Int.J.Curr.Microbiol.App.Sci (2018) *7*(4): 794-802

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 7 Number 04 (2018)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2018.704.089

Correlation and Path Coefficient Analysis of Selected Red Tamarind (*Tamarindus indica* var *rhodocarpha*) Genetic Resources

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Keywords

Red tamarind, Correlation, Path analysis, Yield, Quality

Article Info

Accepted:
07 March 2018
Available Online:
10 April 2018

A B S T R A C T

Correlation and path coefficient analysis was carried out to identify suitable selection indices in 21 red tamarind genotypes for 15 characters. Correlation analysis revealed that length of inflorescence (cm), number of flowers/inflorescence, number of fruits/inflorescence, fruit length (cm), fruit breadth (cm), fruit weight (g), pulp weight (g) and anthocyanin content (mg/litre) contributed to a large extent to yield per tree. Hence these characters could be effectively used in red tamarind improvement programme for selecting genotypes with higher yield and quality as they show positive and significant association. However in path coefficient analysis, the length of inflorescence, fruit length, anthocyanin content and total sugar contributing directly to the yield and most other characters associated to fruit yield are contributing indirectly through these characters. Hence it might be inferred that these traits could be considered as most important yield contributing traits in red tamarind.

Introduction

Tamarind is a diploid species (2n = 24) (Purseglove, 1987), large evergreen or semi-evergreen tree growing up to 20 meters in height, sometimes with trunk up to 4.0 meters in width and with a dense spreading crown (Allen and Allen, 1981). The branches are crooked, thick and wide spread thus tamarind has poor tree form (Storrs, 1995). It is a potential multipurpose forest genetic resource, awaiting large-scale domestication. Every part such as wood, roots, leaves, bark and fruits has some value of commerce, particularly in the subsistence of rural people (Gunasena and Hughes, 2000). Tamarind could be a potential tree species in the livelihood of the arid and semi-arid regions (Nagarajan *et al.*, 1998). India is the major exporter of tamarind pulp and seeds with an annual trade worth 2.1 million dollars (Vinning and Moody, 1997). Traditionally, tamarind fruit pulp is used for culinary, flavoring, food preservatives, jelly making, pickle, jams and beverages (Zablocki, 1995). Industrial use of tamarind includes extraction of polysaccharides, starch, tartarates, textile sizing, paper binding, jute weaving, adhesive making, dyeing, tanning, mordanting, purifying water and in coagulation of natural rubber (Shankaracharya, 1998). A wide variation could be observed on tree growth, canopy size, flowering pattern, fruit productivity and pulp colour in Tamarind. Based on the pulp colour tamarind is classified as red tamarind and brown tamarind. The red tamarind is taxonomically known as *Tamarindus indica* var *rhodocarpa.* This red tamarind is a rare mutant with scattered distribution and availability of this phenotypic variant is not well known in different parts of the country as well as in the world. The fruit colour in unripe stage is red due to presence of anthocyanin.

The content of anthocyanin is high in red tamarind (180 to 360 mg/g of unripe fruit), while comparing with other anthocyannin rich fruits like grapes (80-90 mg/g), cherry (70-75 mg/g) and jamun (120-130 mg/g). Red tamarind's anthocyanin also has rich antioxidant properties. Hence it will have wide scope for utilizing as potential bio-colorant in food processing, pharmaceutical, brewary and confectionery industries to replace the existing use of carcinogenic inorganic colorants.

Fruit yield is a very complex economic character and outcome of association of number of factors inherent in plant, genetic linkage and the environment in which the plant is grown. In any tree improvement program, it is essential to know the association among yield and yield related traits in the material generated, for effectual selection. Selection based on simply inherited and highly heritable yield attributes is most effective and reliable approach as compared to direct selection on yield itself. Understanding the nature and extent of association of different yield components with yield and inter relationship among themselves is an essential pre requisite for the formulation of breeding procedure for effective improvement of yield (Prabhu *et al.*, 2016).

The correlation and path analysis studies are important in fruit crops like tamarind, mango and citrus, where in quantity and quality traits are important in improvement program. Together it will provide knowledge on interrelationships and relative contribution of independent characters on dependent variable which enables a tree breeder to apply suitable selection procedures in tree improvement program. The knowledge on nature and magnitude of interrelationship among yield and its contributing factor is mandatory for the simultaneous improvement of characters and yield. Hence, an attempt was made in the present study to understand the direction and extent of character association, and the direct and indirect effect of other component traits on yield in red tamarind.

Materials and Methods

An experiment was conducted to evaluate 21 selected genotypes of red tamarind at Forest Research Station, Institute of Forest Genetics and Tree Breeding, Kurumbapatty, Salem, Tamil Nadu. A well planned survey was conducted for selection of red tamarind germplasm from different parts of Tamil Nadu, Puducherry, Karnataka and Andhra Pradesh for a period of 3 years from 2006-2008. Detail of red tamarind genotypes used for the present study is presented in Table 1. The selected red tamarind plus trees were multiplied through cleft grafting and planted in random block design (RBD) with 4 replications. Clones were planted in the spacing of 5×5 meters and 3 ramets/replication were maintained. The field trail was established in 2008 and evaluated during fruiting season of 2014-2016. Observations were recorded in 21 genotypes for 15 characters *viz.*, length of inflorescence (cm), number of flowers/inflorescence, number of fruits/inflorescence, fruit length (cm), fruit breadth (cm), fruit weight (g), pulp weight (g), number of seeds, seed weight (g), anthocyanin content (mg/litre), total soluble solids (TSS), total sugar (%), acidity (%), ascorbic acid (mg/gm) and yield/tree (kg). Simple correlation coefficient analysis for yield and yield components were carried out employing the formula propounded by Al-jibouri *et al.*, (1985). Path analysis was adopted to partition the correlation coefficient into direct and indirect effects as suggested by Dewey and Lu (1959). The path coefficients were ranked on the scales given by Lenka and Misra (1973).

Results and Discussion

Association analysis

The aim of correlation studies is primarily to know the suitability of various characters for indirect selection (Prabhu *et al.*, 2015). Correlation studies provide information on the nature and extent of association between any two metric traits and it will be possible to bring about genetic upgradation in one trait by selection of the other of a pair. The association of yield with different quality and yield components in 21 genotypes were estimated and presented in Table 2.

Taking all the 15 characters into consideration, yield/tree (kg) expressed significant and positive relationship with length of inflorescence (cm), number of flowers/inflorescence, number of fruits/inflorescence, fruit length (cm), fruit breadth (cm), fruit weight (g), pulp weight (g) and anthocyanin content (mg/litre). Hence it might be inferred that these traits could be considered as most important yield contributing traits in red tamarind. This is in accordance with the findings of Shivanandam and Raju (1988), Prasad *et al.*, (1998), Divakara *et al.*, (2008) and Singh and Nandhini (2014).

Number of flowers/inflorescence recorded significant and positive correlation with length of inflorescence (cm) in all the 21 genotypes taken for the study. These findings were also reported earlier by Prasad *et al.*, (1998) and Divakara *et al.*, (2008). All the 21 genotypes expressed significant and positive association with length of inflorescence (cm) and number of flowers/inflorescence for number of fruits/inflorescence. Similar results were reported by Challapillai *et al.*, (1995).

The character fruit length (cm) exhibited significant and positive correlation with length of inflorescence (cm), number of flowers/inflorescence and number of fruits/inflorescence in all the 21 genotypes. Shivanandam and Raju (1988), Prasad *et al.*, (1998), Divakara *et al.*, (2008) and Singh and Nandhini (2014) also observed similar associations with one or more characters for the trait fruit length (cm). Fruit breadth (cm) possessed significant and positive association with length of inflorescence (cm), number of flowers/inflorescence, number of fruits/inflorescence and fruit length (cm). These results are confirmative with findings of Shivanandam and Raju (1988) and Singh and Nandhini (2014).

The character fruit weight (g) exhibited significant and positive association with length of inflorescence (cm), number of flowers/inflorescence, number of fruits/inflorescence, fruit length (cm) and fruit breadth (cm) in all the 21 genotypes.

Challapilli *et al.*, (1995) and Divakara *et al.*, (2008) reported that the fruit weight is positively and significantly associated with pulp, fibre, seed weight, fruit length and breadth. All the 21 genotypes expressed significant and positive association with fruit length (cm), fruit breadth (cm) and fruit weight (g) for pulp weight (g). Prasad *et al.*, (1998), Divakara *et al.*, (2008) and Singh and Nandhini (2014) were also reported similar results.

Table.1 Geographic position of selected red tamarind genetic resources

S. No.	Tree Code	Tree name	GPS Position		Elevation
1	TVTVR-1	Vengalapuram Red - 1	N 11°45.140'	E 78°09.417'	367
2	TTCER-1	Eraiyur Red - 1	N 12°06.186'	E 78°54.464'	369
3	TVAMR-1	Machempattu Red - 1	N 12°51.479'	E 78°42.390'	360
4	TVGPR-1	Peranampet Red - 1	N 12°55.671'	E 78°42.916'	358
5	TDNNR-1	Natham Red - 1	N 10°18.241'	E 78°03.677'	348
6	TTPJR-1	Jayamangalam Red - 1	N 10°06.164'	E 77°36.182'	352
7	TTPJR-2	Jayamangalam Red - 2	N 10°06.164'	E 77°36.181'	272
8	TTPJR-3	Jayamangalam Red - 3	N 10°06.176'	E 77°36.176'	272
9	TTPPR-4	Podi Red - 4	N 10°01.249'	E 77°20.341'	349
10	TVRRR-1	Rajapalayam Red - 1	N 10°06.164'	E 77°36.182'	352
11	TVGSR-4	Shivaraj Nager Red - 4	N 12°56.048'	E 78°42.243'	364
12	TKUNR-1	Nelluvai Red - 1	N 11°00.885'	E 76°56.655'	419
13	TVAKR-1	Kedampur Red - 1	N 12°50.248'	E 78°42.548'	413
14	TMPKR-1	Kuvalapuram Red - 1	N 09°41.091'	E 77°45.504'	389
15	TCPPR-1	Pollachi Red - 1	N10° 44' 52.85"	E77° 6' 0.73"	354
16	PKKKR-1	Karaikal Red - 1	N 10°57.013'	E 79°46.519'	3
17	PKKKR-2	Karaikal Red - 2	N 10°56.992'	E 79°46.519'	3
18	AHHMR-1	Meduk Red - 1	N18° 3'11.78"	E78° 16'2.42"	467
19	AHHMR-2	Meduk Red - 2	N18°3'13.28"	E78°16' 3.26"	468
20	KKPCR-1	Chittampalli Red - 1	N13°0' 32.89"	E78°29' 28.74"	725
21	KCKKR-1	Kadur Red - 1	N13°33' 11.02"	E76 °0' 52.57"	773

Table.2 Simple correlation coefficient matrix for yield and quality traits in red tamarind

Character	Length of inflorescence (cm)	Number of flowers/inflorescence	Number of fruits/inflorescence	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	Pulp weight (g)	Number of seeds	Seed weight (g)	Anthocyanin content (mg/litre)	Total soluble solids (TSS)	Total sugar (%)	Acidity (%)	Ascorbic acid (mg/gm)	Yield/tree (kg)
Length of inflorescence (cm)	1.00	0.98**	0.74**	0.56**	0.56**	0.49*	0.25	0.40	0.05	0.28	0.01	0.06	0.24	-0.23	0.81**
Number of flowers/inflorescence		1.00	0.70**	0.63**	0.60**	0.52*	0.24	0.44*	0.09	0.25	-0.01	0.06	0.31	-0.26	0.74**
Number of fruits/inflorescence			1.00	0.52*	0.62**	0.57**	0.39	0.43	0.03	0.44*	-0.21	-0.16	0.24	-0.29	0.68**
Fruit length (cm)				1.00	0.80**	0.86**	0.66**	0.75**	0.55**	0.19	0.07	-0.05	0.14	-0.19	0.59**
Fruit breadth (cm)					1.00	0.82**	0.47*	0.61**	0.37	0.27	0.06	0.07	0.02	-0.12	0.50*
Fruit weight (g)						1.00	0.81**	0.80**	0.44*	0.37	0.18	0.03	0.10	-0.17	0.57**
Pulp weight (g)							1.00	0.71**	0.42	0.46*	0.09	-0.24	0.34	-0.29	0.44*
Number of seeds								1.00	0.62**	0.21	0.04	0.12	0.25	-0.28	0.38
Seed weight (g)									1.00	0.27	0.07	-0.12	0.08	-0.15	0.09
Anthocyanin content (mg/litre)										1.00	0.21	-0.30	0.27	-0.06	0.44*
Total soluble solids (TSS)											1.00	0.17	-0.28	0.37	0.19
Total sugar (%)												1.00	-0.50*	0.51*	0.02
Acidity (%)													1.00	-0.79**	0.06
Ascorbic acid (mg/gm)														1.00	-0.14
Yield/tree (kg)															1.00

*, ** Significant at P=0.05 and P=0.01 level of probability, respectively

Table.3 Direct and indirect effects of different quantitative and qualitative characters on yield of red tamarind

Character	Length of inflorescence (cm)	Number of flowers/inflorescence	Number of fruits/inflorescence	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	Pulp weight (g)	Number of seeds	Seed weight (g)	Anthocyanin content (mg/litre)	Total soluble solids (TSS)	Total sugar (%)	Acidity (%)	Ascorbic acid (mg/gm)	Simple correlation with Yield/tree (kg)
Length of inflorescence (cm)	**2.18**	-1.86	-0.11	0.74	-0.18	-0.12	-0.04	-0.02	-0.01	0.15	-0.01	-0.01	-0.05	0.15	0.81**
Number of flowers/inflorescence	2.12	**-1.91**	-0.10	0.83	-0.19	-0.13	-0.04	-0.02	-0.03	0.13	-0.01	-0.01	-0.07	0.16	0.74**
Number of fruits/inflorescence	1.60	-1.32	**-0.15**	0.68	-0.20	-0.14	-0.07	-0.02	0.00	0.25	-0.03	-0.09	-0.04	0.21	0.68**
Fruit length (cm)	1.18	-1.18	-0.07	**1.35**	-0.26	-0.21	-0.12	-0.03	-0.23	0.09	-0.01	-0.05	-0.02	0.14	0.59**
Fruit breadth (cm)	1.19	-1.13	-0.09	1.07	**-0.32**	-0.20	-0.08	-0.03	-0.15	0.14	-0.01	-0.01	0.01	0.11	0.50*
Fruit weight (g)	1.04	-0.97	-0.08	1.16	-0.26	**-0.25**	-0.15	-0.04	-0.18	0.21	0.00	-0.02	-0.01	0.12	0.57**
Pulp weight (g)	0.49	-0.42	-0.05	0.88	-0.15	-0.20	**-0.18**	-0.03	-0.18	0.27	-0.01	-0.09	-0.07	0.18	0.44*
Number of seeds	0.82	-0.80	-0.06	1.00	-0.19	-0.20	-0.13	**-0.05**	-0.26	0.09	-0.01	-0.01	-0.05	0.20	0.38
Seed weight (g)	0.06	-0.15	0.00	0.73	-0.12	-0.11	-0.08	-0.03	**-0.43**	0.15	0.00	-0.05	-0.01	0.10	0.09
Anthocyanin content (mg/litre)	0.53	-0.42	-0.06	0.20	-0.08	-0.09	-0.08	-0.01	-0.11	**0.61**	-0.01	-0.13	-0.05	0.10	0.44*
Total soluble solids (TSS)	-0.60	0.58	0.11	-0.30	0.07	0.01	0.03	0.02	0.04	-0.10	**-0.03**	-0.23	0.21	0.25	0.19
Total sugar (%)	-0.14	0.13	0.07	-0.31	0.02	0.03	0.08	0.00	0.11	-0.40	-0.04	**0.20**	0.22	-0.06	0.02
Acidity (%)	0.44	-0.53	-0.03	0.13	0.01	-0.01	-0.06	-0.01	-0.02	0.13	-0.03	-0.19	**-0.24**	0.44	0.06
Ascorbic acid (mg/gm)	-0.96	0.91	0.09	-0.54	0.10	0.09	0.10	0.03	0.12	-0.18	-0.03	0.03	0.31	**-0.34**	-0.14

Residual effects: 0.219; Bold figures denote direct effect; *, ** Significant at P=0.05 and P=0.01 level of probability, respectively

Among the 15 characters studied, number of seeds recorded significant and positive correlation with number of flowers/inflorescence, fruit length (cm), fruit breadth (cm), fruit weight (g) and pulp weight (g) in the all the 21 genotypes of red tamarind. These results are confirmative with findings of Singh and Nandhini (2014). Seed weight (g) possessed significant and positive correlation with fruit length (cm), fruit weight (g) and number of seeds in all the 21 genotypes taken for the study. These findings were also reported earlier by Samiullah *et al.,* (1993).

The character anthocyanin content (mg/litre) exhibited significant and positive correlation with number of fruits/inflorescence and pulp weight (g). In all the 21 genotypes, the traits total soluble solids (TSS) and total sugar (%) does not show significant/association with any of the remaining traits studied. Ascorbic acid (mg/gm) recorded significant and positive correlation with total sugar (%) whereas; it expressed significant and negative association with acidity (%). However, the character acidity (%) expressed significant and negative association with total sugar (%). Kaiser and Hulmani (1993), Abilash *et al.,* (2016) in guava, Chakrawar and Jathure (1980) in lime, Saha (2004) in lemon and Krishna *et al.,* (2017) in mango also observed similar associations with one or more characters experimented.

Path analysis

Path analysis is a form of multiple regression statistical analysis used to evaluate causal models by examining the relationships between a dependent variable and two or more independent variables. The results on direct and indirect effects of different quantitative and qualitative traits on fruit yield are presented in Table 3. The estimated residual effect is 0.219 indicating that 80 % of the variability in fruit yield was contributed by the quantitative and qualitative characters studied in the path analysis.

Path coefficient analysis revealed that, the length of inflorescence (2.18) is the most pronounced character contributing directly to the yield followed by fruit length (1.35), anthocyanin content (0.61) and total sugar (0.20). Therefore, direct selection of these traits could be useful in red tamarind improvement programme. While the number of flowers/inflorescence recorded negative direct effects (-1.91). Hence, such character should never consider as a parameter in selection programmes. Most other characters associated to fruit yield are contributing indirectly through above characters. Similar findings were reported by Kulkarni *et al.,* (1995), Prasad *et al.,* (1998), Divakara *et al.,* (2008) and Singh and Nandhini (2014).

Tamarind fruit pulp is an important economic trait which governs with several qualitative and quantitative attributes. The results of correlation coefficient analysis revealed that length of inflorescence (cm), number of flowers/inflorescence, number of fruits/inflorescence, fruit length (cm), fruit breadth (cm), fruit weight (g), pulp weight (g) and anthocyanin content (mg/litre) attributes contributed to a large extent to yield per tree. Hence these characters could be effectively used in tamarind improvement programme for selecting genotypes with higher yield and quality as they show positive and significant association. However in path coefficient analysis, the length of inflorescence is the most pronounced character contributing directly to the yield followed by fruit length, anthocyanin content and total sugar, and most other characters associated to fruit yield are contributing indirectly through these characters. Hence it might be inferred that this trait could be considered as most important yield contributing trait in red tamarind.

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How to cite this article:

Mayavel, A., B. Nagarajan, K. Muthuraj, A. Nicodemus and Prabhu, R. 2018. Correlation and Path Coefficient Analysis of Selected Red Tamarind (*Tamarindus indica* var *rhodocarpha*) Genetic Resources. *Int.J.Curr.Microbiol.App.Sci.* 7(04): 794-802.
doi: https://doi.org/10.20546/ijcmas.2018.704.089