Discussion
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5.1. Taxonomic revision

5.1.1. An overview of present taxonomic status of genus *Momordica* in India

As different workers have treated it differently there was no clarity and consensus in the interspecific taxonomy of the genus *Momordica* L. The botanical names and common names are often incorrect or used interchangeably and are misleading (Ram et al. 2002). Similarly, the descriptions of morphological features of many species are incorrect or incomplete. *Momordica dioica* folders displayed at MH and CAL include three distinct entities that vary for many morphological features and represents geographically isolated areas. The Eastern Himalayan, Central Indian-Deccan Plateau and Western Ghat specimens are distinct from each other and deserve separate taxon status. A perusal of the 700 Herbarium sheets lodged in major herbaria in India reveals mis-identification and incomplete labeling.

Generic characters used to distinguish the genus *Momordica* in most of the earlier works include calyx tube closed with incurved scales. Instead of the calyx tube, it is the corolla which is having scales at its base. Similarly, male inflorescence morphology needs explanation as to branched or unbranched nature. Chakravarthy (1982) ignored important traits such as anthesis time, nectar guides on petals and ridged nature of the fruit. Longitudinally alate or ridged fruits are the key character for *Momordica subangulata* (Jeffrey 1980) and purple-blotched petals are very specific to *Momordica subangulata* and *Momordica cochincherensis*. He has retained separate taxon status for *M. macrophylla*, distinct from *M. cochincherensis* for the unlobed nature of the leaves. Heterophyllly is observed in *M. dioica* and *M. sahyadrica*. Primary leaves, fully grown leaves and late growth stage leaves of these taxa vary in shape especially in lobing even in tuber sprouts. However, *M. charantia*, *M. balsamina* and *M. renigera* exhibit uniform leaf shape in the same plant. Hence, leaf shape may not be a reliable character in distinguishing species in the dioecious group.

The descriptions are incomplete like many other previous treatments in the sense either male or female plant could not be studied, besides the fruit and seed morphology details
arc often scanty Perennial nature of the plant and tuber morphology does not find a place in his treatment. The morphological features of the flower, which is very striking within the dioecious group representing lower elevations and arid belt, mid and high elevation Western Ghats and North Eastern Hills, were not taken in to account while devising the key.

5.1.2. Delimitation of the taxa

5.1.2.1. proposed grouping the species in two sub-genera

Two clear cut evolutionary divergences can be derived; the monoecious, more primitive - *M. charantia* and *M. balsamina* group and the dioecious more advanced - *M. dioica* group. The monoecious group has basic chromosome number *n*=11 and the dioecious group has *n*=14, whereas *Luffa cymbalaria* (*M. cymbalaria*) has the basic number *n*=8. The two subgenera can be distinguished using the following characters (Table 63). Crossability relationships and chromosome number also support the naturalness of this sub generic classification.

5.1.2.2. Elimination of *M. denudata*, a probable case of mis-placement

The Travencore specimens (Meebold, 12241, Kavalay Cochin) identified by the collector as *M. dioica* has been determined by Chakravarty as *M. denudata*, which is female specimen much resembling *M. dioica* of Kerala in all aspects. It is not clear how he arrived at this identification. This taxon requires a great deal of further research with living material and until complete specimen with seed and tubers have been studied in detail, no conclusions could be arrived at the validity of *M. denudata*. Interpretation of male inflorescence needs clarification. According to de Wilde and Duyfjes (2002) in Asiatic *Momordica* species, the part up to bract is peduncle and between bract and flower base is pedicel. Extensive field surveys conducted throughout reported areas of occurrence, i.e. low elevation coastal areas especially Quilon (Gamble 1919) and Kodungalloor (van Rheede 1688) failed to locate a specimen matching with Type specimen CP 1615.
### Table 63: Proposed sub generic classification of Indian *Momordica*

<table>
<thead>
<tr>
<th>Character</th>
<th>Sub genus A</th>
<th>Sub genus B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breeding behaviour</td>
<td>Monoecious</td>
<td>Dioecious</td>
</tr>
<tr>
<td>Germination</td>
<td>Epigeal</td>
<td>Hypogeal</td>
</tr>
<tr>
<td>Perennation</td>
<td>Annual</td>
<td>Perennial</td>
</tr>
<tr>
<td>Fruit surface</td>
<td>Muricate - tubercled</td>
<td>Echinate - soft papillate</td>
</tr>
<tr>
<td>Seed sides</td>
<td>Rectangular, squarish</td>
<td>Cog wheel, round, oval</td>
</tr>
<tr>
<td>Seed colour</td>
<td>Brown-yellow</td>
<td>Black or grey</td>
</tr>
<tr>
<td>Leaf shape</td>
<td>Angular</td>
<td>Roundish</td>
</tr>
<tr>
<td>Male flower bract position</td>
<td>Mid way or towards axis- not</td>
<td>Just below the flower-</td>
</tr>
<tr>
<td></td>
<td>protective</td>
<td>protective</td>
</tr>
<tr>
<td>Male flower calyx</td>
<td>Broad, touching each other,</td>
<td>Narrow, spaced and less</td>
</tr>
<tr>
<td></td>
<td>protecting the nectary</td>
<td>protection to the nectary</td>
</tr>
<tr>
<td>Male flower nectary</td>
<td>Open from above</td>
<td>Closed by corolla scales</td>
</tr>
<tr>
<td>Relative size of ♂ and ♀ flowers</td>
<td>♂ flowers larger than ♀ (corolla)</td>
<td>Of equal size</td>
</tr>
</tbody>
</table>
There is possible evidence to suspect that earlier records of collection and chromosome studies of *Momordica denudata* (Beevy and Kuriachan. 1989) is probably *M. dioica* as it has male flowers in loose fascicles and many flowers emerging from the same axil, giving the look of a branched inflorescence as *Momordica denudata*. This feature is common in the high rainfall areas and was located in *M. sahyadrica*, *M. cochinchenensis*, *Momordica dioica* and a collection of *M. charantia var. muricata* from Uttara Kannada (SBJ170). Hence, the need to find out a reliable key character replacing the branched male inflorescence to distinguish *M. denudata* is important.

Rheede’s plate in Hortus Malabaricus with the vernacular name “bempavali” is a male specimen of *Momordica dioica* with flowers in a pseudo-raceme, which is equated by many botanists as *Momordica denudata*. Unfortunately, as a live plant could not be located during the exploration and because the lone specimen at Type Herbarium CP1615 could not be spared for detailed analysis, this aspect remains incomplete. However, based on descriptions of Trimmen (1895), de Wilde (2002), Cooke (1903) and own observations of CP 1615 (Type Specimen, CAL), a conclusion is arrived at (Figure 33). According to C.B. Clarke (1879), it is altogether remote from *M. dioica* and evidently closely allied to *M. cymbalaria* which should be shifted to *Luffa* by virtue of its exert anthers, long pedicelled flowers and distinct flower shape. *Luffa cymbalaria* is treated under *Momordica* by many even to date (de Wilde and Duyfjes 2002). Roxburgh placed it under *Momordica* because of its simple tendrils. Characters like absence of prominent male bracts and branched male inflorescence indicate the remoteness of *M. denudata* from the genus *Momordica*.

5.1.2.3. *M. cochinchenensis* vs. *M. macrophylla.*

Leaf lobing is more of an environmental character in dioecious taxa as evidenced by both lobed and unlobed leaves in the same plant at different stages of plant growth. *Momordica cochinchenensis* shows various leaf lobing patterns even nearly 3-foleolate with minute petiolule, giving the superficial appearance of a palmately compound leaf. Hence, the taxonomic treatment of *Momordica macrophylla* as a separate taxon does not stand valid and is in conformity with de Wilde and Duyfjes (2002).
Fig. 33. Momordica denudata - CP1615 (Type)
5.1.2.4. Revision of *M. dioica*

The pattern of morphological variation especially floral morphology in *M. dioica* justifies bifurcation into *M. dioica* senso stricto and *M. sahyadrica* sp. nov. (Table 64). Teasle gourd, variously known as 'Assam kakrol' or 'bhatkarela' is placed under *M. subangulata* ssp. *renigera*. This removes the confusion in horticultural parleys where it was treated interchangeably as *M. dioica* (tetraploid) or *M. cochinchinensis* without any justification. *M. sahyadrica* and *M. subangulata* spp. *renigera* are added to the existing list of *M. dioica* and *M. cochinchinensis* in the dioecious taxa, besides the monoecious taxa.

The classification of variability up to intraspecific categories highlights the need for consideration of this diversity in conservation programmes. Enumeration of specific landraces in *M. charantia* var. *muricata* is an example in this regard. However, taxons that were merged with other species such as *M. macrophylla* should warrant consideration as a morphological variant with ecogeographic significance for conservation of genetic diversity.

5.1.2.5. Modified key

A modified taxonomic key incorporating all the morphological variations has been proposed. It stands apart for being based on the study of live specimens and diverse collections. Except in *M. cochinchinensis*, live specimens at all stages of plant growth were considered for morphological description. Reliance on more number of characters to distinguish between species has given more clarity in understanding the interspecific diversity in the genus. With the present key, the Indian component of the genepool can be identified up to species level without any confusion. This will be of great use for botanists and genebank managers as the existing classification of various dioecious *Momordica* specimens are erroneous and that there is a need to assign correct botanical name and correspond it with the common and vernacular names.
Table 64: Comparative morphology of the entities treated under *M. dioica* in Indian Herbaria

<table>
<thead>
<tr>
<th>S.N</th>
<th>Character</th>
<th><em>M. dioica senso stricto</em></th>
<th><em>M. sahyadrica sp. nov.</em></th>
<th><em>M. sub. ssp. renigera</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Flower</td>
<td>actinomorphic</td>
<td>actinomorphic</td>
<td>zygomorphic</td>
</tr>
<tr>
<td>2</td>
<td>Petal imbrication</td>
<td>faintly imbricate</td>
<td>Imbricate (overlapping) at mid point</td>
<td>Highly imbricate except at apex</td>
</tr>
<tr>
<td>3</td>
<td>Hypanthium shape</td>
<td>Cupular narrow</td>
<td>Cupular broad</td>
<td>Saucer shaped</td>
</tr>
<tr>
<td>4</td>
<td>Calyx cup colour</td>
<td>Pale yellow</td>
<td>Purple black</td>
<td>blackish</td>
</tr>
<tr>
<td>5</td>
<td>Male sepals</td>
<td>Linear acute, thin</td>
<td>Broad scarious, thin</td>
<td>Broad ovate-round, thick</td>
</tr>
<tr>
<td>6</td>
<td>Corolla colour</td>
<td>Pale yellow</td>
<td>Bright yellow</td>
<td>Creamish yellow</td>
</tr>
<tr>
<td>7</td>
<td>Nectar guides on</td>
<td>absent</td>
<td>Green yellow shade at base</td>
<td>3 inner petals with purple bull’s eye blotch at base</td>
</tr>
<tr>
<td></td>
<td>petals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Corolla scales</td>
<td>inconspicuous</td>
<td>Conspicuous, yellow</td>
<td>Very prominent, fleshy, orange yellow</td>
</tr>
<tr>
<td>9</td>
<td>Corolla hairiness</td>
<td>inconspicuous</td>
<td>Short hairs at base</td>
<td>Very long glandular hairs in profusion</td>
</tr>
<tr>
<td>10</td>
<td>Connective</td>
<td>Pale yellow, thin</td>
<td>Light yellow, medium thick</td>
<td>Black on faces, very thick</td>
</tr>
</tbody>
</table>
5.2. Ecogeographic survey

The findings of the ecogeographical analysis give a clear-cut picture of areas of distribution, hot spots, intra specific variability, ethnobotany, phenology and an assessment of the extent of genetic erosion in the habitat range. The distribution maps pinpoints the areas of occurrence of the taxon, using which a perspective collector can have access to the site. Gaps in germplasm collection can be ascertained by comparing the genebank passport data with this map. The genus distribution map gives a holistic picture of the distribution of component taxa, areas of overlapping distribution and higher concentrations that needs to be targeted for maximum harvest/collection of genetic diversity. Thus, the question of ‘Where’ to collect *Momordica* wild genepool has been answered.

A comprehensive analysis of the geographic distribution of *Momordica* species is done for the first time. Geographical Information System (GIS) tool was used to analyze the distribution of *Momordica* species using the database prepared after survey of major Indian herbaria and supplemented with field studies. Although a digital distribution map for *Momordica* species diversity has been prepared (Ganeshiah 2003), it is based on secondary data from floras of the region and fail to pinpoint the exact site of occurrence. This is the first study in which *Momordica* species diversity has been plotted based on actual field observations, eliminating wrong identifications and guess estimates of species presence. *Momordica denudata* and *M. cymbalaria* do not figure in these maps, as they are not considered valid species as per the revised species concept.

Analysis of species distribution maps based on herbarium locality data and actual collection reveal the need for more intensive exploration in species hot spots (Fig. 34). A good representation of diversity in *M. charantia* var. *muricata* and *M. sahyadrica* has been amassed from Western Ghats. However, other species and areas need extensive coverage. In the absence of any earlier attempt to collect and conserve this diversity, immediate steps need to be taken in this direction. This also serves as introspection to the poor state of germplasm collection and conservation in the National Agricultural Research System.
FIG. 34: COLLECTION LOCALITIES IN COMPARISON TO ITS DISTRIBUTION IN INDIA
5.2.1. Ecological considerations

As the majority of the herbarium specimen labels did not contain ecological information, these conclusions are based on actual field observations. Except *M. charantia* var. *muricata*, all the other species have clear geographic ranges, some of them occurring in specialized microhabitats/niches. Sympatric distribution was not observed except for *M. charantia* var. *muricata*, otherwise the species occupy mutually exclusive areas. *M. charantia* var. *muricata* is ubiquitous in distribution with *f. muricata* towards high rainfall areas and *f. spontanea* opting for drier habitats. *M. dioica* is another species with wide distribution, having many ecotypes adapted to various ecological conditions prevailing in the country, the major distribution areas being Peninsular India extending beyond Deccan Plateau to Central India. Two clear morphological varieties could be distinguished, markedly varying for seed characters and pollination biology.

A more detailed field study extending to the entire ecological amplitude may reveal the occurrence of distinct forms. Incidentally, *M. dioica* could be located from wet lowlands of Kerala to arid Rajasthan and from costal Islands to lower Himalayas. Study of a single character such as leaf shape in the taxon reveals innumerable types, adapted to high rainfall climate to desert climate. The Kerala specimens have very large, less lobed leaves much allied to *M. sahyadrica*, whereas the Rajasthan specimens have small much dissected fan shaped leaves, closely resembling *M. balsamina*. The dry belt specimens seem more prolific and highly branched; the branching pattern may be an adaptation to the higher grazing pressure in the drier habitat as evidenced in *M. balsamina* and *M. charantia* var. *muricata* f. *spontanea*. The other dioecious taxa on the one hand and *M. balsamina* on the other hand occupy entirely different climatic regimes, the former localized in high rainfall, moniane cooler habitats and the latter occupying hot arid plains. *M. balsamina* is restricted to Rajasthan and Gujarath and has a clear-cut preference for low pH soils. Natural distribution of *M. sahyadrica* is restricted to low and mid elevation range of Western Ghats whereas *M. subangulata* ssp. *renigera* has higher concentrations in Naga-Khasi-Jaintia hills, Kokrajar and Manipur hills. This species occurs in cultivation in homesteads all over Assam, Mizoram, North Bengal and other North Eastern states including Sikkim. Cultivated forms occur in Bangladesh and Nepal too. It
again has a clear preference for fertile loamy soils in humid high rainfall areas, not tolerating climatic extremes. It starts sprouting with the onset of pre-monsoon showers, completes its life cycle, availing the fairly long rainy season and perennates by the onset of winter and hibernating throughout summer.

*M. cochinchinensis* also exhibit a clear cut preference for heavy rainfall-high humidity regions with two divergent areas in India. To a higher extent, it occurs in low elevation areas in South Andamans, which is in continuation of its distribution in Philippines. Another hotspot is Assam, Manipur-Nagaland forests bordering Myanmar, where the fruit resembles *M. subangulata ssp. renigera* for its echination, although the leaves are distinctly trilobed and petiole gland dotted. The Andaman specimens had larger, less echinate fruits rather tubercled and soft warted.

It is difficult to distinguish between two forms of *M. charantia var. muricata* unless live plants are studied or seeds examined. Many workers consider *M. charantia var. abbreviata* (synonymous with *M. muricata*) as the progenitor of cultivated bitter gourd (Degener 1947). However, *M. ch.var. muricata f. muricata* has much closeness than *f. spontanea*. The form *muricata* has relatively wider distribution in Western Ghats in comparison to *f. spontanea*, which occur more in the drier tracts across Deccan Plateau. Morphological variation parallel to that of cultivated could be located in the muricata form met with in the Western Ghats. A cross section of such diversity in cultivated “uchie” could be collected from Eastern India. Hence, it may be possible that two centers of origin, the Chinese - East Indian for large fruited types and Western Ghats - Sri Lanka Centre for small-fruited “uchie” types. Roxburgh (1832) mentions the former in cultivation in all warmer parts of Asia and equates with “pandipaval” of Rheede. The smaller form, he equates with “paval” of Rheede and mentiones it under extensive cultivation and as more esteemed. Hence, in every possibility both evolved in mutually exclusive areas and the present day large fruited varieties might have reached West coast through trade relations with China.
The species *M. sahyadrica* is restricted to humid Western Ghats and *M. subangulata* ssp. *renigera* to North East Himalayan hills. If the inter and intra specific diversity is taken as a criteria supported by innumerable indigenous usages, cultural significance, ritual importance and linguistic evidences, Deccan Plateau for *M. dioica* and Western Ghats for *M. sahyadrica* and Assam hills for *M. subangulata* ssp. *renigera* may be considered as the centers of origin.

This information has wider implications in selecting areas for *in situ* conservation of these species. The prevalence of low plant population densities suggests the need for *ex situ* plant regeneration for rehabilitation of the species in *in situ* sites. In this context, the identification of preferred habitats and the characterization of meteorological and soil characteristics at the home range of the taxon will facilitate conservation of diversity.

### 5.2.2. Indigenous Traditional Knowledge

Barring bitter gourd, all the species are wild gathered delicacies, of the rainy season. The taboos discouraging *M. sahyadrica* husbandry has deep roots in conservation ethics. As seed germination is a difficult proposition, being a high value delicacy, without the protection of this 'tuber-planting ban', the species is bound to become extinct in the wild. Female plants are named 'madahagali' and male plants 'mathagali' in Karnataka high ranges, coinciding with 'kattupavakka' and 'sappu' in Wyanad, where only male tubers are prescribed for medicinal uses. Tender twigs and leaves of male plants are cooked as vegetable and are recommended for pregnant women and anaemic patients in the "Paniya" community of Wynad. As the pollinisers are needed only in lesser proportion (1:15) and the sex ratio being 1:1, this choice of male plants might have been a purposively introduced belief by the primitive societies as a conservation measure. The medicinal uses of *M. sahyadrica* for mastitis, hydrocele, breast swelling and pain in the early days after child birth and painful eruptions underlie its anti-inflammatory value which needs to be scientifically evaluated. The abortifacient uses are similar to that of *M. angustisepala* in Nigerian folk medicine (Aguwa and Mittal 1983). Secondary metabolites like momorcharin, trichosanthin are known for their ribosome inhibiting properties and may be responsible for the abortifacient properties. The species being little
known, there is no published ethnobotanical information and this is the first report. Use of tuber paste as detergent and toilet soap hold promise in the cosmetic and health care industry. Villagers consider its food value equivalent with mutton, giving credence to its high nutritional value, thus the nutraceutical potential of the fruits needs to be further investigated. Some of the apparently unimportant claims like raw consumption of seed aril and ripe fruits for rejuvenating and refreshing effects give indications of its antioxidant-flavanoid value. Ripe fruits being bright orange giving intact round rings on slicing, non-bitter taste and aromatic flavour add to its salad potential. Seed aril is a good source of lycopene imparting deep red colour to water and may be investigated as natural food colourant, herbal lipstick and in facial creams. The medicinal uses of M. charantia var. muricata and M. dioica by various tribes across the Western Ghats area is in conformity with the observations of Rheede (1688), Watt (1891) and Kirtikar & Basu (1933). Anti-ulcerogenic effect of Momordica charantia in Turkish folk medicine (Gurbuz et al. 2000) and gastro protective and ulcer healing properties of Momordica species in Sri Lanka (Fernandopulle 1997) are in conformity. Similar uses with related taxa are reported from indigenous societies in Africa and South East Asia (Ng.T.B. et al.1986, Aguwa & Mittal 1983). More intense study involving the forest dwelling tribes such as ‘cholanaikan’ in Nilambur, ‘mahadeo’, ‘koli’, katakari’ tribes in Maharashtra and ‘sholigo’ tribe in Karnataka is needed to document the unknown uses of this plant.

The patronage extended to M. sahyadrica as a high value vegetable might have arisen after the introduction of coffee in Karnataka high ranges. Vast stretches of forest openings, higher population of berry eating birds, ideal habitat for trailing and care provided by coffee growers might have contributed to its increase in population as the maximum population density was found in the Plantation Districts. Further, diversified culinary uses and dishes are found only in the upper class Brahmans and Konkanis who enjoy a financially better position in the society. Observations of indigenous people such as high preponderance of M. dioica in forests subject to summer fire gives clue to dormancy breaking effects of forest fire. Similarly, the practice of keeping seeds exposed to smoke may have an effect on dormancy breaking.
Numerous medicinal values ascribed to these species indicate their long association with the people. Local people manage it when it is not readily available in the market. Volunteer plants (self sown) in coffee estates are given a special management package to ensure good yield during festive season. This may have some evolutionary repercussions as thinning of plants growing from the same heap of bird castings effects genetic drift and lead to selection. The ceremonial use of the plant during ‘poojas’ reflects upon and implics an intensification of human-plant relationship because the plant has acquired a cultural significance beyond the mere satisfactions of a biological need.

Market survey reveals that ‘madagalikai’ fetches a competitive price (Rs. 80-120 per Kg) in the local market, resulting in a substantial financial return with relatively no inputs. Mangalore, Goa, Karwar, Haliyal, Yellapur, Ummachi, Dandeli, Sagara, Somavarpet and Sanivarasanthe are the main markets where ‘madagalikai’ is brought for sale. Peak season is August-September. No special skills are needed for harvesting. Even though 10-12 days mature fruits are ideal, the older ones can be used after deseeding. Keeping quality and shelf life of tender fruits are good according to vegetable vendors of Sagara market in Shimoga district.

The whole of ‘madahagalikkai’ is cooked (mature fruits deseeded) in a variety of ways. The manner of preparation is often dictated by customs, taste of particular ethnic group or creativity of the woman who cooks. In Hassan district, it is cooked in to curries with chickpea and potatoes. Konkanis prepare mouth-watering pakkodas (hot snacks) by dipping green slices in chickpea batter and deep-frying. For Shimoga Brahmins, it makes tasty rasam (sour soup) even in small quantities. In the Kerala part of Western Ghat, sliced tender fruits are cooked in to dry vegetables of different types and tastes by manipulating other components. Small quantity fruits are consumed as chutney by roasting the fruits wrapped in banana leaves in hot ash. ‘Paniyars’ use the leaves as dry vegetable or curried in to dhal. *M. muricata* is cooked in many ways like bitter gourd; however, the surplus being sun dried as preserve for off season use. Thus depending upon the ingenuity and fancy of a chef, wild bitter gourds can be curried, fried, pickled, dried or stuffed to suit different palates. However, in more progressed and urbanized tribal
societies in Kerala, the knowledge and interest in culinary preparations of wild *Momordica* are eroding, as the younger generation depends heavily on store brought food and the consumption pattern has changed drastically. *M. balsamina* was used as a salted and sun dried vegetable for lean months in olden times. The vernacular name ‘bhatkarela’ owes its origin to the method of its cooking once prevalent in North Bengal and Assam. Whole fruits after stuffing with condiments was cooked in rice and served. Unlike the Western Ghat species, *M. balsamina* in Rajasthan and *M. subangulata* ssp. *renigera* in the North East do not appear to have multiple ethnobotanic importances. However, this needs detailed study across their distribution range.

Interpretation of vernacular names given to a plant can provide evidence for evaluating the human interaction with the plant. A descriptive prefix combined with a generic root forms the specific names in the natural folk classification system (Gates 1939, Nutall 1924). Thus for *M. charantia* varieties and races in Western Ghats, the generic root (pavakka=bittergourd) preceded by trait specific epithets such as ‘nadan’ (=local), ‘kattu’ (=wild), ‘chunda’ (=small), ‘karandaka’ (= very bitter) and ‘mullen’ (=spiny) describes and demarcates genotypes and races. Vernacular names vary from place to place. For a collector, it is very essential to know the vernacular name of the plant in local dialect. Often, the same plant is known by different names in adjacent regions or two plants known by same name. However, the generic root broadly remains the same in the same language and only the prefix often changes according to species and dialect. The specific prefix has something to do with a quality trait or habitat of the species, often a web of mutually inclusive words. A perusal of the vernacular names of *Momordica* shows that same or related specific prefix are used in different regions by different communities. Thus, ‘Erumappaval’ ('she-buffaloe' bitter gourd), which is the vernacular name for *M. dioica* in Malayalam has become ‘Pothupaval’ ('he-buffaloe' biter gourd) for *M. sahyadrica* in Peechi-Vazhani where both have overlapping distribution. However, robust plant type, showy flower and slightly large fruits might have prompted the primitive gatherers to ascribe this gender-based designation. The adjectives, ‘ven’ (=white, milky), ‘pal’ (=milk), ‘nai’ (=butter, soft, delicious), ‘kuttathi’ (=kid) are used to describe sought after traits in beauty-food context and hence indicates social value.
attached to these plants. Where the species is given less patronage, the epithets like 'kadu-kundu-padu,' all meaning 'wild' is used to distinguish it from the cultivated. However, in South Western Karnataka, where *M. sahyadrica* has a higher distribution, the male-female plant concept is made clear by assigning different vernacular names.

*M. charantia* var. *muricata* landraces, even though of small size, are esteemed for its taste and flavour and is cultivated in restricted ranges and have fruit fly tolerance. Through a continuous cycle of planting and harvesting seeds, traits conferring adaptation to an agro ecosystem are fixed, thereby initiating the domestication process (Harlan 1973). ‘Kuttathipaval’ of Neyyar Wildlife Sanctuary, ‘Rudrakshahagalikai’ of Hassan, ‘Karandakai’ of Central Travancore and ‘Undapaval’ of Malabar fall in the category of semi-domesticates where one or two plants are raised in the backyards for own consumption.

All these information indicate that the genus *Momordica* has a significant ethnobotanical history in Western Ghats. Divergence of variant populations of *M. charantia* var. *muricata* from the truly wild type (SBJ - 120 from Achencovil, SBJ -112 from Chimmony and SBJ -61 from Malayattur) is the result of their association with human activities over time in several locations across Western Ghats. This association is manifested by encouragement of local variant populations through plant utilization and habitat modification and it represents progression towards domestication.

Sal-ukhan (1984) considers the following four criteria for new plant domestication to broaden the human diet. The ideal candidate plants should qualify the following criteria: (1) consumed directly by humans (2) high nutritional value (3) do not require intermediate processing between cultivation and (4) plants that are preferably natives.

Our candidate species fulfill all these criteria. Moreover, the plant and its fruits already occupy a niche in traditional agro eco systems, cuisines, diet, culture and economy in several places across Southern Western Ghats, the species is in many ways pre adapted for a renewed level of exploitation.
5.3. Reproductive Biology

5.3.1. Phenological observations

Understanding the phenological events is useful in evolving proper management strategy of the crop/species. Studies from different parts of the world has shown climatic factors such as rainfall, water availability, temperature, photoperiodism, duration of dry spell and change in day length and temperature as the main factors responsible for vegetative and reproductive phenology at both community and species level (Bhat and Murali, 2001)).

The phenological information generated here will help the prospective collector in planning the collection time so as to gather maximum diversity both at interspecific and intraspecific level. Tubers at late senescent stage, vine cuttings at early flowering stage and fruits (seeds) at ripe split stage are the ideal propagules. Hence, the collector has to plan the mission logistics judiciously in order to get more than one type of propagule in rare collections in order to ensure establishment in ex situ holdings. In the dioecious taxa, seedlings before caudex transition stage are difficult to establish on transplanting.

The phenological studies conducted in this genus reveal that for a germplasm collection programme for *M. dioica* in Kerala, mid August will be ideal time, where one can collect herbarium, cuttings, seeds and male and female tubers. Similarly for *M. sahyadrica*, mid September to mid October will be the best time when one will be able to locate male and female plants in various stages of reproductive maturity. *M. charantia* var. *muricata* collection programmes may be taken up in August-September, when one will find maximum fruit ripening coinciding with the dry spell after peak South West Monsoon. Senescence in *M. dioica* indicated by yellowing and drying up of aerial parts started by September-October and in *M. sahyadrica* slightly late but completing by mid November. However, in wet, shady slopes and evergreens, it prolongs to mid December, as observed in a few coffee estates in Chickamangalore and Hassan Districts.

The vegetative phenology in *Momordica* species is distinctly seasonal. Plants emerge and attain reproductive maturity in pre-monsoon period characterized by discontinuous but frequent rains that ensure adequate soil moisture for plant growth, high temperature and
increasing day length. This process of sprout emergence from storage roots, with the advantages of an established root system, stored food and water ensures that the plants are ready with fully developed foliage to take advantage of the favourable wet and warm conditions for growth by the onset of the South West Monsoon. Flowering and fruiting before the peak monsoon may have the advantage of enhanced visibility of flowers and fruits to pollinators and dispersal agents as most of the species in the community come to flowering and fruiting in the post monsoon period, availing the congenial growing environment. Whereas, *M. sahyadrica* which is restricted to Western Ghats only where the most favourable time for plant growth is the monsoon period, peak flowering and fruiting occurs in the post-monsoon season. This probably ensures greater seed predation by avian fauna. However, because of dormancy, the seeds remain viable in the forest floor for about six months, by then pre-monsoon showers start, ensuring favourable conditions for seed germination and seedling growth.

### 5.3.2. Pollination biology

Honeybees (Roubik 1995) and halictids (Grewal and Sidhu 1998) are reported to be the principal pollinators of Cucurbits including Bitter gourd. However, there is no published information available on the pollinators of other *Momordica* species. Without reliable information on the breeding system and mechanisms of pollination, explanations for success or failure of a crop and its field genebank will be incomplete.

Breeding systems in *Momordica* are of two types. *M. charantia* and *M. balsamina* by virtue of their monoecious nature have both options of Xenogamy and geitonogamy. In the dioecious members comprising *M. dioica*, *M. sahyadrica*, *M. subangulata* ssp *renigera* and *M. cochinchinensis* obligate xenogamy is the rule. In *M. dioica*, the pale yellow colour and musky aroma can be sensed from a distance to the human sensory organs. *M. sahyadrica* and *M. subangulata* ssp. *renigera* have floral guides or specialized patterns in blossom that act as near goal orientation cues to flower visitors to assist them in obtaining rewards while pollinating. In *M. sahyadrica* petal bases are greenish yellow, with striped veins and a characteristic feeble scent whereas in *M. subangulata* ssp. *renigera*, the three inner petals have bulls eye pattern- a purple blotch at the base, which
is of fairly large size. The functional significance of guides has been demonstrated by many workers (Sprengel 1993, Kugler 1943, Jones and Buchmann 1974). Muller (1876) noted that guides occur most frequently in flowers with hidden rewards. Generally, butterfly flowers have the largest frequency of guides. Nilsson (1979b) suggests that in addition to olfactory cues, the greenish yellow colour is a visual orientation cue at the close range for the small wasps in the case of *Herminim monorchis*. Vogel (1966a) is of the opinion that pollinating insects is attracted from a distance by floral fragrance and the close range orientation is cued by visual aspects of the flower. The musky odour and pale yellow colour of *M. dioica* may be serving these two purposes. However, it is interesting to note that ecotypic variations with respect to colour and odour intensity occur in *M. dioica*. Bundelkhand collections (Jhansi, Uttar Pradesh) of *M. dioica* have less musty-less intense odour and flowers have lemon yellow colour, probably to suit to the species of moth present there. Variations in anthesis time, floral cues and pollinator specializations are thus of biosystematic importance to distinguish between dioecious taxa of *Momordica* in India.

Being introduced from North Eastern India, the pollinators of *M. subangulata* subsp. *renigera* in its native habitat needs to be studied for better fruit set. All the taxa being insect pollinated, seed regeneration for genebanks must be done using hand pollination or sib-mating using insects in cages. Enumeration of specific pollinators assumes significance in *ex situ* conservation in selection of pesticides non-toxic to pollinators and timing to avoid maximum pollinator activity. For *M. dioica*, pesticide application should be done early in the morning and for other species in the evening. All the *Momordica* spp. produces enormous quantity of pollen. By virtue of pollen dehiscence taking place before anthesis and nectar being protected in the nectary concealed in the receptacle cup of the male flower, pollinators get their body loaded with pollen before access to the nectar, thus prompting the nectar starved insect to visit the female flower where nectar is available in exposed nectaries, ensuring cross pollination.

Many of the floral features such as hidden nectar and nectar guides are apparently designed to limit by exclusion forager access to the food rewards, enabling only the
specialized visitor access to pollen and nectar. The co-adaptive features of the plants with pollinators, presence of floral visual cues, olfactory cues and nectar cues that stimulate or reward pollen gathering and pollination are the results of continued evolution. This constancy of the pollinator to one kind of flower which is a kind of ecological isolation prevents interspecific foraging thus blocking interspecific hybridization because of heritable difference among species, whereas fertile hybrids between *M. subangulata ssp. renigera*, *M. sahyadrica* and *M. dioica* could be produced through hand pollination. Even though some species of ants were found foraging on two or more species of dioecious taxa, they are of negligible importance compared to winged pollinators. Successful production of spine and sweet gourd in non-traditional areas involves the understanding of the bionomics of both the plant and pollinator, too often the latter is overlooked.

5.3.3. Fruit ripening

Days taken to fruit ripening stage vary from species to species. *M. balsamina* has the shortest and *M. subangulata ssp. renigera* has the longest ripening span. Build up of red tinge in spine tips do not indicate seed coat hardening in *M. subangulata ssp. renigera*, whereas, full size and turgid appearance are a reliable indicator of fruit maturity. Harvested physiologically mature fruits soften within 24-48 hours in *M. sahyadrica* and *M. dioica* whereas *M. subangulata ssp. renigera* fruits remain green and fresh for longer periods. Thus, *M. subangulata ssp. renigera* has better keeping quality and shelf life than others.

5.3.4. Seed dispersal

Strong pendulous fruit stalks, attractive orange red colour, splitting open from base and rolling back and expanding in a star like configuration, exhibiting rows of scarlet red aril (covered seeds) and small round or flat dented seeds are adaptations for bird feeding. *Megalima virdis* was the most frequent visitor, spending most of the time feeding on seeds. Although crows, koyal, crow-phetant (Uppan) and sparrows were found as infrequent visitors, seed feeding was not observed. Even though, seeds per fruit varied from 15 to 30 (up to 50 in *M. sahyadrica*), no depulped seed was found on the floor (the
fleshy fruit wall is not eaten by any of these birds), giving credence to the inference that while feeding on the fleshy aril, the seeds are gulped. All the native species have very thick seed coat, enabling their passage through bird gut undamaged, but slightly reduced in size as it is partially digested. Feeding to captive chicks resulted in significantly reduced seed size in some cases and in such case the seed coat was digested considerably. Some seeds passed undigested and such seeds germinated slightly earlier than control even though speed of emergence was not uniform and significant.

Ripe fruits of all species are densely covered with ants and they were found predating on red fleshy sweet aril. Many species of ants were found carrying dry seeds of *M. dioica*, *M. sahyadrica* and *M. subangulata* subsp. *renigera* and were recovered from their hives. Besides, carrying to small distance, ant feeding may help to scarify the seeds by releasing formic acid.

*M. dioica* seeds are reported to contain up to 39 percent oil (Dubey and Gaur 1990). The ant genera falling under Formicidae family in general has been reported primary seed dispersing ants and *Crematogaster* species has been found important dispersal agents in tropical forests (Beattie 1985). Dependence on animals for seed transport means that the plants are susceptible to dispersal failure when their seed vectors become rare or extinct. Disruption of this mutualism can have serious consequences for the maintenance of plant /species populations. This again highlights the need for devising a holistic approach to conservation of *Momordica* germplasm involving the biotic agents.

5.3.5. Seed macro and micro morphology
SEM results were much encouraging as fine distinction could be derived between taxa. Between *M. dioica* *sensu stricto* and *M. sahyadrica* sp. *nov.*, SEM pictures showed clear difference on surface pattern, even between specimens collected from close geographical range, validating the bifurcation of the species. *M. dioica*, *M. sahyadrica* and *M. subangulata* subsp. *renigera* exhibited a broad pattern of reticulate honey comb like arrangement of testa cells with variation in the mesh size. *M. balsamina* stood apart in its uniformly creviced and ridged spermoderm surface pattern. *M. charantia* var. *muricata* f.
*spontanea* had some resemblance with *f. muricata*, but all the six taxa studied showed specific pattern. Variation in spermoderm pattern observed in SEM photographs corroborates the morphological distinction between the taxa.

5.3.6. **Seed dormancy and regeneration in nature**

Even though initial germination and soil seed banks are good for all species, continued monitoring of the forest habitat (Kuthiran, Trissur District, Kerala) for *M. sahyadrica* revealed that the number of individuals reaching reproductive maturity is less than 10% owing to various biotic and abiotic stresses. Antelopes were found to feed on its foliage. In *M. charantia* var. *muricata*, germination is very fast and high in response to first rain. *M. dioica* seeds are very shy and slow in emergence taking a time span of 6 months between the first and last seed emergence. In *M. sahyadrica*, seed germination was better, the first good rain inducing germination of maximum seeds at a stretch. The main abiotic stress being drying of shallowly rooted seedlings as they germinate often within layers of rotting leaves. Mortality due to vagaries in rainfall and termite predation was also observed in all three species. Cut worms (*Argotis* *sp.*) were found to cause extensive mortality to *Momordica dioica* and *M. sahyadrica* seedlings at 2-4 leaves stage in cultivation. However, *M. charantia* var. *muricata* was comparatively more robust and deep-rooted.

Dispersed seeds of wild species sometimes show a period of rest termed dormancy (Harper 1977). Usually, species of evergreen and semi evergreen forests lack seed dormancy (Hoi 1972). Dormancy is by far the chief factor determining germination in the dioecious *Momordica* group. Even in Achencoil forest and coastal lowlands in Ernakulam where there are two distinct peak rainy seasons, there is only one season for seed germination; the peak being within the first fifteen days of pre monsoon showers in March-April.

5.3.7. **Breaking seed dormancy**

Germination was erratic in all the three species. No single technique was found uniformly acceptable, as the response to each treatment was different. The natural adaptive
mechanism of bird feeding effects seed abration and reduction in thickness, allowing imbibition, further the gut temperature may have a role in cracking the seed coat. This has some analogy with con. \( \text{H}_2\text{SO}_4 \) and fire treatment. \( \text{Con.H}_2\text{SO}_4 \) causes rapid desiccation of the seed coat resulting in the fragmentation of the integument thus allowing passage of moisture to the embryo. With progressive increase in after-ripening period up to 8 months, there is a decrease in seed dormancy as indicated by pre-monsoon boom in all the species. Seeds of domesticated species, \textit{M.subangulata} subsp. \textit{renigera} has lesser dormancy than truly wild species, as domestication has reduced the taxons' wild nature of adaptation to insecure natural growth environment releasing seed dormancy at different rates in different seeds.

With no single method to effective 100 % dormancy breakage, a multi-pronged strategy is needed to enhance availability of planting material. By raising seedlings/tuber sprouts well ahead of planting season, rooted cuttings could be prepared from the mother/father plants which may be planted in a 15:1 proportion in the normal cropping season. The original tuber sprout and seedling tuber may be retained as mother stock, which will enable availability of cuttings well ahead of season up to 4 years of age.

Seed dormancy may be the prime culprit preventing domestication of \textit{M. dioica} and \textit{M. sahyadrica}. Establishment of dormancy free types in the wild may not be advantageous because a hard seed coat regulates germination over time and ensures durability, while seedlings of the dormancy free types may be swept away by the long droughts following inconsistent rains. It has been suggested that temporary establishment of a dormancy free type in wild population is possible if appropriate growing conditions lasted for 8-12 consecutive generations of growth seasons whereby the dormancy free type would increase (Ladizinsky 1998, Harlan 1973). The higher germination percentages of \textit{M. sahyadrica} collections from Soraba and Kannavam may be due to their domestication lineage as domesticates are observed to shed dormancy behaviour (Schwanitz 1996).

Seed to seed variation in dormancy of individual seeds from the same fruit was observed in all the three dioecious taxa. Fresh seeds started germination after 40 days and continued
beyond one year in *M. dioica* and *M. sahyadrica*, whereas in *M. subangulata ssp. renigera*, it started within 20 days and continued up to 4 months. Polymorphic seeds in the same fruit with respect to dormancy have been reported in some Asteraceae (Fenner 1991). A viable seed may fail to germinate because of quiniscence or dormancy or both. Drying to very low moisture content renders the seed absolutely and irreversibly impermeable until the hard seed coat is broken (Quinlivan 1971). Quiniscence is the failure of viable seeds to germinate due to environmental factors. Organic inhibitors may be responsible for the poor germination in the dioecious taxa as reported by Watanabe *et al.* (1988 a & b) in *M. cochinchinensis*. Natural inhibition by autotoxic phenolic compounds produced in the seeds has been reported in *Parthenium hysterophorum* (Picman & Picman 1984). Phenolic compounds may have other functions as preventing seed decay and inhibition of microbial attack (Rice 1983). Whether there is any organic stimulants, as in the case of root parasites or whether passage through bird gut and ant predation serve this purpose needs to be studied.

Alexander and Doijoide (1995) reports the use of electromagnetic fields in increasing germination and seedling vigour of quiniscent seeds of onion and rice seeds. Poor or delayed germination of deshelled healthy seeds indicate more than seed coat impermeability, some internal mechanism preventing germination whereas ready germination of 3 months buried seeds (SBJ-159) after deshelling indicate seed coat impermeability. Thus, dormancy in *M. sahyadrica* is a complex phenomenon involving both seed coat and internal mechanism. However, more than seed coat, internal mechanism is stronger as none of the physical treatments to reduce seed coat thickness invoked any positive response. Passage through bird gut might effect a complex process involving exposure to temperature, enzymes and microbes, besides partial digestion of seed wall.

Deshelling was very difficult in *M. sahyadrica* and *M. dioica*, often injuring the cotyledon. The injured seeds decayed in soil, whereas in SBJ-159, after three months burial in sand during monsoon, seed coat opened with slight pressure without injuring the cotyledon. Thus the results are inconclusive, only a general inference can be made that
prolonged exposure to natural weathering, ant predation and bird gulping act as germination promoters in nature. The meager 2-3 percent germination of fresh seeds from 40 days after sowing (M. dioica and M. sahyadrica) may be attributed to leeching out of inhibitory chemicals during heavy monsoon period.

5.3.8. Tuber dormancy and natural Regeneration

Germination of the tubers before pre monsoon showers suggest environmental factors such as high temperature and lack of moisture during hot dry season to play a role in breaking tuber dormancy. With the advantages of a well-developed root system and stored food, the subterranean sprouts are very vigorous and give rise to robust plants, which attain reproductive maturity quite earlier than seedling plants of the same age. Similar trend has been reported in Cyperus esculentus L. (chufa) from Latin America where enhanced aeration and soil and air temperature was found effective in breaking tuber dormancy (Pascual et al. 2000)

Juvenility in the dioecious group is a recurring occurrence. The morphological features associated with juvenile phase of the tuber sprouts imitate that of the seedlings for smaller leaf size and less lobed primary leaves. However, the tuber sprouts are more robust and early to reach reproductive maturity than seedlings.

5.3.9. Seedling morphology

Vegetative characters are least studied and relied in taxon identification owing to the prevalent botanical notion that these characters are more flexible and hence less reliable. However, in the absence of floral features at a given growth stage these characters can be useful. Usefulness of vegetative characters in the identification of forest trees and seedlings abound in literature.
5.3.10. Vegetative propagation methods

Usefulness of various vegetative propagation techniques can be fruitfully applied as alternate germplasm collection tools. As small clutch size, shattering nature and bird predation prevents assemblage of a desired (seed) sample size; alternate propagules can be collected and later raised in field genebanks to get a satisfactory seed crop.

5.3.10.1. Tuber splitting

The experiment proved that adventitious shoot buds occurs only in *M. subangulata* spp. *renigera* and its hybrid, whereas the shoot primordia in the root-shoot transition region in the storage tap root only can give rise to shoots in *M. dioica* and *M. sahyadrica*. Also, there is a clear root shoot polarity in *M. dioica* and *M. sahyadrica* whereas *M. subangulata* spp. *renigera* is toti-potent, capable of giving rise to root and shoot from any part of the storage tuber irrespective of whether being tap root or side root. Cutting of tuberous roots is a highly efficient method for multiplication in *M. subangulata* spp. *renigera* and its hybrids, whereas whole tubers or at best longitudinal splits in to two or four equal halves with intact apical meristem may work in the case of *M. dioica* and *M. sahyadrica*, where anti-fungal wound healing treatments has to be done to protect the tuber splits.

5.3.10.2. Sprouting of adventitious tubers

The results are same as in the case of sprouting tuber cuttings. Cent percent sprouting of adventitious tubers could be obtained only in *M. subangulata* spp. *renigera* and its inter specific hybrid. In *M. dioica* and *M. sahyadrica*, shoot primordia are localized at the root-shoot transition zone in the taproots; whereas the secondary storage roots developed at the base of stem cuttings do not possess shoot primordia. Hence, ratooning is possible in these species only with seedling taproot tubers, which are more of an organ of perennation than reproduction. In the case of *M. subangulata* spp. *renigera* and its interspecific hybrid, the seedling taproot behave like the former, but branched side tubers also give rise to multiple shoots, thus establishing a colony and spread of plants like runners. Here adventitious buds occur on the bulged tubers as well as on the wiry stalk of the storage roots and emerge as vigorous sprouts, which can be used for propagation.
Upon degeneration of the main rootstock, these side tubers or runner tubers helps to establish a colony and spread laterally.

Adventitious root propagation in *M. subangulata* ssp. *renigera* is unique to the species that can be used fruitfully in the breeding of this species. By virtue of dioecy and obligate cross pollination each seedling plant is heterozygous and this genetic make up is maintained indefinitely through adventitious root tubers. Clonal selection of outstanding plants and seedling segregates and their vegetative propagation offer scope for improvement of this crop. On the contrary, in *M. dioica* and *M. sahyadrica*, as the tuber does not have the capacity to perpetuate immortally, tuber collection cannot be treated as vegetative or clonal from the genetic point of view. Each tuber represents a distinct genotype of hybrid origin. Without conscious human efforts, a clone cannot be perpetuated in *M. dioica* and *M. sahyadrica*. Earlier reports of cultivation of kakrol (Ram *et al.* 2000) using stem cuttings and its ratooning do not make a distinction between taproot and adventitious root tubers regarding their sproutability.

5.3.10.3. Layering

Damaging the roots while removing the vine segments may lead to poor establishment. While planting the 2-node segments in poly bags, upper node was always exposed, leading to drying up of roots and burial of the stem and petiole lead to etiolation, which may affect plant health. This method is not advisable for propagation of any of the *Momordica* species.

5.3.10.4. Rooting of vine cuttings

Vine cuttings with fruits at varying stages of maturity could be rooted and healthy seeds collected using CMS technique. It is a very convenient, low cost, user-friendly technique for rescue collection of rare genotypes. Any number of cuttings can be rooted successfully using this technique. Cuttings can be rooted throughout the year by placing the sachets in humid, cool, shaded places.
5.3.10.5. Development of leaf micro tubers
Development of leaf micro tubers in *M. subangulata* spp. *renigera* widens the scope for conservation by virtue of its ease of production, convenient small size for packing and transportation. However, the leaf micro tubers take two growth seasons to reach reproductive maturity.

5.4. Characterization and Evaluation of collected Germplasm

5.4.1. Descriptor

There is no published descriptor for Bitter gourd, sweet gourd or spine gourd or any other *Momordica* species by IPGRI or any other organizations. The lone descriptor for *Momordica* was seen in NATP Minimal Descriptor for Vegetable Crops (Anon. 2001) where bitter gourd, sweet gourd and spine gourd are treated together. They being evolutionarily divergent groups, bitter gourd on the one hand, sweet gourd and spine gourd on the other hand should be treated separately as they vary for more than 75% characters by virtue of their breeding behaviour and growth forms.

The elaborate analysis of various descriptors has wider applicability for use in numerical taxonomy. This descriptor is unique in its extensive analysis of various morphological and agronomical traits. It provides ample choice for selection of easily recognizable traits that could be used for characterization in order to determine the integrity of an accession when compared with data from the original source. A detailed enumeration of the biotic stresses, even if (when) observed to a lesser extent, is given as with changing environment they may acquire significance.

5.4.2. Interspecific crossability

*Momordica dioica* *M. sahyadrica* and *M. subangulata* ssp. *renigera* are interfertile reciprocally. The comparatively low fruit set percentage in crosses involving *M. dioica* as male and female parent may be attributed to reduction in stigma receptivity and pollen viability of 12-13 hours old flowers. 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 genepool.

*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 a neo-endemic. 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 clues to support its ancestry (Ladizinsky 1998).

Crossability failure of *M. dioica* x *M. charantia*, *M. dioica* x *M. balsamina* and *M. charantia* x *M. balsamina* are in conformity with earlier experiments where complete incompatibility has been reported (Vahab 1989, Trivedi et al. 1972). The interspecific hybrids of *M. subangulata* ssp. *renigera* x *M. sahyadrica* and *M. subangulata* ssp. *renigera* x *M. dioica* offer good potential as leafy vegetable crops with ratoonability and ease in propagation through adventitious tubers and tuber cuttings. deWilde and Duyfjes (2002) mentions about a female specimen of a *Momordica* species of uncertain identity, probably a hybrid allied to *M. subangulata* being grown in Thailand for the young leafy shoots and propagated through division of rootstock. All these hybrids offer potential as ornamentals.

The intermediate behaviour of ‘hybrid-3’ (*M. dioica* x *M. sahyadrica*) for flower size and anthesis time sheds clear light on the variant forms of *M. dioica* occurring in South East Mumbai. Presence of open flowers in herbarium specimens indicate flowers remaining open beyond 6 AM, thus the material from this region may be of hybrid origin between *M. dioica* and *M. sahyadrica*. de Wilde and Duyfjes (2002) after observing collections [PD 762 (♂), 1027 (♂), 1028 (♂), 2388 (♀), 2389 (♀) BLAT] from South East Bombay, observes them as a separate taxon of uncertain status, probably of hybrid origin. This study validates his view of hybrid origin of variant *M. dioica* specimens from South East Bombay.
5.4.3. Similarity index and divergence analysis

5.4.3.1. Qualitative characters

In the cluster analysis of qualitative trait data, maximum dissimilarity was observed between *M. charantia* var. *muricata* and other dioecious species (*M. dioica*, *M. sahyadrica* and *M. subangulata* ssp. *renigera*), thereby suggesting evolutionary significance of this species. Within the monoecious group, *M. charantia* var. *muricata* was more related morphologically to the cultivated form *M. charantia* (*r* = 0.60-0.75) than to *M. balsamina* (*r* = 0.52-0.58). Between them, *M. balsamina* and *M. charantia* exhibited more than 50 percent resemblance. Either this species, *M. charantia* var. *muricata*, might have originated first or spatially separated from rest of the species. No other species showed morphologically significant resemblance (*r* < 0.50) among them. Species specific differences were well pronounced or preserved between species suggesting taxonomic validity for these six species established following natural taxonomy system.

The correlation coefficients among accessions within a species were greater than 70 percent thereby, signifying closeness or similarity among them. *M. dioica* and *M. charantia* are typical examples. At 90 percent phenon line, there were only one and three clusters for *M. charantia* and *M. dioica* respectively. However, at the same phenon level, *M. charantia* var. *muricata* segregated into four clusters indicating greater genetic variability.

Within a given species, considerable variation or differences was observed irrespective of the geographical place from where it was collected suggesting qualitative traits were not affected by geography as exemplified from accn Nos. 7, 8, 10, 11, 12, 13 and accn No. 2 and 4 of *M. dioica* and accessions 1, 2, 3, 4, 5 and 7 of *M. charantia* var. *muricata* However, variation among accessions was pronounced in some cases. Examples are *M. sahyadrica* collected from Pallivasal (accn 11) and Sakleshpura (accn 12) versus rest of the *M. sahyadrica* collections, *M. dioica* accn no. 14 and 15 versus rest of collections, *M. renigera* accn no. 2 versus remaining collections and in *M. charantia* var. *muricata*, accn no. 23 versus accn. no. 1, 2, 3, 4, 5, 7 and accn no. 23 versus remaining collections at higher
levels. The specific ecological niche may have contributed to the specific morphological character preservation.

5.4.3.2. Quantitative characters

Analysis of variance for the quantitative characters from six *Momordica* species has showed significant differences between species invariably for all the characters suggesting presence of inter-specific mean differences among the species. Characters like leaf area, fruit weight, fruit yield per plant recorded highest coefficient of variability thereby signifying environmental sensitivity for these traits. These characters might be controlled by polygenes.

The cultivated species of bitter gourd, *M. charantia* was robust/high/large in all the quantitative characters under study (fruit length, fruit circumference, fruit diameter, fruit weight, yield per plant, seed length and seed width) except for no. of fruits per plant, fruit cavity diameter, clutch size and seed thickness. This species despite low number of fruits per plant, as compared to other wild species, had recorded high fruit yield per plant owing to its large fruit size. Although the number of fruits is more in *M. balsamina*, it could not compete with *M. charantia* for fruit yield per plant owing to its small fruit size. *M. subangulata* var. *renigera* had thick seed, in comparison, and recorded second rank for yield per plant. Fruit clutch size was large in *M. sahyadrlica*. Whereas, *M. balsamina* closely followed by *M. charantia* var. *muricata* was small or least in almost all quantitative traits like fruit length, fruit circumference, fruit diameter, fruit cavity diameter, fruit weight, clutch size, number of fruits per plant fruit yield per plant and seed thickness. As regard to seed length and seed width, these two species were intermediate in size and for these traits *M. dioica* is least.

5.4.4. Biotic stress tolerance

None of the species was resistant to fruit fly. Cultivated species *M. Charantia* was highly susceptible to fruit fly. However, low infestation was seen in *M. sahyadrlica* followed by *M. dioica*. None of the species was free from infestation of aulocophora beetles. *M. balsamina* showed low degree of infestation while *M. dioica* was infested heavily.
Barring *M. subangulata* var. *renigera* with low level of infestation, all species were free from infestation of Pumpkin caterpillar. *M. dioica*, *M. balsamina* and *M. charantia* were totally free from gallfly incidence whereas, *M. subangulata* var *renigera* followed by *M. sahyadrica* showed little infestation. While *M. charantia* and *M. balsamina* were free from attack of epilachna beetle, others were affected very low to low level. Three species namely *M. dioica*, *M. charantia* var. *muricata* and *M. charantia* were absolutely free from collar rot infection while the remaining three species were infested (little). No fruit rot infection was recorded from *M. subangulata* var. *renigera*, *M. balsamina* and *M. sahyadrica*. It was interesting to note that these three species were affected by collar rot. Other species were infected very low to low degree. Two species, *M. subangulata* var. *renigera* and *M. balsamina*, were free from infection of little leaf. Very low to medium score were recorded from other species.

High level of pesticide application and its residual effects in bitter gourd can be eliminated through the cultivation of fruit fly resistant varieties. The high level of fruit fly tolerance in *M. charantia* var. *muricata* collections can be transferred to cultivated bitter gourd through conventional breeding techniques. However, the small fruit size of the wild and semi domesticates, being dominant in the F1 needs to be improved through repeated back crossing. High level of fruit fly, pumpkin caterpillar and nematode tolerance observed in *M. dioica* and *M. sahyadrica* collections offer scope for incorporation of these highly desirable traits in teable gourd improvement. Even though, viable hybrids could be produced, problems with regard to advancement of generations through seed propagation need to be resolved. Development of root knot nematode resistant varieties will enhance the ratoon potential of sweet gourd in nematode infested areas.
5.5. Genetic erosion and threat analysis

5.5.1. Quantifying genetic erosion

Collection and conservation strategies and priorities are formulated based on importance of the germplasm by way of utility and more importantly genetic erosion. Studies conducted in this group of taxa revealed that the threat of genetic erosion to a great extent in *M. dioica* and *M. sahyadrica* in the Western Ghats. In *M. charantia* var. *muricata*, the wild and feral components are not facing any imminent threat; however the semi domesticates landraces are under severe threat.

As per the field studies, *M. sahyadrica* in Karnataka seems to be out of danger because of the patronage it avails in coffee estates. Being a high value vegetable with many of the taboos associated with use of tubers as planting material, self-sown plants (female and few pollenizors) are well taken care of in coffee estates. Medicinal uses are restricted to few tribes only, where fortunately there is good population of this species and they cultivate it as a vegetable, hence destructive collection of tubers would not lead to endangerment. However, in the Kerala forest, it is subjected to severe threat especially from invasive weeds such as *Mikania micrantha* and *Lantana camara*. *Mikania* covers the entire forest floor and smothers emerging seedlings, thus preventing regeneration of seedlings and tuber sprouts. Wild boars and porcupines damage the tubers and antelopes graze heavily on its foliage. Having preference to well drained ridges and slopes of forest openings, it is vulnerable to landslides, invasion of cover crops such as *Mucuna sp.* from rubber plantations, herbicide application in juvenile rubber plantations and sickle weeding of forest seedling plantations continuously for 2-3 years thus not allowing its reproductive maturity. On a conservative estimate, less than 200 plants only could be spotted throughout Kerala, out of which about half in a small area in Olakara range of Peechi Forest Division. Hence, the taxon is in a vulnerable state and needs protection and rehabilitation. The species was spotted inside Agasthyavanam Biological Park, Periyar Wild life Sanctuary, Peechi-Vazhani Wildlife Sanctuary, Chimmony WLS, Aralam WLS, Wynad WLS, Muthanga WLS, Silent Valley National Park and Iddukki WLS in Kerala, Kudremukh WLS, Anaci National Park, Mukambika WLS, Dandeli WLS and Someswar WLS in Karnataka, Dudhsagar WLS in Goa, Koyna W.L.S and Radhanagari W.L.S in
Mere spotting do not mean complete protection in the light of emerging threats especially alien weeds. An in depth study of the population dynamics of various *Momordica* species in these protected areas needs to be done to arrive at a meaningful conclusion regarding “in situ on farm” conservation, as *ex-situ* conservation has not been attempted in these species yet.

*M. dioica*, even though figured to have wider distribution in the Indian sub continent as per herbarium survey, has a very restricted distribution and poor frequency in Kerala. Destructive harvest of tubers for medicinal preparations is rampant. Single tuber under the name “paval kizhangu” fetches Rs. 10/- at the Ayurvedic drug stores in Ernakulam – Alappuzha districts and wild gathered tubers are stocked for sale in “pettimarunnu kada”, ie, native drug store. Like *M. sahyadrica*, this taxon is also subject to habitat loss (more severe due to invasive weeds). It occupies partial shades of well-drained low elevation forests or undisturbed riverbanks and partially opened woodlands. With urbanization, privately owned woodlands are being developed for commercial activities. A few plants have been spotted in the coastal low lands of Ernakulam, Alapuzha, Kottayam, Thrissur and Palakkad where human population density is one of the highest in the World. In the four forest spots, ie, Achenkovil and Aryankavu in Quilon District, Malayatoor in Ernakulam District and Neriyamangalam in Idukki District, *Mikania* was found to be spreading at a faster rate. At Tripunithura in Ernakulam District, the bearing female vine (spotted during 2001 September) or any seedlings could not be located during subsequent visits, where the introduced cover crop *Mucuna* has covered the entire floor and started climbing on support trees also. At Ramavarmapuram in Thrissur, where around 68 individual plants were spotted in 2001 August, the present population has dwindled and *Mimosa incisa* was found to be spreading rapidly preventing seedling emergence. There is no domestication attempt and this taxon has inherent problems associated with seed dormancy, dioccy and pollination and dispersal syndrome. Less than 100 mature individuals only could be located in Kerala. Outside Kerala, it could be located at Kadayanellor in Tirunelveli District, Kolli hills, Salem District (both in Tamil Nadu) and in Nagarhole WLS towards Biligirirangan forests in Karnataka. By virtue of its very restricted distribution in a narrow range, population pressure in the habitat and market
demand leading to destructive harvest of tuber, the species is in an endangered state and needs immediate attention. A genetic reserve may be established at Achenkovil forest on Achenkovil- Kottavasal ridge for in-situ conservation. The species could be spotted in Shendurney Wildlife Sanctuary, Kumarakan Bird Sanctuary and Thattekad Bird Sanctuary, but all these sites were subjected to heavy human pressure and do not offer any guaranteed protection.

*M. charantia* var. *muricata* is by far the most well distributed species occurring throughout the range of Western Ghats. Its population is sporadic and less dense in Kerala forests whereas in Goa and Karnataka forests especially in Uttar Kannada, it has good population. Maximum density is seen near tribal homesteads probably because of the role of man in inadvertent distribution of seeds of wild gathered fruits. Partial opening of the forests and tillage may be another reason for its concentration near habitats. However, in Kerala, two distinct forms differing for plant, fruit and seed morphology could be located. Fruits are gathered regularly by locals but not subjected to any destructive harvest. Other than habitat loss, the species is not facing any threat, more over it is well represented in all the wildlife sanctuaries and protected areas in Kerala, Karnataka, Goa and Tamil Nadu.

Primack (1993) considers eight behavioural traits of taxa which are indicators of vulnerability to extinction. The species most vulnerable to extinction have one or more of the following characters. (1) very narrow geographical range (2) only few populations (3) very small population size (4) low population density with a few individuals per unit area (5) little genetic variability (6) specialized niche requirements (7) low rate of population increase (8) prefer stable environment – unable to tolerate the changes in the microclimate due to environmental change. A critical study of *M. dioica* and *M. sahyadrica* in Western Ghats (and West Coast) reveals that except for genetic variability all the other clauses apply to both species to a greater or lesser extent according to location and site. By applying this scale to analyze the results, it becomes clear that *M. dioica* and *M. sahyadrica* by virtue of their inherent biological traits are vulnerable to extinction.
However, the semi domesticate primitive landraces of *M. charantia* var. *muricata* unravel an entirely different picture. A few landraces, all having small fruits but with esteemed medicinal properties, flavour, taste and more than anything else fruit fly tolerance used to occur in homesteads and tribal hamlets. The study indicated grave loss of this valuable diversity, in its centre of origin and domestication. “Kuttathippaval”, a landrace of Southern Travancore forest dwellers could be located only at two tribal homesteads within Neyyar Wildlife Sanctuary. Similarly, “Rudrakshahagalikkai”, a miniature fruited type with eight continuous ridges, once prevalent in Hassan - Sakleshpura – Coorg area is now dwindling at an alarming rate. Only two locations could be spotted where this is being grown. ‘Karandakakka’ in Central Travancore homesteads is in a better position, as around 15 homestead sites could be spotted spread over a few villages. A few vines are grown in homesteads and no special care is given except providing support or trailing to treetops or roof. On the contrary, ‘Methipavai’, another small-fruited type is grown to a small extent in Tamil Nadu for commercial markets. It could be collected from Tanjore and Tirunelveli markets. This resembles the “uchie” of Kolkata market.

Barring ‘methipavai’ the other landraces are nearly extinct. Lack of avenues for commercialization, non-competability with commercial bitter gourd cultivars for yield and poor seed production are some of the reasons hindering its cultivation. An extensive survey in selected pockets would enable to locate more sites and few more named landraces. A careful breeding strategy for seed multiplication, followed by on-farm conservation in the native habitat along with subsequent ‘ex-situ’ conservation would only save this precious resource from peril. Roxburgh (1832) states ‘uchie’ (*M. charantia* var. *muricata*) as a commonly cultivated vegetable all over India, being more prevalent and more esteemed than the large fruited type. Over a period of 150 years, the trend has reversed with “uchie” almost wiped out from cultivation except from a few pockets. The wild domesticates has been almost wiped out from agroecosystems, due to the advancement of large fruited types and this has happened well before the modern released varieties became popular with the farmers.
Fig. 35: Exploration and germplasm collection in *Momordica*. (Top) *M. subangulata* ssp. *renigera* collection from Meghalaya

(Row I Left) *M. subangulata* ssp. *renigera* tuber collection from Assam forests.

(Row I Right) *M. subangulata* ssp. *renigera* ♀ plant in Assam forest.

(Row II Left) Tuber collection of bhatkarela

(Row II Right) *M. subangulata* ssp. *renigera* collection from Sikkim
Fig. 36: Rescue collections of rare semi-domesticates of *Momordica*

Kuttathipval - a rare landrace of 'Kani' tribes (Top Left)

Methipavai - a landrace from Tamil Nadu (Top Right)

Rudrakshahagali (SBJ-151) - a rare landrace from Hassan District, Karnataka (Bottom).
5.6. Conservation strategies and priorities

5.6.1. An overview of conservation approaches

Awareness of the increasing threats to biodiversity and of the scientific problems associated with conservation and sustainable utilization has highlighted the need for more efficient and effective protocols and methodologies. As stressed by Maxted et al. (1997 a), no one conservation strategy alone can effectively conserve the gene pool; greater biodiversity security results from the application of a range of ex-situ and in-situ techniques applied in a complimentary manner.

5.6.2. Present Conservation status of wild Momordica genepool in India

Before establishing collection strategy and conservation priorities, the present status of conservation of the genus must be considered. A total of 187 accessions of bitter gourd, 30 accessions of *M. charantia* var. *muricata* and 3 accessions of *M. sahyadrica* are maintained at national Genebank of NBPGR. The ex situ field genebanks at Rahuri (MPKV) maintains a population of about 200 plants collected from a small area in Maharashtra. Similarly, the less than a dozen collections of sweet gourd maintained at AAU Research center, Kahikuchi (they are all *M. subangulata* ssp. *renigera* and not *M. cochinchinensis*) do not adequately represent the variability across the species. The other valid species viz. *M. cochinchinensis*, *M. sahyadrica* and the vast array of variation in wild and feral forms of *M. charantia* var. *muricata* are not conserved anywhere. A handful of collections of *M. dioica* are being maintained at SK Nagar (Gujarat) and Ambikapur under the AICRP on Under Utilized and Underexploited Plants (Personal communication, Sarode 2003). A total of 14 accessions falling under five species has been maintained at Krishna Chandra Mishra Institute of Wild Vegetables (Bettencourt and Konopka 1990). Therefore, the ex situ conservation status of Momordica wild genepool is practically negligible.

Coming to the in situ scenario, there are no designated Genetic Reserves for any crop wild relatives except citrus in India. However, a cross sectional survey of the Western Ghat forests, revealed the spotting of various *Momordica* species in the Wildlife Sanctuaries and other protected areas.
There are reports of successful *in vitro* multiplication of kakrol (Hoque and Rahman, 2003). Even though, bitter gourd seeds are reported to be cryo non-tolerant (Zhang et al. 1990), experiences in seedbanks show good storability in medium term storage. Reports of storability of pollen upto 45 days in *M. dioica* under desiccation and low temperature (Dubey and Gaur 1989) gives scope for carrying out cryopreservation protocols. Hence, all these options also need to be worked out as complementary *ex situ* conservation strategies.

### 5.6.3. Future Collection and Conservation Priorities and strategies

#### 5.6.3.1. *Ex situ* Conservation

Having assessed the genetic erosion status and potential of wild *Momordica* genepool, different taxa need different level of conservation approach. However, in the absence of any earlier initiative to collect these resources by any of the Government agencies, it is necessary that extensive collection programmes be carried out throughout the range of the taxa and the seeds multiplied and stored in *ex situ* genebanks. The importance of bitter gourd and other *Momordica* species is bound to increase as nutraceuticals. Fruit fly tolerant lines of *M. charantia* var. *muricata* abound 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 genebank storage is a priority (Table 65).

A series of exploration trips involving National Bureau of Plant Genetic Resources (NBPGGR), Indian Institute of Vegetable Research (IIVR) and concerned State Agricultural Universities (SAU) needs to be planned in the hotspot areas to collect maximum diversity, which needs to be maintained in a simulated *in situ* habitat for seed increase (Table 66). For this, an *ex situ* site needs to be identified within the home range of the species. A few farmers may be identified and entrusted with the job of seed multiplication under buy back agreement. The timing should coincide with fruit ripening but before senescence so that cuttings also could be collected. A general recommendation is August-September, before South West Monsoon withdraws.
Table 65: Proposed *ex situ* conservation priorities for *Momordica* species

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Spp./ Landrace</th>
<th>Conservation intervention</th>
<th>Area/Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rudraksha hagali</td>
<td>On-farm seed increase, <em>Ex situ seed storage</em></td>
<td>Sakleshpura and Hassan in Karnataka</td>
</tr>
<tr>
<td>2</td>
<td>Methipavai</td>
<td><em>Ex situ field genebank and seed storage</em></td>
<td>Madurai, Tanjore and Tirunelveli in Tamil Nadu</td>
</tr>
<tr>
<td>3</td>
<td>Karandakakkai</td>
<td>On-farm seed increase, <em>Ex situ seed storage</em></td>
<td>Low hills of Kottayam, Pathanamthitta, Kollam and Thiruvananthapuram Districts of Kerala</td>
</tr>
<tr>
<td>4</td>
<td>Kuttathippaval</td>
<td>On-farm seed increase, <em>Ex situ seed storage</em></td>
<td>Neyyar WLS, Thiruvananthapuram Dt.</td>
</tr>
<tr>
<td>5</td>
<td><em>M. dioica</em></td>
<td>On-farm in simulated forest habitats through tribal co-operatives</td>
<td>Low elevation Coastal Kerala, Western and Coastal Maharashtra and Central India</td>
</tr>
<tr>
<td>6</td>
<td><em>M. sahyadrica</em></td>
<td><em>Ex situ</em> genebank, Domestication and cultivation in home gardens</td>
<td>Mid and high ranges of Western Ghats</td>
</tr>
<tr>
<td>7</td>
<td><em>M. balsamina</em></td>
<td><em>Ex situ</em> field and seed genebank</td>
<td>Gujarat, Rajasthan and adjoining areas of Haryana</td>
</tr>
<tr>
<td>8</td>
<td><em>M. subangulata</em></td>
<td><em>Ex situ</em> seed storage and maintenance in home gardens, ssp. renigera</td>
<td>Assam, Sikkim, Meghalaya, Mizoram and North Bengal hills</td>
</tr>
<tr>
<td>9</td>
<td><em>M. cochinchinensis</em></td>
<td><em>Ex situ</em> field and seed genebanks and maintenance in home gardens</td>
<td>Sunderbans, Assam plains and Andaman forests</td>
</tr>
<tr>
<td>S.N.</td>
<td>Target area</td>
<td>Target spp./ hotspots</td>
<td>Maintenance site/ agency</td>
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</tr>
<tr>
<td>1</td>
<td>Southern Western Ghats- low elevation and coastal Kerala</td>
<td><em>M. dioica</em></td>
<td>RARS, Kumarakam</td>
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<tr>
<td></td>
<td></td>
<td>Achenkovil</td>
<td></td>
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<tr>
<td>2</td>
<td>Mid elevation and high ranges- Iddukki, Wynad, Nilambur, Peechi WLS</td>
<td><em>M. sahyadrica</em></td>
<td>RARS, Ambalavayal, SHREYAS (on-farm)</td>
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<td>Begur</td>
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<td>3</td>
<td>Southern Western Ghats of Karnataka - Karnataka midlands and high ranges-</td>
<td><em>M. sahyadrica</em> and <em>Rudrakshahagali</em></td>
<td>KVK Shimoga, SHREYAS, Wynad</td>
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<td></td>
<td>coffee estates, Agumbe, Belgaum</td>
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<td>4</td>
<td>Northern Western Ghats (low elevation) - Wada, Mumbai Rural, Thane Rural</td>
<td><em>M. dioica</em></td>
<td>MPKVV, Rahuri, Vanavasi</td>
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<td></td>
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<td></td>
<td>Kalyan Sabha, Dheena Bhandu</td>
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<td>Charitable Trust, Thane</td>
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<td>5</td>
<td>Mid elevation Western Maharashtra - Mahabaleswar, Khandala, Kolhapur, Radhanagiri</td>
<td><em>M. sahyadrica</em></td>
<td>MPKVV, Lonarvala</td>
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<td></td>
<td></td>
<td></td>
<td>MPKVV, Khandala, ADS, Karjat</td>
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<tr>
<td>6</td>
<td>Rajasthan and Gujarath</td>
<td><em>M. balsamina</em></td>
<td>NBPG, Jodhpur</td>
</tr>
<tr>
<td>7</td>
<td>Andaman forests, Sunderban, Khasi &amp; Jaintia</td>
<td><em>M. cochinchinensis</em></td>
<td>CARI, Port Blair</td>
</tr>
<tr>
<td></td>
<td>Hills and Mizoram</td>
<td><em>M. subangulata ssp. renigera</em></td>
<td>NBPG, Shillong</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>ICAR, Mizoram</td>
</tr>
</tbody>
</table>

Collaborator: IIVR, Varanasi and concerned SAU
5.6.3.2. 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, North East and Andaman Islands these species can be afforded in situ protection (Figure 37). In Andaman and Nicobar Islands, an area of 1,529.27 Sq.Km is declared protected under 96 Wildlife Sanctuaries (Rodgers et al., 2002). Being islands, geographical isolation mechanisms must be working stronger and hence there must be every possibility of locating distinct forms in M. cochinensis.

Inventorization is the starting point for in situ conservation. In the absence of inventories, wild species of Momordica are not identified or managed as crop wild relative 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 in situ conservation in the case of Momordica species

This study has brought out the areas of higher concentration of inter specific and intra specific diversity in the genus in Western Ghats. As there is no checklist of the occurrence of Momordica spp. in the various protected areas, the information gathered in the present study, though based upon just a cross sectional spotting, serves the purpose to highlight the importance of setting up Genetic Reserves for the taxa concerned. River bank vegetation of Achenkovil, the coastal riverine highly fragile ecosystem of Vembanad at Vaikkam, low elevation Neriyammagalam forest and Achenkovil-Kottavasal-Aryankavu forests are to be considered for setting up in situ reserves for M. dioica. The coastal riverine ecosystem, being prone to high human population density, faces extreme threat. Hence, it may be ideal to rehabilitate a representative collection of M. dioica from coastal Kerala in Kumarakam Bird Sanctuary - a small patch representing this habitat and somewhere in the Shendurny WLS. A genetic reserve may be established at Achenkovil forest on Achenkovil- Kottavasal ridge for in situ conservation. M. dioica
was spotted growing in sacred groves at Kodungaloor and Muthuvara near Thrissur and herbarium records indicate collection from few sacred groves in Ernakulam district. Artificial seeding and in situ protection in sacred groves especially for *M. dioica* needs consideration in the light of its endangerment especially in coastal lowlands in Kerala.

5.6.3.3. *In situ on farm conservation*

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, ie, the tuber is collected from the forest. *M. charantia* var. *muricata* being exclusively seed propagated, domestication attempts have progressed further. With a little financial support, selected tribal farmers can be persuaded to continue and extent this on farm conservation attempts.

In *M. charantia* var. *muricata* and *M. sahyadrica*, on-farm performance was better than in home gardens. This may be due to the narrow adaptability of the semi domesticate - wild species to the changed environmental conditions. 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.

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 satisfies the material and cultural needs of the local people.
Fig. 37: Proposed in-situ genetic reserves for Momordica genepool in India.
5.6.3.4. *Ex situ* home garden conservation

The experiment on home garden conservation was taken up on an exploratory basis to assess the prospects of farmer participation in germplasm conservation. Since the taxa being wild or at the most semi domesticate, not much information on package of practice for the crop was available. Hence, the farmer was at liberty to experiment with his ideas at all levels of execution of the programme in his farm. Green revolution had nothing to do with genetic erosion in these taxa as they are still wild or semi domesticate. Being at the wild-domesticate 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 leads to further spread of the taxa in homesteads, adding to domestication efforts. Simple methodologies are particularly useful for those conservationists working in centers of diversity where genetic erosion is severe and conservation finances are limited (Maxted *et al.* 2002). Entrusting of the same accession to more than one farmer ensure survival of the plant in at least one locality. Conduct of the trial through the involvement of a social agent such as an NGO or a recognized community leader would have given better response than direct selection of individual clients. Also selection of the clients giving due weightage to their orientation for conservation values and ethics is also equally important. Zeven (1996) has argued that farmers will continue to grow landraces only when they are paid to do so and in situations where sustainability of long term funding of National gene banks are at stake, paying farmers for on-farm conservation will not be feasible in the long run. However, if the rewards or incentives are carefully tailored in the genetic resource to be maintained such as fruit fly resistance in *Momordica*, there will be many takers for on farm conservation. Limiting the conservation intervention to supply of planting material and information on basic ecology and biology of the target taxa such as preferred soil types, breeding behaviour, pollination and seed dispersal mechanism enabled individual clients to modify the growing environment and cultural interventions according to their convictions. This non-homogeneity in cultural
environment has manifested in yield and decision to continue with the on-farm conservation and more refined farming practices.

Long term monitoring of the diversity in home gardens could be carried out by the farmers themselves. A structured home garden network would contribute to preserving species and varieties and improving sustainable vegetable production by means of rational use of plant genetic resources with a low ecological cost. Maintenance in tribal homesteads would also help to preserve valuable traditional practices and cultural values in ethnic societies with their younger generation being oriented to and developing an aptitude and love for it. Thus, the use of homesteads for in situ conservation of wild and semi-domesticate *Momordica* germplasm can be a key complimentary approach to the ongoing biodiversity conservation strategies and programmes aimed at the empowerment of weaker sections. Establishment of medicinal plant farms for cultivation of "kaattupaval kizhangu" (*M. dioica* tubers) will minimize the collection of this plant from the forests. Collection from wild is rampant in Kollam, Alapuzha, Kottayam, Ernakulam and Pathanamthitta districts as it is remunerative and in high demand in traditional indigenous medicine.

*Momordica* species including balsam pear, balsam apple, spine gourd and sweet gourd are treated as ornamentals in Europe and America where it was grown in glass houses since Victorian times for its beautiful foliage, pendant orange ripe fruits embedded in green foliage and star like configuration of bursting fruits (Walters and Walters 1988, Robinson and 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.

This exploratory study proved the worthiness of a localized, strategy to conserve biological diversity in integrated agricultural landscapes. In the case of *M. dioica* and *M. sahyadrica*, it seems the best practice to promote conservation and sustainable use of
genetic diversity at production system and ecosystem level. Covering different cropping systems, mainly low input agriculture and involvement of local people, this is an example of the valuation of private and public benefits from the direct uses of resources. It also demonstrated the reduced use of and improved management of agrochemicals and fertilizers with an orientation for organic farming, thus helping in maintenance of healthy ecosystems. Yield/plant ranging between 0.350-1.500 Kg/plant is satisfactory considering the conservation value when compared to the reported average yield of 1.94 Kg/plant (Ram et al. 2001) in experimental plots using unspecified wild collected planting material. As some of the on-farm sites were close to the natural habitats (Aymanam on the banks of Vembnad lake) the participants were aware of the usefulness of the target plant and it contributed to rehabilitation and restoration of taxa to the level of a natural population. The results of this exploratory on farm conservation attempt provides guidelines for replicating in a more elaborate participatory and decentralized approach for assessing, monitoring and evaluating directly useful biological diversity in partnership with local level forums and networking arrangements between research and social organizations. Such an attempt will be a measure of the empowerment of indigenous and local communities to enhance their capacity for in situ conservation and sustainable use of agricultural biodiversity, building on their traditional knowledge system.

The decision of the participatory farmers to continue with the maintenance of the taxa and landraces without any extraneous incentives is a proof that the material adopted on farm is self sustainable- should have sufficient positive traits to reinforce the farmers likings for on-farm conservation. In the case of *M. charantia* var. *muricata*, farmers opined that fruit fly tolerance, taste, year round availability, pesticide free fruits, medicinal properties, health food value are some of the factors which prompted them to continue the cultivation over the years. Similarly, in the case of *M. dioica*, *M. sahyadrica* and *M. subangulata* ssp. *renigera*, farmers continue to grow the material over the years (or decide to continue its cultivation and gift it to their neighbours and friends) because they relish the taste of the vegetable, it fetches premium price, or it ensures a better social status among their peers.
5.6.4. 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. Ullada, Koraga, Paniya, Gowlì, Siddhi and Malaarayar womenfolk were found practicing cultivation of *M. dioica* or *M. sahyadrica* in kitchen gardens. 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 around tribal women in hotspots of diversity. Except Gowlì, all other communities were found very cooperative and friendly in sharing information. Kurichiya and Muthuvan women were also reluctant to share information about ethnic uses of *Momordica*, but that was more due to social taboo regarding appearance in front of strangers. However, in the presence of their malefolk, they shared information regarding uses of various *Momordica* species. Ullada women know more about medicinal plants than their male counterparts as they are the wild gatherers while men mostly do other works. While collecting tubers for medicinal preparations, they retain a certain population of female and male plants for perpetuation of species. Siddhi women were found much associated with utilization of plant wealth and their cultivation in comparison to male counterpart.

Ullada women practitioners of Cherthala-Muhamma-Vaikom were very informative about exact location of *M. dioica* male and female plants, but was very reluctant to disclose the locality details for concern about extinction of species due to overexploitation. Details of culinary preparations and most of the traditional knowledge on medicinal uses of various *Momordica* species provided in this study were disclosed by mostly tribal women.
5.6.5. Recommendations

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