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Original Research Article

Morphological Characterization among Identified Distinct Tamarind Genotypes of Karnataka

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A B S T R A C T

The medicinally important and nutritionally rich tree tamarind is grown widely in India. Many tamarind grooves are existing in Karnataka, which is a wide source of morphological and genetic variations for breeders to crop improvement. Every part of the tree has number of applications in many trades. Owing to its importance in multi-sectors, aim of the present study is to understand the morphological diversity existing among the 96 identified tamarind genotypes collected from all the district of Karnataka at college of Horticulture, Bengaluru (2017-2019). The fifteen qualitative traits were observed and recorded. The identified genotypes revealed the wide variations for fruit and seed related traits. The selection of desirable genotypes based on the morphological variations such as fruit and seed related traits could be effectively used in the tree crop improvement.

Keywords

Morphological variation, tamarind genotypes, fruit, pod, seed, pulp

Introduction

The tropical tree Tamarind (*Tamarindus indica* L.) is belongs to family *Fabaceae* (*Leguminosae: Caesalpinioideae*) with 2n=24 chromosome number. The various geological areas have been put forward for the origin of tamarind: India or the Far East or Africa (Coates-Palgrave, 1988) but the consensus is that it is Africa.

India is the world's largest producer of tamarind products (Bagula, *et al.,* 2015). It is particularly abundant in the states of Madhya Pradesh, Bihar, Andhra Pradesh, Karnataka, Tamil Nadu and West Bengal. India has traditionally exported processed tamarind pulp to Western countries, mainly the European and Arab countries and more recently to the United States of America.

Tamarind has a wide geographical distribution in the subtropics and semiarid tropics and it is cultivated all over South India. The adaptation of the species to some of the geographies is deep and has become part of the culture and food system. Being a drought-tolerant tree, it is the source of

income in dry land agriculture ecosystems besides serving diverse uses including industry, medicine and wood. The fruit is the most commonly used part. Tamarind fruit beverage made from pulp is the most popular drink (100%). Tamarind fruit ate as a snack and has most (98.3%) citations. The lowest percent citations were on ethno- medicinal (13%) and ethno-veterinary (15%) uses of tamarind. Here the percent citations indicate the potential benefits of direct consumption of fruit. (Satya, *et al.,* 2018). Tamarind fruit supplies vitamin A in the form of pro-vitamin-A containing carotenoids and is bioavailable to supply the required amount of recommended retinol equivalents (500-600) per day (Othieno, *et al.,* 2017).

Flowers are bisexual. The flower color is same for each genotypes and they are not mixed. Stamens are three (-5) fertile and 4 minute sterile ones. Fertile stamen's filaments are connate and alternate with six brittle-like staminodes (El-Siddig, *et al.,* 2006). Stamens are united below into a sheath open on the upper side and inserted on the anterior part of the mouth of the calyx tube. The anthers are transverse, reddish-brown and dehisce longitudinally. The normal flowers of tamarind are zygomorphic with two reddish boat-shaped bracteoles falling before flower opening. Flowers are irregular and hypogynous. The sepals, four, reflexed ovate and cream-colored. The calyx tube is normal, imbricate and membranous. Petals are three unequal, borne on the top of the thalamus, obovate, pale yellow streaked with red color (Tania, *et al.,* 2018). The number of sepals varies from three to four. Generally, four sepals are present in each flower. The petal numbers vary from three to five and in some flowers, and the stamenoid petals could be observed. Normally, the flower has three fertile stamens of equal size alternating with staminodes. The stamens generally ranged from two to four in number. The flower is protogynous, entomophilous and highly cross-pollinated. The flower is nectiferous, nectar being produced by hairs at the ovary base (Shivanandam and Thimaraju, 1988; Tucker, 2000). The self-pollination also observed sometimes (Coronel, 1991). A cross-pollinated crop though the flowering is profuse in tamarind, the fruit set under natural conditions is very low ranging from three to five per cent (Nicodemus, *et al.,* 1997*).* The flowering in this species is asynchronous at the individual level but it is synchronous at the population level (Diallo, 2007).

Flowering was generally observed from March to August in India on the previous season's wood and about 36% of the new growth on bearing trees produced terminal inflorescences (panicles). There was a positive relationship among panicle length, number of flowers and fruits per panicle. On average, 5-6 months of heat units required from flowering to maturity. Distinct flowering durations of 104, 93 and 69 days respectively, for late flowering (May-August), mid flowering (May- July) and early flowering (April-May) types was observed in seedling populations of tamarind (Usha, 1990).

Open-pollinated syndrome and preferred by man and faunivory a lot of heterogeneity and heterozygosity is expected to occur in the tamarind populations, which is traditionally prevailing in Karnataka. Movement of tamarind for culinary purposes is also expected to add the spread of material over time. The multipurpose tamarind tree is important for people's livelihood. However, the ongoing overexploitation of this species has caused a decline of tamarind trees. Tamarind trees are mainly used as supplementary food, as well as for traditional ceremonies, charcoal production and medicinal purposes (Ranaivosona, *et al.,*

2015).The highly cross-pollinated tree plant exhibits huge variations for morphological traits, studying such variations in tamarind genotypes is worth for selecting best genotypes for tamarind tree improvement, hence present study is an effort to understand the morphological variations in the identified tamarind genotypes.

Material and Methods

Study material

The tamarind genotypes that were distinct and popular were identified and collected from the thirty district of Karnataka. The random survey was carried out and total 95 genotypes and one check variety *i.e.* GKVK17 was collected during the year 2017-2019. Fifteen major qualitative traits were observed and recorded (Table 1). Five randomly selected branches/fruits of each genotype were used for recording the observations. The morphological characterization was done according to the tamarind descriptors, International Union of Plant Protection of New Vegetal Variants (UPOV 1987), International Committee of Genetic Resources of Plant for the description of tropical plants (IPGRI, 1991; Fandohan *et al.*, 2010, Singh *et al.*, 2017).

Results and Discussion

The observations recorded on morphological traits from each of 96 tamarind genotypes indicated a considerable amount of variation in all the fifteen traits. Four different types of tree arrangement were recorded, most genotypes of tamarind are semi-erect (55 per cent), erect (20 per cent), bushy (18 per cent) and few exhibited vertical (7 per cent) shape of tree arrangement. Three types of canopy density *viz.*, medium (43 per cent), sparse (29 per cent) and dense (28 per cent) types were recorded in the 96 tamarind genotypes. The leaf colour varied for 55 per cent dark green and others exhibited various colours including green (33 per cent), and light green (12 per cent). All the genotypes exhibited the alternative type of leaf arrangement. Leaf density varied from medium (23 per cent) to dense (70 per cent) with few genotypes exhibiting sparse (7 per cent) type. The tamarind genotypes exhibited the complete flower type in 96 tamarind genotypes.

The genotypes exhibited 57 per cent yellow with red veins, and others exhibited pale yellow with red veins (43 per cent). All the genotypes of tamarind showed the alternate type of flower arrangement and the bisexual type of flowers (Figure 1 and 2).

The fruit character of tamarind genotypes varied notably. The fruit shape recorded straight (54 per cent) and curved (44 per cent) fruit shape. Over 70 percent of the fruits exhibited, the regular and 29 percent irregular type of fruit bearing habit. The pod shape varied as straight (54 per cent) and curved (44 per cent). Tamarind genotypes recorded 61 per cent of flattened, 23 per cent seeds exhibited rhomboid and few genotypes exhibited 16 per cent of irregular types of seed shape. The variation for seed colour recorded as 40 per cent of reddish-brown, 39 per cent dark brown and 21 per cent of brown types of seed colour. The variations for pulp colour recorded as dark brown (50 per cent), brown (42 per cent), light brown (7 per cent) and a genotype from Kolar recorded pinkish-brown (1 per cent) colour of pulp (Figure 1 and 2). These morphological traits could be considered as important phenotypic marker.

The phenological variations are tightly linked with climatic factors such as high rainfall, land use types, abiotic stress and biotic stress will affect the vegetative and reproductive growth of genotypes (Fandohan *et al.*, 2015; Okello, *et al.*, 2018).

Table.1 Morphological variation for qualitative traits among the 96 distinct genotypes of the tamarind

Sl. No.	Genotypes	Tree arrangement	Canopy density	Leaf color	Leaf density	Leaf arrangement	Fruit shape	Pod shape	Seed shape	Seed colour	Flower Pigmentation	Pulp color	Bearing habit
1	**TAM_ BAG1**	Semi-erect	Medium	Green	Dense	Alternate	Straight	Straight	Rhomboid	Brown	Yellow with red veins	Light brown	Regular
2	**TAM_ BAG2**	Semi-erect	Medium	Green	Dense	Alternate	Straight	Straight	Rhomboid	Brown	Yellow with red veins	Dark brown	Regular
3	**TAM_BEN(U)1**	Semi-erect	Medium	Dark green	Dense	Alternate	Straight	Straight	Flattened	Reddish brown	Yellow with red veins	Dark brown	Regular
4	**TAM_BEN(U)2**	Semi-erect	Dense	Dark green	Dense	Alternate	Curved	Curved	Flattened	Dark brown	Yellow with red veins	Dark brown	Regular
5	**TAM_BEN(U)3**	Bushy	Dense	Green	Dense	Alternate	Straight	Straight	Flattened	Dark brown	Yellow with red veins	Brown	Regular
6	**TAM_BEN(U)4**	Bushy	Medium	Green	Dense	Alternate	Curved	Curved	Rhomboid	Dark brown	Yellow with red veins	Dark brown	Regular
7	**TAM_BEN(U)5**	Semi-erect	Dense	Dark green	Dense	Alternate	Straight	Straight	Flattened	Dark brown	Yellow with red veins	Dark brown	Regular
8	**TAM_BEN(R)1**	Semi-erect	Sparse	Dark green	Medium	Alternate	Straight	Straight	Rhomboid	Reddish brown	Yellow with red veins	Dark brown	Regular
9	**TAM_BEN(R)2**	Semi-erect	Sparse	Dark green	Medium	Alternate	Curved	Curved	Rhomboid	Dark brown	Yellow with red veins	Dark brown	Regular
10	**TAM_BEN(R)3**	Bushy	Medium	Light green	Dense	Alternate	Curved	Curved	Irregular	Dark brown	Yellow with red veins	Brown	Irregular
11	**TAM_BEN(R)4**	Erect	Sparse	Green	Medium	Alternate	Curved	Curved	Irregular	Reddish brown	Yellow with red veins	Brown	Irregular
12	**TAM_BEN(R)5**	Erect	Sparse	Green	Medium	Alternate	Curved	Curved	Rhomboid	Brown	Yellow with red veins	Brown	Irregular
13	**TAM_BEG1**	Semi-erect	Medium	Dark green	Dense	Alternate	Curved	Curved	Flattened	Brown	Yellow with red veins	Dark brown	Regular
14	**TAM_BEG2**	Semi-erect	Medium	Green	Dense	Alternate	Curved	Curved	Flattened	Reddish brown	Yellow with red veins	Dark brown	Regular
15	**TAM_BEG3**	Erect	Sparse	Green	Medium	Alternate	Curved	Curved	Flattened	Reddish brown	Yellow with red veins	Brown	Irregular
16	**TAM_BEG4**	Erect	Sparse	Dark green	Medium	Alternate	Curved	Curved	Flattened	Reddish brown	Pale Yellow with red veins	Brown	Irregular
17	**TAM_BEL1**	Semi-erect	Medium	Dark green	Dense	Alternate	Curved	Curved	Flattened	Dark brown	Yellow with red veins	Brown	Regular
18	**TAM_BEL2**	Semi-erect	Medium	Dark green	Dense	Alternate	Curved	Curved	Flattened	Dark brown	Yellow with red veins	Dark brown	Regular
19	**TAM_BEL3**	Erect	Sparse	Dark green	Medium	Alternate	Curved	Curved	Flattened	Brown	Pale Yellow with red veins	Brown	Irregular

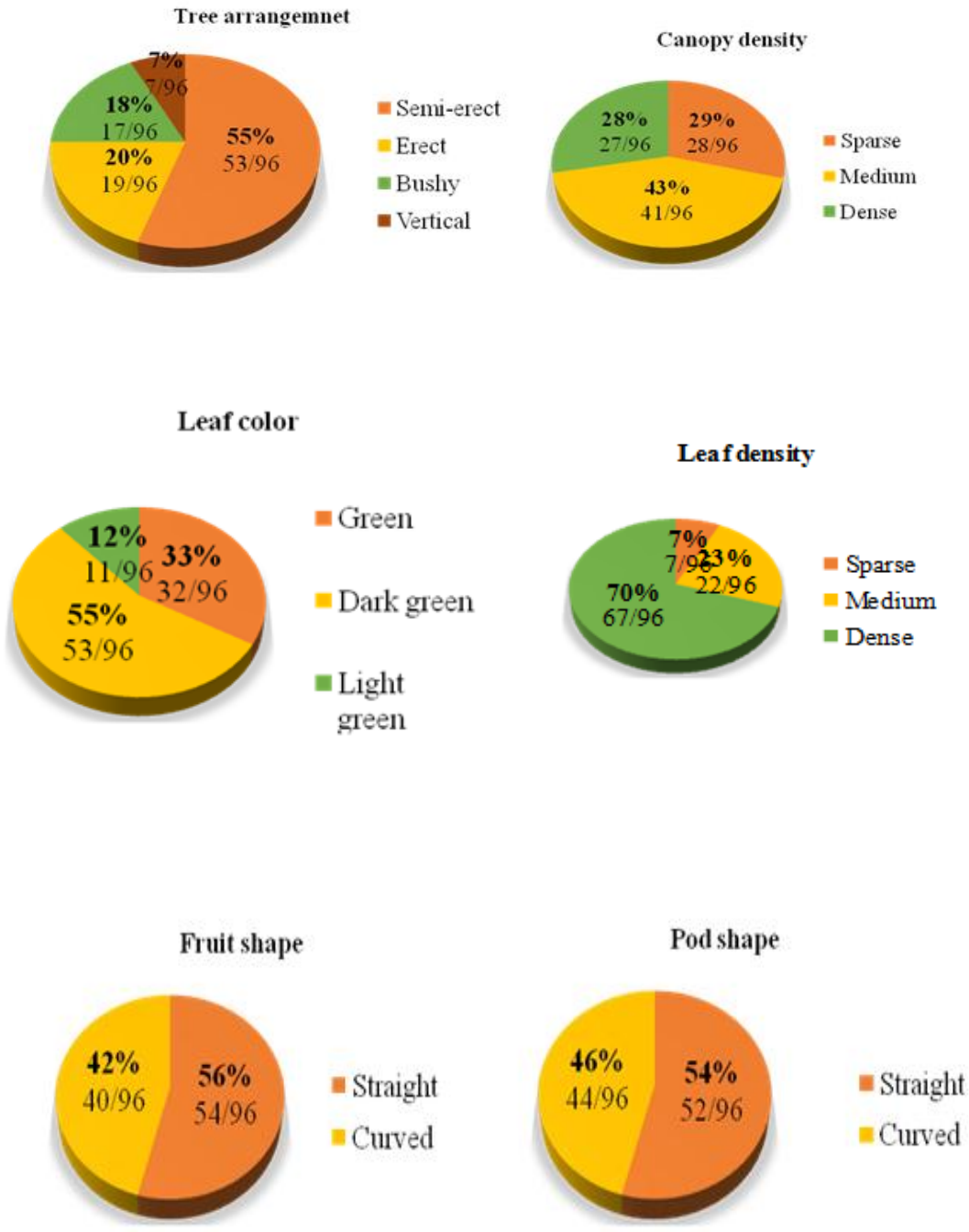
20	**TAM_BID1**	Semi-erect	Medium	Green	Dense	Alternate	Straight	Straight	Flattened	Dark brown	Pale Yellow with red veins	Dark brown	Regular
21	**TAM_BID2**	Semi-erect	Medium	Dark green	Dense	Alternate	Curved	Curved	Rhomboid	Reddish brown	Yellow with red veins	Light brown	Regular
22	**TAM_BID3**	Erect	Sparse	Dark green	Medium	Alternate	Curved	Curved	Irregular	Dark brown	Yellow with red veins	Dark brown	Irregular
23	**TAM_BID4**	Erect	Sparse	Dark green	Medium	Alternate	Straight	Straight	Rhomboid	Dark brown	Pale Yellow with red veins	Brown	Irregular
24	**TAM_BIJ1**	Semi-erect	Medium	Dark green	Dense	Alternate	Straight	Straight	Flattened	Reddish brown	Yellow with red veins	Brown	Regular
25	**TAM_BIJ2**	Semi-erect	Medium	Green	Dense	Alternate	Straight	Straight	Flattened	Dark brown	Yellow with red veins	Light brown	Regular
26	**TAM_BIJ3**	Semi-erect	Medium	Green	Dense	Alternate	Curved	Straight	Flattened	Dark brown	Yellow with red veins	Brown	Irregular
27	**TAM_CHA1**	Bushy	Dense	Dark green	Dense	Alternate	Curved	Curved	Irregular	Reddish brown	Pale Yellow with red veins	Brown	Regular
28	**TAM_CHA2**	Semi-erect	Dense	Light green	Dense	Alternate	Curved	Curved	Flattened	Reddish brown	Pale Yellow with red veins	Brown	Regular
29	**TAM_CHA3**	Semi-erect	Dense	Green	Dense	Alternate	Curved	Curved	Rhomboid	Dark brown	Pale Yellow with red veins	Brown	Irregular
30	**TAM_CHK1**	Bushy	Dense	Green	Dense	Alternate	Curved	Curved	Flattened	Brown	Yellow with red veins	Brown	Regular
31	**TAM_CHK2**	Semi-erect	Dense	Dark green	Dense	Alternate	Curved	Curved	Flattened	Reddish brown	Pale Yellow with red veins	Dark brown	Regular
32	**TAM_CHK3**	Semi-erect	Dense	Dark green	Dense	Alternate	Straight	Straight	Rhomboid	Reddish brown	Yellow with red veins	Brown	Regular
33	**TAM_CHM1**	Erect	Sparse	Green	Medium	Alternate	Straight	Straight	Irregular	Dark brown	Pale Yellow with red veins	Dark brown	Regular
34	**TAM_CHM2**	Erect	Sparse	Light green	Medium	Alternate	Straight	Straight	Rhomboid	Dark brown	Pale Yellow with red veins	Dark brown	Regular
35	**TAM_CHM3**	Vertical	Sparse	Green	Sparse	Alternate	Curved	Straight	Flattened	Dark brown	Pale Yellow with red veins	Dark brown	Regular
36	**TAM_CHT1**	Semi-erect	Medium	Green	Dense	Alternate	Curved	Curved	Flattened	Reddish brown	Pale Yellow with red veins	Dark brown	Regular
37	**TAM_CHT2**	Semi-erect	Medium	Dark green	Dense	Alternate	Curved	Curved	Flattened	Dark brown	Pale Yellow with red veins	Brown	Irregular
38	**TAM_DK1**	Vertical	Sparse	Dark green	Sparse	Alternate	Straight	Straight	Irregular	Dark brown	Pale Yellow with red veins	Brown	Irregular
39	**TAM_DK2**	Vertical	Sparse	Green	Sparse	Alternate	Straight	Straight	Flattened	Dark brown	Pale Yellow with red veins	Brown	Irregular
40	**TAM_DAV1**	Semi-erect	Sparse	Light green	Medium	Alternate	Straight	Straight	Flattened	Reddish brown	Yellow with red veins	Brown	Regular
41	**TAM_DAV2**	Semi-erect	Medium	Green	Medium	Alternate	Curved	Straight	Flattened	Dark brown	Yellow with red veins	Dark brown	Regular

42	**TAM_DHA1**	Bushy	Dense	Dark green	Dense	Alternate	Curved	Curved	Flattened	Reddish brown	Pale Yellow with red veins	Dark brown	Regular
43	**TAM_DHA2**	Semi-erect	Medium	Dark green	Dense	Alternate	Straight	Straight	Flattened	Dark brown	Pale Yellow with red veins	Dark brown	Regular
44	**TAM_DHA3**	Semi-erect	Medium	Dark green	Dense	Alternate	Curved	Curved	Flattened	Dark brown	Pale Yellow with red veins	Brown	Regular
45	**TAM_DHA4**	Erect	Sparse	Dark green	Medium	Alternate	Straight	Straight	Flattened	Brown	Pale Yellow with red veins	Brown	Irregular
46	**TAM_GAD1**	Semi-erect	Medium	Dark green	Dense	Alternate	Curved	Curved	Flattened	Reddish brown	Yellow with red veins	Dark brown	Regular
47	**TAM_GUL1**	Semi-erect	Medium	Dark green	Dense	Alternate	Straight	Curved	Flattened	Reddish brown	Yellow with red veins	Brown	Regular
48	**TAM_GUL2**	Semi-erect	Medium	Dark green	Dense	Alternate	Straight	Straight	Irregular	Brown	Yellow with red veins	Dark brown	Regular
49	**TAM_GUL3**	Semi-erect	Medium	Dark green	Dense	Alternate	Straight	Straight	Flattened	Brown	Yellow with red veins	Brown	Regular
50	**TAM_HAS1**	Bushy	Dense	Dark green	Dense	Alternate	Curved	Curved	Flattened	Reddish brown	Pale Yellow with red veins	Dark brown	Regular
51	**TAM_HAS2**	Bushy	Dense	Green	Dense	Alternate	Curved	Curved	Flattened	Reddish brown	Pale Yellow with red veins	Brown	Regular
52	**TAM_HAS3**	Bushy	Dense	Dark green	Dense	Alternate	Curved	Curved	Flattened	Reddish brown	Yellow with red veins	Dark brown	Regular
53	**TAM_HAS4**	Semi-erect	Medium	Green	Dense	Alternate	Straight	Straight	Flattened	Reddish brown	Yellow with red veins	Brown	Regular
54	**TAM_HAV1**	Semi-erect	Medium	Green	Dense	Alternate	Curved	Curved	Flattened	Dark brown	Yellow with red veins	Dark brown	Regular
55	**TAM_HAV2**	Semi-erect	Dense	Dark green	Dense	Alternate	Curved	Curved	Flattened	Brown	Yellow with red veins	Brown	Regular
56	**TAM_KOD1**	Erect	Sparse	Dark green	Medium	Alternate	Straight	Straight	Flattened	Dark brown	Yellow with red veins	Brown	Irregular
57	**TAM_KOD2**	Vertical	Sparse	Dark green	Sparse	Alternate	Curved	Curved	Flattened	Reddish brown	Yellow with red veins	Brown	Irregular
58	**TAM_KOD3**	Vertical	Sparse	Dark green	Sparse	Alternate	Straight	Straight	Rhomboid	Brown	Yellow with red veins	Light brown	Irregular
59	**TAM_KOL1**	Bushy	Dense	Green	Dense	Alternate	Curved	Curved	Rhomboid	Reddish brown	Yellow with red veins	Brown	Regular
60	**TAM_KOL2**	Bushy	Dense	Dark green	Dense	Alternate	Curved	Curved	Irregular	Brown	Yellow with red veins	Brown	Regular
61	**TAM_KOL3**	Semi-erect	Medium	Dark green	Dense	Alternate	Straight	Straight	Rhomboid	Brown	Pale Yellow with red veins	Pinkish brown	Regular
62	**TAM_KOL4**	Semi-erect	Medium	Green	Dense	Alternate	Straight	Straight	Flattened	Reddish brown	Pale Yellow with red veins	Brown	Regular
63	**TAM_KOL5**	Erect	Medium	Dark green	Dense	Alternate	Curved	Curved	Flattened	Dark brown	Yellow with red veins	Dark brown	Irregular

64	**TAM_KOP1**	Semi-erect	Medium	Green	Dense	Alternate	Straight	Straight	Rhomboid	Dark brown	Yellow with red veins	Dark brown	Regular
65	**TAM_KOP2**	Semi-erect	Medium	Dark green	Dense	Alternate	Straight	Straight	Irregular	Dark brown	Pale Yellow with red veins	Dark brown	Regular
66	**TAM_KOP3**	Semi-erect	Medium	Green	Dense	Alternate	Curved	Curved	Flattened	Dark brown	Pale Yellow with red veins	Brown	Regular
67	**TAM_MAN1**	Bushy	Dense	Dark green	Dense	Alternate	Curved	Curved	Rhomboid	Brown	Pale Yellow with red veins	Light brown	Regular
68	**TAM_MAN2**	Bushy	Dense	Dark green	Dense	Alternate	Straight	Straight	Flattened	Brown	Pale Yellow with red veins	Dark brown	Regular
69	**TAM_MAN3**	Semi-erect	Dense	Green	Dense	Alternate	Curved	Curved	Flattened	Reddish brown	Pale Yellow with red veins	Brown	Regular
70	**TAM_MAN4**	Semi-erect	Dense	Green	Dense	Alternate	Straight	Straight	Flattened	Reddish brown	Yellow with red veins	Brown	Regular
71	**TAM_MAN5**	Semi-erect	Dense	Dark green	Dense	Alternate	Straight	Straight	Irregular	Brown	Yellow with red veins	Brown	Regular
72	**TAM_MYS1**	Bushy	Dense	Dark green	Dense	Alternate	Curved	Curved	Rhomboid	Brown	Pale Yellow with red veins	Brown	Regular
73	**TAM_MYS2**	Bushy	Dense	Green	Dense	Alternate	Straight	Straight	Irregular	Reddish brown	Yellow with red veins	Dark brown	Regular
74	**TAM_MYS3**	Bushy	Dense	Green	Dense	Alternate	Straight	Straight	Irregular	Brown	Pale Yellow with red veins	Brown	Regular
75	**TAM_MYS4**	Semi-erect	Medium	Dark green	Dense	Alternate	Curved	Curved	Flattened	Brown	Yellow with red veins	Dark brown	Regular
76	**TAM_RAI1**	Semi-erect	Medium	Light green	Dense	Alternate	Straight	Straight	Irregular	Dark brown	Yellow with red veins	Dark brown	Regular
77	**TAM_RAI2**	Semi-erect	Medium	Light green	Dense	Alternate	Curved	Curved	Irregular	Brown	Pale Yellow with red veins	Light brown	Regular
78	**TAM_RAI3**	Erect	Sparse	Light green	Medium	Alternate	Curved	Curved	Rhomboid	Dark brown	Pale Yellow with red veins	Brown	Irregular
79	**TAM_RAI4**	Erect	Sparse	Light green	Medium	Alternate	Straight	Straight	Rhomboid	Reddish brown	Pale Yellow with red veins	Brown	Irregular
80	**TAM_RAM1**	Semi-erect	Dense	Dark green	Dense	Alternate	Straight	Straight	Flattened	Reddish brown	Yellow with red veins	Dark brown	Regular
81	**TAM_RAM2**	Semi-erect	Dense	Dark green	Dense	Alternate	Straight	Straight	Irregular	Reddish brown	Yellow with red veins	Dark brown	Regular
82	**TAM_SHI1**	Semi-erect	Medium	Dark green	Dense	Alternate	Curved	Curved	Irregular	Dark brown	Pale Yellow with red veins	Dark brown	Regular
83	**TAM_SHI2**	Erect	Medium	Green	Dense	Alternate	Curved	Curved	Flattened	Reddish brown	Yellow with red veins	Brown	Irregular
84	**TAM_SHI3**	Erect	Sparse	Dark green	Medium	Alternate	Curved	Curved	Flattened	Reddish brown	Pale Yellow with red veins	Brown	Irregular
85	**TAM_THM1**	Semi-erect	Medium	Green	Dense	Alternate	Straight	Straight	Rhomboid	Reddish brown	Yellow with red veins	Dark brown	Regular

86	**TAM_THM2**	Semi-erect	Medium	Green	Dense	Alternate	Curved	Curved	Rhomboid	Reddish brown	Yellow with red veins	Dark brown	Regular
87	**TAM_UDP1**	Semi-erect	Sparse	Dark green	Medium	Alternate	Curved	Curved	Rhomboid	Dark brown	Pale Yellow with red veins	Dark brown	Regular
88	**TAM_UDP2**	Erect	Sparse	Dark green	Medium	Alternate	Straight	Straight	Flattened	Dark brown	Pale Yellow with red veins	Brown	Irregular
89	**TAM_UDP3**	Erect	Sparse	Dark green	Medium	Alternate	Curved	Curved	Flattened	Dark brown	Pale Yellow with red veins	Brown	Irregular
90	**TAM_UK1**	Erect	Sparse	Dark green	Medium	Alternate	Straight	Straight	Flattened	Reddish brown	Pale Yellow with red veins	Brown	Irregular
91	**TAM_UK2**	Vertical	Sparse	Light green	Sparse	Alternate	Straight	Straight	Flattened	Brown	Pale Yellow with red veins	Brown	Irregular
92	**TAM_UK3**	Vertical	Sparse	Light green	Sparse	Alternate	Straight	Straight	Flattened	Reddish brown	Pale Yellow with red veins	Brown	Irregular
93	**TAM_YAD1**	Semi-erect	Medium	Light green	Dense	Alternate	Curved	Curved	Flattened	Dark brown	Yellow with red veins	Dark brown	Regular
94	**TAM_YAD2**	Semi-erect	Medium	Dark green	Dense	Alternate	Curved	Curved	Flattened	Dark brown	Yellow with red veins	Brown	Regular
95	**TAM_YAD3**	Semi-erect	Medium	Dark green	Dense	Alternate	Curved	Curved	Flattened	Dark brown	Yellow with red veins	Brown	Regular
96	**GKVK17**	Bushy	Dense	Dark green	Dense	Alternate	Curved	Curved	Flattened	Brown	Yellow with red veins	Dark brown	Regular

Fig.1 Relative proportions of different types of qualitative trait exhibited among the 96 genotypes of tamarind



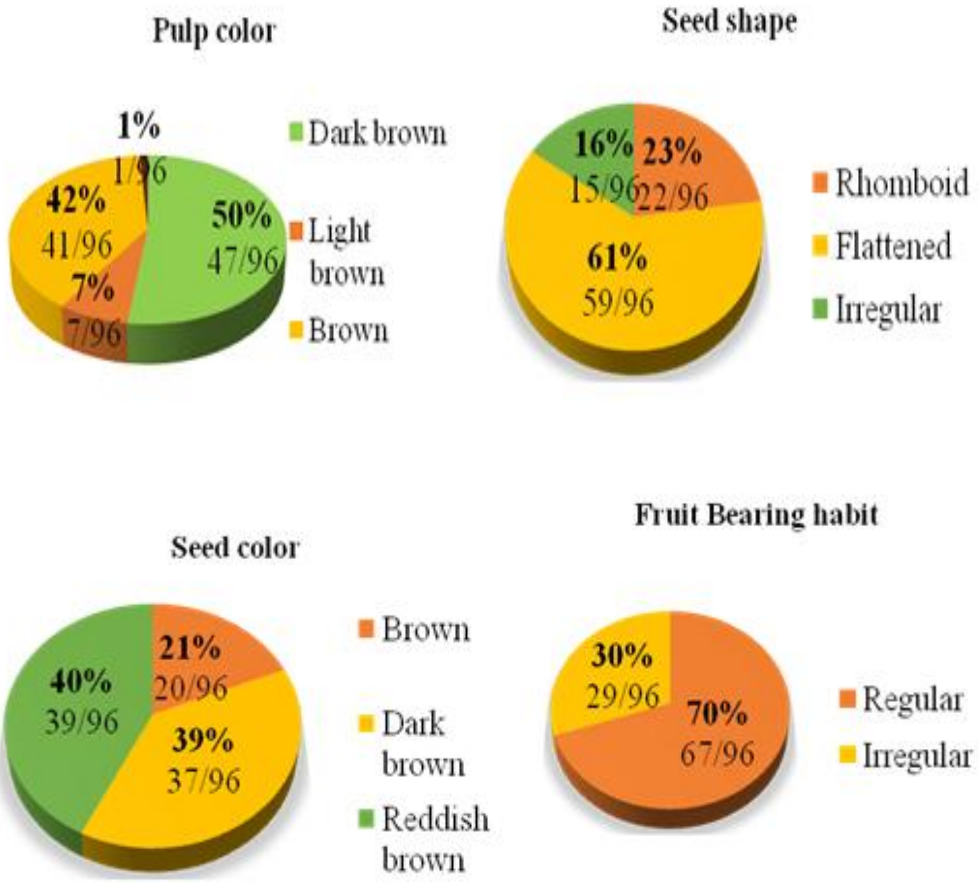

Pulp color
1%
1/96
42%
41/96
50%
47/96
7%
7/96
Dark brown
Light brown
Brown
Seed shape
16%
15/96
23%
22/96
61%
59/96
Rhomboid
Flattened
Irregular
Seed color
21%
20/96
40%
39/96
39%
37/96
Brown
Dark brown
Reddish brown
Fruit Bearing habit
30%
29/96
70%
67/96
Regular
Irregular
Flower pigmentation
43%
41/96
57%
55/96
Yellow with red veins
Pale Yellow with red veins

Fig.2 The variation for various qualitative traits exhibited by the 96 tamarind genotypes

Tree arrangement

Bushy **Semi-erect** **Erect** **Vertical**

Canopy density

Dense **Medium** **Sparse**

Straight type pods **Curved type pods** **Straight type fruits** **Curved type fruits**

Dark brown pulp **Brown pulp** **Light brown pulp** **Pink brown pulp**

Rhomboid shape seeds **Flattened shape seeds** **Irregular shape seeds**

Yellow with Red veins flower **Pale Yellow with Red veins flower**

It is suggested that the colour variation in reproductive organs is mainly due to climate characterized by mild temperatures (Nagarajan *et al.*, 1998, Singh *et al.*, 2008 and Bhogave *et al.*, 2018). Singh and Nandini (2014), reported that the colouration in reproductive organs can be used not only as morphological marker in progeny testing programme but can also enhance the mean value of fruit set by enhancing the pollinators. The marketing price of the pulp is decided based on pulp colour (Karale, 2001; Prabhushankar and Melanta, 2004; Rao and Subramanyam, 2015; Bhogave, *et al.*, 2018) in tamarind.The dark brown pulp colour of fruits is due to presence of anthocyanin and has a great scope for utilizing as bio colourant in food processing, pharmaceutical, brewery and confectionery industries. The knowledge of genotypic and geographical variations is of fundamental importance for the development of new varieties with good quality and higher yield, which provides the wide scope for the selection of suitable initial breeding material for tamarind tree improvement.

The study revealed wide morphological variation for fifteen qualitative morphological traits among identified 96 tamarind

genotypes. The variation is mainly affected by the factors such as different agro-ecological zones and land-use types such as environmental and climatic factors may be possible due to gene flow/genetic drift of gene for a particular trait. The spontaneous mutation possibly occurred in a particular trait over the years, which may be expressed in one geographical area and not in the other may be counted among the reasons for variation in a particular morphological trait. The various factors such as changes in the climatic condition, availability of nutrients, presence of human/animal activities in the natural habitat and abiotic and biotic stress may also cause the variability in morphological traits within a species as well as different species. Understanding the diversity at phonological and fruit traits will lead to developing principles to conserve the diversity and pin down the productive types which could help breeder to select the desirable genotypes for tree crop improvement.

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