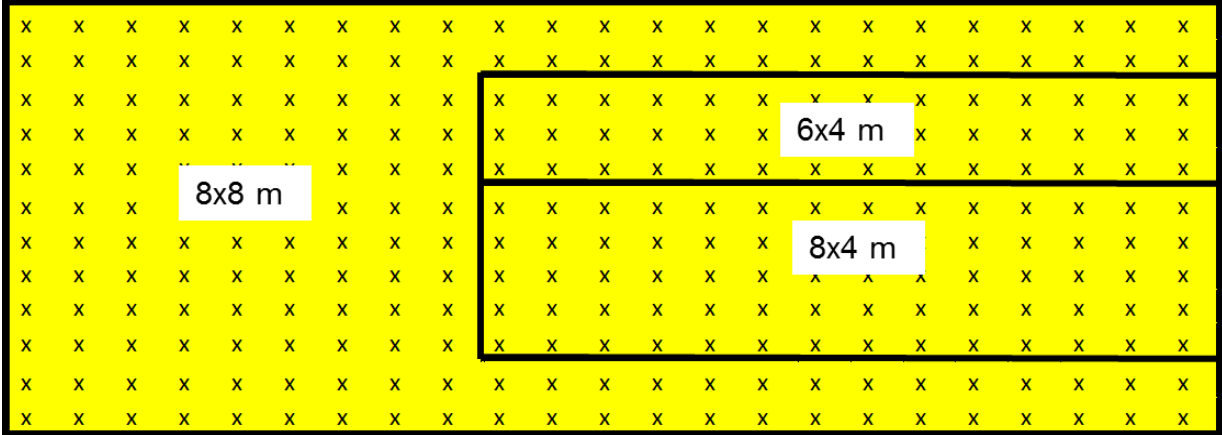
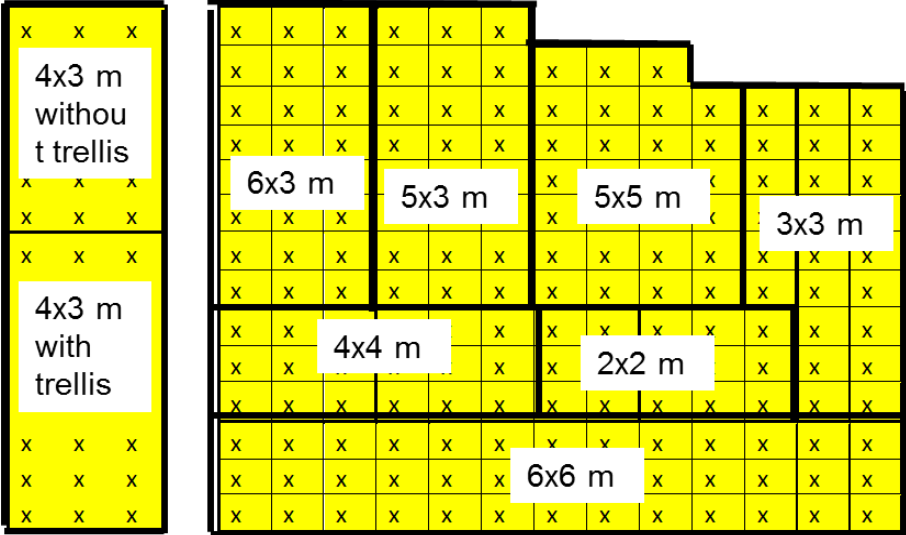
Soil characteristics

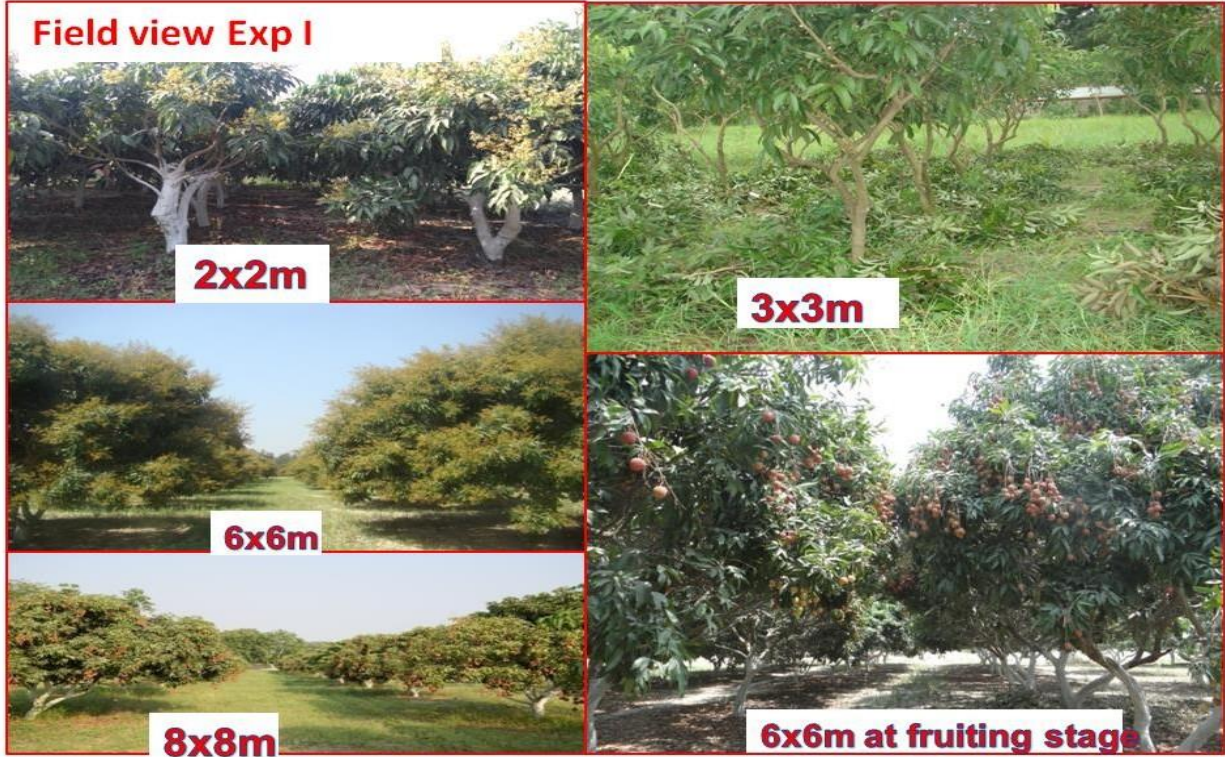
Parameters	Observations
Soil type	Sandy loam, calcareous soil
pH	8.34 – 8.1
EC	0.09 – 0.19 dsm-1
Orgainc Carbon	0.12 – 0.33%
Nitrogen (N)	100.17 – 143.35 kg/ha
Phosphorous (P ₂ O ₅)	18.28 – 27.42 kg/ha
Potassium (K ₂ O)	67 – 219 kg/ha

Weather data

Months	Temperature(°C)		Relative Humidity (%)		Wind speed (Km/hr.)	Rainfall (mm)	Evaporation (mm)
	Max	Min	Morning	Evening			
Jan-19	22.85	8.25	86.25	56.25	2.20	0.30	1.65
Feb-19	24.53	9.98	83.75	54.00	5.25	3.30	2.28
Mar-19	29.30	12.58	75.50	45.50	3.15	3.05	4.33
Apr-19	33.68	19.85	76.75	50.00	3.68	2.95	5.55
May-19	38.65	24.30	75.25	49.00	4.18	0.25	6.53
Jun-19	37.93	25.65	79.75	54.00	7.58	6.65	6.35
Jul-19	35.08	26.60	84.25	69.00	6.23	61.08	4.55
Aug-19	33.95	26.63	87.75	74.50	5.33	48.65	4.08
Sep-19	34.03	26.78	89.00	73.50	4.95	27.23	4.43
Oct-19	30.05	24.18	93.50	83.75	3.75	102.40	2.43
Nov-19	29.48	21.48	91.25	81.50	0.55	0.00	2.70
Dec-19	28.15	15.85	92.75	66.50	1.00	0.00	1.75
Jan-20	19.60	9.40	92.00	75.00	-	6.20	1.00

Layout





CURRICULUM VITAE

The author of this thesis Ms **Jyoti Singh** D/O Mr. Ashwini Singh was born on 12th August, 1992 in the lap of Ganga River at village Chhitauni, Post Lohta, District Varanasi (U.P.) She has qualified ICAR-NET (Horticulture) with 70%. She has also qualified ICAR-SRF in 2017 with all India 4th rank and obtained 1st rank in UPCATET examination in 2017. She has been selected in Haryana Public Service Commission as District horticulture officer. She has completed her education from different institution are given below:



Name of Certificate/Degree	University/Institute	Year of Completion	Marks (%)
Ph.D. (Horticulture-Fruit Science)	JNKVV, Jabalpur, MP	2020	75
M.Sc. (Ag) in Horticulture	CSAUAT, Kanpur, UP	2017	81.7
B.Sc. (Horticulture)	MGKV, Varanasi, UP	2015	82.5
Higher Secondary School Certificate	UP Board, Varanasi, UP	2009	72.5
High School Certificate	UP Board, Varanasi, UP	2007	64.5

The author carried her Doctorate studies from the Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.). This thesis is a bonafide research being submitted by her as a partial fulfillment for the award of Ph.D. (Horticulture) in Fruit Science degree.

Publication:

Research Paper:

- I Jyoti Singh^{1*}, A.K. Dwivedi¹, Poornima Devi¹, Jyoti Bajeli², Arunima Tripathi² and Sunil Kumar Maurya¹. Effect of Plant Growth Regulators on Growth and Yield Attributes of Tomato (*Solanum lycopersicom* Mill.) *Int.J.Curr.Microbiol.App.Sci* (2019) 8(1): xx-xx.
- II. Jyoti Singh, AK Dwivedi and Poornima Devi. Effect of plant growth regulators on yield attributes and quality trait of tomato (*Lycopersicon esculentum* Mill.) . *International Journal of Chemical Studies* 2019; 7(1): 1798-1801.
- III. Jyoti Singh, SK Pandey, Vishal Nath and Evening Stone Marboh Morpho- physiological responses of Litchi in Shahi under rectangular system of planting. *Journal of Pharmacognosy and Phytochemistry* 2020; 9(4): 1879-1883.
- IV. Jyoti Singh^{1*}, S. K. Pandey¹ , H. K. Rai¹ , Vishal Nath² , Evening Stone Marboh² and Shiv Poojan³. Influence of Spacing and Planting System on Light Interception, Physiological Parameters, Yield and Quality of Litchi cv. Shahi, *Int.J.Curr.Microbiol.App.Sci* (2020) 9(9): xx-xx.
- V. Vishal Nath^{*}, **Jyoti Singh²**, S.K. Pandey³, Sanjay Kumar Singh⁴, E.S. Marboh⁵. Influence of Plant Spacing and System of Planting on Tree Physiology, Yield and Quality of litchi cv. Shahi. *International Journal of Innovative Horticulture*. 9(1):62-68, 2020.
- VI. Poornima Devi^{1*}, R.K.S. Gautam¹, **Jyoti Singh¹** Effect of Foliar Application of NAA, GA3 and Zinc Sulphate on Fruit Drop, Growth and Yield of Ber (*Zizyphus mauritiana* Lamk.) c.v. Banarasi Karaka *Int.J.Curr.Microbiol.App.Sci* (2019) 8(1): 1679-1683.

Book Chapter:

Jyoti Singh, S. K. Pandey, Vishal Nath REJUVENATION AND CANOPY MANAGEMENT IN LITCHI ORCHARD., *Progressive horticulture*.

Review papers

- I. Light interception under different training systems and high density planting in fruit crops. (Journal of pharmacognosy and phytochemistry)
- II. Effect of 2,4 -D, NAA and GA3 on morphological, yield and quality traits in vegetable crops. (International journal of chemical studies)

Article:

- i. Jyoti Singh ,Girdling Technique in Litchi, Bimolecular repoter, Popular Article J singh, BR/02/20/04.
- i. Jyoti Singh ,severe Problem in Litchi Production: Flower and Fruit Drop, AGROBIOS NEWSLETTER.
- ii. Jyoti Singh¹, Vishal Nath² and Narayan Lal Sahu³ Rejuvenation of old Litchi Orchard. Indian Farmer 6(4): 275-279; April-2019.
- iv. Jyoti Singh ,sunburn and Fruit Cracking in Litchi Agribios newsletter.
- vi. Farmer doubling income through litchi orchard. ICAR-Indian farming.