Chapter 10
Momordica

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10.1 Introduction

The genus name *Momordica* derives from the Latin word "mordeo" (means to bite) in allusion to the jagged seeds as bitten; ironically species such as *Momordica balsamina* L. do not follow this generic character. Generic and species descriptions (along with keys in some cases) are found in various monographic and floristic treatises (Willdenow 1805; Blume 1826; Seringe 1828; Wight and Walker-Arnott 1841; Thwaites 1864; Hooker 1871; Clarke 1879; Keraudren-Aymonin 1975; Jeffrey 1980). It got a prominent mention in van Rheede's Hortus Malabaricus (1678; Vol. 8), the oldest regional flora for any part of the world with descriptions and plates. Many of the provincial (regional) flora also provide a small description of various *Momordica* species. *Momordica charantia* L. (commonly known as bitter gourd, karela or balsam pear or bitter melon) is the most widely cultivated species of *Momordica*. It is grown in India, Sri Lanka, Philippines, Thailand, Malaysia, China, Japan, Australia, tropical Africa, South America, and the Caribbean. Bitter gourd is consumed regularly as part of several Asian cuisines and has been used for centuries in ancient traditional Indian, Chinese, and African pharmacopoeia. It is a common cucurbit in the wild flora of Africa, occurring almost throughout tropical Africa and occasionally collected from the wild as a vegetable or medicinal plant. Other species, apart from their importance as wild relatives of bitter gourd, have direct utility as nutritious vegetables and multipurpose medicinal plants. Species of *Momordica* have been in use in indigenous medical systems in various countries in Asia and Africa. In India, all the *Momordica* species are being grown in wild and/or cultivated forms. Their cultivation is restricted to specialized geographical pockets in different agrogeographical regions mainly by tribals and poor farming communities. The wild species offer great resources for breeding of cultivated bitter gourd for desirable edible/qualitative traits (such as non-bitterness), tolerance to abiotic stresses (e.g., tolerance to drought), and resistance to several insect pests. Besides their use in improvement of bitter gourd, they have great potential to be exploited as alternative crops.

10.2 Basic Botany of the Species

10.2.1 Taxonomy

Momordica belongs to the tribe Joliffieae, family Cucurbitaceae (Jeffrey 1980) and is native to the Paleotropics (Robinson and Decker-Walters 1997). No comprehensive monographs covering its taxonomy and nomenclature are known to exist. Botanists have described over 150 species of *Momordica*. Taxonomic confusion exists because of the widespread use of common names. Schafer (2005) considers the genus *Momordica* to comprise 47 species including eight Asian species, which are all dioecious, and 39 African species of which 20 are dioecious and 19 monoecious. According to de Wilde and Duyfjes (2002), 10 species are reported in Southeast Asia, of which six occur in Malaysia and India (Fig. 10.1), where *M. balsamina* L.,

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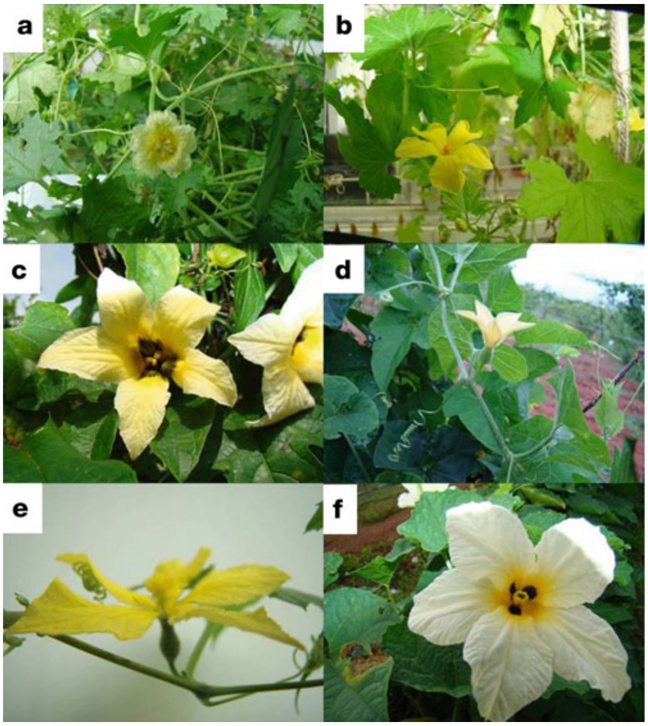

Fig. 10.1 Six different species of *Momordica* of Indian occurrence. (**a**) *M. balsamina*, (**b**) *M. charantia*, (**c**) *M. cochinchinensis*, (**d**) *M. dioica*, (**e**) *M. sahyadrica* and (**f**) *M. subangulata* ssp *renigera*

M. charantia L., *M. subangulata* Blume (ssp. *renigera* (G. Don) W. J. de Wilde), and *M. cochinchinensis* (Lour.) Spreng. are common. A few species have been described recently (Thulin 1991; de Wilde and Duyfjes 2002; Jongkind 2002; Joseph John and Antony 2007), and some of the species described by earlier workers were subsequently relegated to sub-specific status or as synonyms. As evident, there is no clarity and consensus on the interspecific taxonomy of the genus, and the botanical names and common names are often used incorrectly or interchangeably (Joseph John et al. 2007).

10.2.2 Morphology

The botanical description of different *Momordica* spp. is not systematic and scanty information is available in the literature. The information related to morphological features and distribution of a few important *Momordica* spp. is described below.

2.1.1. *M. angustisepala* Harms: A large forest climber occurs in Ghana, South Nigeria and Camaroun. The plant is cultivated in Ghana for its stem, which is used for washing sponge.

2.1.2. *M. anigosantha* Hook. f.: A perennial dioecious sparingly hairy climber with pedately five foliate leaves and male flowers in pseudopanicles. Petals are creamish white to apricot orange, the lowermost largest with a horseshoe shaped marking on the claw (male flower). Fruits fleshy 4.5–6.5 × 1.6–3.8 cm, fusiform, beaked bright red ornamented with fleshy tubercles in eight longitudinal rows. It is distributed in tropical Africa.

2.1.3. *M. balsamina* L.: An annual, monoecious herbaceous climber with small lobed leaves and ovoid ellipsoid softly warted fleshy fruits. It is essentially an African species with distribution extending to western India through West Asia. Endowed with medicinal properties, it is a wild gathered vegetable (leaves and tender fruits) and has the potential as an ornamental.

2.1.4. *M. boivinii* Baill.: A monoecious perennial with a tuberous root and annual herbaceous stem. Flowers orange, fruits fleshy, elongated, fusiform cylindrical 2.3–10 × 0.4–0.9 cm longitudinally angled or ribbed. The plant is used as camel fodder, and roots are used in folk medicine. Distributed in Kenya, Tanganyika, and Uganda.

2.1.5. *M. calantha* Gilg: A monoecious perennial climber with tuberous rootstocks and herbaceous stem. Leaf broadly ovate, triangular in outline. Male flowers in umbels; corolla white or tinged pale orange with black centre. Fruits shortly stalked, fleshy, velvety reflexed strap-shaped receptacle lobes. The fruits are used as a vegetable, animal feed, folk medicine, and the plant is used for soil conservation. Distributed in Kenya, Tanganyika, and Uganda.

2.1.6. *M. cardiospermoides* Klotzsch: A monoecious glabrous perennial climber with tuberous rootstock and annual stems. Leaves two ternately compound. Male flowers solitary, flowers 5 cm in diameter, yellow with a purple eye. Fruit ovoid–oblong, acute 10 cm long, fleshy, orange–red when ripe. The leaves are used as a vegetable and in folk medicine. Distributed in Tanzania, Malawi, Zambia, Zimbabwe, Mozambique, and Botswana, down to Swaziland and South Africa.

2.1.7. *M. charantia* L.: An annual monoecious herb with lobed leaves and ovoid–ellipsoid to elongate fruits varying in size from 5 to 500 g. Fruit surface is clothed with crocodile-back-like tubercles and murication. The small-fruited form *M. charantia* var. *muricata* is wild in India and parts of Nepal and also cultivated to some extent in India for its fruits esteemed with medicinal and culinary properties. The large-fruited form M. *charantia* var. *charantia* shows extreme variability in fruit size, shape, and color and is cultivated in whole of South and Southeast Asia.

2.1.8. *M. cissoides* Planch.: A dioecious glabrous extensive climber with three foliately compound leaves and large (2.5–5 cm in diameter) floral bract. Male flowers crowded. Flowers white with black eye. Fruits ovoid, narrowed at both ends densely clothed with spreading pubescent spines. The leaves are used in folk medicine and kernels are used as a food. Distributed in upper Guinea and Sierra Leone.

2.1.9. *M. clarkeana* King: A dioecious perennial climber with simple leaves and ovoid broadly round beaked fruits, 4.5–7 × 3.5–5 cm. Pericarp hard leathery with smooth surface turning orange on ripening. Distributed in peninsular Malaysia.

2.2.10. *M. cochinchinensis* (Lour.) Spreng.: A dioecious, stout perennial with tuberous roots and palmately lobed gland dotted leaves (petiole). Flowers light cream to white with purple–black bull's-eye mark on three inner petals. Fruits very large weighing 350–600 g or more and is used as a vegetable (sweet gourd). It occurs wild in India (Andaman Islands, northeastern states), Philippines, Vietnam, Thailand and is cultivated in Vietnam, Japan, and other Asian countries for its fruits endowed with many medicinal properties.

2.1.11. *M. corymbifera* Hook.f.: A monoecious foetid perennial climber with a large woody tuberous rootstock and slender stem. Leaves palmately three-lobed, pubescent on both sides. Male flowers in 6–8 flowered corymbs, inconspicuously bracteate. Flowers yellow, petals unequal, 2 much large and very concave. Fruit 9 × 5 cm, ellipsoid, shortly rostrate with 16 longitudinal ridges. Distributed in Mozambique.

2.1.12. *M. dioica* Willd.: A dioecious tuberous perennial with ornamental lobed or unlobed small leaves. Flowers are small lemon yellow sweetly scented and open in the evening. Fruits are small, broadly ovoid–oblong clothed with soft spines. It is a wild gathered vegetable (tender fruits) and medicinal plant native of Peninsular India and has the potential for cultivation as a crop.

2.1.13. *M. denticulata* Miq.: A dioecious perennial allied to *M. cochinchinensis*, leaves entire 7–9 × 12–15 cm, not foetid. Male flowers solitary or grouped in racemes. Petals creamy white, elliptic–oblong, 3.0–5.0 cm long. Fruits ovoid ellipsoid, oblong, apex beaked, 8–14 × 5–10 cm, pericarp leathery without ornamentation or with fine sandpaper-like murication. Distributed in North and Central Sumatra, Peninsular Malaysia, and Borneo.

2.1.14. *M. denudata* Thwaites: A perennial, dioecious delicate herb with a tuberous root. Leaves simple, ovate–lanceolate, 4.5–2.5 × 3.5–8.0 cm. Male flowers on branched peduncles, bracts minute, petals yellow, broadly lanceolate, ca. 10 mm long. Fruits broadly ovoid, 3.0–3.5 × 2 cm, beaked. Endemic to Sri Lanka.

2.1.15. *M. foetida* Schumach: A dioecious, perennial climber rooting at nodes and with dark green, flecked stem and simple leaves. Fruit is a long stalked ellipsoid berry with densely soft spiny exocarp, 7 × 5 cm. It is widely distributed in tropical Africa and occasionally cultivated in its native area for leaves, and tender fruits are used as a vegetable and also in traditional medicine.

2.1.16. *M. friesiorum* (Harms) C. Jeffrey: A dioecious perennial climber with a tuberous rootstock and 3–5 foliate, pedately compound leaves. Petals pale yellow with a dark base. Fruits 6 × 2 cm, fusiform, rostrate, longitudinally ridged or winged turning orange and dehiscing in to three valves when ripe. Roots are used in the treatment of Malaria. Distributed in Kenya, Tanganyika, Uganda, Ethiopia, Tanzania, and Malawi.

2.1.17. *M. glabra* A. Zimm.: A monoecious herbaceous climber with simple to shallowly trilobed leaves (5.5–8.5 × 5.0–7.0 cm). Male flowers 5–7 in subumbels, subtended by a sessile broad bract. Corolla zygomorphic; petals 1.3–2.0 × 0.2–0.3 cm. Fruit ovoid, green with eight fleshy longitudinal undulated ridges. Distributed in Tanganyika and Zanzibar.

2.1.18. *M. kirkii* (Hook. f.) C. Jeffrey: A monoecious herbaceous climber with a perennial rootstock. Leaves membranous, orbicular, cordate, obscurely 3–5 angled, lobes entire or margins toothed. Male flowers 1–4 subumbellate subtended by a broad foliar bract. Male flowers larger than female, corolla orange 1.5–2.0 × 0.7–1.0 cm in male and 1.0–1.1 × 0.7–0.8 cm in female. Fruit fleshy, fusiform, pubescent, and beaked, 2.4–3.2 × 0.4–0.6 cm, ribbed, crowned with persistent receptacle. Distributed in Tropical Africa and Mozambique.

2.1.19. *M. leiocarpa* Gilg: A dioecious climber with dark green flecked stem and broadly ovate cordate leaves, 8.5–14 × 7.0–13.0 cm. Male flowers caducous 2–7 fasciculate subtended by a broad bract. Anthesis occurs in the evening. Petals apricot orange, rounded, slightly apiculate 2.8–3.7 × 1.9–3.0 cm. Fruits fleshy, ovoid ellipsoid with eight conspicuous remotely serrate longitudinal wings or ridges. Distributed in Kenya and Tanganyika.

2.1.20. *M. littorea* Thulin: A monoecious climber with a tuberous woody rootstock and hastate leaves and orange yellow flowers. Fruits subterate, 1.7–2.2 × 0.15–0.35 cm, dry when mature one seeded. Distributed in Ethiopia, Kenya, and Somalia.

2.1.21. *M. multiflora* Hook. f.: A monoecious medium climber with cordate simple leaves and male flowers in many flowered pseudopanicles. Fruits cylindrical 11 × 3.5 cm, longitudinally striped, shortly beaked and covered with persistent floral bracts. Essentially a tropical African species distributed in upper and lower Guinea and Angola.

2.1.22. *M. parvifolia* Cogn.: A dioeciuos medium-sized climber with broadly ovate–cordate simple or palmately lobed leaves. Male flowers in many flowered pseudopanicles, flowers white with black nerves below (petals). Fruits cylindrical, longitudinally ribbed, 11 × 3.5 cm. Distributed in Tropical Africa.

2.1.23. *M. peteri* A.Zimm.: A dioecious, robust perennial with biternately pedate 6–9 foliate leaves (5.5–7.0 × 3.2–4.8 cm) and gland dotted petioles. Male flowers subumbellate, subtended by a large bract with numerous stalked obconic reddish disc-glands on its upper surface. Flowers creamy to brownish yellow with a dark eye. Petals 2–2.1 × 0.9–1.0 cm. Fruits fleshy ovate pyriform 7.0–11.2 × 4.2–7.3 cm with eight longitudinal rows of elongate tubercles and smaller ones in the interspace. Distributed in Kenya and Tanganyika.

2.1.24. *M. pterocarpa* Hochst.: A dioecious robust perennial with a tuberous rootstock and pedately 3–5 foliate leaves. Male flowers 4–18, subumbellate, petals yellow. Fruit ellipsoid, beaked with 8 ± 1 longitudinal toothed wings or ridges, fleshy bright orange (when ripe). Leaf sap and dried root tubers are used in folk medicine. Distributed in Tropical Africa – Abyssinia and Nile.

2.1.25. *M. repens* Bremek.: A monoecious climber with a perennial rootstock and deeply cordate, multilobate leaves, 1.3–3.1 × 3.4–5.5 cm. Male flowers 3–5 in subumbels subtended by a foliar bract. Petals 1.4–3.6 cm long, yellow, dark-veined fruit 5–6 × 4–7 cm, ellipsoid to subglobose, rostrate with ten longitudinal ribs and murication on surface. Distributed in South Africa, Botswana, and Zimbabwe.

2.1.26. *M. rostrata* A. Zimm.: A dioecous tuberous perennial with a woody stem and pedately 5–12 foliate leaves. Male flowers in an umbel-like cluster. Fruit is an ovoid berry 3–7 × 1.5–3 cm, beaked rounded or slightly angled bright red with many seeds embedded in yellow pulp. The leaves and fruits are used as vegetables, and the leaves and stem serve as a fodder especially for donkeys and the leaves are also used in traditional medicine. Distributed in Tropical Africa.

2.1.27. *M. rumphii* W.J. de Wilde: A dioecious slender perennial with three foliate leaves, 8–11 cm diameter, male flowers solitary occasionally three per node. Petals elliptic–oblong, 1.3–1.5 × 6 cm fruit broadly ovoid–ellipsoid or subglobose, beaked, 4.5 × 4.0 cm, sparsely muricate on surface. Distributed in West Seram and Ambon.

2.1.28. *M. sahyadrica* Joseph John and Antony: A robust dioecious perennial, rainy season climber endemic to Western Ghats of India. Leaves are triangular-cordate and has large showy yellow flowers and fairy large softly spinicent (50 g) fruits. The fruits are esteemed as a vegetable and have potential for domestication as a high value vegetable.

2.1.29. *M. sessilifolia* Cogn.: Herbaceous monoecious climber with a tuberous woody rootstock. Leaves hastate, amplexicaul. Male flowers solitary occasionally two per node. Fruit 17–22 mm long and 1.5–3.5 mm diameter, dry when mature, subterete, slightly constricted at about one third of its length from the base.

2.1.30. *M. spinosa* (Gilg) Chiov.: A dioecious perennial climber with a woody tuberous rootstock and a pair of blunt spine at each node. Leaves subpentagonal to suborbicular in outline, 7.0–7.2 × 2.3–5.8 cm, shallowly three lobed. Male flowers in many flowered fascicles, petals yellow, rounded above, 1.0–1.1 × 0.6 cm with three inner petals having black basal markings. Fruit ovoid, beaked, yellow–orange, 7.0 × 3.5 cm, ornamented with ten longitudinal ribs. Distributed in Ethiopia, Somalia, and Kenya.

2.1.31. *M. subangulata* Blume: A dioecious rainy season climber, perennating with both taproot and adventitious tubers. It has two subspecies: *M. subangulata* subspp. *subangulata* and *M. subangulata* subspp. *renigera*. The former is more robust and is cultivated and wild in submontane Himalayas, whereas the latter is a delicate herb restricted to Malaysia and Southeast Asia. Both have large showy creamy flowers with a purple bull's-eye blotch on three inner petals. Fruits are ridged prominently in the former and remnant in the latter. Fruits and tender leaves are used as vegetables.

2.1.32. *M.welwitschii* Hook.f.: A monoecious slender climber with membranous leaves 3–5 cm in diameter. Male peduncles slender, minutely bracteate, flowers yellow, 3 cm across. Fruits ovoid, smooth or slightly warted, 2.5–5 cm long. A monoecious slender climber with membranous leaves 3–5 cm in diameter. Male peduncles slender, minutely bracteate, flowers yellow, 3 cm across. Fruits ovoid, smooth or slightly warted, 2.5–5 cm long. Distributed in Tropical Africa, Lower guinea, Angola, and Mozambique.

2.1.33. *Momordica enneaphylla* Cogn.: IUCN (2006) Red Listed as Threatened species from Africa, Gabon, Congo basin, and Cameroon.

10.2.3 Cytology

The monoecious group has $2n = 2x = 22$, whereas the dioecious group has $2n = 2x = 28$. In *M. balsamina*, $n = 11$ was recorded by Whitaker (1933) and McKay (1931), and in *M. charantia*, $2n = 22$ was recorded by McKay (1931) and Bhaduri and Bose (1947). Richharia and Ghosh (1953) reported 14 bivalents at diakinensis and I-metaphase as being distinctly observed in *M. dioica*. In a recent study (Bharathi et al. unpublished), a polyploid chromosome number ($2n = 4x = 56$) has been observed in *M. subangulata* subsp. *renigera* and $2n = 2x = 28$ was observed in *M. sahyadrica* $2n = 2x = 28$.

Yasuhiro Cho et al. (2006) reported that most of the "cultivated kakrol" (most probably *M. subangulata* ssp. *renigera* and not *M. dioica* Roxb. as assigned by the authors) plants in Bangladesh were confirmed to be tetraploid ($2n = 4x = 56$). Polyploidy is normally associated with vigorous growth with large size of vegetative and reproductive plant parts and, in some cases, sterility as well. However, true *M. dioica* has slender and fragile vines (not stout), small-sized floral parts and fruits. The results of previous work on chromosome numbers are summarized in Table 10.1.

Trivedi and Roy (1972) worked out the karyotypes of *M. charantia*, *M. balsamina*, and *M. dioica*.

Table 10.1 Chromosome numbers of some *Momordica* spp.

Species	2*n*	References
Momordica balsamina L.	22	Whitaker (1933), McKay (1931), Roy et al. (1966), Trivedi and Roy (1972)
M. charantia L.	22	McKay (1931), Bhaduri and Bose (1947), Roy et al. (1966), Trivedi and Roy (1972)
M. cohinchinensis (Lour.) Spreng.	28	Jha et al. (1989)
M. denudata C.B. Clarke	28	Beevy and Kuriachan (1996)
M. dioica Wall.	28	Richharia and Ghosh (1953)
M. subangulata Bl.	28	De Sarkar and Majumdar (1993)
M. subangulata ssp. renigera	56	Bharathi et al. (unpublished)
M. sahyadrica	28	Bharathi et al. (unpublished)
M. rostarata	22	Bosch (2004)
M. foetida	44	Mangenot and Mangenot (1957)

They reported that *M. charantia* and *M. balsamina* have almost the same number of median and submedian chromosomes, although the chromosomes of *M. balsamina* are slightly smaller. But the karyotype of *M. dioica* is more asymmetrical than the other above mentioned species. Therefore, it is assumed that *M. dioica* may be the advanced taxon among these three species. The cytological works in other Indian *Momordica* spp. is under progress at the Indian Agricultural Research Institute, New Delhi.

10.3 Conservation Initiatives

Being well distributed and their habitats being intact, the African taxa are reported not to face any imminent threat (Bosch 2004). However, there are a few reports expressing apprehension of *Momordica* spp. as being "endemic," "endangered," or "nearing extinction" in India (Dwivedi 1999; Jha and Ujawane 2002) and neighboring Bangladesh. The only reference to threatened status of *Momordica* is given in 1997 IUCN Red Data Book (Walter and Gillett 1998), where *M. subangulata* Blume from Wynad (Kerala) and South Canara (Karnataka state of India) is accorded "threatened-indeterminate" status. Infact, the species referred to as *M. subangulata* might be *M. sahydrica,* as true *M. subangulata* does not occur in South India (Joseph John and Antony 2007). In Tanzania, *M. pterocarpa* and *M. rostrata* are assessed as vulnerable species (Mitawa et al. 1996).

Field studies in India (Joseph John 2005; Joseph John and Antony 2008c) revealed a grave threat to *M. dioica* in its entire range and *M. sahyadrica* in the Western Ghats of Kerala. Overall, the wild and feral forms of *M. charantia* var. *muricata* face 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 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. In view of their excellent culinary traits and perceived tolerance to biotic and abiotic stresses, these landraces need to be collected and conserved from the whole range of their distribution across India.

Before establishing collection strategy and conservation priorities, the present status of conservation of the genus must be considered. The germplasm holdings in various institutes are presented in Table 10.2.

10.3.1 Collection and Conservation in Ex Situ Gene Banks

Having assessed the genetic erosion status and potential of wild *Momordica* gene pool, different taxa need different level of conservation approach. However, in the absence of any earlier initiative to collect these resources, it is necessary that extensive collection programs be carried out throughout the range of the taxa and the seeds multiplied and stored in ex situ gene banks. The importance of bitter gourd and other *Momordica* species is bound to increase as nutraceuticals (Kole et al. 2010a, b). Fruit fly tolerant lines of *M. charantia* var. *muricata* were abundant in the whole of Peninsular India; some of them still thrive in homesteads as landraces. Rescue collections and rehabilitation in on-farm, thus effecting seed increase leading to gene bank storage is a priority.

10.3.2 In Situ Conservation

Observations of in situ conservation in forest habitats indicate the possibility of setting up genetic reserves for various *Momordica* species in India. In the context of niche requirements, pollinator specificity, and dependence on biotic agents for seed dispersal and possible dormancy break, an ex situ conservation strategy alone may not make much headway. By establishing a few genetic reserves in selected protected areas in Western Ghats, East, North East, and Andaman Islands of India, these species can be afforded in situ protection.

Inventorization is the starting point for in situ conservation. In the absence of inventories, wild species of *Momordica* are not identified or managed as wild crop relatives in the protected areas like any other wild relative. In the context of alien weeds, passive management by according official protection to a forest pocket would not serve to achieve the goals of in situ

Table 10.2 Present status of germplasm holdings in *Momordica* species

S. No	Crop	Number of accessions	Institute	References
1	*M. charantia* var. *charantia*	519	National Gene Bank of NBPGR, New Delhi	Ram and Srivastava (1999)
		1	Institute of Agrobotany, Hungary (ABI)	Horvath (2002)
		15	NI 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 (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)
	M. charantia var. *muricata*	11	National Genebank of NBPGR, New Delhi	Joseph John and Antony (2008a)
2	*M. cissoides*	1	Aburi Botanic Gardens, Ghana	Harriet (2002)
3	*M. foetida*	Few	New York State Agricultural Experiment Station, USA and National Gene Bank, Kenya	Bosch (2004)
4	*M. cochinchinensis*	6	AVRDC, Taiwan	AVGRIS (2009)
		3	Central Horticultural Expt. Station, Bhubaneswar, India	Bharathi et al. (2006b)
		2	Krishna Chandra Mishra Research Institute of Wild Vegetable Crops	Ghosh and Kalloo (2000)
5	*M. dioica*	60	Central Horticultural Expt Station, Bhubaneswar	Vishalnath et al. (2008)
		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)
6	*M. subangulata* ssp. *renigera*	25	Central Horticultural Expt Station, Bhubaneswar, India	Vishalnath et al. (2008)
		< 12	AAU Research Centre, Kahikuchi	Ram et al. (2002)
		2	Krishna Chandra Mishra Research Institute of Wild Vegetable Crops	Ghosh and Kalloo (2000)
7	*M. balsamina*	1	AVRDC, Taiwan	AVGRIS (2009)
		1	NBPGR, New Delhi	Joseph John (2005)
		1	Krishna Chandra Mishra Research Institute of Wild Vegetable Crops	Ghosh and Kalloo (2000)
8	*M. sahyadrica*	10	NBPGR, New Delhi, India	Joseph John (2005)

conservation in the case of *Momordica* species. 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 the Kerala state of India.

10.3.3 In Situ On-Farm Conservation

Cultivation of *M. dioica*, *M. sahyadrica*, and *M. charantia* var. *muricata*, though rare, has been spotted across Western Ghats, India (Joseph John 2005).

Several tribal families across Western Ghats 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 (tuber) is collected from the forest. Non-availability of female tubers, poor seed germination, and non-availability of seedlings seem to be the important factors preventing its domestication and spread. *M. charantia* var. *muricata* being exclusively propagated by seeds, domestication attempts have progressed further and the landrace is known by a name, mostly associated with a trait.

With an increasing agronomic input, yield also increased indicating its adaptability to cultivated ecosystem. Even when only female plants are raised, fruit setting is not affected as indicated by higher yield. Being in the forest ecosystem, the natural ecological processes such as pollination and dispersal ensuring establishment of new plants are not hindered. With a little financial support, selected tribal farmers can be persuaded to continue and extend these on-farm conservation attempts. A strong ethnobotanical component will ensure that conservation goes beyond basic authoritarian protective measures. It will help in developing conservation methods that are egalitarian, in harmony with the environment and satisfy the material and cultural needs of the local people.

Hence, home garden adoption within the distribution range must be attempted. In these on-farm attempts, even though the primary aim of the farmer is economic gain, it effects population increase and thereby conservation. The farmer ensures establishment of the tuber uprooted from the forest, and better management care and non-competition leads to production of higher number of fruits and seeds, a certain percentage of which is returned back to nature, even as the mother plant survives as it was in nature.

10.3.4 Ex Situ Home Garden Conservation

An experiment on home garden conservation was taken up on an exploratory basis to assess the prospects of farmer participation in germplasm conservation (Joseph John 2005). Since the taxa being wild or at the most semi-domesticate, not much information on package of practices for the crop was available. Hence, the farmer was at liberty to experiment with his ideas at all levels of execution of the program in his farm. Being at the wild–domestication interphase, on-farm management was considered ideal, as it involves "continued evolution of the taxa in its natural surroundings." Perpetuation of soil seed bank in homesteads indicates operation of basic ecological processes involving pollinators and dispersal agents. These seedlings upon potting and transplanting lead to further spread of the taxa in homesteads, adding to domestication efforts.

In homesteads adopting a tree-based cropping system, the habitat is ideal for seedbank regeneration as in a forest floor. No tillage and low weed growth under partial shade offer ideal habitat for *Momordica* species. Farmers reported abundant seedling populations in *M. charantia* var. *muricata* and *M. sahyadrica* and good tuber production in *M. subangulata* spp. *renigera*. In majority of the cases, the planting materials reached out to their neighbors and friends in the subsequent season. *M. dioica*, *M. sahyadrica,* and selected germplasm of *M. charantia* var. *muricata*, by virtue of their sustainable yield, quality of the fruits, and ease in cultivation or rationability, offer scope for adoption and consequently conservation in homegardens.

Balsam pear, balsam apple, spine gourd, and sweet gourd are treated as ornamentals in Europe and America, where it was grown in glasshouses since Victorian times for their 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 a star-like configuration. All this offers scope for adoption by urban gardeners, thus giving another dimension to on-farm conservation.

10.3.5 Role of Women in Conservation of Genetic Diversity

It has been observed that in the primitive societies, gathering of wild vegetables are usually done by women. Often, they do this while collecting firewood, 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 woman who cooks food, it is she who throws out mature or ripe seeds, some of which germinates and develop as new plants. Men also collect wild *Momordica* species either for home consumption or for sale. Mostly, this is carried out along with minor forest produce gathering. In addition, they are a storehouse of information related to various uses and culinary preparations involving *Momordica* species. Hence, any in situ on-farm conservation should center on tribal women in hotspots of diversity.

10.4 Role in Elucidation of Origin and Evolution of Allied Crop Plants

Phylogeny of this group has not been studied adequately. This genus is essentially a native of tropical regions of Asia, Polynesia besides tropical Africa. There is no systematic study on the origin of this group, which made Zeven and Zhukovsky (1975) to regard the genus as one of unidentified origin.

Many workers (Degner 1947; Walters and Decker-Walters 1988) consider the smaller wild variety (var. *muricata* synonymous with *M. charantia* var. *abbreviata* Ser.) as the progenitor of cultivated bitter gourd. The original place of domestication of this flagship species, *M. charantia,* is unknown (Li 1970; Marr et al. 2004). The putative areas proposed by various workers include southern China, eastern India (Walters and Decker-Walters 1988; Raj et al. 1993; Marr et al. 2004) and even southwestern India (Joseph John 2005). It is believed to have taken to rest of tropical Asia and Africa and thence to Brazil and rest of tropical South America with the slave trade (Nguyen and Widodo 1999). A recent study (Marr et al. 2004) based on morphological parameters, isozymes, and nutritional profile of domesticates and wild types from southern China, Southeast Nepal, and northern Laos failed to pinpoint the exact place, though strongly suggested a single place of domestication. Admittedly, the handful of collections from Nepal was not true representative of the wide spectrum of variability encountered in India. Further phylogenetic studies with truly representative wild types from the Northeast and Southwest India may help to resolve the enigma.

The dioecious group is characterized by the non-overlapping distribution in India and rest of South Asia. The floral morphology and pollinators were found to be specific for each species (Joseph John 2005). The morphological distinctness in the wild species is not associated with the evolvement of reproductive barriers except for contrasting anthesis time and consequent pollinator specificity. Here, the species delimitation is based on morphology and geographic isolation. All the three taxa fall under the primary gene pool.

The history of evolution of *M. dioica* and *M. subangulata* ssp. *renigera* (referred to as "wild kakrol" and "cultivated kakrol" by Mondal et al. 2006) is not adequately known. *M. dioica* is indigenous to India and possibly evolved in Central India. Trivedi and Roy (1972) have hypothesized *M. dioica* as having possibly originated from *M. charantia*. Morphological similarity and interspecific crossability suggest the origin of *M. subanulata* ssp. *renigera* from *M. dioica* and/or *M. cochinchinensis*. Character combinations suggest that it may be an amphidiploid between *M. dioica* and *M. cochinchinensis*, arising through hybridization and chromosome doubling (Mondal et al. 2006).

M. sahyadrica having wider pollinator choice has assured fertilization and is more advanced and may have evolved from *M. dioica* in the Western Ghats and may be considered as neoendemic. Fruit and seed morphology has much in common between the two. Seed production following crosses between the taxa and its suspected wild progenitor and the normal growth of the hybrids are evidences to support its ancestry (Ladizinsky 1998). The intermediate behavior of F_1 hybrids of *M. dioica* × *M. sahyadrica* for flower size and anthesis time sheds clear light on the variant forms of *M. dioica* occurring in Southeast Mumbai, for which de Wilde and Duyfjes (2002) assign a separate "taxon of uncertain status, probably of hybrid origin."

M. cochinchinensis must have originated in South Asia, probably in the Cochinchina region of Vietnam (from where originally collected and described) and/or the Andaman Islands (where substantial diversity exists). Pre- and post-zygotic reproductive barriers suggest an origin independent of *M. dioica* (Mondal et al. 2006).

The ongoing phylogenetic studies in the genus, based on nuclear, mitochondrial and chloroplast DNA markers being carried out in University of Munich, Germany (Susane Renner personal communication) and in Asian taxa being carried out in Indian Agricultural Research Institute (L.K. Bharathi personal communication) will hopefully clarify the species delimitation and possible origin of these species. A compiled list of *Momordica* species and their synonyms are listed in Table 10.3.

10.5 Role in Crop Improvement Through Traditional and Advanced Tools

The breeding system depends upon the reproduction system of the plant. Information on floral biology is the basic need before setting up a breeding program. There is very little information about the floral biology and genetic system including number of genes and chromosomes, details of meiosis and pairing, breeding system, sex determination and sex modification, and regulation of gene actions in these species except for bitter gourd (*M. charantia*) and to some extent in *M. dioica*.

10.5.1 Sex Form

M. charantia and *M. balsamina* are monoecious annuals, while the tuberous perennials, *M. dioica*, *M. subangulata* ssp. *renigera*, *M. cochinchinensis*, *M. sahyadrica*, *M. foetida*, and *M. rostrata* are dioecious. However, hermaphrodite flowers in *M. dioica* (Jha and Roy 1989), *M. charantia,* and *M. subangulata* ssp. *renigera* (T.K. Behera unpublished) has been observed. Gynoecious lines originating in India were identified by Behera et al. (2006; lines DBGy-201 and DBGy-202) and Ram et al. (2002; line Gy263B) for use in hybrid development programs. Gynoecism in bitter gourd is under the control of a single, recessive gene (*gy*-1) (Behera et al. 2009) and gynoecious inbred, DBGy-201 showed maximum genetic combining ability (GCA) effect for different yield related traits (Dey et al. 2010). Trivedi and Roy (1973) have reported the appearance of various intermediate sex forms such as andromonoecious, gynoecious, and trimonoecious in colchicine-treated plants of *M. charantia*, but remaining as diploids.

10.5.2 Cytology of Sex Differentiation

Richharia and Ghosh (1953) reported the presence of 14 bivalents in *M. dioica*, with a heteromorphic pair disjoining earlier than the other bivalents. Jha (1990) reported the sexual mechanism in *M. dioica* as an incipient type of sexual dimorphism (an intermediate stage toward X/Y chromosome basis), in which a pair of autosomes is responsible for sexual dimorphism. Sinha et al. (2001) reported the presence of a sex-linked 22 kDa polypeptide (p-22) in the female sex, which was not detected in its male counterpart. Moreover, variation in the intensity of 29 kDa and 32 kDa polypeptides of male and female sex forms suggest that the interplay of these two sex-linked polypeptides may be the contributing factor in controlling sex mechanism of dioecious *M. dioica*. Seshadri and Parthasarathi (2002) considered the differentiation of sex in *M. dioica* to be entirely genic or genetical without any cytological evidence of heterogamety.

In *M. charantia*, Wang et al. (1997) found that initially plants bear hermaphroditic bud primordia, which then yields to the hormone-regulated development of either staminate or pistillate flowers. This process is correlated with RNA and protein synthesis where soluble protein profiles of hermaphrodite flower buds, and male and female flowers differ at three early developmental stages (7, 10, and 13 days after initial bud formation) (Wang and Zeng 1998). Two predominant protein bands, 11 and 30 kDa, are present in pistillate and staminate flowers, respectively, and it is speculated that these proteins may be directly associated with sex expression (Wang and Zeng 1998).

10.5.3 Sex Modification

The principle in sex modification in cucurbits lies in altering the sequence of flowering and sex ratio. Foliar sprays with $AgNO_3$ (400 ppm) at pre-flowering stage could induce 70–90% hermaphrodite flowers in *M. dioica* vines (Rajput et al. 1993). Application of

Table 10.3 List of *Momordica* species

SN	Species	Other names
1	*M. angustisepala* Harms	*Momordica bracteata* Hutch. & Dalz.
2	*M. anigosantha* Hook. f.	*Momordica anigosantha* var. hirtella Cogn.
3	*M. angolensis* R. Fern.	
4	*M.balsamina* L.	*Momordica involucrata* E.Mey. ex Sond., *M. schinzii* Cogn.
5	*M. boivinii* Baill.	*Raphanistrocarpus boivinii* (Baill.) Cogn., *R. asperifolius* Cogn.
6	*M. cabrae* (Cogn.) C. Jeffrey	*Dimorphochlamys mannii* Hook.f., *D. cabrae* Cogn., *D. glomerata* Cogn., *D. crepiniana* Cogn.
7	*M. calantha* Gilg	*Peponia umbellata* Cogn., *Peponium umbellatum* (Cogn.) Engl., *M. umbellata* (Cogn.) A. Zimm.
8	*M. camerounensis* Keraudren	
9	*M. cardiospermoides* Klotzsch	*Momordica clematidea* Sond.
10	*M. charantia* L.	*Momordica thollonii* Cogn., *M. chinensis* Spreng., *M. elegans* Salisb., *M. indica* L., *M. operculata* Vell., *M. sinensis* Spreng., *M. zeylanica* Mill., *M. anthelmintica* Schumach., *M. senegalensis* Lam.
11	*M. cissoides* Planch.	*Momordica gracilis* Cogn.
12	*M. clarkeana* King	
13	*M. cochinchinensis* (Lour.) Spreng.	*Muricia cochinchinensis* Lour., *Momordica mixta* Roxb., *M. meloniflora* Hand.-Mazz.; *M. macrophylla* Gage
14	*M. corymbifera* Hook. f.	*Momordica henriquesii* Cogn.
15	*M. dioica* Willd.	*Momordica roxburghii* G. Don, *M. wallichii* M.J. Roem.
16	*M. dissecta* Baker	
17	*M. denticulata* Miq.	*Momordica racemifera* (Miq.) Cogn., *M. denticulata* var. racemifera Miq. *M. acuminata* Merr.
18	*M. denudata* Thwaites	*Momordica dioica* Willd var. *denudata* Thwaites
19	*M. enneaphylla* Cogn.	*Momordica diplotrimera* Harms
20	*M. foetida* Schumach.	*Momordica mannii* Hook. f., *M. cordifolia* E.Mey. ex Sond., *M. cucullata* Hook. f., *M. schimperiana* Naudin, *M. morkorra* A. Rich., *M. cordata* Cogn.
21	*M. friesiorum* (Harms) C. Jeffrey	*Momordica anigosantha* var. trifoliolata Cogn., *Calpidosicyos friesiorum* Harms
22	*M. glabra* A.Zimm.	
23	*M. gilgiana* Cogn.	*Momordica cogniauxiana* Gilg non De Wild.nom.illegit. (ill.) *M. wildemaniana* Cogn.
24	*M. humilis* (Cogn.) C.Jeffrey	*Raphanocarpus welwitschii* Hook.f. *R. humilis* Cogn. *R. welwitschii* Hook.f. *Momordica welwitchii* Hook. f., *Raphidiocystis welwitschii* Hook.f. *Raphanocarpus humilis* var. *prostratus* Suess
25	*M. jeffreyana* Keraudren	
26	*M. kirkii* (Hook. f.) C. Jeffrey	*Raphanocarpus kirkii* Hook. f.
27	*M. leiocarpa* Gilg	
28	*M. littorea* Thulin	*Raphanocarpus stefaninii* Chiovenda, *Momordica stefaninii* (Chiovenda) Cufodontis
29	*M. macrosperma* (Cogn.) Chiov.	*Momordica bricchettii* Chiov. *Kedrostis macrosperma* Cogn.
30	*M. multiflora* Hook. f.	*M. gaboni* Cogn., *M. laurentii* De Wild., *M.multicrenulata* Cogn., *M. parvifolia* Cogn., *M. affinis* DeWild., *M. gaboni* var. *lobata* Harms, *Coccinia macrocarpa*
31	*M. obtusisepala* Keraudren	
32	*M. parvifolia* Cogn.	*Momordica affinis* De Wild., *M. multicrenulata* Cogn.
33	*M. pauciflora* Cogn. Ex Harms	
34	*M. peteri* A. Zimm.	*Momordica macrocarpa* Jex-Blake

(*continued*)

Table 10.3 (continued)

SN	Species	Other names
35	*M. pterocarpa* Hochst.	*Momordica macrantha* Gilg, *M. grandibracteata* Gilg, *M. runssorica* Gilg, *M. bequaertii* De Wild., *M.rutschuruensis* De Wild.
36	*M. repens* Bremek.	*Momordica marlothii* Harms
37	*M. rostrata* A.Zimm.	*Momordica microphylla* Chiov.
38	*M. rumphii* W.J. de Wilde	*Momordica trifolia* L., *M. trifoliolata* L.
39	*M. sahyadrica* Joseph John and Antony	
40	*M. sessilifolia* Cogn.	*Momordica stephanii* (Chiov.) Cufod. var. membranosa (Chiov.) Cufod., *Raphanocarpus stefaninii* Chiov., *R. stephanii* Chiov. var. membranosus Chiov.
41	*M. silvatica* Jongkind	
42	*M. spinosa* (Gilg) Chiov.	*Kedrostis spinosa* Gilg, *K. brevispinosa* Cogn., *Momordica brevispinosa* (Cogn.) Chiov.
43	*M. subangulata* Blume	
44	*M.welwitschii* Hook. f.	

ethepon to male plants of kakrol (probably *M. subangulata* ssp. *renigera*) did not affect the plants at any level of concentration tested while application of $AgNO_3$ (400 ppm) produced highest number of bisexual flowers per vine (Ali et al. 1991). Spraying of gibberellic acid at 25–100 ppm increases female flower production in *M. charantia*.

Sex expression is affected by environmental conditions under which *M. charantia* seedlings grow (Wang et al. 1997). Short-day cultivars, when grow under short photoperiods, exhibit rapid development and comparatively high gynoecy. To encourage a high frequency of pistillate flowers, such short-day treatments should begin at seedling emergence and proceed to sixth-leaf stage (~20 days post-emergence under growing optimal conditions). While low temperature enhances short-day effects, relatively high temperatures typically delay reproductive growth, weakening short-day responses. Likewise, pistillate flower production under short-days is increased by low temperatures (e.g., 20°C) and nighttime chilling (e.g., 25°C day/15°C night) (Yonemori and Fujieda 1985). Consequently, optimal conditions for *M. charantia* seedling growth are short days and low temperatures (Wang et al. 1997).

The concentration of endogenous growth regulators and polyamines (e.g., spermine, spermidine, cadaverine, and putrescine) in shoot meristems of bitter gourd changes during plant development (Wang and Zeng 1997a). For instance, female flower number increases as IAA and zeatin concentration decreases after anthesis (Wang and Zeng 1997b). Cadaverine content is also higher in staminate and pistillate flowers when compared to vegetative tissues (e.g., leaf and stem) suggesting its possible role in sex detemination (Wang and Zeng 1997a). Likewise, it has been hypothesized that the variation in spermidine content is related to the initiation and development of pistillate flowers, while increases in endogenous putrescine concentrations is related to staminate flower initiation (Wang and Zeng 1997a).

Foliar application of growth regulators can also modify sex expression (Ghosh and Basu 1982). For example, foliar application of gibberellic acid (GA_3) treatment (25–100 mg/l) can dramatically increase gynoecy in bitter gourd, while cycocel (CCC; chlormequat/CCC @ 50–200 mg/l) promotes staminate flower development (Wang and Zeng 1996). Moreover, the appearance of the first staminate flower is delayed and pistillate flower initiation is promoted by relatively low concentrations of GA_3 (0.04–4 mg/l) (Wang and Zeng 1997b). Likewise, foliar application of CCC promotes staminate flower development at 50–200 mg/l, and gynoecy at 500 mg/l. The effects of GA and CCC are sustained for over 80 days, which allows for their use in genetic experiments, the increase of gynoecous lines, and in commercial hybrid production (Wang and Zeng 1996).

Foliar application of ethrel (ethephon), malic hydrazide (MH), GA_3, naphthalene acetic acid (NAA), kinetin, indole acetic acid (IAA), 3-hydroxymethyl oxindole (HMO), morphactin, silver nitrate, and boron when applied at 2- and 4-leaf stage of bitter gourd plants can dramatically affect sex expression (Prakash 1976). Foliar application of silver nitrate (i.e., 250 mg/l at the 5-leaf stage or 400 mg/l at the 3-leaf stage) induces bisexual flower formation, where ovaries and petals are larger than typical pistillate flowers (Iwamoto and Ishida 2005). Likewise, dramatic increases in early pistillate flower appearance can result from foliar application of MH (250 ppm) and ethrel (200 ppm), and staminate flower development can be promoted by application of GA_3 (i.e., 50–75 ppm) (Damodhar et al. 2004). Interestingly, foliar treatment of bitter gourd plants with IAA or HMO at 35 mg/l increases total flower formations, a result that may be due in part to increased ethylene evolution (Damodhar et al. 2004). Regarding such ethylene-dependent sex determination processes, foliar application of ethrel at relatively low concentrations (i.e., 25 mg/l) enhances pistillate flowering, while application of moderately high concentrations (i.e., 100 mg/l) depresses pistillate flower development (Damodhar et al. 2004). Likewise, although exogenous application of GA_3 (i.e., 20–40 mg/l) increases pistillate and staminate flower number, comparatively high concentrations of GA_3 (60 mg/l) increases only pistillate flower number (Ghosh and Basu 1982). Finally, foliar sprays containing 50 ppm NAA stimulate early and abundant pistillate flower development (Shantappa et al. 2005), and boron at 4 ppm enhances pistillate flowers production, and fruit number and weight (Verma et al. 1984).

10.5.4 Parthenocarpy

Singh (1978) has reported the induction of parthenocarpy in *M. dioica* with pollen of related taxa (*M. charantia* and *Lagenaria leucantha*) and mixture of the two pollens. The parthenocarpic fruit setting was higher with the stimulus of extraneous pollen (66% against 36%), compared to natural pollination. The lower fruit setting in natural pollination may be attributed to non-synchronization of anthesis and duration of corolla opening.

10.5.5 Germplasm Development

The importance of germplasm as a basic tool for crop improvement is well recognized. Wild relatives and progenitors of cultivated plants together with semi-domesticates represent a strategic part of germplasm collections. 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. Thus the knowledge of the taxonomic range, morphological similarities, crossing ability and reaction to various biotic and abiotic stresses derived from a germplasm is not only important from a botanical view point, but also it accelerates and increases the potential for its utilization (Dolezalova et al. 2003). Identifying a limited set of accessions likely to be of most interest to specific users from a large collection necessitates the use of a full-fledged descriptor as a tool to provide a generalized search strategy. It helps to differentiate between accessions and to describe the variability in characters of interest. Preliminary characterization and evaluation are prerequisites for successful utilization of plant genetic resources.

There is no published descriptor for bitter gourd, teasle gourd, sweet gourd or spine gourd or any *Momordica* species by IPGRI. The lone reference to a descriptor to *Momordica* was seen in NATP Minimal Descriptor for Vegetable Crops (Srivastava et al. 2001) where bitter gourd, sweet gourd and spine gourd are treated together. These, 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 for more than 75% characters by virtue of their breeding behavior and growth forms (Joseph John 2005). Rasul et al. (2004) have proposed a kakrol descriptor, which can be used in characterization of kakrol (*M. dioica*) cultivars and accessions. Joseph John and Antony (2008c) have recently proposed a set of highly discriminating descriptors and descriptor states for the dioecious *Momordica* species of South Asia comprising *M. dioica*, *M. sahyadrica*, *M. subangulata* ssp. *renigera* and *M. cochinchinensis*.

10.5.6 Characterization and Evaluation of Variability

The nature and magnitude of genetic diversity in any crop determines and often limits its utilization in breeding programs. Eleven named landraces of small bitter gourds (*M. charantia* var. *muricata*) have been collected from South Western Ghats and Tamil Nadu plains and their seeds are conserved in the gene bank of National Bureau of Plant Genetic Resources (NBPGR), New Delhi (Joseph John and Antony 2008a).

Random amplified polymorphic DNA (RAPD) marker analysis was found to be a useful tool for genotype identification and estimation of genetic similarity in spine gourd (Rasul et al. 2006). More recently, molecular markers including RAPD (Dey et al. 2006), intersimple sequence repeat (ISSR; Singh et al. 2007), and amplified fragment length polymorphism (AFLP; Gaikwad et al. 2008) have been used to assess the genetic diversity of Indian bitter gourd genotypes including two promising gynoecious lines (DBGy-201 and DBGy-202). A wide range of genetic diversity was detected, indicating that a standard accession reference array for future analyses might include "Pusa Do Mausami-green," "Pusa Do Mausami-white," DBTG-2, Mohanpur Sel-215, and Jaynagar Sel-1. Regardless of the type of marker analysis, however, Mohanpur Sel-125, DBTG-101, and Jaynagar Sel-1 from West Bengal (eastern Indian province) are genetically distinct from other common landrace accessions from North Indian provinces (genetic similarity, GS = 0.57–0.72). Genetic differences between *M. charantia* var. *charantia* and *M. charantia* var. *muricata* accessions are indicative of their use as potential parents for the establishment of narrow- and wide-based mapping populations (Behera et al. 2008). Kole at al. (2010a, b) conducted comprehensive studies on 22 accessions of *M. charantia* var. *charantia* and *M. charantia* var. *muricata* of seven countries. Using 255 AFLP markers they observed wide genetic divergence among the accessions and also detected many AFLPs linked to three fruit quality traits employing association mapping. They also detected wide genetic variability among the accessions with regard to the content of anticancer and antidiabetes phytomedicines in the germplasm. Such exotic populations have been informative for the characterization of qualitative and quantitative traits in other cucurbit species (Serquen et al. 1997; Zalapa et al. 2007).

The entities collected represented the wide range of variability from almost near to wild types, semi-domesticated to cultivated types. In the case of cultivated material, selection criteria might have included fruit size, bitterness, ascribed medicinal quality and other specific traits based on established knowledge and experience of local farmers and/or gatherers.

There is very little information on genetic variation, and no cultivar selection has been reported in *M. cochinchinensis*. Wild and semi-domesticates are maintained on-farm by tribal settlers in Andaman Islands. Two distinct types are found in the wild: the NE specimens having unlobed cordate leaves earlier designated as *M. macrophylla* Gage and the Andaman specimens having trilobed leaves. At the Central Horticultural Experiment Station (CHES, IIHR), Bhubaneswar, India three genotypes from Andaman and Nicobar islands are being maintained in field gene bank (Bharathi et al. 2006b). Individual fruit of these genotypes ranged from 250 to 530 g and days to flowering varied from 140 to 160 days after planting. The β-carotene content and lycopene (from the epicarp of the fruit) was 11.47–16.40 mg/100 g fresh weight and 5.12–8.68 mg/100 g fresh weight, respectively.

Two distinct fruit types are met with in *M. subangulata* ssp. *renigera*: light green oblong (6–10 cm long), weighing up to 80 g ("lambawala") and dark green medium sized (4–6 cm long) round fruits, weighing up to 40 g ("golwala") observed under cultivation in Assam and Andaman Islands. Assam materials grow luxuriantly and are of shy flowering in nature whereas Andaman collections are prolific and come to flower from the 15th node. Reduced vine length, high branching, increased female flower production, early flower initiation and flowering at every node are some of the desirable traits for higher yield/unit area. Like *M. dioica,* it has the unique advantage of tolerance to high rainfall monsoon climate (prevailing in most parts of South Asia), when a very few vegetables grow and produce fruits. At the Central Horticultural Experiment Station (CHES, IIHR), Bhubaneswar, India a high yielding selection from the naturally available variability each in spine gourd (CHSG 28) and teasle gourd (CHTG 2) were identified for commercial cultivation (Vishalnath et al. 2008) and Rasul and Okubo (2002) have evaluated a few teasle gourd genotypes in Bangladesh.

Selection for highly heritable characters such as number of fruits per plant, individual fruit weight, fruit volume are more important for yield improvement in spine gourd (Bharathi et al. 2006a). Rasul et al. (2004) have characterized 29 accessions of *M. dioica* along with one accession of *M. cochinchinensis* collected from different agro-ecological zones of Bangladesh. Considerable morpho-physiological variation was observed among the genotypes (with dissimilarity value ranging from 4.6 to 58.6), though no relationship could be established between genetic divergence and geographical distribution.

10.5.7 Polyploidy Breeding

Polyploids can be produced by treating the seedlings at the cotyledon stage with an emulsion of 0.2% colchicine. Yasuhiro Cho et al. (2006) reported that seed treatment with 0.2, 0.4% colchicine or 0.003% amiprophos-methyl was effective for chromosome doubling, among which the treatment with 0.4% colchicine was most effective. Amiprophos-methyl treatment also produced octoploid plants with high rate of seed germination. Multiple shoot treatments with 0.05% colchicine for 12 and 24 h, and 0.1% colchicine for 24 h also produced octoploid plants. Leaf and guard cell size were bigger, and leaf shape index (leaf length/leaf width) was lower in the octoploid than in tetraploid plants. Leaves of the octoploid plants were uneven on the surface with clear serrations.

Triploid plants of *M. charantia* were obtained by crossing the tetraploid (colchicines induced) and diploid plants (Saito 1957). In seedlings of bitter gourd, colchicine at 0.2% for 18 h to the shoot tip produced tetraploids (Kadir and Zahoor 1965). However, polyploids were inferior to diploids with regard to economic characters.

10.5.8 Heterosis Breeding

As all the species of *Momordica* are cross-pollinated, there is ample scope for exploitation of heterosis. More pronounced hybrid vigor could be observed with the inclusion of diverse parents. Heterosis for earliness, higher number of fruits, and bearing at each flowering node should be exploited. Selection for divergent parent based on number of fruits, fruit weight, fruit length, internodal length, pedicel length and yield will be useful as these characters were the major traits contributing to divergence in *M. dioica* (Bharathi et al. 2005).

Heterosis in *M. charantia* was investigated at the Indian Agricultural Research Institute, New Delhi as early as 1943 (Pal and Singh 1946). Evidence of heterotic effects is supported by genetic analyses that have defined the presence of dominance and complementary gene action for yield as distinguished by its components (Mishra et al. 1998). Heterosis for yield per vine ranges from 27 to 86% depending on genotype (Behera 2004). This heterosis is likely attributable to earliness, first node to bear fruit (first female flowering node), and total increased fruit number (Celine and Sirohi 1998). A few hybrids developed by both private and public sectors are cultivated in Asia including China and India.

10.5.9 Mutation Breeding

In *M. charantia*, progeny (M_1) derived from radiation mutagenesis can possess economically important unique characters, which are controlled by single recessive genes (Raj et al. 1993). One such bitter gourd variety, MDU 1, developed as a result of gamma radiation (seed treatment) of the landrace MC 103 was found to possess improvement for yield (Rajasekharan and Shanmugavelu 1984). Likewise, the white bitter gourd mutant “Pusa Do Mausami” (white-fruited type) was developed through spontaneous mutation from the natural population “Pusa Do Mausmi” (green-fruited type) at the Indian Agriculture Research Institute, India.

10.5.10 Tissue Culture

Nabi et al. (2002) obtained best performance for micropropagation with cotyledon as explant of spine gourd. They also induced the highest number of multiple and vigorous shoots on MS medium fortified with 1.0 mg/l BAP and 0.1 mg/l NAA. Hoque and Rahman (2003) obtained adventitious shoot bud differentiation from the petiolar cut ends of leaf explants cultured on MS medium supplemented with 2.0 mg/l BA and 0.2 mg/l NAA. Callus cultures were also established from leaf, cotyledon and root explants (Bhosle and Paratkar 2005). The excised embryos in case of spine gourd showed a high potential for de novo multiple shoot regeneration and rooting (Meemaduma and Ramanayake 2002). Among different explants and treatments tried auxillary buds in case of explant, MSHP + Ads + BAP + 10 mg/l + IBA at 5 mg/l + gelrite for crop establishment and MSHP + Ads + IBA at 1 mg/l + agar for induction and development of roots survival was observed when plantlets were transferred in sterilized water for 6 h, transferred to soilrite trays, covered with polyethylene and kept open in a polyhouse (Deokar et al. 2003). When MS medium was supplemented with 1.5 mg/l BA and 0.1 NAA, 88% of hypocotyls explant regenerated shoots with an average number of 8.8 shoots per explant (Hoque et al. 1995). Media supplemented with BA at 10 mg/l and IBA at 5 mg/l produced the highest shoot number and optimum establishment and maximum rooting was obtained in media supplemented with 3 mg NAA/l and 0.2% activated charcoal (Pawar et al. 2004).

10.5.11 Interspecific Hybridization in *Momordica* Species

The identification and incorporation of resistance to economically important pests such as fruit fly and various foliar pathogens is important to bitter gourd production. Genes for resistance to several crop-limiting pests and pathogens are, however, not found in the cultivated *M. charantia* var. *charantia*. Fruit fly is the most serious pest of *M. charantia*. Some of the wild germplasm (var. *muricata*) shows high level of tolerance to fruit fly. It crosses with the cultivated bitter gourd and gene exchange occurs freely within the complex. But *M. charantia* var. *muricata* has dominant trait in F_1 for fruit shape and size, which is not desirable as the size is reduced. *M. charantia* wild and cultivated plants cross readily and there are many intermediate types. Singh (1990) reported 1% fruit set in the cross *M. charantia* × *M. balsamina* and the progeny had a high bivalent frequency with normal meiotic cycle, indicating the close relationship between them and they probably have developed pre-fertilization barrier ensuring their reproductive isolation. Wild African types can be exploited as potential source of disease resistance. *M. foetida* and *M. rostrata* may play a major role in breeding programs of *M. charantia* especially in resistance breeding (Njoroge and van Luijk 2004). Regarding leaf damage due to Aulocophora, *M. balsamina* is highly tolerant. *M. balsamina* may contribute aulocophora tolerance in *Momordica* species.

There have been few attempts at interspecific crosses between *M. charantia* and *M. dioica*, the bitterless, small fruited, tuberous perennial to seek possibilities of transferring desirable attributes of the latter (especially the "bitterless" trait) to the former. Joseph John (2005) reported crossability failure of the dioecious taxa with the two monoecious members (*M. balsamina* and *M. charantia*). Dutt and Pandey (1983) reported that the failure of embryo formation in *M. charantia* × *M. dioica* is due to the abnormal behavior of a number of pollen tubes and heavy deposition of callose at their tips, which obstructed transfer of male gamete and fertilization. However, Vahab and Peter (1993) have reported over 90% success in interspecific crosses between *M. charantia* (cultivated bitter gourd) and *M. dioica* (the dioecious perennial species with bitterless fruits) using pollen stored at 10°C. They attribute the failure in earlier studies to non-synchronization of anthesis in the two species. The study indicated the possibility of utilizing the bitterless, perennial tuberous *M. dioica* in transferring the desirable attributes to the commercially cultivated large fruited bitter gourd.

Ali et al. (1991) have highlighted the scope for transfer of useful traits from the related species to *M. dioica* through interspecific hybridization. There are a few reports of interspecific hybridization between *M. dioica* and *M. cochinchinensis* (Mohanty et al. 1994; Mondal et al. 2006). Joseph John (2005) has reported that both direct and reciprocal crosses were successful within the dioecious group. *M. dioica, M. sahyadrica* and *M. subangulata* ssp. *renigera* are reciprocally interfertile. The highest fruit setting was observed in *M. subangulata* ssp. *renigera* × *M. sahyadrica* crosses. The comparatively low fruit set percentage in crosses involving *M. dioica* as male and female parent may be attributed to the reduction in stigma receptivity and pollen viability of 12–13 h old flowers.

The F_1 plants were intermediate between parents for most of the qualitative traits. Morphologically, the F_1 plants were intermediate between parents. However, expression of maternal character was more dominant especially in the tuber morphology and floral nectar guides. Intermediate behavior in anthesis time was very striking in crosses involving *M. dioica*. When *M. dioica* was used as pollen parent in *M. subangulata* ssp. *renigera*, clutch size was reduced with proportionate reduction in fruit size. When

M. sahyadrica was used as pollen parent in *M. dioica*, days to fruit ripening was extended considerably, beyond that of both the parents. However, the poor germination of F_1 seeds, unsatisfactory growth and flowering in F_1 seedlings, and complete sterility in backcrossing indicate the rather limited potential of hybrids in conventional crop improvement.

10.5.12 Genetic Mapping and Molecular Breeding

Till today, no genetic linkage map has been reported for bitter melon. Kole et al. (2010a, b) have developed a large F_2 population derived from a cross between a horticultural variety, Taiwan White that belongs to the botanical variety *charantia* and produces fruits with higher size and quality but with low content of anti-diabetic and anticancer phytomedicines and a medicinal variety, CBM12 that belongs to the botanical variety *muricata* and bears fruits of inferior size and quality but with high content of phytomedicies (Kole et al. 2009a, b). This population is segregating for fruit size, color, luster, surface and shape. The first genetic linkage map for bitter melon using the above interbotanical variety cross is expected to be developed soon (C. Kole personal communication).

10.6 Quality Attributes

The use of cucurbits, in general, as food plants is not primarily for calorie, mineral or vitamin values, since they are poor or at best only modest sources of these nutrients. However, there are few exceptions including bitter gourds, rich in vitamin C, spine gourd (*M. dioica*), having high protein content, and sweet gourd (*M. cochinchinensis*) containing high carotenoid and lycopene pigments. Local uses of *Momordica* gene pool by the indigenous people in India and rest of SE Asia, and tropical Africa is very extensive.

Despite the use of these plants in such purposes, they have not been given due research attention in terms of their nutritional content, bioavailability and feasibility of their usage as food supplements for major nutritional and antinutritional factors. An attempt is made to bridge the information gap by collating available information on the proximate, minerals and amino acid compositions of these wild vegetables, with hope that it would rekindle the interest in these nature's bounties. Based on the available literature the nutrient composition of some *Momordica* species is given in Table 10.4.

The nutritional value of small bitter gourds is higher or at par for most of the components except phosphorus than that of large bitter gourds. The defatted meals contained 52–61% protein and would be a good source of methionine, compared to the traditional protein-rich legumes. *Momordica* is noted for acids with conjugated double bonds (pumicic acid, alpha-oleo stearic acid). High levels of antioxidant activity (96%) were noticed in *M. balsamina* (Odhav et al. 2007). Teasle gourd is rich in carotene, protein, carbohydrate (Rashid 1993) and vitamin C (154.7 mg/100 g of edible portion) (Bhuiya et al. 1977).

Aberoumand and Deokule (2009) have studied the nutritional values of eight traditional wild edible plants native to Indo-Persian region. In comparison to the other species, *M. dioica* have medium protein content (19.38 mg/g), fat (4.7 mg/g) and phenolic compounds (3.69 mg/g) and have maximum calorie value (4,125.83 kcal/kg). *M. sahyadrica* being recently established taxonomic entity; reliable estimates of its nutritional contents are not available. However, being closely related to *M. dioica*, it can be reasonably assumed to be similar to it.

Sweet gourd (*M. cochinchinensis*) has β-carotene and lycopene at very high levels, with those of lycopene being up to 308 μg/g in the seed membrane, about 10-fold higher than in other lycopene-rich fruits and vegetables (Vuong 2001; Vuong and King 2003; Aoki et al. 2002). Aril tissues contained 2,227 μg total lycopene and 825 μg total carotenoids (718 μg total β-carotene; and 107 μg α-carotene/g FW). Sweet gourd aril contained 22% fatty acids by weight, which are essential for the absorption and transport of β-carotene (Vuong and King 2003; Ishida et al. 2004). Oil extracted from the fruit aril showed a total carotenoid concentration of 5,700 μg/ml, with 2,710 μg of that being β-carotene. This oil also included high levels of vitamin E (Vuong and King 2003). Thus, sweet gourd provides an acceptable source of high levels of valuable antioxidants that have good bioavailability.

Table 10.4 Nutritive value of *Momordica* species

		Moisture (g)	Protein (g)	Fat (g)	Minerals (g)	Fiber (g)	Carbohydrates (g)	Energy (K. cal.)	Calcium (mg)	Magnesium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (mg)	Carotene (mg)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Vitamin C (mg)
1	*M. charantia* var. *muricata*[a]	83.2	2.1	1.0	1.4	1.7	10.6	60.0	23.0	–	38.0	2.0	–	0.13	0.07	0.6	0.4	96
2	*M. charantia* var. *charantia*[a]	92.4	1.6	0.2	0.8	0.8	4.2	25.0	20.0	–	70.0	1.8	–	0.13	0.07	0.9	0.5	88.0
3	*M. balsamina*[b] (Leaves)	89.4	3.0	0.1	–	0.9	3.6	–	340	87.1	27.7	12.7	0.9	–	0.01	0.09	0.7	0.4
4	*M. balsamina*[b]	89.4	2.0	0.1	–	1.8	5.1	–	35.9	41.2	35.8	2.6	1.0	–	0.04	0.06	–	0.5
5	*M. balsamina*[c] (Leaves)	85.0	5.0	0.5	–	2.75	6.82	–	2688	613	356	23	12	–	–	–	–	–
8	*M. dioica* (fruits)[a]	84.1	3.1	1.0	1.1	3.0	7.7	52.0	33.0	–	42.0	4.6	–	1620	0.05	0.1	0.6	–
9	*M. subangulata* ssp. renigera[a]	90.4	0.6	0.1	0.9	1.6	6.4	29.0	27.0	–	38.0	–	–	–	–	–	–	–
10	*M. cochinchinensis*[a] (fruits)	88.6	1.5	0.1	1.1	1.1	7.6	37.0	64.0	–	89.0	–	–		–	–	–	–
9	*M. cochinchinensis*[d] (fruits)	93	0.94	–	–	1.03	–	–	23	–	–	0.34	–	91	–	–	–	0.04
10	*M. foetida*[e]	–	3.3	–	–	3.2	–	22	1.1	–	–	3.4	0.4	5.4	–	–	–	20.6

[a]Gopalan et al. (1982)
[b]Arnold et al. (1985)
[c]Odhav et al. (2007)
[d]AVRDC (2002)
[e]Nesamvuni et al. (2001)

10.7 Genomics Resources Developed

Online search of public domain databases like that of National Centre for Biotechnology Information (NCBI) have revealed that genomic resources in *Momordica* is rather limited. *M. charantia* is by far the most studied species with nucleotide sequence (63), expressed sequence tag (EST) records (7), protein sequence (127) and three-dimensional macromolecular structures (21). In *M. cochinchinensis,* five nucleotide sequences, ten protein sequences, and five three-dimensional macromolecular structures are available. In *M. balsamina,* single record of nucleotide sequence and two protein sequences are only known.

10.8 Scope for Domestication and Commercialization

10.8.1 Traditional Medicinal Uses

Usefulness of various *Momordica* species in SE Asia as anthelmintic, vermifuge, cathartic, hypoglycemic, aphrodisiac, antipyretic, antiulcerogenic and hepatoprotective and in the treatment of burns, bilious disorders, diabetes, cataract, hypertension, leprosy, jaundice, snake bite, haemorrhoids and piles have been mentioned by Van Rheede (1678), Kirtikar and Basu (1933), Walters and Decker-Walters (1988), Yang and Walters (1992), Fernandopulle and Ratnasooriya (1996), Decker-Walters (1999), Dwivedi (1999), Jeffrey (2001), and Deshmukh and Rothe (2003). Traditional knowledge related to use of these species by indigenous tribes is not yet fully documented in published literature. Some of these ethnobotanical claims are validated by phytochemical/animal studies in recent years.

10.8.1.1 *M. charantia*

Whole plant, leaves and especially fruits are used in the folk medicine to treat diabetes in Asia (Perry 1980; Khajuria and Thomas 1993; Platel and Srinivasan 1995; Fernandopulle and Ratnasooriya 1996; Decker-Walters 1999), West Africa (Burkill 1935), and even in the New World (Coe and Anderson 1996; Marr et al. 2004). Lira and Caballero (2002) have reported the use of the feral wild type as an aphrodisiac in Mexico.

10.8.1.2 *Momordica balsamina*

Common and widespread uses are as anthelminthic, against fever and extreme uterine bleeding, to treat syphilis, rheumatism, hepatitis and skin disorders, stomach and intestinal complaints (Hutchings et al. 1996). Other uses include abortifacient, lactogenic including veterinary (Geidam et al. 2004) and hypoglycaemic (Hutchings et al. 1996).

10.8.1.3 *M. dioica*

It was reported to possess hypoglycemic, hepatoprotective, gastroprotective and ulcer healing activities, analgesic, expectorant, post coital antifertility, nematocidal, antiallergic, antimalarial, antifeedant, antibacterial and antifungal activity (Fernandopulle and Ratnasooriya 1996).

10.8.1.4 *M. shyadrica*

Tender fruits are consumed as health food for asthmatic and intestinal ulcer patients. The medicinal uses for mastitis, hydrocele, breast swelling and pain in the early days after child birth and painful eruptions underlie its anti-inflammatory properties, which however needs to be scientifically evaluated. Use of tuber paste as detergent and toilet soap hold promise in the cosmetic and health care industry.

10.8.1.5 *M. cochinchinensis*

The fruits are esteemed as the fruit from Heaven for its ability to promote longevity, vitality and health. It is traditionally used for wound healing, to improve eye health and to promote normal growth in children. The seeds are known in traditional Chinese medicine as “Mubiezi,” reported to have resolvent and cooling properties, are used for treating liver and spleen disorders, chest complaints, abdominal pains and dysentery, wounds, hemorrhoids, bruises, swelling, and pus (Voung 2001).

10.8.1.6 *M. foetida*

The juice of crushed leaves is used to relieve cough, stomach-ache, intestinal disorders, headache, earache, toothache and as an antidote for snakebites. Leaves are also used to ameliorate the effects/scars caused by smallpox, boils, spitting cobra poison and malaria. The other uses are as emmenagog, ecbolic, aphrodisiac and abortifacient. The roots, said to be poisonous, and the crushed seeds are used in East Africa to cure constipation (Njoroge and Newton 2002). The fruit pulp is said to be poisonous to weevils, moths and ants, and is used as an insect repellent in Tanzania (Watt and Breyer-Brandwijk 1962).

10.8.2 Scientific Documentation/ Validation of Health Benefits

Even today almost 80% of the human population in developing countries is dependent on plant resources for healthcare (Farnsworth et al. 1985). Indigenous healthcare practices provide low cost alternatives in situation, where modern healthcare services are not available, too expensive and/or ineffective. Documentation of traditional knowledge especially on the medicinal uses of plants has lead to the discovery of many important drugs of the modern day (Cox and Ballick 1994; Fabricant and Farnsworth 2001). Natural products are the basis of many standard drugs used in modern medicine and at least 50 plant derived drugs are developed from ethnobotanical leads (Cox and Ballick 1994). Besides, plants seem to have served as models for drug development also (Fabricant and Farnsworth 2001).

10.8.2.1 Antidiabetic Properties

Over a hundred research papers have been published on pharmacological especially hypoglycaemic properties, and phytochemical characterization. A number of patents have been submitted on actives and processes of *Momordica* spp. for insulin-type properties. In vitro and in vivo studies in animals have shown that karela acts to inhibit glucose absorption, acts as an insulin secretogog, and exerts insulinomimetic effects, though not all of these effects have been supported by in vivo studies. Antifertility side effects and hepatotoxicity have been reported in animals administered with karela, with pregnant animals being especially susceptible. However, no such adverse effects in humans seem to have reported, despite its widespread use medicinally and as a vegetable.

In small-scale clinical trials with limited patients, karela juice/powder have been shown to significantly improve glucose tolerance without increasing blood insulin levels and to improve fasting blood glucose levels (Aslam and Stockley 1979; Leatherdale et al. 1981; Akhtar 1982). Oral administration of powdered fruit (Srivastava et al. 1993) and seeds (Grover and Gupta 1990) have lead to a fall in blood and urine sugar levels and post prandial blood glucose levels also fell.

Studies in *M. balsamina* have confirmed the acclaimed hypoglycaemic property of the stem–bark extract of the plant that could be used in the management of hypoglycaemic conditions (Geidam et al. 2007). Olaniyi (1975) has isolated the hypoglycaemic principle foetidin, consisting of equal parts of beta glucoside and 5,25-stigmatastadien-3 beta-ol glucoside (similar to charantin from *M. charantia*) from whole plants and unripe fruits of *M. foetida*. Foetidin was shown to lower blood glucose levels in normal rats, but it had no significant effect in diabetic animals except at 18 h samples (Marquis et al. 1977; Raman and Lau 1996; Bosch 2004).

10.8.2.2 Anticancer Properties

Antitumour activity of crude extracts of *M. charantia* and *M. cochinchinensis* have been demonstrated in vivo (West et al. 1971; Jilka et al. 1983).

10.8.2.3 Antiviral Activity

The leaf extracts of *M. charantia* has been demonstrated to inhibit the growth of Herpes simplex virus 1 (Foa-Tomasi et al. 1982) and human immuno deficiency virus 1 (Lifson et al. 1988; Lee et al. 1990; Zhang 1992b). The proteins α- and β-momorcharin and MAP are believed to be the active antiviral components of *Momordica charantia* (Zhang 1992b). *M. balsamina* fruit pulp was reported to be commonly used for its antiviral efficacy in poultry and even claimed to be having healing effects for human AIDS in northern Nigeria. An anti-HIV property of the fruit pulp extract (aqueous) was studied for in vitro (in humans) by Bot et al. (2007). The results showed that the plant extract treatment significantly ($p < 0.05$) increased CD4+ lymphocytes count when compared to the untreated peripheral blood mononuclear cells (PBMC), indicating its ameliorative role.

10.8.2.4 Analgesic and Anti-inflammatory Effects

A methanolic extract of the seeds from unripe fruit of *M. charantia* has been shown to produce a marked dose-dependent analgesic effect in mice (Biswas et al. 1991). Karumi et al. (2003) has established the analgesic and anti-inflammatory effect of the aqueous leaf extract of *M. balsamina* in mice.

10.8.2.5 Antifertility Effects

Several components with abortifacient properties (α-,β-momorcharins) have recently been isolated from *M. charantia*. Aqueous and ethanol extracts from the roots were found to be most effective in causing significant abortifacient activity besides showing moderate estrogenic activity in female rats (Shreedhar et al. 2001). A protein isolated from fresh tubers of *M. cochinchinensis* was found capable of inducing mid-term abortion in mice.

10.8.2.6 Hepatotoxicity

Ng et al. (1994) have found that α- and β-momorcharins can induce cytoplasmic blebs and other morphological changes in rat hepatocyte in vitro. Secretion of various enzyme markers of cell damage is also raised. However, in a recent study (Semiz and Sen 2007), *M. charantia* fruit extract exhibited hepatoprotective effects in CCl4-intoxicated rats. The results suggest that the *M. charantia* fruit extract possess the protective activities, antioxidant effects besides having hypoglycemic and antidiabetic effects in rats. *M. dioica* leaves (Jain et al. 2008) and fruits (Thirupathi et al. 2006) have potent hepatoprotective action and ethanolic extract was found more potent.

10.8.2.7 Toxicity in Humans

Although toxicity has been observed in some animal studies (Sharma et al. 1960; Zhang 1992a), there are no published reports of fatal or serious effects in humans at normal doses (50 ml, given orally). Karumi et al. (2006) and Geidam et al. (2007) have conducted toxicity studies in *M. balsamina*. Graded doses of aqueous leaf extract were administered orally and intraperitonially to separate groups of rats to determine the acute toxicities and it was concluded that *M. balsamina* at low dosages is safe.

10.8.3 Phytochemistry and Active Ingredients Isolated

M. charantia fruit contains steroids, charantin, momordicosides (G, F1, F2, I, K, L), acyl glucosyl sterols, linolenoyl glucopyranosyl elenosterol, amino acids, fatty acids, and phenolic compounds. The seeds contain galactose-binding lectins, vicine, amino acids, fatty acids, terpenoids, and momordicosides (A, B, C, D and E). The phytochemicals isolated from the whole plant, vines or leaves include saponins, sterols, steroidal glycosides, alkaloids, amino acids and proteins (Raman and Lau 1996).

Phytochemical screening of *M. balsamina* leaves revealed the presence of tannins, saponins and lectins (Akinniyi et al. 1983). The alkaloids include momordicin (Watt and Breyer-Brandwijk 1962), momordocins (Karumi et al. 2004) and cucurbitacins, which impart bitter taste along with saponins. Phytochemicals of pharmaceutical importance (anti-inflamatory, antiviral, antibacterial and antioxidant activities) like momordin II (ribosome inactivating protein) and rosmaric acid (caffeic acid ester) have been isolated from *M. balsamina* (Bosch 2004).

Phytochemical investigations in *M. dioica* have revealed the presence of traces of alkaloids and ascorbic acid in fruits. Lectins, β-sitosterol, saponin glycosides, triterpenes of ursolic acid, hederagenin, oleanolic acid, α-spiranosterol, stearic acid, gypsogenin, momodicaursenol and some aliphatic constituents were isolated from different parts of this plant (Ghosh et al. 1981; Sadyojatha and Vaidya 1996; Ali and Srivastava 1998; Luo et al. 1998).

Trypsin inhibitors are known to produce a cancer-preventive effect in humans and to confer in crops resistance against insects. Hernandez et al. (2000) have separated three trypsin inhibitors from *M. cochinchinensis* seeds. Five trypsin isoinhibitors (TI-1 to TI-5 of the squash-type) differing in molecular mass, specific trypsin-inhibitory activity, and N-terminal amino acid sequence were isolated from *M. cochinchinensis* seeds (Wong et al. 2004). Tien et al. (2005) have investigated in vivo and in vitro the antitumor activity of the crude water extract from Gac fruit (*M. cochinchinensis*). The antitumor component was confirmed as a protein with molecular weight of 35 kDa, retained in the water-soluble high molecular weight fraction as distinct from lycopene, another compound with potential antitumor activity.

Cochinin B, a novel ribosome-inactivating protein (RIP) with a molecular weight of 28 kDa, was purified from the seeds of *M. cochinchinensis* (Chuethong et al. 2007). The purified Cochinin B displayed a strong inhibitory activity on protein synthesis and strong antitumor activities. RIPs have been linked to defense by antiviral, antifungal and insecticidal properties demonstrated in vitro and in transgenic plants (Nielsen and Boston 2001).

Mulholland et al. (1997) have isolated several cucurbitane triterpenoids from the leaves of *M. foetida* including a few novel compounds. Momordicines and foetidin (identical to charantin) were reported from fruits and leaves of *M. foetida*. Momordicines have been found to be both bacteriostatic and insecticidal; foetidin has slight antispasmodic and anticholinergic effects.

10.8.4 Use as Dietary Supplements

Inequitable food availability and inadequate food intake among population at the lower socio-economic strata and especially among children, pregnant and lactating mothers is a grave problem in the developing countries (Andersen et al. 2003; Seena et al. 2005). The major food crops being roots and tubers besides cereals, the diets in these parts are predominantly starchy. Thus, nutrient deficiency especially of protein, macro- and micro-elements are prevalent. A long-term sustainable solution to alleviate the problem is to enlarge the food basket by exploiting under-exploited and lesser-known wild plants as sources of nutrient supplements. In this direction, many researchers have reported the nutritional composition of various types of edible wild plants including those of *Momordica* genus in use in the developing worlds.

10.8.5 Protein and Mineral Supplements

Communities in Africa have a long history of using traditional indigenous leafy vegetables to supplement their diets (Odhav et al. 2007; Rensburg et al. 2007). Introduction and extensive cultivation of more remunerative and aggressive crops, first from Asia and subsequently from Europe and South America during colonization, have marginalized several of these traditional native species. Presently, urbanization and the influence of urban lifestyle on the rural African population have resulted in replacing the traditional vegetables with introduced modern vegetables. Besides, the indigenous traditional knowledge related to the cultivation and uses of these traditional vegetables are also at risk of getting lost at household and community level. Considering their potential nutritional value, these traditional vegetables could contribute in a major way to the food security and balanced diets of rural households and possibly urban households as well. However, further research on other aspects like nutritional profile and bioavailability, genetic improvement and better cultivation practices are warranted.

The leaves of *M. balsamina* are a popular vegetable, consumed regularly in the eastern parts of South Africa (Fox and Norwood Young 1982; Van Wyk and Gericke 2000; Hart and Vorster 2006; Rensburg et al. 2007; Odhav et al. 2007). The study by Hassan and Umar (2006) has detected 17 amino acids with glutamic acid, leucine and aspartic acid being the predominant amino acids. Isoleucine, leucine, valine and aromatic acids were found to be higher than WHO/FAO/UNU (1985) requirement pattern for children, while sulphur containing amino acids are the only limiting amino acids for adults. Comparing the leaves' mineral contents with RDA values, the results indicated that the *M. balsamina* leaves could be good supplement for some mineral elements particularly K, Ca, Mg, Fe, Cu and Mn.

Compared with cabbage, lettuce and spinach, these wild Momordica vegetables contain more protein and fat, while the fiber content is less. Among the minerals analyzed, the leaves of *M. balsamina* had higher values than those reported for the exotic vegetables, except for sodium. The wild vegetables like *M. balsamina* leaves could be promoted as a protein supplement for cereal-based diets in poor rural communities, while its high potassium content could be utilized for the management of hypertension and other cardiovascular conditions. The relatively high concentrations of zinc, iron and manganese could contribute toward combating the problem of micronutrient deficiencies (Flyman and Afolayan 2007).

Odhav et al. (2007) have presented preliminary nutritional data for 20 traditional leafy vegetables including *M. balsamina*. The results of this study provide evidence that these local traditional vegetables, which do not require formal cultivation, could be important contributors to improve the nutritional content of rural and urban people. From this study, it was determined that most of the leafy vegetables provide mineral concentrations exceeding 1% of plant dry weight and are much higher than typical mineral concentrations in conventional edible leafy vegetables; they are thus recommended for future commercial cultivation. High levels of antioxidant activity (96%) were also noticed in *M. balsamina*.

From the results of these analyses, it can be seen that *M. balsamina* leaves could be important green leafy vegetable as a source of nutrients to supplement other major sources. However, chemical analysis alone should not be the sole criteria for judging the nutritional importance of a plant's parts. Thus, it becomes imperative to consider other aspects such as presence of antinutritional and toxicological factors and biological evaluation of nutrients' form, content, availability and utilization. However, research efforts in these areas are rather meager.

The use of leaves in human nutrition is not considered in general with the importance it deserves in some low protein diets. When limiting amino acid of main foods is lysine (as in the case of cereal based diets) the protein of leaves may be of a great importance in its supplementation. The leaves and fruits of *M. balsamina* are used as spinach along with groundnut meal in a traditional cooking called "cacana" in Mozambique. Oliveira and De Carvalho (1975) have studied its nutritional value from the standpoint as a protein supplement of common diets. Along with *Amaranthus spinosus* and *Colocasia antiquorum*, *M. balsamina* leaves have high protein content and scores high in all indices of nutritional value of leaf proteins. However, the use of *M. balsamina* in a traditional dish with groundnut meal is of no interest, since S-amino acids are limiting in both cases. The substitution with/addition of maize meal would be a corrective procedure to be envisaged.

10.8.6 Vitamin Supplements

Malnutrition is an ugly specter in most parts of Africa and Asia and chronic vitamin A deficiency stands out as one of the most persistent nutritional problems though in most cases a food source of retinol and provitamin A carotenoids is plentiful. Sustainable solutions to micronutrient deficiencies that capitalize upon indigenous resources and foodstuffs offer a long-term mechanism for elevating the health status of disadvantaged people. The gac fruit (*M. cochinchinensis*) is an excellent source of β-carotene (17–35 mg/100 g of edible part). This fruit is familiar to the people within its distribution range and is easy to grow.

Nutritional supplementation trials in Vietnam have shown that children fed with "xoi gac" (rice cooked with fruit pulp of *M. cochinchinensis*, popularly called gac) have significantly higher plasma β-carotene, compared to those who received synthetic β-carotene powder or none (control). Increases in plasma retinol, α-carotene, zeaxanthin, and lycopene levels were also significantly greater in children given gac (Vuong et al. 2002). It is likely that the fatty acids in gac are what make its β-carotene more bioavailable than that of the synthetic form (Vuong et al. 2002).

Voung (2001) and Vuong et al. (2002) have described an exemplary case study in Vietnam where the use of the traditionally cultivated gac fruit (*M. cochinchinensis*) was demonstrated to be an ideal tool in managing chronic cases of vitamin A deficiency in children. This is an example of a highly successful long-term and sustainable strategy using the indigenously available food resources. Extended cultivation coupled with better pre- and post-harvest technologies can make its availability throughout the year. Research efforts toward breaking seed dormancy, development of improved cultivars, and better package of cultivation practices can contribute toward higher productivity and production. More importantly, better efforts are needed to educate the local population about the health benefits of this nature's bounty, "the fruit from heaven" as this fruit is known in Vietnam.

10.9 Prospects as Alternative Crops

Indigenous vegetables have great potential in poverty and malnutrition alleviation and diversification of agricultural environment (Engle and Faustino 2007). They are relatively neglected crops, being left out from research agenda and marginalized from development schemes. They are being increasingly replaced by a handful of cultivated species and their improved varieties. The indigenous knowledge associated with their collection/cultivation, sustainable utilization, and conservation is also under serious threat of being lost in the long run.

Though the current exploitation of these indigenous perennial vegetables by the rural and tribal populations is restricted in the areas of their distribution, some of these have shown equal acceptability among the urban population as well (Chadha and Patel 2007). The dioecious perennial bitterless species native to Asia, i.e., *M. dioica*, *M. sahyadrica*, *M. subangulata* ssp. *renigera* and *M. cochinchinesis* have tremendous potential as cultivated crops on their own. There is better consumer preference for "bitterless bitter gourds," as vegetables, though much of the traditional medicinal properties are ascribed to the bitter constituents. Though rich in minerals, vitamins, and antioxidants such as carotene, lycopene and flavonoids, their potential health benefits are still unknown to the large section of society. Being perennial hardy species propagated by tubers, cultivation of these species is less demanding and ideal for homestead/on-farm cultivation.

M. sahyadrica has come up very well as a natural component in cardomom and coffee estates in the high ranges of Western Ghats of India. In fact, all these species can be very well integrated into any cropping pattern suitable or prevalent in their geographic range. These plants can perenniate under natural conditions for up to 5 years and are highly adapted to organic farming. Being high-value vegetables with wide acceptability, their cultivation will lead to diversification in diet besides nutritional security. Besides, they are an ideal component for home gardens and marginal and subsistence farming.

In spite of being promising fruit vegetables, there has been not much research thrust paid on kakrol's genetic improvement, though there have been few efforts on addressing the problems related to propagation and agronomic aspects (Ali et al. 1991; Mishra and Sahu 1983). Though reported to have *Ctenoplectra* bees as pollinators in South China (Schafer 2005), and the floral characteristics suggest the possibility of such a plant–pollinator mutualism, no such pollinators are reported from India or rest of Asia. The natural fruit set is rather poor and requires hand pollination in the cultivated kakrol (*M. subangulata* ssp. *renigera*).

The dioecious species are shown to have varying degrees of seed dormancy. Hence, tubers serve as better propagules because of their vigorous growth, precocious flowering and fruiting, besides the great advantage of plants of desired sex (10:1 is ideal). Several workers have pointed out the inadequate availability of female tubers in dioecious species as the single most limiting factor in their large-scale cultivation. Recently, Joseph John et al. (2008) have reported that longitudinal splitting of tubers into 2–4 segments (with a portion of apical meristem) in *M. dioica* and *M. sahyadrica*, whereas longitudinal/cross-sectional cutting into several pieces in *M. subangulata* ssp. *renigera* is efficient in multiplication of propagules. However, studies on tuber morphology, germination behavior, and tuber multiplication have yet to be conducted in the other three species.

Though these crops are traditionally raised as rainfed crop, pure rainfed crop cultivation especially in dry zones cannot be practiced at present due to the erratic nature of rainfall prevailing in most parts of South Asia. Navaratne and Kodithuwakku (2006) have explored the possibility of enhancing indigenous vegetable production in Sri Lanka through low-cost microirrigation approach. The yield obtained from the crop grown under designed irrigation system is two-times higher than the yield of crop grown under rainfed condition. Irrigation water consumption by crops under subsurface irrigation system was 1.6-times less when compared to manual irrigation. Meerabai et al. (2006) advocate biofarming in bitter gourd, incorporating the use of organic manures and biofertilizers. This enables the production of superior quality produce devoid of toxic residues and preferred for their flavor, taste, nutritive value, and extended shelf-life. A similar approach incorporating the essentials of traditional farming practices, organic cultivation, and low-cost irrigation and other production technologies can make cultivation of these crops profitable for the farmers, thereby ensuring a sustainable system.

M. balsamina leaves, an important component of the traditional African leafy vegetables, are a good source of supplements for protein and micronutrients to the cereal-based African traditional diets. The same is true in Asian taxa, though its use as leafy vegetable is limited to a handful of ethnic/linguistic tribes. The phytochemical analyses show that these locally adapted indigenous vegetables are rich in proteins (including most of essential amino acids), minerals, and antioxidants, much better than many of the modern vegetable crops. In fact, proximate analysis show leaves are better source of nutrients than fruits with the exception of carotenoids. However, bioavailability of these nutritional components and conflicting reports on toxicity in humans need to be further investigated. Collection of diverse types from wide ranging areas and further evaluation and selection can lead to less bitter and non-toxic types. Research efforts in these aspects can help in promotion of these traditional wild vegetables for the benefit of a much larger population.

Besides their diversified uses, the underexploited indigenous vegetables such as *M. balsamina* have a great innate capacity of giving good returns under scanty and erratic monsoon conditions, prevailing in arid regions of India and a larger part of Africa.

These vegetables provide the nutritional security to the people particularly during the drought year. In drought years, only these vegetables can give good yield when most other vegetables fail. However, very less attempts have so far been made to improve the existing landraces of these indigenous vegetables (Maurya et al. 2006; Rai et al. 2006).

10.10 Utilization as Breeding Resources

The genetic variability present in the wild and underutilized vegetables is of importance for the successful breeding of improved cultivars with desirable qualitative traits and for biotic stress tolerance. The wild species offer great resources for breeding of cultivated bitter gourd for desirable edible/qualitative traits (such as non-bitterness), abiotic stresses (tolerance to drought) and resistance for several insect pests. There are several genotypes of wild bitter gourds (var. *muricata*) that have been collected from southwestern India and reported to have high fruit fly tolerance (Joseph John and Antony 2008b). *M. balsamina* is highly tolerant to most of the typical cucurbit diseases and pests including ladybird beetle (*Epilacna septima*), red pumpkin beetle (*Aulocophora fevicoli*), pumpkin caterpillar (*Margaronia indica*), gall fly (*Lasioptera falcata*), root-knot nematode (*Meladogyne incognita*), cucurbit yellow mosaic, and little leaf disease (Joseph John and Antony 2008b). Small-fruited wild types of bitter gourd (*M. charantia* var. *muricata*) are, in general, tolerant to pumpkin caterpillar and root-knot nematode, whereas some specific accessions with fruit fly tolerance have also been reported from Western Ghats of India. *M. dioica* has been found to be tolerant to pumpkin caterpillar, gall fly, and root-knot nematode, whereas *M. sahyadrica* is highly tolerant to pumpkin caterpillar and root-knot nematode, and most importantly to fruit fly incidence. *M. subangulata* ssp. *renigera* is highly susceptible to most of the diseases and pests, most notably root-knot nematode, whereas it is resistant to cucurbit yellow mosaic and little leaf diseases (Joseph John 2005). The African taxa, especially *M. foetida* and *M. rostrata*, are reputed for their insect-repellant properties (Bosch 2004) and offer great promise in resistance breeding in *M. charantia*.

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