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RESEARCH ARTICLE

Exploring genetic diversity of *Garcinia lanceifolia* Roxb. (Clusiaceae), a highly medicinal and endangered fruit of north-east India

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Abstract The present investigation was carried out during 2015–2017 to identify superior accessions of *Garcinia lanceifolia* Roxb., a highly medicinal fruit of Mizoram, North-east India. The ripe fruits of 25 selected accessions from six districts of Mizoram, north-east India were analyzed for fruit weight, fruit length, fruit diameter, fruit volume, pulp weight, peel weight, pulp: peel ratio, seed weight, seed length, seed diameter, number of seeds, TSS, acidity, ascorbic acid, reducing sugars and total sugars. The study reveals that there was significant variation among the accessions with respect to all these characters. Individual fruit weight ranged from 31.90 to 105.47 g; fruit volume 25.53–95.40 cm^3; seed weight 12.98–46.98 g; peel weight 1.45–4.96 g; pulp weight ranged from 12.69 to 53.88 g. There was wide variation in chemical characters of the fruits also. TSS varied from 5.29 to 8.64%, titratable acidity varied from 3.27 to 5.72%, ascorbic acid 42.03–49.34 mg/100 g; total sugars 5.00–6.86%; reducing sugar ranged from 2.57 to 4.16%. From the results of the present investigation, MZU-HAMP-GC-1, MZU-HAMP-GC-2 and MZU-HAMP-GC-10 can be considered as elite *G. lanceifolia* Roxb. accessions for use in future breeding programmes.

Keywords *Garcinia lanceifolia* Roxb. · Genetic diversity · Mizoram · North-east India

Introduction

The genus *Garcinia* is a large genus of polygamous trees or shrubs belongs to the family Clusiaceae (Guttiferae) consisting of over 400 species of mostly small to medium sized trees. The genus is distributed in tropical Asia, Africa, and Polynesia more particularly in the southern part of Thailand and Peninsular Malaysia to Indonesia, and South East Asian region (Mabberley 2005). Among the various species of *Garcinia* in the world it is estimated that only 40 species produce edible fruits (Yapattanphum et al. 2002) of these some species are found to be domesticated as fruits of minor species. These include *Garcinia atroviridis* and *Garcinia hombroniana* in Malaysia; *Garcinia indica* in India; *Garcinia multiflora* in Vietnam and *Garcinia pedunculata* in Assam and Bangladesh. Species of the genus have various biological properties such as antioxidant (Muharni et al. 2009), cytotoxin (Wahyuni et al. 2004) and antimicrobial activities (Dachriyanus et al. 2004).

Garcinia is a source for a hydroxycitric acid (HCA) which is an anti-obesity compound present in the fruit rind and leaves of *Garcinia* (Cuong and Quang 2007). In India, about 35 species are found, many of which are endemic and economically important, with

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immense medicinal properties. The plants are found extensively in states such as Maharastra, Goa, coastal areas of Karnataka, Kerala, evergreen forest of Assam, Khasi and Jaintia hills of Meghalaya, West Bengal and Gujarat. Among the different species of India, 15 species are present in NE India and 8 species from Assam (Kar et al. 2008). *G. pedunculata*, *Garcinia cowa*, *Garcinia lanceaefolia* are the most important species of North-eastern India. Most species of *Garcinia* have several uses. Gambage is a gum resin which collected from *Garcinia morella* Dees distributed in India, Indo-China and southeast Asian region. A non-drying oil similar to Kokam butter, is extracted from the seeds of *G. indica*, *G. morella* and *Garcinia cambogia* for use in cooking and confectionary. Few species of *Garcinia* are used in traditional system of medicines. Some species have potential properties for treatment of HIV (Rukachaisirikul et al. 2003) and cancer (Nabandith et al. 2004). *G. lancifolia* is rich source of bioactive substances such as xanthones, biflavonoides, benzophenones with antimicrobial, cytotoxic and antioxidant acivities (Doley and Jha 2015; Chowdhury and Handique 2012).

Although *Garcinia lanceifolia* Roxb. is very important as a source of medicine in the socio-economic life of rural and tribal people of Mizoram, the information on extent of genetic variation among the accessions is very limited. Since the fruits are propagated only from seeds, there is tremendous variation among its population with respect to morphological and physico-chemical traits. In addition, due to lack of selection of any superior types among the population of the high valued species, the farmers have been planting seedlings of uncertain origin with low yield potential and quality. Till now, there is no concrete report on characterization of genetic diversity in the natural populations and no systematic studies have been undertaken to screen out superior genotypes of *G. lanceifolia* Roxb. in terms of physico-chemical properties of the fruits.

Although, newly developed molecular markers are valuable in gene based diversity studies, however the procedures used for the molecular markers analysis have disadvantage of high cost (Bouhadida et al. 2005). In contrast, morphological traits could feasibly be used for parental selection and along with molecular techniques are of highly appreciated procedures for description and germplasm classification of plants. Morphological criteria have been widely used as important markers in plant breeding programs (Kumar et al. 2015). Identification and description of the genetic variability available in the genotype are preliminary requirements for the exploitation of useful traits in plant breeding. The obtained data from the present investigation will be helpful to select the most promising genotype for use in breeding and to identify their desirable fruit and yield characteristics. The results will provide some guidance for screening of breeding resources for improving fruit quality and serve as a base for economically valuable phenotypes.

Use of available genetic resources is a major part of any crop improvement programme. The success of any improvement programme depends mostly on the identification and selection of superior parents for hybridization (Prakash et al. 2010). For improvement programme of any fruit crops, the rich gene pools incorporating extensive variability from basic ingredients are very important (Kumar et al. 2010). Therefore, exploitation of existing variability, identification of superior genotypes and their conservation are important in context of the present day scenario of rapid extinction of such useful unexploited fruit. Due to unawareness of the knowledge of biodiversity among local people, some germplasm is almost extinct and very little attention has been given for the characterization, evaluation and conservation of available accessions. In order to enrich the information and acquaint the breeders to interpret phenotypic values in terms of potential genetic gain, the present study was done to find out superior genotypes of *G. lanceifolia* Roxb.

Materials and methods

The present investigation was undertaken at six different districts of Mizoram, north-east India during 2015–2017 to assess the genetic diversity and identify the superior types of *G. lanceifolia* Roxb.

Mizoram, has an area of 21,081 km^2 and lies between 21°56′N and 24°31′N latitude and 92°16′E and 93°26′E longitude. The state has international borders with Bangladesh in the west and Myanmar in the east and south. On the northern side it borders with three states of India viz. Tripura in north west, Assam in north and Manipur in the north east. Being sandwiched between Bangladesh and Myanmar, its location is geographically and politically significant

(Fig. 1). The hilly state is covered with tropical and subtropical forest cover. It is one of the hot spots of biodiversity.

Garcinia lanceifolia Roxb. trees are found scattered throughout the states from homestead garden to forest areas. The collection of fruits from six districts i.e. Aizawl, Serchhip, Lunglei, Kolasib, Mamit and Champhai comprising of 25 different accessions was conducted during the fruiting season of 2015–2017. Details of the accessions and their sources are given in Table 1. The collected fruits 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, 20 randomly selected fruits were taken from each replication. Quality parameters like juice, TSS, acidity, ascorbic acid, reducing, non-reducing and total sugars were estimated following standard procedures. The standard method (AOAC 1995) was followed to determine the qualitative parameters of fruit. 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 (Panse and Sukhatme 1985). By comparing different treatments among themselves critical difference were calculated at 5% probability level.

Results and discussion

Among all the accessions, the highest fruit weight was recorded in MZU-HAMP-GC-10 (105.47 g) which was followed by MZU-HAMP-GC-1 (101.96 g), and MZU-HAMP-GC-2 (99.34 g) (Table 2). Similarly, the maximum fruit length was recorded in MZU-HAMP-GC-1 (57.80 mm), which was significantly higher than all other accessions except MZU-HAMP-GC-2 (53.41 mm), and MZU-HAMP-GC-10 (53.01 mm), with which it was statistically *at par*. This variation in fruit length might be due to different genetic make-up of the genotypes (Hazarika et al. 2013a).

The maximum fruit diameter (67.17 mm), and fruit volume (95.66 cm^3) was recorded in MZU-HAMP-GC-10. There was no significant difference among the accessions with respect to specific gravity (Table 2). However, MZU-HAMP-GC-3 (1.24) and MZU-HAMP-GC-18 and MZU-HAMP-GC-11 (1.03), recorded the highest and lowest value of specific gravity. The highest number of locules was observed in MZU-HAMP-GC-10 (8.24), followed by MZU-HAMP-GC-2 (7.97), MZU-HAMP-GC-1 (7.84), and MZU-HAMP-GC-21 (7.53). The variation in locules number might be due to different genetical constitution of the individual genotypes. Our study is in close conformity with the findings of Hazarika et al. (2013b), who also obtained significant variation in number of segments among different accessions.

Peel weight and pulp weight of the accessions ranged between 1.45–4.96 g and 12.69–53.88 g respectively. MZU-HAMP-GC-2 recorded the highest peel weight (4.96 g), which was significantly higher than all other accessions except MZU-HAMP-GC-1 (4.91 g), and MZU-HAMP-GC-10 (4.61 g), whereas, MZU-HAMP-GC-10 (53.88 g), recorded the highest pulp weight, followed by MZU-HAMP-GC-1 (51.54 g), and MZU-HAMP-GC-2 (50.64 g). Our finding is in agreement with the findings of Hazarika et al. (2017).

The analysis of variance presented in Table 2 revealed a correlation among fruit weight and pulp weight. The genotypes produced higher fruit weight may be due to more pulp 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. Our study is in close conformity with the findings of Hazarika et al. (2013b), who also obtained significant variation in pulp weight among a number of accessions.

In the present study, there was no significant difference among the accessions with respect to pulp peel ratio (Table 2). However, MZU-HAMP-GC-10 (11.79) and MZU-HAMP-GC-3 (6.47), recorded the highest and lowest value of pulp peel ratio.

It is evident from the data presented in Table 2 that the accessions varied significantly with respect to seed characters. MZU-HAMP-GC-1 recorded the highest number of seeds (6.83), followed by MZU-HAMP-GC-10 (6.41), MZU-HAMP-GC-2 (6.23), MZU-HAMP-GC-12 (6.06), MZU-HAMP-GC-13 (6.03) and MZU-HAMP-GC-9 (5.92) (Table 2). Likewise,

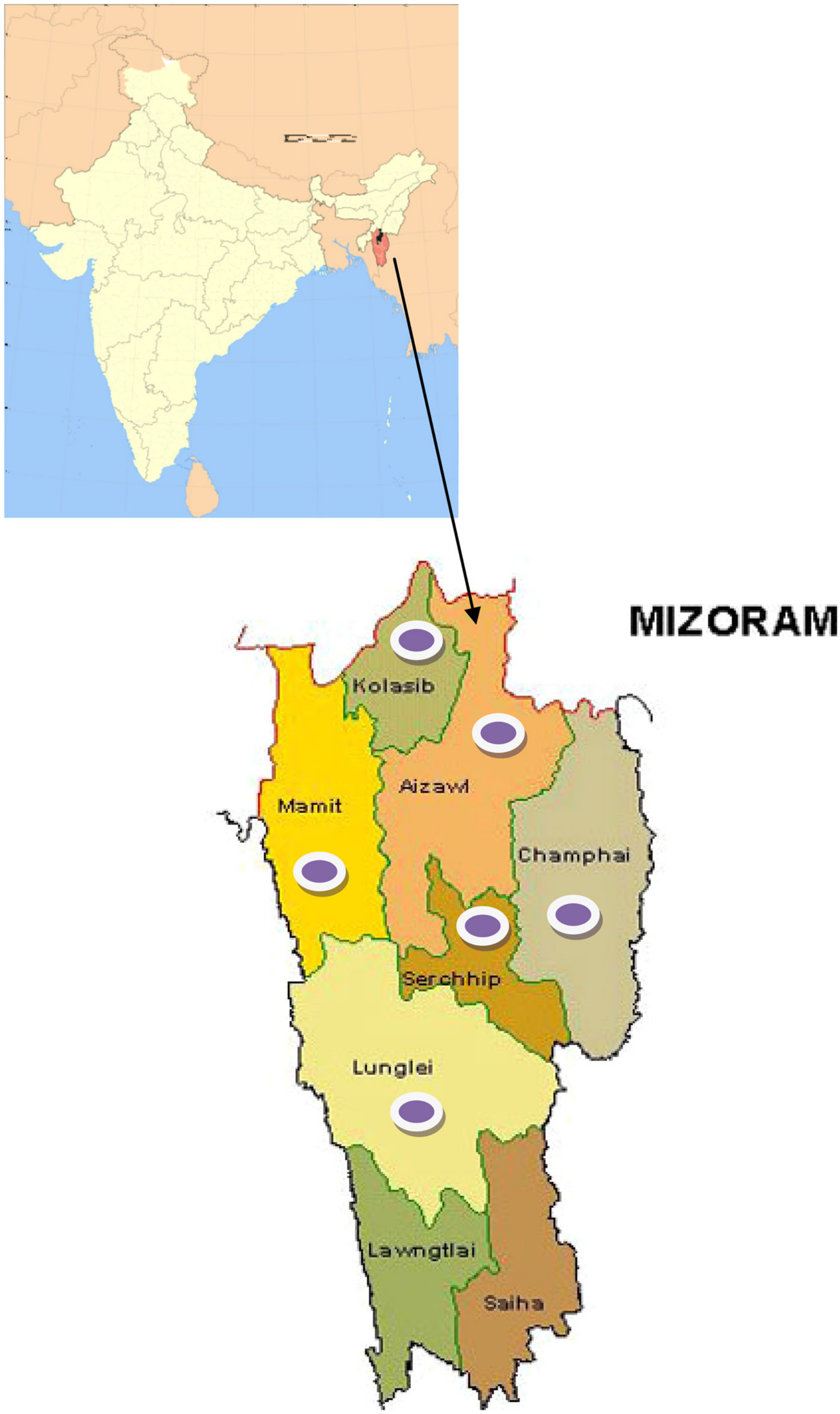

Fig. 1 Map of the study area

Table 1 Accession of *Garcinia lanceifolia* Roxb. and their sources

Accession		Location	Latitude	Longitude	Elevation (m)
1	MZU-HAMP-GC-01	Sihphir	23°.81′79.4″N	92°.73′69.2″E	1200
2	MZU-HAMP-GC-02	Durtlang	23°.79′73.1″N	92°.72′69.6″E	1340
3	MZU-HAMP-GC-03	Thingsultliah	23°.68′79.2″N	92°.85′89.5″E	900
4	MZU-HAMP-GC-04	Thingdawl	24°.16′79.9″N	92°.69′58.1″E	733
5	MZU-HAMP-GC-05	N.Lungleng	23°.65′85.4″N	92°.67′22.9″E	997
6	MZU-HAMP-GC-06	Tanhril	23°.74′17.8″N	92°.67′70.7″E	951
7	MZU-HAMP-GC-07	Kawnpui	24°.04′33.3″N	92°.67′20.1″E	820
8	MZU-HAMP-GC-08	Bilkhawthlir	24°.33′50.3″N	92°.72′06.7″E	407
9	MZU-HAMP-GC-09	Lungdai	23°.88′02.7″N	92°.74′18.9″E	1162
10	MZU-HAMP-GC-10	Bualpui	24°.09′22.8″N	92°.68′22.3″E	950
11	MZU-HAMP-GC-11	Keitum	23°.23′19.6″N	92°.91′13.5″E	703
12	MZU-HAMP-GC-12	Suangpuilawn	23°.95′92.7″N	93°.04′06.4″E	1066
13	MZU-HAMP-GC-13	Phuaibuang	23°.92′65.5″N	93°.12′15.1″E	1388
14	MZU-HAMP-GC-14	Ngopa	23°.88′60.8″N	93°.21′18.6″E	1184
15	MZU-HAMP-GC-15	Serkhan	23°.91′07.8″N	92°.73′87.8″E	998
16	MZU-HAMP-GC-16	Zanlawn	23°.98′09.6″N	92°.71′88.9″E	706
17	MZU-HAMP-GC-17	Serchhip	23°.34′16.5″N	92°.85′02.3″E	803
18	MZU-HAMP-GC-18	Lunglei	22°.86′70.6″N	92°.76′55.3″E	1045
19	MZU-HAMP-GC-19	Reiek	23°.67′76.6″N	92°.60′37.1″E	1335
20	MZU-HAMP-GC-20	Sairang	23°.80′89.4″N	92°.65′61.5″E	157
21	MZU-HAMP-GC-21	Bairabi	24°.18′53.4″N	92°.53′71.2″E	52
22	MZU-HAMP-GC22	Lengpui	23°.83′32.3″N	92°.62′63.7″E	404
23	MZU-HAMP-GC-23	Kolasib	24°.22′45.6″N	92°.67′60.2″E	662
24	MZU-HAMP-GC-24	Vairengte	24°.49′10.2″N	92°.75′84.1″E	237
25	MZU-HAMP-GC-25	Mamit	23°.64′73.8″N	92°.53′96.0″E	690

the maximum seed weight (46.98 g) and seed length (13.19 mm) was observed in MZU-HAMP-GC-1. Similarly, MZU-HAMP-GC-13 recorded the highest seed diameter (17.95). The variation in seed characteristics among the different accessions may be due to different genetical constitution of the individual genotypes. The variation in seed characters might be due to genetical constituents of the accessions (Hazarika et al. 2016).

The accessions varied significantly with respect to quality parameters of the fruits. Among all the accessions, the highest moisture percent was recorded in MZU-HAMP-GC-10 (94.77%), which was followed by MZU-HAMP-GC-1 (94.68%) and MZU-HAMP-GC-23 (93.97%) (Table 3). The highest value of TSS was recorded in MZU-HAMP-GC-10 (8.64%). The variation in TSS may be due to different genetical constitution of the individual genotypes. Fruits growing in an arid region with limited water tended to more accumulation of dry matter and lower moisture content which may result in higher TSS in fruits (Meghwal and Azam 2004). The breeders during selection of superior genotypes should emphasize total soluble solids content of the fruits. Korikanthimath and Desai (2006) and Patil et al. (2005) reported variation in TSS among a number of Garcinia species.

Ascorbic acid is also one of the most important criteria, which also determine the quality of fruits. In our study, the highest value of ascorbic acid was recorded in MZU-HAMP-GC-1 (49.34 mg/100 g) followed by MZU-HAMP-GC-10 (48.43 mg/100 g), and MZU-HAMP-GC-2 (47.45 mg/100 g). Our study is in close conformity with the findings of Hazarika et al. (2013b), who also obtained significant variation

Table 2 Fruit physical parameters of different accessions

Accession	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	Fruit volume (cm^3)	Specific gravity (g/cm^3)	No. of locules	Pulp weight (g)	Peel weight (g)	Pulp-peel ratio	Seed weight (g)	No. of seeds	Seed length (mm)	Seed diameter (mm)
MZU-HAMP-GC-1	101.96+10.77	57.8±7.14	60.46±5.00	95.4±11.81	1.07±0.02	7.84±0.20	51.54±11.80	4.91±1.01	10.48±0.68	45.51±9.26	6.83±0.87	13.19±1.29	16.82±3.30
MZU-HAMP-GC-2	99.34±3.99	53.41±1.22	65.22±2.04	84.64±11.40	1.19±0.15	7.97±0.15	50.64±8.98	4.96±0.82	10.19±0.31	43.74±12.12	6.23±0.82	8.13±1.62	13.56±1.90
MZU-HAMP-GC-3	34.22±5.67	31.59±1.22	37.79±5.63	25.57±5.00	1.24±0.08	6.53±0.64	12.69±3.36	1.94±0.28	6.47±0.95	19.59±3.79	3.38±0.47	8.11±2.17	11.78±3.24
MZU-HAMP-GC-4	45.93±3.69	39.95±1.00	50.17±2.84	39.13±7.35	1.19±0.16	5.16±0.10	16.61±2.09	1.71±0.12	9.67±0.58	27.61±2.02	4.68±0.22	9.15±1.23	13.73±1.62
MZU-HAMP-GC-5	31.90±8.02	37.89±5.10	42.45±5.63	28.97±3.01	1.09±0.19	5.71±0.34	17.1±3.24	1.82±0.29	9.13±1.25	12.98±4.69	3.79±1.04	8.42±1.23	13.92±3.39
MZU-HAMP-GC-6	35.52±5.45	35.93±2.53	49.88±1.84	32.63±2.78	1.08±0.08	6.76±0.10	18.02±0.35	2.21±0.34	8.28±1.22	15.29±5.14	4.53±0.22	9.25±1.09	15.27±1.10
MZU-HAMP-GC-7	42.03±5.57	51.17±3.25	49.95±3.42	38.07±4.77	1.1±0.02	6.26±0.81	17.53±1.98	1.83±0.26	9.62±1.04	22.66±3.46	3.98±0.84	8.13±1.02	14.12±2.01
MZU-HAMP-GC-8	35.69± 0.09	50.4±2.12	53.12±3.20	31.93±0.96	1.12±0.03	4.82±0.10	16.35±0.92	1.45±0.33	11.7±3.01	17.89±0.98	3.8±0.54	8.82±0.74	16.26±0.65
MZU-HAMP-GC-9	70.50±5.40	49.52±4.80	52.47±2.40	65.03±4.60	1.08±0.01	6.16±0.10	25±3.46	2.52±0.34	9.91±0.10	42.97±1.70	5.92±0.88	11.82±1.28	16.48±0.92
MZU-HAMP-GC-10	105.47±13.10	53.01±3.48	67.17±2.66	95.66±21.79	1.12±0.16	8.24±0.11	53.88±14.56	4.61±1.43	11.79±0.79	46.98±14.87	6.41±0.84	10.19±1.29	15.73±1.62
MZU-HAMP-GC-11	53.33±2.89	50.8±0.87	59.36±1.38	51.77±3.35	1.03±0.01	4.96±0.86	25.33±1.85	2.59±0.05	9.77±0.64	25.41±1.23	4.35±0.37	10.15±1.03	16.13±1.80
MZU-HAMP-GC-12	68.6±3.14	41.67±2.43	57.17±2.66	63.16±2.60	1.09±0.02	6.38±0.10	28.02±2.69	2.45±0.22	11.47±1.17	38.13±1.27	6.06±0.31	12.45±1.73	15.75±0.66
MZU-HAMP-GC-13	66.17± 1.61	41.33±1.96	64.77±2.78	58.4±3.49	1.14±0.09	7.19±0.10	30.41±1.95	3.2±0.29	9.51±0.27	32.55±2.79	6.03±0.32	11.07±0.90	17.95±1.07
MZU-HAMP-GC-14	68.57±3.11	42.58±2.22	48.55±2.53	64.76±2.92	1.06±0.04	6.58±0.68	30.36±0.97	2.81±0.38	10.92±1.13	35.4±2.40	5.75±0.42	13.09±0.86	17.07±0.90
MZU-HAMP-GC-15	40.27±4.61	41.82±3.12	45.59±4.70	37.22±1.97	1.08±0.12	5.11±0.10	21.13±1.57	2.07±0.61	10.75±2.80	17.07±3.91	3.27±0.37	9.25±0.66	13.19±1.73
MZU-HAMP-GC-16	53.59±7.74	41.21±1.85	45.06±2.83	50.05±6.42	1.07±0.02	6.1±0.96	26.14±4.59	2.79±0.41	9.38±1.08	24.66±2.90	4.63±0.53	10.82±0.74	17.12±1.02
MZU-HAMP-GC-17	55.17±4.75	40.51±2.06	45.54±0.51	51.15±3.19	1.08±0.03	6.17±0.10	24.78±2.07	2.53±0.13	9.78±0.36	27.86±4.31	4.6±0.28	8.42±0.73	13.22±1.35
MZU-HAMP-GC-18	55.00±5.00	39.67±3.29	45.16±6.88	53.5±1.63	1.03±0.06	6.48±1.41	26.95±1.79	2.46±0.18	10.98±0.39	25.6±4.54	5.43±0.10	11.22±1.03	17.18±0.75
MZU-HAMP-GC-19	50.22±4.67	40.54±1.47	48±2.95	46.09±3.99	1.09±0.01	6.64±0.58	21.81±2.30	2.16±0.34	10.18±0.90	26.26±2.11	3.76±0.48	8.52±0.63	15.5±0.87
MZU-HAMP-GC-20	51.78±2.80	41.3±0.96	45.84±5.42	48.1±3.08	1.08±0.09	5.93±0.31	26.24±1.38	2.38±0.55	11.41±2.62	23.15±1.57	5.23±0.10	9.22±1.07	15.48±1.30
MZU-HAMP-GC-21	50.26±4.62	39.17±1.02	42.28±1.41	41.39±5.86	1.22±0.08	7.53±1.10	21.79±2.02	2.02±0.65	11.48±3.33	26.45±2.56	4.21±0.70	9.44±1.39	14.6±1.64
MZU-HAMP-GC-22	50.31±4.54	37.76±1.49	42.93±3.13	46.73±3.96	1.08±0.03	6.43±0.10	22.92±2.54	2.4±0.37	9.62±0.76	24.99±2.08	4.67±0.54	8.09±0.87	11.49±2.80
MZU-HAMP-GC-23	55.22±4.67	40.25±2.58	42.7±2.74	49.47±3.44	1.12±0.02	6.14±0.11	23.4±1.68	2.22±0.35	10.67±1.15	29.6±3.93	4.91±0.21	10.6±1.64	16.08±2.78
MZU-HAMP-GC-24	55.26±5.02	44.46±2.05	47.87±1.44	52.97±4.36	1.04±0.01	6.74±0.11	25.17±3.02	2.56±0.48	9.92±1.04	27.53±1.70	4.88±0.22	8.91±0.15	10.27±0.64
MZU-HAMP-GC-25	61.85± 2.74	39.27±0.78	41.29±0.72	52.65±2.74	1.18±0.11	6.25±0.25	26.88±3.14	2.58±0.26	10.44±0.77	32.4±6.09	5.47±0.37	11.11±1.17	17.22±1.35
Range	31.90-105.47	31.59-57.80	37.79- 67.17	25.57-95.66	1.03-1.24	4.82-8.24	12.69-53.88	1.45-4.96	6.47-11.79	12.98-46.98	3.38-6.83	8.11-13.19	10.27-17.95
Mean	57.53	44.12	51.05	53.86	1.13	6.53	26.43	2.61	10.52	28.49	5.07	10.27	15.57
S.Em (±)	4.59	2.30	2.83	5.40	-	0.44	3.87	0.42	-	4.29	0.45	0.96	1.49
$CD_{0.05}$	9.57	4.81	5.89	11.27	NS	0.91	8.07	0.87	NS	8.94	0.94	2.00	3.11

Table 3 Chemical characteristics of the fruits among different accessions

Accession	Moisture (%)	TSS (%)	Acidity (%)	Ascorbic acid (mg/100g)	Total sugars (%)	Reducing sugar (%)	Non reducing sugar (%)	Sugar: acid ratio	TSS : acid ratio
MZU-HAMP-GC-1	94.68±3.72	8.52±0.37	3.42±0.10	49.34±0.55	6.59±0.32	3.94±0.36	2.85±0.24	1.93±0.14	2.5±0.16
MZU-HAMP-GC-2	93.37±2.52	8.47±0.25	3.27±0.08	47.45±0.51	6.83±0.10	3.85±0.43	3.17±0.34	2.09±0.04	2.59±0.02
MZU-HAMP-GC-3	86.33±1.62	6.93±0.74	4.75±0.14	44.67±2.27	5.58±0.42	3.6±0.10	2.16±0.35	1.17±0.09	1.46±0.15
MZU-HAMP-GC-4	90.13±4.75	7.98±0.48	4.5±0.50	45.21±0.83	5.48±0.17	3.55±0.11	2.1±0.26	1.23±0.17	1.79±0.28
MZU-HAMP-GC-5	88.77±4.54	8.04±0.45	4.00±0.20	46.74±1.09	6.5±0.32	3.84±0.95	2.85±0.62	1.63±0.02	2.02±0.21
MZU-HAMP-GC-6	82.38±2.53	5.29±0.25	4.3±0.23	43.51±0.99	6.29±0.34	3.21±0.13	3.24±0.23	1.46±0.04	1.23±0.03
MZU-HAMP-GC-7	83.6±1.85	5.49±0.19	5.72±0.75	45.76±0.91	6.17±0.30	3.76±0.10	2.6±0.35	1.09±0.18	0.97±0.12
MZU-HAMP-GC-8	85.33±2.90	6.49±0.29	4.97±0.50	46.96±1.95	5.86±0.40	3.69±0.25	2.36±0.49	1.19±0.09	1.31±0.11
MZU-HAMP-GC-9	93.4±3.57	8.44±0.24	5.03±0.06	42.43±0.91	5.57±1.00	3.82±0.09	1.94±0.92	1.11±0.21	1.68±0.03
MZU-HAMP-GC-10	94.77±2.03	8.64±0.20	3.45±0.33	48.43±0.75	6.86±0.28	4.16±0.59	2.92±0.82	2.00±0.16	2.52±0.09
MZU-HAMP-GC-11	82.12±2.52	6.27±0.25	4.87±0.36	47.67±0.19	5.14±0.60	3.60±0.34	1.71±0.37	1.06±0.10	1.29±0.05
MZU-HAMP-GC-12	86.37±2.52	6.77±0.25	5.27±0.38	43.65±1.64	5.35±0.50	3.75±0.65	1.79±0.69	1.02±0.08	1.29±0.14
MZU-HAMP-GC-13	81.9±2.60	7.15±0.26	5.08±0.27	42.03±0.69	5.24±0.69	3.66±0.11	1.77±0.62	1.03±0.08	1.41±0.06
MZU-HAMP-GC-14	84.07±4.68	7.04±0.17	5.51±0.26	44.80±0.67	6.32±0.23	3.70±0.34	2.81±0.09	1.15±0.03	1.28±0.03
MZU-HAMP-GC-15	84.4±3.61	6.27±0.25	4.54±0.31	46.64±1.09	5.45±0.51	3.31±0.47	2.3±0.95	1.21±0.18	1.39±0.15
MZU-HAMP-GC-16	86.68±2.54	7.39±0.35	5.1±0.30	43.75±2.04	6.46±0.81	3.21±0.13	3.4±0.93	1.26±0.09	1.45±0.05
MZU-HAMP-GC-17	84.7±3.61	6.27±0.25	5.35±0.34	42.10±0.87	5.49±0.44	2.57±0.09	3.06±0.41	1.03±0.13	1.17±0.08
MZU-HAMP-GC-18	93.73±1.53	8.47±0.15	4.76±0.45	45.83±1.58	5.00±0.13	3.08±0.10	2.08±0.22	1.06±0.08	1.79±0.20
MZU-HAMP-GC-19	85.43±2.20	7.51±0.22	3.91±0.11	43.12±0.76	5.88±0.72	3.64±0.57	2.42±0.36	1.51±0.18	1.93±0.11
MZU-HAMP-GC-20	93.4±2.00	8.5±0.20	4.65±0.86	43.36±2.17	5.68±0.29	3.69±0.10	2.17±0.28	1.25±0.22	1.88±0.40
MZU-HAMP-GC-21	90.85±1.28	8.14±0.13	5.11±0.21	47.03±2.66	5.44±0.52	3.47±0.15	2.14±0.45	1.07±0.14	1.60±0.09
MZU-HAMP-GC-22	92.8±1.01	8.41±0.10	4.37±0.26	46.82±1.01	6.60±0.31	2.59±0.10	4.14±0.32	1.52±0.16	1.93±0.13
MZU-HAMP-GC-23	93.97±4.56	8.36±0.46	4.03±0.18	44.25±0.59	5.39±0.36	3.04±0.16	2.5±0.37	1.34±0.07	2.08±0.15
MZU-HAMP-GC-24	91.97±2.89	8.5±0.50	5.08±0.61	47.84±0.93	5.43±1.05	3.05±0.57	2.54±1.37	1.07±0.11	1.69±0.21
MZU-HAMP-GC-25	90.07±7.64	7.83±1.04	5.17±0.26	43.80±0.68	6.55±0.33	3.03±0.60	3.67±0.76	1.27±0.03	1.52±0.20
Range	81.90-95.92	5.37-8.70	3.30-5.97	42.26-49.53	5.04-6.86	2.62-4.35	1.84-3.31	1.04-2.10	1.01-2.59
Mean	89.61	7.59	4.76	45.71	6.03	3.57	2.76	1.35	1.71
S.Em (±)	2.71	0.31	0.31	1.06	0.41	0.31	0.48	0.10	0.13
$CD_{0.05}$	5.67	0.65	0.64	2.21	0.86	0.65	1.01	0.21	0.27

in ascorbic acid content of the fruits. Similarly, MZU-HAMP-GC-2 (3.27%), recorded the lowest titratable acidity which was significantly lower than all other accessions except MZU-HAMP-GC-1 (3.42%), and MZU-HAMP-GC-10 (3.45%), with which it was statistically *at par*. The highest acidity was recorded in MZU-HAMP-GC-7 (5.72%). This is a fact in many fruits that, when TSS is increasing acidity is decreased. This may be major factor for minimum acid content in MZU-HAMP-GC-2, MZU-HAMP-GC-1 and MZU-HAMP-GC-10. The variation among genotypes for acidity might be due to genetic make of plant (Prakash et al. 2010) which has also proved in our study.

There was significant variation among the accessions with respect to sugar content also. The highest value of total sugars (6.86%), and reducing sugars (4.16%) was recorded in MZU-HAMP-GC-10 which was significantly higher than most of the accessions. MZU-HAMP-GC-22 (4.14%) recorded the highest value of non-reducing sugars followed by MZU-HAMP-GC-25 (3.67%), MZU-HAMP-GC-16 (3.40%), MZU-HAMP-GC-6 (3.24%), and MZU-HAMP-GC-2 (3.17%). The variation in sugar content among the accessions may be due to different genetical constitution of the individual genotypes.

The variation among the different accessions in sugar: acid ratio was also found significant (Table 3). Among all the accessions, MZU-HAMP-GC-2 recorded highest value of sugar: acid ratio (2.09) but it was found statistically *at par* with MZU-HAMP-GC-10 (2.00), and MZU-HAMP-GC-1 (1.93). The significantly lowest sugar: acid ratio was recorded in MZU-HAMP-GC-12 (1.02). Variation in sugar:acid ratio among a number of accessions was also reported by Singh and Singh (2003). Similarly, the highest TSS: acid ratio was recorded in MZU-HAMP-GC-2 (2.59), followed by MZU-HAMP-GC-10 (2.52), and MZU-HAMP-GC-1 (2.50).

Preference of consumers always depends on physical parameters of fruits like fruit weight, fruit diameter, pulp content and pulp: peel ratio of any fruit. In *G. lanceifolia* Roxb. more fruit weight, bigger size, more pulp content and pulp: peel ratio, greater is the acceptability by the consumer. Likewise, among the biochemical constituents of the fruits, consumers always prefer the fruits with high juice content, ascorbic acid, TSS, low acidity and high sugar: acid ratio. Similarly, for development of a new cultivar, breeders also choose accessions with these desirable qualities. From the summary of the present investigation, it has been observed that, among all the accessions of *G. lanceifolia* Roxb. collected from different locations of Mizoram, MZU-HAMP-GC-1, MZU-HAMP-GC-2 and MZU-HAMP-GC-10 having all the desirable physical and chemical parameters for the farmer, consumer as well as breeders. Therefore, from the present investigation, it can be concluded that MZU-HAMP-GC-1, MZU-HAMP-GC-2 and MZU-HAMP-GC-10 can be considered as elite *G. lanceifolia* Roxb. accession for use in various purposes from Mizoram, north-east India.

Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest in whatsoever.

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