Characterization of litchi genotypes based on flowering and fruit characters

Abstract

Twenty genotypes of litchi were assessed based on traits related to fruit and flowering. There are numerous variations between the genotypes that have been noted. The flower disc color in the current study was light yellow for all genotypes. Shahi took the longest (26.25 days) to flower, while GG-2 took the lowest (20.~~95~~ 75 days). Panicle length varied greatly across the 20 genotypes of litchi that were evaluated; it ranged from a minimum of 38.95 cm in genotype DP-2 to a maximum of 48.20 cm in genotype KD-2. Panicles with ~~a minimum width of 19.98 cm and~~ a maximum width of 30.34 cm and a minimum width of 19.98 cm were produced by the genotype KS-1 and GC-2, respectively. Nine genotypes were not more likely to break than the 11 genotypes that were, based on the fruit cracking data. Eleven genotypes showed red color, whereas nine genotypes showed the color of crimson fruit. Plate 1 shows that genotype DP-2 (11.84) had the fewest fruits per cluster, whereas genotype DB-2 (14.03) had the most fruits per cluster. Fruit lengths varied, with GC-1 having the longest at 38.44 mm and DP-2 having the shortest at 34.26 mm. With a fruit diameter of 33.13 mm, the genotype GC-1 displayed the highest size, while DP-2 displayed the smallest (30.11 mm). Fruit weight varied by genotype, with DB-2 having the highest weight (23.38 g) and DP-2 having the lowest (20.52 g). Genotype DP-2 had the lowest aril weight (13.43 g) and GP-2 had the greatest aril weight (15.28 g). Total soluble solids (TSS) varied by genotype; genotype KT-1 displayed the highest TSS (19.99 °Brix) and genotype DT-2 the lowest (18.40 °Brix). Based on a quick review of the data, China (0.51 %) had the highest titratable acidity, and KS-1 (0.34 %) had the lowest. Genotype KS-1 produced the fruit with the highest TSS/acidity ratio (57.50), whereas genotype GC-1 produced the lowest (37.04) TSS/acid ratio. The longest seeds (23.66 mm) were found in fruit of genotype GP-2, whilst the shortest seeds (21.17 mm) were found in genotype DP-2. Analogously, genotype DT-1 exhibited the smallest seed breadth, measuring 11.94 mm, whereas genotype DB-2 demonstrated the biggest seed breadth, measuring 13.88 mm. Genotypes GC-1 had the lowest seed weights (3.24 and 3240 g), while DB-2 and DP-1 had the highest seed and test weights (4.15 and 4150 g).

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Key words: Litchi, flower disc colour, panicle length, fruit weight, seed length

Introduction

Litchi (*Litchi chinensis* Sonn.), a prominent member of the Sapindaceae family, is an evergreen subtropical fruit tree with notable mycorrhizal relationships (Lal et al., 2017a; Marboh et al., 2019~~,~~ ; ~~Lal et al., 2017a,~~ Lal et al., 2019; Lal and Nath, 2020a). The fruit crop litchi is an evergreen, subtropical crop with important nutritional and medicinal qualities. It is a great source of phenolics (Lal et al., 2018b) and vitamin C (Lal, 2018~~,~~ ; Lal et al., 2018a). It has extremely specific climate needs (Lal et al. 2017b). Fruit cracking and sunburn are two conditions that some genotypes are prone to (Lal et al., 2022a; Lal et al., 2023a~~,~~ ; Lal et al., 2023b~~,~~ ; Lal and Sahu, 2022). Selection or hybridization are necessary to broaden the limited genetic base (Lal et al., 2023c; Lal et al., 2023d). The shapes of the leaves and trees differ greatly amongst the litchi cultivars. Because cultivars range in terms of agroclimatic conditions, growth habits, fruit color, form, and size, there has been a significant lot of uncertainty around their nomenclature. As a result, a cultivar may go by multiple names in various circumstances. In India, litchi has little genetic variation because it was introduced as a crop. It is possible that new cultivars will develop in the future. To differentiate between cultivars, different attributes are used. Flower disc color, panicle color, fruit quality, and seed characteristics vary. Identification of Litchi based on morphological traits is a valid and straightforward method of differentiation. Using morphological characteristics including leaves, fruits, and flowers, litchi genotypes can be identified (Khurshid et al., 2004). In India, there are comparatively few exotic varieties available that are grown vegetatively. The current experiment was initiated to investigate genetic variety in several blooming and fruit morphological qualities of different genotypes of litchi collected from different locales. It was expected to provide a simple and intuitive method of distinguishing litchi cultivars based on morphological traits, providing a theoretical basis for early identification as well as information for generating cultivars and optimal genotype maintenance.

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Materials and Methods

For the current study, twenty genotypes of litchi, ages ranging from 10 to 20 years, were chosen because of their consistent size and vigor. Cultural methods were applied consistently to these plants. When recording the observations, consideration was given to all three trees for each genotype. The experiment was conducted using a Randomized Block Design approach. The observations were conducted in Khushinagar, Gorakgpur, and Deoria districts of Uttar Pradesh for two consecutive years (2023 and 2024) using the litchi descriptor, IPGRI, Rome. The fruit and aril weight, the length and width of the panicle, the acidity, the TSS, and the length and width of the seed were all measured using standard methods. Fruit cracking and the color of the mature fruit were observed by visually examining the floral disc. For the study, ten panicles from each genotype were chosen at random. The mean trait values for both years were combined and subjected to an analysis of variance (ANOVA) after a randomized block design and homogeneity test to see if genotypes differed significantly from each other (Panse and Sukhatme 1967).

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Results and Discussion

Flowering characters

The flower disc color in the current study was light yellow for all genotypes (Table 1). Litchi variations are identified exclusively by the color of the flower disc, which is a hereditary trait. Lal (2018) also observed variations in the floral disc's color. They observed that the flowers of Gola were pale yellow, whereas the blooms of Bombay, Calcuttia, and Bedana were yellowish. Similar to this, Kumari (2016) showed that the colors of flowers varied from greenish white to pale yellow and cream. The genotypes of litchi that were analyzed revealed variable flowering durations (Table 2), which varied from 20.~~95~~ 75 to 26.25 days. Shahi took the longest (26.25 days) to flower, while GG-2 took the lowest (20.95 days). The findings showed that whereas cultivars flowering later in the season require less time to fully flower, those flowering early in the season require more time. This variation is brought about by the later season's higher temperatures. The genetic composition of the different genotypes of litchi as well as environmental elements like wind, high temperatures, and low humidity that promote higher transpiration may be responsible for the variations in flowering dates between them. According to Lal et al. (2023e), litchi blooms last for 15 to 24 days. Variations in floral attributes could be due to cultivar genetic behavior because floral traits are less affected by outside influences. Therefore, variations in flowering to maturity may be caused by the genetic makeup of the cultivars as well as local environmental conditions. Kumari (2016) reported that flowering times ranged from 9.33 to 19 days for various genotypes of litchi.

It has been discovered that the length of the inflorescence serves as a trustworthy signal for classifying specific types of litchi. Panchal length varied greatly across the 20 genotypes of litchi that were evaluated (Table 2); it ranged from a minimum of 38.95 cm in genotype DP-2 to a maximum of 48.20 cm in genotype KD-2. Genotype KD-2 showed a significant advantage over all other genotypes studied. These differences result from the genetic makeup of the cultivars. Lal et al. (2023e) reported that the panicle length varied between 16.20 and 47.50 cm. However, the environment at the time of emergence, shoot maturity, and panicle emergence all have an impact on panicle length. The physiological mature shoot and the early onset of panicle are trustworthy markers of significant panicle. Lal et al. (2022b) report that the largest inflorescences were produced early in the season at lower temperatures. Conversely, the panicle that developed later had a little inflorescence. According to Chen et al. (2016), litchi has specific temperature requirements for anthesis, inflorescence growth, and induction. Panicles with ~~a minimum width of 19.98 cm and~~ a maximum width of 30.34 cm and a minimum width of 19.98 cm were produced by the genotype KS-1 and GC-2, respectively. Trees with longer panicles have a broader inflorescence. The breadth of the panicle ranged widely, from 9.15 to 33.50 cm (Lal et al., 2023e). A wider panicle is formed at medium intensity of panicle production because food material is diverted from the leaf to increase the length and width of the panicle. As a result, there is much less rivalry among the emerging panicle. The variation in panicle length and width is explained by the genetic composition of the litchi genotypes and, in particular, by the physiological condition of the shoot on which the panicle is developed. Similar results were also observed in litchi variations by Khurshid et al. (2004) and Dabral and Misra (2007).

Fruit characters

Nine genotypes were not more likely to break than the 11 genotypes that were, based on the fruit cracking data (Table 1). One of the main problems with litchi is that low soil moisture, low humidity, and high temperatures can cause the skin of the developing fruit to split. When the fruit grows rapidly following irrigation or rainfall, its internal pressure rises and the hard skin that forms from inadequate moisture during the early stages of fruit development may burst. Genotypes immune from cracking showed thicker peels and spongy layers together with a compact of tubercles on the skin, in contrast to genotypes susceptible to cracking, which had thin peels, spongy layers, and sparsely dispersed tubercles on the skin. Variations in fruit cracking have also been observed by other researchers (Rani et al., 2007,; Lal and Nath, 2020b). Fruit quality is decreased by fruit cracking, a serious physiological issue (Rangare et al., 2022a and b). Lower cuticle and spongy layer thickness combined with higher fruit surface temperature may be the cause of burning and cracking in fruit (Lal et al., 2023a and b). Two important traits of litchi to consider in breeding projects to produce clones or variations resistant to sunlight and fruit cracking are their heavy bunches and the proximity of the fruit to the leaf (Lal and Kumar, 2024). It has been demonstrated that warmer temperatures along with less rainfall can cause litchi fruit to crack (Lal et al., 2022a; Lal and Sahu, 2022; Lal and Nath, 2021a). Early cultivars are particularly susceptible to this problem.

There was a noticeable difference in the fruit's color at maturity between genotypes (Table 1). Two distinct fruit color variants were identified within the genotypes that were being studied. Eleven genotypes showed red color, whereas nine genotypes showed the color of crimson fruit. According to Pereira (2002), the cultivars Early Large Red, Mclean, Piazi, and Seedless matured with pink coloring, but Kasba and Purbi produced scarlet-colored fruits. Both Chandola and Mishra (2015) and Chavaradar (2016) reported differences in the color of the fruit in litchi. The pericarp is dark red or crimson in color because it has a high anthocyanin concentration per unit area. The genotype with the most fruits per cluster was DB-2 (14.03), whereas the genotype with the fewest fruits per cluster was DP-2 (11.84) (Table 2). Lal et al. (2023e) found one to 13.51 fruits per cluster in litchi. According to Pereira (2002), cultivar Bedana (2.62) had the lowest fruit retention, whereas McLean (5.49), Piazi (5.48), Early Large Red (5.33), and Rose Scented (532) had the largest number of fruits per panicle at harvest. The difference in the amount of fruits that different types keep at harvest maturity may be an indicator of their differential capacity to handle crop load. Furthermore, Chavaradar (2016) found that each cluster or blossom contains six to eighteen fruits. The maximum number of fruits/cluster (18) was found in Colls. 2 and 13, followed by Colls. 9 (17) and 10 (16).

Fruit lengths significantly varied (Table 2), with GC-1 having the longest at 38.44 mm and DP-2 having the shortest at 34.26 mm. The length of litchi fruit varied from 27.95 to 42.45 mm (Lal et al., 2023e). It has been discovered that the variance in fruit size is caused by both cultivar differences and environmental influences. The longest fruit of the genotype GC-1 is caused by the longest seed, which in turn increases the fruit's length and diameter. Fourteen days after anthesis, the pericarp starts to divide its cells; different parts of the pericarp stop dividing at different times. With a fruit diameter of 33.13 mm, the genotype GC-1 displayed the highest size, while DP-2 displayed the smallest (30.11 mm) (Table 2). According to Lal et al. (2023e), the fruit diameter of litchi varied from 35.81 to 27.97 mm. Calcuttia had the longest fruit length, whereas Longia had the smallest, according to Dabral and Misra (2007). The species that followed in order of fruit length were Rose Scented, Mandraji, and Dehra Dun. According to Singh et al. (2010), the cultivar Kasba produced the maximum mean fruit length and diameter, measuring 3.78 and 3.37 cm, respectively, while the cultivar Dehradun produced the lowest (2.82 and 2.41 cm). The Rose Scented and Early Seedless types had the greatest fruit breadth of 3.17 cm, while Longia showed the least (2.70 cm). The differences in physical characteristics between cultivars could be attributed to genetic varietal characteristics. A preliminary examination of the data (Table 3) showed that, among the genotypes, DP-2 had the lowest fruit weight (20.52 g) and DB-2 had the highest fruit weight (23.38 g). The mean fruit weight of different cultivars varied greatly, according to Dabral and Misra (2007). The variation in fruit weight has been seen by other researchers (Lal et al., 2023f, Lal et al., 2023e). Cultivar Kasba had the highest fruit weight (28.19 g/fruit), whereas cultivar Longia had the lowest (13.96 g/fruit), according to Singh et al. (2010). The differences in physical characteristics between cultivars could be attributed to genetic varietal characteristics. Chandola and Mishra (2015) state that Longia had the lowest fruit weight, followed by Late Seedless, and Rose Scented had the highest fruit weight, followed by Dehradoon. Genetic factors affect the fruit weight of litchi cultivars (Khurshid et al., 2004). Similar disparities were noted in the earlier study carried out by ~~Rab and~~ Haq and Rab (2012). Luchooman and Ramburn (2016) noted a big fruit weight of 20.1g in the cultivar Yook Ho Pow under Mauritius circumstances. Singh (1990) postulated that there are two likely explanations for the variation in fruit size: either the pericarp's properties (such cell size and laticiferous canals) or the intercellular space in different fruit tissues.

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When evaluating a cultivar, the amount of aril is very important because it is the part of the fruit that is used at the end. According to a ~~quick~~ scan of the data (Table 3), DP-2 had the lowest aril weight (13.43 g) and GP-2 had the largest aril weight (15.28 g). Lal et al. (2023e) report that the weight of arils in litchi varied from 7.27 to 17.66 g.Dabral and Misra (2007) reported that the fresh weight of aril varied greatly across Mandraji (8.83 g) and Late Seedless (14.60 g), with Early Seedless (13.16 g) having the maximum fresh weight. The litchi fruit's pulp weight matched that of the fruit, with cultivars Gola weighing the most (16.58 g), China and Surahi (16.27 and 15.90 g, respectively), and cultivar Bedana (11.19 g) weighing the least. The pulp weight of litchi fruit in cultivar Gola was 34.14%, 10.35%, and 4.59% higher than that of cultivars Bedana, Surahi, and China, respectively, according to Haq and Rab (2012). Since the weight of the fruit and pulp in litchi cultivars depends on genetic factors (Khurshid et al., 2004), nutrition (Cronje et al., 2009), and fruit orientation (Waseem et al., 2002), there may be variations in fruit and pulp weight between different cultivars. The differences in physical characteristics between cultivars could be attributed to genetic varietal characteristics. Examining the data revealed that the genotypes differed significantly in total soluble solids (Table 3). Total soluble solids (TSS) varied by genotype; genotype KT-1 displayed the highest TSS (19.99 °Brix) and genotype DT-2 the lowest (18.40 °Brix). Lal et al. (2023e) reported that TSS in litchi genotypes ranged from 17.04 to 19.98 °Brix. Furthermore, according to Rani (2006), there were significant differences in total soluble solids across several cultivars of litchi. TSS was highest (19.66°Brix) for the cultivar Rose Scented, lowest (16.23°Brix) for Longia, and highest (19.33°Brix) for Late Seedless. Cultivar Deshi had the greatest TSS (°Brix) at 22.82, followed by Trikolia at 22.43, while Late Bedana had the lowest at 18.17 °Brix, according to Singh et al. (2010). Compared to Bedana, Surahi, and China, cultivar Gola showed a higher TSS (22.13 °Brix) (Haq and Rab, 2012). The variations in TSS have been documented by Kumar et al. (2015), Waseem et al. (2002), Islam et al. (2003), and Dhillon and Gill (2010). Based on a ~~quick~~ review of the data in Table 3, China (0.51 %) had the highest titratable acidity, and KS-1 (0.34 %) had the lowest. According to Lal et al. (2023e), the acidity of litchi varied from 0.23 to 0.55%. Rani (2006) also observed that pulp from Rose Scented had the lowest acidity, at 0.30%, and that pulp from Longia, McLean, Calcuttia, Shahi, and Late Large Green had the highest acidity, ranging from 0.61 to 0.66%. These differences arise from the innate characteristics of different genotypes. One method pyruvic acid might manifest and reveal its role in respiration

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Commented [A7]: Add it to the References, please is by titratable acidity. Titratable acidity of pyruvic acid suggests that it may be involved in respiration (Singh et al., 2010).

The fruit's TSS/acidity ratio varied significantly between the genotypes (Table 3) that were the subject of the study. Genotype KS-1 produced the fruit with the highest TSS/acidity ratio (57.50), whereas genotype GC-1 produced the lowest (37.04) TSS/acid ratio. ~~Given its significant correlation with eating quality,~~ T~~t~~he TSS/acid ratio is the ideal litchi maturity standard. The range of TSS to acid ratios in litchi was 32.69 to 82.42 (Lal et al., 2023e). According to Rani's (2006) findings, Late Seedless and Dehrarose had the highest TSS: acid ratios, while Longia had the lowest. Moreover, Kumari et al. (2017) found that Bedana had the highest TSS/acid ratio (67.64). Cultivar China had the greatest TSS and Acid ratio (71.18), followed by Purbi (70.57), while cultivar Kasba (50.76) had the lowest, according to Singh et al. (2010). These differences in TSS and Acid ratios were caused by varying amounts of TSS and acid in various cultivars. The increase in the total soluble solids/acidity ratio was due to a buildup of soluble solids and a drop in organic acid. The TSS/acid ratio, which has a higher link with flavor than TSS, is the best indicator for harvesting litchi.

Seed Characters

It appears from Table 4. that t~~T~~he longest seeds (23.66 mm) were found in fruit of genotype GP-2, whilst the shortest seeds (21.17 mm) were found in genotype DP-2. The seed reached its maximum size when both the fruit and seed grew normally. Analogously, genotype DT-1 exhibited the smallest seed breadth, measuring 11.94 mm, whereas genotype DB-2 demonstrated the biggest seed breadth, measuring 13.88 mm. Variations in seed length (16.36 to 23.42 mm) and seed width (8.18 to 13.84 mm) have been reported by earlier researchers (Lal et al., 2023e). An other explanation for the genotype-to-genotype variation in seed size was early-stage seed abortion.

Similar results were achieved by Kumari (2016). Genotypes GC-1 had the lowest seed weights (3.24 and 3240 g), while DB-2 and DP-1 had the highest seed and test weights (4.15 and 4150 g). Lal et al. (2023e) report that the weight of litchi seeds varied from 1.72 to 4.39 g. Calcuttia (3.83 g) and Kasba (3.83 g) had the highest seed weights, according to Dabral

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and Misra (2007); Early Seedless (0.88 g) and Late Seedless (1.11 g) had the lowest seed weights. Rani (2006) also observed that Late Seedless had the lowest seed content, followed by Shahi, while Calcuttia had the most. Pereira and Mitra (2004) report that when fruits grew closer to being ready for harvest, the seed weight increased initially but then stayed the same or even declined. The seed weight rose rapidly during the first phase and then climbed gradually in the following phases (Dhillon and Gill, 2010).

Conclusion

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The main conclusions regarding the diversity, effectiveness, and potential of many genotypes with regard to their blooming behavior, fruit yield, and quality attributes are usually highlighted at the end of the characterization of litchi genotypes based on flowering and fruit characters. Among the genotypes of litchi that have been investigated, there is a considerable genetic variety that can be used in breeding programs to increase fruit quality, yield, and flowering time. It is possible to choose superior genotypes for commercial cultivation that have desired fruit qualities. The genotype characterisation of litchis based on fruit and flowering characteristics offers useful information for choosing cultivars and promising types for breeding and commercial production.

Table 1. Characterization of genotypes of litchi based on qualitative traits

Genotypes	Flower disc colour	Fruit cracking	Mature fruit colour	
Shahi	Light yellow	Highly prone	Red	
KD-1	Light yellow	Highly prone	Red	
KD-2	Light yellow	Highly prone	Red	
KS-1	Light yellow	Highly prone	Red	
KS-2	Light yellow	Highly prone	Red	

KT-1	Light yellow	Highly prone	Red	
KT-2	Light yellow	Highly prone	Red	
China	Light yellow	Not prone	Crimson	
GC-1	Light yellow	Not prone	Crimson	
GC-2	Light yellow	Not prone	Crimson	
GP-1	Light yellow	Not prone	Crimson	
GP-2	Light yellow	Not prone	Crimson	
GG-1	Light yellow	Not prone	Crimson	
GG-2	Light yellow	Not prone	Crimson	
DB-1	Light yellow	Highly prone	Red	
DB-2	Light yellow	Highly prone	Red	
DP-1	Light yellow	Highly prone	Red	
DP-2	Light yellow	Prone to cracking	Red	
DT-1	Light yellow	Not prone	Crimson	
DT-2	Light yellow	Not prone	Crimson	

Table 2. Characterization of genotypes of litchi based on flowering and fruit traits

Genotypes	Duration of flowering (Days	Length of panicle (cm)	Width of panicle (cm)	Number of fruit per cluster	Fruit length (mm)	Fruit diameter (mm)
Shahi	26.25	48.15	29.00	13.45	36.36	31.46
KD-1	25.00	47.05	27.05	13.91	35.49	30.64
KD-2	22.75	48.20	29.60	13.47	35.70	30.94
KS-1	22.00	42.69	28.85	13.49	36.42	30.84
KS-~~1~~2	24.75	44.55	30.34	13.47	35.46	31.42
KT-1	24.25	45.745	28.05	13.64	35.79	31.10

KT-~~1~~2	23.25	46.06	29.03	13.50	37.49	30.95
China	22.25	42.00	20.13	12.96	37.48	32.34
GC-1	21.25	40.85	22.43	13.79	38.44	33.13
GC-2	21.75	41.03	19.98	11.85	38.2	32.66
GP-1	22.25	41.93	22.38	12.29	36.84	32.91
GP-2	23.25	42.83	23.54	12.54	38.40	32.66
GG-1	21.25	43.70	21.40	13.19	38.43	32.66
GG-2	20.75	41.88	20.46	12.80	37.51	31.08
DB-1	25.25	45.927	27.41	13.89	36.00	30.49
DB-2	24.25	47.95	26.47	14.03	35.26	30.69
DP-1	23.75	45.75	30.23	13.61	36.18	30.97
DP-2	22.25	38.95	22.59	11.84	34.26	30.11
DT-1	22.00	41.70	21.53	12.62	36.80	32.14
DT-2	23.25	42.70	22.43	12.85	36.62	32.55
SEm ±	0.270	0.589	0.369	0.174	0.546	0.506
CD at 5%	0.776	1.692	1.061	0.500	1.570	1.454

Table 3. Characterization of genotypes of litchi based on quality

Genotypes	Fruit weight (g)	Aril weight (g)	**TSS (Brix)**	Acidity (%)	**TSS/Acidity**
Shahi	22.53	14.47	19.72	0.41	47.52
KD-1	22.61	13.6	19.66	0.35	55.41
KD-2	23.33	14.13	19.59	0.36	53.68
KS-1	22.60	13.59	19.55	0.34	57.50
KS-~~1~~2	22.56	13.49	19.41	0.37	51.77
KT-1	22.70	14.31	19.99	0.37	53.31
KT-~~1~~2	21.96	13.47	19.47	0.36	54.08
China	21.94	14.71	19.17	0.51	37.23
GC-1	21.47	14.96	18.70	0.50	37.04
GC-2	21.84	14.68	18.55	0.48	38.25
GP-1	22.46	14.24	19.25	0.47	40.97
GP-2	21.64	15.28	19.22	0.42	45.76
GG-1	21.66	14.71	18.85	0.47	40.12
GG-2	22.30	14.32	19.18	0.43	44.09
DB-1	22.80	13.68	19.45	0.38	50.54
DB-2	23.38	14.29	19.19	0.38	49.85
DP-1	22.16	14.30	19.75	0.36	54.13
DP-2	20.52	13.43	18.70	0.34	54.23
DT-1	21.75	14.39	18.75	0.36	52.08

DT-2	21.85	14.48	18.40	0.37	49.08
SEm ±	0.288	0.182	0.317	0.006	0.699
CD at 5%	0.829	0.523	0.910	0.017	2.008

Table 4. Characterization of genotypes of litchi based on **Seed Characters**

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