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Character association studies in tamarind (*Tamarindus indica* L.) for yield and yield contributing characters

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Abstract
"Character Association Studies in Tamarind (*Tamarindus indica* L.) For yield and yield contributing Characters" was conducted at Main Garden, Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the year 2016-17 with objectives to study genotypic, phenotypic and environmental correlation for yield and yield contributing characters of tamarind genotypes. The experimental evidences point out that, analysis of variance revealed that highly significant difference among the genotypes for all the traits studied. The mean performance of 22 genotypes showed wide variation. On the basis of yield and yield contributing characters the genotype viz., MGNT7, MGNT5, MGT1/1 and AGT-3 were found promising for future improvement programmer. Hence, these genotypes may be given consideration while formulating selection indices for the improvement of yield and pod qualities of tamarind. Qualitative parameters revealed a wide range of variation for the characters under investigation.

Keywords: Tamarind, *Tamarindus indica* L., sugar ratio, reducing sugar, contributing characters

Introduction

Tamarind, *Tamarindus indica* L., is a multipurpose tropical fruit tree used primarily for its fruits, which are eaten fresh or processed, used as a seasoning or spice, or the fruits and seeds are processed for non-food uses. The species has a wide geographical distribution in the subtropics and semiarid tropics and is cultivated in numerous regions (El-Siddig *et al.*, 2006) [16]. It is grown throughout India and being a cross pollinated species vast diversity is available in the states of Maharashtra, Andhra Pradesh, Chattisgarh, Tamil Nadu, Gujarat, Rajasthan and North Eastern Indian states (Malik *et. al.*, 2010) [67]. Tamarind belongs to the dicotyledonous family Fabaceae (Leguminosae) and has a somatic chromosome number of 2n=24. It is thought that Linnaeus gave the specific epithet *indicus* because the name tamarind itself was derived from Arabic which combined Tamar meaning 'date' with Hindi meaning 'of India'. The full Arabic name was Tamar-u'l-Hind and the word date included because of the brown appearance of tamarind pulp. Although tamarind is an ancient domesticate, little attempt has been directed to its genetic improvement. This is understandable because tree improvement research that combines developmental and operational phases is time consuming and the large scale cultivation of tamarind is still in its early stages. Indigenous farmers have however selected planting materials from natural populations based on desirable and observable characteristics but such phenotypic selection means the growing stocks are virtually wild (El-Siddig *et al.*, 2006) [16]. Since the variation in pod length and pod width was found to be genotypic similarly for other traits the potential for improvement depends on sampling the genetic variability available within and between populations. Hence, knowledge of genetic variation and structure of a species and genetic parameters of important traits are essential to develop effective improvement and conservation strategies. The genetic improvement goals are straightforward based on the available material. They are faster growth and higher yielding lines for selection for different uses. Since normal crossing is not an option, more trait specific work is needed so that provenance trials can lead to selections which combine the desirable characters and then to cultivars developed from them. These should be developed to fit the different land-use systems of agro forestry, orchards/plantations as well as certain stress conditions inherent in a number of wastelands which need to be rehabilitated (El-Siddig *et al.*, 2006) [16]. Tamarind was recorded over a century ago as a variable species especially for pulp colour and sweetness. Since there is such extensive variation in characters such as foliage, flower and pod production and timber quality, there is a considerable scope to improve the species.

Improvement holds the key for boosting productivity and yield of the orchards and involves development of genotypes possessing desirable characters like fast growth, good tree form, high yield and resistance or tolerance to major pests, diseases and drought (Radhamani *et al.*, 1998) [39].

Present investigation is carried out to find out genetic variability on the basis of yield and yield attributes of different genotypes will helpful to conserve valuable germplasm and could be protected from being eroded. And its further utilization in tamarind improvement program. It is however, possible to estimate these various genetic parameters with the help of statistical techniques as analysis of variance and covariance by using biometrical methods of analysis. There is a considerable genetic variation exists in tamarind with regard to quantitative character as well as traits contributing to quality of fruits. The size of fruits i.e. length as well as weight of fruits etc. are the yield contributing characters while pulp contain and fiber contain determine the quality of the fruit. While, evaluating the yield potential of any variety, it is necessary to give attention to all yield contributing characters. Under such circumstances knowledge of interrelationship among different traits is also necessary. It is essential to access the degree of association of various quantitative characters in order to initiate effective selection program. In view of the above facts, the present studies in tamarind reported in this dissertation were undertaken with 22 genotypes with following objectives. To estimate the extent of genotypic and phenotypic variability among tamarind genotypes. Correlation studies help in finding out the degree of interrelationship among various characters and in evolving selection criteria for improvement (Atta *et al.*, 2008) [2].

Material and Methods

The present studies entitled "Genetic variability studies in tamarind." was carried out on tamarind trees during the year 2016-17 at Main Garden Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Material used and methods adopted during the course of investigations.

1. MGT1/1	12. MGNT7
2. MGT2/3	13. MGNT8
3. MGT3/2	14. MGNT9
4. MGT4/1	15. MGST1
5. MGT7/3	16. AGT1
6. MGNT1	17. AGT2
7. MGNT2	18. AGT3
8. MGNT3	19. Akola Smruti
9. MGNT4	20. Prathisthan-5/1
10. MGNT5	21. PKM-1 6/2
11. MGNT6	22. DTH-1 8/1

MGT - Main Garden Tamarind
MGNT - Main Garden Nursery Tamarind
MGST - Main Garden Storage Tamarind
AGT - Agronomy Tamarind

The data obtained from the present investigation will be analyzed as per the procedure suggested by Panse and Sukhatme (1978) [33].

Results and Discussion

The result of an experiment entitled "Genetic Variability Studies in Tamarind (*Tamarindus Indica*. L)" was carried out during 2017-18 at Main Garden, Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, and Akola with the following objectives. To study genotypic, phenotypic and environmental correlation for yield and yield contributing characters of tamarind. The experimental results obtained from the present investigation regarding on both qualitative and quantitative morphological characters in tamarind (*Tamarindus indica* L.) are statistically analysed, presented and discussed under the following subheadings.

Estimation of correlation coefficients

Genotypic, Phenotypic and Environmental correlation

Genotypic, Phenotypic and Environmental correlation coefficients are presented in Table 1, 2 and 3 respectively. Understanding of the interaction of characters among themselves and with the environment has been of great use in plant breeding. Correlation studies provide information on the nature and extent of association between any two pairs of metric characters. From this, it would be possible to bring about genetic up gradation in one character by selection of the other of a pair. With a view to determine the extent and nature of relationship prevailing among yield contributing characters, an attempt has been made here to study the character association. The pod length highly significant and positively correlation for the genotypic and phenotypic level with pod weight (r_g = 0.9079 and r_p = 0.9022), pulp weight (r_g = 0.8803 and r_p = 0.8722), shell weight (r_g = 0.8680 and r_p = 0.8594), seed weight /pod(r_g = 0.7333 and r_p = 0.7278), number of seed/pod(r_g = 0.6123 and r_p = 0.5559), pulp recovery (r_g = 0.4986 and r_p = 0.4950), inflorescence length (r_g = 0.4941 and r_p = 0.4908), non-reducing sugar (r_g = 0.3040 and r_p = 0.3020). Number of pods/ kg (r_g = -0.8651 and r_p = -0.8567), seed: pulp ratio (r_g = -0.4159 and r_p = -0.4130), tartaric acid (r_g = -0.3884 and r_p = -0.3822), acid: sugar ratio (r_g = -0.3711 and r_p = -0.3519) was highly significant and negative correlation both at genotypic and phenotypic levels. Its correlation was found to be highly significant and positive at environmental level reducing sugar (r_e = 0.2981), acid: sugar ratio (r_e = 0.3444).

Pod thickness expressed positive correlation for the pod width (r_g = 0.1810 and r_p = 0.1724), pulp weight/pod (r_g = 0.1476 and r_p = 0.1450), pulp recovery (r_g = 0.0442 and r_p = 0.0357), number of seed/pod (r_g=0.2390 and r_p = 0.1959), inflorescence length (r_g = 0.0668 and r_p = 0.0645), acid: sugar ratio (r_g = 0.2081 and r_p = 0.1538) both at genotypic and phenotypic level. At phenotypic and phenotypic level had highly significant and positive association with rag weight/pod (r_g = 0.7622 and r_p = 0.7084), pulp: shell ratio (r_g = 0.4284 and r_p = 0.3825) and highly significant and negative association with number of pods/kg (r_g = -0.3060 and r_p= -0.2916), seed: pulp ratio(r_g = -0.6247 and r_p = -0.5904), stem girth (r_g = -0.4093 and r_p = -0.3897), total sugar (r_g = -0.3453 and r_p = -0.3300), reducing sugar (r_g = -0.3313 and r_p = -0.3168) at genotypic and phenotypic level respectively.

Pod width expressed positive associated for the pulp: shell ratio (r_g = 0.0.1072 and r_p = 0.1019). TSS (r_g = -0.1407 and r_p = -0.1388), reducing sugar (r_g = -0.0918 and r_p = -0.0914) negatively correlation at genotypic and phenotypic level respectively. It was positively and highly significant associated with pod weight (r_g = 0.7662 and r_p = 0.7579), shell weight (r_g = 0.6890 and r_p = 0.6801), pulp weight (r_g = 0.8254 and r_p=0.8158), seed weight/pod (r_g = 0.5041 and r_p = 0.4983), pulp recovery (r_g = 0.6735 and r_p = 0.6671), number of seed /pod (r_g = 0.3485 and r_p = 0.3164), inflorescence length (r_g = 0.4218 and r_p = 0.4167), total sugar (r_g = 0.3107 and r_p =

0.3070), non-reducing sugar (r_g = 0.4270 and r_p = 0.4222) at genotypic and phenotypic levels. Highly significant and negatively correlation with number of pods/kg (r_g = -0.7677 and r_p = -0.7554), seed: pulp ratio (r_g = -0.3336 and r_p = -0.3290), tartaric acid (r_g = -0.4026 and r_p = -0.3955) at genotypic and phenotypic level.

Pod weight manifested highly significant and positively associated with shell weight/pod (r_g = 0.9831 and r_p = 0.9800), pulp weight/pod (r_g = 9577 and r_p = 0.9545), seed weight/pod (r_g = 0.8494 and r_p = 0.8468), pulp recovery (r_g = 0.4582 and r_p = 0.4569), pulp: shell ratio (r_g = 0.3350 and r_p = 0.3161), number of seed /pod (r_g = 0.6836 and r_p = 0.6324), inflorescence length (r_g = 0.4769 and r_p = 0.4763) at genotypic and phenotypic level. Highly significant and negatively associated with number of pods/kg (r_g = - 0.8828 and r_p = -0.8781), seed: pulp ratio (r_g = - 0.5423 and r_p = -0.5371). Pod weight expressed positive correlation for the non-reducing sugar (r_g = 0.1108 and r_p = 0.1107), yield/plant (rg 0.0472 and r_p = 0.0472), rag weight/pod (r_g = 0.1196 and r_p = 0.1155). At environmental level it expressed highly significant and positive association with TSS (r_e = 0.5794).

Number of pods per kg expressed highly significant and negative association with shell weight/pod (r_g = -0.8519 and r_p = -0.8475), pulp weight/pod (r_g = -0.8599 and r_p = - 0.8540), seed weight/pod (r_g = -0.7309 and r_p = -0.7278), pulp recovery (r_g = -0.5508 and r_p = - 0.5471), pulp: shell ratio (r_g = -0.3624 and r_p = -0.3358), number of seed/pod (r_g = -0.5815 and r_p = -0.5424), inflorescence length (r_g = -0.3325 and r_p= -0.3311), non-reducing sugar (r_g = -0.2809 and r_p = -0.2801) at genotypic and phenotypic level and negatively non-significant association with total sugar (r_g = -0.1559 and r_p = -0.1551), yield/plant (r_g = -0.1478 and r_p = -0.1471), rag weight/pod (r_g = -0.2149 and r_p = =0.2084).

Shell weight

Shell weight expressed positive association with rag weight/pod (r_g = 0.1945 and r_p = 0.1839), non-reducing sugar (r_g = 0.0592 and r_p = 0.0589), yield/plant (r_g = 0.0224 and r_p = 0.0223) and negative association with stem girth (r_g = -0.1438 and r_p = - 0.1434), tartaric acid (r_g = -0.0981 and r_p = -0.0974), TSS (r = -0.1092 and r_p = -0.1024), total sugar (r_g = - 0.0536 and r_p = -0.0531), reducing sugar (r_g= -0.1856 and r_p = -0.1855), acid: sugar ratio (r_g = -0.0240 and r_p = -0.0263) but not significant at genotypic and phenotypic levels respectively. It was highly significant and positively correlated with pulp weight/pod (r_g = 0.9136 and r_p = 0.9095), seed weight /pod (r_g = 0.8525 and r_p = 0.8496), pulp recovery (r_g = 0.3486 and r_p = 0.3470), pulp: shell ratio (r_g = 0.3824 and r_p = 0.3650), number of seed/pod (r_g = 0.7204 and r_p = 0.6695), inflorescence length (r_g = 0.4964 and r_p = 0.4949). Highly significant and negatively correlated with seed: pulp ratio (r_g = -0.5737 and r_p = - 0.5680) at genotypic and phenotypic levels respectively.

The rag weight exhibited positive association with seed weight/pod (r_g = 0.2061 and r_p = 0.2032), inflorescence length (r_g = 0.0623 and r_p = 0.595) at genotypic and phenotypic level and negative association pulp recovery (r_g = -0.2991 and r_p = -0.1269), stem girth (r_g = -0.1870 and r_p= -0.1838), non-reducing sugar (r_g = -0.0957 and r_p = -0.0945) but not significant at genotypic and phenotypic level. It was highly significant and positively associated with pulp: shell ratio (r_g = 0.3473 and r_p = 0.3226), number of seed/pod (r_g = 0.3110 and 0.3060), tartaric acid (r_g = 0.2818 and r_p = 0.2752), acid: sugar ratio (r_g = 0.4392 and 0.4250) at genotypic and phenotypic levels. It was highly significant and negatively associated with seed: pulp ratio (r_g = -0.4587 and r_p = -0.4446), TSS (r_g = -0.3615 and r_p= -0.3558), total sugar (r_g = -0.3870 and r_p = -0.3804), reducing sugar (r_g = -0.5403 and r_p = -0.5308), yield /plant (r_g = -0.2841 and r_p = -0.2762).

Pulp weight was highly significant and positively associated with seed weight/pod (r_g = 0.6757 and r_p = 0.6739), pulp recovery (r_g = 0.6783 and r_p = 0.6755), number of seed/pod (r_g = 0.4827 and r_p = 0.4431), inflorescence length (r_g = 0.4988 and r_p = 0.4974). It was positively associated with total sugar (r_g = 0.0454 and r_p = 0.0449), yield/plant (r_g = 0.0975 and r_g = 0.0969) but not significant at genotypic and phenotypic levels. Highly significant and negatively associated with seed: pulp ratio (r_g = -0.4295 and r_p = -0.4181) at genotypic and phenotypic level.

Seed weight pod^{-1}

Association of seed weight/pod was highly significant and positively correlation with pulp: shell ratio (r_g = 0.3694 and r_p = 0.3540), number of seed /pod (r_g=08824 and r_p = 0.8326) at genotypic and phenotypic level respectively. Highly significant and negative correlation with seed: pulp ratio (r_g = -0.6418 and r_p = -0.6348), stem girth (r_g = -0.2748 and r_p = -0.2745) and positive association with pulp recovery (r_g = 0.0119 and r_p = 0.0118), acid: sugar ratio (r_g = 0.0403 and r_p = 0.0401) but not significant. Seed weight was negatively associated with TSS (r_g = -0.1171 and r_p = -0.1170), total sugar (r_g = -0.1306 and r_p = -0.1305), non-reducing sugar (r_g = -0.1431 and r_p = -0.1430).

Shell weight expressed highly significant and positive correlation with non-reducing sugar (r_g = 0.4644, r_p = 0.4642 and r_e = 0.3298) at genotypic, phenotypic and environmental levels respectively. At genotypic and phenotypic levels it was highly significant and positive correlation with inflorescence length (r_g = 2801 and r_p = 0.2793). At genotypic and phenotypic levels it was highly significant and negatively tartaric acid (rg = -0.2798 and r_p = -0.2765), reducing sugar (r_g = -0.3337 and r_p = -0.3325).

The association of pulp: shell ratio was positive associated with number of seed/pod (r_g = 0.2028 and r_p = 0.1956), inflorescence length (r_g = 0.0547 and r_p = 0.0523), tartaric acid (r_g = 0.1321 and r_p = 0.1250), TSS (r_g = 0.2119 and r_p = 00.2017), acid: sugar ratio (r_g = 0.2073 and r_p = 0.1994) at genotypic and phenotypic levels. At genotypic and phenotypic level it was highly significant and negatively correlated with seed: pulp ratio (r_g = -0.8359 and r_p = -0.7951), stem girth (r_g = -0.3308 and r_p = -0.3165).

Seed: pulp ratio exhibited highly significant and positively correlation with stem girth (r_g = 0.5175 and r_p = 0.5128), reducing sugar (r_g = 0.2849 and r_p = 0.2817) at genotypic and phenotypic level. At genotypic and phenotypic levels it had positive associated with TSS (r_g = 0.0272 and r_p = 0.0257) and non-reducing sugar (r_g = 0.0927 and r_p = 0.0919) and negative correlation with inflorescence length (r_g = -0.0327 and r_p = -0.0316), tartaric acid (r_g = -0.0060 and r_p = -0.0085), acid: sugar ratio (r_g = -0.1239 and r_p = -0.1219).

Number of seed/pod exhibited positive correlation with inflorescence length (r_g = 0.1776 and r_p = 0.1623), tartaric acid (r_g = 0.1084 and r_p = 0.0946), reducing sugar (r_g = 0.0503 and r_p = 0.0482), acid: sugar ratio (r_g = 0.0680 and r_p = 0.0549) at genotypic and phenotypic levels. At genotypic and phenotypic levels it had negative associated with TSS (r_g = -0.1529 and r_p

= -0.1470), total sugar (r_g = -0.0330 and r_p = -0.0304), non-reducing sugar (r_g = -0.0720 and r_p = -0.0666), yield /plant (r_g = -0.0466 and r_p = -0.0372).

Inflorescence length exhibited highly significant and positively correlation with stem girth (r_g = 0.2967 and r_p = 0.295) at genotypic and phenotypic level. Association of inflorescence length with yield/plant (r_g = 0.1986 and r_p = 0.1983) was positive and with TSS (r_g = -0.0699 and r_p = -0.0694) total sugar (r_g = -0.0830 and r_p = -0.0830), reducing sugar (r_g = -0.0144 and r_p = -0.0144), non-reducing sugar (r_g = -0.0933 and r_p = -0.0933) was negative at genotypic, phenotypic and environmental levels, respectively.

Stem girth exhibited negative association with tartaric acid (r_g = -0.0528 and r_p = -0.0525), TSS (r_g = -0.0972 and r_p = -0.0970), total sugar (r_g = -0.0754 and r_p = -0.0754), non-reducing sugar (r_g = -0.0885 and r_p = -0.0884). Acid: sugar ratio (r_g = 0.0331 and r_p = 0.0325) was positive at genotypic and phenotypic levels respectively. Stem girth exhibited highly significant and positively associated with yield/plant (r_g = 0.3099 and r_p = 0.3090) at genotypic and phenotypic level. Reducing sugar (r_e = 0.3371), non-reducing sugar (r_e = 0.4185) was highly significant and positively at environmental levels.

Tartaric acid exhibited highly significant and negatively correlation with total sugar (r_g = -0.3673 and r_p = -0.3635), reducing sugar (r_g= -0.3812 and r_p = -3761), yield/plant (r_g = -0.3154 and r_p = -0.3115). Highly significant and positively correlation with acid: sugar ratio (r_g = 0.8532 and r_p = 0.8195) at genotypic and phenotypic level respectively.

Association of TSS with acid: sugar ratio (r_g = -0.1183 and r_p = -0.1172) was negative and with reducing sugar (r_g = 0.1278 and r_p = 0.1275), non-reducing sugar (r_g = 0.1672 and r_p = 0.1671), yield/ plant (r_g = 0.1469 and r_p = 01458) was positive at genotypic and phenotypic levels.

Association of total sugar with reducing sugar (r_g = 0.5331 and r_p = 0.5325), non-reducing sugar (r_g = 0.8251 and r_p = 0.8248), yield/plant (r_g = 0.3484 and r_p = 0.3474) was highly significant and positively correlated. Highly Significant and negatively correlation with acid: sugar ratio (r_g = -0.8004 and r_p = -0.7798).

Reducing sugar was highly significant and positively correlation with yield/plant (r_g = 0.4481 and r_p = 0.4460) at genotypic and phenotypic level. The negative association with non-reducing sugar (r_g = -0.0384 and r_p = -0.0382) at genotypic and phenotypic level.

Non-reducing sugar highly significant and negative correlation with acid: sugar ratio (r_g = -0.5614 and r_p = -0.5466) at genotypic and phenotypic level. Positive association with yield/ plant (r_g = 0.1133 and r_p = 0.1131) at genotypic and phenotypic level.

Acid: sugar ratio was highly significant and negative correlation with yield/plant (r_g = -0.3673 and r_p = -0.3575) at genotypic and phenotypic level.

The pod length highly significant and positively correlation for the genotypic and phenotypic level with pod weight, pulp weight, shell weight, seed weight /pod, number of seed/pod, pulp recovery, inflorescence length, non-reducing sugar. Number of pods/ kg, seed: pulp ratio, tartaric acid, acid: sugar ratio was highly significant and negative correlation both at genotypic and phenotypic levels. Its correlation was found to be highly significant and positive at environmental level reducing sugar, acid: sugar ratio. Similar results in tamarind were also reported by Challapilli *et al.* (1995) [10], Shivanandam and Thimmaraju (1998) [52], Shivanandam and Thimmaraju (1998) [52] and Singh and Nandini (2014) [63].

Pod thickness expressed positive correlation for the pod width, pulp weight/pod, pulp recovery, number of seed/pod, inflorescence length, acid: sugar ratio both at genotypic and phenotypic level. At phenotypic and phenotypic level had highly significant and positive association with rag weight/pod, pulp: shell ratio and highly significant and negative association with number of pods/kg, seed: pulp ratio, stem girth, total sugar, reducing sugar at genotypic and phenotypic level respectively. Shivanandam and Thimmaraju (1988) [52] and Challapilli *et al.* (1995) [10] observed fruit thickness had negatively correlated with fiber weight, seed weight and seed number in tamarind.

Pod width expressed positive associated for the pulp: shell ratio. TSS, reducing sugar negatively correlation at genotypic and phenotypic level respectively. It was positively and highly significant associated with pod weight, shell weight, pulp weight, seed weight/pod, and pulp recovery, number of seed /pod, inflorescence length, total sugar and non-reducing sugar at genotypic and phenotypic levels. Highly significant and negatively correlation with number of pods/kg, seed: pulp ratio, tartaric acid at genotypic and phenotypic level. Similar results were observed in tamarind by Challapilli *et al.* 1995) [10].

Pod weight manifested highly significant and positively associated with shell weight /pod, pulp weight/pod, seed weight/pod, pulp recovery, pulp: shell ratio, number of seed /pod, inflorescence length at genotypic and phenotypic level. Highly significant and negatively associated with number of pods/kg, seed: pulp ratio. Pod weight expressed positive correlation for the non-reducing sugar, yield/plant and rag weight/pod. At environmental level it expressed highly significant and positive association with TSS. The present results are conformity with the findings of Shivanandam and Thimmaraju (1988) [52], Challapilli *et al.* (1995) [10], Karale *et al.* (1999) [23], Biradar (2001) [7] and Divakara (2008) [13] in tamarind.

Number of pods per kg expressed highly significant and negative association with shell weight/pod, pulp weight/pod, seed weight/pod pulp recovery, pulp: shell ratio, number of seed/pod, inflorescence length, non-reducing sugar at genotypic and phenotypic level and negatively non-significant association with total sugar, yield/plant, rag weight/pod.

Shell weight expressed positive association with rag weight/pod, non-reducing sugar, yield/plant and negative association with stem girth, tartaric acid, TSS, total sugar, reducing sugar, acid: sugar ratio but not significant at genotypic and phenotypic levels respectively. It was highly significant and positively correlated with pulp weight/pod, seed weight /pod, pulp recovery, pulp: shell ratio, number of seed/pod, inflorescence length. Highly significant and negatively correlated with seed: pulp ratio at genotypic and phenotypic levels respectively. Similar results were also reported by Divakara (2008) [13] in tamarind.

The rag weight exhibited positive association with seed weight/pod, inflorescence length at genotypic and phenotypic level and negative association pulp recovery, stem girth, non-reducing sugar but not significant at genotypic and phenotypic level. It was highly significant and positively associated with pulp: shell ratio, number of seed/pod, tartaric acid, acid: sugar ratio at genotypic and phenotypic levels. It was highly significant and negatively associated with seed: pulp ratio, TSS, total sugar, reducing sugar, yield /plant.

Pulp weight was highly significant and positively associated with seed weight/pod, pulp recovery, number of seed/pod, inflorescence length. It was positively associated with total sugar, yield /plant but not significant at genotypic and phenotypic levels. Highly significant and negatively associated with seed: pulp ratio at genotypic and phenotypic level. Similar results were observed by Challapilli *et al.* (1995) [10], Karale *et al.* (1999) [23].

Association of seed weight/pod was highly significant and positively correlation with pulp: shell ratio, number of seed /pod at genotypic and phenotypic level respectively. Highly significant and negative correlation with seed: pulp ratio, stem girth and positive association with pulp recovery, acid: sugar ratio but not significant. Seed weight was negatively associated with TSS, total sugar, non-reducing sugar. The present findings are conformity with Challapilli *et al.* (1995) [10] and Karale *et al.* (1999) [23] where seed weight was significantly correlated with number of seed pod^{-1}.

Shell weight expressed highly significant and positive correlation with non-reducing sugar at genotypic, phenotypic and environmental levels respectively. At genotypic and phenotypic levels it was highly significant and positive correlation with inflorescence length. At genotypic and phenotypic levels it was highly significant and negatively tartaric acid, reducing sugar.

The association of pulp: shell ratio was positive associated with number of seed/pod, inflorescence length, tartaric acid, TSS, acid: sugar ratio at genotypic and phenotypic levels. At genotypic and phenotypic level it was highly significant and negatively correlated with seed: pulp ratio, stem girth.

Seed: pulp ratio exhibited highly significant and positively correlation with stem girth, reducing sugar at genotypic and phenotypic level. At genotypic and phenotypic levels it had positive associated with TSS and non-reducing sugar and negative correlation with inflorescence length, tartaric acid, acid: sugar ratio.

Number of seed/pod exhibited positive correlation with inflorescence length, tartaric acid, reducing sugar, acid: sugar ratio at genotypic and phenotypic levels. At genotypic and phenotypic levels it had negative associated with TSS, total sugar, non-reducing sugar, yield /plant.

Inflorescence length exhibited highly significant and positively correlation with stem girth at genotypic and phenotypic level. Association of inflorescence length with yield /plant was positive and with TSS totals sugar, reducing sugar; non-reducing sugar was negative at genotypic, phenotypic and environmental levels, respectively.

Stem girth exhibited negative association with tartaric acid, total sugar, and non-reducing sugar. Acid: sugar ratio was positive at genotypic and phenotypic levels respectively. Stem girth exhibited highly significant and positively associated with yield/plant at genotypic and phenotypic level. Reducing sugar, non-reducing sugar was highly significant and positively at environmental levels

Table 1: Estimation of Genotypic correlation coefficient between different traits in tamarind

Characters	Length of pod (cm)	Thickness of pod (cm)	Pod width (cm)	Pod weight (g)	No. of pods/Kg	Shell weight pod^{-1} (g)	Rag weight pod^{-1} (g)	Pulp weight pod^{-1} (g)	Seed weight pod^{-1} (g)	Pulp recovery (%)	Pulp: shell ratio	Seed: pulp ratio
Length of pod (cm)	1	0.2013	0.8408**	0.9079**	-0.8651**	0.8680**	0.0866	0.8803**	0.7333**	0.4986**	0.2013	-0.4159**
Thickness of pod (cm)		1	0.1810	0.2208	-0.3060**	0.2746	0.7622**	0.1476	0.2571	0.0442	0.4284**	-0.6247**
Pod width (cm)			1	0.7662**	-0.7677**	0.6890**	-0.0138	0.8254**	0.5041**	0.6735**	0.1072	-0.3336**
Pod weight (g)				1	-0.8828**	0.9831**	0.1196	0.9577**	0.8494**	0.4582**	0.3350**	-0.5423**
No. of pods/Kg					1	-0.8519**	-0.2149	-0.8599**	-0.7309**	-0.5508**	-0.3624**	0.5291
Shell weight pod^{-1} (g)						1	0.1945	0.9136**	0.8525**	0.3486**	0.3824**	-0.5737**
Rag weight pod^{-1} (gS)							1	0.0124	0.2061	-0.1291	0.3473**	-0.4587**
Pulp weight pod^{-1} (g)								1	0.6757**	0.6783**	0.2770*	-0.4295**
Seed weight pod^{-1} (g)									1	0.0119	0.3694**	-0.6418**
Pulp recovery (%)										1	0.1174	-0.0859
Pulp: shell ratio											1	-0.8359**
Seed: pulp ratio												1
No. of seed/pod												
Inflorescence length (cm)												
Stem girth (cm)												
Tartaric acid (%)												
TSS (^{0}Brix)												
Total sugar (%)												
Reducing sugar (%)												
Non-reducing sugar (%)												
Acid: sugar ratio												
Yield per plant (Kg)												

Significant at 5% level-*, Significant at 1% level-**

Table 1: Conti....

Characters	No. of seed pod^{-1}	Inflorescence length (cm)	Stem girth (cm)	Tartaric acid (%)	TSS (^{0}Brix)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Acid: sugar ratio	Yield per plant (Kg)
Length of pod (cm)	0.6123**	0.4941**	-0.0846	-0.3884**	-0.0660	0.2333*	-0.0441	0.3040**	-0.3711**	0.2377*
Thickness of pod (cm)	0.2390	0.0668	-0.4093**	-0.0377	-0.2682*	-0.3453**	-0.3313**	-0.1872	0.2081	-0.1131
Pod width (cm)	0.3485**	0.4218**	-0.1335	-0.4026**	-0.1407	0.3107**	-0.0918	0.4270**	-0.4051	0.2270
Pod weight (g)	0.6836**	0.4769**	-0.1764	-0.1514	-0.0863	-0.0116	-0.1890	0.1108	-0.0832	0.0472
No. of pods/Kg	-0.5815**	-0.3325**	0.2405	0.1662	0.1812	-0.1559	0.1474	-0.2809**	0.1657	-0.1478
Shell weight pod^{-1} (g)	0.7204**	0.4964**	-0.1438	-0.0981	-0.1029	-0.0536	-0.1856	0.0592	-0.0240	0.0224
Rag weight pod^{-1} (g)	0.3110**	0.0623	-0.1870	0.2818**	-0.3615**	-0.3870**	-0.5403**	-0.0957	0.4392**	-0.2841**
Pulp weight pod^{-1} (g)	0.4827**	0.4988**	-0.1521	-0.1809	-0.0159	0.0454	-0.2637	0.2274*	-0.1253	0.0975
Seed weight pod^{-1} (g)	0.8824**	0.2296*	-0.2748**	-0.0243	-0.1171	-0.1306	-0.0165*	-0.1431	0.0403	-0.0744
Pulp recovery (%)	-0.2180	0.2801**	-0.1808	-0.2798**	0.0468	0.2066	-0.3337**	0.4644**	-0.2582	0.1583
Pulp: shell ratio	0.2028	0.0547	-0.3308**	0.1321	0.2119	-0.2106	-0.2618	-0.0759	0.2073	-0.2126
Seed: pulp ratio	-0.5408	-0.0327	0.5175**	-0.0060	0.0272	0.2389	0.2849**	0.0927	-0.1239	0.2604
No. of seed pod^{-1}	1	0.1776	-0.2432	0.1084	-0.1529	-0.0330	0.0503	-0.0720	0.0680	-0.0466
Inflorescence length (cm)		1	0.2967**	-0.2567	-0.0699	-0.0830	-0.0144	-0.0933	-0.0920	0.1986
Stem girth (cm)			1	-0.0528	-0.0972	-0.0754	0.0003	-0.0885	0.0331	0.3099**
Tartaric acid (%)				1	0.0864	-0.3673**	-0.3812**	-0.1790	0.8532**	-0.3154**
TSS (^{0}Brix)					1	0.2156	0.1278	0.1672	-0.1183	0.1469
Total sugar (%)						1	0.5331**	0.8251**	-0.8004**	0.3484**s
Reducing sugar (%)							1	-0.0384	-0.5750**	0.4481**
Non-reducing sugar (%)								1	-0.5614**	0.1133
Acid: sugar ratio									1	-0.3673**
Yield per plant (Kg)										1

Significant at 5% level-*, Significant at 1% level-**

Table 2: Estimation of Phenotypic correlation coefficient between different traits in tamarind

Characters	Length of pod (cm)	Thickness of pod (cm)	Pod width (cm)	Pod weight (g)	No. of pods/Kg	Shell weight pod^{-1} (g)	Rag weight pod^{-1} (g)	Pulp weight pod^{-1} (g)	Seed weight pod^{-1} (g)	Pulp recovery (%)	Pulp: shell ratio	Seed: pulp ratio
Length of pod (cm)	1	0.1861	0.8305**	0.9022**	-0.8567**	0.8594**	0.0855	0.8722**	0.7278**	0.4950**	0.1917	-0.4130**
Thickness of pod (cm)		1	0.1724	0.2138*	-0.2916**	0.2661*	0.7084**	0.1450	0.2451*	0.0357	0.3825**	-0.5904**
Pod width (cm)			1	0.7579**	-0.7554**	0.6801**	-0.0172	0.8158**	0.4983**	0.6671**	0.1019	-0.3290**
Pod weight (g)				1	-0.8781**	0.9800**	0.1155	0.9545**	0.8468**	0.4569**	0.3161**	-0.5371**
No. of pods/Kg					1	-0.8475**	-0.2084	-0.8540**	-0.7278**	-0.5471**	-0.3358**	0.5231**
Shell weight pod^{-1} (g)						1	0.1839	0.9095**	0.8496**	0.3470**	0.3650**	-0.5680**
Rag weight pod^{-1} (g)							1	0.0091	0.2032	-0.1269	0.3226**	-0.4446**
Pulp weight pod^{-1} (g)								1	0.6739**	0.6755**	0.2638*	-0.4181**
Seed weight pod^{-1} (g)									1	0.0118	0.3540**	-0.6348**
Pulp recovery (%)										1	0.1130	-0.0867
Pulp: shell ratio											1	-0.7951**
Seed: pulp ratio												1
No. of seed pod^{-1}												
Inflorescence length (cm)												
Stem girth (cm)												
Tartaric acid (%)												
TSS (^{0}Brix)												
Total sugar (%)												
Reducing sugar (%)												
Non-reducing sugar (%)												
Acid: sugar ratio												
Yield per plant (Kg)												

Significant at 5% level-*, Significant at 1% level-**

Table 2: Conti….

Characters	No. of seed pod^{-1}	Inflorescence length (cm)	Stem girth (cm)	Tartaric acid (%	TSS (^{0}Brix)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Acid: sugar ratio	Yield per plant (Kg)
Length of pod (cm)	0.5559**	0.4908**	-0.0842	-0.3822**	-0.0655	0.2320*	-0.0426	0.3020**	-0.3519**	0.2337*
Thickness of pod (cm)	0.1959	0.0645	-0.3897**	-0.0390	-0.2517*	-0.3300**	-0.3168**	-0.1798	0.1538	-0.1050
Pod width (cm)	0.3164**	0.4167**	-0.1320	-0.3955**	-0.1388	0.3070**	-0.0914	0.4222**	-0.3827**	0.224*
Pod weight (g)	0.6324**	0.4763**	-0.1761	-0.1486	-0.0843	-0.0118	-0.1882	0.1107	-0.0827	0.0472
No. of pods/Kg	-0.5424**	-0.3311**	0.2395*	0.1634	0.1796	-0.1551	0.1468	-0.2801**	0.1627	-0.1471
Shell weight pod^{-1} (g)	0.6695**	0.4949**	-0.1434	-0.0974	-0.1024	-0.0531	-0.1855	0.0589	-0.0263	0.0223
Rag weight pod^{-1} (g)	0.3060**	0.0595	-0.1838	0.2752**	-0.3558**	-0.3804**	-0.5308**	-0.0945	0.4250**	-0.2762**
Pulp weight pod^{-1} (g)	0.4431**	0.4974**	-0.1518	-0.1795	-0.0155	0.0449	-0.2629*	0.2270*	-0.1258	0.0969
Seed weight pod^{-1} (g)	0.8236**	0.2291*	-0.2745**	-0.0241	-0.1170	-0.1305	-0.0168	-0.1430	0.0401	-0.0743
Pulp recovery (%)	-0.1991	0.2793**	-0.1804	-0.2765**	0.0466	0.2065	-0.3325**	0.4642**	-0.2472*	0.1590
Pulp: shell ratio	0.1956	0.0523	-0.3165**	0.1250	0.2017	-0.2018	-0.2496*	-0.0737	0.1994	-0.2022
Seed: pulp ratio	-0.5020**	-0.0316	0.5128**	-0.0085	0.0257	0.2362*	0.2817**	0.0919	-0.1219	0.2565*
No. of seed pod^{-1}	1	0.1623	-0.2261*	0.0946	-0.1470	-0.0304	0.0482	-0.0666	0.0549	-0.0372
Inflorescence length (cm)		1	0.2965**	-0.2535*	-0.0694	-0.0830	-0.0144	-0.0933	-0.0894	0.1983
Stem girth (cm)			1	-0.0525	-0.0970	-0.0754	0.0004	-0.0884	0.0325	0.3090**
Tartaric acid (%)				1	0.0851	-0.3635**	-0.3761**	-0.1774	0.8195**	-0.3115**
TSS (^{0}Brix)					1	0.2150*	0.1275	0.1671	-0.1172	0.1458
Total sugar (%)						1	0.5325**	0.8248**	-0.7798**	0.3474**
Reducing sugar (%)							1	-0.0382	-0.5583**	0.4460**
Non-reducing sugar (%)								1	-0.5466**	0.1131
Acid: sugar ratio									1	-0.3575**
Yield per plant (Kg)										1

Significant at 5% level-*, Significant at 1% level-**

Table 3: Estimation of Environmental correlation coefficient between different traits in tamarind

Characters	Length of pod (cm)	Thickness of pod (cm)	Pod width (cm)	Pod weight (g)	No. of pods/Kg	Shell weight pod^{-1} (g)	Rag weight pod^{-1} (g)	Pulp weight pod^{-1} (g)	Seed weight pod^{-1} (g)	Pulp recovery (%)	Pulp: shell ratio	Seed: pulp ratio
Length of pod (cm)	1	-0.1434	0.2333*	0.1065	0.0560	-0.2990**	0.0517	-0.1754	-0.2552*	-0.0429	-0.0064	-0.2202*
Thickness of pod (cm)		1	0.0423	0.2296*	-0.0525	0.2569*	-0.0701	0.2286*	0.0387	-0.3714**	-0.0949	-0.0183
Pod width (cm)			1	0.1866	0.0671	0.0411	-0.1328	0.1634	0.0336	0.2673*	0.0097	-0.1009
Pod weight (g)				1	0.0033	0.1626	-0.1579	0.1379	-0.2605*	0.0699	-0.2696*	-0.0622
No. of pods/Kg					1	-0.1075	0.1080	0.0967	-0.0581	0.1763	0.40868*	0.0526
Shell weight pod^{-1} (g)						1	-0.5323**	0.0178	-0.1648	-0.0903	-0.0333	-0.0661
Rag weight pod^{-1} (g)							1	-0.2318*	0.1390	-0.0321	-0.0740	0.0687
Pulp weight pod^{-1} (g)								1	0.1101	-0.0496	-0.0513	0.7209**
Seed weight pod^{-1} (g)									1	-0.0127	0.0312	0.1520
Pulp recovery (%)										1	0.0424	0.0551
Pulp: shell ratio											1	-0.2197*
Seed: pulp ratio												-0.0360
No. of seed pod^{-1}												1
Inflorescence length (cm)												
Stem girth (cm)												
Tartaric acid (%)												
TSS (^{0}Brix)												
Total sugar (%)												
Reducing sugar (%)												
Non-reducing sugar (%)												
Acid: sugar ratio												
Yield per plant (Kg)												

Significant at 5% level-*, Significant at 1% level-**

Table 3: Conti…

Characters	No. of seed pod^{-1}	Inflorescence length (cm)	Stem girth (cm)	Tartaric acid (%	TSS (^{0}Brix)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Acid: sugar ratio	Yield per plant (Kg)
Length of pod (cm)	-0.3174**	-0.0432	-0.0720	0.0212	0.0094	-0.0222	0.2981**	-0.1157	0.3444**	-0.2273*
Thickness of pod (cm)	-0.1474	0.0771	0.0418	-0.0794	0.1967	-0.2115*	-0.1382	-0.2365*	-0.5781**	0.0964
Pod width (cm)	-0.0891	0.0015	0.0394	-0.0672	0.0181	-0.0522	-0.1256	0.0492	0.2319*	0.0650
Pod weight (g)	-0.1955	0.2303*	0.0244	0.1375	0.5794**	-0.1426	0.1804	0.0818	-0.1400	0.0532
No. of pods/Kg	-0.0735	-0.0247	-0.262*	-0.0422	-0.1532	0.0749	0.0125	-0.1443	0.0939	-0.0605
Shell weight pod^{-1} (g)	-0.0292	-0.0165	0.2445*	-0.0512	0.0369	0.2804**	-0.1734	-0.0667	-0.2050	0.0125
Rag weight pod^{-1} (g)	0.3095**	-0.2050	-0.2293*	0.0477	-0.1321	-0.1520	-0.1125	-0.1260	0.1098	0.1083
Pulp weight pod^{-1} (g)	-0.2352*	0.0687	-0.0447	-0.0808	0.0778	-0.2185*	-0.0305	0.1374	-0.2582*	-0.0113
Seed weight pod^{-1} (g)	0.1023	-0.1060	-0.0049	-0.0166	-0.0384	-0.0263	-0.2120*	0.0259	0.0895	-0.0589
Pulp recovery (%)	0.1906	-0.0626	0.2916**	0.0036	-0.0211	0.2369*	0.1798	0.5054**	0.3298**	0.3177**
Pulp: shell ratio	0.1393	-0.0120	0.2511*	-0.0088	-0.0670	-0.0134	0.0899	-0.1595	0.0895	0.0306
Seed: pulp ratio	-0.0450	0.1522	-0.0553	-0.1367	-0.1620	-0.2122*	-0.0813	0.0262	-0.0720	-0.0754
No. of seed pod^{-1}	1	-0.2136*	0.3057**	-0.1057	-0.2319*	0.0475	0.0910	0.0633	-0.0857	0.2043
Inflorescence length (cm)		1	-0.0515	0.0683	0.1204	-0.1262	-0.0092	-0.1250	0.0158	0.1577
Stem girth (cm)			1	-0.2485*	0.0800	0.1102	0.3371**	0.4185**	0.1754	0.1732
Tartaric acid (%)				1	-0.0465	0.0256	0.1966	-0.0620	-0.1235	-0.0333
TSS (^{0}Brix)					1	-0.1795	-0.0005	0.1833	-0.1672	-0.0758
Total sugar (%)						1	-0.0456	0.0911	0.0633	0.1630
Reducing sugar (%)							1	0.2458*	0.2109*	-0.0755
Non-reducing sugar (%)								1	0.0963	0.1011
Acid: sugar ratio									1	-0.0359
Yield per plant (Kg)										1

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