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Morpho-biochemical Characterization of Tamarind (*Tamarindus indica* L.)

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ABSTRACT

Background: The research was conducted at the ICAR-CRIDA Hayatnagar Research Farm in Hyderabad, India. The plant material consists of tamarind trees planted in 1998 with 5m spacing to improve the morphological and reproductive characteristics of elite genotypes as well as quality and biochemical characters among the twenty tamarind accessions maintained at the research farm. The experiment was started in 1998 and observations were taken over the fruiting season of 2021-2022 with twenty tamarind accessions; the experiments were established in a randomized block design. The trees were identified for their consistent health and development.

Methods: Biometric observations mainly average number of flowers per inflorescence, average number of inflorescence per branch, average number of branches per tree, average fruit weight (g), average yield per plant (kg), fruit, pulp, seed weights as well as shell, fiber, fruit, number of normal seeds per pod as well as damaged number of seeds per pod, Carbohydrates g/ 100 g, Polyphenols g/100 g, Anthocyanin mg/100 g, % Antioxidant activity and % Tartaric acid were recorded and analyzed statistically.

Result: Significant differences among the tamarind accessions evaluated, NZB(S), Hasanur #5, Salem 132, NTI-14 and SMG-3 recorded the highest values in all the growth, pod and yield characters. NZB(S) recorded the highest number of flowers per inflorescence (14.62) while Hasanur # 5 recorded the highest number of inflorescence per branch (13.87). In yield attributes, NZB(S) recorded the highest average yield per plant (kg) (15.72) followed by Hasanur #5 (15.09), Salem 132 (14.81) and NTI-14 (14.65). The results revealed that NZB(S) showed the highest mean performance in terms of growth, yield and quality characters. The best performing accessions are being multiplied through vegetative propagation methods for planting on large scale in different locations.

Key words: Accessions, Biochemical characters, Flowering, Tamarind, Yield.

INTRODUCTION

The purpose of this research was to “Morpho–biochemical characterization of Tamarind”. In many regions around the world, the exploration of novel high-quality and low-cost food sources is a key concern of governments and organizations concerned for food and nutrition (Balogun and Fetuga 1986). Based on existing developments, projections indicate a gap between human population and food supply (Vijayakumari *et al*., 1997). As a consequence, research efforts are being focused on finding and analyzing underutilized crops that have been neglected to the disadvantage of human development as future food crops (Egbe and Akinyele, 1990; Adekunle and Ojerinde, 2004).

Tamarind is a member of the dicotyledonous Leguminosae family, which is the third biggest flowering plant family with 727 genera and 19,327 species (Lewis *et al*., 2005). The term tamarind comes from the Arabic word”Tamar-E Hind” meaning “Date of India”. It is almost found throughout the tropics and sub-tropics of the world and has naturalized in many places, particularly in India, South East Asia, Tropical America, the Pacific Islands and the Caribbean. The Asian countries, such as India and Thailand, are the primary producers. Tamarind popularly known as Imli is one of the auspicious, versatile tree in the Indian subcontinent and is particularly abundant in the States of Madhya Pradesh, Bihar and Andhra Pradesh, Telangana, Chhattisgarh, Karnataka, Tamil Nadu and West Bengal (Singh *et al*., 2007). It is a diploid species with 2n=26 chromosomes (Purseglove, 1987). India is the world’s largest producer of tamarind and it is estimated that 300,000 tons are produced annually. Tamarind is an important cash crop of India and enjoys sixth position in terms of export earnings. The trees act as windbreaks in many areas and are also suitable for drought prone areas. Tamarind thrives in a tropical climate with hot, dry summers and moderate winters. It can withstand drought but is prone to frost. Tamarind can be grown in almost all types of soil even on poor and margin soils, since; its life- span is long, deep loamy soils with adequate soil moisture holding capacity is ideal. A typical fruit contains about 55% pulp, 34% seeds and 11%

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shell and fiber on a weight basis (Rao *et al*., 2001; De Caluwe *et al*., 2010). Processing into value-added products is one means of preserving this commodity and improving its use for human health. Soups, jams, chutneys, sauces and juices all use the edible pulp of ripe fruit as a flavouring component (Isholoa *et al*. 1990). The tamarind fruit pulp has the most tartaric acid (8–18%) of any natural source. Moreover, pulp is the only material used for culinary purposes (Balan *et al*., 2017).

The majority of tamarind pulp's ingredients are carbohydrates (50.07g) and moisture (35.29 g^{1}); it is also an excellent source of dietary fiber (4.13 g). The high antioxidant activity of *Tamarindus indica* is thought to be caused by the plant's widespread distribution of polyphenol and flavonoid components. Tamarind contains phenolic chemicals that play a unique role in antibacterial and anticancer properties as well as being good for the heart and immune system. The most important kind of water soluble polyphenolic flavonoids pigments anthocyanin is responsible for the range of pigmentation found in various parts of plants. Anthocyanins have several advantages for both appearance and health, including anti-cancer, anti-inflammatory and vasoprotective actions that reduce the risk of coronary heart disease and enhance visual function. Natural antioxidants are less expensive, safer and more environmentally friendly than manufactured ones (Dorlo, 1994). Tartaric acid, reducing sugars, pectin, protein, fiber and cellulose components are all present in the fruit's pulp. Tartaric acid ranges from 8 to 18%, reducing sugars are 25 to 45%, pectin is 2-3.5% and protein is 2-3% depending on the sample. Hence the present investigation on morpho-biochemical characterization of Tamarind was carried out at Hayatnagar Research Farm, ICAR-CRIDA.

Principle component analysis (PCA) is a multivariate statistical method for exploring and simplifying large data sets, in which each principal component is a linear combination of the original variables, allowing the meaning of the components to be ascribed (Lewis and Lisle, 1998). The PCA explains the relationship between the eigenvector and eigenvalues and economic yield and it aids in identifying the principal component of yield in diverse populations.

MATERIALS AND METHODS

The study was conducted at Hayatnagar Research Farm, ICAR-CRIDA Hyderabad, India, from 2021 to 2022 with the objective of recording the flowering and fruiting characteristics of elite genotypes as well as quality and Biochemical among the twenty tamarind accessions kept at the research farm. The field trial was established in 1998 and evaluated during the fruiting season of 2021-2022 (23 years aged plants). Three replications and 20 genotypes were used for the experiment, which has been arranged in a randomized block design *viz*., Hasanur #3, Vellore #2, Salem 132, Urigam CT 164, PKM-1, Urigam, Vantoor, Sweet, Red, NZB (S), KRMR, PKM (Red), Prathistan, HYD (Local), NTI-56, NTI-60, NTI-84, CMK-5, CMK-7and BDM-3. The findings of eleven quantitative characters' observations *viz*., number of flowers per inflorescence, number of inflorescence per branch, number of fruits per branch, fruit weight (g), pulp weight per fruit (g), seed weight per fruit (g), shell weight per fruit (g), fiber weight per fruit (g), total number of seeds per pod (normal and damaged) were taken account of for all of the genotypes selection of study. For recording horticultural traits, five observations of each genotype were chosen at random from each replication. At a 5% level of probability, the significance of the mean was assessed using the Critical Differences (CD) test (Panse and Sukhatme, 1985).

A correlation matrix or a variance-covariance matrix is the starting point for principal component analysis. After determining the matrix eigenvalues and eigenvectors, the strongly correlated variables can be grouped together on components or factors. The eigenvectors (loadings) are sorted by eigenvalue, from highest to lowest, indicating the importance of the components. The eigenvectors of the most significant components can be used to obtain the scores (=reduced data set) for each subject by selecting the most 68 significant components.

The Phenol-Sulphuric Acid method (Dubois *et al*., 1956; Krishnaveni *et al*., 1984) is a colorimetric method that is widely used to determine the total concentration of carbohydrates present in foods.

Total polyphenol content (TPC) was determined using the Folin–Ciocalteu method (Malick *et al*., 1980). This reaction occurs under alkaline conditions provided by sodium carbonate. The intensity of the blue colour reflects the number of polyphenol compounds, which can be measured at 650 nm by UV/Vis spectrophotometer (UV 3200xe, Lab India).

The hydrogen donating or radical scavenging ability of *T. indica* fruit extract was determined by the stable radical 2, 2-diphenyl-1-picrylhydrazyl (DPPH) (Parejo *et al*., 2002). The reaction mixture having DPPH methanol solution (0.2 mg/mL) and crude extract (methanol for the control) was incubated at 37°C for 20 min and the absorbance was measured at 517 nm using UV/Vis spectrophotometer (UV 3200xe, Lab India,). The percent of DPPH discoloration of the sample was then calculated.

Tartaric acid is an organic acid that is extracted from tamarind pulp blended, centrifuged and filtered through cheesecloth. The pH of each sample was measured and made up to 50 mL with distilled water. Each sample was titrated with 0.1N NaOH using phenolphthalein indicator to an endpoint of 8.2 pH and recorded the mL of NaoH used for each titration. Titratable acidity (Garner *et al*., 2003) is calculated by the following formula:

$$\% \text{ Acid} = \frac{[\text{mL NaOH used}] \times [0.1 \text{ N NaOH}] \times [\text{milli equivalent factor}]}{\text{Grams of sample (5 g)}} \times [100]$$

Where,

Millie equivalent factor for tartaric acid = 0.075, NaOH = 0.1

RESULTS AND DISCUSSION

The results obtained on the Morphological and biochemical characterization of Tamarind are presented below. Development of high yielding varieties of crops/ trees requires information about the nature and magnitude of variability present in the available accessions in phenotypic characters that are connected with yield. The morphological and biochemical parameters of twenty tamarind accessions are described in Table 1 and 2. Significant differences among twenty tamarind accessions were observed. The findings revealed that among twenty tamarind accessions, NZB (S) (15.72 kg/plant) recorded the highest values in case of pod and yield characters, PKM (R) (40.67 mg/100 g) recorded the highest values of Anthocyanin mg/100g. The findings revealed that Ave. no. of flowers/inflorescence ranged from 8.47 to14.62. The highest value of Ave. no. of flowers/ inflorescence was recorded in NZB (S) (14.62) followed by SLM-132 (13.61), PRATISTAN (12.87) and SWEET (12.67) and the lowest in UT - 164 (8.47) followed by VELLORE - 2 (10.17), NTI - 56 (10.36) and VANTOOR (10.92). In case of average number of inflorescence/Branch NZB (S) accession recorded the highest value of 12.94 followed by PKM (R) (12.61), NTI - 60 (12.54) and CMK -7 (12.46) and the lowest was noticed in UT - 164 (7.62) followed by NTI - 56 (8.92), VANTOOR (9.28) and LOCAL (9.69).

The highest value of Average number of branches per tree was recorded in NZB (S) (5.94) followed by SLM-132 (5.92), KRMR (5.81) and CMK-7 (5.68) and the lowest in UT-164 (3.57) followed by NTI - 56 (3.81), VANTOOR (3.84) and LOCAL (3.95). The highest value of Average fruit weight (g) was recorded in NZB (S) (19.24) followed by SLM-132 (19.08), PKM (R) (16.34) and NTI - 60 (15.47) and the lowest in KRMR (9.05) followed by UT-164 (9.37), HASNUR-3 (9.42) and RED (9.45). The highest value of Average yield per plant (kg) was recorded in NZB (S) (15.72) followed by SLM-132 (14.81), KRMR (13.94) and CMK -7 (13.62) and the lowest in UT - 164 (4.83) followed by NTI – 56 (8.47), VANTOOR (8.79) and LOCAL (8.84). The highest value of Pulp weight per fruit (g) was recorded in NZB (S) (9.27) followed by VANTOOR (8.93), SLM-132 (8.72) and NTI – 56 (7.25) and the lowest in UT - 164 (3.54) followed by HASNUR-3 (3.83), RED (4.26) and URIGAM (4.38). The highest value of Seed weight per fruit (g) was recorded in SLM-132(6.42) followed by VANTOOR (5.76), NTI - 60 (5.58) and NZB (S)(5.32) and the low est in RED (2.59) followed by KRMR (2.63), BDM-3 (2.96) and HASNUR-3 (3.15).The highest value of Shell weight per fruit (g)was recorded in SLM-132(3.86) followed by VANTOOR (3.67), NTI – 60 (3.27) and PRATISTAN (3.25) and the lowest in NTI -84 (1.17) followed by KRMR (1.63), CMK - 5(2.96) and PKM - 1 (1.93).The highest value of Fiber weight per fruit (g) was recorded in PRATISTAN (0.72) followed by BDM - 3 (0.71), VANTOOR (0.70) and CMK -5 (0.65) and the lowest in NZB (S) (0.22) followed by SLM-132 (0.24), VELLORE -2 (0.25) and NTI - 84 (0.32). The highest value of Total seed per Pod (no's) was recorded in NZB (S) (10.78) followed by PRATISTAN (10.54), LOCAL (9.78) and URIGAM(8.93) and the lowest in KRMR(6.28) followed by RED (6.97), HASNUR-3 (7.23) and PKM - 1 (7.34).The highest value of Normal seed per pod (no's)was recorded in NZB (S) (9.38) followed by LOCAL (8.24), VELLORE - 2 (7.83) and URIGAM (7.68) and the lowest in KRMR (5.38) followed by RED (5.81), PRATISTAN (6.18) and NTI - 84 (6.25).The highest value of Damaged seed per Pod (no's) was recorded in LOCAL (1.54) followed by UT - 164 (1.51), CMK-5 (1.35) and BDM -3 (1.25) and the lowest in KRMR (0.9) followed by NZB (S)(0.62), VELLORE - 2(0.84) and NTI – 60(0.89).

The highest value of Carbohydrates g/100 g was recorded in SWEET (54.78) followed by Red (53.07), HASNUR - 3 (46.02) and UT 164 (30.88) and the lowest in

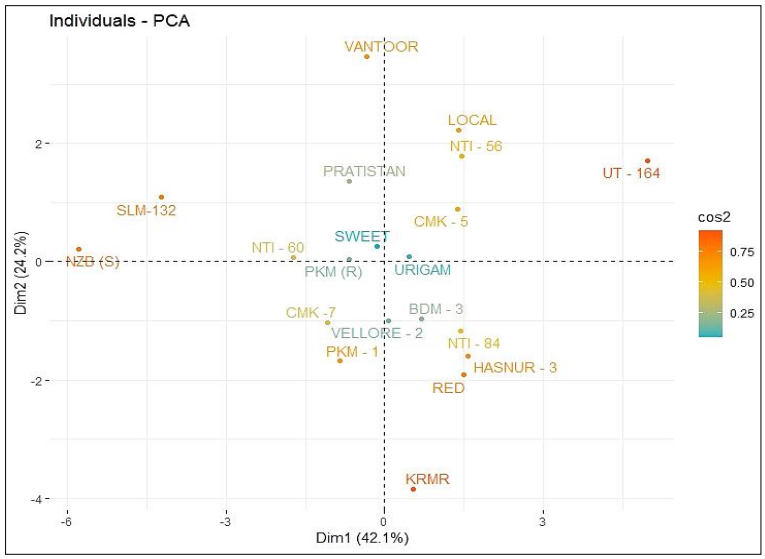

Fig 1: PCA scatter diagram showing the dispersion of Tamarind genotypes across PC1 and PC2.

Table 1: Evaluation of 20 tamarind accessions for flowering, fruiting and yield characters.

Name	Avg.no.of flowers/ inflorescence	Avg. no.of inflorescence/ Branch	Avg. no.of branches /tree	Avg. fruit weight (g)	Avg. yied/ plant (kg)	Pulp wt/ Fruit (g)	Seed wt/ fruit (g)	Shell wt/ fruit (g)	Fibre wt/ fruit (g)	Total seed/ Pod (no's)	Normal seed/ pod (no's)	Damaged seed/ Pod (no's)
BDM-3	12.31	11.52	5.21	10.08	12.83	4.43	2.96	1.98	0.71	8.74	7.49	1.25
CMK-5	11.36	10.18	4.52	12.49	9.33	5.83	4.13	1.88	0.65	8.49	7.14	1.35
CMK-7	11.64	12.46	5.68	14.13	13.62	6.48	4.32	2.79	0.54	7.34	6.26	1.08
Hansur-3	11.49	9.73	5.14	9.42	12.27	3.83	3.15	2.12	0.32	7.23	6.61	1.23
KRMR	12.34	11.77	5.81	9.05	13.94	4.41	2.63	1.63	0.38	6.28	5.38	0.9
Local	10.93	9.69	3.95	12.82	8.84	5.87	4.13	2.37	0.45	9.78	8.24	1.54
NTI-56	10.36	8.92	3.81	14.69	8.47	7.25	4.74	2.13	0.57	7.48	6.35	1.13
NTI-60	11.38	12.54	5.17	15.47	12.64	6.13	5.58	3.27	0.49	7.63	6.74	0.89
NTI-84	11.92	10.64	4.62	10.54	10.23	4.79	4.26	1.17	0.32	7.48	6.25	1.23
NZB (S)	14.62	12.94	5.94	19.24	15.72	9.27	5.32	2.21	0.22	10.78	9.38	0.62
PKM-1	11.81	12.35	5.66	12.79	13.54	5.74	4.64	1.93	0.48	7.34	6.37	0.97
PKM (R)	11.21	12.61	4.92	16.34	12.13	5.92	4.21	2.32	0.54	8.37	7.21	1.16
Pratistan	12.87	10.48	4.79	14.50	11.38	6.27	4.26	3.25	0.72	10.54	6.18	1.16
Red	12.15	11.36	4.82	9.45	11.51	4.26	2.59	2.38	0.47	6.97	5.81	1.16
SLM-132	13.61	10.96	5.92	19.08	14.81	8.72	6.42	3.86	0.24	8.54	7.48	1.06
Sweet	12.67	10.81	4.73	12.89	11.17	5.85	3.82	2.84	0.38	8.56	7.31	1.25
Urigam	12.17	11.41	4.65	11.26	10.54	4.38	3.73	2.72	0.43	8.93	7.68	1.25
UT-164	8.47	7.62	3.57	9.37	4.83	3.53	3.22	2.15	0.47	7.41	7.34	1.51
Vantoor	10.92	9.28	3.84	13.92	8.79	8.93	5.76	3.67	0.70	8.38	7.45	0.93
Vellore-2	10.17	11.41	5.13	10.64	12.36	4.81	3.22	2.36	0.25	8.72	7.83	0.89
S.E.	1.30	1.11	0.47	0.92	0.79	0.94	0.64	0.35	0.06	0.76	0.91	0.18
CD (0.05%)	2.59	2.22	0.93	1.84	1.58	1.88	1.28	0.70	0.13	1.52	1.82	0.37

Table 2: Evaluation of 20 tamarind accessions for pod characters.

Name	Carbohydrates g/100 g	Polyphenols g/100 g	Anthocyanin mg/100 g	% Antioxidant Activity	% Tartaric acid
BDM-3	19.18	2.76	1.84	36.58	40.2
CMK-5	21.44	2.56	0.71	36.53	56.7
CMK-7	28.64	3.41	0.69	37.15	47.3
HASNUR-3	46.02	3.52	1.24	36.64	60.6
KRMR	27.84	3.32	0.63	36.60	52.0
Local	26.83	4.20	0.54	34.00	56.6
NTI-56	21.99	3.45	0.96	36.35	51.9
NTI-60	25.83	3.69	0.78	36.49	52.4
NTI-84	27.98	5.23	0.69	51.89	46.2
NZB (S)	21.98	2.99	0.75	36.35	48.7
PKM-1	23.71	3.23	1.03	36.38	57.2
PKM (R)	27.20	3.78	40.67	36.62	48.1
Pratistan	27.77	2.72	0.93	36.55	46.3
RED	53.07	7.37	33.63	53.22	47.9
SLM-132	27.04	3.18	0.91	36.74	52.6
Sweet	54.78	2.96	1.26	36.65	30.9
URIGAM	24.95	3.42	0.81	36.36	36.3
UT-164	30.88	3.12	1.19	36.68	46.0
Vantoor	27.96	3.19	0.64	36.46	52.1
Vellore-2	24.13	2.73	0.75	37.33	53.6
S.E.	0.32	0.06	0.17	0.63	0.65
CD (0.05%)	1.34	2.08	4.65	2.04	1.64

Table 3: Eigen value and contribution of the principal component axes towards variation in Tamarind genotypes.

Principal component	Eigen value	Variance per cent	Cumulative variance per cent
PC 1	5.046	42.051	42.051
PC 2	2.900	24.166	66.218
PC 3	1.339	11.160	77.377
PC 4	0.924	7.702	85.079
PC 5	0.557	4.645	89.724
PC 6	0.466	3.880	93.604
PC 7	0.344	2.869	96.473
PC 8	0.152	1.266	97.739
PC 9	0.125	1.038	98.777
PC 10	0.092	0.769	99.547
PC 11	0.036	0.301	99.847
PC 12	0.018	0.153	100.000

BDM - 3 (19.18) followed by CMK - 5 (21.44), NZB (S) (21.98) and NTI-56 (21.99).The highest value of Polyphenols g/ 100 g was recorded in Red (7.37) followed by NTI-84 (5.23), LOCAL (4.20) and PKM (R) (3.78) and the lowest in CMK - 5 (2.56) followed by PRATISTAN (2.72), VELLORE - 2 (2.73) and BDM - 3 (2.76).The highest value of Anthocyanin mg/ 100 g wasrecorded in PKM (R) (40.67) followed by RED(33.63), BDM-3 (1.84) and SWEET (1.26) and the lowest in LOCAL (0.54) followed by KRMR (0.63), VANTOOR (0.64) and NTI - 84 (0.69). The highest value of % Antioxidant Activity wasrecorded in RED (53.22) followed by NTI-84 (51.89), VELLORE - 2 (37.33) and CMK -7 (37.15) and the lowest in LOCAL (34.00) followed by NZB (S) (36.35), NTI - 56 (36.35) and URIGAM (36.36). The highest value of % Tartaric acid was recorded in HASNUR -3 (60.6) followed by PKM- 1 (57.2), CMK-5 (56.7)and LOCAL (56.6) and the lowest in SWEET (30.9) followed by URIGAM (36.3), BDM - 3 (40.2) and UT - 164 (46.00).

Principal component analysis (PCA)

Principal component analysis (PCA) is a type of multivariate analysis that brings down the large data set into components without modifying data originality. It helps to understand the type of variation and diversity of large set of data by quantifying the degree of divergence among the biological population at genotypic level. In the present study, the 20 genotypes for 12 different traits are presented in Table 3 and Fig 1.

The results of PCA in the present study was used to determine which traits were the major sources of variation within the parental lines which revealed that the present data was divided into twelve principal components. Among them, four principal components PC1, PC2, PC3 and PC4 with eigenvalues 5.04, 2.90, 1.33 and 0.92 respectively accounted for 85.07% of the total cumulative variability among genotypes (Table 3). Out of twelve factors, the first three principal components PC1, PC2 and PC3 showed eigenvalues of more than one and cumulatively they explained 77.37% variability.

Scree plot is a graph which order the Eigen valve from largest to smallest and also showed the % of variability in

terms of Eigen value and principal component. PC 1 showed 42.1% variability with Eigen value 5.04 and then the graph gradually decline for other PC. Steep curve followed by bend and then straight found for different PCs. This graph showed clear cut explanation of variability which was maximum for PC1.

The distribution of tamarind genotypes based on the first and second PC exhibited the phenotypic variation among the population and explains how these widely dispersed along both the axes. The genotype wise scatter diagram of the 20 tamarind genotypes (scores) across the first two PC axes (Fig 1).

CONCLUSION

Among the forty tamarind accessions evaluated, NZB (S), Hasanur #5, Salem 132, NTI-14 and SMG–3 recorded the highest values in all the growth, pod and yield characters. NZB (S) recorded the highest number of flowers per inflorescence (14.62), Hasanur #5 recorded the highest number of inflorescence per branch (13.87). NZB(S) recorded the highest average fruit weight (g) (19.24), pulp weight per fruit (g) (9.27), Total seed per Pod (no's) (10.78), Normal seed/pod (no's) (9.38) compare to remaining all tamarind accessions and also NZB(S) recorded the lowest fiber weight per fruit (g) (0.22), Damaged seed per pod (no's) (0.62). In case of yield characters, NZB(S) recorded the highest average yield per plant (kg) (15.72) followed by Hasanur #5 (15.09), Salem 132 (14.81) and NTI - 14 (14 .65). Based on performance, yield and quality parameters, NZB (S), Hasanur #5, Salem 132, NTI-14 and SMG-3 accessions have been identified as the most promising in dry land situation representing semi-arid tropics and their further evaluation on large scale is recommended. PC also helps in ranking of genotypes on the basis of PC scores in corresponding component. It is cleared that the principal component analysis highlights the characters with maximum variability.

Conflict of interest

All authors declared that there is no conflict of interest.

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