Genetic Resources, Germplasm Characterisation/Evaluation and Maintenance

7

Abstract

Gene pool serves as a tool for conceptualising the ability of plant populations to cross with the conspecific population and with those of other species. Classification of gene pool of *Momordica* spp. has been discussed here on the basis of hybridisation studies. *M. dioica* and *M. subangulata* in India are reported under endangered category. However, these reports are based on assumption and do not have the support of authentic fieldwork. A large collection of *M. charantia* is maintained in the national gene bank and by different organisations in India and other countries. A good representation of diversity in *M. charantia* has been assembled from the Western Ghats, India, though there are still a few grey areas to be explored more intensely. However, other species and areas need extensive coverage. *Momordica* species assume significance for conservation as crop relative, source of economic product of aesthetic and ecological interest, of potential horticultural value and as future raw material for the medicinal and pharmaceutical industry. Establishment of genetic reserves within protected areas must be attempted for conserving diversity in *M. dioica* and *M. sahyadrica*. Ex situ conservation in home gardens and on-farm conservation in tribal homesteads in forest pockets are viable options for conservation of *Momordica* gene pool as the taxa are still wild or semi-domesticate with high dependence on biotic agents for pollination and seed dispersal.

Keywords

Momordica gene pool · Endangered · In situ and ex situ conservation · Genetic reserves

L. K. Bharathi and K. J. John, *Momordica Genus in Asia: An Overview*,
DOI: 10.1007/978-81-322-1032-0_7, © Springer India 2013

Genetic Resources

The importance of germplasm as a basic tool for crop improvement is well recognised. They provide the basic material for selection and improvement through breeding to ensure food security needs of the world's rapidly rising population. Wild relatives and progenitors of cultivated plants together with semi-domesticates represent a strategic part of germplasm collections. Genetic variation is fast eroding as natural habitats of wild relatives of cultivated species are being destroyed. As the genetic base of modern varieties is narrow and variability fast eroding, introgression of genes from wild species can substantially influence the breeding progress. Generally, the Indian genetic resources of *Momordica* are not threatened.

Gene Pool Classification

Gene pool serves as a tool for conceptualising the ability of plant population to cross with the conspecific population and with those of other species (Harlan and de Wet 1971). Based on the available literature on inter-specific hybridization and evaluation of their progeny, the following gene pool classification of the cultivated/semi-cultivated species is proposed (Bharathi et al. 2012a). The nature of these relations is important for the application of appropriate technologies to transfer desirable genes from wild *Momordica* species to the cultivated/semi-cultivated species.

Gene pools of *M. charantia.* The primary gene pool of *M. charantia* is again divided into two subclasses I and II. Gene pool I consists solely of its various commercial cultivars and its interfertile variety, the wild-type var. *muricata*. There is evidence for introgression of *M. charantia* var. *charantia* genes into wild-type in Taiwan (Liao et al. 2012). There are a great many commercial cultivars with particular characteristics that together with local land races and populations of wild varieties constitute extraordinary genetic resources. The next level of compatibility involves the *M. balsamina* (wild species). Despite the high degree of morphological/cytological similarity between these two species, they are reproductively isolated from each other in terms of barriers to hybridisation and is very difficult to obtain hybrid seeds (that too only in one direction—*M. charantia* as seed parent) and therefore *M. balsamina* is placed in primary gene pool II. The dioecious species represent the tertiary gene pool.

Gene pools of *M. dioica*. None of the dioecious species is reproductively isolated from the other completely. The primary gene pool is represented by its land races/varieties and *M. sahyadrica*. The anthesis of *M. dioica* occurs in the evening while that of *M. sahyadrica* and their hybrid progeny in the morning, which can be explored to get greater pollinator choice. Its secondary gene pool includes *M. cochinchinensis* and *M. subangulata* subsp. *renigera* while all the monoecious species are included in tertiary gene pool.

Gene pools of *M. subangulata* subsp. *renigera*. As it is a tetraploid species and the rest of the dioecious species is diploid, the hybrid progeny are triploid and sterile. Therefore, primary gene pool includes only infra-specific types and secondary gene pool includes the rest of the dioecious species and tertiary gene pool is formed by monoecious species.

Genetic Erosion and Threat Status

The only reference to the threatened status of *Momordica* is found (Anonymous 1997) in ICUN Red Data Book where *M. subangulata* Blume. from Wyanad (Kerala) and south Canara (Karnataka) is accorded threatened-indeterminate status (taxa known to be extinct, endangered, vulnerable or rare but where there is not enough information to say which of the four categories is appropriate). The material referred to as *M. subangulata* from Kerala and Karnataka is actually *M. sahyadrica* and true *M. subangulata* is of restricted distribution in north–east India. Jha and Ujawane (2002) consider *M. balsamina* as nearing extinction in Saurashtra, Gujarat and *M. cochinchinensis* as endemic to

Assam forests. However, *M. cochinchinensis* is not endemic to Assam as the authors have spotted the species in abundance in the north, south and middle Andamans and also there are reports of its distribution in a vast region in South–East Asia. Zuberi and Biswas (1998) reports *M. dioica* in Bangladesh in the endangered category. Dwivedi (1999) considers *M. dioica* as endangered in Madhya Pradesh. However, most of these reports are based on certain assumptions and do not have the support of authentic fieldwork. Recent studies revealed a grave threat for *M. dioica* in its entire range and *M. sahyadrica* in the Western Ghats of Kerala. Overall, *M. charantia* var. *muricata* faces a medium level of threat across its geographic range. Habitat loss and fragmentation brought about by population pressure and developmental activities, poor distribution and low population density of *Momordica* species coupled with inadequate in situ conservation efforts, and acculturation of the forest dwelling communities are the major factors attributed to their heightened threat status affecting their long-term survival in the wild (Joseph and Antony 2007).

Present Status of Germplasm Holdings

Bettencourt and Konopka (1990) have given a compilation of ex situ holdings of *Momordica* germplasm worldwide. A large collection of *M. charantia* is maintained in the national gene bank and by different organisations in India and in other countries (Table 7.1). Species representation of the genus *Momordica* in various herbaria/gene banks around the world is presented in Table 7.2. It seems that wild *Momordica* are underrepresented in gene banks. Recently, descriptors for dioecious *Momordica* spp. have been published (Joseph and Antony 2011). Evaluations of genetic resources for traits of horticultural interests are regularly conducted for yield and fruit quality or for pest and disease resistance.

Plant Descriptors

Habit

All dioecious species [*M. subangulata* (subsp. *renigera*, subsp. *subangulata*), *M. dioica*, *M. sahyadrica*, *M. cochinchinensis*, *M. rumphii*, *M. clarkeana*, *M. denticulata*, *M. denudata*] and a monoecious species (*M. cymbalaria*) are perennial climbers with tuberous roots. Monoecious species, viz. *M. charantia* and *M. balsamina* are annuals with fibrous roots. Perennial species undergo dormancy during winter/summer months and new shoots are produced upon favourable conditions. However, in *M. cochinchinensis*, the aerial stem does not wither or dry up completely upon cessation of favourable growth season.

Seedlings

All species have distinct seedling morphology. Annual species have epigeal germination (Fig. 7.1a), whereas perennial species have hypogeal germination (Fig. 7.1b). Polyembryony was observed rarely in *M. dioica*, *M. subangulata* subsp. *renigera* and *M. sahyadrica* (Fig. 7.2). Robustness and size of the cotyledon was greater in *M. charantia* var. *charantia* and progressively reduced to *M. charantia* var. *muricata* and *M. balsamina* was most fragile. In the dioecious group, *M. cochinchinensis* is most robust and fast in emergence and has triangular non-cordate leaves. *M. dioica* and *M. sahyadrica* differ in lobing of first few leaves, *M. dioica* being more deeply lobed and very fragile.

Roots

The annual species produce fibrous roots, which die at senescence along with the aerial parts. However, the perennial taxa produce storage roots with which they perennate during the unfavourable growth period. In *M. sahyadrica* and *M. dioica*, the seedling tap root gets

Table 7.1 Present status of germplasm holdings in *Momordica* species

Crop	Number of accessions	Institute	Reference
M. charantia var. *charantia*	519	National Genebank of NBPGR, New Delhi	Ram and Srivastava (1999)
	1	Institute of Agrobotany, Hungary (ABI)	Horvath (2002)
	15	N.I.Vavilov Research Institute of Plant Industry (NIR), Russia	Piskunova (2002)
	1	Cukurova University, Turkey	Kucuk et al. (2002)
	95	Kerala Agricultural University, Vellanikkara, India	Raj et al. (1993)
	65	Indian Institute of Horticultural Research, Bangalore, India	Raj et al. (1993)
	219	Indian Institute of Vegetable Research, Varanasi, India	Ghosh and Kalloo (2000)
	30	Vivekananda Parvathiya Krishi Anusandhan Shala, Uttar Pradesh, India	Ghosh and Kalloo (2000)
	2	Aburi Botanic Gardens, Ghana	Harriet Gillett (2002)
	281	AVRDC, Taiwan	AVGRIS (2009)
	12	Southern Regional Plant Introduction Station, Georgia, USA	Raj et al. (1993)
	1	National Seed Storage Laboratory, Fort Collins, USA	Raj et al. (1993)
	2	National Institute of Agricultural Sciences, Ibaraki, Japan	Raj et al. (1993)
	72	Institute of Plant Breeding, Laguna, Philippines	Raj et al. (1993)
	7	Division of Plant and Seed control, Pretoria, South Africa	Raj et al. (1993)
	250	Kasetsart University, Bangkok, Thailand	Raj et al. (1993)
	Unknown	National Centre for Genetic Resources and Biotechnology (NACGRAB), Ibadan, Nigeria	Borokini et al. (2010)
M. charantia var. *muricata*	11	National Genebank of NBPGR, New Delhi	Joseph and Antony (2009)
M. cochinchinensis	6	AVRDC, Taiwan	AVGRIS (2009)
	8	Central Horticultural Expt. Station, Bhubaneswar, India	Collected during 2011–2012 by the authors
	2	Krishna Chandra Mishra Research Institute of Wild Vegetable Crops	Ghosh and Kalloo (2000)
M. dioica	60	Central Horticultural Expt. Station, Bhubaneswar	Vishalnath et al. (2008a, b)
	8	Indian Institute of Vegetable Research, Varanasi, India	Ghosh and Kalloo (2000)
	2	AVRDC, Taiwan	AVGRIS (2009)
	5	Krishna Chandra Mishra Research Institute of Wild Vegetable Crops	Ghosh and Kalloo (2000)
	93	AICRP on UU crops	Joshi et al. (2002)
M. subangulata ssp. *renigera*	70	Central Horticultural Expt. Station, Bhubaneswar, India	Collected during 2011–12 by the authors
	<12	AAU Research Centre, Kahikuchi	Ram et al. (2002)
	2	Krishna Chandra Mishra Research Institute of wild vegetable crops	Ghosh and Kalloo (2000)

(continued)

Table 7.1 (continued)

Crop	Number of accessions	Institute	Reference
M. balsamina	1	AVRDC, Taiwan	AVGRIS (2009)
	1	NBPGR, New Delhi	Joseph (2005)
	1	Krishna Chandra Mishra Research Institute of wild vegetable crops	Ghosh and Kalloo (2000)
	3	Czech gene bank, Czech Republic	Karlova (2008)
M. sahyadrica	10	NBPGR, New Delhi, India	Joseph (2005)
Momordica species	31	European gene bank	Diez et al. (2002)

Source Modified from Behera et al. (2011)

thickened with the accumulation of food and secondary thickening and side roots which are formed from the base of the bulged part are fibrous and non tuberous. In the case of *M. subangulata* subsp. *renigera* tap root gets branched slightly below the caudex, gets swollen at intermittent places and undergoes repeated branching (Fig. 7.3a). The number of swollen tubers in the case of *M. dioica* and *M. sahyadrica* were one each (taproot sometimes forked), whereas in the case of *M. subangulata* subsp. *renigera*, it varied from 5 to 15. In *M. cochinchinensis*, the tap root and its primary branches becomes woody (Fig. 7.3b) and areal stem remains alive to a considerable height during unfavourable season. After a period of active growth, with the advent of unfavourable season for growth, the plants of these dioecious species show symptoms of senescence, leaves become yellow and dry up, vine also withers and the plant perennates with the help of storage roots underneath. In case of *M. dioica* the stem portion consisting of basal 2–3 nodes remains alive while in *M. cochinchinensis* all the nodes of the main vine remain alive with only reduction in new foliar growth, which upon favourable conditions, put forth branched sprouts. In case of *M. sahyadrica*, sprouts emerge from the root–shoot transition zone (caudex). In case of *M. subangulata* subsp. *renigera*, there is no polarity and specification; sprouts emerge from any part of the tuber surface, even from wiry roots.

Sexual Reproductive System

Most of the species (*M. subangulata* (subsp. *renigera* and subsp. *subangulata*), *M. dioica*, *M. sahyadrica*, *M. cochinchinensis*, *M. denudata*, *M. denticulata*, *M. rumphii*, *M. clarkeana*) are dioecious and only three (*M. charantia*, *M. balsamina* and *M. balsamina*) are monoecious. Occasionally, hermaphrodite flowers in *M. subangulata* subsp. *renigera* are observed in nature (unpublished).

Tendrils

Tendrils are simple and unbranched. However, in some wild varieties of *M. charantia* bifid tendrils (Fig. 7.4) are also observed. In *M. cochinchinensis*, tendrils are robust.

Leaves

In *Momordica* the leaves are simple, with the blade either entirely or variously (deeply) lobed or (sub) pedately 3–5 foliate. The lobing may be variable within a species. The leaves of *M. subangulata* subsp. *renigera* are entire or angled while the leaves of other species are much dissected. However, in *M. dioica* mixed occurrence of entire as well as lobed leaves in the same plant has also been noticed. Umbilical glands in

Table 7.2 Species representation in various herbaria/gene banks around the world

SN	Country/herbaria/gene bank	Species/accessions	Source country
1	Virtual herbarium, Cayman Islands	*M. charantia* var. *abbreviata*	Asiatic
2	Argentina	*M. charantia*	Asiatic
3	Peru	*M. charantia*	Asiatic
		M. balsamina	African
4	Amazonas, Manaus	*M. charantia*	Asiatic
5	Bangladesh National Herbarium, Dhaka	*M. dioica*	Asiatic
		M. cochinchinensis	Asiatic
		M. charantia var. *charantia*	Asiatic
		M. charantia var. *muricata*	Asiatic
6	Forest Research Institute of Malaysia, Kuala Lumpur	*M. charantia*	Asiatic
		M. subangulata	Asiatic
		M. cochinchinensis	Asiatic
7	Natural History Museum, Seychelles	*M. charantia*	Asiatic
8	Philippines	*M. cochinchinensis*	Asiatic
		M. charantia	Asiatic
9	Institute of Jamaica, Jamaica	*M. charantia*	Asiatic
		M. balsamina	African
10	South Pacific Regional Herbarium, Suva, Fiji	*M. charantia* var. *abbreviata*	Asiatic
11	Bolus Herbarium, University of Cape Town, South Africa	*M. balsamina*	African
		M. charantia	Asiatic
12	National Botanical Institute of Tropical Africa consisting of Namibia, Botswana, Swaziland, Lesotho	*M. balsamina*	African
		M. charantia	Asiatic
13	National Herbarium of Surinam	*M. charantia*	Asiatic
14	Honduras	*M. charantia*	Asiatic
15	Jardin Botanico, Dominican republic	*M. charantia*	Asiatic
16	Nicaragua	*M. charantia*	Asiatic
17	LMU Herbarium, Universidale	*M. balsamina*	African
		M. charantia	Asiatic
18	CAL Herbarium, Kolkata, India	*M. charantia*	Asiatic
		M. balsamina	Asiatic
		M. cochinchinensis	Philippine
		M. subangulata	Malaysian

Source Joseph (2005)

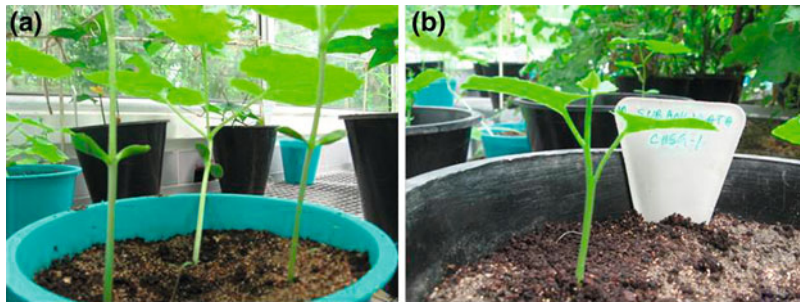


Fig. 7.1 Germination behaviour. **a** *M. charantia* showing epigeal germination, **b** *M. subangulata* showing hypogeal germination

Fig. 7.2 A polyembryonic seedling of *M. dioica*

petiole and lamina base (which is present in *M. cochinchinensis*) act as a good taxonomic trait (Fig. 7.5).

Inflorescences/Flowers

Male flowers are solitary or in short loose pseudo-racemes, each flower stalk with a persistent hooded bract (Fig. 7.6). Female flowers are solitary, in axils also with a conspicuous or rudimentary bract. Male flower pedicels are short or long; the receptacle is short, cupular (*M. charantia*, *M. balsamina*, *M. dioica*, *M. sahyadrica*, *M. rumphii*, *M. clarkeana*) or saucer shaped (e.g. *M. cochinchinensis*, *M. subangulata* subsp. *renigera*, *M. denticulata*) or obconical (*M. cymbalaria*) calyx lobe entire or scarious, adnate at base. Petals 5, free, entire; stamens 5, anthers 3, 1—one thecous, 2—two thecous, filaments very short, free inserted at mouth of the receptacle tube; thecae usually coherent, connective sometimes swollen, pistil lode absent. Female flowers calyx as in the male or distinct, petals as in the male, ovary oblong-fusiform, warty or soft papillose, ovules mostly many, horizontal, stigma 3-lobed; staminode absent.

Fruits

The fruit is fleshy, various in size and shape, pyriform, globose, ovoid or ellipsoid. Fruits are spiny (*M. dioica*, *M. subangulata* subsp. *renigera*, *M. sahyadrica*, *M. cochinchinensis*) or warty (*M. balsamina*) or tuberculate (*M. charantia*) or ribbed (*M. cymbalaria*, *M. subangulata* subsp. *subangulata*). The nature of epicarp is delicate in all the species except *M. cochinchinensis* which is shell like and leathery. The

Fig. 7.3 Nature of roots. **a** Teasel gourd showing adventitious root tubers. **b** Woody roots of *M. cochinchinensis*

Fig. 7.4 Bifid tendril of *M. charantia*

Fig. 7.5 Leaf of *M. cochinchinensis* with umbilical glands

soft pulp inside the mesocarp cavity contains the seeds and has a scarlet red colour and slimy aril (Fig. 7.7) characteristic of the genus.

Seeds

Many enclosed in orange red sarcotesta or creamish yellow (aril), small or large, flattened or turgid on faces, smooth or sculptured margins often undulate and dentate. *M. balsamina* and *M. cymbalaria* stand out in its seed shape and sculpturing. *M. charantia* var. *muricata* has close resemblance to cultivated bitter gourd and is difficult to distinguish except for the small size. The dioecious group has a general resemblance, all being basically black and cog wheel shaped. Fresh seeds of *M. dioica* have golden striation on testa which fades away on drying. *M. subangulata* subsp. *renigera* had short rectangular seeds with six projections. *M. cochinchinensis* has the biggest seed with deep sculpturing and irregular projections on the sides in a broadly stellate fashion. The surface is flat without any sculpturing. Seeds of *M. cymbalaria* are ovoid-subglobose and obscurely sculptured and are different from the seeds of other Asiatic *Momordica* spp.

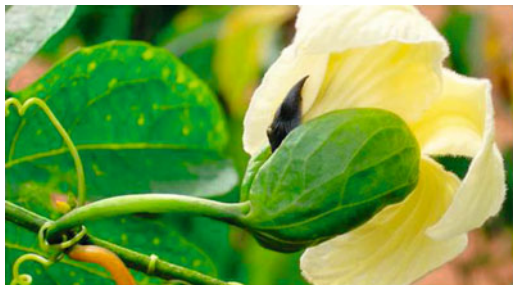


Fig. 7.6 Male flower of *M. cochinchinensis* with hooded bract

Fig. 7.7 *M. subangulata* subsp. *renigera* fruit exposing the seeds with *red* coloured arils

Descriptors and Descriptor States

Internationally recognised descriptor lists are published by Biodiversity International for major crops. However, there is no published descriptor for bitter gourd, teasel gourd, sweet gourd or spine gourd or any *Momordica* species by Biodiversity International. Only few references to *Momordica* descriptor are available (Srivastava et al. 2001; Rasul et al. 2004; Joseph 2005; Joseph and Antony 2011). As a preliminary step, sets of most significant descriptors (minimal descriptor list) for *Momordica* (Srivastava et al. 2001) were prepared under the National Agricultural Technology Project in which bitter gourd, sweet gourd and spine gourd were treated together. They, being evolutionarily divergent groups (bitter gourd on the one hand, sweet gourd and spine gourd on the other hand), should be treated separately as they vary by more than 75 % characters by virtue of their breeding behaviour and growth forms (Joseph 2005).

Rasul et al. (2004) proposed a descriptor with 29 morphological and physiological characters for *M. dioica*. Descriptor lists for monoecious species (Joseph 2005) and dioecious species (Joseph and Antony 2011) have been developed (Tables 7.3, 7.4, 7.5, 7.6 adapted from Joseph 2005; Joseph and Antony 2011) based on the observed variability in national collections (observable from herbarium sheets), published descriptions of these taxa in various flora together with ex situ study of germplasm collections comprising *M. dioica*, *M. sahyadrica*, *M. subangulata* subsp. *renigera* and *M. cochinchinensis*. Exploitation of some characters for inter- and infra-specific categorisation is based on the current state of the author's knowledge of both levels of variation. Further collection and study of variability across the country will lead to spotting of more diverse types and accordingly the descriptor states need elaboration and modification. Present treatment of some traits such as leaf shape, fruit shape, etc., are not exhaustive as numerous types are difficult to describe in technical terms, but easy to depict through illustrations found in the existing collection itself.

Collection, Regeneration and Maintenance

Lack of information about a taxon's precise distribution in different ecosystems is a major constraint to biodiversity conservation (Arora 1998). The findings of the ecogeographical analysis give a clear-cut picture of areas of distribution, hotspots, infra-specific variability and phenology. The distribution maps give a holistic picture of the distribution of component taxa, areas of overlapping distribution and higher concentrations that need to be targeted for maximum assemblage of genetic diversity, using which a prospective collector can have access to the exact site.

Table 7.3 Descriptors and descriptor states for characterization of balsam pear and balsam apple

Number	Descriptor name	Scale and descriptor state
A.	**Vegetative characters**	
A1	Seedling growth habit	1. Robust
		2. Fragile
A2	Seedling stem thickness	1. Very thin
		2. Medium
		3. Thick
A3	Cotyledon size I	1. Very small
		2. Medium
		3. Large
A4	Epicotyls length (cm)	
A5	Hypocotyls length (cm)	
A6.1	Primary leaf size I	1. Very small
		2. Medium
		3. Large
A6.2	Primary leaf shape	1. Squarish angular
		2. Reniform
		3. Fan shaped
		4. Others (describe)
A6.3	Primary leaf margin	1. Smooth (entire)
		2. Dentate
		3. Serrate
		4. Wavy (undulate)
A6.4	Primary leaf gland dottedness	1. On the margins
		2. Absent
A6.5	Primary leaf colour	1. Dark green
		2. Light green
A7	Vine tip pubescence I	1. Glabrous
		2. Scarcely pubescent
		3. Densely pubescent
		4. Wooly
A8.1	Leaf shape (to be recorded at flowering stage-describe)	
A8.2	Leaf colour	1. Light green
		2. Green
		3. Dark green
A8.3	Leaf thickness	1. Thin
		2. Medium
		3. Thick
A8.4	Leaf glossiness of upper side	1. Absent or very weak
		2. Weak
		3. Medium
		4. Strong
		5. Very strong

(continued)

Table 7.3 (continued)

Number	Descriptor name	Scale and descriptor state
A8.5	Leaf margin I	1. Entire
		2. Serrate
		3. Dentate
		4. Wavy
		5. Others (describe)
A8.6	Dentation of margin	1. Fine
		2. Medium
		3. Coarse
A8.7	Leaf pubescence	1. Glabrous
		2. Sparse
		3. Medium
		4. Wooly
		5. Others (specify)
A8.8	Leaf lobing	1. Absent (entire)
		2. Shallowly lobed
		3. Deeply cleft
A8.9	Lobe tip	1. Acute
		2. Acuminate
		3. Ovate
		4. Obovate
		5. Others (specify)
A9.1	Tendril robustness	1. Fragile
		2. Medium
		3. Robust
A9.2	Tendril length (measure from axil to tip of coil)	1. Short
		2. Medium
		3. Very long
A10	Vine branching (at full growth) I	1. Less branched
		2. Medium branched
		3. Densely branched forming thickets
B.	**Reproductive characters**	
B1	Days to first male flower opening	
B2	First male flower node (node number)	
B3	Days to first female flower opening	
B4	First male female flower node (node number)	
B5	Male flower bract shape	1. Scar like
		2. Foliar
		3. Reniform
		4. Hooded
		5. Frilled
		6. Others (describe)

(continued)

Table 7.3 (continued)

Number	Descriptor name	Scale and descriptor state
B6	Male bract position on flower stalk I	1. Towards axil
		2. Mid way
		3. Towards flower base
		4. Others
B7	Flower colour	1. Light yellow
		2. Orange yellow
		3. Creamish yellow
B8	Flower size I	1. Small
		2. Medium
		3. Large
B9	Petal shape	1. Ovate
		2. Obovate
		3. Linear
		4. Rhomboid
		5. Others (specify)
B10	Petal tip	1. Cleft
		2. Lipped
		3. Entire
B11	Petal base colouration (if any describe)	
B12	Male flower petal size (average length and breadth of five petals)	
B13	Female flower bract size	1.Scar-like remnant
		2. Small
		3. Medium
		4. Large
B14	Female bract position	1. Towards axis
		2. Midway
		3. Below gynoecium
B16	Ovary shape I	1. Round
		2. Fusiform
		3. Urn shaped
		4. Cylindrical
		5. Others
B17	Ovary surface	1. Smooth
		2. Warty
		3. Tubercled
		4. Bumps and ridges
		5. Others (specify)
B18	Ovary colour	1. Light green
		2. Whitish green
		3. Dark green
B19	Staminal column colouration S	1. Absent
		2. Black
		3. Orange
		4. Others

(continued)

Table 7.3 (continued)

Number	Descriptor name	Scale and descriptor state
B20	Days to first maturity (at dead ripe split stage)	
B21	Days to first fruit harvest (number of days from sowing to first marketable fruit harvest)	
B22	Days to last harvest (number of days from sowing to last marketable fruit harvest)	
B23	Fruit stalk length (from axil to fruit attachment)	
B24	Fruit shape	1. Disc
		2. Rhomboid
		3. Cylindrical
		4. Spindle shaped
		5. Elliptical
		6. Oblong
		7. Globular
		8. Others (specify)
		
B25	Fruit colour (at marketable stage) I	1. White
		2. Whitish green
		3. Light green
		4. Green
		5. Dark green
		6. Others (specify)
B26	Fruit size	1. Small
		2. Medium
		3. Large
B27	Fruit ends I	1. Both ends pointed
		2. Only blossom end pointed
		3. Both ends round
		4. Others (describe)

(continued)

Table 7.3 (continued)

Number	Descriptor name	Scale and descriptor state
B28	Fruit ribs I	1. Continuous
		2. Broken
		3. Not distinct
		
B29	Density of tubercles	1. Sparse
		2. Medium
		3. Dense
		4. Others (describe)
B30	Nature of fruit tubercles I	1. Soft and flat
		2. Sharp and pointed
		3. Soft and raised
		4. Merging with bumps
		5. Others
B31	Seed colour I	1. White
		2. Brownish tan
		3. Brownish yellow
		4. Black
		5. Black and brown patched
		6. Cement colour
		7. Straw colour
		8. Whitish brown
		9. Others (describe)
B32	Seed luster (on washed de-pulped seeds extracted from ripe fruits)	1. Matt
		2. Intermediate
		3. Glossy
		4. Others (specify)
B33	Seed size I	1. Large
		2. Small
		3. Very small
B34	Seed surface evenness	1. Flat and creeked
		2. Pitted (uniformly)
		3. Invaginated
B35	Seed sides	1. Dented-bitten appearance
		2. Smooth
B36	Seed ends	1. Clearly sub tridentate
		2. Oval
		3. Feebly sub tridentate
		4. Smooth
		5. Others (specify)
B37	Seed surface sculpturing	1. Markedly sculptured
		2. Feebly sculptured
		3. Only pitted

(continued)

Table 7.3 (continued)

Number	Descriptor name	Scale and descriptor state
B38	Seed shape	1. Broad triangular
		2. Narrow triangular
		3. Squarish oval
		4. Round
		5. Others

Source Joseph (2005)
I - discriminates an infraspecific variation
S - indicates a species characterising descriptor

Table 7.4 Descriptors and descriptor states for evaluation of balsam pear and balsam apple

Descriptor number	Descriptor name	Scale
1	Leaf size (L × B)—average of five leaves at first flowering node	
2	Number of primary branches—to be recorded at the end of flowering stage	
3	Number of secondary branches—to be recorded at the end of flowering stage	
4	Number of tertiary branches—to be recorded at the end of flowering stage	
5	Inter node length (in cm)—at early flowering nodes	
6 7	Plant height (length of main stem from base to terminal branch, measured at senescence)	
8	Fruit length (average of five well developed fruits)	
9	Fruit circumference (average of five well developed fruits)	
10	Fruit cavity (measure at the central part, diameter of C.S. of mature fruits	
11	Fruit flesh thickness (measure with a caliper)	
12	Clutch size	
13	Single fruit weight (g)	
14	Seed size (L × B)—measure with a caliper	
15	Seed thickness measure with a caliper	
16	Seed germinability (% germination and speed of emergence—combined assessment)	
17	Number of fruits per plant	
18	Yield/plant	
19	Senescence (months after planting)	
20	100 seed weight (g)	
	Biotic stress tolerance	
21	Reaction to prevalent diseases (score in 1–9 scale)	
	21.1 Cucurbit mosaic virus, 21.2 Witches broom, 21.3 Damping off, 21.4 Downey mildew, 21.5 Leaf spot, 21.6 Fruit rot, 21.7 Root knot nematode	

(continued)

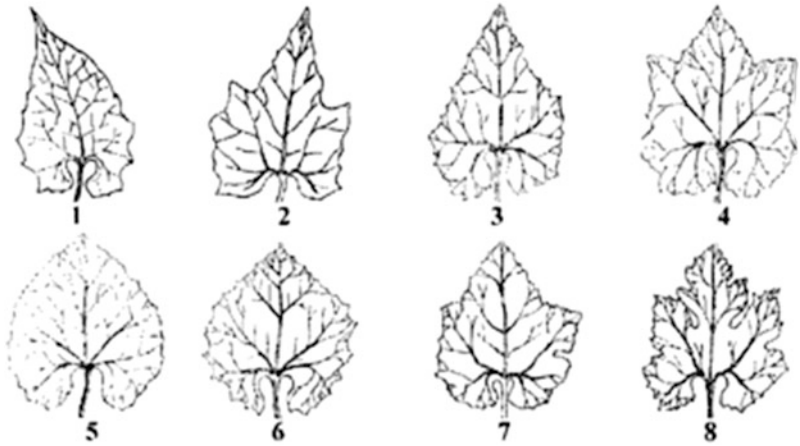
Table 7.4 (continued)

Descriptor number	Descriptor name	Scale
22	Reaction to prevalent pests (score in 1–9 scale)	
	22.1—Fruit fly, 22.2—fruit borer 22.3—Vine gall fly, 22.4—Lady bird beetle, 22.5—Leaf miner, 22.6 Leaf hopper 22.7—Red pumpkin beetle, 22.8—Cut worm infestation at seedling stage, 22.9—Aphid	
23	Reaction to abiotic stresses (a combined assessment based on growth, survival and yield)	
	23.1—drought, 23.2—high temperature, 23.3—shade, 23.4— heavy monsoon	
24	Organoleptic tests	
	24.1 Bitterness of fruits (cooked mature fruits)	1. Very bitter
		2. Medium
		3. Low
	24.2 Taste	1. Very good
		2. Good
		3. Average
		4. Poor
25	Consumer acceptability	1. High
		2. Medium
		3. Low
26	Economics of production in homesteads	1. High
		2. Medium
		3. Low
27	Physico-chemical evaluation of tender fruits	
	27.1—Moisture, 27.2—carbohydrate, 27.3—protein, 27.4—fat, 27.5—calcium, 27.6—phosphorus, 27.7—Iron, 27.8—magnesium, 27.9—vitamin C, 27.10—antioxidants, 27.11—flavonoids, 27.12—dietary fibre, 27.13—others (specify)	

Source Joseph (2005)

Area-wise gaps in germplasm collection can be ascertained by comparing the gene bank passport data with the distribution maps. Analysis of species distribution maps based on herbarium survey and locality data of collections reveal the need for more intensive exploration in species hotspots. A good representation of diversity in *M. charantia* has been assembled in India through various explorations conducted by various organisations like NBPGR, New Delhi; Indian Institute of Vegetable Research (IIVR), Varanasi, Uttar Pradesh; Indian Agricultural Research Institute (IARI), New Delhi; Indian Institute of Horticultural Research (IIHR), Bengaluru, Karnataka; Vivekananda Parvathiya Krishi Anusandhan Shala (VPKAS), Almora, Uttar Pradesh; Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu; Kerala Agricultural University (KAU), Thrissur, Kerala, University of Agricultural Science, Dharwad, Karnataka; Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad, Andhra Pradesh; Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra; Govind Ballabh Pant University of Agriculture and Technology (GBPUAT), Pantnagar, Uttaranchal; Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, etc., though there are still a few grey areas to be explored more intensely. However, other species and areas need extensive coverage. Similarly, more than 70 samples of teasel gourd were collected from north-eastern India by the Central Horticultural Experiment Station, Bhubaneswar, in collaboration with NBPGR, New Delhi, which represent good morphological variability.

Table 7.5 Descriptors and descriptor states for characterisation of sweet gourds (to be used in continuation of passport data)

Descriptor number	Descriptor name	Descriptor state (with code)
1.1.1 S	Germination (Except 1.1.1, all other traits may be recorded in tuber sprouts/ratoon crop also)	1. Epigeal
		2. Hypogeal
1.1.2 S	Primary leaf size	1. Minute
		2. Small
		3. Medium
		4. Large
1.1.3	Primary leaf shape (See figure and describe)	
		
1.1.4 I	Primary leaf margin	1. Smooth
		2. Wavy
		3. Dentate
		4. Lobed
1.2.1	Vine tip pubescence	1. Glabrous
		2. Scarcely pubescent
		3. Pubescent
1.2.2	Stem nodal region—shape	1. Quadrangular
		2. Round
1.2.3	Leaf shape (to be recorded at flowering stage—see figure and describe)	
		
1.2.4 S	Leaf margin	1. Entire
		2. Serrate
		3. Dentate
		4. Wavy
		5. Other (describe)

(continued)

Table 7.5 (continued)

Descriptor number	Descriptor name	Descriptor state (with code)
1.2.5	Leaf pubescence	1. Glabrous
		2. Sparse
		3. Medium
		4. Dense
		5. Wooly
		6. Other (describe)
1.2.6	Leaf colour (fresh leaf)	1. Light green
		2. Green
		3. Dark green
1.2.7 S	Leaf venation	1. Fine network (areoles)
		2. Spaced network
		3. Intermediate
1.2.8 S	Leaf lobing (1st flowering node)	1. Entire
		2. Lobed
		3. Mixed occurrence in same plant
		4. Other (specify)
1.2.9	Extent of lobing	1. Shallowly lobed
		2. Broadly angled margins
		3. Deeply lobed and sub-lobed
1.2.10	Lobe tip	1. Acute
		2. Acuminate
		3. Ovate
		4. Obovate
		5. Other (specify)
1.2.11 S	Leaf smell (odour when crushed)	1. Foetid (intense)
		2. Not foetid
		3. Mild
1.2.12	Leaf thickness	1. Thin
		2. Medium
		3. Thick
1.2.13 I	Extent of leaf margin dentation	1. Close
		2. Spaced
		3. Remote
1.2.14 S	Petiole-Lamina juncture shape	1. Subangulata
		2. Round
		3. Cordate
		4. Other (describe)
1.2.15 S	Petiole-umbilical glands (viewed with naked eye)	1. Absent
		2. Present
1.2.16 S	Tendril robustness	1. Robust
		2. Fragile
		3. Medium

(continued)

Table 7.5 (continued)

Descriptor number	Descriptor name	Descriptor state (with code)
1.2.17	Tendril length (when uncoiled)	1. Short (5–10 cm)
		2. Medium (11–20 cm)
		3. Very long (21–30 cm)
2.1.1 S	Male inflorescence—nature of branching	1. Solitary
		2. Psuedo raceme
		3. Loose fascicle
		4. Truly branched (above the bract)
2.1.2 S	Bract—position on peduncle	1. At base
		2. Midway
		3. At tip
2.1.3	Male bract shape	1. Scar like
		2. Small foliar
		3. Reniform
		4. Fan shaped (cleft)
		5. Hooded
		6. Frilled
		7. Any other (specify)
2.1.4 S	Male bract size	1. Minute
		2. Small
		3. Medium
		4. Large
2.1.5 I	Male bract pubescence	1. Stiff short hairy-conspicuous
		2. Sparse
		3. Absent
2.1.6	Male bract colour	1. Light green
		2. Dark green
		3. Whitish green
2.1.7	Male bract tip	1. Coloured black–purple
		2. No colour distinction
2.1.8 S	Flower colour (petal colour at full bloom). Use RHS colour charts (1995)	1. Lemon yellow
		2. Dull yellow
		3. Bright yellow
		4. Creamish yellow
		5. Whitish yellow
		6. Any other (specify)
2.1.9 S	Flower size	1. Small
		2. Medium
		3. Large
2.1.10 S	Floral scent	1. Odourless
		2. Faint
		3. Detectable from 1 m distance
2.1.11 S	Floral odour sensation	1. Musky
		2. Other (specify)

(continued)

Table 7.5 (continued)

Descriptor number	Descriptor name	Descriptor state (with code)
2.1.12 S	Petal spot	1. Absent
		2. Present
2.1.13 S	Nature of petal spot	1. Purple blotch on 3 inner petals
		2. Purple blotch on all 5 petals
		3. Light greenish yellow region on base of petals
		4. Other (describe)
2.1.14 S	Male flower calyx shape	1. Linear acute
		2. Round oval
		3. Broad elliptic
		4. Ovate oblong
		5. Other (specify)
2.1.15 S	Calyx cup colouration	1. Non pigmented
		2. Pigmented purple–blackish
		3. Light creamish yellow
		4. Greenish yellow
		5. Blackish
2.1.16 S	Corolla tip	1. Acute
		2. Broad ovate
		3. Round
		4. Other (specify)
2.1.17 S	Petal base	1. Just touching each other
		2. Overlapping
		3. Spaced
		4. Other (specify)
2.1.18	Petal pubescence	1. Glabrous
		2. Glandular hairy
2.1.19 S	Petal shape	1. Ovate
		2. Linear acute
		3. Rhomboid
		4. Other (specify)
2.1.20 S	Petal spur (at base) = scale	1. Absent
		2. Present, but inconspicuous
		3. Prominent
2.1.21 S	Petal venation	1. Less prominent
		2. Medium
		3. High (embossed)
2.1.22 S	Pollen dust colour	1. Yellow
		2. Orange
		3. Brown
2.1.23 S	Pollen abundance	1. Scanty
		2. Medium
		3. Abundant
2.1.24 S	Male flower anthesis	1. Early morning 2. Evening

(continued)

Table 7.5 (continued)

Descriptor number	Descriptor name	Descriptor state (with code)
2.1.25	Insect visitors observed (list out)	
2.2.	Female inflorescence and flower	
2.2.1 I	Female flower bract size	1. Minute (scar like)
		2. Medium large
		3. Large
2.2.2 I	Female flower bract position	1. Just below gynoecium
		2. Midway on pedicel
		3. Near axis
2.2.3 S	Gynoecium	1. Small
		2. Medium
		3. Large
2.2.4	Ovary surface	1. Smooth
		2. Warty
		3. Tubercled
		4. Echinate (softly)
		5. Ridged
		6. Other (describe)
2.3.	Fruit	
2.3.1 S&I	Fruit size	1. Small
		2. Medium
		3. Large
2.3.2 I	Immature fruit colour	1. Whitish green
		2. Light green
		3. Dark green
2.3.3 I	Fruit surface echination	1. Absent = smooth
		2. Mild sparsely echinate
		3. Densely echinate
2.3.4 I	Fruit surface bumps and ridges	1. No ridges
		2. Obscurely ridged (feeble)
		3. Clearly ridged
		4. Ridged at base only
		5. Ridged at base and top
		6. Other (describe)
2.3.5 S	Fruit C.S (mature fruit at equatorial point)	1. Uniformly soft echinate
		2. Clear cut ridges and echination
		3. Ridges faint but echinate
		4. Other (describe)
2.3.6 I	Fruit shape (see figure)	1. Round oval
		2. Winged
		3. Doom shaped
		4. Ellipsoid oblong
		5. Top shaped
		6. Others (specify with drawing)

(continued)

Table 7.5 (continued)

Descriptor number	Descriptor name	Descriptor state (with code)
		
2.3.7 S	Fruit pericarp reddening	1. Slowly building up
		2. Sudden expression leading to ripening
2.3.8 I	Fruit (blossom end) rostration	1. Faint
		2. Medium
		3. Appreciable length
2.3.9	Fruit blossom end surface murication	1. Ridged and flat
		2. Ridged and echinate
		3. Uniformly echinate
		4. Uniformly smooth
		5. Other (describe)
2.3.10 S	Calyx persistence	1. Caducous
		2. Semi persistent
		3. Persistent
2.3.11 I	Fruit bitterness (chewing)	1. Not bitter
		2. Slightly bitter
		3. Very bitter
2.4.	Seed	
2.4.1	Seed aril colour (at ripening)	1. Yellow
		2. Orange
		3. Scarlet
		4. Blood red
2.4.2 S	Seed shape	1. Oval
		2. Round
		3. Globular
		4. Stellate
		5. Squarish
		6. Cog-wheel
		7. Rectangular
		8. Other (describe)
2.4.3 I	Seed sculpturing	1. Absent
		2. Present
2.4.4 I	Extent of sculpturing	1. Faint
		2. Medium
		3. Filigree type
		4. Pitted and ridged
		5. Other (describe)

(continued)

Table 7.5 (continued)

Descriptor number	Descriptor name	Descriptor state (with code)
2.4.5	Seed ornamentation	1. Absent
		2. Present
2.4.6	Type of ornamentation	1.Golden lines on black seed coat
		2. Other (specify)
2.4.7 I	Seed sides (margins	1. Smooth
		2. Wavy = bitten
2.5	Tuber (Specify age of tuber—only seedling tuber to be observed)	
2.5.1	Seedling (tap root) tuber shape	1. Conical
		2. Napiform
		3. Round bulged
		4. Fusiform
		5. Other (describe with drawing)
2.5.2 S	Protrusion of lenticels on tuber surface	1. Weak
		2. Medium
		3. Strong
2.5.3	Seedling tuber branching	1. Absent
		2. Present
2.5.4 S	Occurrence of adventitious tubers	1. Absent
		2. Present
2.5.5	Seedling tuber life span	1. 1–5 years
		2. 2 < 5 years
		3. 3 > 5 years

I - discriminates an infraspecific variation
S - indicates a species characterising descriptor

Experience of germplasm collection of *Momordica* species across the Western Ghats revealed certain general factors affecting wild species survival. *Momordica* species were found to be subjected to varied types of threats such as changes in agricultural practices affecting species dependent on prevailing agricultural systems and other factors such as forestry plantations, monoculture practices, continuous weeding preventing reproductive maturity, pressure from introduced plants (smothering by *Mekania micrantha*, competition from *Mimosa incisa*, *Lantana camera,* etc.) and collecting for horticultural purpose thus leading to critically low population level with subsequent danger of breeding collapse (Rajashekaran et al. 2011).

Characterisation and Evaluation

The nature and magnitude of genetic diversity in any crop determines and often limits its utilisation in breeding programmes. Genetic diversity was studied by various authors using various tools and materials. Characterisation studies employing solely morphological methods typically focused on revealing valuable horticultural traits. Indian researchers gave considerable attention to the evaluation of local *M. charantia* germplasm with the goal of identifying valuable accessions for breeding which resulted in the development of many varieties across India. However, other *Momordica* species of Indian

Table 7.6 Descriptors and descriptor states for sweet gourds evaluation

Descriptor No.	Descriptor name	Descriptor state with code
1. Seedling		
1.1	Days to emergence (specify after ripening period)	
1.2	Germination percentage	
1.3	Seedling vigour (visual score at 3–5 leaf stage)	1. Low
		2. Medium
		3. High
2. Mature vines		
2.1. Stem characteristics		
2.1.1	Growth habit	1. Less viny
		2. Moderately viny
		3. Highly viny
2.1.2	Plant height (vine length measured at senescence) [m]	
2.2. Leaf		
2.2.1	First flowering node leaf size (L × B)	
2.2.2	Petiole length (average of five leaves at flowering node) [cm]	
2.2.3	Lamina—gland dottedness (10X) on lower surface	1. Sparse
		2. Dense
		3. Medium
2. 3. Flowers		
2.3.1	Days to first male flower opening (specify seed or tuber origin)	
2.3.2	Days to 50 % male flowering	
2.3.3	Days to first female flower opening	
2.3.4	Days to 50 % female flowering	
2.3.5	Male flower prolificacy—number of flowers/plant/day (average count of 5 days)	
2.3.6	Female flower prolificacy (average count of 5 days)	
2.3.7	Male bract size (L × B—average of five flowers)	
2.3.8	Female bract size (L × B—average of five flowers)	
2.3.9	Male Peduncle length (axis to base of bract) [cm]	
2.3.10	Female peduncle length (axis to bract base) [cm]	
2.3.11	Male pedicel length (bract to calyx base) [cm]	
2.3.12	Female pedicel length (bract to gynoecium) [cm]	
2.3.13	Male flower diameter (average of five flowers) [cm]	
2.3.14	Female flower diameter (average of five flowers) [cm]	
2.3.15	Male flower receptacle size	1. Small
		2. Medium
		3. Large
2.3.16	Pollen viability (fruit set upon hand pollination)	1. Up to 12 h
		2. Up to 18 h
		3. Up to 24 h
		4. Beyond 24 h

(continued)

Table 7.6 (continued)

Descriptor No.	Descriptor name	Descriptor state with code
2.3.17	Stigma receptivity (fruit set upon hand pollination)	1. Up to 12 h
		2. Up to 18 h
		3. Up to 24 h
		4. Beyond 24 h
2.4. Fruit		
2.4.1	Days to first fruit maturity (flowering to fruit-split)	
2.4.2	Fruit length (including rostration) [cm]	
2.4.3	Fruit circumference (around fruit) [cm]	
2.4.4	Fruit diameter [cm] (measured in C.S of fruit)	
2.4.5	Cavity size (measured at widest point in fruit CS) [cm]	
2.4.6	Flesh thickness (measured from C.S of ripe fruit) [cm]	
2.4.7	Single fruit weight (average of five fruits) [g]	
2.4.8	Number of fruits/plant/season	
2.4.9	Seediness (number of seeds/fruit, average of five fruits)	
2.4.10	Fruit stalk length (average of five fruits) [cm]	
2.4.11	Inter specific crossability (extent of fruit set with pollen of related species—specify pollen parent)	1. Above 95 %
		2. 50 %
		3. 25 %
		4. Aborted
		5. No response
2.4.12	Fruiting period (number of days from first to last female flower opening)	
2.4.13	Fruit tenderness index (from pollination to seediness calculated as days up to which a sharp knife easily passes through)	
2.4.14	Fruit preference for vegetable preparation (based on consumer preference after organoleptic tests)	1. Excellent
		2. Good
		3. Average
		4. Poor
2.4.15	Suitability of ripe fruits as vegetable salads (based on organoleptic tests and eye appeal)	1. Excellent
		2. High
		3. Medium
		4. Low
2.4.16	Usefulness as pot herb and leafy vegetable	1. Excellent
		2. Good
		3. Average
		4. Poor
2.4.17	Suitability for organic farming (a combined assessment of yield and biotic tolerance)	1. Good
		2. Average
		3. Poor
2.4.18	Shelf life under refrigeration (vegetable stage)	1. High (2 weeks)
		2. Medium (1 week)
		3. Low (<1 week)

(continued)

Table 7.6 (continued)

Descriptor No.	Descriptor name	Descriptor state with code
2.4.19	Shelf life under room temperature	1. High (1 week)
		2. Medium (3 days)
		3. Low (1 day)
2.5.	Seed	
2.5.1	100-seed weight [g]	
2.5.2	Seed storability (viability under normal storage)	1. 6 months
		2. 1 year
		3. Above o1 year
2.6	Biotic stress susceptibility (on a 0–9 scale)	1. No incidence
		2. Very low
		3. Low
		4. ntermediate
		5. High
		6. Very high
2.6.1	Witches broom/little leaf disease, seedling damping off, fruit rot, powdery mildew, anthracnose, root knot nematode, fruit fly, lady bird beetle, vine gall fly, pumpkin caterpillar, leaf miner, leaf hopper, red pumpkin beetle	
2.7	Abiotic stress susceptibility (indicator- yield performance)	
2.7.1	Susceptibility to shade	1. Low
		2. Medium
		3. High
2.7.2	Susceptibility to high temperature	1. Low
		2. Medium
		3. High
2.7.3	Susceptibility to heavy monsoon	1. Low
		2. Medium
		3. High
2.7.4	Susceptibility to drought	1. Low
		2. Medium
		3. High
2.8	Biochemical evaluation of (a) tender fruits, (b) green leaves/tips	
	2.8.1—Moisture, 2.8.2—Carbohydrates, 2.8.3—Proteins, 2.8.4—Fat, 2.8.5—Calcium, 2.8.6—Iron, 2.8.7—Magnesium, 2.8.8—Vitamin A (ripe fruit arils), 2.8.9—Vitamin C, 2.8.10—Antioxidants, 2.8.11—Flavonoids, 2.8.12—Dietary Fibre	

Source Joseph and Antony (2011)

occurrence are not given due attention in collection and characterisation of germplasm and reports are scanty.

Morphological characters have been widely used to characterise the collections while lately, DNA markers are popular in these studies. Wide morphological variations have been reported in *M. charantia* accessions collected from six countries namely India, China, Japan, Taiwan, Thailand and USA (Kole et al. 2010), Asia (Marr et al. 2004; Dalamu et al. 2012); India (Sirohi and Choudhury 1983; Behera 2004;

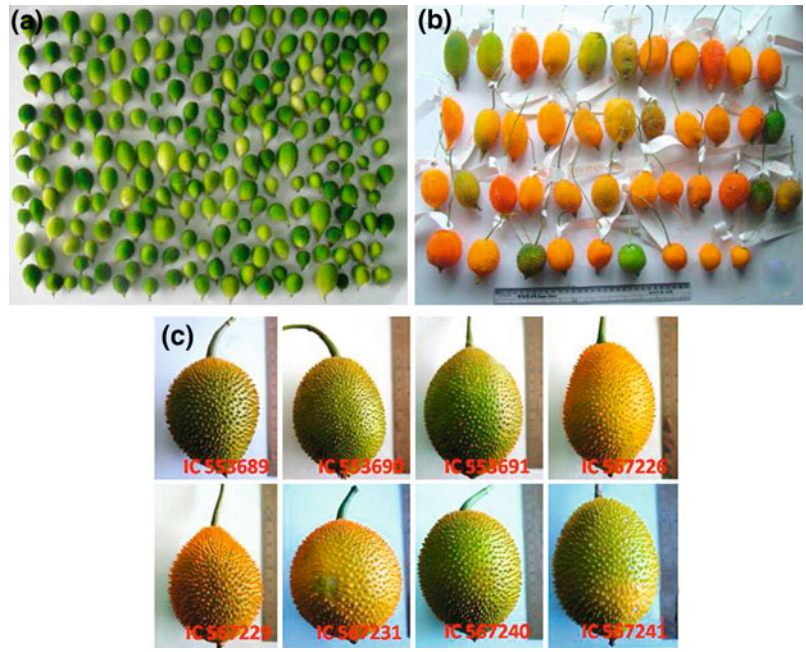


Fig. 7.8 Variability for fruit shape in dioecious *Momordica* species. **a** *M. dioica*, **b**. *M. subangulata* subsp. *renigera*, **c**. *M. cochinchinensis*

Yadav et al. 2008; Joseph and Antony 2009; Paul et al. 2010); Bangladesh (Islam et al. 2010); Thailand (Promote et al. 2011) and Romania (Botau et al. 2010). The accessions of *M. dioica* collected from eastern and northern India (Ram et al. 2001; Bharathi et al. 2005, 2010) and Bangladesh (Rasul and Okubo 2002; Rasul et al. 2004) also showed a considerable range of diversity in qualitative and quantitative traits. The above studies provide broad phenotypic species variation in morphological (qualitative and quantitative) characters like sex expression, growth habit, maturity, fruit shape, fruit size, fruit length, fruit colour, surface texture, number of fruits per plant, yield per plant, etc. The entities collected represented a wide range of variability from almost near wild-types, semi-domesticated to cultivated types.

Based on evaluation the accessions of bitter gourd viz. IC-44428B, IC-85604A, IC-85608BC, IC-85611, IC-85636, EC-110596 have been identified as high yielders (Ghosh and Kalloo 2000). At the Central Horticultural Experiment Station (CHES, IIHR), Bhubaneswar, India, 60 accessions each of *M. dioica*, and *M. subangulata* subsp. *renigera* and 8 accessions of *M. cochinchinensis* have been studied for morphological variability (Fig. 7.8) which lead to identification of two high yielding clones, viz., Arka Neelachal Sree and Arka Neelachal Gaurav in *M. dioica* and *M. subangulata* subsp. *renigera,* respectively, for commercial cultivation (Vishalnath et al. 2008a, b).

Isozyme variation in *M. charantia* germplasm supported a single domestication event but did not clarify the place of domestication (Marr et al. 2004). In domesticated *M. charantia,* the absence of multiple alleles at allozyme loci and fixation for the same alleles across a great geographical distance indicate that gene flow from wild *M. charantia* into the domesticate is rare. This suggests that the morphological variation is due to conscious or unconscious selection on a local scale, rather than to introgression with the wild form. In a genetic diversity study involving seven genera of the family Cucurbitaceae, isozymes could not distinguish between *Momordica* and *Luffa* (Sikdar et al. 2010).

Many molecular markers have been used to characterise *Momordica* germplasm including both plastid and nuclear markers. The random molecular markers like random amplified polymorphic DNA (RAPD) and inter simple sequence repeat (ISSR) are particularly useful

Table 7.7 Molecular characterization of *Momordica* accessions

Taxon	Marker type	Number of accessions	Reference
M. charantia	RAPD	45	Changyuan et al. (2005)
M. charantia	RAPD	38	Dey et al. (2006)
M. dioica, *M. cochinchinensis*	RAPD	29	Rasul et al. (2007)
M. charantia	ISSR	38	Singh et al. (2007)
M. charantia	RAPD	20	Rathod et al. (2008)
M. charantia	AFLP	38	Gaikwad et al. (2008)
M. charantia	RAPD, ISSR	38	Behera et al. (2008b)
M. charantia	RAPD, ISSR, AFLP	38	Behera et al. (2008a)
M. charantia	AFLP, SSR	22	Kole et al. (2009)
M. charantia	SSR	36	Wang et al. (2010)
M. charantia	RAPD, SCAR	12	Paul et al. (2010)
M. charantia	RAPD, ISSR	50	Dalamu et al. (2012)
M. charantia, *M. balsamina*, *M. s.* subsp. *renigera*, *M. dioica*, *M. cochinchinensis*, *M. cymbalaria*, *M. sahyadrica*	RAPD, ISSR	35	Bharathi et al. (2012b)
M. cochinchinensis	RAPD	25	Bootprom et al. (2012)

for studying polymorphism and genetic diversity pattern in plant species where no genomic information is available. Species-specific fragments detected by RAPD and ISSR have potential applications in introgression breeding of *Momordica* and these markers can be utilised for inter-specific hybridisation followed by marker-assisted monitoring of introgression. A wider range of molecular diversity detected in various studies (Table 7.7) by both RAPD and ISSR markers reflected the presence of high level of genetic variation among the species. High level of polymorphism was detected in dioecious species than monoecious species (Bharathi et al. 2012b). Genetic affinities among the cultigens were defined by their geographic origin, suggesting that opportunities exist for broadening the existing Indian germplasm collection (Behera et al. 2008a). RAPD and ISSRs to describe patterns of genetic variation among seven species of *Momordica* gave similar results for each marker type (Bharathi et al. 2012b); however, ISSR was more effective than RAPD analysis at intra-specific variation studies in *M. charantia* (Behera et al. 2008b).

Apart from RAPD, ISSR other molecular markers such as simple sequence repeats (SSRs), sequence characterised amplified region (SCAR), amplified fragment length polymorphism (AFLP) have also been used to assess the genetic diversity of different *Momordica* species in India and Bangladesh (Table 7.7). Simple sequence repeats due to the advantage of high variability, co-dominance and ubiquity in eukaryotic genomes, have become a useful molecular marker in population genetic analysis (Walter and Epperson 2001). AFLP analysis was discriminatory and allowed for a more complete dissection of unique differences within and between collection sites (Behera et al. 2008a) while RAPD and ISSR were not able to uniquely discriminate (Dey et al. 2006; Singh et al. 2007).

Recently, Wang et al. (2010) developed polymorphic microsatellite markers which will be useful to study the genetic diversity and population structure within and between *M. charantia* and other related species. Among the Asiatic *Momordica* species only *M. charantia* germplasm have been characterised for SSR variation (Kole et al. 2009; Wang et al. 2010).

Plastid markers are typically conserved, making them especially valuable for revealing phylogenetic relations at or above species level (Chung and Staub 2004). The first report investigating mt, cp and n DNA sequence analysis was presented by Schaefer and Renner (2010). They studied 122 accessions of 58 *Momordica* species including the Asiatic species and suggested that the genus consists of 11 well-supported clades and monoecy evolved from dioecy seven times independently.

Conservation Strategies

In agro biodiversity conservation, wild plant genetic resources have received relatively lesser emphasis and attempts to conserve them face considerable constraints basically due to lack of information about the biology and ecology of the species and their precise distribution in different ecosystems (Arora 1998). The presence of genetic resistance to pathogens in wild populations is a reason frequently cited for the importance of conserving the genetic diversity present in the wild ancestors of domesticated species. Genetic erosion is very high due to habitat destruction, spread of alien weeds and anthropogenic factors. In this context, conservation of genetic diversity in the genus *Momordica* assumes significance by virtue of being a wild relative of bitter gourd which is an important vegetable and has manifold medicinal uses, e.g. to treat cancer, diabetes, psoriasis and many infectious diseases. References to conservation of *Momordica* species are scanty. Neglect of genetic resources of wild species and semi-domesticates in ex situ gene banks has been a universal feature (Heywood 1998). *Momordica* species assume significance for conservation as crop relative, source of economic product of aesthetic and ecological interest, of potential horticultural value and as future raw material for the medicinal and pharmaceutical industry.

Tissue culture, pollen storage and in situ conservation can be a valuable conservation tool especially in species which are amenable to vegetative propagation, viz., spine gourd, teasel gourd, sweet gourd and *M. sahyadrica*. In vitro conservation was attempted in dioecious *Momordica* species, viz., *M. subangulata* ssp. *renigera*, *M. sahyadrica* and *M. dioica* (Rajashekaran et al. 2011). The species were established in vitro (MS medium supplemented with growth regulators) and the cultures could be maintained in vitro (standard culture conditions) for 6 months without any subculture. Application of cryogenic techniques for conserving nuclear genetic diversity of rare, endangered and threatened plant species sourced from wild habitats would enable extended use of the male gametophyte for providing access to the conserved nuclear genetic variability, biotechnology research besides genetic enhancement of derived crops. The pollen of *M. dioica* can be stored at 0° C for 45 days (Islam and Khan 1998) but pollens showed little tolerance under long-term freezing conditions (−5 °C). However, the pollen viability was determined based on aceto-carmine staining which is not a vital stain (Lebeda et al. 2006). Cryopreserved pollen (−196 °C) of *M. dioica* and *M. sahyadrica* showed 67–74 % germination after 48 h (Rajashekaran et al. 2010).

By establishing a few genetic reserves in selected protected areas in the Western Ghats, North–East and Andaman Islands *Momordica* species can be afforded in situ protection. Good populations of *M. balsamina* thrive in Machia safari park, Jodhpur, Rajasthan, India. Artificial seeding and in situ protection in sacred groves, especially for *M. dioica* needs consideration in the light of its endangerment especially in coastal lowlands in Kerala. Several tribal families across India were found to grow various species of wild *Momordica* in their homesteads

in a simulated in situ condition. Often in the case of *M. dioica* and *M. sahyadrica*, the planting material, i.e. tuber is collected from the forest. *M. charantia* var. *muricata* being exclusively seed propagated, domestication attempts have progressed further. Hence, the conservation of semi-domesticates and pre-domesticates in home gardens is a viable option.

Momordica species including balsam pear, balsam apple, spine gourd and sweet gourd are treated as ornamentals in Europe and America, where it is grown in glasshouses since Victorian times for its beautiful foliage, pendant orange ripe fruits embedded in green foliage and star-like configuration of bursting fruits (Walters and Decker-Walters 1988; Robinson and Decker-Walters 1997). Miniature fruited *M. charantia* var. *muricata* and *M. balsamina* have beautiful foliage and orange red fruits. *M. dioica* has musky scented flowers and *M. sahyadrica* has large showy yellow flowers in profusion, besides both have ivy-like beautiful foliage and pendant fruits turning orange and bursting in star-like configuration. All this offers scope for adoption by urban gardeners, thus giving another dimension to on-farm conservation.

It has been observed that in primitive societies, gathering of wild vegetables is usually done by women. Often they do this while collecting firewood or fodder, which is a regular work, carried out by tribal women. On-farm conservation is carried out by them intentionally or unknowingly. As it is always the women who cook food, it is she who disburses mature or ripe seeds, some of which germinate and develop as new plants.

A careful breeding strategy involving extensive field survey in the fruiting season followed by rescue collection and seed multiplication in on-farm sites and a subsequent ex situ approach is needed for the conservation of variability in semi-domesticate landraces of *M. charantia* var. *muricata*. Artificial seeding and rehabilitation in sacred grooves may be attempted for *M. dioica* in coastal Kerala. Establishment of genetic reserves inside protected areas must be attempted for conserving diversity in *M. dioica* and *M. sahyadrica* in the Western Ghats. Ex situ conservation in home gardens and on-farm conservation in tribal homesteads in forest pockets is a viable option for conservation of *Momordica* gene pool as the taxa are still wild or semi-domesticate with high dependence on biotic agents for pollination and seed dispersal. Popularisation as ornamental plants and kitchen garden vegetables will enhance survival of the taxa and establishment of farms for tuber production will reduce pressure on wild population.

The study of genetic diversity, population ecology and conservation of *Momordica* species is inadequate and limited. As all wild *Momordica* species are potential vegetables besides genetic resources of bitter gourd, sweet gourd and spine gourd, IPGRI through AVRDC should initiate a collection and ex situ conservation programme for all the Asiatic wild *Momordica* species. A good representation of diversity in *M. charantia* has been assembled from India though there are still a few grey areas to be explored more intensely. However, other species and areas need extensive coverage. In the absence of any earlier attempt to collect and conserve this diversity, immediate steps need to be taken in this direction. This perhaps also serves as introspection to the poor state of wild *Momordica* gene pool collection and conservation in the National Agricultural Research System (NARS).

There is a need to conserve the highly heterozygous germplasm of dioecious species by establishing field gene banks. Further, under MTA, it should be made available to gene banks across South and SE Asia for domestication and utilisation. *M. clarkeana, M. denticulata, M. rumphii* (all SE Asia-Malesia) and *M. denudata* (Sri Lanka) need special attention. AVRDC/National agricultural research agencies should develop a strategy for (a) an update of conservation (ex situ) status of wild *Momordica* genetic resources, (b) ex situ regeneration protocol for rare endemics, (c) regulated supply of genuine planting materials to researchers across nationality borders under MTA, (d) clear and concise distribution maps for individual species based on field and herbarium survey and (e) a database on ethno-botanical uses of various species by aboriginal people.

References

Anonymous (1997) ICUN red list of threatened plants, p 230

Arora RK (1998) Plant genetic resources of north eastern region: diversity domestication trends, conservation and uses. Proc Indian Natl Sci Acad 63:175

AVGRIS (2009) AVRDC vegetable genetic resources information system. http://203.64.245.173/avgris/. Accessed 11 Feb 2009

Behera TK (2004) Heterosis in bitter gourd. In: Singh PK, Dasgupta SK, Tripathi SK (eds) Hybrid vegetable development. Haworth Press, New York, pp 217–221

Behera TK, Gaikwad AB, Singh AK, Staub JE (2008a) Relative efficiency of DNA markers (RAPD, ISSR and AFLP) in detecting genetic diversity of bitter gourd (*Momordica charantia* L.). J Sci Food Agric 88:733–737

Behera TK, Singh AK, Staub JE (2008b) Comparative analysis of genetic diversity of Indian bitter gourd (*Momordica charantia* L.) using RAPD and ISSR markers for developing crop improvement strategies. Sci Hortic 115:209–217

Behera TK, Joseph JK, Bharathi LK, Karuppaiyan R (2011) Momordica. In: Kole C (ed) Wild crop relatives: genomic and breeding resources. Springer, Netherlands. ISBN 978-3-642-20449-4, pp 217–246

Bettencourt E, Konopka J (1990) Directory of crop germplasm collections. 4. Vegetables. IBPGR, Rome, p 147

Bharathi LK, Naik G, Dora DK (2005) Genetic divergence in spine gourd (*Momordica dioica* Roxb.). Veg Sci 32:179–181

Bharathi LK, Munshi AD, Behera TK, Joseph JK, Vishalnath, Bisht IS (2010) Genetic resources of spine gourd (*Momordica dioica* Roxb. Ex Willd.): an underexplored nutritious vegetable from tribal regions of eastern India. Plant Genet Resour 8:225–228

Bharathi LK, Munshi AD, Behera TK, Vinod, Joseph JK, Bhat KV, Das AB, Sidhu AS (2012a) Production and preliminary characterization of novel inter-specific hybrids derived from *Momordica* species. Curr Sci 103:178–186

Bharathi LK, Parida SK, Munshi AD, Behera TK, Raman KV, Mohapatra T (2012b) Molecular diversity and phonetic relationship of *Momordica* spp. of Indian occurrence. Genet Resour Crop Evol 59:937–948

Bootprom N, Songsri P, Suriharn B, Chareonsap P, Sanitchon J, Lertrat K (2012) Molecular diversity among selected Momordica cochinchinensis (Lour.) Spreng accessions using RAPD markers. SABRAO J Breed Genet 44:406–417

Borokini TI, Okere AU, Giwa AO, Daramola BO, Odofin WT (2010) Biodiversity and conservation of plant genetic resources in field Genebank of the National Centre for Genetic Resources and Biotechnology, Ibadan, Nigeria. Int J Biodiversity Conserv 2:37–50

Botau D, Ciulca S, Frant A (2010) The variability study of some quantitative traits at *Momordica charantia* L. Bull UASVM Hortic 67:230–234

Changyuan Z, Ni S, Kailin H (2005) RAPD analysis in genetic relationship among varieties of balsam pear. Mol Plant Breed 3:515–519

Chung SM, Staub JE (2004) Consensus chloroplast primer analysis: a molecular tool for evolutionary studies in Cucurbitaceae. In: Lebeda A, Paris HS (eds) Proceedings of Cucurbitaceae 2004, 8th EUCARPIA meeting on Cucurbit genetics and breeding. Palacky University, Olomouc, Czech Republic, pp 477–483

Dalamu, Behera TK, Gaikwad AB, Swati S, Bharadwaj C, Munshi AD (2012) Morphological and molecular analyses define the genetic diversity of Asian bitter gourd (*Momordica charantia* L.) Australian J Crop Sci 6:261–267

Dey SS, Singh AK, Chandel D, Behera TK (2006) Genetic diversity of bitter gourd (*Momordica charantia* L.) genotypes revealed by RAPD markers and agronomic traits. Sci Hortic 109:21–28

Diez MJ, Pico B, Nuez F (2002) Cucurbit genetic resources in Europe. Ad hoc meeting, 19 Jan 2002, Adana, Turkey. International Plant Genetic Resources Institute, Rome, Italy

Dwivedi SN (1999) Traditional health care among tribals of Rewa district of Madhya Pradesh with special reference to conservation of endangered and vulnerable species. J Econ Taxon Bot 2:315–320

Gaikwad AB, Behera TK, Singh AK, Chandel D, Karihaloo JL, Staub JE (2008) AFLP analysis provides strategies for improvement of bitter gourd (*Momordica charantia*). HortScience 43:127–133

Ghosh SP, Kalloo G (2000) Genetic resources of indigenous vegetables and their uses in South Asia. Technical Bulletin No 4, IIVR, Varanasi, UP, India, pp 36–37

Harlan JR, de Wet JMT (1971) Toward a rational classification of cultivated plants. Taxon 20: 509–517

Harriet G (2002) Conservation and sustainable use of medicinal plants in Ghana medicinal plant accession data. Aburi Botanic Garden, Botanic Gardens Conservation International, Ghana, 53 p

Heywood V (1998) Conservation and sustainable use of wild species of importance in Human activities. In: Proceedings of international conservation conference, The Jawaharlal Nehru Tropical Botanic Garden and Research Institute (TBGRI), Thiruvananthapuram

Horvath L (2002) Status of the national cucurbit collection in Hungary. In: Diez MJ, Pico B, Nuez F (eds) First ad hoc meeting on cucurbit genetic resources, Adana, Turkey, 30 p

Islam MS, Khan S (1998) Pollen viability of *Momordica dioica* Roxb. as affected by storage period and temperature. Bangladesh J Bot 27:153–155

Islam MR, Hossain MS, Bhuiyan MSR, Hasan GN, Syed A (2010) Multivariate analysis of bitter gourd (*Momordica charantia* L.). Middle-East J Sci Res 5:86–90

Jha UC, Ujawane RG (2002) Collection, evaluation and utilization of *Momordica* species. Contributed paper in the international seminar on vegetables at Bangalore

Joseph JK (2005) Studies on ecogeography and genetic diversity of the genus *Momordica* L. in India. Dissertation, Mahatma Gandhi University, Kottayam

Joseph JK, Antony VT (2007) A quantitative analysis of genetic erosion in the genus *Momordica* L. in South Peninsular India. Indian J Plant Genet Resour 20:186–192

Joseph JK, Antony VT (2009) Collection and preliminary evaluation of small bitter gourd (*Momordica charantia* L.) a relict vegetable of Southern Peninsular India. Genet Resour Crop Evol 56:99–104

Joseph JK, Antony VT (2011) Developing descriptors for dioecious *Momordica* species for germplasm characterization and evaluation. Indian J Plant Genet Resour 24:31–39

Joshi V, Gautham PL, Bhagmal, Sharma GD, Kochhar S (2002) Conservation and use of underutilized crops. An Indian perspective. In: Engles JMM, Ramanatha Rao V, Brown AHD, Jackson MT (eds) Managing plant genetic diversity, IPGRI, Rome

Karlova K (2008) Cucurbitaceae genetic resources in the Czech gene bank. Current status of the collection. In: Pitrat M (ed) 9th EUCARPIA meeting on genetics and breeding of Cucurbitaceae, INRA, Avignon, France, 21–24 May 2008

Kole C, Olukolu B, Kole P, Abbott AG (2009) Characterization of a *Momordica charantia* germplasm with AFLP and SSR markers. In: Molecular markers in horticulture symposium, Oregon State University, Corvallis, 29 July–1 Aug 2009

Kole C, Olukolu BA, Kole P, Abbott AG (2010a) Towards phylomedomics with bitter melon (*Momordica charantia* L.) as a model. In: International conference on the status of plant and animal genome research, San Diego, CA, USA, 9–13 Jan 2010, p 164

Kucuk A, Abak, K, Sari N (2002) Cucurbit genetic resources collections in Turkey. In: Diez MJ, Pico B, Nuez F (eds) First ad hoc meeting on cucurbit genetic resources, Adana, Turkey, p 46

Lebeda A, Widrlechner MP, Staub J, Ezura H, Zalapa J, Kristkova E (2006) Cucurbits (Cucurbitaceae; *Cucumis* spp., *Cucurbita* spp., *Citrullus* spp.) In: Ram J Singh (ed) Genetic resources, chromosome engineering and crop improvement, vol 3-Vegetable crops. CRC Press, Taylor and Francis group, Boca Raton, pp 271–376

Liao PC, Tsai CC, Chou CH, Chiang YC (2012) Introgression between cultivars and wild populations of *Momordica charantia* L. (Cucurbitaceae) in Taiwan. Int J Mol Sci 13:6469–6491

Marr KL, Xia YM, Bhattarai NK (2004) Allozyme, morphological and nutritional analysis bearing on the domestication of *Momordica charantia* L. (Cucurbitaceae). Econ Bot 58:435–455

Paul A, Bandyopadhyay S, Acharyya P, Raychaudhuri SS (2010) Studies on genetic diversity of twelve accessions of *Momordica charantia* L. using morphological, RAPD and Scar markers. Asian J Plant Sci 9:471–478

Piskunova T (2002) Status of the cucurbit collections in Russia. In: Diez MJ, Pico B, Nuez F (eds) First ad hoc meeting on cucurbit genetic resources. Adana, Turkey, 19 Jan 2002, pp 37

Promote P, Pornthip P, Numuen C (2011) Phenotypic diversity and classification of Thai bitter melon (*Momordica charantia* L.) land races from three provinces in central region of Thailand. J Agric Technol 7:849–856

Raj NM, Prasanna KP, Peter KV (1993) Bitter Gourd. In: Kalloo G, Bergh BO (eds) Genetic improvement of vegetable plants. Pergamon Press, Oxford, UK, pp 239–246

Rajashekaran PE, Sunitha B, Joseph JK, Eapen KP, Antony VT (2010) Pollen cryopreservation feasibility studies in *Momordica dioica* and *M. sahyadrica*. IUP J Genet Evol 3:53

Rajashekaran PE, Sunitha B, Joseph JK, Eapen KP, Antony VT (2011) In vitro multiplication and conservation of Wild *Momordica sahyadrica*. IUP J Biotechnol 6:50–56

Ram D, Srivastava U (1999) Some lesser known minor cucurbitaceous vegetables: their distribution, diversity and use. Indian J Plant Genet Resour 12:307–316

Ram D, Banerjee MK, Pandey S, Srivastava U (2001) Collection and evaluation of kartoli (*Momordica dioica* Roxb. Ex. Willd.) Indian J Plant Genet Resour 14:114–116

Ram D, Kumar S, Banerjee MK, Singh B, Singh S (2002) Developing bitter gourd *(Momordica charantia* L.) populations with very high proportion of pistillate flowers. Cucurbit Genet Coop Rep 25:65–66

Rasul MG, Okubo H (2002) Genetic diversity in teasel gourd (*M. dioica* Roxb.) Bangladesh. J Plant Breed Genet 15:7–15

Rasul MG, Hiramatsu M, Okubo H (2004) Morphological and physiological variation in Kakrol (*M. dioica* Roxb.) J Fac Agric Kyushu Univ 49:1–11

Rasul MG, Hiramatsu M, Okubo H (2007) Genetic relatedness (diversity) and cultivar identification by randomly amplified polymorphic DNA (RAPD) markers in teasel gourd (*Momordica dioica* Roxb.). Sci Hortic 111:271–279

Rathod V, Narasegowda NC, Papanna N, Simon L (2008) Evaluation of genetic diversity and genome fingerprinting of bitter gourd genotypes (*Momordica charantia* L.) by morphological and RAPD markers. Int J Plant Breed 2:79–84

Robinson RW, Decker-Walters DS (1997) Cucurbits. CABI Publishers, Wallingford, pp 97–101

Schaefer H, Renner SS (2010) A three-genome phylogeny of *Momordica* (Cucurbitaceae) suggests seven returns from dioecy to monoecy and recent long-

distance dispersal to Asia. Mol Phylogenet Evol 54:553–560

Sikdar B, Bhattacharya A, Mukherjee A, Banerjee A, Ghosh E, Ghosh B, Roy SC (2010) Genetic diversity in important members of Cucurbitaceae using isozyme, RAPD and ISSR markers. Biol Plantarum 54:135–140

Singh AK, Behera TK, Chandel D, Sharma P, Singh NK (2007) Assessing genetic relationships among bitter gourd (*Momordica charantia* L.) accessions using inter simple sequence repeat (ISSR) markers. J Hortic Sci Biotechnol 82:217–222

Sirohi PS, Choudhury B (1983) Diallel analysis for variability in bitter gourd (*Momordica charantia* L.) Indian J Agric Sci 53:8–88

Srivastava U, Mahajan RK, Gangopadyay KK, Singh M, Dhillon BS (2001) Minimal descriptors of agri-horticultural crops. Part-II: Vegetable crops. NBPGR, New Delhi, India, pp 61–66

Vishalnath, Mandal S, Bharathi LK, Naik G, Singh HS (2008a) CHTG 2 (Neelachal Gaurav): a soft-seeded teasel gourd variety. ICAR News 14:15

Vishalnath, Mandal S, Bharathi LK, Naik G, Singh HS (2008b) CHSG 28 (Neelachal Shree): an elegant spine gourd variety. ICAR News 14:15

Walters TW, Decker-Walters DS (1988) Balsam pear (*Momordica charantia*, Cucurbitaceae). Econ Bot 42:286–288

Walter R, Epperson BK (2001) Geographic pattern of genetic variation in *Pinus resinosa*: area of greatest diversity is not the origin of postglacial populations. Mol Ecol 10:103–111

Wang SZ, Pan L, Hu K, Chen CY, Ding Y (2010) Development and characterization of microsatellite markers in *Momordica charantia* (Cucurbitaceae). Am J Bot 97:e75–e78

Yadav M, Singh DB, Chaudhary R, Singh D (2008) Genetic variability in bitter gourd (*Momordica charantia* L.). J Hortic Sci 3:35–38

Zuberi ML, Biswas A (1998) Biodiversity degradation in Bangladesh: wild kakrol (*Momordica dioica* Roxb.) an endangered species. Asia Pac J Environ Develop 5:66–74