



Characterization of small bitter gourd germplasm collections from various agro-ecological zones of India

Azhakan Suma*, Joseph J. K., Madhavan Latha, M. A. Alfia and A. C. Asna**

ICAR-National Bureau of Plant Genetic Resources, Regional Station, Thrissur-680 656, Kerala, India

ABSTRACT

Crop wild relatives can evolve into crop plants through conscious selection by a process known as domestication, usually involving an early hybridization event followed by selective breeding. *M. charantia* var. *muricata* Willd. (Chakrav.), commonly known as wild bitter gourd or small bitter gourd, is an annual monoecious climber, with fruit varying from spindle-rhomboid to discoid and globose shape. The present study aimed to characterize the available small bitter gourd germplasm for major leaf, flower, fruit, and seed characters to demarcate the true wild types from the semi-domesticates and large-fruited cultivated types using key morphological markers, and also to investigate the extent of domestication of the crop in India. The results indicated that, the fruit and seed characters can be considered reliable indicators to delineate the wild and semi-domesticates from large-fruited cultivated types, rather than leaf and floral characters. As a result of domestication, gene flow occurred between the wild and the cultivated types, leading to the development of variant populations of small bitter gourds, with remarkable variations favouring mostly fruit characters. Further, morphological field keys pertaining to leaves, flowers, fruits, and seeds were also developed to differentiate the wild types from the semi-domesticates and large-fruited cultivated types.

Key words: *Momordica charantia* var. *muricata*, wild bitter gourd, morphological characters, fruit characters, genetic diversity.

INTRODUCTION

Crop wild relatives are an important source of genes for breeding stress-tolerant high-yielding varieties as they have a much higher degree of adaptability. There are many examples of wild relatives of crop plants being domesticated over time and achieving crop status [Teasel gourd (*Momordica subangulata* subsp. *renigera* (Wall. ex G. Don) W.J. de Wilde) in North-Eastern states, Moth bean (*Vigna aconitifolia* (Jacq.) Marechal) in drier tracts like Rajasthan and Tuber cowpea (*V. vexillata* (L.) A. Rich.) in tribal pockets of Indian hills]. *M. charantia* L. consists of two taxa viz., *M. charantia* L. var. *muricata* Willd. (Chakrav.), with small and round or spindle-shaped fruits, and *M. charantia* L. var. *charantia*, with fairly large fusiform fruits (Chakravarty, 7). The presumed areas of domestication of *M. charantia* proposed by various workers include, Eastern Asia covering Southern China or India (Degner, 8), Eastern India (Yang and Walters, 21), South Western India (Joseph, 13) or Southeast Asia (Renner, 19).

Small bitter gourds are known by different names in various parts of India viz., *Kuttathipavall*/*Nadanpavall*/*Undappavall*/*Chundapavall*, *Kattupavall*, *Neypavall*, *Nadanpavall* and *Kundupavall* (Kerala),

Chikkuhagali and *Rudrakshahagali* (Karnataka), *Mithipavai* and *Chinnapavai* (Tamil Nadu) and *Uchie* (Eastern India) (Joseph and Antony, 15). Besides fruits, tender clippings and leaves are also used as a leafy vegetable in Odisha, Mizoram, and elsewhere in tribal areas of India. As they grow naturally or as weedy escapes or are maintained as feral forms and open-pollinated plants in semi-forest ecosystems or under homestead cultivation, there are ample chances of cross-pollination between the wild and cultivated forms, yielding intermediate introgressed forms known as semi-domesticates, in the succeeding generations.

The present study was designed to characterize the small bitter gourd germplasm collections from various agro-ecological zones of India, for important traits that get changed during domestication, to identify morphological markers for leaves, flowers, fruits, and seeds that differentiate the wild types from the semi-domesticates and large-fruited cultivated types. Besides, being the center of diversity for small and large-fruited bitter gourd, studies on the extent of domestication of small bitter gourds in the Indian sub-continent is hitherto, scanty.

MATERIALS AND METHODS

Thirty-five accessions of small bitter gourds collected from various parts of India [Andaman &

*Corresponding author: Suma.A@icar.gov.in; sumaaagri@gmail.com

**Cashew Research Station, Kerala Agricultural University, Thrissur, Kerala, India- 680656

Nicobar Islands (02), Kerala (07), Madhya Pradesh (02), Mizoram (11), Rajasthan (01), Tamil Nadu (07), Uttar Pradesh (03), Uttarakhand (01), and West Bengal (01)], formed the material for the study. The preliminary characterization was done during 2013-14 and validated during Kharif 2020-21 in augmented block design. Morpho-agronomic characterization of these accessions was done following the minimal descriptor of NBPGR (19) and Joseph (13) designed for characterizing the cultivated bitter gourd (*M. charantia*) with modifications. The mean temperature during the crop growth period was 22.3 - 36.7° C, with an average annual rainfall of 0.50 mm. Data were recorded for five qualitative and 24 quantitative characters [leaves (03 characters), flowers (08), fruits (11), and seeds (07)]. Based on the source of collection and cultivation status (commercial or homestead), and fruit and seed morphology, the accessions were categorized as true wild and semi-domesticates, and statistical analysis was done separately for the two groups, and compared with the characters of cv. Preethi, one of the most popular cultivars of bitter gourd belonging to var. *charantia*, released by Kerala Agricultural University, Thrissur, Kerala, India. The data pertaining to cv. Preethi was taken from our previous study.

RESULTS AND DISCUSSION

The broad morphological resemblances and high cross-compatibility between the two botanical varieties of bitter gourd give credence to the fact that the var. *muricata* is the progenitor of cultivated *charantia* types (Chakravarty, 7). In this study, we designate the small-fruited ones, the intermediate hybrids (introgressed forms) and the domesticates as wild, semi-domesticates and large-fruited cultivated types respectively, following the designations given by Marr *et al* (16), who referred the large-fruited cultivated types (var. *charantia*) as domesticates and small-fruited ones as wild types. Accordingly, twenty-two of the total collected accessions were categorized as wild and the remaining as semi-domesticates (not referred to as semi-wild, as they are under the process of domestication). Joseph and Antony (14) were the first to categorize a few distinct landraces viz., '*Kuttathipaval*', '*Rudrakshahagalikai*', '*Karandakai*', '*Undapaval*' and *Mithipavai* etc as semi-domesticates.

With respect to leaf shape and depth of lobing, ovate, obovate, orbicular to reniform shapes with shallow to deep lobing were observed in true wild, semi-domesticates as well as large-fruited cultivated types. The cultivated variety, Preethi, exhibited higher values for all leaf and floral characters compared to wild and semi-domesticates except for the number

of flowers per plant. However, there was overlap in values of leaf and flower characters among true wild and semi-domesticates, thus proving them untenable for delineating the accessions into wild and semi-domesticates based on lamina and floral characters. However, Asna *et al.* (2) observed that var. *charantia* and var. *muricata* could be readily distinguishable even at the seedling stage by the size of the cotyledonary leaves and shoots.

Selection based on the fruit morphology, yield and yield contributing traits, is the most common traits considered during plant domestication. There was a clear morphological distinction between wild, semi-domesticates, and cultivated bitter gourds for fruit morphology (Fig. 1). Narrow and broad spindle-shaped fruits were the characteristic feature of wild, whereas semi-domesticates possessed elliptical, oblong, and rhomboid shapes. The bitter gourd variety, Preethi, exhibited the typical whitish green colour and elliptical shape, which is one of the characteristic features of large fruited cultivars. In small bitter gourds, fruit ends were pointed either at both ends or only at the blossom end. The fruits of wild and semi-domesticates had 8-10 broken tubercles or rarely continuous ridges (Fig. 2). Fruits attain green, dark green, light green, or rarely white colour at marketable stage, all turning orange-yellow on ripening. Wild types were characterized by small spindle, discoid and globose fruits with four colours viz., white, whitish- green, green and dark green (Fig. 3).

The presence of whitish-green or white coloured fruits with soft raised continuous tubercles similar to the fruit morphology of cultivar Preethi among

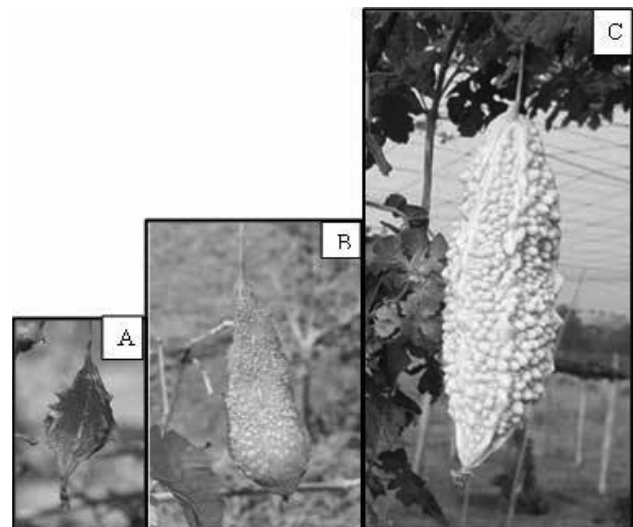


Fig. 1. Fruit of wild (A), semi-domesticated (B) and cultivated types (C).

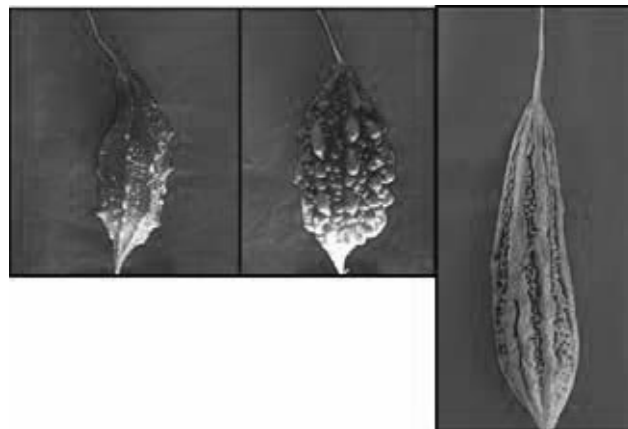


Fig. 2. Sharp pointed vs soft raised vs continuous tubercles in small bitter gourd (C).

the wild and semi-domesticates, confirms the gene flow between var. *muricata* and var. *charantia*, which might have occurred in semi-disturbed and disturbed habitat due to limited habitat isolation, but not always expressed due to the recessive nature. However, Bharathi and John (5) proposed that due to lack of multiple alleles at allozyme loci and fixation for the same alleles across geographical locations reduced the gene flow between wild into the domesticate. This suggests selection occurred consciously or unconsciously leading to morphological variation. The fruit characters of bitter gourd have received more attention as it is a direct factor deciding the consumer choice. For instance, Pusa Do Mausami and Arka Harit are varieties with long unbroken continuous ridges. The preference of consumer's varies from region to region even with in India with respect to fruit shape, size and colour.

Across India, long or medium-long, with elliptic shaped glossy green fruits are preferred, however in the West coast (Kerala), medium size (200-300 g) but white coloured fruits are the preferred choice with respect to var. *charantia*. Small and dark green fruited *muricata* types known as *Uchie*, are preferred in eastern parts of the country, than the white fruits (Dey *et al.*, 9). We have observed that majority of the collections from Vindhyachal hills (Madhya Pradesh) were with rhomboid shapes, which were grown as kitchen garden vegetable. At the global level, highly bitter fruits with smaller size and spiny dark green features are highly preferred by South Asians, whereas Southeast Asians prefer less bitter fruits with light green and smooth skin (Dhillon *et al.*, 11).

Length of fruit ranged from 2.10 cm (IC582403) to 7.22 cm (IC598170) in wild types (Table 1) supporting the observations of Marr *et al.* (16), who reported

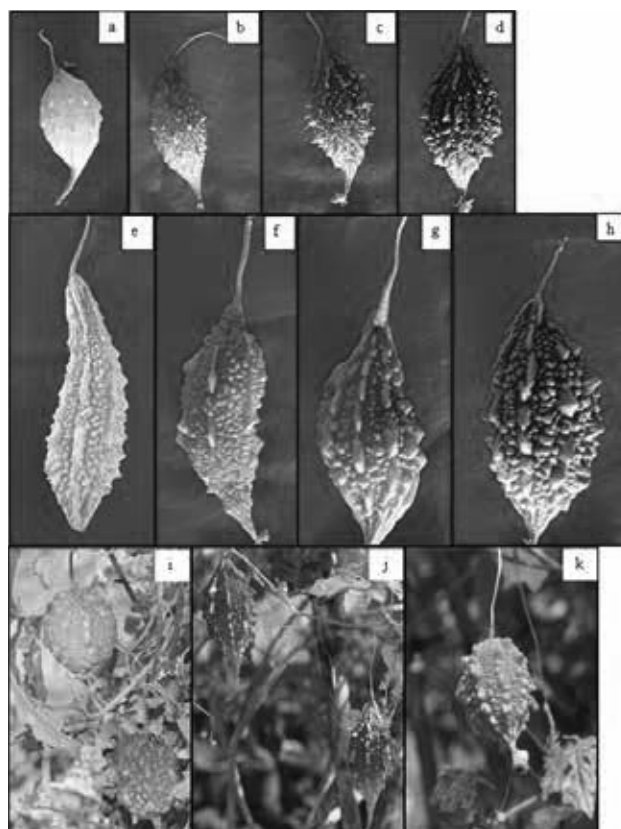


Fig. 3. Variability in fruit colour and shape of wild and semi-domesticated types. a-whitish; b-whitish green; c-green; d-dark green coloured fruits of wild types; e-whitish; f-whitish green; g-green; h-dark green coloured fruits of semi-domesticated types; Shapes - i- globose; j-spindle; k-discoid in wild types.

2-7 cm length for fruits of wild types. However, semi-domesticates produced fruits with length ranging from 6.71 to 9.78 cm. Joseph (13) reported that small bitter gourds were characterized by small fruits of 3.00 to 9.00 cm length whereas 2.91 to 11.60 cm length by Saranyadevi *et al.* (20). Semi-domesticates possessed intermediate fruits, larger than wild types but smaller than large fruited cultivated bitter gourd, with length ranging from 6.71 to 9.78 cm, supporting the view that semi-domesticates might have gradually evolved by natural introgression between the wild and the large-fruited cultivated types during domestication (Bai and Beevi, 3). Therefore, one of the most obvious changes that occurred during domestication was the selection of large-fruited types (Matsumura *et al.*, 17), followed by an increase in pericarp volume, bump height, the number of solid ribs, the number of ribs, and a decrease in the tubercle base ratio (Marr *et al.*, 16). However, the wild types were observed to produce

Table 1. Morphological features of wild, semi-domesticated and cultivated bitter gourds.

Characters	Wild	Semi-domesticated	Preethi (large fruited cultivated type -mean)
PL (cm)	3.74-8.40	4.84-7.66	5.90
LL (cm)	4.84-11.22	6.46-8.94	10.00
LW (cm)	3.52-11.58	9.52-13.64	12.05
LNB (cm)	0.11-2.28	0.35-2.08	2.25
LBC (cm)	0.36-6.16	1.92-5.63	4.00
FD (cm)	1.90-3.72	2.38-3.50	3.10
SL (cm)	0.51-0.61	0.42-0.65	0.65
SW (cm)	0.02-0.34	0.24-0.39	0.40
PtL (cm)	0.93-1.69	1.25-1.74	1.95
PtW (cm)	0.11-1.21	0.80-1.27	1.05
CCL (cm)	0.03-0.44	0.22-0.31	0.95
PdL (cm)	0.77-1.82	0.57-2.35	0.85
PdcL (cm)	1.49-6.34	2.30-6.30	5.50
SFW (g)	2.40-19.60	23.00-54.80	160.00
FrL (cm)	2.10-7.22	6.71-9.78	30.18
FrW (cm)	1.71-3.54	3.10-4.28	5.67
FrC (cm)	5.46-10.86	9.72-13.52	16.82
FT (cm)	0.20-0.45	0.40-0.59	0.86
NFPP	6.80-112.00	12.00-49.83	19.56
YPP (g)	39.84-1133.16	360.00-1848.84	2558.00
NSPF	3.60-14.20	7.60-18.60	21.50
SdL (cm)	0.78-1.15	1.12-1.32	1.48
SdW (cm)	0.48-0.81	0.60-0.85	0.86
SdT (cm)	0.28-0.43	0.33-0.43	0.38
FrS	Spindle, discoid, globose	Oblong, rhomboid, elliptical	Elliptical, cylindrical
SdC	White, brownish yellow, black, black and brown patched appearance, straw colour, whitish brown	Brownish tan	Brownish tan
SdLr	Matt, intermediate, glossy	Matt	Matt
SdO	Surface-pitted, sides- smooth, end- feebly sub-tridentate, sculpturing-only pitted	Surface-flat and creeked, sides- dented, end- clearly sub-tridentate, feebly to markedly sculptured	Surface-flat and creeked, sides- dented, end- clearly sub-tridentate, markedly sculptured

PL- Petiole length; LL- Lamina length; LW-Lamina width; LNB- Length of stalk from node to bract of flower; LBC-Length of stalk from bract to calyx; FD-Flower diameter; SL-Sepal length, SW-Sepal width; PtL- Petal length, PtW- Petal width; CCL- Calyx cup length; PdL- Peduncle length (node to bract of fruit); PdcL-Pedicle length (bract to fruit base); SFW- Single fruit weight (g); FrL- Fruit length; FrW- Fruit width; FrC- Fruit circumference; FT- Flesh thickness; NFPP- Number of fruits per plant; YPP- Yield per plant; NSPF- Number of seeds per fruit; SdL- Seed length; SdW- Seed width; SdT- Seed thickness; FS- Fruit shape; FrC- Fruit colour; SdC- Seed colour; SdLr- Seed lustre, SdO- Seed Ornamentation

a significantly higher number of fruits than semi-domesticates and large-fruited cultivated bitter gourd (Islam *et al.*, 12). In the present study, IC541250, a wild genotype from Tamil Nadu state produced as high as 112 fruits per plant, can be a promising

candidate in future breeding programmes. It may be due to the high vinyess and a large number of primary and secondary branches in *muricata* types (Asna *et al.*, 2), with extended growth span, and the capability to grow even under water stress conditions.

The small fruit size of wild genotypes was evident from the lesser weight of single fruit ranging from 2.40 g (IC541249) to 19.60 g (IC541384), than the semi-domesticates with weight ranging from 23.00 g (IC467645) to 54.80 g (JB-11/170A) supporting the observations of Bai and Beevi (3). However, Islam *et al.* (12) reported a fruit weight range of 5.65–42.57 g, and Joseph and Antony (15) in the range of 6.0–35.0 g, upon evaluation of small bitter gourds. Flesh thickness ranged from 0.20 to 0.45 cm in wild types and 0.40 to 0.59 cm in semi-domesticates. Thin fleshed genotypes are more preferred for stuffed preparations (Joseph and Antony, 15). Increase in flesh thickness in semi-domesticates could be an indication of the domestication process occurring on small bitter gourds (Marr *et al.*, 16). JB/11-170A, which exhibited maximum flesh thickness (0.59 cm), a collection from Tripura, India; can be considered as a typical candidate of domesticated small bitter gourd as the other key characters like fruit length (9.78 cm), fruit width (4.28 cm), fruit weight (5480 g), seed length (1.32 cm), seed width (0.80 cm) and elliptical fruit shape were corroborating with the characters of semi-domesticates. Yield was maximum in the wild accession, IC598168 (1133.16 g per plant), with an individual fruit weight of 14.20 g and fruit length of 5.76 cm as against 1848.84 g per plant in the semi-domesticated, IC467680, with a single fruit weight of 42.60 g and fruit length of 7.98 cm. In the present investigation, the yield and yield contributing characters were intermediate in semi-domesticates when compared to the wild and large fruited cultivated variety. Hence, this indicates co-existence of wild relatives and crops in an area paves the way for gene flow between them, leading to the occurrence of intermediate types and, people decide to favour or not, to such geneflow leading to incipient domestication (Casas *et al.*, 6).

Seed characters also play an important role in distinguishing wild *muricata* types from the large-

fruited varieties. Wild bitter gourds generally produce small seeds whereas large-fruited types develop comparatively large, broadly rectangular seeds, with end clearly sub-tridentate and markedly sculptured (Fig. 4, 5a, 5b) (Bharathi and John, 5). The wild-type seeds with white, brownish yellow, black, black and brown patched appearance, straw coloured, with matted or glossy lustre, feebly sub-tridentate apex and pitted ornamentation, were present in majority of wild accessions. As expected, the seed size was highest in the cultivated variety, intermediate in semi-domesticates and lowest in wild forms. The resemblance of seed morphology of few wild accessions to the var. *charantia* also indicates that such wild accessions are under domestication. Thus, fruit and seed characters were found to be reliable morphological markers to delineate wild, semi-domesticates and large-fruited var. *charantia* types. The number of seeds per fruit ranged from 3.6 - 14.2 in wild, 7.6 - 18.6 in semi-domesticates, and exceeds 20 seeds in large fruited cultivated types, a progressive function of size of fruits

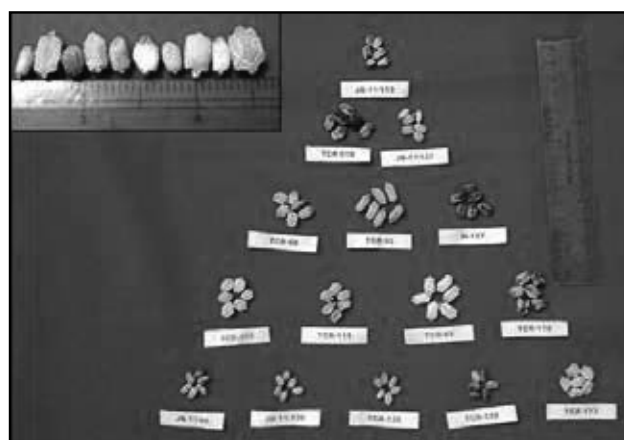


Fig. 4. Variability in seed morphology of small bitter gourd (Inset: variability in seed lustre).

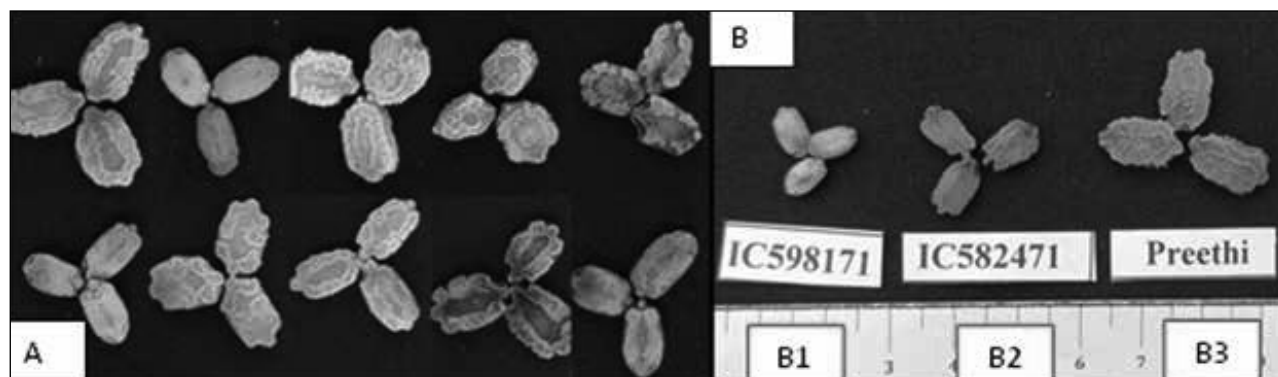


Fig. 5a (2x resolution). Variability in seed ornamentation of small bitter gourds 5b. Pattern of sculpturing on the seed surface of wild (b1), Semi-domesticates (b2) and Preethi (b3).

(Table 1). As the fruit size was less in wild types, the edible portion of the fruit becomes very less, when the fruits are deseeded compared to large-fruited types, one of the reasons for the low acceptability of var. *muricata* among general consumers. Hence, small bitter gourd fruits are preferred for culinary purpose at immature stage (15-20 days after anthesis) only, along with the seeds. The large-fruited cultivated types are preferred for modern cooking as the bigger size is suitable for easy handling/chopping. However, there are certain tribal hamlets in the Chakma belt in Mizoram (North Eastern state), where wild types have been domesticated to such an extent that the large-fruited types are not even seen in cultivation. Samples of small bitter gourds were also collected from local markets of Port Blair (Andaman and Nicobar Islands), West Bengal, and North Eastern states like Mizoram and Tripura indicating the domestication potential of this crop.

The crop was raised during summer season (January- April) and irrigation was provided on alternate days during the active flowering and fruiting stage. Towards the end of the crop growth period, irrigation was withdrawn. However, drought tolerance was manifested through continuous flowering and fruiting in IC582434 (Rajasthan), IC582449 (Uttar Pradesh), IC582420 (Madhya Pradesh), IC598170 (Mizoram), IC598171 (Mizoram), IC598172 (Mizoram) and IC598168 (Mizoram), even when irrigation was not given for seven consecutive days. As Rajasthan, being an arid and Uttar Pradesh and Madhya Pradesh, being in semi-arid regions of India, germplasm from these states need to be evaluated critically for drought tolerance. Asna *et al.* (1) also reported field-level resistance/tolerance of small bitter gourd genotypes to viral diseases. Small fruited wild types, in general, are reported to have tolerance to pumpkin caterpillar and root-knot nematode, and some specific accessions tolerant to fruit fly attack from Western Ghats of India (Behera *et al.*, 4), in addition to resistance against *Bactrocera cucurbitae* (Dhillon *et al.*, 10).

The findings of the study indicated that the divergence of small bitter gourds is the result of their association with human activities in several locations, which is manifested by the cultivation of small bitter gourd as sole crop in Tamil Nadu, West Bengal and Andaman Islands (Joseph and Antony, 15) and, as a homestead vegetable in other parts of India except in temperate and sub-tropical regions, all these ultimately progressing to the domestication of this crop over time. Wide genetic variability, prevalence of pre-domesticates, its varied uses, and religious and cultural beliefs regarding small bitter gourds, led to the conclusion that they have already been a pre-domesticated among tribals in Western Ghats (Joseph and Antony, 14). Further, there exists clear morphological

distinctness between the wild, semi-domesticated types and cultivated bitter gourd for fruit and seed characters, however, the phenotypic divergence was not discrete in the lamina and floral characters. Distinct fruit and seed characters may be identified as morphological markers for unique genotypes. Also developed field keys on morphological characters pertaining to leaves, flowers, fruits, and seeds to differentiate the wild types from the semi-domesticated and large-fruited cultivated types. IC598168 with a yield potential of 1133.16 g per plant, single fruit weight of 14.20 g, and fruit length of 5.76 cm was identified as promising genotype among wild types. The threat of genetic erosion of small bitter gourds is accelerating at a faster rate due to the abandoning of homestead ecosystems and destruction of natural populations from the roadsides as a part of the blanket weeding of the natural habitats, consumer preference for the commercially grown large-fruited cultivated types from the market, reduction in number of traditional farmers, deviation from farming culture by tribal communities, which is being witnessed in most of the crop wild relatives.

AUTHORS' CONTRIBUTION

Characterization work, writing of manuscript (SA, ACA), Conceived the idea of the topic, exploration, and collection of small bitter gourd germplasm & editing (JJK), Interpretation of results and final editing (ML), Statistical analysis and interpretation of results (MAA).

DECLARATION

The authors declare that they have no conflict of interest on the manuscript's content and study undertaken.

ACKNOWLEDGEMENT

Authors are thankful to the Director, ICAR-NBPGR, New Delhi for providing the facilities for undertaking the characterization work. Also grateful to the Head, Division of Germplasm Evaluation for his help and logistic support in carrying out this work. Authors are also thankful to the Department of Biotechnology, Govt. of India for the financial support provided under the project "Collection, conservation, taxonomy, diversity, cytology, molecular characterization and nutritional analysis of *Momordica subangulata* Blume subsp. *subangulata* and other edible species of *Momordica* L. from Northeast India".

REFERENCES

1. Asna A. C., Jiji J., Sainamole K. P., Joseph J. K. 2018. Identification of bitter gourd genotypes with field tolerance to viral diseases. *J. Trop. Agric.* **56**: 9-16.

2. Asna, A. C., Joseph, J. K, and Jiji, J. 2020. Botanical description of bitter gourd. In: *The bitter gourd genome*. Compendium of plant genomes, Kole C, Matsumura H, Behera TK (eds). Springer, Cham, pp. 7-31.
3. Bai, H. N., and Beevi, S. S. 2012. Characterization of intraspecific F₁ hybrids of *Momordica charantia* L. based on morphology, cytology and palynology. *Cytologia*. **77**: 301–10.
4. Behera, T. K., Joseph John K., Bharathi, L. K. and Karupaiyan, R. 2011. *Momordica*. In: *Wild Crop Relatives: Genomic and Breeding Resources Vegetables*, Kole C (ed). Springer, Berlin, Heidelberg pp. 217-46.
5. Bharathi, L. K., and John, K. J. 2013. *Momordica Genus in Asia: An Overview*. Springer, New York, p 147.
6. Casas, A., Blancas, J., Otero-Arnaiz, A., Cruse-Sanders, J., Lira, R., Avendaño, A., Parra, F., Guillén, S., Figueredo, C.J., Torres, I. and Rangel-Landa, S. 2016. Evolutionary ethnobotanical studies of incipient domestication of plants in Mesoamerica. In: *Ethnobotany of Mexico*. Lira, R., Casas, A. and Blancas, J. (Eds.), Springer: New York, NY, USA, pp. 257–85.
7. Chakravarty, H. L. 1982. *Fascicles of Flora of India*, Fascicle II, Cucurbitaceae, Botanical survey of India, Howrah
8. Degner O. 1947. *Flora Hawaiiensis*. 5th Edn.. Honulu, HI, USA.
9. Dey, S. S., Behera, T. K., and Munshi, A.D. 2010. Gynoecious inbred with better combining ability improves yield and earliness in bitter gourd (*Momordica charantia* L.). *Euphytica* **173**: 37-47.
10. Dhillon, M. K., Singh, R., Naresh, J. S., and Sharma, N.K. 2005. Influence of physico-chemical traits of bitter gourd, *Momordica charantia* L. on lanai density and resistance to melon - fruit fly, *Bactrocera cucurbitae* (Coquillett). *J. App. Entomol.* **129**: 393-99.
11. Dhillon, N. P. S., Sanguansil, S., Schafleitner, R., Wang, Y. W., McCreight, J. D. 2016. Diversity among a wide Asian collection of bitter gourd landraces and their genetic relationships with commercial hybrid cultivars. *J. Am. Soc. Hortic. Sci.* **141**: 475-84.
12. Islam, S., Mis, M. A. B., Das, M. R., Hossain, T., Ahmed, J. U., Hossain, M. M. 2014. Sex phenology of bitter gourd (*Momordica charantia* L.) landraces and its relation to yield potential and fruit quality. *Pak. J. Agric. Sci.* **51**: 651-58.
13. Joseph, J. K. 2005. Studies on ecogeography and genetic diversity of the genus *Momordica* L. in India. *Ph. D. Thesis*, Mahatma Gandhi University, Kottayam, Kerala.
14. Joseph, J. K. and Antony, V. T. 2008. Ethnobotanical investigations in the genus *Momordica* L. in the Southern Western Ghats of India. *Genet. Res. Crop. Evol.* **55**: 713-21.
15. Joseph, J. K. and Antony, V. T. 2009. Collection and preliminary evaluation of small bitter gourds (*Momordica charantia* L.) a relict vegetable of Southern Peninsular India. *Genet. Resour. Crop Evol.* **56**: 99-104.
16. Marr, K. L., Mei, X. Y., and Bhattarai, N. K. 2004. Allozyme, morphological and nutritional analysis bearing on the domestication of *Momordica charantia* (Cucurbitaceae). *Econ. Bot.* **58**: 435–55.
17. Matsumura, H., Hsiao, M. C., Lin, Y. P., Toyoda, A., Taniai, N., Tarora, K., Urasaki, N., Anand, S. S., Dhillon, N. P. S., Schafleitner, R., and Lee, C. R. 2020. Long-read bitter gourd (*Momordica charantia*) genome and the genomic architecture of non-classic domestication. *Proc. Natl. Acad. Sci. U.S.A.* **117**: 14543–51.
18. NBPGR. 2001. *Minimal Descriptors of Agri-Horticultural Crops. Part-II. Vegetable Crops*. National Bureau of Plant Genetic Resources, Pusa, New Delhi, 262p.
19. Renner, S. S. 2020. Bitter gourd from Africa expanded to Southeast Asia and was domesticated there: A new insight from parallel studies. *Proc. Natl. Acad. Sci. U.S.A.* **117**: 24630–31.
20. Saranyadevi, G., Lakshmanan, V., and Rohini, N. 2017. Performance evaluation and correlation analysis in mithipagal genotypes (*Momordica charantia* var. *muricata*). *Electron. J. Pl. Breed.* **8**: 652-59.
21. Yang, S. L., and Walters, T. W. 1992. Ethnobotany and the economic role of the Cucurbitaceae of China. *Econ. Bot.* **46**: 349–67

Received : April, 2022; Revised : August, 2022;
Accepted : September, 2022