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Generative traits of litchi (*Litchi* × *chinensis* Sonn.) cultivars in Shiwalik foothills of North-West Himalayas

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ABSTRACT

Full-bearing litchi trees (20-year-old) of five cultivars, namely, Early Large Red (ELR), Dehradun, Calcuttia, Rose Scented (RS) and Seedless Late (SL) were examined for cropping behaviour, flowering, fruit yield and quality traits in the Shiwalik foothills of north-west Himalaya. The findings revealed a significant difference between cultivars in terms of growth indices, flowering, fruiting and fruit quality traits. Dehradun had the highest trees spread, with corresponding values of 35.2, 18 and 14 per cent in SL, RS and ELR. In most cultivars, flower bud differentiation began in December and finished in the first week of February cultivar. ELR documented the earliest to bud burst. Maximum fruit set was recorded in Dehradun followed by ELR when compared to SL and Calcuttia. In terms of deviation from optimum percentage (DOP) indexing, ELR, Dehradun, and Calcuttia exhibited positive values for leaf N, P, and K except SL and RS, where it was negative for leaf N and K contents.

Keywords: Generative traits, yield, fruit cracking, litchi.

INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is indigenous to Southern China, notably the provinces of Kwantung and Fukien. It belongs to family Sapindaceae. The fruit is highly popular in both regional and domestic markets, with increasing demand for fresh, canned, and dried litchi fruits, both domestically and for export. It has a total cultivable area of 92,000 hectares and ranks second after China with production of 600,000 MT. However, there is still a significant productivity gap between the current average of 7-8 tonnes per hectare and the potential productivity of 14-15 tonnes per hectare. It is commercially grown in Bihar, West Bengal, Uttarakhand, Assam, and Jharkhand which account for 78% of total production in the country. In Himachal Pradesh, it is grown on an area of 5,407 hectares, producing 6,071 MT (Anon, 2). Juice makes up 60% of the fruit, followed by rag, seeds and peel according on the variety. Fruits are rich in vitamin C, pectin, proteins, lipids, Ca, P and Fe as mineral nutrients (Rajwana *et al.*, 11).

Winters that are moderate, chilly, and dry are ideal for litchi to flowers (Chaudhary *et al.*, 5). However, tropical and sub-tropical litchi trees do not display the seasonal natural phenomena that enable plants to adapt to different climates and avoid damage (Singh *et al.*, 12; Anjum *et al.*, 1). Successful litchi production depends mainly on recurrent winter cold snaps (between 1 and 5°C). Being an entomophilous crop, litchi completes its growth cycle through a number of stages, including the development of buds, leaves, and shoots, full flower emergence, and fruit (Soni and Agrawal, 13). In order to address the demand for developing this fruit crop, it is important to actively evaluate and carry out a critical evaluation of genotypes regarding growth, flowering, and fruiting. For litchi cultivation to be economically viable, it is essential to choose genotypes based on growth, fruit set, fruit maturity, and yield. Furthermore, it's crucial to keep in mind that a cultivar that performs well in one area might not do so in another. Despite having a long history of cultivation, litchi has a limited genetic base. There have been few attempts to improve genotypes using hybridization and contemporary breeding techniques. Litchi cultivars differ greatly in yield and quality from region to region, emphasizing the significance of region-based varietal evolution. The right cultivar must be chosen in order to successfully grow fruit and improve fruit quality. On the adaptability of litchi cultivars for particular agro-climatic situations, there is little information available. In order to assess the horticultural performance, the study evaluated the horticultural performance *vis-à-vis* generative traits, flowering, fruiting and quality in the Shiwalik foothills of Himachal Pradesh.

MATERIALS AND METHODS

Five full-bearing trees of litchi cultivars having uniform growth were chosen at Regional Horticulture Research and Training Station, Dr YS Parmar University of Horticulture and Forestry at

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Dhaulakuan, Sirmour, Himachal Pradesh (35.5° N latitude, 77.5° E longitudes and 468 m amsl). Twenty-year-old full-bearing litchi trees of Early Large Red (ELR), Dehradun, Calcuttia, Rose Scented (RS) and Seedless Late (SL) were examined. During the growth period, the climate was typically subtropical with maximum mean temperatures of 39.5°C and lowest mean temperatures of 17.3°C. Annual average rainfall was 1,100 mm. The trees were transplanted in rows in north-south direction and were spaced at 10 m × 10 m apart. At the start of the trial, all trees were uniform and showed no signs of disease or pest infestation. Observations on cropping behaviour, flowering, fruiting and quality traits were recorded using standard procedures (AOAC, 3). Representative sample size of 50 leaves was taken from middle shoot for leaf nutrient estimation during May-June after harvest. Total leaf N was determined by Kjeldhal's method; phosphorus by Vanado-Molybdate-Phosphoric yellow colour method; K was estimated using flame photometer. Besides, the quantity each nutrient in plants is measured by DOP index. DOP nutrient index was estimated as optimal (DOP = 0), deficient (DOP0), or excess (DOP > 0) according to Montanes *et al.* (9). Data were analyzed using MS-Excel and OPSTAT. The data obtained in the Randomized Block Design was analyzed using analysis of variance (ANOVA) in accordance with Gomez and Gomez (6).

RESULTS AND DISCUSSION

The data presented in Table 1 on tree habit of different cultivars of litchi showed that the cultivars, ELR, SL and RS showed upright growth habit, whereas, Dehradun and Calcuttia had spreading type of growth habit. The cultivar Dehradun exhibited maximum plant height (6.8 m) and was significantly higher compared to other litchi cultivars. Dehradun (41.66%) showed highest per cent increase in plant height. Further, substantial increase in trunk girth of 29.77 per cent was observed in Dehradun preceding Calcuttia (13.87%), RS (13.27%) and SL (8%). Maximum tree spread was reported in Dehradun (8.63, 9.66 m) whereas, it was minimum in Calcuttia, *viz*. 5.00 m (N-S), 5.56 m (E-W). No significant difference in shoot growth was observed among litchi cultivars. SL was categorized as semi-dwarf, while, all others cultivars, namely, ELR, and RS are semi-vigorous to vigorous as in Dehradun in tree vigour. Dehradun had the most leaf area, measuring 46.29 cm^2, while, ELR had the smallest (37.67 cm^2).

Data on generative traits revealed the cultivar Dehradun recorded highest TCSA of 424.96 cm^2 followed by ELR (265.06 cm^2), while, SL recorded the lowest TCSA (205.76 cm^2). Among all litchi cultivars, the tree volume of Dehradun was significantly higher whereas, lowest was observed in Calcuttia (Table 2). Cultivar ELR had the largest canopy area of 33.73 m^2 and Dehradun variety had the smallest canopy area of 17.87 m^2. The cvs. Dehradun and Early Seedless showed the greatest plant height and canopy spread, respectively. These results are also supported the findings of Yadav *et al*. (15) and Chandola and Mishra (4) who noted comparable changes in litchi cultivars cultivated under Uttrakhand conditions. The varying genetic and climatic effects may be the cause of the observed disparities in growth traits. In another study, Rai *et al*. (10) found genetic diversity for a variety of variables, including tree spread and canopy volume.

Different cultivars have varied in time of flowering due to the environmental conditions at the prevailing location specificity. In our results, majority of cultivars started flower bud burst in December and ended in the first week of February. The earliest bud burst occurred in the ELR, followed by Dehradun, Calcuttia, and RS, while it was most delayed in Seedless Late. Several cultivars started to generate flower panicles in January, and they continued to do so until the first week of March. Compared to SL, Dehradun and Calcuttia cultivars exhibited early flowering. The

Table 1. Growth indices of litchi cultivars grown in Shivalik foothills area.

Cultivar	Tree habit	Plant height (m)	Trunk girth (cm)	Shoot growth (cm)	Tree vigour	Canopy diameter (m)		Leaf area (cm^2)
						East-West	North-South	
Early Large Red	Upright	5.1	50.61	36.83	Semi-vigorous	5.70	6.50	37.67
Dehradun	Spreading	6.8	65.68	53.72	Vigorous	8.63	9.66	46.29
Calcuttia	Spreading	5.7	57.63	45.10	Semi-vigorous	5.00	5.56	43.54
Seedless Late	Upright	4.8	54.66	35.96	Semi-Dwarf	6.76	7.40	44.59
Rose Scented	Upright	5.6	57.33	42.36	Semi-vigorous	5.90	9.56	41.97
$CD_{0.05}$		0.70	5.06	NS		0.79	0.99	NS

NS, non-significant

Table 2. Generative traits of some litchi cultivars in Shiwalik foothills.

Cultivar	TCSA (cm^2)	TCV (m^3)	CA (m^2)
Early Large Red	265.06	141.38	33.73
Dehradun	424.96	496.01	17.87
Calcutta	261.90	105.56	23.47
Seedless Late	205.76	222.77	20.40
Rose Scented	208.96	234.91	22.36
$CD_{0.05}$	89.04	70.56	NS

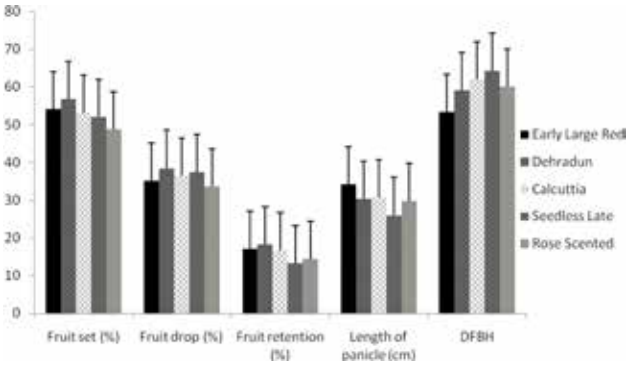

Fig. 1. Flowering and fruiting characters of litchi cultivars

difference in flowering time between SL and ELR was 12 days. ELR had a maximum panicle length (34.16 cm) compared to other litchi cultivars (Fig. 1).

The shortest period from full bloom to harvest for ELR was 55.33 days, while, the longest period for Seedless Late was 66.33 days. ELR was harvested first, followed by Dehradun, RS and Calcuttia. The variability in the number of days needed to reach full bloom stage may result from genetic variances and interactions between genes and environments. The variability in the number of days needed to reach full bloom stage might have caused genetic variances, interaction between genes and environmental conditions. Panicle length variation attributed to physiological development of the shoot and genotypes. Dehradun recorded the maximum fruit set of 56.71 per cent, whereas, it was minimum in Rose Scented of 48.70 per cent. However, minimum fruit drop was noted in RS (33.66%) followed by ELR (35.06%). Maximum fruit drop was recorded in Dehradun (38.46%), which was statistically at par with SL (37.35%). Data clearly shown in Table 3 that Dehradun cultivar provided the best yield (70.40 kg/tree), while the SL considerably produced the lowest yield (49 kg/tree).

The present study also examined changes in trunk cross-sectional area (TCSA), tree canopy volume (TCV), canopy area (CA), leaf area (LA) and the number of fruits produced (Table 3). There was no distinct variation in the yield per TCSA of some cultivars. RS cultivar had highest average yield efficiency value of 0.249 kg/cm^2 of TCSA, which was followed by SL (0.238 kg/cm^2 TCSA), ELR (0.236 kg/cm^2 TCSA), whereas, it was found lowest in Dehradun (0.166 kg/cm^2). Calcuttia (0.568 kg/m^3 of TCV) recorded maximum yield efficiency in terms of TCV while, Dehradun exhibited minimum value (0.142 kg/m^3 of TCV). Maximum yield efficiency with respect to CA was noted in Dehradun (3.94 kg/m^2 of CA). Dehradun cultivar exhibited the highest average yield efficiency compared to other cultivars. In terms of LA, ELR and Dehradun had the highest yield efficiency per LA (1.66 kg/cm^2 of LA), followed by Dehradun (1.52 kg/cm^2 of LA), while, SL had the lowest production efficiency per leaf area (1.10 kg/cm^2 of LA). There were considerable differences in fruit output amongst litchi cultivars, which could be attributed to genetic variability, climate effects, and differences in how effectively plants absorb nutrients from the soil. Additionally, these differences among cultivar might be due to agro-climatic circumstances, blooming and fruiting behavior, the total number of panicles per variety and tree age that contribute to variability in yield between various cultivars.

Data depicted in Table 4 on the physical characteristics of the fruits clearly demonstrated a significant variation in fruit length, with Dehradun

Table 3. Crop load and yield efficiency of litchi cultivars under Shivalik foothills.

Cultivar	Fruit yield (kg/tree)	Yield efficiency			
		Y/ TCSA (kg/cm^2)	Y/ TCV (kg/m^3)	Y/CA (kg/m^2)	Y/ LA (kg/cm^2)
Early Large Red	62.66	0.236	0.443	1.85	1.66
Dehradun	70.40	0.166	0.142	3.94	1.52
Calcuttia	60.00	0.229	0.568	2.56	1.38
Seedless Late	49.00	0.238	0.220	2.40	1.10
Rose Scented	52.03	0.249	0.221	2.33	1.24
$CD_{0.05}$	2.84	NS	0.080	0.46	0.21

exhibited the largest (35.54 mm) and SL, the smallest (29.88 mm). Dehradun cultivar also had the widest fruits, measuring 29.16 mm, while, Rose Scented the least (28.42 mm). Maximum average fruit weight was recorded by ELR at 21.51 g, followed by Calcuttia (20.18 g), SL (19.18 g), and Dehradun (17.38 g).

Maximum average peel weight (1.48 mm) was also recorded by Early Large Red. Among different litchi cultivars, there were no significant differences in the specific gravity or shape index of the fruits. According to Table 5, Dehradun variety had the highest stone weight (17.71 g), and Rose Scented had the lowest (13.62 g). Seedless Late cultivar had the highest pulp to stone ratio (7.35), while, Calcuttia had the lowest (4.02). Fruit cracking varied significantly, with Seedless Late recording the highest percentage of 17.06 and Early Large Red recorded the lowest (4.46%). Early Large Red and Calcuttia, two cultivars, had grey orange Group 166-A seed colour, while Seedless Late and Rose Scented were classified as having grey orange Group 176-A (chocolate hue) seeds. The different litchi cultivars did not exhibit any of the noticeable diversity in fruit colour. However, Early Large Red (crimson to carmine red) and Dehradun (rose pink) were identified in Red Group 46-C category (bright brick-red hue), Calcuttia and Rose Scented in Red Group 47-B (purple rose colour), and Seedless Late. Furthermore, a strong correlation between the development of abnormal fruit skin and high temperatures or drought during fruit growth, which caused increased fruit cracking of litchi fruits is also documented. Wei *et al.* (16) observed that the anthocyanin content comprises of 93% of the pigment known as cyanidin-3-rutinoside, affected the pericarp colour of fruits.

Litchi cultivars had noticeably variable fruit biochemical traits (Table 5). When compared, Early Large Red had the highest total soluble solids (16.95 °B), while, Seedless Late had the lowest (14.12°B). The variations in cultivars, environmental factors, and cultivar stage of maturity might be claimed for the variation in total soluble content in fruit samples. The largest TSS/acid ratio was obtained by the Rose Scented variety (58.70), which was statistically equal to the Early Large Red (52.09) while the lowest TSS/acid ratio was reported by the Dehradun variety (28.48). Early Large Red had the highest content of total sugars (15.10%), and Seedless Late had the lowest (11.64%). The information in Table 7 clearly shows that there were no appreciable differences in leaf P and K between cultivars. However, the amount of nitrogen in the leaves varied significantly, with Early Large Red having a high of 2.56% and Seedless Late having a minimum of 1.56%.

Positive DOP values for the leaf N, P, and K were exhibited by ELR, Dehradun, and Calcuttia

Table 4. Physical characteristics of fruits of five litchi cultivars.

Cultivar	Fruit dimension (mm)		Fruit weight (g)	Peel weight (g)	Specific gravity (g/cc)	Shape index
	Length	Breadth				
Early Large Red	35.07	28.63	20.18	1.48	0.97	1.22
Dehradun	35.54	29.16	21.51	1.27	0.96	1.22
Calcuttia	34.88	26.34	19.18	1.40	0.99	1.32
Seedless Late	29.88	28.57	17.38	1.35	1.00	1.05
Rose Scented	33.85	28.42	17.32	1.32	0.95	1.19
$CD_{0.05}$	2.17	2.62	0.97	0.06	NS	NS

NS = non-significant

Table 5. Stone weight, aril, pulp:stone ratio, and fruit cracking percent in litchi cultivars.

Cultivar	Stone weight (g)	Fresh weight of aril (g)	Pulp: stone	Fruit cracking (%)	TSS (°Brix)	Titratable acidity (%)	TSS : acid	Total sugars (%)
Early Large Red	3.45	15.25	4.42	10.50	16.95	0.38	44.61	14.10
Dehradun	2.53	17.71	7.00	14.04	15.68	0.46	34.09	13.94
Calcuttia	3.54	14.24	4.02	17.06	15.24	0.34	44.82	13.95
Seedless Late	1.92	14.11	7.35	4.46	14.12	0.39	36.21	12.64
Rose Scented	2.38	13.62	5.72	9.86	15.71	0.32	49.09	13.77
$CD_{0.05}$	0.49	1.48	1.63	1.03	1.09	0.10	5.47	0.51

TSS = Total soluble solids

Table 6. Leaf nutrient content and DOP indexing determined from leaf nutrients of litchi cultivars in Shiwalik foothills.

Cultivar	Leaf nutrients (%)			DOP indexing			
	N	P	K	N	P	K	ΣDOP
Early Large Red	2.56	0.20	1.22	+38.4	+25	+15.1	+78.5
Dehradun	2.33	0.19	1.12	+25.9	+18.8	+5.7	+50.4
Calcuttia	2.10	0.18	1.19	+13.5	+12.5	+12.3	+38.3
Seedless Late	1.56	0.17	0.89	-15.7	+6.3	-16.0	-25.4
Rose Scented	1.78	0.18	1.01	-3.8	+12.5	-4.7	+4.0
$C.D_{0.05}$	0.15	NS	NS	+11.7	+15.1	+2.5	

NS = non-significant

cultivars except SL and RS (Table 6). In contrast to inadequacies for leaf N and K (SL and RS), DOP indexes were in close agreement to diagnosis N, P, and K excess. For any element, the deficiency exists when the DOP index is negative, whereas, an excess exists when it is positive. In addition, it uses the DOP index to determine the overall nutritional status of nutrients, regardless of sign. Negative DOP for N and K in SL and RS indicates that the cultivars were sensitive to nutrient deficiencies due to low availability in soils and further poor mobility in the plant system. Moreover, improved leaf NPK attributed to the reduced rate of organic matter decomposition during harvest times. The intensity of nutrient imbalances increases as the DOP value decreases, while, the intensity of nutrient balancing increases as the DOP value increases. The intensity of nutritional imbalances increases with increasing DOP (Kumar *et al*., 7), and the intensity of nutrient balance increases with decreasing DOP (Kumar *et al*., 8).

CONCLUSIONS

The experimental findings revealed that there is considerable difference among litchi cultivars in terms of vegetative growth, blooming and fruit quality traits studied under Shiwalik foothills. In terms of fruit set, yield effectiveness, fruit weight, total soluble solids, and percent reduction in fruit cracking and early maturity ,the cultivar Early Large Red has been determined to be the excellent.

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AUTHORS' CONTRIBUTION

Conceptualization of research (PK, US, GS); Designing of the experiments (MA, PK, US, PC, GS); Contribution of experimental materials (MA, PK); Execution of field/lab experiments and data handling (MA); Analysis of data and interpretation (MA, PC); Preparation of the manuscript (PK, PC); Review and Editing (PK, PC).

DECLARATION

The authors declare no conflict of interest.

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