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Genetic variability, heritability and genetic advance in litchi (*Litchi chinensis*)

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ABSTRACT

Litchi (*Litchi chinensis* Sonn.) is one of the most important subtropical fruit crops of the world. Improvement in this crop is constrained by its narrow genetic base, which is a major bottleneck in reaching the desired objectives. Studies on the nature and extent of genetic variability are highly relevant to yield information that can be useful for genetic improvement programmes. In the present study, 22 litchi genotypes including three new varieties were assessed for the variability, heritability and genetic advance and principal component analysis on the basis of 13 quantitative fruit traits. High phenotypic and genotypic coefficients of variation were recorded for pulp weight (32.86 and 31.11%), seed weight (30.56 and 27.93%), peel thickness (25.07 and 20.21%), pulp thickness (24.79 and 22.22%) and fruit weight (22.65 and 21.17%).The heritability and genetic advance were found maximum for fruit yield/plant. High heritability coupled with high genetic advance was recorded for fruit weight, fruit length, fruit width, pulp weight, pulp thickness, seed weight, peel thickness, peel weight, seed width (y-axis) and yield/plant, indicating ample scope of improvement for these traits through selection. From PCA and variability estimates, fruit weight, pulp weight, peel weight, peel thickness, seed weight and seed size were identified as important traits for identifying high-yielding genotypes.

Key words: Genetic advance, Genetic variability, Heritability, Litchi, Principal component analysis

Litchi (*Litchi chinensis* Sonn.), originated in China, is an important sub-tropical evergreen fruit tree of the family Sapindaceae. A considerable genetic variations in fruit traits exists in litchi which leads to marked differences in fruit shape, skin colour and texture, the fragrance and flavour, colour of the flesh, the amount of rag in the seed cavity, and the size and form of the seed (Singh and Nath 2012). Despite of having a very narrow genetic base, selection of genotypes from the existing population under different ecological conditions, can be attempted to widen the diversity pool in litchi. The presence of significant variation in morphological, biochemical and yield characters of various cultivars of litchi can be used for identification and breeding purpose (Chandola and Mishra 2015). Babita *et al.* (2010) also reported the variation in yield and quality traits among litchi cultivars. Since variability within the breeding material is a pre-requisite for any successful breeding programme, the presence of high variability coupled with high heritability in respect of the traits of interests provide greater scope for further improvement. Such improvement in commercially important traits such as fruit weight, size, quality and yield/plant would contribute a significant prospects and possibilities for increasing production of quality litchi (Gupta *et al.* 2017). The biometrical attributes like variability, heritability and genetic advance are of prime importance in providing information about the relative contribution of various growth and yield related traits to total fruit yield. Hence, studies of variability based on genotypic coefficient of variation, heritability and genetic advance are absolutely necessary for a successful breeding programme (Mishra *et al*. 2015). Further, it becomes imperative to identify significant traits greatly vital in deciphering the nature of variability existing within the breeding materials. Therefore, in this study, an attempt was made to estimate the variability, heritability, genetic advance and to identify various economically important traits contributing to the fruit yield and quality, which could generate necessary information for selection of superior litchi genotypes in future breeding programs.

MATERIALS AND METHODS

In the present study, 12 years old 22 litchi genotypes, collected from different sources and conserved in a field gene bank at ICAR-National Research Center on Litchi, Muzaffarpur, Bihar, were evaluated for economically important fruit traits. Three newly released varieties, viz. Gandaki Lalima, Gandaki Sampada and Gandaki Yogita were also included in the study (Nath *et al.* 2016). All the trees were subjected to uniform cultural practices.

The observations were recorded for two consecutive years (2015 and 2016) on 13 fruit physico-chemical parameters and each genotype was replicated thrice. The

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weight of fruits, pulp, seed and peel was measured on a digital weighing balance while physical dimensions related to fruit size, seed size, peel thickness and pulp thickness was recorded using digital vernier caliper and expressed in mm. Seed with in 'x' and 'y' axis was measured transversely and longitudinally at the widest point in a direction perpendicular to each other. TSS was determined by placing 3 ml juice on the prism-plate of the digital hand refractometer (range 0–52%) and reading was directly recorded as total soluble solids (°Brix). For evaluation, a random sample of ten fruits per replication was collected from all directions.

After testing the homogeneity, the mean values of 13 characters for both the years were pooled and subjected to analysis of variance (ANOVA) for testing the presence of significant differences among genotypes (Panse and Sukhatme 1954) following randomized block design.The phenotypic and genotypic coefficients of variation were computed using the formula suggested by Burton (1952). Broad sense heritability was estimated using the formula adopted by Singh and Chaudhary (1977). Genetic advance in absolute unit (GA) and percent of the mean (GAM), assuming selection of superior 5% genotypes were estimated in accordance with the methods illustrated by Johnson *et al.* (1955). In order to examine the relationships between morphological characters among litchi genotypes, principal components analysis (PCA) was used (Everitt and Dunn 2010), following *prcomp* function from the built-in R stats package v3.4.2 (R Core Team, 2017). A scatter diagram visualizing the association among principal components and traits was also plotted.

RESULTS AND DISCUSSION

Phenotypic variability

Data pertaining to quantitative traits among studied litchi genotypes are presented in Table 1. In this study, genotypes exhibited considerable variation ranging from 1.19 to 4.30 g for seed weight, 0.82 to 2.14 mm for peel thickness, 3.30 to 7.04 g for peel weight, 11.64 to 17.10 mm for seed width in 'x' axis and 9.69 to 16.31 mm for seed width in 'y' axis. Significantly maximum fruit weight was noted in Gandaki Sampada (36.85 g), Gandaki Lalima (28.99 g) and Bedana (25.92 g). Fruit size also varied significantly among genotypes and maximum fruit length was observed in Gandaki Lalima (46.47 mm) followed

Table 1 Analysis of variance for quantitative characters in different litchi genotypes

Genotype	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Pulp weight (g)	Pulp thick-ness (mm)	Seed weight (mm)	Peel thick-ness (mm)	Peel weight (mm)	Seed length (mm)	Seed width-x (mm)	Seed width-y (mm)	TSS (°Brix)	Yield (kg/ tree)
Shahi	24.35	41.65	35.99	17.09	8.44	3.58	1.15	3.68	25.35	15.98	13.66	21.79	61.67
China	20.62	40.78	33.70	12.14	7.53	3.98	1.64	4.50	30.64	15.29	13.64	19.24	68.45
Gandaki Lalima	28.99	46.47	32.21	18.34	8.33	4.40	2.14	7.04	30.42	15.98	12.52	18.17	64.76
Bedana	25.92	15.62	15.66	19.91	13.20	1.48	1.48	4.53	18.31	12.07	10.93	20.56	43.72
Gandaki Sampada	36.85	43.89	41.92	29.32	13.47	1.19	1.51	5.99	20.23	11.64	9.69	20.00	63.27
Gandaki Yogita	17.61	31.77	31.94	12.84	9.30	1.51	0.82	3.61	19.13	11.23	10.55	18.99	37.29
Longia	17.31	38.07	31.97	11.37	6.85	2.02	1.28	3.91	24.37	12.07	10.65	19.71	49.38
Rose Scented	23.75	38.04	30.14	15.65	7.45	4.19	1.57	4.50	25.74	15.50	13.50	19.39	54.29
Ajhauli	22.40	41.42	35.91	13.08	7.20	4.21	1.39	4.76	31.73	15.25	12.43	19.99	59.24
Bombai I	17.18	38.09	30.93	9.11	5.62	4.02	1.56	4.06	29.70	14.16	12.40	18.73	65.73
Bombai II	20.61	40.29	33.38	9.03	7.97	3.23	1.60	4.96	31.05	15.62	12.59	20.43	66.25
Purbi	20.29	38.01	34.89	11.90	8.70	3.53	1.74	4.28	28.80	14.96	11.39	18.86	73.51
Trikolia	24.72	39.56	35.64	17.57	7.88	3.47	1.47	3.68	24.69	15.33	13.63	19.27	67.24
Mandraji	22.91	41.26	34.80	12.48	7.99	4.30	1.64	4.55	31.18	16.53	13.10	16.57	55.21
Dehradun	15.65	33.14	33.80	8.23	7.96	3.02	1.71	3.86	22.09	15.26	13.83	15.54	48.44
Green	25.40	37.06	37.47	12.13	8.50	3.82	0.96	3.30	22.90	17.10	14.73	20.12	57.26
Kasailia	16.17	31.69	29.70	8.67	7.95	2.73	1.45	3.45	21.29	14.79	13.36	20.63	45.32
Dehra Rose	22.54	36.83	33.80	13.57	6.50	3.75	1.03	3.86	22.94	16.32	16.31	20.15	52.53
Sharguja Sel.	20.63	40.92	33.65	12.90	7.03	3.32	1.10	4.42	21.37	14.99	14.03	19.63	38.39
CHL 3	20.99	42.80	33.87	13.20	7.36	4.06	1.86	3.73	23.36	15.67	12.77	19.09	63.51
CHL 5	19.85	39.20	32.79	12.36	6.97	3.50	1.95	3.98	30.15	15.55	11.72	20.00	56.21
CHES II	18.83	37.99	33.30	10.51	6.60	3.72	1.63	3.83	29.60	15.67	11.92	19.99	48.25
Mean	21.98	37.93	33.07	13.70	8.13	3.32	1.48	4.29	25.68	14.86	12.70	19.40	56.36
CD (P=0.05)	2.88	2.16	5.33	0.75	0.74	0.15	0.04	0.31	14.12	0.88	0.66	0.33	4.20
CV (%)	8.03	4.03	7.26	6.58	10.99	12.31	14.83	13.58	15.22	6.55	6.68	3.06	4.51

by Gandaki Sampada (43.89 mm) which was *at par* with CHL 3 (42.80 mm). However, fruit length was observed maximum in Gandaki Sampada (41.92 mm) followed by Green (37.47 mm) that was *at par* with Ajhauli (35.91 mm) and Trikolia (35.64 mm). Pulp weight was maximum in Gandaki Sampada (29.32 g) and Bedana (19.91 g), which also had the maximum pulp thickness and pulp content. Seed weight was the lowest in Gandaki Sampada (1.19 g), Bedana (1.48 g) and Gandaki Yogita (1.51 g) while the highest seed weight was recorded in Gandaki Lalima (4.40 g) that was *at par* with Mandraji (4.30 g) followed by Ajhauli (4.21 g) and Rose Scented (4.19 g). Peel thickness was minimum in Gandaki Yogita (0.82 g) followed by Green (0.96 g), which also registered the lowest peel weight. A significant variation in seed size was also observed. Minimum seed length was noted in Bedana (18.31 mm), Gandaki Yogita (19.13 mm) and Gandaki Sampada (20.22 mm), which also recorded the lowest seed width in 'x' and 'y' axis. The maximum TSS was observed in Shahi (21.79 °Brix) while TSS above 20 °Brix was recorded in Kasailia, Bedana, Bombai II, Dehra Rose and Green and minimum TSS was recorded in Dehradun (15.54 °Brix). The maximum yield (kg/tree) was recorded in Shahi (73.51), followed by China (68.45), Trikolia (67.24), Bombai-II (66.25) and Bombai-I and minimum in Gandaki Yogita (37.29) and Sharguja Selection (38.39).This variation observed in the present study can be attributed to genotypes and was in agreement with Rai *et al.*(2002) and Singh and Nath (2015).

Genotypic variability

Assessment of existing variability is a prerequisite in breeding program for selecting desirable genotypes. The range of variation, average mean performance, genotypic and phenotypic coefficients of variation, heritability and genetic advance (Table 2) revealed a wide range of variability for most characters studied. Phenotypic and genotypic coefficients of variation were high for pulp weight (32.86 and 31.11%), seed weight (30.56 and 27.93%), peel thickness (25.07 and 20.21%), pulp thickness (24.79 and 22.22%) and fruit weight (22.65 and 21.17%) and moderate to low for other traits. The estimates of GCV were lower in magnitude than PCV and the range was nominal indicating that there is lesser influence of environment on the traits studied and showed consistency in their expression irrespective of growing conditions. Moderate PCV but low GCV was recorded for seed width in 'x' axis while low PCV and GCV were observed for TSS. These observations were in agreement with the findings of Attri *et al.* (1999) and Patel *et al.* (2015) who reported high PCV and GCV for fruit length, fruit diameter, fruit weight and seed per cent. From the foregoing discussions, it is clear that these characters offer good scope for selection in litchi. The higher values of both PCV and GCV for various traits like pulp weight, seed weight, peel thickness, pulp thickness and fruit weight indicate that greater improvement can be expected through selection based on these characters. However, the genotypic coefficient of variation does not offer full scope to estimate the variation that is heritable in nature and therefore, estimation of heritability becomes necessary.

Heritability and genetic advance

Since most of the desired traits like yield are quantitative in nature, complex in their inheritance and greatly influenced by environmental conditions, heritability can play a useful role to estimate the scope of improvement by selection. This indicates that selection will be effective for selecting genotypes having traits with high heritability which are useful in predicting the expected progress to be achieved. This is because there would be a close correspondence between the genotypes and the phenotype due to smaller environmental effects. As depicted in Fig 1, the heritability in broad sense was more than 80% for fruit yield (93.86%), fruit length (94.07%), fruit weight (87.43%), pulp weight (89.58%), pulp thickness (80.34%), seed weight (83.54%) and TSS (82.63%) while seed length had low heritability (48.14%). The high heritability indicates that the traits under

Table 2 Estimates of various genetic parameters of litchi genotypes

Parameter	Range	Mean	PV	PCV	GV	GCV	h2	h2 (%)	GA	GA (%)
Fruit weight (g)	15.65-36.85	21.98	24.78	22.65	21.66	21.17	0.87	87.43	8.96	40.78
Fruit length (mm)	15.62-46.47	37.93	39.46	16.56	37.12	16.06	0.94	94.07	12.17	32.09
Fruit width (mm)	15.66-41.92	33.07	25.78	15.36	20.01	13.53	0.78	77.63	8.12	24.56
Pulp weight (g)	8.76-18.28	14.33	22.18	32.86	19.87	31.11	0.90	89.58	8.69	60.65
Pulp thickness (mm)	5.62-13.47	8.13	4.06	24.79	3.26	22.22	0.80	80.34	3.33	41.03
Seed weight (g)	1.19-4.30	3.36	1.05	30.56	0.88	27.93	0.84	83.54	1.76	52.59
Peel thickness (mm)	0.82-2.14	1.48	0.14	25.07	0.09	20.21	0.65	64.98	0.50	33.55
Peel weight (g)	3.30-7.04	4.29	0.96	22.83	0.62	18.35	0.65	64.62	1.30	30.39
Seed length (mm)	18.31-31.73	25.68	29.47	21.14	14.19	14.67	0.48	48.14	5.38	20.96
Seed width in x axis (mm)	11.64-17.10	15.10	3.46	12.32	2.12	9.65	0.61	61.39	2.35	15.58
Seed width in y axis (mm)	9.69-16.31	12.70	2.80	13.18	2.08	11.36	0.74	74.32	2.56	20.17
TSS (°Brix)	15.54-21.79	19.40	2.03	7.35	1.68	6.68	0.83	82.63	2.43	12.51
Yield (kg/tree)	37.29-73.51	56.36	105.10	18.19	98.64	17.62	0.94	93.86	19.82	35.17

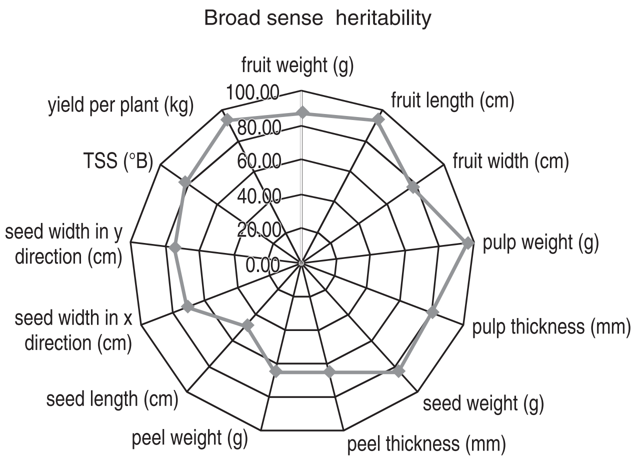

Fig 1 Graphical representation of heritability for different characters.

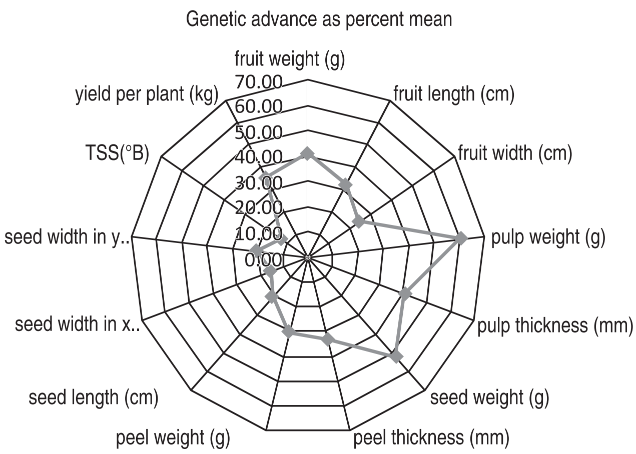

Fig 2 Graphical representation of genetic advancement as percentage of mean 5%.

study had great scope for genetic improvement. Rajan *et al.* (2009) also observed high heritability for different characters in several fruit crops. Moderate to low estimates indicate a limited scope of improvement through selection. Hence, computation of heritability alone will not be sufficient to bring about an efficient improvement in fruit traits unless there is a higher genetic gain, involving additive gene action which can be achieved through selection.

Estimated heritability associated with genetic advance is more reliable than heritability alone for predicting the impact of selection. A high heritability coupled with high genetic advance gives the most effective criteria for selection (Johnson *et al.* 1955). In the present study, higher heritability estimates accompanied with greater genetic advance were observed for fruit weight, fruit length, fruit width, pulp weight, pulp thickness, seed weight, peel thickness, peel weight, seed width in 'y'axis and yield/plant (Fig 2), indicating that these characters are exhibiting additive gene action and phenotypicselectionmay be more fruitful for all these traits.

High values of heritability for the traits clarified that they were least affected by environmental modification and selection based on phenotypic performance would be reliable. Similar findings were also reported by several workers (Rajan *et al.* 2009, Srivastava *et al.* 2014)who reported high heritability with high genetic gain for different attributes in other fruits crops.

Principal components analysis

Principal component analysis together with biplot allows reducing the dimensionality of interrelated variables and visualizes the trait-genotypes relationships. The first (PC1: 34%), second (PC2: 31%), third (PC3: 10%) and fourth (PC4: 10%) principal components with eigen values above unity explained the total variability. Together, they explained 85.20% of the total variation (Table 3). The traits that contributed most weight to the first principal component axis were seed weight (0.449), seed width in 'x' axis (0.422), seed width in 'y' axis (0.335), fruit length (0.347) and seed length (0.34). These characters are relevant criteria for selection of genotypes with big fruit size. The second principal component axis was associated mainly with fruit weight (0.485), pulp weight (0.455), peel weight (0.411), pulp thickness (0.343) and yield/plant (0.357). This component reflects that there is a strong genetic correlation between traits responsible for higher yield. The traits that contributed most weight to the third principal axis is peel thickness (0.545), whereas seed width in 'y' axis (0.509) and TSS (0.609) contributed the most weight to the fourth principal component axis.

Fig 3 shows the association among various traits. Here, the angle size between two or more traits is directly proportional to correlation between these characters, that is, the closer the traits are to each other, the higher the correlation. Consequently, a high correlation was observed between traits related to seed weight, seed width in 'x'

Table 3 Eigen values and percent of variation in respect of 13 characters of litchi as explained by the first 4 principal components

Trait	PC1	PC2	PC3	PC4
Fruit weight	0.022	0.484	-0.018	0.085
Fruit length	0.347	0.149	-0.368	-0.316
Fruit width	0.263	0.171	-0.546	-0.227
Pulp weight	0.142	0.455	-0.059	0.069
Pulp thickness	0.307	0.343	0.064	0.087
Seed weight	0.449	-0.038	0.185	0.089
Peel thickness	0.121	0.291	0.545	0.019
Peel weight	0.059	0.411	0.226	-0.196
Seed length	0.340	-0.040	0.234	-0.256
Seed width (x)	0.422	-0.030	0.125	0.262
Seed width (y)	0.335	-0.045	0.001	0.509
TSS	-0.084	0.056	-0.289	0.609
Yield/plant	0.249	0.357	-0.149	0.134
Eigen values	2.089	2.0171	1.157	1.141
Proportion of variance (%)	33.50	31.30	10.30	10.00
Cumulative proportion (%)	33.60	64.90	75.20	85.20

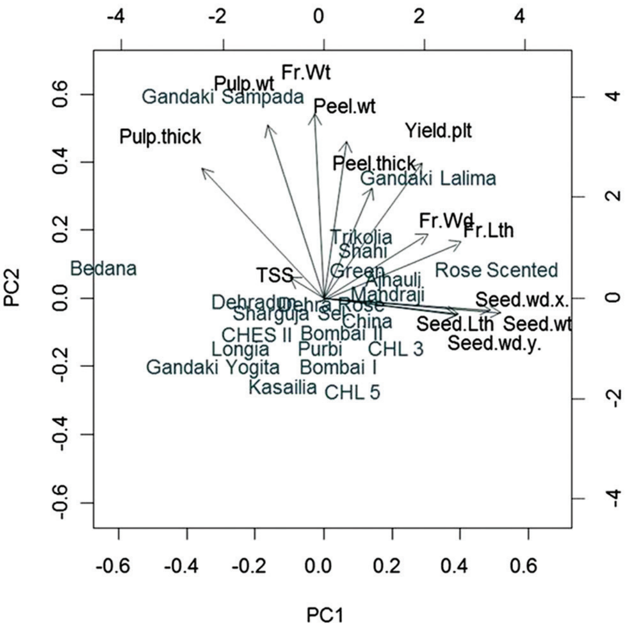

Fig 3 PCA plot showing the association among traits correlated with the first and second principal components, accounting for 33.50% and 31.30% of total variation, respectively.

axis, seed width in 'y' axis and seed length and maximum genotypes were found clustering in PC1 under the influence of these traits. A high correlation was also observed between traits related to fruit weight, pulp weight, pulp thickness and peel weight which are responsible for discriminating Gandaki Sampada, high in pulp content, from the rest of the genotypes.These results were consistent with findings of Marboh *et al.* (2015) and Ranpise and Desai (2003) in citrus in which genotypes were classified together on the biplot based on fruit attributes. The character contributing the maximum to the divergence should be given greater emphasis for selection in breeding.

It could be concluded that the genotypes understudy exhibited morphological variability and genetic diversity in terms of fruit characteristics. This variability and diversity holds key in future litchi breeding programmes. The higher values of both PCV and GCV for various traits like pulp weight, seed weight, peel thickness, pulp thickness and fruit weight indicate that greater improvement can be achieved through selection based on these characters. High heritability estimates coupled with high genetic advance observed for fruit weight, fruit length, fruit width, pulp weight, pulp thickness, seed weight, peel thickness, peel weight, seed width in 'y'axis and yield/plant were indicative of additive gene action and selection based on these characters would be more reliable. The characters with high heritability coupled with high genetic advance further indicated the possibility of making selections in earlier generations. Combining the results from the PCA, ANOVA and variability and heritability estimates, the most important traits identified which are useful in discriminating genotypes with high yield were fruit weight, pulp weight, peel weight, peel thickness, seed weight and seed size.

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