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### Abstract

Twelve species of *Momordica* have been botanically described from Asia. All the species grow well in hot, humid areas and seems to be almost day-neutral and like most cucurbits prefer a well-drained soil with a pH of 6.0–6.5. In annual species, direct seeding is the usual production practices while all the dioecious taxa exhibit varying degrees of gradual release of seed dormancy. Low temperature and hard-seededness are reported to be the main reason for slow and poor germination in *M. dioica* and saponins are reported to inhibit seed germination in *M. cochinchinensis*. Tuber pieces are commercially used as planting material in teasel gourd while in sweet gourd, a better and reliable method is to use rooted vine cuttings/wedge grafting. Though many workers proposed rooted vine cuttings as an alternative propagation tool for *M. dioica*, there are no reports on ratooning behaviour of such propagules. Tissue culture propagation would be of immense importance for production of *M. dioica* and *M. sahyadrica* where propagation through stem cuttings, root tubers and seeds are difficult. Protocols have been established for direct shoot regeneration from nodal segments, cotyledons and plantlet regeneration from the cell suspension cultures. In monoecious species, male and female flowers are borne separately on the same plant while for dioecious species, provision of 10 % male plant in the field is considered imperative for good fruit set. In case of teasel gourd, artificial pollination gave 95–100 % fruit setting, but natural pollination contributed only about 25–50 % fruit set. Experimental data on nutrient management of *Momordica* species are not very extensive. However, generous amounts of organic matter in the soil, from animal source are beneficial for the growth. Harvesting starts about 50–60 days after sowing and is done twice or thrice a week and fruit responds quickly to the presence of ethylene and should be isolated from fruits that produce large amounts of ethylene to prevent post-harvest ripening. Fruit borer, fruit fly, powdery mildew, downy mildew are the major pests of *Momordica* species.

### Keywords

Seed germination • Breaking dormancy • Tissue culture • Pollination management • Insect pests

## Description

### *Momordica* L.

Climbers, annual or perennial; glabrous or pubescent. Leaves simple, entire or lobed or (sub) pedately 3–5 (12–15 in African) foliate. Tendrils simple, unbranched. Flowers medium to large, monoecious or dioecious, sometimes ± zygomorphic, petals imbricate off white, cream or yellow. Inflorescence of male flowers solitary or in short loose pseudo-racemes, each flower stalk with a persistent hooded bract; female flowers solitary, in axils, also with a conspicuous or rudimentary bract. Male flower pedicels minute or long, receptacle tube short, cupular or saucer shaped, calyx lobes entire or scarious, adnate at base. Petals 5, free, entire, 1–3 with an incurved scale inside at the base-receptacle juncture. Stamens 3, anthers 1-one thecous, 2-two thecous, filaments very short, free, inserted at the mouth of the receptacle tube; thecae usually coherent, connective sometimes swollen, pistillode absent. Female flowers calyx as in the male or distinct, petals as in the male; ovary oblong-fusiform, ribbed, warty or soft papillose, ovules mostly many, horizontal; stigma 3-lobed; staminode absent. Fruit ovoid ellipsoid to fusiform, fleshy, ornamented with soft spines, warts or tubercles and ridges, irregularly or regularly 3 valved, dehiscent, rarely indehiscent. Seeds many, enclosed in orange-red sarcotesta (aril). Small or large, flattened or turgid on faces, smooth or sculptured, margins often undulate and dentate.

#### 1. *M. charantia* L. (Source Joseph 2005)

Annual, slender climber, 2–4 m high, scarcely to densely pubescent (tender parts wooly), monoecious. Leaves: blade usually deeply palmately 5–9 lobed, reniform to orbicular or sub orbicular in outline, 2.5–8 × 4–10 cm, cordate

at base, acute or acuminate at apex, lobes ovate or obovate, narrowed at base, margins sinuate to undulate, mucronate, petioles 1.5–5 cm long. Flowers solitary, pubescent, petals yellow. Male flowers: stalks slender with bract mid way or towards base; peduncle 2–5 cm long; bract reniform, 5–11 mm diameter, green, mucronate at apex, margins entire; pedicel 2–6 cm long; receptacle tube cup shaped, 2–4 mm long and 2–3 mm wide; sepals ovate-elliptic, 4–6 × 2–3 mm, pale green touching each other and protecting the corolla tube; petals obovate, 10–20 × 7–15 mm, mucronate at apex, scales 2; filaments 1.5–2 mm long, inserted in the throat of the receptacle tube; anthers coherent; disc shortly cup shaped, c. 1.5 mm diameter. Female flowers: peduncle 1–6 cm long; bract 1–9 mm diameter; pedicel 1–8 cm long; sepals narrow, oblong lanceolate, 2–5 mm long; petals smaller than or equal to that in male, 7–10 mm long; ovary fusiform, narrowly rostrate, 5–11 × 2–3 mm, muricate, tuberculate or longitudinally ridged: style c. 2 mm long; nectary 3 at stylar base. Fruit pendulous, stalk 2–15 cm long; discoid, ovoid, ellipsoid to oblong or blocky, often narrowed at ends, sometimes finely rostrate, 3–8 × 2–5 cm, white or green turning orange on maturity, soft tuberculate with 8–10 broken or continuous ridges, splitting from base into 3 valves exposing the arillate seeds; seeds 5–15, squarish rectangular, ends subtridentate, faces compressed, sculptured, 5–9 × 3–6 mm, margins grooved, testa brown or black.

#### 2. *M. balsamina* L. (Source Joseph 2005)

Slender trailing herb, 1.5–3 m high, annual, sub glabrous, monoecious; stems round, internodes 5.5–6 cm; tendrils delicate, 11–13 cm long, basal 1–1.5 cm uncoiled. Leaves 3–5(–7) lobed to c. halfway or more, sub circular in outline, 4–6 cm diameter, base cordate with a cuneate petiole-blade juncture, mucronate at

apex, lobes rhomboid, margins acutely 3–7 lobulate; petiole 1–4 cm long, slender, puberulous. Flowers solitary. Male flowers 2–3 cm across, bigger than in female; peduncles slender (2) 3–5 cm long; bract sub apical, sub orbicular, up to  $0.6 \times 0.5$  cm, pale green, filmy, cordate at base, margins finely dentate; pedicel 0.3–0.4 cm long,  $\pm$ pubescent; receptacle tube cup shaped (obconical), up to 2 mm long; sepals ovate, up to  $0.7 \times 0.3$  mm, obtuse, faint green or pale cream, pubescent; petals obovate,  $1-1.3 \times 0.7-0.9$  cm, pale yellow to creamish yellow with green sub parallel veins and undulate margins, scales in 2 petals only; filaments up to 2 mm long, inserted on the rim of the receptacle tube, anthers up to 1.2–1.8 mm long,  $\pm$ coherent at base only; thecae bright orange, disc inconspicuous by deep orange coloured nectary, open from above. Female flowers 1.7–1.8 cm across; peduncles 0.2–0.3 cm long; pedicels 0.4–0.6 cm long; bracts small; calyx minute, thread like, thin, recurved; petals  $0.8 \times 0.8$  cm, pale yellow to creamish yellow with green sub parallel veins and undulate margins; ovary ovoid to fusiform, shortly rostrate, 5–7 mm long,  $\pm$ pubescent, finely remotely warty in rows, style short, slender, whitish yellow. Fruit stalk 1–2 cm long, fruits broadly ovoid-ellipsoid, bulged at middle, 2.5–3.5 (4.0) cm long, 1.8–2 cm circumference, shortly rostrate, ashy olive green with 2–3 white tubercles in lines across the whole length of fruits, bumps (murication in interspace between ridges) absent. Fruits turning orange and later scarlet red on ripening, pericarp thin, seeds 3–5, covered by deep red sarcotesta, ovate oblong compressed,  $8.5-9.5 \times 5.9-6.2$  mm, margins finely grooved, crenulate, testa grey or light brown, delicately verrucose.

3. *M. cymbalaria* Fenzl ex Naudin (Source: Cooke 1901–1908)

Monoecious, roots woody, tuberous, perennial; stems very slender, scandant, branched, striate, pubescent or sub-glabrous. Tendrils filiform, slightly pubescent, simple. Leaves orbicular-reniform in outline,  $1.90-4.50 \times 2.50-5.00$  cm, glabrous or with a few scattered hairs, punctuate on both surfaces, deeply cordate at the base, obtusely but not deeply 5–7 lobed,

the lobes short, acute or obtuse; petioles 1.25–3.80 cm long, striate, pubescent. Male flowers in 2–5 flowered racemes; peduncle 0.60–2.50 cm long, filiform, pubescent, ebracteate; pedicels 0.30–1.00 cm long. Calyx hairy; tube short, broadly campanulate, narrowed at the base, lobes 0.60 cm long, lanceolate, acute. Corolla pale yellowish white, segments obovate, obtuse, 0.30–1.25 cm long. Stamens 2; filaments very short, thick, flattened; anther 10.20 cm long, the connective broad. Female flowers: peduncle 1.90–3.80 cm long, slender, ebracteate. Ovary fusiform, beaked; Fruit 1.90–2.50 cm long, up to 3 g, pyriform or broadly fusiform, narrowed into a curved peduncle, fleshy, dark green, 8-ribbed, sparsely hairy, placenta spongy to fibrous, white. Seeds 2–3, 0.40–0.60 cm long, broadly ovoid, slightly compressed, strophiole, not margined; testa polished and shining, dark brown.

4. *M. dioica* Roxb. (Source: Joseph 2005)

A dioecious vine, climbing up to 3–10 m high; the tap root perennial, tuberous, fusiform in the first year, subsequently getting elongated and bulged, rarely branched or forked below,  $9-18 \times 6-11$  cm, weighing between 180 and 350 g, occasionally up to 800 g. Stems slender, the internodes 3–8 cm long, cylindrical, nodes in the mature basal region quadrangular. Tendrils axillary, 4–12 cm long, the basal 2–4 cm straight and the rest in a coiled position. Leaf blades thin, light green to green, ovate to cordate, nearly triangular in outline, lobed and sub lobed to various degrees or unlobed; cordate and cuneate at base, acute or acuminate at apex, the margins entire, undulate, irregularly or coarsely crenulate or regularly dentate; venation ending up in spatulate hydathodes which is sometimes like broad short bristles at margins and dent tips, lateral veins 4–5 pairs on each side of the midrib, the lower most pair running parallelly closer to the margin of the cordate sinus, but soon branching out into 3–4 veinlets; the upper surface and margins with scattered short hairs ( $10\times$ ), the lower surface densely short hairy; petiole slender to medium thick, 3–7 cm long, 1–1.5 mm in diameter, longitudinally grooved. Staminate flowers solitary in axils or often a

loose fascicle with a separate lower one; peduncles 3–7.5 cm long (usually 5–6 cm), light green, thin; pedicels sub sessile, 2–3 mm long, whitish yellow, subtended by and protected inside a reniform clasping swollen bract, 4–5 × 8–20 mm, light green, cucullate with 8–12 longitudinal veins, attached to the pedicel by base at one side; calyx (cup) funnel shaped, lobes 5, light green, narrow acute, up to 6 × 1 mm. Petals 5, free, pale yellow, glandular, oblong-lanceolate, 12–22 × 5–8 mm; acute at apex with 3–5 sub parallel veins branching sideways. Stamens 3, two of them with a pair of anthers and the other with a single anther, filaments 2–3 mm long, anthers sub triangular, 2–3 mm long, extrose, yellowish brown on inner side, each anther with a single ‘S’ shaped pollen locule, filaments at base extended to petal base covering the nectary; disc inconspicuous. Pistillate flowers solitary in leaf axils; peduncles thin, very short 0.5–2 cm long; pedicels thin, 2–4 cm long, subtended by a small bract of 3–4 × 2–6 mm; bracts reniform with acute tip just like in male but of small size; sepals 5, semi-persistent, green, narrow, 3–6 × 0.8 mm, acute at apex; petals 5, same as in male flower; ovary oblong-ovoid to urn shaped, 6–9 × 2–3 mm, rounded at base; nectary 5, small, white, butt-like cylindrical structures between petals at stylar base on the disc; styles short, up to 4 mm long, glandular hairy, stigmatic lobes 3, each lobe ‘V’ shaped, up to 3 × 5 mm, lemon yellow, cushiony, glandular. Fruits broadly ovoid-oblong, rounded at base, abruptly conical with rostrate tip at apex, 3–4 × 2–3 cm, the entire surface covered with soft short spines (except the beak), light green to dark green, turning uniformly orange on ripening, splitting from base into three pieces and rolling back exposing scarlet red arils (seeds); seeds 2–3 mm across, black lustrous and golden lined (when fresh), sculptured on surfaces, small round to slightly oval or shortly stellate (Central Indian specimens had round ovate and smooth seeds), seed coat brittle, shell hard, membrane thin whitish, endosperm oily with characteristic aromatic odour (common to *Momordica* spp.) when crushed.

5. *M. sahyadrica* Joseph and Antony (*Source: Joseph 2005*)

A dioecious robust tendrillar climber, vines up to 5–6 m high, the tap root perennial, tuberous, fusiform when young, sub globose or bulged irregularly when matures, 10–18 cm long, 5–10 cm across, outer skin brownish and inner flesh whitish yellow. Stems stout, cylindrical turning quadrangular as it matures, the internodes 5–10 cm long, nodes quadrangular, blackish green, distinctly long hairy. Tendrils medium thick, unbranched, 8–15 cm long, 4–5 cm of base uncoiled, the rest coiled. Leaves heterophyllous. Petiole 3–8 cm long, 1–1.5 mm in diameter, medium thick, longitudinally grooved above. Leaf blades medium thick, ovate, broadly triangular in outline, 3–5 lobed or entire, 10–16 × 8–18 cm, deeply cordate at base with a subangulate juncture with petiole, sometimes hastate, acute or acuminate at apex, margins highly variable, entire, undulate or coarsely crenulate; Lateral veins 5–7 pairs, the lower pair running close to the margin of the subangulate petiole juncture, hairs short, scattered without, snowy white within. Male flowers axillary, solitary or a loose fascicle of 5–7 (up to 15) flowers and in such case the lowermost flower produced separately and early; peduncles 2–5 cm long, dark green, pedicels short, 0.8–1 cm long, whitish green subtended and covered by an inflated bract, up to 1 × 1.5 cm, reniform, margins cucullate; calyx base funnel shaped, up to 8 mm long and 1 cm across, purplish black, lobes free, up to 1 × 0.6 cm, yellowish white at center and blackish purple at base and margins, elliptic oblong, recurved at apex, margins and apex scarious, densely hairy within and sparsely hairy without; petals 5, free, fleshy, obovate, up to 4 × 1.5 cm, bright yellow with a greenish yellow narrow base, veins prominent (embossed), each petal bearing a small tongue-like ciliate appendage near the base; stamens 3, 2 of them with a pair of anthers, the third one with a single anther, filaments up to 3 mm long, anther 2–3 × 1–2 mm, extrose, thecae dull black, ‘S’ shaped with abundant orange pollen, pollen grains tricolpate. Pistillate flowers solitary in leaf axils; peduncles

0.5–2 cm, often less than 1 cm; pedicels short, up to 5 cm long, subtended by a small rudimentary bract, 1–3 × 0.5–5 mm; sepals 5, green, persistent, 0.8–1.3 × 1–3 mm, equal, lanceolate, acuminate at apex densely glandular hairy within and without; petals 5, free, fleshy, up to 4 × 2 cm, narrow, greenish yellow and ciliate at base, widening towards middle, bright yellow, veins 5–7, sub parallel; nectary 5, white, short cylindrical, alternating with petals, protected by a spur at the base of petals; ovary inferior, oblong-ovoid, 1–1.5 × 0.2–0.4 cm, more or less densely clothed with soft papillae of 1 mm length; style up to 6 mm long, whitish yellow, stigma up to 4 × 9 mm, cushiony, trifid, each lobe again sub lobed dichotomously. Fruits broadly ellipsoid, ovoid to fusiform or top shaped with round blossom end and rostrate distal end, 5–7.5 × 3–4.2 cm in size, 9–12 cm in circumference, 35–50 g in weight, dark green turning bright orange on ripening, densely clothed with soft short spines; spines 2–4 mm long; arils sweet to taste, ripe fruits aromatic and slightly bitter. Seeds black, shining, losing its luster on drying, round to slightly cogwheel shaped, warty dentate on margins sculptured on faces with irregular furrows and ridges, 0.2–0.3 × 0.2–0.3 cm, seed coat brittle, hard shell like, the membrane very thin, smooth, blackish green, conspicuously veined, endosperm oily, distinctly aromatic when crushed.

6. *M. cochinchinensis* (Lour.) Spreng. (Source: Joseph 2005)

Stout perennial climber up to 20 m high, primary roots woody, all parts glabrous, dioecious. Leaves: blade entire or 3–5 palmately lobed, or 3 foliate (leaflets ± elliptic with minute petiolule), broadly ovate or sub orbicular in outline, up to 10 × 16 cm, base cordate (sometimes with 2–4 glandular bead-like projections towards cordate margin), acute or acuminate at apex, margins entire, undulate or remotely dentate; petiole 5–12 cm long, usually with 2–6 glandular bead-like crateriform glands (Assam and Andaman specimen). Flower solitary, axillary, male sometimes in a loose fascicle of 5–7, with a separate basal one. Male flowers with sub apical bract; peduncles 8–12 cm long, bract

cucullate, sub orbicular or reniform, 20–40 mm wide, ±scabrous, rounded at base, acute at apex, margins undulate, veins sub parallel, very prominent outside; pedicels 5–8 mm long, receptacle tube saucer shaped, 4–5 × 8–12 mm, blackish outside; sepals coriaceous, 10–12 × 4–8 mm, ovate-oblong or triangular, acute at apex, blackish, finely scabrid; petals sub elliptic 2.5 × 6–7 cm, conspicuously sub parallel veined, scales 3, at the base of the blotched petals, protecting the nectary; inner 3 petals with purple bull's eye mark at base, filaments short, fleshy, 5–6 mm long, inserted at the base of the receptacle tube, anthers variable in size, 'S' shaped, connective swollen. Female flower: bract small or just as in male; sepals: linear oblong, 4–10 mm long or just as in male; petals as in male; ovary ellipsoid oblong, 12–15 mm long, densely soft muricate; style 8–9 mm long. Fruit stalk 5–12 cm long, fruit ovoid or oblong-ovoid, bulged at middle, 10–15 × 6–10 cm, shortly rostrate at base; pericarp densely tuberculate with uniformly short round conical structures or interspersed with larger tubercles; single fruit weighing between 350 and 500 g or more, green turning orange on ripening and non bursting as epicarp is leathery; seeds many, variable in size, 1.5–2 × 0.8–1.2 cm, broadly ovate penta-hexangular with flat sculptured surfaces, subtridentate ends and dentate margins, testa black.

7. *M. subangulata* Blume subsp. *renigera* (G. Don) W. J. de Wilde (Source: Joseph 2005)

A dioecious vine, climbing up to 8–10 m high, the roots (tap root, secondary and tertiary roots) tuberous, tubers both sessile and non sessile, fusiform to globoid or sub globoid to irregularly bulged, often branched, bulging 3–7 × 2–5 cm. Stems stout, the internodes 7–11 cm long, quadrangular, grooved, nodes slightly bulged, often twisted. Tendrils simple, axillary, 15–17 cm long, the basal 5–7 cm straight, the rest when uncoiled measuring up to 10–12 cm long. Leaf blade medium thick, light green, ovate cordate, unlobed, 8–12 × 7–11 cm, acuminate at apex, cunctate at base, the basal flaps almost touching the petiole or overlapping giving rise to two sinus or cavities, the margins

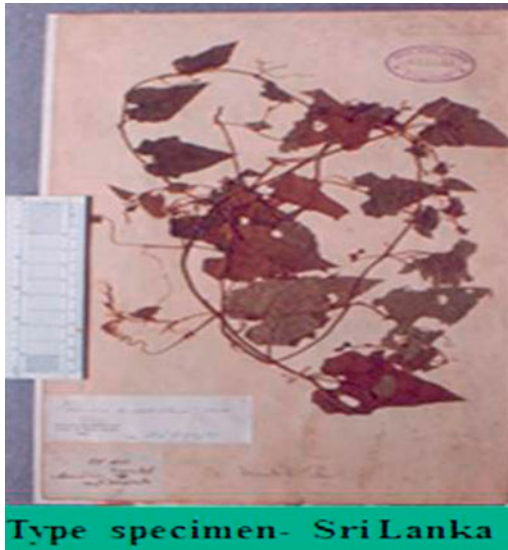
undulate and coarsely denticulate with fine bristles projecting as continuation of veinlets; veins 3–5, ascending and many pinnate from midrib ending up in fine network of areolas, 4–5 mm across, glabrous above, glandular hairy below; petioles 7–10 cm long, thick, channeled longitudinally, margins finely ridged. Flowers large, showy, creamish yellow, up to 9 cm across, opening early in the morning, withering by afternoon and falling (petals) by evening. Male and female flowers solitary, axillary. Staminate flowers: peduncles 4–6 cm long, pedicel 0.5–1 cm long, subtended and covered by a reniform bract, 2 × 2.5 cm, light green, plicate with about 15 ribs, shining, glabrescent inside, pubescent outside; calyx cup saucer shaped, sepals 5, greenish crimson, united at the base, 10 × 7 mm, ovate, acuminate at apex; petals 5, 5–6 × 3–4 cm, free, fleshy, prominently networked with 5–7 sub parallel veins and intricate cross veins, creamish yellow with intense colouration towards base, obovate, acuminate at apex, narrow at base, highly imbricate, 3 inner petals with blackish purple blotch of 7 × 6 mm size and long glandular hairs; nectary orange yellow, enclosed in calyx cup, scales 3, very prominent, flap like; stamens 3, two of them with a pair of anthers, the other with a single anther, filaments up to 4 mm long, black on sides, thecae yellowish white and dull brown bearing abundant orange yellow pollen. Pistillate flower: peduncles short, 1–1.3 cm long, pedicels 10–17 cm long (Mizoram, Gangtok, Kahikuchi Tripura specimens); bracts minute, rudimentary, near axil, often a scar of 2 × 1 mm size; sepals 5, 5–9 × 1–1.5 mm persistent, acute at apex; corolla and scales as in male; ovary oblong ovoid, dark green, 1.5–2 × 0.6 cm, rounded at base, finely echinulate on surface; nectary 5, white butt-like cylindrical structures protected inside the petal base, touching the style; style 5–7 mm long, pale yellow, stigma cushiony up to 4 × 6 mm, trilobed. Fruits broadly ovoid-ellipsoid, with doom shaped ends and a prominent rostration (3–5 mm) at base, 7–8 × 13–14 cm, each weighing 50–80 g; densely softly echinate, rarely with remnant ridges at base, spines 2–3 mm long, light green turning

yellow and finally bright orange on ripening, exposing the seeds (35–50/fruit) by basal splitting of the fruit and rolling back of the split lobes. Flesh thick, (5–6 mm), aril deep red; seeds flat, sub orbicular to sub tridentate, rectangularly stellate-cogwheel shaped, 6 × 3 mm and up to 4 mm thick, sculptured on faces with grooves and dented edges, margins with a double row of wart-like small protuberances.

8. *M. denudata* (Thwaites) C. B. Clarke  
(Source: Trimen 1893–1900)

Perennial, stems compressed, two-edged, furrowed, glabrous. Leaves 3–10 cm, cordate, ovate in outline, very acute, more or less deeply 3–5 lobed at base, distantly denticulate, glabrous, punctate beneath, petiole channeled above, slightly pubescent. Flowers dioecious, male in a small raceme of 4–8 and a separate basal one, pedicel about 1.5 cm, puberulous, bracts minute or inconspicuous. Female flower solitary. Calyx segments linear-lanceolate or linear, acuminate, longer in female. Petiole 0.5–2.5 cm, lanceolate, acute, pubescent, narrower in female. Ovary densely covered with long acute papillae. Fruit about 3.8 cm, ovoid, usually lopsided, suddenly narrowed into a strong blunt beak, covered with short pointed processes. Seeds large, over 0.6 cm, ovoid, not compressed, tuberculate. A photograph of the herbarium specimen is provided in Fig. 2.1.

It is endemic to Sri Lanka and is said to be rather common in moist and lower montane zone at 1500–4000 ft. The leaves are very variable; the central lobe is, however, always large and is often elongate and very acuminate. A perusal of the type specimen (CP 1615) indicates its distinctness from other *Momordica* species in its branched male inflorescence, scar-like inconspicuous male bracts and small round buds. Reported occurrence of it in Kerala part of India is based on wrong identification of *M. dioica* specimens (Joseph 2005). Rheede's plate in *Hortus Malabaricus* with the vernacular name "bempaval" is a male specimen of *M. dioica* with flowers in pseudoracemes, which is equated by many botanists as *M. denudata*. According to Clarke (1879), it is altogether remote from *M. dioica* and evidently closely allied to



**Fig. 2.1** *M. denudata* type specimen

*M. cymbalaria* which should be shifted to *Luffa* by virtue of its exert anthers, long pedicellate flowers and distinct flower shape. Characters like absence of prominent male bracts and branched male inflorescence indicates the remoteness of *M. denudata* from other species of *Momordica*.

9. *M. subangulata* Blume subsp. *subangulata* (Source: de Wilde and Duyfjes 2002)

Diocious, perennial climber, with annual aerial stem. Stem angular. Tendrils unbranched, short. Leaves simple, 3–5-palmately lobed, thin, 3–5-veined; petiole up to 5 cm long; leaf-blade ovate-reniform, 6–13 × 4–9 cm, base cordate, margins denticulate. Flowers solitary in leaf axils, yellow, up to 5 cm in diameter. Male flowers with long peduncle up to 12 cm long, subtended with an apical, reniform bract, c. 2 cm long; pedicel short, c. 2.5 mm long; calyx tubular, 5-lobed, lobe ovate, apex emarginate; corolla 5, free petals; stamens 3. Female flower solitary, peduncle 6–7 cm long, bearing a small bract at base, perianth the same as in male flower; ovary superior, 3-carpellate, stigma 3-lobed. Fruit a pepo, ovoid, 6–7 by 3–4 cm, longitudinal wings (Fig. 2.2). Seed 1 × 1 × 0.5 cm, grey. A photograph of the herbarium specimen is provided in Fig. 2.3.

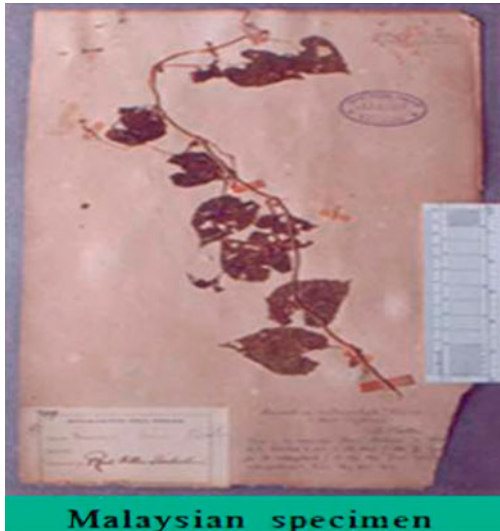
10. *M. rumphii* W. J. de Wilde (Source: de Wilde and Duyfjes 2002)

Slender perennial climber; glabrous; dioecious. Leaves: blade 3-foliolate, sub circular in outline, 8–11 cm diameter, apex acuminate, leaflets ovate-oblong, the two outer unequal-sided, 5–7 × 2–3.5 cm, margin sparsely dentate, petiolule 0.6–0.8 cm long; petiole 2–4 cm, glands absent. Flowers solitary, or male occasionally up to 3 per node, (sub) glabrous; petals are yellowish (?). Male flowers: stalk with bract sub apical; peduncle 1.5–2 cm long; bract rather closely subtending the flower, sub orbicular, 10–15 mm diameter, base ± cordate, apex rounded with minute acuminate tip, margin puberulous; pedicel 7–10 mm; receptacle-tube cup shaped, tapered, 2.5–3 × 3–4 mm, somewhat blackish; sepals oblong, c. 5 × 2 mm, narrowly obtuse, pale (green-) brown, puberulous, petals ± elliptic oblong, 13–15 × 5–6 mm, base ± clawed, apex obtuse or sub acute, puberulous. Female flowers unknown. Fruit: solitary, stalk slender, c. 2 cm long (fide Rumphius, t. 152, f.2); fruit broadly ovoid-ellipsoid or sub globose, 1–2 mm beaked at apex, c. 4.5 × 4 cm, sparsely muricate, orange. Seeds: few, c. 5 per fruit, thick but flat, circular in outline, c. 15 mm diameter, c. 8 mm thick; margin with a double row of 8–9 coarse warts or undulations; testa brown-black, finely corrugated.

11. *M. clarkeana* king (Source: de Wilde and Duyfjes 2002)

Climber 6–8 m, perennial; (sub) glabrous; dioecious. Leaves: blade unlobed, ovate in outline, 4–14 × 3–12 cm, base cordate, apex acute-acuminate, short-mucronate, margin remotely dentate, teeth minutely mucronate; petiole 2–8 cm long, without glands. Flowers: male (solitary or) (1–) 2–4 fascicled, the fascicles sub axillary to reduced leaves, usually arranged on loose raceme like lateral shoots to 10 cm long; petals pale yellow. Male flowers: peduncle (almost) absent; bract basal, spatulate, minute, 1–2 mm, ±dentate, glandular; pedicel slender, 15–30 mm long; receptacle-tube cup shaped, c. 2 × 2.5 mm, brownish; sepals broadly ovate, c. 4 × (2–3) mm, obtuse, brown, paler to the

**Fig. 2.2** Fruits of *M. subangulata* subsp. *subangulata* (Source JIRCAS, Japan)



**Fig. 2.3** *M. subangulata* subsp. *subangulata* type specimen

margin, glabrous, margin short-fimbriate; petals obovate-elliptic, c.  $10 \times 6$  mm, apex obtuse (or sub acute), papillose-pubescent. Female flowers unknown. Fruit solitary (or rarely 2/node); peduncle absent; bract not seen (absent?); fruiting pedicel (fruit stalk) slender, 3–5 cm long; fruit (broadly) ovoid, base and apex broadly rounded, apex 2–3 mm beaked,  $4.5\text{--}7 \times 3.5\text{--}5$  cm, smooth, glabrous; pericarp thin, hard-leathery, orange or red. Seeds few (c.6), elliptic or sub circular, compressed, large, 15–18 mm diameter; margin with c. 8 conspicuous undulations (cogwheel shaped, resembling seeds of *M. cochinchinensis*); testa (black–) brown, faces sometimes sculptured.

12. *M. denticulata* Miq. (Source: de Wilde and Duyfjes 2002)

Perennial climber to 8 m; most parts (excl. inflorescences) glabrous; older bark whitish grey, fissured, not tuberculate; dioecious. Leaves: blade entire, sometimes coriaceous, ovate-oblong or oblong, (7–) 9–15 (–20)  $\times$  4–9 (–12) cm, base truncate or cordate, apex sub obtuse or acute-acuminate, hardly fetid when crushed, greenish on drying,  $\pm$ shiny on both sides, margin entire or variously (sparsely) sharply dentate, sometimes only a sharp tooth on each basal lobe; veins 3(–5) palmate from base, ascending and few pinnate from midrib, ultimate nervation sharp, forming areolas c.1 mm diameter; glands on blade surface absent; petiole 2–4 cm long, without or with few glands in the upper half and/or on the basal blade margin. Flowers like those of *M. cochinchinensis*, scabridulous or pubescent, solitary or male solitary or up to 30 grouped in bracteate racemes to 5(–15) cm long; petals creamy-white, the inner three with or without a black blotch at base, pubescent or bearded towards the base. Male flowers: stalk with bract sub apical; peduncle 2–8 cm long, glabrous or puberulous, bract circular or broadly ovate, (0–15)20–35(–50) mm diameter, scabrid on both surfaces, base cordate, apex obtuse or acute, with or without glands, margin finely puberulous; pedicel 5(–15) mm long; receptacle-tube saucer shaped, 2–3  $\times$  8–12(–15) mm,  $\pm$ blackish or not; sepals sub coriaceous, ( $\pm$ ovate-oblong or) triangular, 10–15  $\times$  5–8 mm, acute (–acuminate), (blackish) green or yellow brown, scabridulous; petals  $\pm$  elliptic or oblong, 30–50 mm long, apex rounded or acute (–acuminate), distinctly veined, scales as in *M. cochinchinensis*; androecium as in *M. cochinchinensis*, 6–10 mm long; each



stamen (or lobe) with or without a conspicuous appendage. Female flowers: stalk (peduncle and pedicel) 4–6 cm long; bract acute, 2–3 mm long, at 5–12 mm from the base; ovary fusiform, narrowed in the apical bract, 18–25 × 4–5 mm, densely minutely hairy (hairs 0.1 mm or less; receptacle-tube, c. 3 mm wide; sepals linear, 7–8(–10) mm long, acute; style slender, 5–7 mm long. Fruit: stalk 5–10 cm long, with bract scar near base; fruit (ovoid-) ellipsoid-oblong, apex narrowed into 10(–15) mm long beak, 8–14 × 5–10 cm, pericarp ± leathery, without ornamentation, sometimes minutely scabrid, like fine sandpaper, green–yellow or red; pulp orange–red. Seeds: numerous, flat, sub orbicular, cogwheel shaped (as in *M. cochinchinensis*), 20–30 mm diameter, 6–7 mm thick; margin with a double row of c. 10 blunt wart like bulges; testa brown blackish, faces finely sculptured in a blotchy pattern.

### Pollen Morphology

Morphology of the pollen has been studied only in three species and their typical description is given below (Awasthi 1961).

*M. charantia*: 3-zonicolporate (Fig. 2.4), prolate (76 × 55 μ; range 70–84 × 49–59 μ). Apocolpium diameter 14 μ. Ectocolpium ends acute, tenuimarginate. Endocolpium very faint. Exine 2.8 μ thick. Ectine is thicker than endine (endine very thin). Columella very clear.

*M. balsamina*: 3-zonicolporate, prolate spheroidal (40 × 34 μ; range 35–43 × 28–36 μ). Apocolpium diameter 10.5 μ. Ectocolpium ends slightly rounded (acute), tenuimarginate.

Endocolpium very faintly demarcated, slightly lalongate, ends rounded. Exine 2.8 μ thick. Ectine thicker than endine, reticulate ± areolate, areolas irregularly shaped. Columella clear.

*M. dioica*: 3-zonicolporate (few grains syncolpate), spheroidal (diameter 58 μ; range 53–70 μ). Apocolpium diameter 21 μ. Colpi ends acute tenuimarginate. Endocolpium very faintly defined, slightly lalongate (17 × 7 μ). Exine 5.6 μ thick. Ectine thicker than endine (ectine 4.2 μ thick), areolate, areolas irregularly shaped. Columella clear.

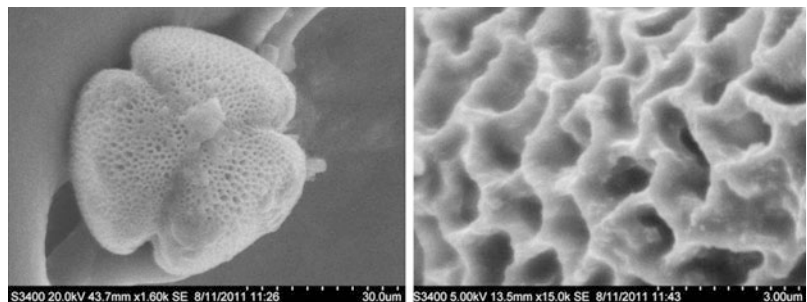
### Crop Production

### Climatic Requirements

Asiatic *Momordica* species are thought to be native to warm, humid and arid regions in different parts of Africa and Asia and they have many ecological requirements in common. They grow well in hot, humid areas but also grow well in subtropical climate. All the species seems to be almost day neutral and grow from the plains to an altitude of 1500 m. The annual species and the stems of perennial species are killed by frost and water stress. But in case of perennial species, new shoots sprout from surviving underground stem tissue (tuberous roots) after cessation of winter. *Momordica* species are mainly cultivated during the spring, summer and more often rainy seasons where winter is severe, while it is cultivated throughout the year in tropical climates.

Bitter gourd requires a minimum temperature of 18 °C during early growth (Larkcom 1991);

**Fig. 2.4** SEM polar view showing 3 colpi (*M. charantia*) and reticulate exine surface



with 24–27 °C being optimum (Desai and Musmade 1998). But when temperature becomes too high (>37 °C) fruit set often becomes problem, depending on the genotype (Njoroge and van Luijk 2004). Seed germinates in a temperature range of 15–45 °C, with large differences among cultivars (Singh 1991). Sex expression in bitter gourd is affected by environmental conditions (Wang et al. 1997). Short day conditions will help in improving female flower production (Yonemori and Fujida 1985) while long days cause male flowers to bloom up to 2 weeks before female flowers (Palada and Chang 2003). A temperature range of 25–30 °C and 1500–2500 mm rainfall are ideal for the growth and expression of teasel gourd and spine gourd (Ram et al. 2002a; Joseph 2008). In South Andaman Islands, characterised by a temperature range of 22–30 °C with an average rainfall of 3000–3500 mm received from May to December and very high relative humidity of 82–85 % throughout the year, a good population of sweet gourd was found to thrive in the wild (Joseph and Bharathi 2008). *M. sahyadrica* prefers a temperature range of 20–25 °C and 2500–3000 mm rainfall prevailing in the high ranges of Western Ghats of India (Joseph 2005).

### Soil Requirements

*Momordica* spp. prefers a well-drained sandy loam soil of shallow to medium depth (50–150 cm) that is rich in humus or organic matter with a pH of 6.0–6.5. *M. charantia* grows best in a well drained sandy loam, rich in organic matter, but will tolerate many type of soils (Cantwell et al. 1996; Reyes et al. 1994) and the optimum soil pH is found to be 6.0–6.7 (Desai and Musmade 1998). Though most of the cucurbits do not perform well in acidic soil, *M. balsamina* thrives well in acidic soil with a pH range of 5.0–6.5 (Mishra et al. 1986; Joseph and Antony 2008). Sweet gourd can tolerate soil salinity up to <4 dS/m (Joseph and Bharathi 2008). Sandy loams, well-drained alluvial soils and worked out laterite soils of pH 6–8 are ideal for the growth of teasel gourd (Joseph 2008).

### Production Technology

Standard production technology have not been developed for *Momordica* species except for bitter gourd, as teasel gourd and spine gourd are still in domestication inter-phase and other species are wild gathered. *M. cochinchinensis* is reported to be grown in most households in Vietnam as a homestead crop usually without much attention (Voung 2001); in contrast, production of bitter gourd is more structured in terms of field preparations and maintenance. Few tips for cultivation of *M. balsamina*, *M. cochinchinensis* and *M. dioica* have been published in the Indian context (Shadeque and Baruah 1984; Maharana and Tripathy 1996; Ram et al. 2002a; Bharathi et al. 2005; Joseph and Antony 2008; Mishra et al. 1986).

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### Propagation

#### Seed Propagation

Freshly collected, depulped seeds show varying degrees of germination. *M. charantia* and *M. balsamina* do not show any dormancy and germinate fast. Direct seeding is the usual production practice in these species; sometimes, seedlings (raised in polybags especially hybrids) are also transplanted in the field. The seed has a hard seed coat and germinates slowly due to slow absorption of water. Poor germination percentage is common at sub optimal temperature (Peter et al. 1998). For rapid germination, the optimum temperature is between 25 and 28 °C. In bitter gourd, pre-sowing treatments such as soaking of seeds in slightly warm water for 30 min, overnight soaking of seeds, soaking of seeds in butter milk (Singh and Singh 1969) and keeping seeds in wet gunny bag or cloth bag in a warm place for 3–4 days speed up germination (Katyal and Chadha 1985). Pre-sowing treatments such as priming (mixing seeds with moist vermiculite for 36 h at 20 °C) and hot water soaking of seeds (for 4 h in water at 40 °C) are recommended for successful seedling

establishment under sub optimal temperature (Lin and Sung 2001; Hsu et al. 2003). Nath et al. (1972) obtained high seed germination of 79.5 % in Cv. Long Green by soaking in 50 ppm GA<sub>3</sub> for 12 h and the germination percent was further improved by exposing the seeds to red light.

The seeds of perennial taxa remain viable in soil for more than a year and occasionally one or two plants germinate before and after the peak germination. All the dioecious taxa exhibit varying degrees of gradual release of seed dormancy. *M. dioica* and *M. sahyadrica* shows strong dormancy while *M. subangulata* subsp. *renigera* shows intermediate behavior with staggered germination, having differential dormancy in different seeds of the same fruit. Cent percent viability was noticed through tetrazolium staining test and the poor germination percentage of fresh seeds indicated presence of strong dormancy factors (Joseph 2005).

On the contrary for crop plants, hard seed-ness is disadvantageous, the lack of simultaneous germination preventing the establishment of uniform stand of seedlings. Treatments applied to break this dormancy are highly species specific and no single method is universally accepted because even within a genus, distinct difference in the seed coat dormancy have been observed for several species of crop plants (Bhattacharya and Saha 1990). Application of GA<sub>3</sub> (100–200 ppm) and thio urea (100 ppm) caused early germination in *M. dioica* (Bhuyar et al. 2000; Patro and Reddy 2009). Traditionally, farmers of Odisha (India) sow the fresh seeds along the sides of irrigation channels or in beds which germinate 6–8 months after sowing and the seedlings are used for planting. Under experimental condition at Central Horticultural Experiment Station (CHES), Bhubaneswar also, 90 % germination was observed in the above method. Sowing of 6-month-old seeds after deshelling showed quick germination within 4–7 days (LKB Pers. Obs.). The seeds on deshelling show better germination indicating quinescence, a condition where seeds fail to germinate due to unfavourable environment.

Higher germination in soil seed banks and ant hives may be attributed to leeching out or breakage of inhibiting metabolites due to natural weathering.

Forest fire by increasing soil temperature breaks physical dormancy. Smoke also has a stimulating effect on germination (Baskin and Baskin 1998). Though many workers (Ram et al. 2001, 2002a; Mishra et al. 1988; Mishra and Sahoo 1983) has mentioned dormancy of the seeds as the main factor preventing cultivation of spine gourd, not much effort has been initiated to find out the reasons for dormancy and methods to break it. Ali et al. (1991) have reported low temperature and hard seededness as the reason for slow and poor germination in *M. dioica*. Saponins are reported to inhibit seed germination in *M. cochinchinensis* (Watanabe et al. 1988a, b) and deshelling is effective in breaking dormancy.

Ethno-botanical studies give hints of involvement of birds and ants in seed dispersal and careful observation revealed predation of fresh seeds by specific species of birds. Again, the tribal people expressed the opinion that there is a preponderance of higher population density of *M. dioica* in forests subjected to summer fire. This gave indications of the role of temperature and gut enzyme scarification in breaking the dormancy of seeds. Good germination was obtained in one accession of *M. sahyadrica* collected from Kurichiya hamlet, which upon enquiry was found to have been after ripened for 8 months over smoke from kitchen. Similarly, seeds of *M. dioica* after ripened for 6 months upon deshelling and maintenance in germination media at 25–30 °C were reported to give very high germination (Ali et al. 1991).

## Vegetative Propagation

In the absence of an easy method of seed propagation, various vegetative propagation options need to be adopted on a species to species basis to ensure maximum production of viable propagules.

**Root tubers.** Tuber pieces are commercially used as planting material in *M. subangulata* subsp. *renigera*. An average plant produces 20–25 adventitious tubers of 60–80 g. Large tubers can be cut into pieces and used as propagule. Cut surface should be treated with fungicide solution (2 %) and shade dried for wound healing before planting. Tubers have a short dormancy of 2–3 months, which can be broken by exposure to air, light and room temperature. In spine gourd tuberous roots of 150–200 g size are usually planted and dipping in 1 % thio urea increased sprouting percentage (Panda et al. 1994). Use of tubers has been advocated for commercial cultivation of *M. dioica* (Mishra and Sahoo 1983; Mishra et al. 1988; Shadeque and Baruah 1984; Ram et al. 2002a) and *M. cymbalaria* (Reddy et al. 2007). In *M. cymbalaria*, tuber weight of 60 g and above recorded significantly higher fruit yield per plant (120 g) over rest of the tubers (Reddy et al. 2007).

*M. subangulata* subsp. *renigera* has the highest reproductive efficiency through root tubers whereas in *M. dioica*, *M. sahyadrica* and *M. cymbalaria* one tuber (tap root) gives rise to one plant only or the maximum of 2–4 plants (Fig. 2.5). In the former tubers are reproductive units whereas in the later three species, they are perennating organs. In *M. cochinchinensis*, the tap root becomes gigantic and woody which is not amenable to uprooting or transplant. Anatomical study of seedling taproot tubers and secondaries of teasel gourd confirmed their root nature. Exarch steele, radial arrangement of xylem and phloem and presence of lenticels indicate their root nature. The study also suggest that mid-February to mid-March is the best time for planting of *M. dioica* and *M. sahyadrica* tubers under Kerala condition, whereas *M. subangulata* subsp. *renigera* can be planted throughout the year under tropical humid (Kerala) conditions.

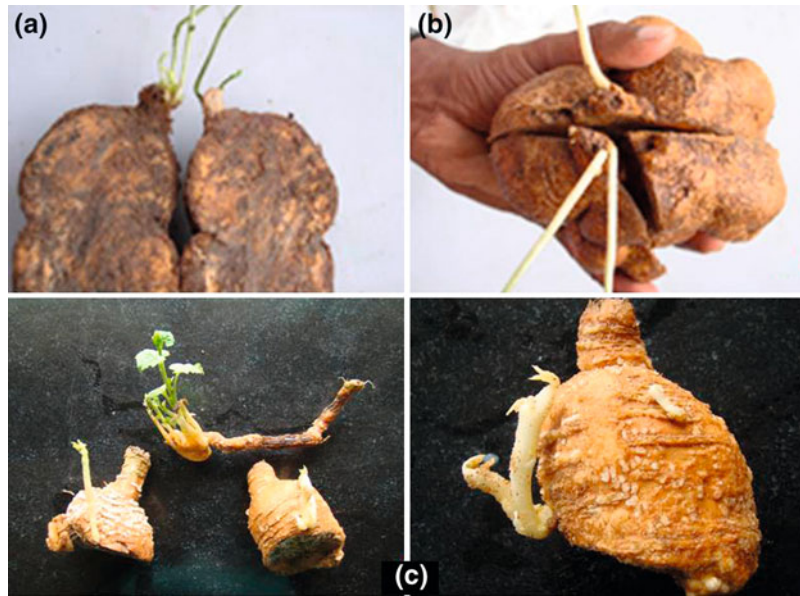
Dormancy of the tubers was observed in all species and *M. subangulata* subsp. *renigera* has the shortest tuber dormancy (Table 2.1). In situ tillage of the tuber base was very effective in initiating sprouting across the species. Allowing moisture loss from the tuber and aeration of the

tubers were found effective in breaking dormancy. *M. subangulata* subsp. *renigera* and its hybrid has the shortest dormancy of 1 month, whereas *M. dioica* has 5 months dormancy and *M. sahyadrica* has about 4–4.5 months dormancy.

**Vine cutting.** All the species are amenable to rooting from vine cuttings. However, there is difference between species, *M. subangulata* subsp. *renigera* being most efficient and *M. charantia* var. *muricata* showing the least efficiency. Young midlevel cuttings are the best to root and establish across species while vine tips are unable to withstand stress induced by detaching from mother plants. Vine cuttings of *M. dioica* and *M. sahyadrica* developed few sessile root tubers, whereas *M. subangulata* subsp. *renigera* develops many root tubers, both sessile and non sessile. Such adventitious root tubers in *M. dioica* and *M. sahyadrica* did not germinate and remain intact in soil over the years, whereas in *M. subangulata* subsp. *renigera*, it sprouted vigorously (Joseph 2005).

In sweet gourd, a better and reliable method is to use rooted vine cuttings as propagules. Mid and top level cuttings root well with rooting hormone treatment. Closed Media Sachet technique may be adopted for home gardens (Joseph and Bharathi 2008). Rooted vine cuttings can also be used in *M. subangulata* subsp. *renigera*, but yield will be higher in tuber raised plants. In case of *M. dioica* and *M. subangulata* subsp. *renigera* 2–3 node cuttings from the basal portion of vine gives better rooting, plant growth and yield (Tripathy et al. 1994; Ram et al. 2002a). However, the cuttings should be taken from vigorously growing mother plants at early flowering stage and before axillary flower buds emerge. Though many workers have mentioned seed dormancy as the main factor limiting cultivation of spine gourds (Mishra et al. 1988; Ram et al. 2001, 2002a) and proposed rooted vine cuttings as an alternative propagation tool, there are no reports on ratooning behaviour of such propagules. Joseph et al. (2009) found that tubers formed at the base of the vine cuttings in the case of *M. dioica* and *M. sahyadrica* are purely storage organs and do not sprout in

**Fig. 2.5** Tubers of dioecious *Momordica* species used as planting material. **a** *M. dioica* longitudinally split tap root **b** *M. sahyadrica*-split tap root tubers with apical meristem **c** Split tubers of *M. subangulata* subsp. *renigera*



**Table 2.1** Effect of physical treatments on sprouting of dormant tubers in various *Momordica* spp.

Treatment	No. of tubers sprouted/days to sprout emergence		
	<i>M. dioica</i>	<i>M. sahyadrica</i>	<i>M. subangulata</i> subsp. <i>renigera</i>
T <sub>1</sub>	12 (90)	13 (110)	15 (20)
T <sub>2</sub>	14 (75)	12 (90)	15 (22)
T <sub>3</sub>	10 (32)	12 (60)	28 <sup>a</sup> (15)
T <sub>4</sub> (control)	15 (120)	15 (148)	36 <sup>a</sup> (90)

Source Joseph (2005)

Values in parenthesis denote days to sprout emergence

<sup>a</sup> including subterranean sprouting of underground tubers

T<sub>1</sub>— unearthed tubers, potted, mulched and without irrigation

T<sub>2</sub>— unearthed tubers, potted, mulched irrigated after 60 days

T<sub>3</sub>—in situ tillage at tuber base, mulch removed

T<sub>4</sub>— control-undisturbed plot

subsequent seasons as they lack shoot primordial. On the contrary, teasel gourd produces roots and shoots from any tuber or tuber piece irrespective of their tuber morphology.

**Leaf rooting.** Rooting of leaves is found useful as an alternative germplasm collection strategy for teasel gourd. *Momordica subangulata* subsp. *renigera*, having got very short tuber dormancy, was the most efficient species amenable to this type of reproduction. Unlike the other dioecious species, *M. subangulata* ssp. *renigera* exhibit totipotency where any part of the tuber, irrespective of whether tap root or

adventitious root tuber, gives rise to shoot sprouts. This unique trait of adventitious sprouting in *M. subangulata* ssp. *renigera* enables the use of leaf tubers as planting materials. Choice of propagating plants of desired sex is an added advantage in this method. Adoption of this technique is expected to boost *M. subangulata* subsp. *renigera* cultivation in non traditional areas due to the increased availability of planting materials. Although, it takes two growth seasons to reach reproductive maturity, this technique can be used effectively as an alternate germplasm collection strategy. Also,

from the conservation point of view this technique will help in rehabilitating the species in natural habitats and popularizing them as ornamental and kitchen garden vegetables. The technique developed (Joseph 2005) for leaf rooting is described in the following paragraph.

Detach fully developed, healthy leaves of 30 days age (in early flowering stage) of known sex from the stem at petiole base with a sharp blade and treat the basal 1 cm portion of petiole and cut surface with rooting hormone (IBA at 3000 ppm). Spread the treated cuttings in shaded condition for 15 min for the hormones to get absorbed. Insert the treated petiole bases in a medium of river sand for induction of callusing and root initiation using the Closed Media Sachet Technique (Srivastava 1996) and sprinkle water periodically for 2 weeks for a mist effect. To avoid overcrowding and subsequent rotting of leaves, remove the dead and rotten leaves periodically. In *M. subangulata* subsp. *renigera*, callus formation is observed between seventh and 9th day and rooting between 12 and 15 days. Transplant the rooted leaves (21 days after planting in sand bed) to a secondary nursery. The leaves come to senescence within 60–90 days and on excavation, micro tubers of 1–2 cm size weighing 5–8 grams are formed from the base of these senescent leaves. After a period of short dormancy (4–6 weeks), these micro tubers start germinating giving rise to tiny plantlets. However, the initial growth of these plants is slow and they come to flowering only after 120 days.

**Grafting.** Although bitter gourd is basically seed propagated, wedge grafting on *Luffa* had been in vogue in China and Taiwan for control of *Fusarium* wilt (Chung Ta and Chin Ho 1996). It also increases the yield of bitter gourd (Palada and Chang 2003). Compatibility with 81.1 % success and 38.4 % yield increase over non grafted control was reported due to freedom from nematode and *Fusarium* wilt infection (Xiangbo et al. 1998). Similarly grafting of *M. dioica* on pumpkin has also been reported successful (Mian and Morokuna 1992, 1993).

In sweet gourd, wedge grafting of growing tips on vigorous sprouts can also be attempted. Such

grafted plants are compact and require less space (4–5 m<sup>2</sup>) compared to uncontrolled vine growth of seedling plants and rooted cuttings (Joseph et al. 2011). Through grafting unproductive surplus male plants can be converted to bearing female plants. They also perenniate over the years as in sweet gourd, the areal stem do not wither completely during unfavourable growth season.

***In vitro* propagation.** Tissue culture propagation would be of immense importance for production of *M. dioica* and *M. sahyadrica* where propagation through stem cuttings, root tubers and seeds are difficult. As most of the Asian species are dioecious nature, micro propagation could be useful for rapid multiplication of genetically uniform planting material of known sex for commercial cultivation. Tissue culture methods from various plant parts like shoot tip, nodal segments, cotyledon, root segment, etc., have been used for regeneration in *M. charantia*, *M. balsamina*, *M. dioica*, *M. subangulata* subsp. *renigera* and *M. cymbalaria*.

Several investigations have been reported on the plant regeneration of *M. charantia* from different explants such as, micro propagation from nodal and shoot tips (Wang et al. 2001; Sultana and Miah 2003; Huda and Sikdar 2006; Malik et al. 2007; Ma et al. 2012; Thiruvengadam et al. 2012a); organogenesis from stem segments (Tang et al. 2011a, b), from leaf segments (Thiruvengadam et al. 2010, 2012b), from cotyledon segments (Halder and Gadgil 1982; Islam et al. 1994; Hoque et al. 2000) and from nodal and root segments (Munsur et al. 2009); and somatic embryogenesis from leaf explants (Thiruvengadam et al. 2006; Paul et al. 2009). Both the micro propagation and organogenesis of shoot have been established using shoot apices, nodal and internodal explants (Agarwal and Kamal 2004). Malik et al. (2007) reported that various explants of leaf, stem and cotyledon induced different types of callus in *M. charantia* but that none of these produced any shoots. In balsam apple micropropagation through anther culture (Tang et al. 2009) and from nodal explants (Thakur et al. 2011) has been established. In case of *M. cymbalaria* multiple shoot regeneration was achieved using nodal segments

and leaf explants (Nikam et al. 2009; Ailinea et al. 2009; Jeyadevi et al. 2012).

Because of ambiguity in taxonomic identity most of the studies on tissue culture pertaining to *M. subangulata* subsp. *renigera* has been reported under the name of *M. dioica*. However, through the description of crop, cultivation status, collection locality and published photographs we have identified and reported here with the correct species name. Among the different explants of *M. subangulata* subsp. *renigera* studied, cotyledon showed high performance in callus induction than shoot tip, leaf and nodal segments (Nabi et al. 2002). The concentration of 1.0 mg/l BAP and 0.1 mg/l NAA gave best response on callus formation (Karim and Ahmad 2010). The best response of shoot proliferation was obtained in medium supplemented with 2.0 mg/l BA + 0.2 mg/l NAA (Hoque and Rahman 2003). The concentrations of different hormones used for callus induction and shoot regeneration in various studies are presented in Table 2.2. Recently, Hoque et al. (2007) reported in vitro adventitious shoot regeneration from embryo axes of seeds from a homosexual hybrid.

Higher success rate was obtained for callus induction with auxillary bud explants (Deokar et al. 2003; Ghive et al. 2006) of *M. dioica* in MS medium containing 1.5 mg/l BAP + 1.0 mg/l NAA and multiple shoot development in MS medium supplemented with 70–80 mg/l AdSO<sub>4</sub> + 1.0 mg/l BAP + 1.0 mg/l NAA (Ghive et al. 2006). Apart from auxillary bud, multiple shoots were induced from nodal segments (Meemaduma and Ramanayake 2002; Rai et al. 2012) and leaf segments (Hoque and Rahman 2003) of *M. dioica*. Protocols for direct shoot regeneration from cotyledons of *M. dioica* (Nabi et al. 2002) and plantlet regeneration from the cell suspension cultures of spine gourd through somatic embryogenesis has also been established (Thiruvengadam et al. 2007). Rajashekaran et al. (2011) attempted in vitro culture of *M. sahyadrica* using nodal and shoot tip explants and a maximum of 8–10 shoots along with slight callusing was obtained in MS medium supplemented with BAP (3 mg/l).

## Plant Establishment and Densities

The *Momordica* spp. may be planted in several ways: (i) by direct field-seeding in hills; (ii) by transplanting of polybag raised seedlings in polyhouse in severe winter; (iii) planting of tuberous roots/rooted cuttings in field. First and second methods are commonly practiced in annual species while the third method is followed in perennial species.

The field should be well ploughed and harrowed twice to remove weeds and other plant debris in the field. Raised beds of 20–30 cm height are prepared using a plough or mechanical bed shaper. Bitter gourd seeds are sown in raised mounds for the rainy season crop and in shallow pits for summer crop (Gopalakrishnan et al. 1983). The rate and distance of planting used by most farmers is one to three meters between furrows and 0.5 m between hills with 3 seeds per hill at 4 inches apart. The stand should be thinned to two plants per hill. It may be advantageous to raise the plants in polybags in polyhouses during winter months. Seedlings at 5–6 leaf stage are transplanted to the field when all danger of frost is over. For sowing one hectare field, 2–3 kg of bitter gourd seed will be required.

Plant densities vary considerably from one location to another depending on the species and cultivars. For example sweet gourd produces larger plants and their planting densities must be lower. In bitter gourd optimum plant density varies with cultivar, from 6500 to 11000 plants/ha (Reyes et al. 1994; Palada and Chang 2003) or 20000 plants/ha (Huyskens et al. 1992). Teasel gourd and spine gourd are generally planted 4500–6000 plants/ha (Ram et al. 2002a; Joseph 2008) while for sweet gourd 1500–2000 plants/ha is optimum (Joseph and Bharathi 2008). A spacing of 2 m between rows and 1 m between plants of *M. dioica* produced higher yield per plant (Patro and Reddy 2009). Higher yield of 10.7 t/ha from main crop and 7.3 t/ha from ratoon crop were obtained in spine gourd from the narrowest spacing of 1 m apart (Seshadri and Parthasarathy 2002). Tuberous roots/vine cuttings of perennial species may be

**Table 2.2** Concentrations of hormones used for callus formation and shoot regeneration in *Momordica* species

Species	Callus formation	Shoot regeneration	Reference
<i>M. charantia</i>	1.0 mg/l 2, 4-D + 1.0 mg/l BAP	1.0 mg/l 2, 4-D + 1.0 mg/l BAP	Munsur et al. (2009)
	2.0 mg/l NAA + 0.5 mg/l BAP + 2 mg/l 2,4 D	2.0 mg/l NAA + 0.5 mg/l BAP	Agarwal and Kamal (2004)
	1–0 mg/l BAP + 1.5 mg/l NAA + 1.0 mg/l 2,4 D	1.0 mg/l BAP + 0.1 mg/l TDZ	Malik et al. (2007)
	5.0 µM 2,4 D + 2.0 µM TDA	4.0 µM TDZ + 1.5 µM 2,4 D + 0.07 mM L-glutamine	Thiruvengadam et al. (2012b)
<i>M. subangulata</i> subsp. <i>renigera</i>		1.5 mg/l BA and 0.1 mg/l NAA	Hoque et al. (1995)
	1.0 mg/l BAP and 0.1 mg/l NAA	1.0 mg/l BAP and 0.1 mg/l NAA	Nabi et al. (2002)
		2.0 mg/l BA + 0.2 mg/l NAA	Hoque and Rahman (2003)
		10.8 mg/l BA + 1.08 mg/l NAA + 0.54 mg/l GA <sub>3</sub> (embryo explants) 16.2 mg/l BA + 2.7 mg/l NAA + 0.54 mg/l GA <sub>3</sub> (Cotyledon)	Hoque et al. (2007)
<i>M. dioica</i>	1.0 mg/l-1 BAP + 0.1 mg/l-1 NAA		Karim and Ahmad (2010)
	1.0 mg/l 2,4-D + 2.0 mg/l BAP	1.5 mg/l BAP + 1.5 mg/l Kn.	Devendra et al. (2009)
	10 mg/l BA + 5 mg/l IBA	3 mg NAA/litre + 0.2 % activated charcoal	Pawar et al. (2004)
		0.9 µM BA + 200 mg/l CH	Rai et al. (2012)
	1.5 mg/l BAP + 10 mg/l NAA	70 mg/l AdSO <sub>4</sub> + 1 mg/l BAP + 1 mg/l NAA	Ghive et al. (2006)
		0.05 mg/l GA <sub>3</sub> + 0.1 mg/l TDZ	Meemaduma and Ramanayake (2002)
<i>M. balsamina</i>		1.0 mg/l BAP + 1.0 mg/l KN	Thakur et al. (2011)
<i>M. cymbalaria</i>	2.5 µM BA	10 µM Kn + 2.5 µM BA NAA	Nikam et al. (2009)
		4.40 mM BA + 4.6 mM Kn	Jeyadevi et al. (2012)

planted with pre-monsoon showers in pits of 60 × 60 × 60 cm size prepared at a spacing of 1.5 × 1.5 m (teasel gourd); 1.0 × 1.0 m (spine gourd) and 3 × 3 m (sweet gourd). For sweet, spine and teasel gourds, provision of 10 % male plant in the field are considered imperative for good fruit set (Bharathi et al. 2006; Joseph 2008; Joseph and Bharathi 2008).

## Training

As *Momordica* species are weak stemmed plants they require a trellis to support the climbing vine. Staking and trellising will increase fruit

yield and size, reduce fruit rot and make spraying and harvesting easier. Under natural conditions *M. cochinchinensis* spreads on big trees and *M. sahyadrica*, *M. dioica*, *M. subangulata* subsp. *renigera* on bush or grasses in forest. If the vines are allowed to spread on the ground, vines start rotting/decaying (Ram et al. 2002a).

There are several methods of trellising (Fig. 2.6) viz., single line trellis, double line trellis, pandal/bower type, lean-to type, arch-type, single plant staking, etc. For the single row vertical trellis, the trellis should be about 6 feet high, constructed from stakes 2 m apart, with a system of vertical strings between horizontal wires. The bottom horizontal line is fixed at



**Fig. 2.6** Various training systems adopted for cultivation of *Momordica* spp. **a** *M. charantia* in single line trellis system. **b** *M. charantia* in double line trellis system. **c** *M. charantia* in single plant staking system



three feet height and the subsequent lines at one feet interval. Train the vines on the vertical trellis regularly by tying the vines to the trellis. Lateral shoot/vine may be pruned every 4–5 days, leaving only the main stem. Initial pruning should be done 1 month after planting or when lateral vines appeared. *M. subangulata* subsp. *renigera* is a dioecious plant pollinated by *Ctenoplectra* bees in its native habitat (Schaefer 2005). But, without hand pollination fruit set is reduced to 15–20 % (Patnaik and Patnaik 1976) and so farmers resort to hand pollination. Hand pollination could be performed perfectly, quickly and easily in vertical net trellis compared to other systems of training (Mian et al. 2001) which compensates with initial cost of training. However, vertical (fence) trellising has been reported to reduce the proportion of marketable fruit of bitter gourd and overhead or T-trellising may increase the proportion of marketable fruit (Huykens et al. 1992). Higher yields are obtained with 2 m than 1 m high trellises and the crop is more accessible (Abusaleha and Dutta 1994a).

For bower type, a bower of suitable dimension with wooden stakes/iron/concrete pillar is erected at a height of 5 feet followed by criss cross wire netting. Sweet gourd is a robust climber with a high aerial biomass and bower

type may be highly suitable for trailing. Usually the plant is trailed to thatched sheds or treetops. In Vietnam sweet gourd is grown as intercrop in orchards and allowed to trail on tree tops.

For the lean-to type, the stakes are joined between two adjoining beds forming an inverted V-shaped structure and at the top horizontal stakes are tied joining all other beds. The stakes support the climbing vines. For the arch type, plants are grown inside an arch-shaped structure made of either PVC or galvanised iron pipe. In homesteads, the farm fencing can be utilised for trailing of plants.

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## Pruning

Non productive side branches should be removed until the vine reaches the top of the trellis. Leave 4–6 laterals and cut tip of the main vine to induce early cropping. Removal of lateral branches in the first 10 nodes has a positive effect on total yield (Palada and Chang 2003) of bitter gourd. In bitter gourd, most of the female flower occurs between 10 and 40th node or at a height of 0.5–2 m and pruning the lower laterals increases the total number of flowers per plant by increasing the number of flowers on higher

laterals (Rasco and Castillo 1990). In case of *M. cochinchinensis* new sprouts will emerge from the main vine and therefore pruning has to be done carefully. Only side and dead branches are removed when the plant undergoes dormancy, while in *M. dioica*, *M. sahyadrica* and *M. subangulata* subsp. *renigera* the aerial part is completely dried and can be removed during dormant period.

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## Weed Management

During initial period of plant growth effective weed control is important to get higher yield. Most of the weeds can be effectively removed manually or mechanically. Deep cultivation should be avoided since *Momordica* species have many shallow roots. Organic or plastic mulching can also be used for controlling the weeds. In plastic mulch, planting holes are bored into the plastic sheet base at specified planting distance. To use the plastic mulch, stretch it over the planting beds, with edges held down by thin bamboo slats, staple well into the soil at every 20 cm. Organic mulch such as paddy straw or dry grass is cheaper than plastic mulch. In case of trellis system the pits are cleaned manually and covered with organic mulch. The interspaces are sprayed with post emergence herbicides like glyphosate. The 'Stale seed bed' technique can also be used to prevent weed growth. The field is ploughed and given a light irrigation. This encourages weed seeds to germinate, and then killed with a non-residual herbicide like glyphosate 3 days before planting.

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## Water Management

Bitter gourd cannot tolerate drought and water stress can severely reduce the yield and good soil moisture should be maintained in the upper 50 cm of soil where the majority of roots are located. Irrigate at least weekly, beginning from the day of sowing (Desai and Musmade 1998). *M. charantia* is intolerant to flooding (Reyes et al. 1994), with 4 days of flooding producing

significant changes in morphology (Liao and Lin 1994). The crop can be furrow irrigated every 10 days during cool dry season and weekly during hot dry season. Drip irrigation is an efficient method of supplying water and nutrients where the necessary equipment is available. Irrigation is likely to increase size and weight of individual fruit. Sweet gourd and spine gourds do not require irrigation if regular rainfall is received. In case of uneven rains, light irrigation at 3–5 days interval will be advantageous. They are highly sensitive to water logging.

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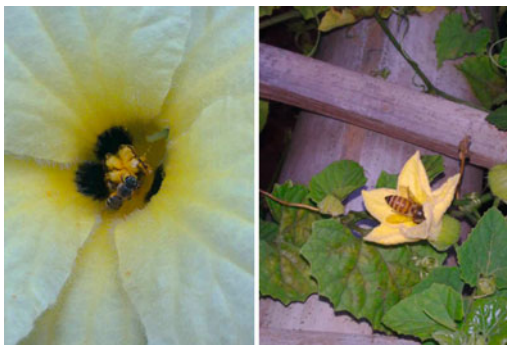
## Flowering and Pollination Management

*M. charantia*, *M. balsamina* and *M. cymbalaria* are monoecious with male and female flowers borne separately on the same plant while other species are dioecious with male and female flowers borne in different plants. All the species of Indian occurrence produce first flower at 45–60 days except *M. cochinchinensis* which takes about 90–120 days. In plants where unisexual flowers exist, staminate flowers are more frequent than pistillate flowers. In *M. charantia* pistillate flowers may be as low as 12–16 % which is a limiting factor in fruit production (Thomas 2008). Yield in bitter gourd can be enhanced by increasing the number of female flowers or decreasing the number of male flowers which can be achieved by spraying growth hormones to alter the sequence of flowering and sex ratio. Spraying of BA 25 ppm or ethephon 200 ppm or GA 25–100 ppm after six to eight true leaf stage (Yonemori and Fujieda 1985); 500 ppm ethrel at germination or 100 ppm GA<sub>3</sub> in adult plants (Thomas 2008) increases the female flowers. Production of male flowers was significantly reduced with 200–600 ppm of ethrel (Ravindran 1971) and female flower production was increased with B-9 (500–5000 ppm) and CCC (500–2000 ppm) (Bose and Ghosh 1968; Ghosh and Bose 1970). Nearly 2.5 times yield increase in bitter gourd was reported with spraying of 500 ppm CCC in the variety HK-8 (Mangal et al. 1981). Application of Boron @

4 ppm (Verma et al. 1984) and  $\alpha$ -NAA @ 100 ppm (Bisaria 1974) also reported to increase the female flower production. In vitro hormone application during seed germination was much more successful than spraying of field grown plants (Thomas 2008). Soaking of seed at 25–100 ppm NAA, kinetin, ethrel for 24 h and keeping at 5 °C for 5–15 days before sowing increased the ratio of pistillate flower to staminate flower (Prakash 1976).

Flowers are pollinated by insects especially bees (Fig. 2.7). Bitter gourd flowers are pollinated by small bees (Sands 1928) while *M. cochinchinensis* and *M. subangulata* subsp. *renigera* are reported to be pollinated by *Ctenoplectra* bees (Schaefer 2005) in its natural distribution range. Hand pollination can be avoided in bitter gourd and spine gourd by introducing bee hives or blowing pollen with an unloaded mister. However, during less favourable environment for insect activity like high temperature and low humidity hand pollination could increase the yield considerably (Abusaleha and Dutta 1994b).

For dioecious species, provision of 10 % male plant in the field is considered imperative for good fruit set. High fruit set was observed in dioecious species under natural condition except *M. subangulata* subsp. *renigera*. In case of *M. subangulata* subsp. *renigera* natural pollination contributed only about 15–50 % fruit set (Patnaik and Patnaik 1976; Hossain et al. 1987; Das 1988) while artificial pollination gave 95–100 % fruit set. Flowers are sufficiently large



**Fig. 2.7** Honey bee pollinating a hybrid plant of *Momordica* spp.

enough to do hand pollination and 90–100 % success can be obtained if pollination is done at optimum stigma receptivity (Joseph 2008). Male flowers are plucked and stamens touched to receptive stigmas between 6 and 10 am for 100 % fruit set. In case of *M. cochinchinensis*, good fruit set under natural condition (climbing on big forest trees) was observed in its home range, whereas under cultivation less fruit set was observed in Odisha (LKB pers. obs.) and hand pollination is essential to get higher fruit set and yield. However, under Kerala conditions good natural insect pollination and high fruit set was observed (JJK Pers. obs.).

Fruit development can be made independent of fertilisation or seed development by providing artificial stimuli which may be dead pollen, pollen extract, incompatible pollen, auxins or synthetic hormones. Development of parthenocarpic fruits are highly useful especially in case of teasel gourd where regular cumbersome hand pollination increases the cost of production (Rasul et al. 2008) and presence of large number of hard seeds in the fruits decreases its palatability (Handique 1988; Rasul et al. 2008). Vijay and Jalikop (1980) reported that application of 2, 4-D at the rate of 50–100 ppm is effective in inducing parthenocarpic fruit set than NAA and IAA in *M. cochinchinensis* while Handique (1988) found that application of NAA 100 ppm induced 95 % parthenocarpic fruit though the fruits are smaller than normal fruits. In *M. dioica*, 2, 4-D (50 ppm) spray at anthesis showed high parthenocarpic fruit development (Choudhury et al. 2007; Rasul et al. 2008). However, it must be noted that, all these studies were in fact carried out in *M. subangulata* subsp. *renigera* and not in *M. dioica* or *M. cochinchinensis*, as reported, consequent of the taxonomic misidentification of entities prevalent hitherto.

Apart from growth regulator spray, interspecific and intergeneric pollinations also induced higher percent of parthenocarpic fruit set in *M. dioica* i.e., when pollinated with *M. charantia*, *Leucanthea leucanthea* (Singh 1978; Bharathi et al. 2012). We have developed an interspecific hybrid between *M. dioica* and *M. cochinchinensis* (F<sub>1</sub>) which produces parthenocarpic fruits

(90–95 % fruit set) of *M. dioica* size when pollinated with *M. cochinchinensis* (Unpublished).

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## Nutrient Management

The kind and quantity of fertilizer needed depend on the soil type and amount of nutrients already available in the soil and is difficult to recommend a blanket fertilizer dose. Experimental data on nutrient management of *Momordica* species are not very extensive. However, generous amounts of organic matter in the soil, from animal manure are beneficial for the growth. In general, compost manure or farmyard manure is added to each planting hole before sowing and a dose of 10–12 t/ha is recommended. The various recommendations of nutrient requirement for different species by different authors are given in Table 2.3. Bitter gourd is quite sensitive to lack of micronutrients such as Boron and application of these elements can strongly improve yield (Njoroge and van Luijk 2004). Mishra et al. (1986) recommended 20 g of 15:15:15 NPK per basin for *M. balsamina*.

In case of teasel gourd, a mixture of 25 kg well-rotten FYM and 250 g neem cake is applied to each pit. Although no specific fertilizer recommendations are available, the application of 40–45 kg N 40 kg P<sub>2</sub>O<sub>5</sub> and 40 kg K<sub>2</sub>O/ha is cost-effective. Half of N and full dose of P and K are applied to the pits at the time of land preparation and the remaining half N top dressed at the time of flowering (Joseph 2008). Application of 150 g Single super phosphate and 50 g Muriate of Potash to the basin and top dressing with Urea @ 15 g twice at 4–5 leaf stage and 30 days age are recommended for good yield in sweet gourd (Mishra et al. 1988).

For spine gourd, basal application of 4–5 kg well-decomposed farmyard manure or compost, 100 g neem or castor cake, 50 g Urea, 225 g Single Super Phosphate and 90 g Muriate of Potash, along with one-fourth sand and remaining quantity of soil has been found to produce optimum growth of the plant. At 25 and 40 days

after planting 50 g Urea should be added to each basin. The subsequent nitrogenous fertilizer dose should be applied 15 cm away from the plant and incorporated well to the basin soil. The plant is sensitive to Potassium deficiency. Therefore spraying of Sulphate of Potash @ 2 g/lit is recommended whenever the symptom is noticed.

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## Harvesting

*Bitter gourd*. Harvesting starts about 50–60 days after sowing and is done twice or thrice a week. Bitter gourd fruit is often harvested based on visual assessment of marketable stage for which size, length, diameter and weight of the fruit (depending on cultivar) are important criteria. Maturity indications include a slight change in fruit colour and the fullness of ridges and bumps. It takes about 15–20 days after fruit set to reach marketable stage (Reyes et al. 1994). It accumulates bitterness with time, due to a buildup of the alkaloid momordicin, and then loses the bitterness during ripening (Cantwell et al. 1996). Fruit should be light green, thick and juicy (Lim 1998) and the seeds should be soft and white creamy (Huyskens et al. 1992) to pale green–brown (Vujovic et al. 2000) at harvest. Harvest at every 2–3 days interval as the fruit ripens quickly (Desai and Musmade 1998). Bitter gourd fruit responds quickly to the presence of ethylene and should be packed separately from fruits that produce large amounts of ethylene to prevent post-harvest ripening. Regular picking is important as fruits will become bitterer as they mature and it can also hamper the growth of new fruits. Average yields of bitter gourd are 8–10 t/ha, but up to 20 t/ha for open-pollinated cultivars has been reported. F<sub>1</sub> hybrids under good management can give yield up to 40 t/ha.

Bitter melon is prone to chilling injury and may be air-cooled to 10–12 °C (Zong et al. 1995). Lower temperature causes chilling injury such as pitting, decay and discolouration and higher temperature causes ripening. USDA storage recommendations are 12–13 °C at 85–90 % RH, with an approximate storage life of 2–3 weeks.

**Table 2.3** Recommended fertilizer rates (kg/ha)

Country/state	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	Reference
<i>M. charantia</i>				
India (Punjab)	100	50	50	Rajan and Markose (2003)
India (Punjab)	56	56	0	Dhesi et al. (1966)
India (Himachal Pradesh)	100	50	50	Rajan and Markose (2003)
India (Karnataka)	62	50	0	Rajan and Markose (2003)
India (Tamil Nadu)	20	50	60	Rajan and Markose (2003)
India (Kerala)	60	30	60	Rajan and Markose (2003)
China	184	112	124	Palada and Chang (2003)
<i>M. dioica</i>				
India (Odisha)	30	30	30	Tripathy et al. (1993)
India (Andhra Pradesh)	240	160	75	Patro and Reddy (2009)
<i>M. subangulata</i> subsp. <i>renigera</i>				
India	80	50	50	Shadeque and Baruah (1984)

*Spine gourd.* The fruits become ready for harvest within 75–80 days in case of seed raised crop and 55–60 days in case of ratoon crop. Ratoon crop gives economic yield up to 5–6 years and fruit yield thereafter declines. Harvesting of fruits twice a week increases the yield. The fruits should be harvested at mature green stage. The fruit attains marketable maturity within 7–10 days of pollination. Under optimum crop management condition fruit yield of 75–100 q/ha can be realised (Bharathi et al. 2006).

*Teasel gourd.* Fruits reach marketable maturity between 12 and 15 days after flowering. Crop is ready for harvest from 60 to 70 days after planting (DAP). Peak harvest starts from 90 DAP and continues up to 6–7 months. Half yellow half green stage is suitable for harvesting and fruits stored in air tight polythene bag showed better moisture retention and keeping quality (Fakir et al. 1992). Delayed harvest beyond 20 days leads to progressive red colouration of fruits and hardening of seeds which reduce the visual appeal and cooking quality. Yield up to 160–180 q can be realised from one hectare (Ram et al. 2002a).

*Sweet gourd.* Fruits reach harvestable maturity by 15–20 days after pollination, beyond which the seeds become hard and skin become leathery. A plant produces 30–60 fruits each weighing between 250 and 500 g in one season

(Vuong 2001; Shadeque and Baruah 1984; Joseph and Bharathi 2008). Raw fruits have an agreeable taste and are slightly bitter. Flavour is similar to spine gourd, though of less intensity. The fruits can be stored safely for 1 week at room temperature. Elsewhere in Vietnam it is harvested at ripe stage (90–100 days after pollination) for its red ripe aril and pulp. Fruits store well for 2–3 days at room temperature and up to 7 days in air tight polybags under refrigeration.

## Pest and Diseases

Although it is considered that foliage pests and diseases tend to be not much of a problem in bitter gourd due to the toxic compounds in the plant (Robinson and Decker-Walters 1997), nowadays there are many insect pests and diseases are observed in bitter gourd and other *Momordica* species of Asia. The most common pests and diseases of *Momordica* species are described hereunder (Figs. 2.8 and 2.9).

**Ladybird beetle** (*Epilachna septima*). *E. vigintiduopunctata* is reported to cause damage to bitter gourd (Mandal et al. 2012). However, *E. vigintiduopunctata* do not feed on *M. charantia* and *Epilachna septima* is reported to damage bitter gourd (Dharmaretnam 2002) and *E. vigintiduopunctata* was unable to complete its lifecycle on Cucurbitaceous plants (Ueno et al. 2001).



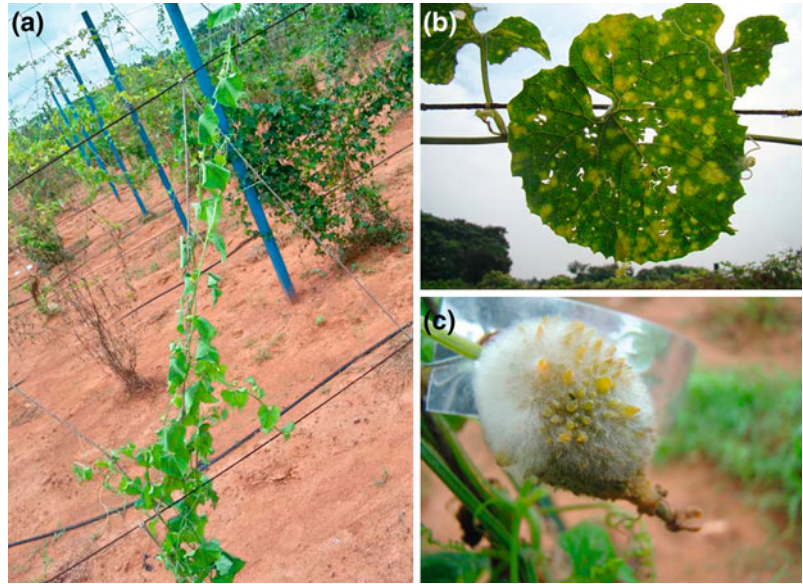
**Fig. 2.8** Insect pests of *Momordica* spp. **a** Adult and larvae of ladybird beetle (*Epilachna vigintipunctata*) feeding on leaf of *M. subangulata* subsp. *renigera*. **b** Fruit fly (*Bactrocera cucurbitiae*) damaged fruit of *M. subangulata* subsp. *renigera*. **c** Fruit borer (*Diaphania*

*indica*) damaged leaf, flower and fruit of *M. subangulata* subsp. *renigera*. **d** Bitter gourd leaf showing the symptom of leaf miner (*Liriomyza trifolii*) damage. **e** Roots of *M. subangulata* subsp. *renigera* heavily infested with root knot nematode

All the dioecious taxa are equally preferred by ladybird beetle, whereas no larval feeding was observed in *M. balsamina* (Joseph 2005). Lace-like skeletonised patches appear on leaves, which turn brown later. The affected leaves dry up and fall down. Collect grubs, adults and egg along with infested leaves during the early stage of attack and destroy them. Spray Deltamethrin 0.028 % or Monocrotophos 0.05 % to keep the insect population under control.

**Fruit Borer (*Diaphania indica*).** It is a serious pest in Asia and Africa. *M. charantia* is one of the host plants for the larvae of *Diaphania indica* (Yasui 2002). Young bright green larvae, initially scrapes the chlorophyll content. Later it folds and webs the leaves and feeds within. It also feeds on flowers and bores into the developing fruits and is a severe problem in spine gourd (Bharathi et al. 2006; Singh et al. 2009) and teasel gourd (LKB Pers. obs.). Early symptoms of infestation are the development of

**Fig. 2.9** Various disease symptoms of *Momordica* spp. **a** A plant of *M. dioica* showing wilting due to *Fusarium*. **b** Downey mildew symptom in *M. subangulata* subsp. *renigera* leaf. **c** Fruit of *M. dioica*



lace-like patches of networks on intact small leaf veins. Damage is most serious in the early stages of fruit formation, when the pests feed on and puncture the skin of young fruit, particularly where they touch leaves or the soil, but well-developed fruits with hard rinds may escape attack (Patel and Kulkarny 1956). The early stage caterpillars should be collected and destroyed. Several insecticides are recommended including Methomyl, Endosulfan or Carbaryl and Dimethoate are also effective, as is the bacterium *Bacillus thuringiensis* @ 2 ml/litre of water.

**Fruit fly** (*Bactrocera cucurbitiae*). Fruit fly is severe in *M. charantia* and all cultivars are highly susceptible. Teasel gourd, sweet gourd, balsam apple and spine gourd are equally susceptible but *M. sahyadrica* shows marked resistance. *M. charantia* var. *muricata* germplasm showed varied response with the wild forms showing tolerance. Fruit fly damage is restricted to localised areas in the fruit and seeds often mature. In bitter gourd, the melon fruit fly damage is the major limiting factor in obtaining good quality fruits and high yield (Srinivasan 1959; Lall and Singh 1969; Mote 1975; Rabinathan and Pillai 1986). It prefers young, green and tender fruits for egg laying. The females lay the eggs 2–4 mm deep in the fruit

pulp, and the maggots feed inside the developing fruits. A few maggots have also been observed to feed on the stems (Narayanan 1953). The fruits attacked in early stages fail to develop properly, and drop or rot on the plant. Since, the maggots damage the fruits internally; it is difficult to control this pest with insecticides. To manage the pest, remove and destroy all infested fruits and also expose the pupae by ploughing and turning over soil after crop harvest. For trapping the adult, sex pheromone blended plywood blocks may be used. For this purpose a mixture of ethanol, cue lure and Malathion in the ratio of 6:4:1 may be prepared. Plywood blocks of 5 × 5 × 1.2 cm is prepared and soaked in this solution for 48 h. These can be used in bottle traps @ 10 blocks/ha. Under severe infestation, 100 g jaggery may be mixed in 1 litre of water with 2 ml carbaryl and sprayed on foliage. Double layer paper bags are used against melon fly in Taiwan and are applied when fruit measure 2–3 cm in length (Fang and Chang 1987). The braconid larval parasitoid *Opius fletcheri* provided considerable suppression of this pest infesting the small fruits of the balsam apple *M. balsamina* (Singh 2004).

**Red pumpkin beetle** (*Aulacophora foveicollis*). Among the Cucurbitaceous vegetables studied, *M. charantia* was found to be highly

resistant to red pumpkin beetle (Mehta and Sandhu 1989; Roy and Pandey 1990, 1991; Saljoqi and Khan 2007). Chandravadana (1987) isolated triterpenoids (momordicine II, 23-*O*- $\beta$ -glucopyranoside of 3, 7, 23-trihydroxycucurbita-5, 24-dien-19-al) from the leaves of *M. charantia* Linn (bitter gourd) which was found to elicit feeding deterrent activity against red pumpkin beetles (*Aulacophora foveicollis*).

A study by Joseph (2005) showed that leaf damage due to red pumpkin beetle is severe in *M. dioica* while *M. balsamina* shows high tolerance. Adult beetle eats the leaves, makes holes on foliage and causes damage to roots and leaves. Incorporation of carbaryl 10 % WP in pits before sowing the seeds destroys grubs and pupae. Adults feed on the cotyledonary leaves at seedling stage. Effective control can be achieved by spraying of Sevin 50 WP (2 g/L). Farmers of India practice dusting of ash mixed with kerosene to repel the insect however, heavy dusting arrests growth of seedling. Alternatively, *Parthenium hysterophorus* plant extract have the ability to minimise the population below critical threshold level of red pumpkin beetle in bitter gourd and the extract can be used instead of synthetic pesticides or can be supplemented to avoid excessive use of chemicals for the safe and friendly environment (Ali et al. 2011).

**Leaf Miner** (*Liriomyza trifolii*). Leaf miner incidence is very rare especially; *M. charantia* was reported to be free from this pest (Patnaik 2000). The main damage caused to the plant is due to the presence of larva mining and if the infestation is severe, the photosynthetic activity is reduced. Observations on the oviposition behaviour by *L. trifolii* demonstrated that among the cucurbitaceous plants, *M. charantia* is rarely attacked by *L. trifolii* (Mekuria et al. 2006). A field survey (Mekuria et al. 2005) has shown that *L. trifolii* fed and laid eggs on Cucurbitaceous vegetables but not on *M. charantia* leaves. The reason is that females are often deterred from ovipositing on *M. charantia* leaves (Mekuria et al. 2005) due to the presence of momordicin I. They form tunnels by burrowing in the leaf between the epidermal layers consuming the green tissue as they go. In case of severe

infestation, leaves will dry and drop. To control the insect, collect and destroy the mined leaves and good field sanitation can also greatly reduce the population of this pest.

**Root-knot nematode** (*Meloidogyne incognita*). Incidence of root-knot nematode is observed in *M. subangulata* subsp. *renigera* (LKB pers. obs.), *M. charantia* (Singh et al. 2012), *M. balsamina* (Kaur and Pathak 2011) whereas *M. dioica* and *M. sahyadrica* are free from nematode attack (Joseph 2005). It is one of the important pests of bitter gourd and is reported to cause 38–48.2 % yield losses (Kaur and Pathak 2011). Root system of the nematode infested plant is heavily knotted and growth of vines is severely arrested. The leaves appear yellow and leaf size is reduced and majority of the veins become dry and wither. Dipping of vine cuttings/root tubers in Monocrotophos 1000 ppm for 6 h before planting and application of neem cake (500 g), and Bionematon (10 g) per pit as basal application with FYM is effective in reducing the severity of the infestation. A second dose of Bionematon @ 10 g/pit at 40 days after planting (DAP) may also be applied to reduce infestation.

**Fusarium wilt** (*Fusarium oxysporum* f. *niveum*). Fusarium wilt, caused by *Fusarium oxysporum* is probably the most common and damaging soil borne disease of cucurbit crops worldwide. Leaves wilt suddenly and vascular bundles in the collar region become yellow or brown. It is difficult to control the disease as the fungus persists in the soil even when effective chemicals are available. Use of disease free planting material for planting and drenching with Captan (1.5 g/L) and Bavistin (2 g/L) around the root zone, long crop rotation and application of *Trichoderma* at the rate of 100 g/pit are recommended to control the disease. It can also be controlled by cleft grafting of bitter gourd shoot as scion on *Luffa cylindrica* rootstock. *Luffa cylindrica* provides an excellent root stock for bitter gourd and grafting can increase yields substantially as reported from Taiwan, mainly through the control of *Fusarium* wilt (Lin et al. 1998).



**Anthracnose** (*Colletotrichum lagenarium*). The disease is reported to be severe in *M. dioica* (Sawant et al. 2000). The small yellowish spot appears on leaves as water soaked areas, which enlarges in size, coalesce and turn brown to black in colour. Seed treatment, proper crop rotation and clean cultivation minimise the initial inoculums. The disease can be effectively controlled by repeated spray of Dithane M 45 at 5–7 days interval.

**Powdery Mildew** (*Sphaerotheca fuliginea*). Initially, white or fluffy growth appear in circular patches or spots on the under surface of the leaves. Severely affected leaves become brown and shrivelled and defoliation may occur. Among the fungicides tested in *M. charantia*, Nimrod (buprimate) was found to be the best in reducing the disease intensity and increasing yield followed by Benlate (Benomyl) and Karathane (Dinocap) (Gupta and Singvi 1980).

**Downy Mildew** (*Pseudoperonospora cubensis*). It is one of the most important foliar diseases of cucurbits, causing significant yield losses. The symptoms of pale green areas separated by dark green areas appear on upper surface of leaf. Under humid conditions, corresponding lower surface of yellowish areas is covered with faint purplish fungal growth. The affected leaf dries up quickly. Use of beds with wider spacing, good drainage, air movement and exposure to sun, help to check the disease development. An aggressive spray programme is essential, as plants must have a protective barrier of fungicide prior to sporangium deposition to avoid yield losses (Elizabeth et al. 2011). Foliar sprays of Dithane M 45 (0.2 %) have been found to be effective in controlling the disease.

**Fruit rot** (*Pythium aphanidermatum*). This disease is observed in *M. charantia*, *M. dioica* (LKB pers. obs.) and *M. cochinchinensis* (Verma and Sengupta 1981). The causal organism causes a water-soaked lesion which develops into a watery soft rot. White, cottony mycelium is also generally associated with *Pythium* lesions. Fungus can enter the fruit through old floral parts or directly from the soil. The fungus can infect any portion of the fruit, producing dark-green, water-soaked lesions. The fruit

become soft very rapidly and may be completely covered with white, cottony mycelium during wet weather. This fruit rot can occur rapidly when conditions are moist since the fungus spreads by fruit-to-fruit contact. Rotation and deep turning are cultural practices that can reduce the amount of disease inoculum near the soil surface. Practices which ensure good drainage can also reduce losses due to these fungi. Systemic fungicides such as Ridomil may aid in suppression of *Pythium*. Avoid picking fruits from infested areas of the field. Infected fruits will contaminate adjacent fruits in storage containers.

**Viral diseases.** Bitter gourd Yellow Mosaic Virus (BGYMV) is a Whitefly transmitted gemini virus that can attack at any stage of the crop. The association of Indian cassava mosaic virus (ICMV) with yellow mosaic disease of *M. charantia* has been detected for the first time in Tamil Nadu, South India (Rajinimala and Rabintran 2007). The symptoms that characterise the yellow mosaic disease of bitter gourd are mosaic and mottling starts at the edges of the leaf and advance inwards. Subsequently, chlorotic patches appear on leaves, and in advanced stages of infection, the entire leaf becomes chlorotic with few, small patches of green tissue remaining over the leaf area. Control the vectors by spraying Dimethoate 0.05 % or Phosphamidon 0.05 %. Uprooting and destruction of affected plants and collateral hosts may prevent further spread of the disease. Ali et al. (2010) reported tomato leaf curl Palampur virus also affecting bitter gourd. Symptoms of the disease included chlorosis, leaf crumpling, vein thickening and stunting of plants.

**Witches' Broom.** Main symptoms of this disease are malformation and proliferation of axillary buds. The diseased plants show many abnormally little leaves, which fail to attain full size but bear many flowers and blossom earlier than healthy plants. Flowers on infected plants show characteristic green, phyllody symptoms. Fruits formed from the infected flowers are very small, cylindrical and deformed. Five to six foliar sprays of Phosphamidon (0.05 %) at 10 days interval control the vector population.

## Seed Production

Most cultural practices for successful seed production are not different from those for successful commercial cultivation for fruit production. Therefore the present discussion of cultural practices will emphasise only those factors most important for a seed crop. The field selected for seed production must not have been sown with bitter gourd in the previous season. This is done to avoid volunteer plants that cause admixture. Seed is very sensitive to weather and selecting the right season is necessary to get good seed yield. Though bitter gourd can be grown throughout the year, seed crop should be sown such that the seed matures in cool dry climate. This will facilitate proper ripening of fruits and reduce the fungal infection.

Selection of seed is the first step in production of quality seed. This involves selection of seeds with the right genetic make-up of the variety chosen to be produced. Seeds must be from an approved source. This is possible if the seed is procured from the breeding firm/university research station or from the breeder himself. Nearly 50 % increase in seed yield was obtained in closer spacing  $1 \times 0.25$  m (Catedral and Mamicpic 1976).

Since *Momordica* species are highly cross pollinated, maintaining the proper isolation distance between the two varieties/inbred lines is necessary. The isolation distance of 400 m for C.S, 800 m for F.S. and at least 1000 m for breeder seed production are recommended. An isolation of 0.8–1 km should be given between two varieties/inbred lines (Sirohi 1997). Another important requirement in production of high quality seed is rouging of infected and off type plants before they start flowering.

In bitter gourd, seed extraction is easy. Open the fruits longitudinally and collect the seeds along with pulp. Crush the pulp with hands and wash with excess quantity of water to remove the pulp. The extracted seeds are to be dried properly. Alternatively, the seeds along with arils are mixed with dry soil for easy removal of the arils. Immediately after seed extraction, it

has to be properly dried, since seeds were extracted from 100 % moist condition. The extracted seeds should be spread on gunny bags in a thin layer and dried under shade for 8–10 h for 1 or 2 days. Avoid drying the seeds in hot sun (during 12 noon to 3 p.m.) as the rays emitting from sun and the heat may affect the seed viability. A seed yield of 60–120 kg can be obtained from one hectare.

Quality and storability of seed is greatly influenced by the processing measures. Therefore, after proper drying, the seeds have to be processed in a proper way. By removing the ill-filled and small size seeds, vigour and viability are improved. For bitter gourd, seed processing BSS 4 wire mesh sieve has to be used. After sieving, those seeds that are broken, fungal infected and seed coat damaged are removed. Seed moisture is the foremost seed physical attribute that contributes to storage life. Lower the seed moisture, longer the shelf life. Short-term storage can be achieved by drying the seeds to 7–8 % moisture content while long-term storage is possible by reducing the seed moisture even further to 6 %. Prior to storage, seeds are treated with fungicide to ward off fungal pathogens. Seeds are mixed with Carbendazim at the rate of 4 g/kg. The minimum certification standards prescribed for certified and foundation seed is presented in Table 2.4.

Apart from seed treatment, the next most important aspect of seed storage is seed container. Container can be chiefly differentiated as moisture pervious and moisture impervious types. Cloth, paper and gunny bags are moisture pervious as the moisture from outside atmosphere can enter and exit freely. Hence, even if the seed is dried to safe moisture levels, when stored in humid climate, the seeds absorb moisture during storage and loose viability. In low humid areas seeds can be safely stored in moisture pervious bags. In hot and humid regions, after drying the seed to safe moisture limit, seeds can be safely stored in moisture impervious bag-like thick polythene bags of 700 gauges or in tin/plastic containers that are sealed tightly. In case of short-term storage

**Table 2.4** Minimum seed certification standards prescribed for foundation and certified seed of bitter gourd

Factor	Foundation	Certified
Pure seeds (minimum limit)	98.0 %	98.0 %
Inert matter (maximum limit)	2.0 %	2.0 %
Other crop seed (maximum limit)	None	None
Total weed seeds (maximum)	None	None
Objectionable weed seeds <sup>a</sup> (maximum)	None	None
Other varietal seeds (maximum)	5/kg	10/kg
Moisture (maximum)	7.0 %	7.0 %
Moisture proof bag	6.0 %	6.0 %

Source Tamil Nadu Seed Certification Department, India

<sup>a</sup> Objectionable weed seed shall be *M. balsamina*, *M. dioica*, *M. cochinchinensis*

(4–6 months) cloth bags will be sufficient. Partial vacuum extended the longevity of primed seeds of bitter gourd up to 12 months by enhancing their antioxidative activities that minimise accumulation of total peroxide during long-term storage (Yeh et al. 2005).

## Hybrid Seed Production

Hybrid seeds can be produced by (i) Bagging and hand pollination, (ii) defloration, removal of male flowers from the female parent and insect pollination, and (iii) use of gynoeious lines. However, commercial seed production of bitter gourd is being accomplished by bagging and hand pollination. Production of hybrid seeds in bitter gourd is highly expensive because it is done mainly through hand pollination. But utilisation of a gynoeious line would be more economical and easier method (Ram et al. 2002b).

In the first method, female flowers are covered with butter paper bags on previous day of flower opening and rebagged after hand pollination. Experienced hands can pollinate 11–12 flowers per hour. In the second method, female and male parents are planted alternatively in an isolated field. Male flower buds in female parent are removed before anthesis. Female flowers are left on seed parent for insect pollination from pollen parent or female flowers are hand pollinated with pollen of male parent during morning hours (6–9 am). Honey bees are chief insect

pollinators for bitter gourd and honey bees should be in abundance in the field at the time of flowering. Hand pollination can be avoided by introducing bee hives.

A planting density of 30000–35000 plants per ha is recommended by Huang et al. (2010) for higher hybrid seed yield. Seed yield and quality were highest in plants fertilised with 240–120–60 kg NPK/ha. The high yield was due to greater number of filled seeds per fruit which were bigger and heavier than the seeds produced from other treatments. Moreover, the above treatment produced seeds with the highest percentage germination and seed vigour index (Islam 1995).

A perusal of the scanty botanical literature available on SE Asian and African species indicates that many of them are incompletely described. As majority of them are dioecious, either male or female flowers or fruits are unknown. Further, no recent collections are reported in these wild species. Distribution data is scanty as herbarium and gene bank representation is meagre. A complete botanical description based on live specimens is warranted. Seed dormancy in dioecious *Momordica* is the single largest obstacle to establishment of a uniform plant stand which inhibits its domestication progress. Methods to break seed dormancy or development of genotypes with good uniform and quick germinability are important for crop husbandry as well as ex situ regeneration. Standard agronomic practices for sweet gourd, spine gourd, teasel gourd and mountain spine gourd are lacking which needs to be developed.

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