DOI : 10.5958/0974-0112.2020.00033.X

Indian J. Hort. 77(2), June 2020: 246-253

Studies on Genetic diversity and selection of elite germplasm of local Tamarind from Mizoram, north-east India

T. K. Hazarika* **and Lalrinpuii**

Department of Horticulture, Aromatic and Medicinal Plants, School of Earth Sciences and Natural Resources Management, Mizoram University, Aizawl 796 004, Mizoram

ABSTRACT

Determination of genetic variation is important to the plant breeders for development of high yielding variety. Crop improvement is a complex process and these results from the interaction of a combination of factors. Such improvement can be achieved genetically, by developing resistant types, by devising improvement agronomic practices, by adapting to diverse environments and by correcting soil nutrient levels. Use of available genetic resources can be a major part of any crop improvement programme. The present investigation was carried out to identify the elite accessions of tamarind among its natural population from selected potential areas of Mizoram, north-east India. The ripe fruits were collected and analysed for physiochemical traits like pod weight, pod length, pod width, beak length, no. of ridges, no. of furrows, pulp weight, pulp percentage, shell weight, shell percentage, seed number, seed weight, seed percentage, moisture percentage, TSS, acidity, ascorbic acid, total sugars, reducing sugar, non-reducing sugar, sugar : acid ratio, TSS : acid ratio. The individual pod weight range from 17.57 - 32.17 g; pod length 104.03 -158.27 mm; pod width 22.13 - 36.22 mm; beak length 0.16 - 0.69 cm; no. of ridges 2.49 - 8.70; no. of furrows 1.45 - 7.77; pulp weight 6.50 - 20.27g; pulp percentage 35.23 - 62.85%; shell weight 3.07-5.82g; shell percentage 12.40 - 23.26%; seed number 5.13 - 8.87; seed weight 6.08 - 9.32g; seed percentage 19.23 - 42.03%; moisture percentage 17.57 - 26.87%; TSS 17.29 -23.69%; acidity 6.55 -11.50%; ascorbic acid 1.63 -5.52 mg; total sugar 27.92 - 38.20%; reducing sugar 15.44 -23.32%; non-reducing sugar 10.35 - 17.82%; sugar: acid ratio 2.55 - 4.83%; TSS: acid ratio 1.59 - 3.51%. The results revealed that among all the germplasm studied, MZU- HAMP-TS-29, MZU- HAMP-TS-23 and MZU- HAMP-TS-8 showed the overall superiority in all the parameters. Hence, MZU- HAMP-TS-29, MZU- HAMP-TS-23 and MZU- HAMP-TS-8 can be considered as elite tamarind accessions for use in future breeding programme.

Key words: *Tamarindus indica*, variability, north-east India, physico-chemical characteristics.

INTRODUCTION

Tamarind (*Tamarindus indica* L) is a monotypic genus tree belonging to the family Leguminosae, sub family Caesalpiniaceae with somatic chromosome number of 2n=24 is popularly known as "Indian Date" that originates from India and is widely distributed in Africa and Asia. It is highly cross pollinated crop with a wide variation in the species and the number of genotypes are estimated to be 19327 (Lewis *et al.*, 13). The species has a wide geographical distribution in the sub tropics and semi-arid tropics and is cultivated in numerous regions. It is a multipurpose tropical fruit tree used primarily for its fruit, which are eaten fresh or processed used as seasoning curries, chutneys, sauces and soups. India is the largest producer of tamarind with an annual production of over 300,000 tonnes most of which are locally consumed and 11,500 tonnes are exported to Europe and North America countries (Spice Board India, 23).

In addition to its high energy and fiber content, the tamarind is a great source of vitamins B and a number of minerals. The fruit pulp is the richest natural source of tartaric acid (8–18%). It is the main acidulate used in preparation of foods in India and other Asian countries. Medicinally the leaves and fruits pulp are used as anti-inflammatory agent, against leucorrhoea and skin disorders (Punjabi and Kumar, 19). Many parts of tamarind plant have long been used in traditional medicines for the treatment of a wide variety of ailments and diseases such as jaundice, gonococci and gastrointestinal disorders. The pulp has been documented in both the British and American pharmacopoeias as anti-pyretic, antiscorbutic, laxative, carminative and remedy for biliousness and bile disorder and the leaves have antihelmintic and vermifuge properties, destroying intestinal parasites (Pamploma-Roger, 15).

The knowledge of genetic diversity and its distribution facilitate selection of the parents with diverse genetic background and thereby make crop improvement more efficient. A better utilization and exploitation of genetic diversity require details information on various traits, the level of association among traits and diversity estimates. The knowledge

---

*Corresponding author's E-mail: tridip28@gmail.com

about variability in any genotypes collected from different parts of the world for various agro-morphological traits, especially with the objectives of using parental lines for improvement of feed and forage purposes is necessary. Genetic diversity in the parent population is a prerequisite for effective selection of desirable recombinants in segregating breeding materials. Information on the nature and degree of divergence among the genotypes helps the plant breeders in choosing the suitable donor parents for initiating hybridization programme, as heterosis is believed to be correlated with genetic divergence among the parents. Genetic diversity among the genotypes is not necessarily associated with geographic diversity or place of origin of the materials. Due to cross pollination and predomination of seed propagation of tamarind over a large period of time, it gives immense opportunity to select the elite gemplasm having desirable horticultural traits.

In order to enrich the information and acquaint the tamarind breeder to interpret phenotypic values in terms of potential genetic gain to be utilized in the hybridization programme, the present study was aimed to assess the extent and pattern of variation and to find out the superior accessions of tamarind (*Tamarindus indica* L.) from natural population of Mizoram, north-east India.

MATERIALS AND METHODS

Mizoram, one of the hot spots of biodiversity with large number of endemic flora and fauna is one small state of North-east India. The state is having an area of 21,081 sq. km., lies between 21°56’ N and 24°31’N Latitude and 92°16’ E and 93°26’E longitude. It has international borders of Bangladesh in the w est and Myanmar in the east and south. The state is having the bordered by other north-eastern states like Tripura in North West, Assam in north and Manipur in north east. The *tamarind* trees are found scattered throughout the states from homestead garden in semi wild state to forest areas in wild state. Considering its vast spread, the surveying of *tamarind* trees and collection of fruits from five districts of Mizoram i.e., Aizawl, Kolasib, Serchhip, Mamit and Lunglei comprising of 30 different populations of Mizoram was conducted during the fruiting seasons of 2016-17 to identify the elite germplasm among natural population. The average age of the trees were 10-15 years. The details of the germplasm and their sources are described in Table 1. The collected specimens were immediately brought to the post-harvest laboratory, dept. of HAMP, Mizoram University for analysis of physio-chemical characters.

For measuring the physical parameters of the fruits, 15 randomly selected pods were taken from each tree were considered as one replication. There were total 3 replications of data from each sample. The data on physical parameters like pod weight, pulp weight, shell weight and seed weight were recorded as per standard procedures with the help of an electronic balance. The pod length, pod width and beak length was measured by taking the longitudinal length between two poles of the fruit with the help of digital Vernier callipers and expressed in mm. The pulp, shell and seed percentage was calculated by dividing the pulp weight, shell weight and seed weight respectively by pod weight and expressed in percentage. Quality parameters like TSS, acidity, ascorbic acid, reducing, non-reducing and total sugars were estimated following standard procedures. The moisture content was analyzed by oven drying method. The standard method (AOAC, 2) was followed to determine the titratable acidity, reducing, non-reducing and total sugars of fruit. Visual titration method (Freed, 6) was followed for the estimation of ascorbic acid content of the fruit pulp and the result was expressed in mg per 100 g. The sugar: acid and TSS: acid ratio was calculated by dividing the total sugars and TSS with the titratable acidity in each location.

The data obtained from different observations during field experimentation and laboratory analysis were subjected to Fisher’s method of analysis of variance (ANOVA) by following completely randomized design. Significance and non-significance of the variance due to different treatments were determined by calculating the respective ‘F’ value and comparing with the appropriate value of ‘F’ at 5 % probability level. By comparing different treatments among themselves critical difference were calculated at 5 % probability level.

RESULTS AND DISCUSSION

Fruit quality is a complex trait, which depends upon a number of other parameters and their interaction. The analysis of variance (ANOVA) of 30 tamarind collections identified in this investigation revealed significant differences in various physico-chemical parameters of the fruits.

The pod weight of the accessions ranged between 17.57 -32.17 g (Table 2). The highest pod weight was recorded in MZU-HAMP-TS-23 (32.17 g) which was followed by MZU-HAMP-TS-13 (31.60 g) and MZU-HAMP-TS-29 (31.06 g), while, the lowest was recorded in MZU-HAMP-TS-19 (17.57 g). The variation in pod weight is attributed to the difference in pod length, pod circumference, number of seeds per pod, seed weight, pulp content, shell weight and fibre weight among the different accessions. The rich variation could also be due to highly heterozygous

Table 1: Germplasms and their sources.

	Germplasms	Location	Latitude	Longitude	Elevation
1.	MZU-HAMP-TS-01	Kolasib	24°.21’88.9”N	92°.68’42.6”E	610m
2.	MZU-HAMP-TS-02	Keitum	23°.23’05.1”N	92°.91’20.6”E	686m
3.	MZU-HAMP-TS-03	Kawnpui	24°.03’58.7”N	92°.67’33.1”E	780m
4.	MZU-HAMP-TS-04	Sesawng	23°.74’87.4”N	92°.85’27.2”E	790m
5.	MZU-HAMP-TS-05	Lengte	23°.77’47.1”N	92°.59’86.5”E	449m
6.	MZU-HAMP-TS-06	Bairabi	24°.18’53.4”N	92°.53’71.2”E	53m
7.	MZU-HAMP-TS-07	Lengpui	23°.80’99.6”N	92°.63’49.9”E	411m
8.	MZU-HAMP-TS-08	Sairang	23°.89’81.67”N	92°.65’24.2”E	110m
9.	MZU-HAMP-TS-09	Mualkhang	23°.77’99.5”N	92°.67’41.7”E	460m
10.	MZU-HAMP-TS-10	Durtlang	23°.77’99.59”N	92°.72’84.3”E	1186m
11.	MZU-HAMP-TS-11	Thingsulthliah	24°.17’99.4”N	92°.85’90.6”E	905m
12.	MZU-HAMP-TS-12	New vervek	23°.97’04.8”N	92°.94’49.2”E	461m
13.	MZU-HAMP-TS-13	Saitual	23°.97’04.8”N	92°.57’58.7”E	799m
14.	MZU-HAMP-TS-14	Zemabawk	23°.73’83.1”N	92°.74’37.3”E	897m
15.	MZU-HAMP-TS-15	Bungtlang	23°.18’61.4”N	92°.90’11.9”E	748m
16.	MZU-HAMP-TS-16	Pangzawl	23°.08’37.9”N	92°.90’17.8”E	693m
17.	MZU-HAMP-TS-17	Zanlawn	23°.98’96.3”N	92°.70’77.6”E	574m
18.	MZU-HAMP-TS-18	Rawpuichip	23°.78’53.3”N	92°.56’07.8”E	741m
19.	MZU-HAMP-TS-19	Ramhlun South	23°.74’63.4”N	92°.72’55.8”E	860m
20.	MZU-HAMP-TS-20	Hualngohmun	23°.65’67.7”N	92°.72’93.3”E	804m
21.	MZU-HAMP-TS-21	Ratu	24°.11’10.1”N	92°.92’33.9”E	769m
22.	MZU-HAMP-TS-22	Hortoki	24°.06’13.2”N	92°.60’28.2”E	84m
23.	MZU-HAMP-TS-23	Kanhmun	24°.23’69.2”N	92°.29’72.4”E	68m
24.	MZU-HAMP-TS-24	Keifang	23°.66’36”N	92°.96’05.2”E	1071m
25.	MZU-HAMP-TS-25	Serchip	23°.33’76.9”N	92°.85’27.6”E	888m
26.	MZU-HAMP-TS-26	Bilkhawthlir	24°.33’49.8”N	92°.71’87.7”E	451m
27.	MZU-HAMP-TS-27	Hnahthial	22°.97’39.6”N	92°.93’27.6”E	570m
28.	MZU-HAMP-TS-28	Rawpui	23°.14’52”N	92°.89’92.4”E	749m
29.	MZU-HAMP-TS-29	Lunglei	22°.88’75.4”N	92°.75’06.1”E	986m
30.	MZU-HAMP-TS-30	Sateek	23°.54’65.7”N	92°.70’58.2”E	860m

and diverse genetic background of parents. The variation in pod weight among different tamarind accessions has also reported by Abraham *et al*. (1) and Rao and Subramanyam (20).

It is revealed from the data presented in Table 2 that the accessions varied significantly with respect to pod length and pod width. Among the different collections, the maximum pod length was recorded in MZU-HAMP-TS-29 (158.27 mm) which was significantly higher than rest of the accessions except MZU-HAMP-TS-8 (157.60 mm), MZU-HAMP-TS-13(156.40 mm) with which it was statistically *at par*, while, MZU-HAMP-TS-10 recorded the lowest pod length (104.03 mm). Similarly, among all the accessions, MZU-HAMP-TS-29 (36.22 mm), recorded the highest pod width which was significantly higher than all other accessions except MZU-HAMP-TS-16 (34.70 mm) and MZU-HAMP-TS-23 (34.42 mm), while, MZU-HAMP-TS-19 recorded the lowest pod width (22.13 mm). This variation in pod length and width might be due to different genetical constitution of the individual genotypes (Hazarika *et al.,* 9). The variation in pod length among different tamarind accessions has also reported by Patil, (16), Ganacharya (7) and Fandohan *et al*. (5). Our study is in close conformity with Kotecha and Kadam (12)

Table 2: Fruit physical parameters of different accessions of tamarind.

Accession	Pod weight (g)	Pod length (mm)	Pod width (mm)	Beak length (cm)	No. of ridges	Pulp weight (g)	Pulp percent-age	Shell weight (g)	Shell percent-age	Seed number	Seed weight (g)	Seed percent-age
MZU-HAMP-TS-01	24.96	130.33	28.82	0.44	4.56	11.56	46.01	4.28	17.45	8.87	9.12	36.54
MZU-HAMP-TS-02	20.50	112.80	27.03	0.24	4.03	8.86	41.43	3.74	18.95	6.88	7.90	39.61
MZU-HAMP-TS-03	18.63	108.87	25.37	0.34	2.49	8.64	46.21	3.42	18.40	6.15	6.57	35.40
MZU-HAMP-TS-04	24.06	125.47	27.08	0.24	5.04	11.00	44.69	5.13	21.72	6.27	7.93	33.59
MZU-HAMP-TS-05	24.67	124.60	28.10	0.16	6.63	10.00	40.41	5.52	22.43	8.10	9.15	37.16
MZU-HAMP-TS-06	20.90	124.33	27.47	0.29	6.92	8.43	39.82	4.84	23.26	7.42	7.62	36.93
MZU-HAMP-TS-07	25.07	124.53	27.74	0.41	3.69	14.07	55.99	3.64	14.62	6.30	7.35	29.38
MZU-HAMP-TS-08	29.67	157.60	33.35	0.60	8.70	17.51	59.09	5.71	19.26	5.25	6.44	21.65
MZU-HAMP-TS-09	27.73	130.67	28.20	0.33	5.79	15.53	55.99	3.92	14.10	6.42	8.28	29.90
MZU-HAMP-TS-10	19.13	104.03	32.39	0.30	4.96	8.83	45.89	3.64	19.13	7.17	6.66	34.98
MZU-HAMP-TS-11	18.40	110.40	28.17	0.51	5.87	6.50	35.23	4.18	22.74	6.87	7.72	42.03
MZU-HAMP-TS-12	18.18	116.27	25.10	0.55	6.63	8.00	44.11	3.89	21.31	8.17	6.29	34.58
MZU-HAMP-TS-13	31.60	156.40	32.53	0.65	7.47	19.47	61.42	5.82	18.53	5.13	6.32	20.05
MZU-HAMP-TS-14	28.07	134.23	29.23	0.32	4.38	13.22	46.85	5.53	19.73	7.68	9.32	33.43
MZU-HAMP-TS-15	24.83	152.73	33.80	0.49	6.27	11.61	46.56	5.47	22.12	7.40	7.76	31.31
MZU-HAMP-TS-16	27.67	132.33	34.70	0.32	5.37	13.28	47.91	5.33	19.31	6.15	9.06	32.78
MZU-HAMP-TS-17	18.10	121.80	33.02	0.52	5.58	7.32	40.23	3.70	20.53	6.19	7.08	39.24
MZU-HAMP-TS-18	24.40	127.07	32.80	0.50	6.32	12.50	50.46	4.83	20.12	6.02	7.07	29.42
MZU-HAMP-TS-19	17.57	108.87	22.13	0.27	3.97	7.14	40.58	3.53	20.11	6.12	6.89	39.31
MZU-HAMP-TS-20	29.67	155.60	30.43	0.24	6.43	16.90	56.98	5.38	18.15	7.10	7.39	24.87
MZU-HAMP-TS-21	27.83	135.93	32.24	0.17	5.53	16.28	58.52	5.16	18.50	6.37	6.39	22.98
MZU-HAMP-TS-22	18.10	126.73	24.52	0.40	5.27	8.21	45.16	3.07	16.94	6.15	6.82	37.90
MZU-HAMP-TS-23	32.17	150.27	34.42	0.66	8.65	20.27	62.85	5.73	17.92	5.17	6.17	19.23
MZU-HAMP-TS-24	27.40	138.40	29.77	0.22	3.92	15.26	55.68	3.40	12.40	6.49	8.74	31.92
MZU-HAMP-TS-25	30.50	154.40	31.63	0.41	4.73	16.72	54.80	5.80	19.01	8.43	7.99	26.19
MZU-HAMP-TS-26	27.70	142.73	28.92	0.33	5.87	15.49	54.98	4.33	15.96	7.63	7.88	29.06
MZU-HAMP-TS-27	28.17	132.38	33.24	0.36	7.01	15.76	55.94	5.32	18.87	5.87	7.09	25.19
MZU-HAMP-TS-28	25.97	148.13	33.75	0.26	7.50	13.63	52.63	5.22	20.08	6.40	7.12	27.28
MZU-HAMP-TS-29	31.06	158.27	36.22	0.69	8.07	19.23	61.86	5.76	18.57	5.22	6.08	19.57
MZU-HAMP-TS-30	28.17	138.03	29.08	0.16	6.67	16.31	57.92	4.72	16.78	8.63	7.14	25.29
S.Em (±)	1.80	6.44	1.78	0.03	0.50	1.81	4.76	0.45	2.41	0.69	0.65	3.31
$CD_{0.05}$	3.00	10.75	2.97	0.06	0.83	3.03	7.95	0.74	4.02	1.16	1.08	5.53

who reported variation in pod width among different tamarind accessions.

Beak length is also another important parameter which also determines the extent of genetic variation. In the present investigation, the beak length of the accessions ranged between 0.16-0.69 cm (Table 2). Among all the accessions, the significantly highest beak length was recorded in MZU-HAMP-TS-29 (0.69 cm), which was significantly higher than all other accessions except MZU-HAMP-TS-23 (0.66 cm), and MZU-HAMP-TS-13 (0.65 cm), with which it was found statistically *at par*, while, the lowest was recorded in MZU-HAMP-TS-5 and MZU-HAMP-TS-30 (0.16 cm). The variation in beak length among different tamarind accessions have also reported by Singh and Nandini (22).

In the present investigation, the number of ridges and furrows also varied significantly among the accessions (Table 2). The highest number of ridges was recorded in MZU-HAMP-TS-8 (8.70), whereas, the lowest was recorded by MZU-HAMP-TS-3 (2.49). Likewise, MZU-HAMP-TS-23 recorded the highest number of furrows, (7.77) and MZU-HAMP-TS-3 (1.45)recorded the significantly lowest number of furrows. The significant variation with respect to ridges and furrows number is due to the arrangement or placement of seeds inside the pod, number of seeds per pod and also distinct feature of the different tamarind genotypes. Our study is in close conformity with the findings of Singh and Nandini (22), who also observed variation in number of ridges and furrows among a number of tamarind accessions.

The accessions varied significantly with respect to pulp weight of the pods (Table 2). Among all the accessions, the highest pulp weight was recorded in MZU-HAMP-TS-23 (20.27 g), followed by MZU-HAMP-TS-13 (19.47 g), MZU-HAMP-TS-29 (19.23 g), and MZU-HAMP-TS-8 (17.51 g), while the lowest was recorded in MZU-HAMP-TS-11(6.50 g). Such variation in pulp weight of pod is attributed to the difference in pod length, pod width and pod thickness. Our study is in close conformity with the findings of Ganacharya (7) and Abraham *et al*. (1), who also observed variation in pulp weight among different tamarind accessions.

Similarly, it is revealed from the data presented in Table 2 that the highest pulp percentage was observed in MZU-HAMP-TS-23 (62.85%), followed by MZU-HAMP-TS-29 (61.86) and MZU-HAMP-TS-13 (61.42%), whereas, the lowest was recorded in HAMP-TS-11 (35.23%). Variation in pulp percentage among tamarind accessions was also reported by Prabhushankar *et al*., (17) and Ganacharya (7).

The shell weight ranged between 3.07-5.82 g (Table 2). Among all the accession, the maximum shell weight was observed in MZU-HAMP-TS-13 (5.82 g), followed by MZU-HAMP-TS-29 (5.76 g), MZU-HAMP-TS-23 (5.73 g), MZU-HAMP-TS-8 (5.71 g), whereas, the lowest was recorded in MZU-HAMP-TS-22 (3.07 g). The difference in shell weight is clearly attributed to the difference in size of the pod and thickness of the shell. Rao and Subramanyam (20), Ganacharya (7) and Patil (16) also observed variation in shell weight in tamarind.

The highest shell percentage was recorded in MZU-HAMP-TS-6 (23.26 %), which was followed by MZU-HAMP-TS-11 (22.74 %), MZU-HAMP-TS-5 (22.43 %) (Table 2). Among the accessions, the lowest shell percentage was recorded in MZU-HAMP-TS-24 (12.40 %). Our study is in close conformity with the findings of Prabhushankar *et al*., (17).

The seed number ranged between 5.13-8.87 (Table 2). Among the accessions, MZU-HAMP-TS-1 recorded the highest no. of seeds (8.87). The lowest number of seeds was recorded in MZU-HAMP-TS-13 (5.13). The variation in seed number is attributed to difference in length of pod, ovule fertility, arrangement or placement of seeds inside the pod and pods having higher or lower length may contain either lower or higher number of seeds depending on seeds size. Variation in seed number among different tamarind accessions was also reported by Ganacharya (7) and Fandohan *et al*. (5).

It is revealed from the data presented in Table 2 that, among the different accessions, the significantly maximum seed weight was observed in MZU-HAMP-TS-14 (9.32 g), followed by MZU-HAMP -TS-5 (9.15 g), MZU-HAMP -TS-1 (9.12 g), MZU-HAMP-TS-16 (9.06 g), MZU-HAMP-TS-24 (8.74 g), and MZU-HAMP-TS-9 (8.28 g). Accession MZU-HAMP-TS-29 recorded the significantly lowest seed weight of 6.08 g. Rao and Subramanyam (20), Ganacharya (7) and Patil (16) also observed variation in seed weight in tamarind.

For an ideal variety lower weight and small size of seed are the desirable characters. These observations revealed a positive correlation among pulp weight, seed weight and fruit weight. The genotypes produced higher pulp weight may be due to higher fruit weight and less seed weight. This clearly indicated that, during selection of any genotype based on fruit, the breeder should give emphasis on fruit pulp content rather than fruit weight alone. This finding is in conformity with Hazarika *et al.* (8).

Among the accessions, the seed percentage ranged from 19.23- 42.03 percent (Table 2). The highest seed percentage was recorded in MZU-HAMP-TS-11 (42.03 %), which was significantly higher than all other accessions, while, the lowest was recorded in MZU-HAMP-TS-23 (19.23 %). Our study is in the line of the findings of Azhakiamanavalan and Vadivel (3) and Singh and Nandini (22) who also reported variation in seed percentage among local and improved tamarind varieties.

The moisture percentage varied from 17.57-26.87 % (Table 3). The lowest moisture content (%) was recorded in MZU-HAMP-TS-29 (17.57 %), it was followed by HAMP-TS-12 (17.69 %) and MZU-HAMP-TS-13 (17.71 %). Accession MZU-HAMP-TS-15 recorded the highest moisture content (26.87 %), which was significantly lower than all other accessions, except, MZU-HAMP-TS-19 (26.11 %). Variation in moisture content among tamarind accessions was also reported by Kaur *et al*., (11), and Kotecha and Kadam (12).

Table 3: Chemical characteristics among different accessions of tamarind.

Accession	Moisture (%)	TSS (°B)	Acidity (%)	Ascorbic acid (mg/100g)	Total sugars (%)	Reducing sugar (%)	Non reducing sugar (%)	Sugar: acid ratio	TSS : acid ratio
MZU-HAMP-TS-01	20.93	18.47	9.29	1.63	28.07	17.01	11.91	3.10	2.03
MZU-HAMP-TS-02	20.79	18.36	11.50	2.73	29.17	18.58	11.52	2.55	1.60
MZU-HAMP-TS-03	23.22	19.63	9.32	3.46	29.91	16.17	14.55	3.23	2.12
MZU-HAMP-TS-04	20.20	17.29	8.15	4.11	30.56	17.17	14.25	3.84	2.16
MZU-HAMP-TS-05	19.26	19.18	9.14	2.02	28.46	17.04	12.27	3.14	2.11
MZU-HAMP-TS-06	20.66	18.65	8.27	1.75	36.87	20.71	17.19	3.45	2.28
MZU-HAMP-TS-07	18.69	19.42	8.52	1.81	28.26	15.44	13.59	3.31	2.28
MZU-HAMP-TS-08	17.75	22.92	6.55	5.17	38.20	23.32	16.05	4.83	3.50
MZU-HAMP-TS-09	20.47	18.39	8.64	3.85	30.30	18.36	12.85	3.54	2.14
MZU-HAMP-TS-10	18.18	17.46	8.83	2.97	29.42	18.74	11.62	3.35	1.99
MZU-HAMP-TS-11	22.08	17.30	8.82	3.86	28.97	15.66	14.09	3.49	1.98
MZU-HAMP-TS-12	17.69	17.50	7.67	4.14	27.92	15.69	13.02	3.99	2.28
MZU-HAMP-TS-13	17.71	22.54	6.93	5.52	36.41	21.80	15.70	4.61	3.25
MZU-HAMP-TS-14	19.01	18.30	7.73	3.24	31.92	17.93	14.89	3.84	2.37
MZU-HAMP-TS-15	26.87	18.28	8.83	4.09	33.87	18.51	16.29	3.47	2.09
MZU-HAMP-TS-16	23.98	18.24	11.48	4.45	34.23	21.62	13.69	2.70	1.59
MZU-HAMP-TS-17	22.22	19.36	10.50	2.82	29.26	17.74	12.41	2.81	1.85
MZU-HAMP-TS-18	20.13	19.52	8.83	3.39	35.30	22.48	13.94	3.41	2.22
MZU-HAMP-TS-19	26.11	17.29	7.83	3.42	29.87	16.14	14.53	3.81	2.22
MZU-HAMP-TS-20	19.64	18.40	10.73	4.25	34.03	19.12	15.87	2.87	1.72
MZU-HAMP-TS-21	18.27	17.63	8.53	2.60	29.05	17.40	12.52	3.40	2.07
MZU-HAMP-TS-22	24.75	20.32	9.83	3.63	30.08	16.90	14.03	3.08	2.08
MZU-HAMP-TS-23	23.47	23.69	6.75	5.08	37.06	20.25	17.82	4.72	3.51
MZU-HAMP-TS-24	21.67	17.29	8.25	2.81	29.26	19.90	10.35	3.57	2.10
MZU-HAMP-TS-25	19.42	17.32	7.89	1.78	28.23	17.11	11.97	3.61	2.21
MZU-HAMP-TS-26	18.48	19.41	7.80	2.32	28.77	18.32	11.36	3.72	2.53
MZU-HAMP-TS-27	23.74	18.26	9.63	3.39	29.51	15.95	14.35	3.16	1.94
MZU-HAMP-TS-28	24.33	17.95	8.69	4.49	31.27	17.57	14.58	3.63	2.12
MZU-HAMP-TS-29	17.57	23.24	6.69	5.34	36.79	22.03	15.86	4.75	3.47
MZU-HAMP-TS-30	23.63	17.84	9.67	3.54	28.65	16.10	13.36	3.12	1.85
S.Em (±)	1.09	0.51	0.78	0.28	2.05	1.16	1.09	0.38	0.19
$CD_{0.05}$	1.83	0.86	1.31	0.46	3.43	1.93	1.83	0.64	0.31

As evidenced from the data presented in Table 3, the highest TSS was recorded in MZU-HAMP-TS-23 (23.69 %), followed by MZU-HAMP-TS-29 (23.24 %) and MZU-HAMP-TS-8 (22.92 %), whereas, the lowest TSS was recorded in MZU-HAMP-TS-4, MZU-HAMP-TS-19 and MZU-HAMP-TS-24(17.29 %). Variation in TSS among different tamarind accessions was also reported by Kaur *et al*. (11), and Prabhushankar *et al*. (17).

Ascorbic acid content is also one of the most important criteria in determining the superiority of any fruits. The highest value with respect to ascorbic acid was recorded in MZU-HAMP-TS-13(5.52 mg/100 g) which was significantly higher than all other accessions except MZU-HAMP-TS-29 (5.34 mg/100 g), MZU-HAMP-TS-8 (5.17 mg/100 g), and MZU-HAMP-TS-23 (5.08 mg/100 g), whereas, the lowest was recorded in MZU-HAMP-TS-1(1.63 mg/100 g)

(Table 3). It is a fact that, if TSS increases, the ascorbic acid also increases because the precursor of ascorbic acid is glucose- 6-phosphate (Prakash *et al.* 18), which also confirmed from our study. The variation in ascorbic acid among different tamarind accessions was also reported by Singh and Nandini (22) and Kaur *et al*. (11).

Titratable acidity of the fruits ranged between 6.55 to 11.50 % (Table 3). Among all the accessions, MZU-HAMP-TS-8 (6.55 %), recorded the lowest titratable acidity, followed by MZU-HAMP-TS-29 (6.69 %) and MZU-HAMP-TS-23(6.75%). The highest acidity was recorded in MZU-HAMP-TS-2 (11.50 %). This is a fact in many fruits that, if total soluble solids are increasing definitely acidity will be decreased. This may be major factor for minimum acid content in MZU-HAMP-HS-8, MZU-HAMP-HS-29, and MZU-HAMP-HS-23. The variation among genotypes for acidity percent might be due to total soluble solids content and genetic make of plant (Prakash *et al.*, 18) which has also proved in our study. Our study is in the line of the findings of Patil (16), Prabhushankar *et al*. (17) and Biradar (4) who reported variation in acidity among different tamarind accessions.

Similarly, sugar content also varied significantly among the collections. The highest total sugar was recorded in MZU-HAMP-TS-8(38.20%) which was followed by MZU-HAMP-TS-23(37.06 %) and MZU-HAMP-TS-29(36.79 %), whereas, the lowest total sugar was recorded in MZU-HAMP-TS-12(27.92%) (Table 3). Likewise, the highest reducing sugar was recorded in MZU-HAMP-TS-8(23.32 %) followed by MZU-HAMP-TS-18(22.48 %) and MZU-HAMP-TS-29(22.03%), while, MZU-HAMP-TS-7 recorded the lowest reducing sugar (15.44%). MZU-HAMP-TS-23(17.82 %) recorded the highest non-reducing sugars, which was followed by MZU-HAMP-TS-6(17.19 %), MZU-HAMP-TS-15(16.29 %), and MZU-HAMP-TS-8(16.05 %), whereas, the lowest non-reducing sugars was recorded by MZU-HAMP-TS-24(10.35 %). Variation in total, reducing and non-reducing sugars among different tamarind accessions was also reported by Kotecha and Kadam (12) and Singh and Nandini (22).

As evidenced from the data presented in Table 3, among all the accessions, MZU-HAMP-TS-8 recorded highest sugar: acid ratio (4.83), followed by MZU-HAMP-TS-29 (4.75) and MZU-HAMP-TS-23(4.72), whereas, MZU-HAMP-TS-2 recorded the lowest sugar: acid ratio (2.55). Our study is in close conformity with the findings of Hazarika *et al*. (10) who also reported variation in sugar: acid ratio among a number of accessions. Similarly, the highest TSS: acid ratio was recorded in MZU-HAMP-TS-23 (3.51), followed by MZU-HAMP-TS-8(3.50) and MZU-HAMP-TS-29 (3.47), while, the lowest was recorded in MZU-HAMP-TS-16 (1.59). Our study is in close conformity with the findings of Madhumathi and Sekhar (14) and Shukla *et al*. (22), who also reported variation in TSS: acid ratio among different fruits.

Tamarind is a popular spice among the consumers for day to day uses in the household preparations. In tamarind, consumers always depends on the physical parameters of fruits like pod weight, pulp content, high sugar and good quality traits. Similarly, for development of a new variety, breeders also choose accessions with desirable physical characteristics like maximum pod length, breadth, high pod weight, pulp weight, less fibre. In addition, breeders are also interested for accessions having good chemical characteristics like high sugar content, total soluble solids, less acidic, high sugar: acid ratio etc. The results of the present investigation revealed that there was significant variation in physico-chemical characteristic among different *tamarind* accessions. It has observed that, among all the accessions of tamarind collected from different locations of Mizoram, MZU-HAMP-TS-29, MZU-HAMP-TS-23 and MZU-HAMP-TS-8 having all the desirable physical and chemical parameters from the consumer as well as breeders. Therefore, it can be concluded that MZU-HAMP-TS-29, MZU-HAMP-TS-23 and HAMP-MZU-TS-8 can be considered as elite *tamarind* accessions for use in future breeding programme.

REFERENCES

1. Abraham, Z., Malik, S.K., Rao, G.E., Narayanan, S.K. and Biju, S. 2006. Collection and characterization of Malabar tamarind [*Garcinia cambogia* (Gaertn.) Desr.] *Genet. Resour. Crop Evol.* **53**: 401-06.

2. A.O.A.C.1995. *Official methods of analysis*, 16th edn. Association of Official Analytical Chemists, Washington

3. Azhakiamanavalan, R.S. and Vadivel, E. 1997. Dry land tamarind PKM-1: Pre and post released status. Paper presented In: Proc. Nat. Symp. *Tamarindus indica* L. Tirupathi (A. P.) Forest Dept. A. P., June 27-28, pp 7-9

4. Biradar, S. 2001. Evaluation of different tamarind (*Tamarindus indica* L.) genotypes. M.Sc.(Hort) Thesis, Univ. Agric. Sci., Dharwad (India)

5. Fandohan, B., Assogbadjo, A.E., Kakai, R.G., Kynd, T. and Sinsin, B. 2011. Quantitative

morphological descriptors confirm traditionally classified morphytes of *Tamarindus indica* L. fruits. *Genet. Resour. Crop Evol.* **58**: 299-309.

6. Freed, M. 1966. *Methods of vitamin assay*. Interscience Publ. Inc, New York
7. Ganacharya, V. 2005. Evaluation and propagation studies in tamarind (*Tamarindus indica* L.) *M.Sc. (Hort) Thesis,* Univ. Agric. Sci., Dharwad (India)
8. Hazarika, B.N., Deka, B.C., Choudhury, S. and Sarma, B. 2009. Studies on variability in physico-chemical characters of different *aonla* accessions from Jorhat region of Assam. *Indian J Hort*. **66**: 190-92.
9. Hazarika, T.K., Lalawmpuii, B. and Nautiyal B.P. 2013a. Studies on variability in physico-chemical characters of hatkora (*Citrus macroptera* Mont.) collections of Mizoram. *Indian J Hort*. **70**: 480-84.
10. Hazarika, T.K., Lalbiakngheti, M. and Nautiyal, B.P. 2013b. Genetic variability in physico-chemical characters of some *pummelo* collections from Mizoram. *Indian J Hort.* **70**: 431-434
11. Kaur, G., Nagpal, A. and Kaur, B. 2006. Tamarind date of India. Sc. Tech Entrepreneur pp 1-14
12. Kotecha, P.M. and Kadam, S.S. 2002. Studies on extraction of pulp and juice from tamarind fruits. *Indian Food Pack.* **56**: 148-52
13. Lewis G, Schrire B, Mackinder B and Lock M. 2005. Legumes of the World, Royal Botanic Garden, Kew, 577 pp
14. Madhumati, C. and Sekhar, M.R. 2015. Genetic variation for morphological and fruit characteristics among sweet orange accessions. *Indian J Hort*. **72**: 121-125
15. Pamploma-Roger, G.D. 1999. Encyclopaedia of Medicinal Plants; Education and Health Library: Madrid, Spain,; Volume 2, p. 536
16. Patil, S.S. 2004. Genetics and propagation studies in Tamarind (*Tamarindus indica* L.). Phd (Hort) Thesis, Univ. Agric. Sci., Dharwad (India)
17. Prabhushankar, D.S., Melanta, K.R. and Chandregowda, M. 2004. Evaluation of elite clones of tamarind. *Karnataka J Agric Sci* **17**: 512-14
18. Prakash, J., Maurya, A.N. and Singh, S.P. 2010. Studies on variability in fruit characters of Jamun. *Indian J Hort.* **67**: 63-66
19. Punjabi, B.L. and Kumar, V. 2002. Folk medicinal plants used for skin disorders in the tribal pockets of Sabarkantha district, Gujarat. *J. Nat. Remed.* **2**: 84-87
20. Rao, K.D. and Subramanyam, K. 2010. Varietal evaluation of tamarind under scarce rainfall zone. *Agric Sci Digest.* **30**: 42-45
21. Shukla, A.C., Dhandar, D.G. and Shukla, A.K. 2010. Evaluation of *aonla* germplasm for growth, yield and quality attributes in hot arid ecosystem. *Indian J Hort.* **67**: 43-46
22. Singh, T.R. and Nandini, R. 2014. Genetic Variation Association and Path Analysis in the Tamarind (*Tamarindus indica*) Population of Nallur Tamarind Grove. *SAARC Agril J.* **12**: 20-25.
23. Spice Board of India, 2009. Ministry of commerce and Industry, Trends in India's spice export. Availaible online: http://www.indianspices.com/html/s0420sts.htm

Received : December, 2019; Revised : June, 2020;
Accepted : June, 2020