Gourds: Bitter, Bottle, Wax, Snake, Sponge and Ridge

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Abstract Bitter gourd, bottle gourd, wax gourd, snake gourd, sponge gourd, and ridge gourd are cultivated and marketed by smallholder farmers, and are important crops in home gardens throughout southern and southeastern Asia. These vegetables provide significant dietary nutrients such as vitamin A and C, iron and calcium. Public sector breeders and germplasm curators release open-pollinated varieties of these cucurbits developed through selection from landraces. Private sector breeders

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develop F_1 hybrid cultivars of these gourds that are popular with growers because of their uniformity, early and total marketable yield, and, in some cases, disease resistance. This chapter reviews the status of germplasm resources for sustained genetic improvement of these cucurbit species. Susceptibility to viruses is currently the major production constraint for these gourds, and systematic evaluation of their germplasm against viruses will be helpful for breeding improved cucurbit lines. The germplasm resources of these gourd species are held in an array of genebanks in several countries and may not be readily available for scientific research or to commercial breeders outside of their respective country. Many accessions of these gourd species listed by the World Vegetable Center and the U.S. Germplasm Resources Information Network are either not available or inactive. More accessions of these gourd species and their relatives need, therefore, to be collected from various regions of the tropics, conserved, and evaluated to ensure continuous genetic gains in breeding programs.

Keywords *Momordica charantia* • *Lagenaria siceraria* • *Benincasa hispida* • *Luffa* spp. • *Trichosanthes* spp. • Genetic resources • Disease resistance • Grafting • Plant breeding

Introduction

"Cucurbits" is a broad term representing all taxa within the highly diverse family known as Cucurbitaceae, which comprises at least 950 species distributed in over 90 genera that are predominantly distributed in the tropics and subtropics (Schaefer and Renner 2011). Major cultivated cucurbit crops of significant economic importance include cucumber (*Cucumis sativus* L.), watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai], melon (*Cucumis melo* L.) and squash and pumpkin (*Cucurbita* spp.). These cucurbits are widely cultivated globally. Six other cucurbit crops of considerable value to growers and consumers in the Old World tropics are bitter gourd (*Momordica charantia* L.), bottle gourd [*Lagenaria siceraria* (Molina.)

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Standley], wax gourd [*Benincasa hispida* (Thunb.) Cogn.], sponge gourd (*Luffa aegyptiaca* Mill., syn. *Luffa cylindrica* Roem.) and ridge gourds (*Luffa acutangula* (L.) Roxb.), and snake gourd (*Trichosanthes cucumerina* L.). These regionally important cucurbits are grown and marketed by smallholder farmers and remain essential components of home gardens in southern and southeastern Asia. Their fruit contain important nutrients such as vitamin A and C, iron and calcium (Pandit and Acharya 2008). This chapter will provide a brief review of genetic resources of these six cucurbit crops.

Bitter Gourd

Bitter gourd (*Momodica charantia* L.) is an important vegetable in Asia where it is grown on approximately 340,000 ha annually by smallholder farmers (McCreight et al. 2013). The crop is cultivated in some African countries, such as Ghana, and fresh fruit is exported to Europe where it is in great demand among expatriate Asian communities. Cultivation of this cucurbit is expanding in Zambia, Congo and Madagascar for local consumption and export. It is also cultivated in smaller volumes in Australia (Northern Territory, Queensland, New South Wales, Victoria), where Asian varieties are grown and consumption is primarily by ethnic communities from Asia (Morgan and Midmore 2002). Bitter gourd fruit is rich in beta-carotene, vitamin C, folic acid, magnesium, phosphorus, and potassium (Yuwai et al. 1991; Dhillon et al. 2016a). In addition to its use as a vegetable, bitter gourd is often used in folk medicine in Asia to manage type 2 diabetes, a non-communicable disease that affects 347 million people worldwide, with 80 % of these living in low- and middle-income countries (World Health Organization 2016).

The species is monoecious (produces separate male and female flowers on the same plant) and tends to cross-pollinate, a mechanism that tends to promote phenotypic and genotypic diversity. Recent biogeographic analyses suggest that *M. charantia* originated in Africa (Schaefer and Renner 2010) and probably was domesticated in eastern India and southern China (Reyes et al. 1994). *M. balsamina* is a wild bitter gourd in northern and eastern states of India. The fruit of this species are spindle shaped, green with 6–9 regular or irregular rows of cream or yellowish blunt spines. It is genetically diverse from the genepool of *M. charantia* and accession THMC 281 has been found resistant to melon fly, *Bactrocera cucurbitae* (Dhillon et al. 2016b). *M. charantia* × *M. balsamina* hybrids are difficult to obtain (Bharathi et al. 2012).

Consumers prefer bitter gourd fruit at a physiologically immature or unripe stage. Immature fruits have a fresh bright appearance and the seed coats are creamy-white. Mature fruits have yellow flesh with red seed coats and usually split, rendering them inedible and unsalable. Consumer preferences for fruit color, shape, skin pattern, and size vary between and within countries. Fruit colors range from white or cream to light-green to dark-green, and shapes include cylindrical, elliptical, spindle and conical types. Fruits develop irregular longitudinal ridges and warty skin, depending upon the variety. Based on these fruit traits, nearly 20 market types of

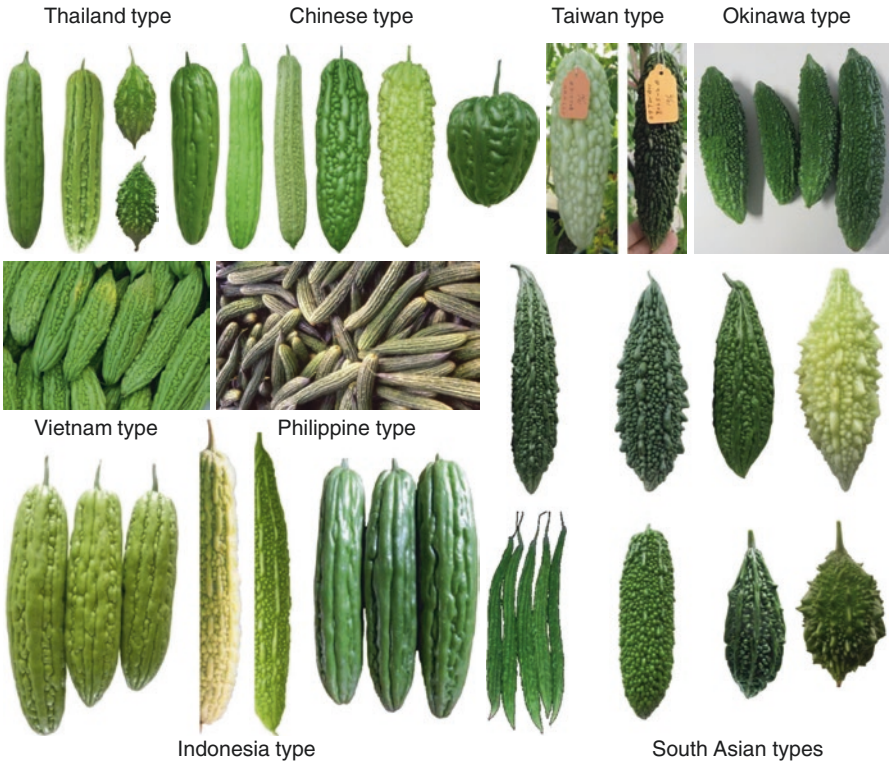

Fig. 1 Bitter gourd: variation within fruit of eight market types

bitter gourd exist in Asia, and nearly half are cultivated in India, China, Nepal, Bangladesh, and Sri Lanka (Fig. 1).

Bitter gourd genetic resources are conserved *in situ* in various genebanks in Asia. Nearly 1000 accessions of bitter gourd are stored in the national genebanks of India at various locations (New Delhi, Jodhpur, Hyderabad, Thrissur, Shillong, Ranchi), and 250 accessions are available in the genebanks of Kasetsart University, Thailand (M. Anil, personal communication). The Chinese Academy of Agricultural Sciences holds 177 bitter gourd accessions in several provinces such as Guangdong, Guangxi and Yunnan (Kai-Lin Hu, personal communication). The World Vegetable Center (WorldVeg) (http://avrdc.org/seed/seeds/) listed 425 bitter gourd accessions in 2016, with 139 (33 %) of them available for distribution, the others were either unavailable (4 %) or inactive (63 %; Table 1). The U.S. Germplasm Resources Information Network (GRIN [Internet]. Beltsville (MD): United States Department of Agriculture, Agricultural Research Service. http://www.ars-grin.gov/) listed 103 *M. charantia* accessions, as seeds, from 22 countries, including 48 from India, but only one accession was available in 2016 (Table 1).

Table 1 Total numbers of accessions of six gourd species listed by the U.S. Germplasm Resources Information Network (GRIN [Internet]. Beltsville (MD): United States Department of Agriculture, Agricultural Research Service. http://www.ars-grin.gov/) and the World Vegetable Center (WorldVeg; http://avrdc.org/seed/seeds/) in 2016, and the respective numbers that are available or not available for distribution, and inactive

		Total		Available		Not available		Inactive	
Common name	Species	GRIN	WorldVeg	GRIN	WorldVeg	GRIN	WorldVeg	GRIN	WorldVeg
Bitter gourd	*Momordica charantia*	103	434	1	139	22	17	80	269
Bottle gourd	*Lagenaria siceraria*	500	329	185	9	254	1	61	319
Ridge gourd	*Luffa acutangula*	67	341	59	18	3	0	5	323
Snake gourd	*Trichosanthes cucumerina*	37	71	0	7	7	0	30	64
Sponge gourd	*Luffa cylindrica*	78	409	64	18	4	0	10	391
Wax gourd	*Benincasa hispida*	106	285	13	36	18	0	75	249

There are few reports of bitter gourd genetic diversity analysis. Random amplified polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLP), and simple sequence repeat (SSR) molecular markers have been used to study genetic diversity of a limited number of bitter gourd accessions that originated from India and China (Dey et al. 2006; Gaikwad et al. 2008; Ji et al. 2012; Yuan et al. 2012). Analysis of 38 Indian bitter gourd landraces from eastern India indicated that genotypes Mohanpur Sel-215 and Jayanagar Sel-1 were highly diverse, based on AFLP markers (Gaikwad et al. 2008). Analysis of 212 bitter gourd accessions from 15 countries in Asia, South America and Africa using 36 SSR markers demonstrated that accessions from China, India and South America were genetically divergent and clustered in three separate subpopulation groups (Kai-Lin Hu, personal communication).

Hybrid bitter gourd cultivars are more popular with Indian farmers than open-pollinated (OP) cultivars. Indian consumers prefer green, shiny, and bitter fruits with spines. Cultivars of different market segments are characterized according to the length of the fruit: short segment (<10 cm), medium segment (10–20 cm), and large segment (> 20 cm). The Indian bitter gourd market is dominated by medium- and long-segment cultivars. Important hybrid cultivars developed in India include Palee and Parachi (East-West Seed), Amanshri (Nunhems), VNR 28 and VNR 32 (VNR Seeds), CT 108 (Chia Tai Seeds), Vivek F_1 (Sun Grow Seeds), Vishesh (Golden Seeds), Abhishek (Seminis), Arjuna, Pallavi, Raja and Parijat (Rasi Seeds), and US1315 (US Agriseeds). Landraces still popular with Indian farmers include Faizabadi Karela, Green long, White long, Jaipur long, Katai, and Jhalari.

In China, popular bitter gourd landraces come in a variety of shapes and sizes. Fruits of cultivars popular in Guangdong, Guangxi, and Hainan provinces of southern China are 20–30 cm long, cylindrical with blunt ends, green and ribbed. Fruits of bitter gourd typical to central China are 30–40 cm long, elongated with pointed ends, warty and light-green to white. One cone-shaped landrace, Dading, is popular in the Pearl River Delta of China. Zhenzhu, another popular landrace, has fruit with pearl-like warts on the rind; its distribution ranges from southwest to central China (Chen et al. 2012; Kang et al. 2010). A miniature-fruited landrace known as Laigua or Laiputao is grown for consumption and ornamental purposes in central China. Resistance to *Fusarium* wilt, powdery mildew and root-knot nematodes have been reported in wild species and landraces that originated from China (Shen et al. 2007; Chen et al. 2014; Tian et al. 2015).

Popular cultivars of bitter gourd derived from landraces in Bangladesh include Ranipukur, Rampali, and Gazkarala. Commercial hybrids are fast replacing landraces in Bangladesh, and important cultivars include BRAC Hybrid 1 and BRAC Hybrid 2 (BRAC Seeds), BARI Karala 1 (BARI), Tia F_1 and Kakoli (Lal Teer Seed), Mukta F_1 (Getco Seed), and Bolder (Metal Seed), Shyama and BT-03 (ACI Seed). Kee Nok ("Bird dropping," which refers to the small size of the fruit) is a bitter gourd landrace-derived cultivar popular with growers and consumers in Thailand. Its fruits are short (5–10 cm), spindle shaped, spiny and green (Fig. 1), but this cultivar captures a small market share because the Thai bitter gourd market is dominated by hybrids with fruit traits such as cylindrical shape, smooth, light-green and blunt ends (Fig. 1). Popular hybrid cultivars include Kiew Yok (East-West Seed),

Morakot (Thai Seed & Agriculture) and Yok Tip (Metro Seeds Thailand). The Philippines bitter gourd market is dominated by hybrid cultivars bred by East-West Seed; popular cultivars include Bonito F_1, Galactica F1, Galaxy F_1 and Jade Star L F_1. The bitter gourd market in Vietnam predominantly belongs to a single market type with cultivars that are slightly spindle shaped, medium-long (10–15 cm), with smooth ridges (Fig. 1). Important cultivars in this market segment include Vino Galaxy B1 (Viet Nong Seed), HN 126 (Vina Seed), Thuy Phi (Known You Seed), Jupiter (En Vang Seed), Apolo – 17 (An Phu Nong Seed) and Sumo 742 (Southern Seed Corporation).

Use of a gynoecious inbred in hybrid development reduces the cost of F_1 hybrid seed production and enhances seed purity. Breeders have developed gynoecious inbreds (DBGy-201, Gy263B, OHB61–5) with better combining ability that improved early and total fruit yield in bitter gourd hybrids (Ram et al. 2006; Iwamoto et al. 2009; Dey et al. 2010). Repeated use of a comparatively small number of closely related bitter gourd lines in commercial breeding has narrowed the genetic diversity within the bitter gourd crop. This is attributed in part to the availability of a few gynoecious bitter gourd lines that are used repeatedly by seed company breeders. Breeders focus primarily on elite × elite crosses to capitalize on previous breeding successes. This has resulted in genetic uniformity among commercial cultivars, which could increase the overall risk to farmers due to pests and diseases. Trait-specific breeding pays rich dividends to commercial breeding programs. Systematic and comprehensive evaluations of the global collection of bitter gourd can provide traits for sustainable production and new genetic diversity. For example, evaluation of the diverse bitter gourd germplasm collection held at the Worldveg led to the development of cucurbit powdery mildew (*Podosphaera xanthii*) resistant lines (Dhillon et al. 2015). Currently, *Cucurbit aphid-borne yellow virus* (CABYV), locally known as "Namamarako," in the Philippines and "Mara Ba″ in Thailand, has become a grave limitation to bitter gourd production (Relevante et al. 2012). Bitter gourd accession VI049946 from the WorldVeg genebank segregated for resistance to this polerovirus (Fatkhu Rokhman, personal communication).

Bottle Gourd

Bottle gourd [*Lagenaria siceraria* (Molina.) Standley] also known as white-flowered gourd or calabash is native to Africa (Richardson 1972), and archaeological findings suggest its arrival in Asia and the Americas over 10,000 years ago via human migration (Erickson et al. 2005). Long-fruited edible bottle gourds were familiar to the Romans and other Mediterranean civilizations of the first centuries CE (Janick et al. 2007). It is annual and monoecious. The species presents the largest variation in fruit shape resulting, presumably, from thousands of years of selection in isolated areas of the world (Yetişir et al. 2008). Fruit shapes include long and cylindrical, elongate, curved, pyriform, crooked necked, and globular (Fig. 2). The young tender peeled fruits are eaten. Fresh bottle gourd juice is used for its cooling, diuretic, antibilious,

Fig. 2 Bottle gourd: variation of fruit shape and size among landraces, varieties and cultivars

and pectoral properties (Minocha 2015). Young shoots and tendrils are also cooked, and oil is extracted from the seed. Heiser (1979) provided a fascinating account of other uses of mature, dried hard shells of bottle gourd including musical instruments, cups, barrels, milk pails, ladles, fishing floats, penis sheaths, carvings, etc. Fruits are also used as herbal medicines in Asia. Five wild species of *Lagenaria* exist in Africa: *L. breviflora* (Benth.), *L. abyssinica* (Hook f.), *L. rufa* (Gilg.) Jeffrey, *L. sphaerica* (Sonder) Naudin and *L. guineensis* (G. Don) Jeffrey. Wild species produce small round fruits with strong bitter taste (Morimoto et al. 2005). During domestication, selection for non-bitter fruits must have been practiced.

A significant number of bottle gourd accessions collected in different regions of the world are held by the National Bureau of Plant Genetic Resources (NBPGR), New Delhi, India (739 accessions). The WorldVeg listed 329 accessions, only nine were available, the majority (97 %) were inactive (Table 1). GRIN listed 500 accessions of *L. siceraria* from 23 countries in 2016; 185 (37 %) were available for distribution; 51 % were not available (Table 1). Africa accounted for 233 of the GRIN accessions: Burundi (1), Ethiopia (5), Nigeria (1), South Africa (8), Zaire (4), Zambia (106), Zimbabwe (108).

Levi et al. (2009) examined genetic diversity among 57 *L. siceraria* accessions that originated from 16 countries in Asia, Africa, and South America, using sequence-related amplified polymorphism (SRAP) markers; they found that collections of Indian origin were genetically distinct from the collections collected in Southern Africa and the Americas. Simple sequence repeat (SSR) genetic analysis of 60 Turkish and 31 exotic accessions of bottle gourd indicated that Indian accessions were not closely related to bottle gourd accessions from other parts of the world, and Turkish accessions were not clustered according to their geographic origin in Turkey (Gürcan et al. 2015). Comprehensive information about the genetic diversity in bottle gourd germplasm with respect to disease/pest resistance is not available.

In Japan, bottle gourd is increasingly used as a rootstock to manage soil-borne diseases, specifically Fusarium wilt of watermelon (Oda 2002), as most of the rootstocks of bottle gourd are non-hosts to *Fusarium oxysporum* f. sp. *niveum*, the pathogen that causes Fusarium wilt of watermelon (Cohen et al. 2007, Bruton et al. 2009). In the United States, interest in grafting has increased due to the phase-out of methyl bromide for soil fumigation. Indian bottle gourd accession PI 271353 was reported resistant to cucurbit powdery mildew caused by *Podosphaera xanthii* (Kousik et al. 2008). USVL#1–8 and USVL#5–5, two breeding lines of bottle gourd derived from Indian accessions were resistant to *Zucchini yellow mosaic virus* (ZYMV), *Papaya ringspot virus* strain watermelon (PRSV-W), *Watermelon mosaic virus* (WMV), and *Squash vein yellowing virus* (SqVYV) (Ling et al. 2013). Resistance to multiple viruses also has been reported in Cow Leg, a variety from Taiwan (Provvidenti 1981). Narendra Shishir, a cultivar from India, has been observed to be resistant to anthracnose, downy mildew, and an unspecified viral disease complex (Singh 2013). Resistance to crown rot caused by *Phytophthora capsici* has been reported in commercial bottle gourd rootstocks 'FR-Strong', 'Emphasis', 'Marcis', and 'WMXP-3938' (Kousik et al. 2012). Commercial bottle gourd rootstocks 'FR-Gold', 'Skopje', and 'Brecik' were reported tolerant to salinity (Yetişir and Uygur 2010). Important hybrid cultivars developed by the private seed sector in India include Warad (Mahyco Seeds), Sharda (Seminis), Sarita (VNR Seeds), Vidya and Swati (Sungro Seeds), Anmol and Gadda (East-West Seed), Mallika (Bio Seeds), and Anokhi (Nunhems India). These hybrids display high-level resistance to Fusarium wilt and have consistently high yields with better fruit quality than open-pollinated cultivars. Bottle gourd hybrid cultivars FR-Ganggeon and FR-Sinsegye are resistant to Fusarium wilt (Huh et al. 2012).

Wax Gourd

Wax gourd [*Benincasa hispida* (Thunb.) Cogn.] is also known by several other names such as ash gourd, white pumpkin, and white gourd. Mature fruits have a thick waxy cuticle. It is an important vegetable in India, China, Bangladesh, Philippines, Vietnam, Thailand, Indonesia, Turkey and Iraq. Immature and mature fruit are edible (Marr et al. 2007). The fruit flesh is white to pale-green, with a weak

flavor. In China and Southeast Asia, thick pieces of the mature fruit are prepared in soup, and in India, fruit pieces are cooked in curries. Big fruit pieces are "candied" in India, China and Cuba (Heiser 1979). In China, a canned beverage is prepared from the fruit. Immature fruit ("Hairy melon") is sliced and eaten raw or cooked (Walters 1989). Young leaves, vine tips and flower buds are also consumed as boiled greens.

The Indo-China region is regarded as the center of origin (Robinson and Decker-Walters 1997), and the genus *Benincasa* is considered monotypic. Related wild species of *Benincasa* are not known. Four major cultivar groups are recognized based on the vegetative, floral, fruit and seed traits (Walters and Decker-Walters 1989, Bates and Robinson 1995):

1. *Unridged winter melon group* comprises large cylindrical fruits (50–100 cm) with a dark-green rind that has little or no waxy bloom and unridged seeds. This group, along with the next two groups, is common in China and parts of western Asia.
2. *Ridged winter-melon group* is similar to the first group with the exception of its ridged seeds.
3. *Fuzzy gourd group* cultivars have small, narrowly cylindrical fruits (20–25 cm), light-green to green fruit skin covered with soft white hairs without waxy bloom and ridged seeds. This group is also common in Southeast Asia.
4. *Wax gourd group* predominates in India and other parts of South Asia. Fruits are covered with a white, waxy bloom; seeds are mostly ridged. Marr et al. (2007) proposed 16 cultivar groups based on the wide range of fruit size, color, shape and intensity of waxy bloom.

   India and China hold maximum diversity in terms of fruit traits (Fig. 3) with fruit weight ranging from 1.5 to 50 kg, and various shapes such as round, oval, oblong, long cylindrical, and short cylindrical. Fruit skin color varies from light-green to dark-green, and speckled green. Fruits may carry strong, medium, or weak wax, or be wax-less. There are five categories of seed size: super small seed (90–95 seeds/g,)very small seed (60–65 seeds/g), small seed (35–40 seeds/g), medium seed (20–25 seeds/g), and large seed (10–12 seeds/g).

   Landraces are still grown by local people in different regions of Asia. Mo-kwa, a high yielding landrace, is heat-tolerant. Cultivar Chi-fon is popular in Taiwan, and is highly resistant to ZYMV, *Cucumber mosaic virus*, PRSV-W, and *Melon vein-banding mosaic virus*. Wax gourd is an important crop in Vietnam, where it is cultivated on more than 33,000 ha annually.

   Round or oblong fruits (6–8 kg) of light-green to dark-green color are preferred by Indian consumers, whereas long cylindrical fruits (1–2 kg) with dark-green color and white specks are preferred by consumers in Vietnam. In northeast India, landraces are genetically divergent from those originating from other parts of the country (Pandey et al. 2012). Popular open-pollinated and hybrid cultivars in India include KAU local, Indu (tolerant to begomoviruses), CO-1, Kashi Ujwal, Kashi Dhawal, Kashi Surabhi (best for *petha,* a sweet dish), Virat F1 (tolerant to begomoviruses) and Siddhi F1 (Rasi Seeds), MAH-1 F1 (Mahyco

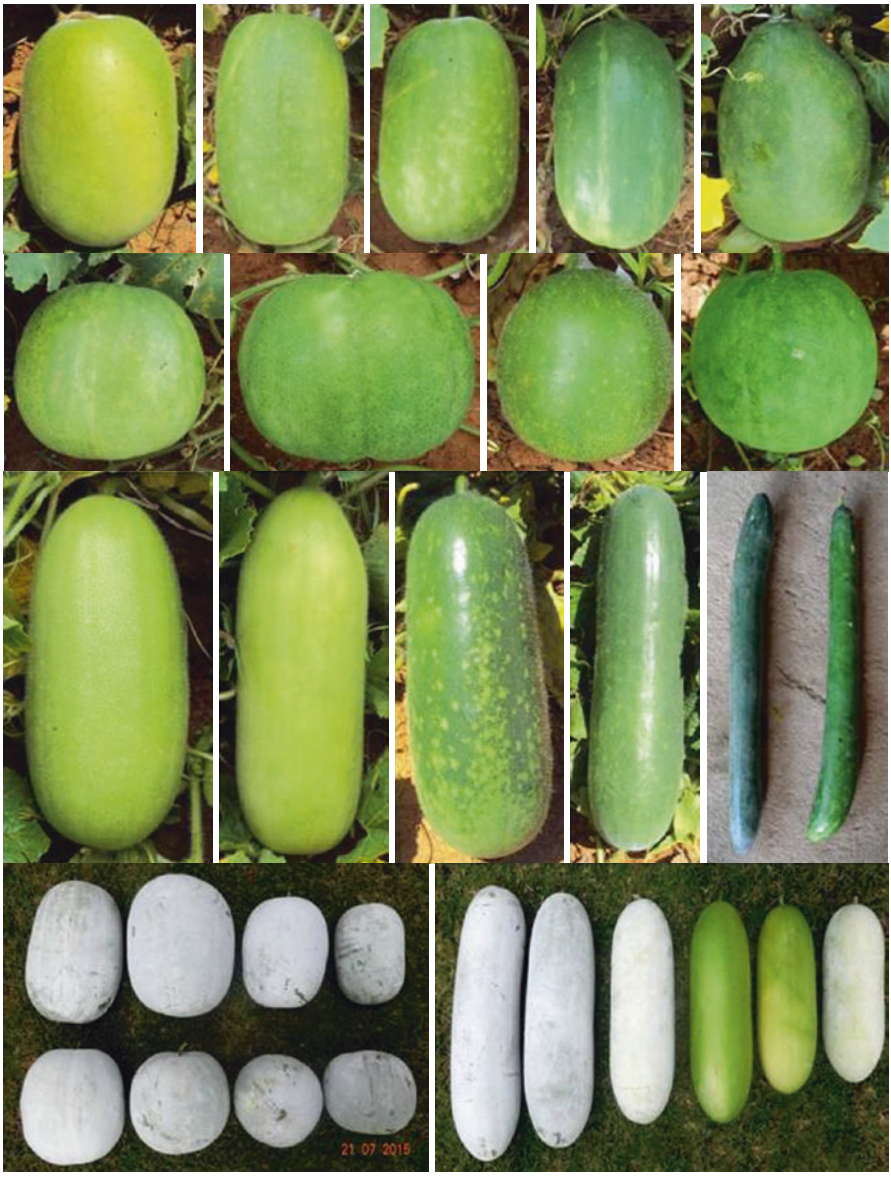

Fig. 3 Wax gourd: variation in fruit among varieties

Seeds), Sowmya F_1 (Beejo Sheetal), No 600 F_1 and No 700 F_1 (Sungro Seeds), Rakhiya F_1 (VNR Seeds), Pearl F_1, Jade F_1 and Gold 195 F_1, a wax-less cultivar (East-West Seeds), Heera F_1 and Greena F_1 (Chia Tai Seed). Wax gourd cultivars popular in Japan are Okinawa No 1 and Kurokawa Early. The Field Crops Research Institute (FCRI) in Vietnam has developed improved lines through

selection from landraces such as Wax gourd No.1, Wax gourd No. 2, Wax gourd Thien Thanh 5, Wax gourd Sac, Wax gourd Chu Thap and Wax gourd Da.

The WorldVeg listed 285 wax gourd accessions in its genebank in 2016; 13 % (36) are available and 87 % are inactive (Table 1). FCRI Vietnam has more than 200 wax gourd accessions stored in its genebank. In India more than 222 accessions are maintained in NBPGR, New Delhi. GRIN listed 106 wax gourd accessions in 2016 from six countries, including 21 from India and 57 from China. Thirteen (12 %) GRIN accessions were available for distribution and 75 (71 %) were inactive (Table 1).

Snake Gourd

Snake gourd [*Trichosanthes cucumerina* L.'Anguina' (L.) K.Pradheep, D.R.Pani&K.C.Bhatt] is an annual, creeping cucurbit well-adapted to humid lowland tropics. The common name refers to the narrow, twisted and elongated fruit that resembles a snake. It is commercially cultivated in India, Sri Lanka, Thailand, China, and Japan. Fully-grown, tender, cooked fruits are eaten. The crop was domesticated in India (Li 1970). The genepool of snake gourd (probably primary) includes *T. cucumerina* (syn. *T. lobata*) and its two subspecies *villosula* (*T. perrottetiana*) and *sublobata* (Pradheep et al. 2015). Both subspecies are localized in peninsular India with the former being restricted in mid- to high-altitudes of southern Western and Eastern Ghats, and the latter confined to parts of Goa, Maharashtra and adjoining areas. Intermediary forms between cultivated ('Anguina') and wild populations of *T. cucumerina* (often designated as *T. lobata*) are richly distributed in the central and eastern India. In India, snake gourd is commonly known as "padwal," "chichinda," and "serpent gourd." Two fruit colors predominate: light-green with white stripes, and dark-green with pale-green stripes (Fig. 4). Popular open-pollinated cultivars developed through selection from local landraces include APAU Swetha, CO-1, CO-2, CO-4, PLR (SG) 1 PLR (SG) 2, MDU-1, PKM-1, TA-2, TA-19, Baby (TA-23), Konkan Sweta, Manusree, Harithasree, and Kaumudi. Hybrid cultivars released in India include MHSN 1 (Mahyco Seeds), BSS 694 (BeejoSheetal), and Snaky White Short (Ashoka Seeds). These hybrids are becoming popular due to their high yield potential, vigorous and strong vines, and attractive milky-white fruits.

The WorldVeg listed 71 accessions of snake gourds in 2016; 90 % were inactive (Table 1). GRIN listed 37 *T. cucumerina* accessions from eight countries with most from India (25 accessions), but none were available (Table 1).

Sponge Gourd and Ridge Gourd

Sponge gourd (*Luffa cylindrica* Roem., syn. *L. aegyptiaca* Mill) and ridge gourd [*L. acutangula* (L.) Roxb.] are the two cultivated species of the genus *Luffa*. Wild species include *L. graveolens* Roxb. (var. *longistyla*), *L. echinata* Roxb., *L.*

Fig. 4 Snake gourd: fruit of local Indian varieties

tuberosa Roxb., and *L. umbellata* Roem. *Luffa* is considered to be an essentially Old World genus (Seshadri and More 2009). *L. quinquefda* (Hook and Arn) Seem. and *L. astorii* Svans. are wild species confined to the New World (Seshadri and More 2009). Another wild species, *L. saccata* was discovered in the Northern Territory of Australia (Telford et al. 2011). In the absence of convincing evidence, Whitaker and Davis (1962) reported Indo-Burma to be the center of diversity of sponge gourd, and it reached the Mediterranean by the third century CE for use as food (Avital and Paris 2014). Slightly later than that, Byzantine mosaics depicted both immature and mature sponge gourds, and it is presumed they were depicted because they were used as food (immature) and for hygiene (mature) (Avital and Paris 2014).

India has been suggested as the center of origin of ridge gourd and this species is represented by three botanical varieties: var. *acutangula,* which is cultivated in southeastern Asia and other tropical areas but to a lesser extent than sponge gourd; var. *amara* (Roxb.) C.B. Clarke, which is a wild form confined to India; and var. *forsakii* (Harms) Heiser & Schilling, a wild form (Robinson and Decker-Walters 1997). Sponge gourd also is known as towel gourd, smooth loofah, vegetable sponge, and dishcloth gourd. Ridge gourd is also known as angled loofah, ribbed gourd, silk gourd, and Chinese okra. The immature, tender fruits of these two species are consumed as cooked vegetables. The mature, fibrous endocarp can be used as a sponge, the loofah scrubbing sponge, and is popular with consumers in the U.S.A., Japan and Asia.

Fig. 5 *Luffa* spp. fruit variation: *L. cylindrica* (**a**–**c**), *L. acutangula* (**d**–**f**), and *L. hermaphrodita* (Satputia) genotype (**g**)

China, India, Korea, Japan and Central America are the major regions of commercial cultivation of *Luffa*. Great variability for fruit size, shape and color is observed in both species of *Luffa* (Fig. 5). Flowers of these two species are monoecious. A variant form of ridge gourd, locally known as "Satputia" in India, is hermaphroditic and bears fruits in clusters of 5–7. It was given a separate taxonomic status as *L. hermaphrodita* (Singh and Bhandari 1963). Gynoecious landraces of ridge gourd have been reported from the Hoogly district of West Bengal, India (Munshi et al. 2010–2011).

Resistance to melon fruit fly (*Bactrocera cucurbitae*) has been observed in Indian ridge gourd cultivars AHRG-29, AHRG-57 and Pusa Nasdar (Haldhar et al. 2015). Sponge gourd cultivar DSG-6, which is resistant to *Tomato leaf curl New Delhi virus* (ToLCNDV) was developed through selection from a landrace that originated from Hoogly district, West Bengal, India (Islam et al. 2011; Munshi et al. 2015). Resistance to this virus is governed by single dominant gene, and two sequence-related amplified polymorphism (SRAP) markers closely linked to the resistance gene have been developed (Islam et al. 2010). 'Arti' is the first begomovirus-resistant ridge gourd hybrid released in India (VNR Seeds).

Popular ridge gourd hybrid cultivars include Naga, Mallika, Rama (East-West Seeds), NS-3 (Namdhari Seeds), Aneeta (Advanta India), MHRG-7, Surekha (Mahyco), Gaurav and Pallavi (Sungro Seeds). These hybrids are widely preferred in India due to their adaptability, prolific fruit setting and best fruit quality (attractive light-green to green color, 25–40 cm long, prominently ridged tender fruits with rich taste). Popular ridge gourd cultivars derived from landraces include Pusa Nasdar, Pusa Nutan, Hisa Kali Tori, Gujarat Anand Ridge Gourd-1, and Pant Tori-1.

Sponge gourd cultivars popular with farmers in India include White Seeded (Century Seeds), Alok (VNR Seeds), Lohit (Tropica Seeds), Nutan and Sonali (Sungro Seeds), NS 441 (Namdhari Seeds), Maya (Bio Seeds), Harita (Mahyco) and NHSG (Nirmal Seeds). These hybrids gained prominence and popularity among

farmers due to their strong and vigorous vines, high yield potential, wide adaptability and nearly cylindrical, 20–30 cm long, tender fruits with attractive dark-green or light-green colors. Popular open-pollinated cultivars developed through selection from landraces of sponge gourd include Pusa Chikni, Pusa Supriya, Pusa Sneha, Azad Tori-2, and Pant Chikni Tori-1. In India, consumers prefer unripe tender fruit of sponge gourds and ridge gourds before it becomes fibrous, irrespective of the size.

The WorldVeg listed 341 accessions of *L. acutangula* in 2016, but 95 % are inactive (Table 1). GRIN listed 67 *L. acutangula* accessions in 2016 from nine countries; 50 of them from India. Fifty-nine of the accessions are currently available (Table 1). The WorldVeg listed 409 accessions of *L. aegyptiaca* in 2016, but 96 % were inactive. There are 78 *L. aegyptiaca* accessions in the GRIN collection from 13 countries; 54 of them are from India. Sixty-four (82 %) of the *L. aegyptiaca* accessions are currently available (Table 1).

Conclusion

These gourd species, except bottle gourd, were domesticated in Asia. Fruits of the wild relatives of these gourds are small, oblong/ovoid/spindle and bitter (Gaikwad et al. 2008; Telford et al. 2011; Pradheep et al. 2015). Selection for large, elongated fruit size and non/less bitterness was practiced during domestication. The selection might have occurred in several independent events in different regions of domestication, as it happened in two separate occasions in the case of evolution of fruit shape from round to elongated in two subspecies of *Cucurbita pepo*: *C. Pepo subsp. Pepo* and *C. pepo* subsp. *Texana* (Paris et al. 2012). These gourds are nutritious and are important sources of livelihood for resource-poor farmers in Asia, and can be grown in various agro-climates. These cucurbits are key components of home and community gardens in the tropics. Landrace-derived cultivars are rapidly being replaced by modern hybrid cultivars, which has already led to a narrowing of their genetic bases. Breeders recycle the genetic material through repeated use of elite hybrids to derive inbred lines for hybrid development. Controlling potyviruses and begomoviruses, and the fungal diseases powdery and downy mildew, are major challenges for cucurbit growers. Development of short-vine and day-neutral cultivars with higher female:male flower ratios is another goal for breeders. Extensive collection, conservation and evaluation of minor cucurbit landraces are necessary to stem genetic erosion and identify sources of resistance to economically important biotic and abiotic stresses.

The germplasm resources of these gourd species are held in an array of genebanks in several countries and may not be readily available for scientific research or to commercial breeders outside of their respective country. Numbers of the WorldVeg and GRIN holdings vary greatly among the species. Their availability ranges from less than 1 % (*T. cucumerina* and *M. charantia*) to 88 % (*L. acutangula*) and many are inactive, ranging from 7 % (*L. acutangula*) to 81 % (*T. cucumerina*). The WorldVeg holdings of these species are larger than GRIN, as might be expected, but their collections suffer from larger percentages of inactive accessions, ranging from 63 % (*M. charantia*) to 97 % (*L. siceraria*).

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