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Genetic variability studies in tamarind (*Tamarindus indica* L.)

Shivam Mishra, AM Bhosale, PA Sasane and Kharat MA

Abstract
Genetic variability revealed that the characters like yield per plant, pod length, pod weight, pulp weight, seed weight, titratable acidity, ascorbic acid, shell weight, rag weight, beak length, rag per cent, real pulp value, pulp: seed, pulp: shell, number of pods kg^{-1}, seed number, edible: non-edible, TSS and non-reducing sugar showing high GCV, heritability and are least affected by environment and governed by additive gene action. Hence, selection will be effective for improvement of these traits. The high value of genetic advance recorded for the numbers of pods per Kg.

Keywords: Genetic variability, heritability, genetic advance, gene action

1. Introduction
Tamarindus indica L. is a economically valuable and multipurpose tropical fruit tree. It is mainly used for its fruits (eaten fresh or processed), seed and timber. Fruits and seeds are also used for non- food use. The botanical name of Tamarind is *Tamarindus indica* L. (syns. *T. occidentalis* and *T. occidentalis*) belongs to dicotyledon, order: fables, family Leguminosae (the third largest family of flowering plant) and sub family caesalpinioideae and the genus Tamarindus is monotypic, containing the sole species T.indicus. (K. El- Siddig *et al*., 2006) [15]. It has diploid chromosome number 2n = 24. Tamarind is now grown in 54 countries around the world, including 18 nations where it is native and 36 places where it has become naturalised. The most important aspects of tamarind in India during 2018-19 with an area of 46,000 hectares and a production of 1,89,000 MT and a productivity 4.1 MT/ha is the world's largest tamarind grower. The area, production and productivity of tamarind in India during 2019-20 (2nd Advance estimate) was 47000 ha, 189000 MT and 4.0 MT/ha respectively (Spices Board India &Ministry of Agriculture and Farmer Welfare, Govt. of India, (ON2287) & past issues. The tamarind exported by India during 2019-20 in monetary value was of 22,19,85,418.10 rupees (Ministry of Commerce and Industry). The production of tamarind in Maharashtra during 2017-18 was 7.85 lakh tonnes (APEDA Agri. Exchange.). The tamarind is highly cross pollinated and seed propagated crop; hence the wide range of variation is common in the tamarind. So, the individual plant has variation within the population. Therefore, for the improvement of breeding programme we may be concentrated on the best tree which suited to the same ecological condition (Rajamanickam, 2020) [16]. This variability could be caused by genetics, the environment, or both. As a result, it may be advantageous to focus exclusively on the best trees in relation to their neighbours and trees may be chosen within ecological zones. The level of variability and quantitative estimation for each character would indicate the tree's potential and the possibility of increasing desirable and economic traits through selection. Information on the nature and extent of variation present as well as the relationship between characteristics and yield can be used to select desirable clones. Understanding the extent of variation across genotypes and applying them to boost pod and pulp output is required before creating any selection programme. (Nicodemus and Colleagues, 1997) [10]. Tamarind is a widely cross-pollinated crop and choosing plus trees and clone propagation can result in major improvements because research on variability, association and divergence studies on Tamarind in the Marathwada region is sparse, so the present research carried out with following objective variability among different genotypes will be helpful in conserving germplasm from being eroded and its further utilization in tamarind improvement programme.

2. Material and Method
The present research was conducted at Parbhani Campus during 2020-21. Experiment was consisting of study of characteristics of 30 seedling originated tamarind genotypes.

Thirty tamarind genotypes are maintained at the campus of Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani Maharashtra. The analytical work was done at Analytical Laboratory, University Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani Maharashtra.

1.	**Name of the crop**	:	**Tamarind (*Tamarindus indica* L.)**
2.	Family	:	Fabaceae
3.	Year of study	:	2020-21
4.	Number of Observations	:	30 genotypes
5.	Replications	:	Two
6.	Season	:	1 (One Season)
7.	Design	:	Randomized Block Design

The observation to be recorded are for tree characteristics stem girth, trunk length, shape of canopy, bark colour, season ability for fruit (pod) characteristics pod length, pod thickness, pod width, pod circumference, pod weight, number of pod kg^1,shell weight, rag (fibre) weight, weight of pulp, real pulp value, pulp recovery, shell percentage, rag (fibre) percentage, pulp: shell ratio, pulp: seed ratio, yield per plant, pod shape, pod size, pod colour, pulp colour, pod beak, number of fibre per pod for seed character seed length, seed width, seed thickness, weight of seed, seed number, seed colour for biochemical analysis of pulp total soluble solids, titratable acidity of the pulp, Ascorbic acid, reducing sugar, non-reducing sugar, total sugar. The data obtained from the present investigation was analyzed as per the procedure suggested by Panse and Sukhatme (1978).

3. Estimation of genetic variability parameters

Genotypic, phenotypic coefficient of variation

The genotypic (GCV) and phenotypic (PCV) of variation was calculated by the formulae given by Burton (1952) [2].

$$GCV = \frac{\sqrt{Genotypic\ variance}}{X} \times 100$$

$$PCV = \frac{\sqrt{Phenotypic\ variance}}{X} \times 100$$

Where,

X= Mean of a character.

To categories the magnitude the scale used as explained by Shivasubramanyam and Menon (1973) was as follows:
> 20% high
10-20% moderate
< 10% low

Heritability (h^2)

Heritability percentage in broad sense was calculated by the formula as suggest by Johnson *et al*. *et al* (1955) [7].

$$h^2 = \frac{Vg}{Vp} \times 100$$

Where,
h2 = Heritability in broad sense. Vg = Genotypic variance.
Vp = Phenotypic variance.

To categories the magnitude the scale used as explained by Robinson *et al.* (1951) [17] as follows:
> 60% high
30-60% moderate
< 30% low

Genetic Advance (GA)

Improvement in the mean genotypic value of selected plants over the parental population is called Genetic Advance. It was calculated by following formula given by Johnson *et al.* (1955) [7].

Genetic Advance (GA) $=h^2\sqrt{Vp}$ x K Where,
h^2 = heritability in broad sense
$\sqrt{Vp}$ = phenotypic standard deviation
K = selection differential at 5% level and value of K = 2.06.

4. Result and Discussion

Variability Parameter

The analysis of variance revealed a significant variance (Table 1) among the genotype for all the character *viz*., yield per plant (2.391**), pod weight (31.97**),weight of pulp (6.238**),seed weight (5.135**), shell weight (2.309**),fiber weight (0.052), pod length (23.641**),pod weight (2.386**), pod thickness (0.095**), pod circumference (1.042**), number of pod (856.467**),seed number (7.242**), pulp recovery (56**), shell percentage (31.07**), rag percentage (4.507**), seed percentage (39.326**),real pulp value (1.648**), pulp: shell ratio (1.025**), pulp: seed ratio (0.259), edible: non-edible ratio (0.071),beak length (0.0003), number of fiber per pod (1.729**), seed length (7.691), seed width (8.646**), seed thickness (0.4005**), TSS (47.76**), titratable acidity (13.068**) that presence of wide spectrum of variability among the genotype. The mean value of all character present in (Table-2) and Genetic variability parameters like phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and genetic advance as percent of mean at 5% are mentioned in. Estimation of mean for all the characters studied where, a wide range was observed The maximum pod length was expressed in genotypes VNMKV-19 (19.66 cm) while genotype VNMKV-2 (8.12 cm) exhibited minimum pod length. These findings are in agreement with the results of Divakara *et al*., (2012) [18] and Jitendar Singh (2020) [19]. The maximum pod thickness was expressed in genotype VNMKV-8 (1.66 cm) while genotype VNMKV-1 (1.03 cm) exhibited minimum pod thickness. These findings are in agreement with the result of Prabhushankar and Melanta (2004) [13] and Bhogave *et al*., (2018) [1] in tamarind. The maximum pod width was recorded in genotype VNMKV-28 (7.92 cm) while genotype exhibited minimum pod width in VNMKV-21 (4.00 cm). These findings are in agreement with the result Divakara (2008) [3] in tamarind. The maximum pod circumference was recorded in genotype VNMKV-19 (7.54 cm) while genotype VNMKV-6 (4.85 cm) exhibited minimum pod circumference. These findings are in agreement with the result of Divakara (2008) [3] and Pooja (2018) [11] in tamarind. The data revealed that the maximum pod weight was 21.52 g, maximum pod weight was recorded in genotype VNMKV-29 (21.52 g). However, it was minimum in VNMKV-21 (8.18 g) genotype. These findings are in accordance with the findings of Rao and Subramanyam (2010) [21] and Sharma *et al*., (2015) [14] in tamarind. The maximum pulp weight was recorded in VNMKV-29 (10.27 g) genotype while genotype VNMKV-21 (4.09 g) exhibited minimum pulp weight. These findings are in agreement with the result of Prabhushankar *et al.,* (2004) [13], Prasad *et al.,* (2009) [22] and Divakara *et al.,* (2012) [18]. Maximum shell weight was recorded in genotype VNMKV-19 (5.43 g) However, it was minimum in genotype VNMKV-21 (1.33 g). These findings are in accordance with the findings of Rao and Subramanyam (2010) [21] and Pooja (2018) [11] of tamarind. The maximum Fibre weight was expressed in VNMKV-11(1.02 g) genotype while genotype VNMKV-15 (0.25 g) exhibited minimum fibre weight. These findings are in agreement with the result of Prabhushankar *et al.,* (2004) [13], Divakara *et al.,* (2012) [18] and Bhogave *et al*., (2017) in tamarind. maximum seed weight per pod was recorded in genotype VNMKV-28 (7.99 g)however, it was minimum in VNMKV-21 (2.13g) genotype. These findings are in accordance with the findings of Fandohan *et al*., (2011) [4] and Pooja (2018) [11] in tamarind. The maximum number of pods per kg was recorded in genotype VNMKV- 21(122.25) while genotype VNMKV-29 (46.47) exhibited minimum number of pods per kg. These findings are in agreement with the result of Bhogave (2017) in tamarind. The maximum seed number was recorded in genotype VNMKV-27 (11.55) while genotype VNMKV-21 (4.45) exhibited minimum seed number. These findings are in agreement with the result of Ganacharya (2005) [5], Divakara (2008) [3] and Fandohan *et al*., (2011) [4] in tamarind. The data revealed that the maximum pulp recovery per cent was recorded in VNMKV-10 (56.18%) however, it was minimum in VNMKV-16 (36.53%) genotype. These findings are in accordance with the findings of Prabhushankar *et al.,* (2004) [13] and Bhogave (2017) in tamarind. The maximum shell per cent was recorded in genotype VNMKV-19 (26.50%) while genotype VNMKV-9 (14.40%) exhibited minimum shell per cent. These findings are in agreement with the result of Kotecha and Kadam (2002) [23], Sharma *et al*., (2015) [14] in tamarind. Maximum rag per cent was recorded in genotype VNMKV-21 (7.70%) however, it was minimum in genotype VNMKV-15 (1.49%) g. These findings are in accordance with the findings of Divakara (2008) [3] and Pooja *et al*., (2018) [12] in tamarind. Maximum seed per cent was recorded in genotype VNMKV-16 (42.06%). However, it was minimum in genotype VNMKV-5 (24.48%). These findings are in accordance with the findings Prabhushankar *(*2001) [13], Pooja *et al*.,(2018) [12] in tamarind. The maximum real pulp value was recorded in genotype VNMKV-24 (5.00) while genotype VNMKV-6 (1.68) exhibited minimum real pulp value. These findings are in agreement with the result of Bhogave (2018) [1] in tamarind. Maximum Pulp: Shell Ratio was recorded in genotype VNMKV-10 (3.88). However, it was minimum in genotype VNMKV-7 (1.47). These findings are in accordance with the findings of Bhogave (2017) in tamarind. Maximum edible: non-edible ratio was recorded in genotype VNMKV-10. However, it was minimum in VNMKV-16 (0.57) genotype. These findings are in accordance with the findings of Bhogave (2017) in tamarind. Maximum pulp: seed ratio was recorded in genotype VNMKV-5 (2.22). However, it was minimum in genotype VNMKV-16 (0.87). These findings are in accordance with the Bhogave (2017) in tamarind. The maximum beak length was expressed in VNMKV-26 (0.059 cm) genotype while genotype VNMKV-11 (0.01 cm) exhibited minimum beak length. These findings are in agreement with the result of Pooja *et al*., (2018) [12] in tamarind. The maximum seed length was expressed in genotype VNMKV-8 (16.90 mm) while genotype VNMKV-15 (9.7 mm) exhibited minimum seed length. These results are in accordance with the findings of Fandohan *et al.*, (2010) [24] in tamarind. The maximum seed width was recorded in genotype VNMKV-8 (14.65 mm) while genotype VNMKV-6 (6.45 mm) exhibited minimum seed width. These findings are in agreement with the result of Bhogave (2017) and Pooja *et al*., (2018) [12] in tamarind. The maximum seed thickness was recorded in genotype VNMKV-8 (7.71 mm) while genotype VNMKV-13 (6.04 mm) exhibited minimum thickness. These findings are in agreement with the result of Bhogave (2017) and Pooja *et al., (*2018) [12] in tamarind. The data revealed that the maximum TSS (^{0} Brix) was 30.57 ^{0}Brix, maximum TSS (^{0} Brix) was recorded in genotype VNMKV-28 However, it was minimum in genotype VNMKV-13 (11.18 ^{0}Brix). These findings are in accordance with the findings of Prabhushankar *et al*. (2004) [13], and Joshi *et al.* (2013) [8] Pooja *et al*., (2018) [12]. The maximum titratable acidity was recorded in genotype VNMKV-13 (12.29%) while genotype VNMKV-28 (3.03%) exhibited minimum titratable acidity. These findings are in agreement with the result of, Sharma *et al.,* (2015) [15] and Pooja *et al*., (2018) [12] in tamarind. The maximum ascorbic acid content was expressed in genotype VNMKV-17 (13.58 mg/100g) while genotype VNMKV-29 (5.86 mg/100g) exhibited minimum ascorbic acid content. These findings are in agreement with the result of Sharma *et al.* (2015) [15] and Pooja *et al*., (2018) [12] in tamarind. The maximum pH was expressed in genotype VNMKV-28 (3.69) while genotype VNMKV-13 (2.01) exhibited minimum pH. These findings are in agreement with the result of Pooja *et al*., (2018) [12] in tamarind. The maximum Reducing sugar was recorded in genotype VNMKV-28 (35.26%) while genotype VNMKV-21(19.43%) exhibited minimum reducing sugar. These findings are in agreement with the result of Bhogave (2017) in tamarind. The maximum non-reducing sugar was recorded in genotype VNMKV-20 (13.34%) while genotype VNMKV-13(4.64%) exhibited minimum non -reducing sugar.These findings are in agreement with the result of Divakara (2009) [20] and Pooja *et al*., (2018) [12] in tamarind. Maximum total Sugar was recorded in genotype VNMKV-28 (48.29). However, it was minimum in VNMKV-13 (25.52%) genotype. These findings are in accordance with the Divakara (2009) [20] and Pooja *et al*., (2018) [12] in tamarind. maximum Yield per plant (q) was recorded in VNMKV-8 (5.72 q) genotype. However, it was minimum in VNMKV-21 (0.52 q) genotype. These findings are in accordance with the Kotecha and Kadam (2002) [23], Kale (2010) [9] and Gawade (2013) [6] in tamarind.

The estimates of Phenotypic coefficient of variation (PCV) was high (>20%) for yield per plant (58.66%), rag per cent (43.01%), beak length (41.47%), shell weight (34.94%), seed weight (33.89%), titratable acidity (32.79%), rag weight (32.71%), pulp: shell (30.45%), real pulp value (29.63%), number of pods $kg^{-}1$ (29.03%), TSS (27.18%), pod weight (26.51%), pulp weight (26.09%), ascorbic acid (25.97%), non- reducing sugar (25.96%), seed number (25.36%), pulp: seed (24.22%), pod length (23.67%) and edible: non edible (22.51%). The value of Phenotypic coefficient of variation was moderate (10-20%) for pod width (19.94%), shell per cent (19.89%), no of fibres per pod (19.54%), seed width (18.54%), reducing sugar (17.87%), total sugars (17.61%), pod thickness (16.91%), pH (15.77%), seed per cent (14.79%), seed length (14.38%), pulp per cent (11.88%), pod circumference (11.29%). Low Phenotypic coefficient of variation (<10%) was estimated low for seed thickness (6.99%)

The estimates of genotypic coefficient of variation (GCV) was high (>20%) for yield per plant (57.84%), shell weight (34.74%), seed weight (33.75%), pod length (23.66%), pod weight (26.47%), pulp weight (26.04%), titratable acidity (32.76%), ascorbic acid (23.12%), rag weight (32.38%), beak length (32.18%), rag per cent (42.52%), real pulp value (29.32%), pulp: seed (23.41%), pulp: shell (29.81%), number of pods kg-1 (28.94%), seed number (25.36%), edible: non-edible (22%), TSS (27.13%). and non-reducing sugar (25.84%). The value of genotypic coefficient of variation was moderate (10-20%) for pod thickness (16.75%), shell per cent (19.15%), number of fibres per pod (18.47%), pod width (19.92%), pH (15.51%), pod circumference (11.23%), pulp per cent (11.4%), seed per cent (13.82%), seed length (14.20%), seed width (18.54%), total sugars (17.61%), reducing sugar (17.85%). Low genotypic coefficient (<10%) of variation was estimated for seed thickness (6.57%). The magnitude of phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) in all traits. The other researchers worked on variability in tamarind and other fruit crops made similar observations were Divakara (2008) [3], Singh and Nandini (2014), Bhogave *et al*., (2018) [1] in tamarind.High heritability was observed for yield per plant (97.2%), pod length (100%), pod weight (99.7%), pulp weight (99.6%), seed weight (99.2%), shell weight (98.9%), real pulp value (97.9%), number of pods kg^{-}1 (99.3%), seed number (100%), seed length (97.6%), ascorbic acid (79.2%), TSS (99.8%), total sugars (99.9%), reducing sugar (99.8%), non-reducing sugar (99.1%), pod width (99.8%), rag weight (97.7%), pulp percent (92.6%), seed per cent (87.3%), seed thickness (88.2%), seed width (99.9), pod circumference (98.90%), pod thickness (99.64%), shell per cent (92.7%), rag per cent (97.7%), pulp: seed (93.5%), pulp: shell (95.8%), edible: non edible (95.5%), beak length (60.2%), number of fibres per pod (89.4%), titratable acidity(99.8%) and pH (96.8%). Divakara (2009) [20], and Bhogave *et al*., (2018) [1] found high heritability with many characters in tamarind.

Higher estimates of genetic advance (>20) was exhibited for number of pods kg-1 (42.42). A moderate estimate of genetic advance (10-20) was exhibited for total sugars (13.13). pulp per cent (10.28) and TSS (10.03). Low estimated of genetic advance(<10) was exhibited for pod length (7.08), pod weight (8.21), Yield per plant (2.20), pulp weight (3.62), seed weight (3.28), pod circumference(1.47), shell weight (2.19), real pulp value (1.84), seed number (3.91), seed length (3.96), seed width (4.28) ascorbic acid (4.16), reducing sugar (9.70), non reducing sugar (5.19), pod width (2.24), rag weight (0.32), seed per cent (8.24), seed thickness (0.83), pod thickness (0.44), shell per cent (7.66), rag per cent (3.04), pulp: seed (0.70), pulp: shell (1.42), edible: non edible (0.37), beak length (0.01), number of fibres per pod (1.76), titratable acidity (5.2), pH (0.89). Many workers have observed varying magnitude of genetic advance for different characters in several fruit crops like Divakara (2008) [3], Bhogave *et al*., (2018) [1] in tamarind.

Table 1: Analysis of variance for characters of Tamarind

Sr. No	Characters	Mean sum of squares		
		Replications (d.f.=1)	Treatment (d.f.=29)	Error (d.f=29)
1	Yield per plant (q)	0.019	2.391**	0.034
2	Pod weight(g)	0.002	31.971**	0.051
3	Weight of pulp(g)	0.003	6.238**	0.011
4	Seed weight(g)	0.047	5.135**	0.021
5	Shell weight(g)	0.020	2.309**	0.012
6	Fibre weight(g)	0.0004	0.052	0.0005
7	Pod length (cm)	0.0001	23.641**	0.0004
8	Pod width(cm)	0.000015	2.386**	0.002
9	Pod thickness(cm)	0.0002	0.095	0.00017
10	Pod circumference (cm)	0.009	1.042**	0.005
11	Number of pods	0.566	856.467**	2.806
12	Seed Number	0.000082	7.242**	0.00019
13	Pulp Recovery (%)	0.0004	56**	2.148
14	Shell percent (%)	0.715	31.07**	1.179
15	Rag Percentage (%)	0.0052	4.507**	0.051
16	Seed percentage	2.847	39.326**	2.667
17	Real pulp value	0.001	1.648**	0.017
18	Pulp: shell ratio	0.00006	1.025**	0.021
19	Pulp: Seed ratio	0.015	0.259	0.008
20	Edible: Non-edible ratio	0.001	0.071	0.001
21	Beak length(cm)	0.0001	0.0003	0.00007
22	No of fibres /pod	0.051	1.729**	0.096
23	Seed Length(mm)	0.032	7.691**	0.093
24	Seed width(mm)	0.007	8.646**	0.002
25	Seed Thickness	0.00004	0.4005*	0.025
26	TSS(°BRIX)	0.0006	47.76**	0.091
27	Titratable Acidity (%)	0.000007	13.068**	0.014
28	Ascorbic acid content	0.967	11.676**	1.353
29	pH	0.004	0.400*	0.006
30	Reducing Sugar (%)	0.029	44.503**	0.0391
31	Non-Reducing Sugar (%)	0.007	12.896**	0.06
32	Total Sugar (%)	0.064	81.336**	0.025

*Significant at 5%= 0.355, ** Significant at 1%=0.455

Table 2: Mean performance of different quantitative traits of 30 tamarind genotypes.

Sr. No.	Yield per plant (q)	Pod weight (g)	Weight of pulp (g)	Seed weight (g)	Shell weight (g)	Fiber weight (g)	Pod length (cm)	Pod width (cm)	Pod thickness (cm)	Pod circumference (cm)	Number of pods
VNMKV-1	1.56	13.36	5.81	4.19	3.10	0.27	14.62	4.67	1.03	5.635	74.87
VNMKV-2	1.81	14.33	5.97	5.33	2.72	0.33	8.13	5.23	1.51	7.19	69.785
VNMKV-3	2.23	19.50	7.57	6.55	4.92	0.46	18.74	5.99	1.64	6.285	51.295
VNMKV-4	0.97	9.55	4.55	3.03	1.63	0.35	13.27	4.20	1.03	7.19	104.715
VNMKV-5	0.86	9.90	5.34	2.42	1.66	0.49	10.54	4.07	1.03	6.765	101.105
VNMKV-6	1.03	11.15	4.34	3.91	2.58	0.34	16.00	4.44	1.09	4.855	89.695
VNMKV-7	1.69	13.05	4.90	4.42	3.34	0.39	9.87	4.87	1.21	5.925	76.665
VNMKV-8	5.72	17.73	7.48	5.14	4.58	0.54	17.71	7.42	1.66	7.225	56.41
VNMKV-9	1.24	12.31	6.79	3.44	1.77	0.32	12.66	4.57	1.14	6.35	81.255
VNMKV-10	1.10	10.63	5.97	2.76	1.54	0.38	12.37	4.91	1.075	5.11	94.19
VNMKV-11	1.23	13.51	5.52	3.55	3.42	1.02	13.55	4.92	1.14	7.48	74.02
VNMKV-12	1.50	14.13	5.68	4.62	3.28	0.56	13.55	5.00	1.315	6.98	70.805
VNMKV-13	1.64	15.05	6.87	4.73	2.85	0.61	15.35	5.07	1.42	6.66	66.455
VNMKV-14	1.17	11.38	5.27	3.94	1.64	0.54	12.55	4.68	1.055	6.44	87.925
VNMKV-15	1.91	16.72	7.84	4.91	3.72	0.25	16.88	5.70	1.175	5.665	59.835
VNMKV-16	1.63	17.45	6.38	7.34	3.36	0.39	17.22	5.25	1.285	6.405	57.31
VNMKV-17	1.92	20.75	9.19	6.36	4.52	0.69	17.42	5.61	1.34	6.835	48.195
VNMKV-18	1.94	15.38	6.94	4.23	3.67	0.55	17.24	5.56	1.295	5.755	65.045
VNMKV-19	4.18	20.49	8.22	6.22	5.43	0.63	18.46	7.85	1.655	7.54	48.805
VNMKV-20	0.64	8.97	4.79	2.32	1.35	0.52	8.70	4.80	1.05	5.925	111.565
VNMKV-21	0.53	8.18	4.09	2.13	1.33	0.63	9.45	4.01	1.04	7.22	122.255
VNMKV-22	1.35	13.16	6.49	3.23	2.89	0.56	13.19	5.27	1.255	7.49	75.99
VNMKV-23	1.35	11.74	5.17	3.28	2.83	0.47	12.90	4.52	1.145	6.7	85.19
VNMKV-24	2.05	19.59	9.90	5.63	3.47	0.60	17.73	6.56	1.43	5.835	51.045
VNMKV-25	2.88	19.72	9.91	5.01	4.31	0.51	18.67	6.84	1.545	6.465	50.71
VNMKV-26	2.29	17.37	7.70	6.44	2.88	0.36	17.88	6.87	1.385	5.87	57.57
VNMKV-27	1.66	16.23	6.53	5.52	3.59	0.61	12.94	5.93	1.145	5.24	61.625
VNMKV-28	3.18	21.47	9.43	7.99	3.62	0.44	18.91	7.93	1.645	6.385	46.58
VNMKV-29	3.51	21.52	10.28	7.59	3.27	0.40	19.67	6.72	1.5	6.3	46.47
VNMKV-30	1.62	18.50	8.43	5.98	3.33	0.77	9.73	4.97	1.58	6.545	54.075
Mean	1.8772	15.0928	6.7758	4.7375	3.0837	0.4967	14.5253	5.4782	1.2938	6.4088	71.3818
S.E.	0.1304	0.1602	0.0771	0.104	0.0803	0.0163	0.0148	0.0372	0.025	0.0536	1.1847
C.D. 5%	0.3772	0.4634	0.2229	0.3008	0.2323	0.0471	0.0427	0.1076	0.0723	0.1551	3.4265

Sr. No	Seed Number	Pulp Recovery (%)	Shell percent (%)	Rag Percentage (%)	Seed percentage (%)	Real pulp value	Pulp: shell ratio	Pulp: Seed Ratio	Edible: Nonedible	Beak lenghth (cm)	No of fibres /pod
VNMKV-1	5.55	43.45	23.195	2.025	31.385	2.52	1.875	1.385	0.77	0.035	5.55
VNMKV-2	6.6	41.635	18.95	2.25	37.175	2.49	2.2	1.125	0.715	0.025	4.075
VNMKV-3	7.7	38.815	25.215	2.345	33.61	2.94	1.54	1.155	0.635	0.045	5.57
VNMKV-4	6	47.6	17.07	3.665	31.665	2.17	2.785	1.51	0.91	0.03	4.25
VNMKV-5	5.4	53.935	16.81	4.96	24.48	2.88	3.225	2.225	1.17	0.025	7.14
VNMKV-6	7.15	38.89	23.09	3.005	35.035	1.685	1.685	1.11	0.635	0.03	4.1
VNMKV-7	4.9	37.565	25.57	2.995	33.88	1.84	1.47	1.11	0.6	0.015	4.24
VNMKV-8	5.95	42.195	25.81	3.045	28.96	3.155	1.635	1.455	0.73	0.045	5.755
VNMKV-9	9.2	55.175	14.4	2.56	27.925	3.745	3.855	1.975	1.23	0.035	4.83
VNMKV-10	5.5	56.185	14.46	3.54	26.055	3.355	3.885	2.195	1.285	0.015	3.65
VNMKV-11	8.7	40.86	25.32	7.55	26.275	2.255	1.615	1.56	0.69	0.01	3.75
VNMKV-12	5.5	40.18	23.23	3.93	32.675	2.28	1.73	1.23	0.675	0.03	4.225
VNMKV-13	8.3	45.655	18.955	4.02	31.405	3.14	2.42	1.455	0.84	0.045	4.615
VNMKV-14	7.05	46.325	14.41	4.685	34.605	2.44	3.22	1.34	0.865	0.035	4.115
VNMKV-15	4.45	46.905	22.24	1.495	29.38	3.68	2.115	1.595	0.885	0.025	4.99
VNMKV-16	8.95	36.535	19.225	2.195	42.06	2.325	1.905	0.87	0.575	0.02	4.18
VNMKV-17	8.85	44.295	21.785	3.3	30.63	4.07	2.03	1.445	0.795	0.025	4.74
VNMKV-18	7.45	45.145	23.84	3.545	27.485	3.13	1.895	1.64	0.825	0.05	3.58
VNMKV-19	6.85	40.105	26.5	3.04	30.36	3.295	1.515	1.32	0.67	0.025	6.61
VNMKV-20	8.05	53.455	15.045	5.81	25.84	2.56	3.595	2.07	1.15	0.015	4.19
VNMKV-21	4.45	50	16.265	7.7	26.045	2.045	3.075	1.92	1	0.055	6
VNMKV-22	8.2	49.28	21.925	4.235	24.545	3.195	2.25	2.005	0.97	0.035	4.57
VNMKV-23	11.1	44.055	24.07	4.005	27.9	2.28	1.83	1.575	0.79	0.04	5.485
VNMKV-24	7.65	50.51	17.715	3.04	28.74	5	2.855	1.76	1.02	0.05	5.675
VNMKV-25	6.7	50.23	21.82	2.56	25.38	4.98	2.305	1.98	1.01	0.03	6.54
VNMKV-26	8.85	44.335	16.55	2.06	37.08	3.415	2.68	1.195	0.795	0.055	5.25
VNMKV-27	11.55	40.215	22.095	3.73	33.99	2.625	1.82	1.185	0.67	0.05	4.495
VNMKV-28	7.995	43.9	16.835	2.04	37.215	4.14	2.605	1.18	0.78	0.045	4.99

VNMKV-29	9.7	47.75	15.17	1.835	35.245	4.905	3.15	1.355	0.915	0.035	3.98
VNMKV-30	10.75	45.59	17.98	4.135	32.31	3.845	2.535	1.41	0.835	0.045	5.55
MEAN	7.5015	45.359	20.1848	3.51	30.9778	3.0795	2.3767	1.5112	0.8478	0.034	4.8897
S.E	0.01	1.0364	0.7679	0.1602	1.1549	0.0936	0.1044	0.066	0.0286	0.0063	0.2198
CD%5	0.0288	2.9978	2.221	0.4633	3.3403	0.2707	0.302	0.191	0.0827	0.0182	0.6356

Sr. No	Seed Length (mm)	Seed Width (mm)	Seed Thickness (mm)	TSS (^{0}BRIX)	Titratable Acidity (%)	Ascorbic Acid Content mg/100g	pH	Reducing Sugar (%)	Non- Reducing Sugar (%)	Total Sugar (%)
VNMKV-1	11.6	8.75	6.21	14.29	9.31	8.665	2.575	23.04	10.25	33.29
VNMKV-2	13.85	10.35	6.405	16.585	7.635	8.245	2.955	24.14	8.985	33.125
VNMKV-3	10.7	8.95	6.295	15.735	7.355	9.44	2.98	23.675	7.7	31.375
VNMKV-4	12.55	11.25	6.145	14.63	9.635	9.53	2.64	23.045	5.655	28.7
VNMKV-5	14.95	14.45	6.935	13.555	10.335	10.225	2.445	22.02	6.445	28.465
VNMKV-6	9.9	6.45	6.105	15.61	7.895	13.125	2.71	23.665	10.96	34.625
VNMKV-7	14.9	11.8	6.59	18.94	6.87	7.175	3.1	28.04	10.19	38.23
VNMKV-8	16.9	14.65	7.715	21.605	5.61	12.275	3.22	33.37	9.17	42.54
VNMKV-9	12.35	10.6	6.255	24.34	4.58	11.67	3.435	33.8	8.745	42.545
VNMKV-10	14.2	11.45	6.08	21.495	5.41	11.375	3.275	33.175	7.655	40.83
VNMKV-11	15.1	10.525	6.585	12.75	10.87	9.685	2.425	21.63	6.315	27.945
VNMKV-12	12.73	9.785	6.42	13.57	10.68	9.935	2.47	22.06	6.545	28.605
VNMKV-13	13.81	9.27	6.04	11.18	12.29	12.97	2.01	20.885	4.64	25.525
VNMKV-14	13.28	7.28	6.44	14.17	9.915	8.835	2.6	22.905	12.32	35.225
VNMKV-15	9.7	10.83	6.44	15.05	7.525	11.955	2.755	23.52	9.935	33.455
VNMKV-16	14.1	13.54	6.44	18.34	6.545	12.535	3.15	27.02	9.21	36.23
VNMKV-17	11.65	10.775	6.155	15.85	8.105	13.58	2.67	23.995	12.87	36.865
VNMKV-18	14.6	12.675	6.3	15.675	9.115	12.895	2.295	23.635	11.375	35.01
VNMKV-19	14.58	12.54	6.18	19.475	6.265	7.365	3.185	29.16	12.72	41.88
VNMKV-20	12.395	9.825	7.44	22.89	5.09	6.125	3.385	31.91	13.34	45.25
VNMKV-21	15.815	13.25	7.39	12.475	11.24	9.345	2.325	19.43	7.06	26.49
VNMKV-22	10.565	9.1	6.35	22.88	4.225	12.48	3.52	32.67	12.165	44.835
VNMKV-23	14.235	10.81	6.83	27.305	3.17	12.475	3.555	34.095	12.01	46.105
VNMKV-24	13.665	13.08	6.815	12.52	10.92	11.23	2.425	20.495	6.6	27.095
VNMKV-25	16.25	13.6	7.15	18.88	8.695	6.625	2.66	27.065	11.025	38.09
VNMKV-26	16.45	11.48	7	17.305	8.905	7.355	2.64	24.515	11.76	36.275
VNMKV-27	14.2	10.01	6.385	17.935	9.135	7.935	2.595	25.965	12.32	38.285
VNMKV-28	15.8	14.075	7.24	30.57	3.03	6.305	3.69	35.26	13.03	48.29
VNMKV-29	14.55	11.405	6.76	27.16	4.005	5.865	3.545	31.15	11.405	42.555
VNMKV-30	16.2	13.79	6.68	16.955	9.58	7.58	2.555	26.705	11.725	38.43
MEAN	13.7192	11.2115	6.5925	17.9907	7.798	9.8267	2.8597	26.4013	9.8042	36.2055
S.E	0.2164	0.0385	0.1119	0.2141	0.0847	0.8227	0.0571	0.1399	0.174	0.1121
CD%5	0.626	0.1113	0.3238	0.6193	0.245	2.3795	0.1651	0.4048	0.5033	0.3242

Table 3: Genetic parameters of different quantitative traits of tamarind genotypes

Character	Range	Mean	Genotypic variance	Phenotypic variance	GCV (%)	PCV (%)	Heritability (BS) (%)	Genetic Advance	Genetic advance as% of mean 5%
Yield /plant	0.52-5.72	1.87	1.17	1.21	57.84	58.66	97.2	2.2	117.468
pod weight(g)	8.18-21.52	15.09	15.96	16.01	26.46	26.51	99.68	8.21	54.44
Weight of pulp(g)	4.09-10.27	6.77	3.11	3.12	26.04	26.09	99.62	3.62	53.54
seed wt(g)	2.13-7.99	4.73	2.55	2.57	33.75	33.89	99.16	3.28	69.23
fibre weight(g)	0.25-1.02	0.49	0.0259	0.0264	32.38	32.71	97.99	0.32	66.03
Shell weight(g)	1.33-5.43	3.08	1.14	1.16	34.74	34.94	98.89	2.19	71.189
Pod length (cm)	8.12-19.66	14.52	11.8203	11.8207	23.6694	23.6699	100	7.08	48.75
Pod width(cm)	4.00-7.92	5.47	1.1916	1.1944	19.92	19.94	99.77	2.24	41.00
Pod thickness(cm)	1.03-1.66	1.29	0.0476	0.0478	16.88	16.91	99.64	0.44	34.71
Pod circumference (cm)	4.85-7.54	6.4	0.51	0.52	11.23	11.29	98.90	1.47	23.01
Number of pods per Kg	46.47-122.25	71.38	426.83	429.63	28.94	29.03	99.35	42.42	59.42
Seed Number	4.45-11.55	7.5	3.6210	3.6212	25.3669	25.3676	99.99	3.91	52.25
Pulp Recovery (%)	36.53-56.18	45.35	26.92	29.07	11.44	11.88	92.61	10.28	22.67
Shell percent (%)	14.40-26.50	20.18	14.94	16.12	19.15	19.89	92.69	7.66	37.98
Rag Percentage (%)	1.49-7.7	3.51	2.22	2.27	42.52	43.01	97.75	3.04	86.61
Seed Percentage (%)	24.48-42.06	30.97	18.32	20.99	13.82	14.79	87.30	8.24	26.6
Real pulp value	1.68-5	3.07	0.81	0.83	29.32	29.63	97.90	1.84	59.76
Pulp: shell ratio	1.47-3.88	2.37	0.50	0.52	29.81	30.45	95.84	1.42	60.12
Pulp: Seed Ratio	0.87-2.22	1.51	0.12	0.13	23.41	24.22	93.49	0.70	46.64
Edible:non-edible	0.57-1.28	0.84	0.0348	0.0364	22	22.51	95.51	0.37	44.29
No of fibres /pod	3.58-7.14	4.88	0.81	0.91	18.47	19.54	89.42	1.76	35.99
Beak length (cm)	0.01-0.05	0.03	0.0001	0.0002	32.18	41.47	60.23	0.01	51.46

Seed length(mm)	9.7-16.9	13.71	3.79	3.89	14.2	14.38	97.59	3.96	28.91
Seed width(mm)	6.45-14.65	11.21	4.3216	4.3246	18.5421	18.5484	99.93	4.28	38.18
Seed thickness (mm)	6.04-7.71	6.59	0.18	0.21	6.57	6.99	88.22	0.83	12.71
Total soluble solids (brix)	11.18-7.71	17.99	23.83	23.92	27.13	27.18	99.62	10.03	55.79
Titratable acidity (%)	3.03-12.29	7.79	6.52	6.54	32.76	32.79	99.78	5.2	67.41
Ascorbic ACID Content (mg/100g)	5.86-13.58	9.82	5.16	6.51	23.11	25.97	79.22	4.16	42.39
pH	2.01-3.69	2.85	0.19	0.2	15.51	15.77	96.80	0.89	31.44
Reducing Sugar (%)	19.43-35.26	26.4	22.23	22.27	17.85	17.87	99.82	9.7	36.75
Non- Reducing Sugar (%)	4.64-13.34	9.8	6.41	6.47	25.83	25.96	99.07	5.19	52.98
Total sugar (%)	25.52-48.29	36.2	40.65	40.68	17.6111	17.6165	99.94	13.13	36.26

5. Conclusion

The genotypic and phenotypic coefficients of variation were high (>20%) for the characters yield per plant, pod length, pod weight, pulp weight, seed weight, titratable acidity, ascorbic acid, shell weight, rag weight, beak length, rag per cent, real pulp value, pulp: seed, pulp: shell, number of pods kg^{-1}, seed number, edible: non-edible, TSS and non-reducing sugar. Moderate (10-20%) for pod thickness, shell per cent, number of fibres per pod, pod width, pH, pulp per cent, seed per cent, seed length, seed width, total sugars, reducing sugar and low for (<10%) seed thickness (6.57%). The differences between PCV and GCV values were less indicating that these traits were less influenced by environment and could be improved by following phenotypic selection.

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