Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(4): 1879-1883
Received: 10-05-2020
Accepted: 11-06-2020

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Morpho-physiological responses of *Litchi* in Shahi under rectangular system of planting

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Abstract
A field experiment was conducted to assess the effect of different spacing and planting system on growth and physiological parameters of *Litchi* cv. Shahi for two consecutive years (2018-19) at ICAR- NRC on *Litchi*, Muzaffarpur (Bihar). The experiment was laid out in Randomized Block Design (RBD) with six different planting spacing namely 4x3 m with supporting, 4 x 3 m without supporting, 5 x 3 m, 6 x 4 m, and 8 x 4 m. The planting spacing at 8 x 8 m was used as control. Each treatment contains four replications. The growth characters in terms of height of plant (m), girth diameter (cm), spread of plant EW-NS (m), canopy diameter (m), canopy area (m), leaf area (cm), total cross sectional area (cm^2), extend of flushes and physiological parameters in terms of total chlorophyll content, stomatal conductance, transpiration rate and PAR were recorded during the present investigation. Maximum plant height (5.54 m), girth diameter (74.67 cm), plant spread EW (5.82 m), NS (6.91 m), canopy diameter (6.23 cm), canopy area (62.25m^2), TCSA (398.21 cm^2), flush length (44 cm), flush diameter (7.60 mm), total chlorophyll content (mg/g) and gas exchanges viz stomatal conductance (62.25 mol.m-2 s-1), transpiration rate (2.48 m.mol m-2 s- 1), PAR (1583.25 µ mol m-2 s-1) was observed in wider spacing plants at a spacing of 8 x 8 m.

Keywords: Spacing, hedge row system, *Litchi*, planting system

Introduction
Litchi (*Litchi chinensis* Sonn.) commonly known as *Queen of fruits*, belongs to family Sapindaceae. It possess attractive color and fragrant juicy aril and good source of vitamin-C (Lal *et al*., 2018a) and phenolics (Lal *et al*., 2018b). *Litchi* is one of the most popular table fruit liked by every age group of the society. *Litchi* is crop of Chinese origin but occupies substantial area in India with annual production of more than 700000 MT from an area of about 100000 ha (Anonymous, 2019). The productivity of *Litchi* in the country is between 7-10 MT/ha. It is highly specific to climate and soil requirement probably due to which its cultivation is restricted to few countries in the world (Kumar *et al*., 2014a). Traditionally, in India a spacing of 8.0 m × 8.0 m or 10.0 x 10.0 m with about 70-80 trees/ha was found to be optimum for *Litchi*. Planting spacing is one of the appropriate for ensuing efficient and profitable use of land. Such plantings can have very high yields on a tree basis after 15 years (Pandey *et al*., 2105). Improper spacing has been assign as one of the reason for low productivity in *Litchi* (Dalal 2013). Therefore selecting optimum plant spacing and system of planting for efficient utilization of land and solar radiation (PAR) is for prime significance for obtaining good quality fruits and yield (Charlo *et al*., 2007; Ara *et al*., 2007; Amundson *et al*., 2012; Mantur *et al*., 2014) [1]. Optimum plant spacing ensures proper growth and development of plant, maximum yield of the crop and the best use of land (Bhatia 2017) [2]. Investigations made in the past have shown a good response of pruning and tree spacing for improving growth and productivity of many fruit crops like apple (Palmer *et al*, 1992) [4], mango (Das and Jana, 2012) [3], grapes (Turkington *et al*. 1980) and ber (Saini *et al*. 1996). In fruit plants, high density planting has been crucial development now a day's which leads to increased productivity, higher early yield and better income per unit area. Dense orchard increases inter plant competitions which is likely to be reflected in the pattern of plant growth, yielding potential of the tree and fruit quality (Sharma 2015). Hence in the present study, an attempt was made to assess the performance of morpho-physiological parameters of *Litchi* cv. Shahi under rectangular system of planting.

Material and Methods
The present investigations were carried out at the ICAR- National Research Centre on *Litchi*, Muzaffarpur (Bihar) during 2018 to 2019 on twelve to fifteen year old *Litchi* plants cv. Shahi under different spacing in rectangular system (table 1).

The soil of the experimental field was sandy loam in texture, alkaline in reaction with low to medium in fertility status. The experiment was laid out in Completely Randomized Block Design with 6 treatment combinations replicated four times. The experimental observations recorded were stem diameter (cm), plant height (m),plant spread (m) EW-NS, canopy diameter (m), canopy area (m^2), TCSA, leaf area (cm), extend of flush growth, total chlorophyll content, photosynthetic rate, transpiration rate, stomatal conductance, photo synthetic active radiation.

Treatment details

Symbol	Rectangular system of planting	No. of plant/ha	Space allocation/ plant (m^2)
T1	4 x 3 m (with supporting system)	834	12
T2	4x3 m (without supporting system)	834	12
T3	5x3 m (hedge row system)	667	15
T4	6x4 m (hedge row system)	416	24
T5	8x4 m (hedge row system)	312	32
T6	8x8 m (control)	156	64

Morpho-physiological characters [number of flush/branch, flush length, net photosynthetic rate, transpiration rate, stomatal conductance, PAR and chlorophyll content were recorded at stage I: 1-2 months after pruning; stage II: December - January; stage III: during Flower emergence during the experimental year. The number of flush/ branch was recorded by counting the number of new flush and length and diameter of flush was recorded by scale and vernier caliper respectively on individual branch. The canopy diameter was measured in both the direction (NS and EW) of the canopy. Plant height (m) was measured by measuring tape (fixed on a bamboo stick). Plant spread was measured by distance between the points to which most of the branches of a tree had grown in the north-south and the east-west directions. Trunk cross sectional area and canopy area was calculated by the formula;

TCSA (cm^2) = {Trunk circumference (cm) x 0.16}^{2}x3.143
Canopy area (m^2) = [{Plant spread (N-S) + (E-W)/2}^{2}x0.785]

The other physiological parameters, viz., net photosynthetic, stomatal conductance, photosynthetic active radiation (PAR) and transpiration rate were measured with the help of Portable Photosynthesis System-I (CIRAS 2, Amesbury, USA version 2.01). Total Chlorophyll content was estimated using Arnon's formula. One gm of fresh leaf tissue was homogenized in 80% of 10 ml acetone, filtered and centrifuged at 5000 rpm for five minutes. The supernatant was collected and made up to known volume. One ml of aliquot was taken and made up to 5 ml by adding acetone. Absorbance was measured by UV-Visible spectrophotometer at 645, 663, and 490 nm against 80% acetone as blank. The data were subjected to analysis of variance as suggested by Panse and Sukhatme (1967). Significance was tested by 'F' value at 5 per cent level of probability. Critical difference (CD) values were calculated wherever the F test was found to be significant.

Result and Discussion

Morphological Characters

1. Stem Girth (cm)

The data presented in Table 1 revealed that *Litchi* planted at 8 x 8 m recorded significantly higher mean stem girth (74.67 cm) closely followed by 6 x 4 m under hedge row system (73.15 cm) while minimum stem girth was recorded at 4 x 3 m with supporting system (28.77 cm) and 4 x 3 m without supporting system (29.46 cm) which was statistically *at par*. The decrease in tree girth at closer plantings may be due to availability of lesser amount of photosynthates and increasing competition for water, light and nutrients among the closely planted trees. Similarly findings of Singh and Bal (2002) [7], Bal and Dhaliwal (2003), Singh *et al*. (2007), Nath *et al*. (2007), and Bhagyashree (2018) [5] also reported an incremental trend in the stem girth with increase plant spacing. This is due to the fact that plants in normal spacing had more foliage or canopy volume as compared to closer spacing as heavy well developed canopy requires a strong supporting stem.

2. Plant Height (m)

Perusal of data presented in table 1 show that mean plant height among treatments ranged from 2.33–5.40 m. Maximum plant height 7.98 m was recorded at a wider spacing (8 x8 m) whereas minimum plant height was found in 4 x 3 m with supporting system (2.33 m) closed to 4 x3 m without supporting system (2.53 m) which was statistically *at par* (table 1). Similar result was reported by Bhagyashree (2018) [5] in which plants with wider spacing recorded highest plant height compared to closer spacing. It is generally expected that in wider spacing plants will have tendency to grow tall (Patel *et al*., 2012) [18], due to vigorous plant growth, less competition for space and nutrients and sufficient availability of space and light. Similar findings were reported by Bal and Dhaliwal (2003) and Kundu. S. (2007) [8].

3. Plant Spread (m) EW-NS Direction

The data presented in Table 1 show that *Litchi* tree planted at 8 x 8 m recorded higher tree spread in east-west direction (5.828 m) followed by at 8 x 4 m under hedge row system (5.51 m) which statistically *at par*. Minimum mean tree spread was recorded at 4x3 m without supporting system (2.831 m) which was even lower than 4x3 m with supporting system because of well distribution of branches and proper development of canopy in Y trellis. Data also reveals that maximum mean tree spread in north-south direction was obtained in 8 x 8 m (6.91 m) which was statistically *at par* with 8 x 4 m in hedge row (6.83 m) while minimum plant spread towards north-south direction was recorded in 4 x 3 m without supporting system (3.16 m) followed by 4 x 3 m with supporting system (3.588 m) and 5 x 3 m (4.094 m). The increase in plant spread (EW-NS direction) with increasing spacing might be due to enhanced competition for nutrients, light and water at closer spacing. Similar result was reported by S P Gaikwad (2017) [9], Bose *et al*., (1992), Pandey *et al*., (1997) [10], Chundawat *et al*., (1992) [11] and Mahajan *et al*., (2005) [14] in different fruit crops under different agro-climatic conditions.

4. Canopy Diameter (m)

Data presented in table 1 revealed that *Litchi* planted at 8 x 8 m recorded significantly higher mean canopy diameter (6.23

m) closely followed by 8 x 4 m under hedge row (6.17 m) while minimum canopy diameter was recorded at 4 x 3 m without supporting system (2.99 m) followed by 5 x 3 m under hedge row (3.71 m) and 4 x 3 m with supporting system (3.73 m) during the present studies.

5. Canopy Area (m^2)

Plant spacing significantly affected mean canopy area during present investigation (Table 1). Significantly maximum mean canopy area was recorded at spacing of 8 x 8 m (31.74 m^2) followed by 8 x 4 m (28.64 m^2) whereas, minimum mean canopy area was recorded at plant spacing 4x 3 m without supporting system (7.04 m^2) followed by 5 x 3 m under hedge row system (10.77 m^2) and 4 x 3 m with supporting system (10.95 m^2) which were statistically *at par*. Reduction in canopy area at closer plant spacing treatment might be due to competition among plants for nutrients and lesser penetration of sun light in high density as compared to widely spaced plants.

6. Total Cross Sectional Area (cm^2)

The results presented in Table 1 showed that maximum mean TCSA was recorded at wider spacing of 8 x 8 m (398.21 cm^2) closely followed by 8 x 4 m under hedge row system (382.56 cm^2) whereas, minimum TCSA was recorded at closely spaced plants of 4 x 3 m without supporting system (60.23 cm^2) followed by 4 x 3 m with supporting system (70.98 cm^2). The least TCSA and canopy area under closer spacing might be due to the competition for substrates under closed spacing. These results are in agreement with the findings of Pandey *et al*., (1997) [10], Prakash *et al*., (2012) [12] and Pratibha *et al*., (2013) [13].

7. Leaf Area (cm^2)

Leaf area at different plant spacing do not differ significantly (table 1). In peach, Yamini S (2015) also reported that both planting systems and spacing had no significant effect on the leaf area. From the table, mean leaf area was found to be maximum in 8 x 4 m under hedge row system (36.35 cm^2) but their difference did not attain a level of significant.

Table 1: Effect of spacing on Vegetative growth of *Litchi* cv. Shahi.

Treatment	Girth diameter (cm)	Plant height (m)	Plant spread E-W(m)	Plant spread N-S(m)	Canopy diameter(m)	Canopy area(m^2)	TCSA (cm^2)	Leaf area(cm^2)
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
1	28.77	2.33	3.97	3.59	3.73	10.953	60.239	35.79
2	29.46	2.54	2.83	3.16	2.99	7.038	70.989	36.17
3	32.44	3.33	3.32	4.09	3.71	10.769	88.889	35.60
4	73.15	4.90	4.86	4.21	4.54	15.501	297.45	35.22
5	54.07	5.36	5.51	6.83	6.17	28.638	382.568	36.35
6	74.67	5.54	5.828	6.91	6.23	31.744	398.218	35.105
C.D.	3.253	0.742	0.584	0.723	0.406	2.986	43.38	N/A
SE(m)	1.069	0.244	0.192	0.238	0.133	0.982	14.261	0.379

Morpho- physiological Parameters

1. Number of flush

Perusal of data (table 2) reveal that maximum numbers of flushes were found under 8 x 4 m hedge row system (12.1) followed by 8 x 8 m (10.8) whereas, minimum number of new flushes was found in 4 x 3 m without supporting system (5.15) and 4 x 3 m by supporting (5.97) which were *at par*. Minimum number of flushes observed in closer spacing of planting may be due to higher interception of light and circulation of air in wider spacing that produces more vegetative growth than closed spaced plants.

2. Length of flushes (cm)

Spacing also affected flushes length significantly (table 2). *Litchi* planted at 8 m x8 m recorded (44.21 cm) significantly higher flush length than 8m x 4m planted trees (41.47 cm). Minimum flush length was recorded at 4x 3 m by supporting system (29.70 cm) followed by 4 x 3 m without supporting system (31.7cm) and 5x 3 m under hedge row system (31.45 cm). The reduction in flush or new shoot length in closer spaced plants may be due to enhanced competition for substrate. Similar results were found by Mika *et al*., (1981) in apple.

3. Diameter of flush (mm)

Data tabulated in table 2 show that maximum mean diameter of flushes were recorded in 8 x 8 m (7.60 mm) closely followed by 8 x 4 m under hedge row system (7.06 mm) whereas, minimum mean diameter of new flushes was found at the spacing of 5 x 3 m under hedge row system (4.12 mm) than 4 x 3 m without supporting system (4.15 mm) and 4 x 3 m with supporting system (5.15 mm).

Table 2: Effect of spacing on extent of flushes and physiological parameters of *Litchi* cv. Shahi.

Treatment	Extend of Flushes			Total Chlorophyll content (mg/g)	Stomatal Conductance (mol.m-2 s-1)	Transpiration Rate.(m.mol m-2 s- 1)	PAR(µ mol m-2 s-1)
	Number of Flush	Flush length (cm)	Diameter of Flush(mm)	Mean	Mean	Mean	Mean
1	5.975	29.70	5.15	5.17	20.75	0.70	954.50
2	5.15	31.70	4.15	4.88	19.00	0.85	973.00
3	6.35	31.45	4.125	6.73	28.75	1.75	1133.50
4	9.6	40.25	5.283	7.60	34.00	1.73	1314.25
5	12.1	41.47	7.063	8.36	49.50	2.18	1481.75
6	10.8	44.21	7.605	9.12	62.25	2.48	1583.25
C.D.	2.328	7.169	1.543	1.075	10.366	0.711	191.314
SE(m)	0.765	2.357	0.507	0.353	3.408	0.234	62.895

4. Total Chlorophyll Content (mg/g)

As presented in table 2 the maximum mean chlorophyll content (9.12) was recorded in 8 x 8 m planted trees as compared to trees planted at 8 x 4 m (8.36 mg/g). Minimum mean chlorophyll content was recorded in 4 x 3 m without supporting system (4.88 mg/g) than 4 x 3 m with supporting system (5.17mg/g). It was observed that chlorophyll content increases with increasing space (Sharma Y. 2016) [16]. This may be due to better utilization of light in 8 x 4 m and 8 x 8 m spaced plants than close spaced plants which affected chlorophyll content Similarly Rud *et al*., (1978) [17], Yakunina and Maslov (1978) [15], Shishkanu and Komarova (1988), and Tanasev (1983), also reported that leaf chlorophyll content decreased with diminishing distance between the trees in apples.

5. Stomatal Conductance (mol.m^2 s^{-1})

Tree density had significant influence on gas exchange characteristics of the canopy. In table 2 data reveals that maximum stomatal conductance were observed in control at 8 x 8 m (62.25 mol.m^{-2} s^{-1}) followed by 8 x 4 m under hedge row system (49.50 mol.m^{-2} s^{-1}) and 6 x 4 m (34.00 mol.m^{-2} s^{-1}), whereas, minimum stomatal conductance were observed in closer spacing at 4 x 3 m without supporting system (19.00 mol.m^{-2} s^{-1}), 4 x 3 m with supporting (20.75 mol.m^{-2} s^{-1}) which was statistically *at par* in table 2. At wider spacing, light interception above and below the canopy is higher than at high density planting and this could be the reason for the low stomatal conductance obtained at lower spacing.

6. Transpiration Rate (m.mol m^{-2} s^{-1})

Significant variation in transpiration rate among tree planted at different spacing was recorded (table 2). Maximum transpiration rate were found in wider spaced tree at 8 x 8 m (2.48 m.mol m^{-2} s^{-1}) followed by 8 x 4 m in hedge row system (2.18 m.mol m^{-2} s^{-1}) whereas, minimum transpiration rate was observed in 4 x 3 m with supporting (0.70 m.mol m^{-2} s^{-1}) followed by 4 x 3 m without supporting system (0.85 m.mol m-2 s- 1) however, transpiration rate of tree planted at 5 x 3 m and 6 x 4 m under hedge row system were *at par*.

7. Photosynthetic Active Radiation (µ mol m^{-2} s^{-1})

In an orchard system, the amount of PAR intercepted by the tree canopy influences the photosynthesis rate and subsequent growth and productivity. Data presented in table 2 show that maximum interception of PAR (1583.25 µ mol m^{-2} s^{-1}) was recorded in 8 x 8 m followed by 8 x 4 m under hedge row system (1481.75 µ mol m^{-2} s^{-1}) and 6 x 4 m under hedge row system (1314.25 µ mol m^{-2} s^{-1}) whereas minimum PAR was obtained at 4 x3 m with supporting system (954.50 µ mol m^{-2} s^{-1}). This may be due to higher rate of light interception in wider spacing plants than dense planting.

Conclusion

Plant spacing plays a determining role in influencing fruit yield and quality in *Litchi*. Planting of *Litchi* at optimum spacing is crucial for successful orcharding. Planting spacing that is lower or higher than the optimum may be detrimental for fruiting potential and plant performance of *Litchi*. In the present study, tree planted at 8x4 m had satisfactory growth with good photo-synthetic ability, transpiration rate and gas exchange and high interception of PAR as compared to closer spacing.

Correlation table

	Number of Flush	Flush length	Diameter of Flush	Chlorophyll cotent	Photosynthetic rate	Stomatal Conductance	Transpiration Rate	PAR
Number of Flush	1							
Flush length	0.939**	1						
Diameter of Flush	0.884*	0.855*	1					
Chlorophyll cotent	0.922**	0.928**	0.826*	1				
Photosynthetic rate	0.855*	0.898*	0.939**	0.922**	1			
Stomatal Conductance	0.887*	0.912*	0.923**	0.953**	0.993**	1		
Transpiration Rate	0.854*	0.866*	0.739^{NS}	0.977**	0.884*	0.928**	1	
PAR	0.946**	0.965**	0.878*	0.987**	0.949**	0.973**	0.956**	1

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