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Research Note

Correlation and path-coefficient analysis for yield and yield components of tamarind (*Tamarindus indica* L.) genotypes

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Abstract
An experiment was conducted during 2017-19 at Forest Research Station (FRS), Govinkovi, Davangere district which is situated in the Southern Transitional Zone of Karnataka with 16 tamarind genotypes (K-9, NTI-52, K-11, S-7, S-8, S-14, S-3, N-6, D-2, C-4, D-9, NTI-89, D-19, S-6, K-10 and K-12). In this study, yield and yield components were analyzed for correlation and path analysis. The results revealed that, the pod yield per tree exhibited significant and positive association with pod weight (0.6417 and 0.6729), pulp weight (0.6324 and 0.6698), shell weight (0.6096 and 0.6520), fibre weight (0.6005 and 0.6458), pod length (0.5712 and 0.6142), seed weight (0.4660 and 0.4755), pod thickness (0.3714 and 0.4162) and pod width (0.3317 and 0.4311). While, the pod length (0.0674), pod thickness (0.0866), pod weight (0.0240), pulp weight (0.2121), shell weight (0.3169), seed weight (0.4787), fibre weight (0.2821) and number of pods per tree (0.3494) exhibited positive direct effect on pod yield per tree. Since the pod length, pod weight and pod thickness are the measures of pod size, the larger the pod, the heavier the pulp weight. Hence, these yield components can be used as criteria in selection programme for developing elite cultivar in tamarind.

Keywords: Correlation, path co-efficient analysis, tamarind, yield and yield components.

Tamarind (*Tamarindus indica* L.) is a hardwood evergreen, multipurpose tree species belongs to dicotyledonous family Leguminosae and sub-family Ceasalpinae. It is a diploid species with chromosome number of 2n=24 (Kumar *et al.,* 2015). It has a wide geographical distribution throughout the world in tropical, subtropical and semi-arid zones with a prime concentration in India, apart from western dry regions and Himalayas. In India, it is mainly grown in Karnataka, Madhya Pradesh, Bihar, Chattisgarh, Andhra Pradesh and Tamil Nadu (Anon, 1993). Some of the best selections made on the basis of higher yield and pulp content are PKM-1, PKM-2, PKM-3 and Urigam in Tamil Nadu; Pratisthan, No.263, Yogeshwari, T-9, T-10, T-11, T-12, T-13 in Maharashtra and DTS-1 and DTS-2 in Karnataka. (Nath *et al.,* 2008). India is the main producer of tamarind in the world with the yearly production of three lakh tonnes, of which 1.15 lakh tonnes of pulp per annum exported to various countries *viz.,* USA, Australia, Sri Lanka, Malaysia, Pakistan beside some European countries etc. (Sinha *et al.,* 2015). It is a hardy and drought tolerant tree and mainly found growing in waste-lands. Now a days this fruit crop is gaining popularity among the farming community as well as processing industries due to its immense demand. In the era of climate change, the performance of this fruit crop is encouraging.

In any crop improvement programme, it becomes necessary to concentrate on more than one character, especially in the complex character like yield which is influenced by many other components. This is due to the physiological and linkage association of genes governing various traits. Hence, knowledge of correlation between different economical components is of significant importance in selection programmes. Positive correlation allows crop improvement with respect to two or more attributes, whereas, negative association indicates the need to compromise between desirable traits. A breeder needs to identify the causes of variability in yield in any given location. Correlation analysis is a tool useful in providing indication of the degree of association between variables. The simple correlation study is inadequate to measure the association as different genotypes are susceptible to environment in varying degrees. Estimates of phenotypic and genotypic correlation gave way for understanding environmental influence on heredity expression. The pod yield has been associated with a number of component characters and these characters themselves are inter-related, showing a complex chain of association. Every component traits will have a direct and indirect effect on yield. Path co-efficient analysis offered a much more realistic interpretation of the factors involved. Hence the study on correlation and path-coefficient analysis for yield and selected yield components of tamarind genotypes are essential which may be further useful in selection programme for the development of new elite tamarind cultivar along with providing valuable information for crop improvement.

The present investigation was carried out during 2017-19 at Forest Research Station (FRS), Govinkovi, Honnali taluk, Davangere district which is situated in the Southern Transitional Zone of Karnataka. The experiment was laid out in a randomized complete block design with 16 genotypes (K-9, NTI-52, K-11, S-7, S-8, S-14, S-3, N-6, D-2, C-4, D-9, NTI-89, D-19, S-6, K-10 and K-12) and three replications (two trees per replication) which were of 14 years old. The data on pod length, pod width and pod thickness were measured using vernier calliper, while, pod weight, shell weight, pulp weight, seed and fibre weight per pod were measured by weighing machine and number of seeds per pod, number of pods per tree and pod yield were recorded by using standard formula method and on counting basis. The data recorded were analyzed through standard statistical method (Gomez and Gomez, 1984). To analyze the relationships between these components, correlation and direct and indirect path analysis were determined using SPSS. 11.0 computer software in which pod yield was considered as dependent variable and all other yield attributing components were considered as independent variables (Al-Jibouri *et al.,*1958).

Correlation co-efficient between the various yield and yield attributing components of the tamarind genotypes is presented in **Table 1 and 2**. The pod yield per tree exhibited highly significant and positive association with pod weight (0.6417 and 0.6729), pulp weight (0.6324 and 0.6698), shell weight (0.6096 and 0.6520), fibre weight (0.6005 and 0.6458), pod length (0.5712 and 0.6142), seed weight (0.4660 and 0.4755), pod thickness (0.3714 and 0.4162) and pod width (0.3317 and 0.4311). While, non-significant positive correlation with number of pods per tree (0.2188 and 0.2461) and number of seeds per pod (0.1682 and 0.2141) at both phenotypic and genotypic levels. Similar results were also reported by Bhogave *et al.* (2018) and Mayavel *et al.* (2018) in tamarind. Pod length was highly significant and showed positive correlation with pulp weight (0.6169 and 0.6692), pod weight (0.5673 and 0.6073), fibre weight (0.4963 and 0.5332), seed weight (0.4621 and 0.4984), shell weight (0.4621 and 0.5009) and number of seeds per pod (0.3920 and 0.4702), while, non-significantly positive correlation with pod width (0.2579 and 0.2908), whereas, pod width showed highly significant and positive correlation with shell weight (0.7583 and 0.8815), pod weight (0.6752 and 0.7546 and 0.8628), pulp weight (0.6752 and 0.8070), seed weight (0.7414 and 0.8065), fibre weight (0.6610 and 0.7562) and pod thickness (0.5255 and 0.6236), while, non-significant positive correlation was observed with pod length (0.2579 and 0.2908) at both phenotypic and genotypic levels, respectively. The results on similar line were also reported by Nasution and Yapwattanaphun (2017), Bhogave *et al.* (2018) and Mayavel *et al.* (2018) in tamarind. The pod thickness exhibited highly significant and positive association with shell weight (0.6918 and 0.7461), pod weight (0.5927 and 0.6334), seed weight (0.5729 and 0.6288), pod width (0.5255 and 0.6236), fibre weight (0.5245 and 0.5626) and pulp weight (0.4831 and 0.5228).

The pod weight showed highly significant and positive correlation with shell weight (0.9280 and 0.9269), pulp weight (0.9231 and 0.9512), seed weight (0.8987 and 0.9425), fibre weight (0.8930 and 0.9171), pod width (0.7546 and 0.8628), pod thickness (0.5927 and 0.6334) and pod length (0.5673 and 0.6073). The shell weight per pod was highly significant and showed positive correlation with pod weight (0.9280 and 0.9269), pulp weight (0.8008 and 0.8923), fibre weight (0.8004 and 0.8272), seed weight (0.7897 and 0.8354), pod width (0.7583 and 0.8815), pod thickness (0.6918 and 0.7461) and pod length (0.4621 and 0.5009) at both phenotypic and genotypic levels, respectively. Similar results were also reported by Singh and Nandini (2014), Nasution and Yapwattanaphun (2017) and Bhogave *et al.* (2018) in tamarind. The pulp weight per pod showed significantly high and positive association with pod weight (0.9231 and 0.9512), fibre weight (0.8903 and 0.9260), seed weight (0.8142 and 0.8811), shell weight (0.8008 and 0.8923), pod width (0.6752 and 0.8070), pod length (0.6169 and 0.6692) and pod thickness (0.4831 and 0.5228). Also seed weight per pod showed highly significant and positive association with pod weight (0.8987 and 0.9425), pulp weight (0.8142 and 0.8811), shell weight (0.7897 and 0.8354), fibre weight (0.7473 and 0.7865), pod width (0.7414 and 0.8065), pod thickness (0.5729 and 0.6288) and pod length (0.4621 and 0.4984) at both phenotypic and genotypic levels. The results on similar line were also reported by Singh and Nandini (2014), Bhogave *et al.* (2018) and Mayavel *et al.* (2018) in tamarind.

Table 1. Phenotypic correlation co-efficient for different yield components in tamarind genotypes

Traits	1	2	3	4	5	6	7	8	9	10	$r_{p\ (Pod\ yield)}$
1	**1.0000**	0.2579	-0.0398	0.5673**	0.4621 **	0.6169 **	0.4621 **	0.4963 **	0.3920 **	-0.0593	0.5712**
2		**1.0000**	0.5255**	0.7546**	0.7583 **	0.6752 **	0.7414 **	0.6610 **	-0.4169 **	-0.5292 **	0.3317*
3			**1.0000**	0.5927**	0.6918 **	0.4831 **	0.5729 **	0.5245 **	-0.3978 **	-0.4130 **	0.3714**
4				**1.0000**	0.9280 **	0.9231 **	0.8987 **	0.8930 **	-0.1560	-0.5667 **	0.6417**
5					**1.0000**	0.8008 **	0.7897 **	0.8004 **	-0.2576	-0.4501 **	0.6096**
6						**1.0000**	0.8142 **	0.8903 **	-0.0546	-0.5102 **	0.6324**
7							**1.0000**	0.7473 **	-0.2414	-0.6660 **	0.4660**
8								**1.0000**	-0.0658	-0.4315 **	0.6005**
9									**1.0000**	0.4153 **	0.1682
10										**1.0000**	0.2188

*and ** indicates significant at 5 and 1 per cent level probability, respectively.
1. Pod length 3. Pod thickness 5. Shell weight per pod 7. Seed weight per pod 9. Number of seeds per pod
2. Pod width 4. Pod weight 6. Pulp weight per pod 8. Fibre weight per pod 10. Number of pods per tree

Table 2. Genotypic correlation co-efficient for different yield components in tamarind genotypes

Traits	1	2	3	4	5	6	7	8	9	10	$r_{g\ (Pod\ yield)}$
1	**1.0000**	0.2908*	-0.0475	0.6073**	0.5009**	0.6692**	0.4984**	0.5332**	0.4702**	-0.0635	0.6142**
2		**1.0000**	0.6236**	0.8628**	0.8815**	0.8070**	0.8065**	0.7562**	-0.5400**	-0.6138**	0.4311**
3			**1.0000**	0.6334	0.7461**	0.5228**	0.6288**	0.5626**	-0.4653**	-0.4405**	0.4162**
4				**1.0000**	0.9269**	0.9512**	0.9425**	0.9171**	-0.1816	-0.5810**	0.6729**
5					**1.0000**	0.8923**	0.8354**	0.8272**	-0.3044*	-0.4662**	0.6520**
6						**1.0000**	0.8811**	0.9260**	-0.0548	-0.5325**	0.6698**
7							**1.0000**	0.7865**	-0.2800	-0.7044**	0.4755**
8								**1.0000**	-0.0869	-0.4385**	0.6458**
9									**1.0000**	0.4695	0.2141
10										**1.0000**	0.2461

*and ** indicates significant at 5 and 1 per cent level probability, respectively.
1. Pod length 3. Pod thickness 5. Shell weight per pod 7. Seed weight per pod 9. Number of seeds per pod
2. Pod width 4. Pod weight 6. Pulp weight per pod 8. Fibre weight per pod 10. Number of pods per tree

The fibre weight per pod exhibited significant positive correlation with pod weight (0.8930 and 0.9171), pulp weight (0.8903 and 0.9260), shell weight (0.8004 and 0.8272), seed weight (0.7473 and 0.7865), pod width (0.6610 and 0.7562), pod thickness (0.5245 and 0.5626) and pod length (0.4963 and 0.5332) while, the number of seeds per pod showed highly significant and positive association with number of pods per tree (0.4153 and 0.4695) and pod length (0.3920 and 0.4702), whereas, the number of pods per tree was highly significant and showed positive association with number of seeds per pod (0.4153 and 0.4695) at both phenotypic and genotypic levels respectively. These results are also in agreement with the findings of Singh and Nandini (2014), Nasution and Yapwattanaphun (2017), Bhogave *et al.* (2018) and Mayavel *et al.* (2018) in tamarind, Shoba *et al.* (2018) in black-gram and Suresh *et al.* (2021) in clusterbean.

Genotypic correlation values were generally higher compared to that of corresponding phenotypic correlation values suggesting that relationships were mainly due to genetic causes. Significantly positive correlations were observed for all the traits, in which highest value was recorded for pulp weight and pod weight. Thus pod weight, pulp weight and number of pods per tree could be considered as an important traits which can be used as a primary component for yield improvement.

Path co-efficient analysis was based on phenotypic correlation and results on the direct and indirect effects of various components on pod yield per tree which are presented in **Table 3**. The pod length showed positively direct effect (0.0674) on pod yield per tree, whereas, positive indirect effect exhibited by seed weight (0.2212) followed by shell weight (0.1465), fibre weight (0.1400)

Table 3. Direct (diagonal) and indirect effects of components characters on yield in tamarind genotypes at phenotypic level

Traits	1	2	3	4	5	6	7	8	9	10	$r_{p\ (pod\ yield)}$
1	**0.0674**	-0.0537	-0.0034	-0.0136	0.1465	0.1308	0.2212	0.1400	-0.0142	-0.0499	0.5712
2	0.0174	**-0.2080**	0.0455	-0.0181	0.2403	0.1432	0.3549	0.1865	0.0151	-0.4453	0.3317
3	-0.0027	-0.1093	**0.0866**	-0.0142	0.2193	0.1025	0.2743	0.1480	0.0144	-0.3475	0.3714
4	0.0382	-0.1570	0.0513	**0.0240**	0.2941	0.1958	0.4302	0.2519	0.0057	-0.4768	0.6417
5	0.0311	-0.1577	0.0599	-0.0222	**0.3169**	0.1699	0.3780	0.2258	0.0093	-0.3787	0.6096
6	0.0416	-0.1405	0.0418	-0.0221	0.2538	**0.2121**	0.3898	0.2512	0.0020	-0.4292	0.6324
7	0.0311	-0.1542	0.0496	-0.0215	0.2503	0.1727	**0.4787**	0.2108	0.0088	-0.5603	0.4660
8	0.0334	-0.1375	0.0454	-0.0214	0.2537	0.1888	0.3577	**0.2821**	0.0024	-0.3630	0.6005
9	0.0264	0.0867	-0.0345	0.0037	-0.0817	-0.0116	-0.1155	-0.0186	**-0.0363**	0.3494	0.1682
10	-0.0040	0.1101	-0.0358	0.0136	-0.1427	-0.1082	-0.3188	-0.1217	-0.0151	**0.8414**	0.2188

Residual effect = 0.3210.

1. Pod length 3. Pod thickness 5. Shell weight per pod 7. Seed weight per pod 9. Number of seeds per pod
2. Pod width 4. Pod weight 6. Pulp weight per pod 8. Fibre weight per pod 10. Number of pods per tree

and pulp weight (0.1308). Pod width revealed the highest negative direct effect (-0.2080) on pod yield per tree while, positive indirect effect exhibited by seed weight (0.3549) followed by shell weight (0.2403), fibre weight (0.1865), pulp weight (0.1432), pod thickness (0.0455), pod length (0.0174) and number of seeds per pod (0.0151). The results on similar line were also reported by Singh and Nandini (2014) and Mayavel *et al.* (2018) in tamarind, Bhoomika *et al.* (2021) in cucumber. The pod thickness exhibited positive direct effect (0.0866) on pod yield per tree and positive indirect effect expressed by seed weight (0.2743) followed by shell weight (0.2193), fibre weight (0.1480), pulp weight (0.1025) and number of seeds per pod (0.0144). Pod weight revealed positive direct effect (0.0240) on pod yield per tree whereas, positive indirect effect exhibited by seed weight (0.4302) followed by shell weight (0.2941), fibre weight (0.2519), pulp weight (0.1958), pod thickness (0.0513), pod length (0.0382) and number of seeds per pod (0.0057). These results are also in agreement with the findings of Mayavel *et al.* (2018) in tamarind.

Shell weight per pod imparted positive direct effect (0.3169) on pod yield per tree while, positive indirect effect exhibited by seed weight (0.3780) followed by fibre weight (0.2258), pulp weight (0.1699), pod thickness (0.0599) and pod length (0.0311) on pod yield per tree. The pulp weight per pod exhibited positive direct effect (0.2121) on pod yield per tree whereas, positive indirect effect exhibited by seed weight (0.3898) followed by shell weight (0.2538), fibre weight (0.2512), pod thickness (0.0418), pod length (0.0416) and number of seeds per pod (0.0020). Seed weight per pod showed positive direct effect (0.4787) on pod yield per tree and positive indirect effect exhibited by shell weight (0.2503) followed by fibre weight (0.2108), pulp weight (0.1727), pod thickness (0.0496), pod length (0.0311) and number of seeds per pod (0.0088). The results on similar line were also reported by Singh and Nandini (2014) and Mayavel *et al.* (2018) in tamarind, Bhoomika *et al.* (2021) in cucumber.

Fibre weight per pod revealed positive direct effect (0.2821) on pod yield per tree and , positive indirect effect exhibited by seed weight (0.3577) followed by shell weight (0.2537), pulp weight (0.1888), pod thickness (0.0454) and number of seeds per pod (0.0024). The number of seeds per pod exhibited negatively direct effect (-0.0363) on pod yield per tree. Whereas, positive indirect effect expressed by number of pods per tree (0.3494) followed by pod width (0.0867), pod length (0.0264) and pod weight (0.0037). The number of pods per tree showed the highest positive direct effect (0.8414) on pod yield per tree while, positive indirect effect exhibited by pod width (0.1101) and pod weight (0.0136). These results are also in agreement with the findings of Singh and Nandini (2014), Bhogave *et al.* (2018) and Mayavel *et al.* (2018) in tamarind, Bhoomika *et al.* (2021) in cucumber and Shanthi *et al.* (2019) in black-gram. While, the residual effect for path analysis was 0.3210.

A positive association indicates that selection for improvement would result in parallel increases in the improvement components. Such type of association was recorded in most of the studied traits. From both direct influence and genetic correlation, increasing pod weight, pulp weight, pod size and number of pods per tree could increase the yield. For getting maximum yield, selection of these characters is of significant importance.

The association and cause effect studies revealed that pod yield per tree was positively and significantly correlated with pod weight, pulp weight, pod length, pod thickness and number of pods per tree. High direct effects were also observed for these traits. So, by improving these traits, yield can be significantly increased. Hence, pod weight, pulp weight, pod length and pod thickness could be considered as important components which can be used as a primary component for yield improvement.

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REFERENCES

Al-Jibouri, H.A., Miller, P.A. and Robinson, H.F. 1958. Genetic and environmental variances and co-variances in upland cotton cross of interspecific origin. *Agron. J.,* **50**: 633-637. [Cross Ref]

Anonymous, 1993. Tamarind (*Tamarindus indica* L.) Tech. Bull. Forest Research Institute, Dehradun.

Bhogave, A.F., Dalal, S.R. and Raut, U.A. 2018. Studies on qualitative traits variation in tamarind (*Tamarindus indica* L.). *Int. J. Chem. Stud.,* **6**(1): 396-398.

Bhoomika, M.R., Adivappar, N., Thippesha, D., Gangaprasad, S. and Sharanabasappa. 2021. Study on correlation and path analysis of F2 population of cucumber (*Cucumis sativus* L.). *Electronic Journal of Plant Breeding,* **12**(3): 1029-1032. [Cross Ref]

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research. A Wiley-Inter Sci., John Wiley and Sons, New York.

Kumar, M., Ponnuswami, V., Rajamanickam, C. and Preethi, T.L. 2015. Assessment of genetic diversity in tamarind (*Tamarindus indica* L.) using random amplified polymorphic DNA markers. *SAARC J. Agri*., **13**(1): 27-36. [Cross Ref]

Mayavel, A., Nagarajan, B., Muthuraj, K., Nicodemus, A. and Prabhu, R. 2018. Correlation and path coefficient analysis of selected red tamarind (*Tamarindus indica var rhodocarpha*) genetic resources. *Int. J. Curr. Microbiol. Appl. Sci.,* **7**(4): 794-802. [Cross Ref]

Nath, V. 2008. Fruit for the future. Satish Serial Publishing House, p. 220-260.

Nasution, F. and Yapwattanaphun, C. 2017. Clustering of five sweet tamarind based on fruit characteristic. *Agrivita J. Agric. Sci.,* **39**(1): 38-44. [Cross Ref]

Shanthi, P., Ganesan, K. N., Manivannan, N. and Natarajan, C. 2019. Correlation and path analysis in black-gram (*Vigna mungo* L.). *Electronic Journal of Plant Breeding,* 10(3): 1218 - 1222. [Cross Ref]

Shoba, D. 2018. Genetic variability and correlation studies in black-gram [*Vigna mungo* (L.) Hepper]. *Electronic Journal of Plant Breeding,* **9**(4):1583-1587. [Cross Ref]

Singh, T.R. and Nandini, R. 2014. Genetic variability, character association and path analysis in tamarind (*Tamarindus indica* L.) population of Nallur tamarind grove. *SAARC J. Agri.,* **12**(1): 20-25. [Cross Ref]

Sinha, G., Patel, S., Agarwal, A.K., Mishra, N.K., Sinha, A.K. 2015. Some studies on assessment of physical properties of tamarind pulp. *Int. J. Res. Stud. Bio Sci*., 4.

Suresh, D., Ananthan, M.C., Vanniarajan, P., Balasubramanian, T., Sivakumar, J., Souframanien and Beaulah, A. 2021. Evaluation of mutants and association studies in nonlodging clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.) mutant lines for yield and yield attributing traits. *Electronic Journal of Plant Breeding,* **12**(3):861 - 867. [Cross Ref]