Handbook of Cucurbits

Growth, Cultural Practices, and Physiology

Edited by
Mohammad Pessarakli

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To the memory of my beloved parents, Fatemeh and Vahab, who regretfully, did not live to see this work and my other works, which, in no small part, resulted from their gift of many years of unconditional love to me.

Contents

Preface

Cucurbits are part of the daily diet of people around the world. Therefore, cucurbit products are important and need special attention in their cultural practices, physiology, and production. There are numerous books and articles available on cucurbits, but these all exist relatively in isolation of each other, covering only one or a few specific topics on cucurbits. Therefore, the information on these important plants is scattered. I felt the need for a single unique comprehensive source of information that includes as many factors as possible on cucurbits, and this resulted in the *Handbook of Cucurbits*. It is a complete collection of the factors on cucurbits.

This comprehensive source is an up-to-date reference book effectively addressing issues and concerns related to cucurbit growth, physiology, cultural practices, diseases, and production. These aspects of cucurbits have efficiently and effectively been addressed in this unique handbook.

While previous authors have indeed competently covered relevant areas separately in various publications, the areas are, nonetheless, interrelated and should be covered comprehensively in a single text, which is the purpose of this book.

The *Handbook of Cucurbits* has been prepared by many competent and knowledgeable scientists, specialists, and researchers in agriculture and horticulture from several countries. It is intended to serve as a resource for both lectures and independent purposes. Scientists, agriculture researchers, agriculture practitioners, and students will benefit from this unique comprehensive guide, which covers issues related to cucurbits from planting to production.

As with other fields, accessibility of knowledge is among the most critical of factors involved with cucurbit production. Without due consideration of all the elements contributing to cucurbit crop production, it is unlikely that a successful production system will be achieved. For this reason, as many factors as possible are included in this handbook. To further facilitate the accessibility of the desired information in various areas covered in this collection, the book is divided into 11 sections: Introductory Chapters; Cucurbit Physiological Stages of Growth and Development I; Cultural Practices of Cucurbits; Cucurbit Physiological Stages of Growth and Development II; Genetics, Genomics, and Breeding of Cucurbits; Cucurbit Grafting; Cucurbit Pathology and Diseases; Weed Control, Pest Control, and Insects of Cucurbits; Therapeutic and Medicinal Values of Cucurbits; Growth Responses of Cucurbits under Stressful Conditions (Abiotic and Biotic Stresses); and Examples of Cucurbit Crop Plants Growth and Development and Cultural Practices. Each of these sections consists of one or more chapters to discuss, independently, as many aspects of cucurbits as possible in that specific topic.

Section I consists of two chapters, including one that provides basic and general introductory information on cucurbit plants/crops.

Section II contains one chapter, which provides details on cucurbit carbohydrate metabolism.

Section III includes five chapters, each of which presents in-depth information on their topic.

Section IV contains four chapters that provide detailed information on various physiological stages of cucurbit growth and development.

Section V consists of two chapters that provide information on muskmelon and ash gourd, respectively.

Section VI includes three chapters that discuss improvements in cucurbit productions and stress tolerance responses of cucurbit plants/crops

Section VII contains one chapter that presents important diseases of cucurbits and their proper management strategies.

Section VIII consists of three chapters that present up-to-date, detailed information on the control and management practices of weeds, pests, and insects of cucurbit plants/crops.

Section IX contains one chapter devoted to the health benefits of cucurbit plants/crops.

Section X consists of three chapters that discuss in detail the responses of cucurbit plants/crops under stressful conditions.

Finally, Section XI, consisting of six chapters, presents detailed information on various cucurbit plants/crops.

Numerous figures and tables are included in the handbook to facilitate comprehension of the presented material. Hundreds of index words are also included to further increase accessibility to desired information.

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I express my appreciation for the assistance I received from the secretarial and administrative staff of the School of Plant Sciences, College of Agriculture and Life Sciences, University of Arizona. The encouraging words of several of my colleagues, which are always greatly appreciated, have certainly been a driving force for the successful completion of this project.

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The collective efforts and invaluable contributions of several experts on cucurbits plants/crops made it possible to produce this unique resource that presents comprehensive information on this subject. Each and every one of these contributors and their contributions are greatly appreciated.

Last, but not least, I thank my wife, Vinca, a high school science teacher, and my son, Dr. Mahdi Pessarakli, MD, who supported me during the course of this work.

Editor

Mohammad Pessarakli, PhD, is a professor in the School of Plant Sciences, College of Agriculture and Life Sciences, University of Arizona, Tucson, Arizona. His work at the University of Arizona includes research and extension services and teaching courses in turfgrass science, management, and stress physiology. He is the editor of the *Handbook of Plant and Crop Stress* and the *Handbook of Plant and Crop Physiology* (both titles published by Taylor & Francis Group, CRC Press [formerly Marcel Dekker, Inc.]), and the *Handbook of Photosynthesis*, and *Handbook of Turfgrass Management and Physiology*. Dr. Pessarakli has written 20 book chapters; has been an editorial board member of the *Journal of Plant Nutrition*, *Communications in Soil Science and Plant Analysis*, *Advances in Plants and Agriculture Research Journal* and the *Journal of Agricultural Technology*; a member of the Book Review Committee of the Crop Science Society of America, and a reviewer of the *Crop Science, Agronomy*, *Soil Science Society of America* and the *HortScience* journals. He is author or coauthor of 185 journal articles and 55 trade magazine articles. Dr. Pessarakli is an active member of the Agronomy Society of America, the Crop Science Society of America, and the Soil Science Society of America, among others. He is an executive board member of the American Association of University Professors (AAUP), Arizona Chapter.

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Section I

Introductory Chapters

1 Cucurbits
History, Nomenclature, Taxonomy, and Reproductive Growth

S. Ramesh Kumar

CONTENTS

1.1 INTRODUCTION

Cucurbits are vegetable crops belonging to the family Cucurbitaceae, which primarily comprise of species consumed as food worldwide. The family consists of about 118 genera and 825 species. Although most of them originated in the Old World, many species originated in the New World and at least seven genera in both hemispheres. There is tremendous genetic diversity within the family, and the range of adaptation for cucurbit species includes tropical and subtropical regions, arid deserts, and temperate regions (Rai et al., 2008). The genetic diversity in cucurbits extends to both vegetative and reproductive characteristics and considerably to the monoploid (x) chromosome number, including 7 (*Cucumis sativus*), 11 (*Citrullus* spp., *Momordica* spp., *Lagenaria* spp., *Sechium* spp., and *Trichosanthes* spp.), 12 (*Benincasa hispida*, *Coccinia cordifolia*, *Cucumis* spp. other than *C. sativus*, and *Praecitrullus fistulosus*), 13 (*Luffa* spp.), and 20 (*Cucurbita* spp.). Chakravarty (1982) estimated 36 genera and 100 species in India. Cucurbits are consumed in various forms: as salads (cucumber, gherkin, long melon), in sweets (ash gourd, pointed gourd), and in pickles (gherkins), desserts (melons), as well as used for other culinary purposes. Some of them (e.g., bitter gourd) are well known for their unique medicinal properties. In recent years, abortifacient proteins with ribosome-inhibiting properties have been isolated from several cucurbit species, which include momordicin (from *Momordica charantia*), trichosanthin (from *Trichosanthes kirilowii*), and beta-trichosanthin (from *Trichosanthes cucumeroides*).

1.2 GENERAL FEATURES

Cucurbit vegetables have the following common features (Goplakrishnan, 2007):

1. *Long tap root system*: Tap root may grow up to 175–180 cm, and laterals are confined to the top 60 cm. Hence, crops like bottle gourd, ash gourd, and pointed gourd are largely part of river bed cultivation.
2. *Branched stem*: The stem is 3–8 branched, prostrate/climbing, and spread up to 9–10 m in *Cucurbita* and *Lagenaria*. Crops like *Cucurbita pepo* have short internodes and are bushy. Nodes usually produce roots upon contact with soil.
3. Leaves are simple and mostly 3–5 lobed, usually palmate, and rarely pinnately lobed (*Citrullus* spp.).
4. *Leaves*: Tendrils on axils of leaves are simple in *Cucumis*, simple or bifid in others, and absent in bush types.
5. *Pollination*: Cucurbits are highly cross-pollinated, and pollination is done by honey bees and bumble bees. Flowers are born in axils of leaves and are solitary or in racemose clusters. Individual flowers are unisexual, large, and showy.
6. *Fruit*: The fruit is essentially an inferior berry and is called "pepo" due to its hard rind when mature. Fruits can be stored for a long period in ash gourd, pumpkin, oriental pickling melon, etc., while keeping quality is less in cucumber, snake gourd, bitter gourd, etc. The fruits of all cucurbits except chayote have many seeds.
7. *Seeds*: Seeds are borne in parietal placentation. Placenta is the edible portion in watermelon, while in ash gourd, ridge gourd, and smooth gourd, it is endocarp. In muskmelon, the edible portion is mostly pericarp with a little mesocarp.
8. *Propagation*: Cucurbits are mostly seed propagated. A few are vegetative propagated like parwal and coccinia.
9. *Life cycle*: Most cucurbits are annuals except chow chow and coccinia, both being perennial.
10. *Cucurbitacins*: A majority of cucurbits are characterized by the presence of bitter principles, cucurbitacins, at some parts of the plant and at some stages of development. Cucurbitacins are tetracyclic triterpenes having extensive oxidation levels. Its highest concentration is in fruits and roots and is less in leaves. Pollen grain also carries a fairly good

amount of bitter principles. This is a common problem in oriental pickling melon, cucumber, and bottle gourd and is rarely noticed in ridge gourd and snake gourd. The consumers usually remove fruit tips during conception to avoid the possibility of bitterness in fruits.

11. *Sex forms*: A wide range of sex forms like monoecious, andromonoecious, gynomonoecious, and dioecious are noticed in the family.
    a. *Hermaphrodite form*: This is the most primitive form, and plants produce only bisexual flowers. This is noticed in the Satputia variety of ridge gourd and in a few lines of cucumber and muskmelon.
    b. *Monoecious form*: This is the advanced form, and plants produce both male and female flowers in a plant. A majority of the cucurbits exhibit monoecious conditions.
    c. *Andromonoecious form*: Muskmelon and some cultivars of watermelon produce both male and bisexual flowers in a plant. However, nondessert forms like oriental pickling melon, phoot under *Cucumis melo* are monoecious.
    d. *Gynomonoecious form*: This is noticed in cucumber, and the plants produce female and bisexual flowers.
    e. *Gynoecious form*: Lines producing female flowers alone are rarely noticed in cucumber and have got a great potential for commercial F_1 production.
    f. *Trimonoecious form*: This is a condition wherein the male, female, and bisexual flowers are produced in a single plant.
    g. *Dioecious form*: Male and female flowers are produced on separate plants in parwal, coccinia, and teasle gourd.
12. *Flowering*: A majority of cucurbits start flowering 30–45 days after sowing and follow a definite sequence.
13. *Cultural requirements*: The cultivation practices of different cucurbits are similar.

1.3 HISTORY

Cucurbits or the gourd family is essentially a group of tropical plants, and it is believed to be a relatively old one. There had been a long and intimate association of humankind with this group. Jeffrey (1980a) estimated the relationship as the longest standing (ca. 15,000 years BP) and of great economic importance. This family is notable for a comparatively large number of species of cultivated plants. Even in prehistoric civilization of the Negritos and then the proto-australoids (called "Nisada" in Sanskrit literature), a cucurbit called "alabu," probably the gourd of "kalinga" identified as watermelon, has been noted by philological studies of Jeen Przyluski, Jules Bosch, and Sylvan Levi (Om Prakash, 1961). Some cucurbits like *Cucumis* spp., melon, colocynth, etc., are important seeds obtained from archaeological sites of the Indian subcontinent (Kajale, 1991).

Sanskrit prose, scriptures, and poetical works like "Vedas," "Upanishads," epics like "Ramayana" and "Mahabharata," "Brahmanas" (ritual texts), "Aranayakas" (text for forest dwellers), dating back to ages before the Christian era, mention several kinds of cucurbits. These suggest many kinds of association of humans, like some plants or trees visualized as being of sacred origin, some plants or parts thereof liked by gods and goddesses, such as fruits of *Momordica dioica* mentioned in "Yogini Tantrum" et (Sensarma, 1998). The "Puranas" (dated between the ages of Vedas and classical literature) contained detailed ethnobotanical information as in "Matsya Purana" on "alabu" (bottle gourd) and "trapusa" (cucumber). Brief historical notes of some of the cultivated cucurbits are given in the following discussion (Seshadri and More, 2004).

1.3.1 Cucumber

Cucumber has a very long ancient history of more than 5000 years and originated in India. It was mentioned in Rigveda (ca. 2000–1500 BC). From India, it spreads eastward to China and westward to Asia Minor, North Africa, and later to other parts of Europe. The Greeks and Romans grew

cucumber in 300 BC. Columbus introduced cucumber into the New World and planted it in Haiti in 1494 from where it moved to the United States by 1539.

1.3.2 Pumpkin and Squashes

The summer squash, *C. pepo*, was the oldest to be domesticated in southern Mexico to southwestern United States, as early as 8000 BC. The pumpkin, *C. moschata*, was cultivated in southern Mexico in 5000 BC and in Peru in 3000 BC. *Cucurbita maxima* was domesticated in southern South America, as evidenced by the excavated seeds that dated to AD 1200 (Vishnu Swarup, 2006).

1.3.3 Melons

Melon was cultivated in Egypt during 2400 BC. It was introduced into the United States by Columbus in 1494. It is now grown in both the Old World and the New World. Colocynth was known as "indravaruni" in medical treatise "Carka Samhita" and "Puranas." Watermelon was known as "kalinga" to the Ptotoaustraloids of prehistoric times and had grown during Indus Valley Civilization (Kajale, 1991).

1.3.4 Gourds

Bitter gourd has domesticated from eastern India and southern China. It has a long history of cultivation. It was introduced from the Old World in Brazil. It widely distributed in India, China, Malaysia, and tropical Africa (Miniraj et al., 1993; Singh, 1990). Bitter gourd has been used for centuries in the ancient traditional medicine of India, China, Africa, and Latin America. Bitter gourd fruits also possess antioxidant, antimicrobial, antiviral, and antidiabetic activities (Raman and Lau, 1996; Welihinda et al., 1986). Based on historical literature (Chakravarty, 1990; Miniraj et al., 1993; Walters and Decker-Walters, 1988a) and recent random amplified polymorphic DNA (RAPD) (Dey et al., 2006), inter simple sequence repeat (ISSR) (Singh et al., 2007) and amplified fragment length polymorphism (AFLP) (Gaikwad et al., 2008) molecular analyses, eastern India may be considered as a probable primary center of diversity of bitter gourd.

Although apparently native to Africa, the bottle gourd had reached Asia and the Americas 9000–8000 years ago, possibly as a wild species whose fruits had floated across the sea (Whitaker and Carter, 1954). The bottle gourd had a broad New World distribution 8000 years ago. Independent domestications from wild populations are believed to have occurred in both the Old World and New World (a variety of plants and animals were independently domesticated in multiple parts of the world between 5,000 and 10,000 years ago). A range of data suggest that the bottle gourd was present in the Americas as a domesticated plant by 10,000 BP, which would make it among the earliest domesticated species in the New World. Comparisons of DNA sequences from archaeological bottle gourd specimens and modern Asian and African landraces identify Asia as the source of its introduction to the New World.

The genus *Luffa*, including another cultivated species ridge gourd (*L. acutangula* [L.] Roxb.) and a few wild species, viz., *L. graveolens* Roxb. (var. *longistyla*), *L. echinata* Roxb., *L. tuberosa* Roxb., and *L. umbellata* Roem, is considered to be an essentially Old World genus (Seshadri and More, 2009). *L. operculata* L. (Cogn.), *L. quinquefida* (Hook. and Arn.) Seem and *L. astorii* Svens are confined to the New World (Seshadri and More, 2009). Whitaker and Davis (1962) stated that "loofah" gourd is either cultivated or grows as an "escape" in practically all of the tropical regions of the world and it is very difficult or even impossible to point out with accuracy the indigenous area of the species. They further stated that pending the emergence of convincing evidence, we can assume with confidence that *L. cylidrica* is indigenous to tropical Asia, probably India. The name "loofah" and "luffa" is of Arabic origin because of the sponge characteristic in Egyptian writing. Kosataki and dharmaragava are the equivalent names in Sanskrit for luffa.

1.4 TAXONOMY OF CUCURBITS (TABLE 1.1)

1.4.1 Tribe-1—Melothrieae

Cucumis L.: It is the most economically important genus with two major cultivated crops *Cucumis sativus* and *C. melo*. The two minor crops are *C. anguria,* the West Indian gherkin confined to Africa and Central America, and *C. metuliferus*, the African horned cucumber confined to Africa only. It can be subdivided into five cross-sterile species groups under two subgenera (Jeffrey, 1980a).

1. *Subgenus*: *Cucumis*: Monoeciuous and adromonoecious species, including *C. sativus* and *C. hystrix* (*C. muriculatus*). There is a record of *C. sativus* var. *sikkimensis* having 7–9 lobed leaves and, five carpelled ovaries (Jeffrey, 1980b). Chakravarty (1982) distinguished two botanical varieties, var. *sativus* and var. *sikkimensis*, on the *basis of higher* number of leaves and higher number of placentae in the latter.
2. *Subgenus*: *Melo*: There are about 25 species mostly in tropical and South Africa.

TABLE 1.1
Classification of Cucurbitaceae

I. Subfamily	**Zanonioideae**	**n = 8 (18 genera and 80 spp.)**
II. Subfamily	**Cucurbitoideae**	**(100 genera, 745 spp.)**
	Tribe-1	Melothrieae (34 genera, 250 spp., n = 12 (13, 11, 7)
		Melothria, *Zeheneria*, *Cucumeropsis*, *Pasadaca*, *Melancium*, *Cucumis*
	Subtribe	Dendrosicynthinae
		Apodanthera, *Kedrostis*, *Corallocarpus*, *Iberivilliea*
	Subtribe	Guraniinae
		Gurania, *Psiguria*
	Tribe-2	Schizopeponeae (1 genus, 8 spp., n = 10)
		Schizopepon
	Tribe-3	Jollifeae (5 genera, 76 spp., n = 14, 11, 9)
		Momordica, *Thladiantha*, *Telfairia*
	Tribe-4	Trichosantheae (10 genera, 75 spp., n = 11)
		Trichosanthes, *Hodgsonia*, *Ampelosicyos*
	Tribe-5	Benincaseae (17 genera, 85 spp., n = 12 (11, 13, 10)
		Subtribe Benincaseae
		Coccinia, *Benincasa*, *Lagenaria*, *Citrullus*, *Acanthosicyos*, *Praecitrullus*
		Subtribe Luffinae
		Luffa
	Tribe-6	Cucurbitae (12 genera, 110 spp., n = 20)
		Cucurbita, *Sicana*, *Cayaponia*
	Tribe-7	Cyclantherae (12 genera, 75 spp., n = 8)
		Cyclanthera, *Marah*, *Elateriopsis*, *Rytidostylis*
	Tribe-8	Sicyoeae (19 genera, 140 spp., n = 12)
		Sechium, Sicyos

Source: Jeffrey, C., An outline of the Cucurbitaceae, in: *Biology and Utilization of Cucurbitaceae*, Bates, D.M., Robinson, R.W., and Jeffrey, C. (eds.), Cornell University Press, Ithaca, NY, 1990, pp. 449–463.

1. *Metuliferus group*: Monoecious annuals with red spiny fruits
2. *Anguria group*: Dioecious, monoecious, or adromonoecious perennials or monoecious or adromonoecious annuals with yellowish or brown stripe fruits; about 20 species including *C. prophetarum*, *C. myriocarpus*, *C. anguria*, and *C. sacluexii*
3. *Melo group*: Monoecious or adromonoecious perennials or annuals with smooth fruits, four species *C. melo*, *C. trigonus*, *C. sagittatus*, and *C. humifructus*
4. *Hirsutus group*: Dioecious perennials with smooth orange fruits, one species *C. hirsutus*

There is another classification proposed by Kirkbride (1993) which consists of two subgenera, viz., *Cucumis* that includes *C. sativus* var. *hardwickii*, var. *sativus*, *xishuangbannaensis*, and *C. hystrix*. The subgenus *melo* comprises of six series (grouping 30 species).

1.4.2 Tribe-2—Schizopeponeae

There are no cultivated taxa and is a small tribe with a single genus.

1.4.3 Tribe-3—Jollifeae

Some species of *Thladiantha*, *Momordica, and Telfairia* are economically important.

Momordica L.: It consists of a large number of species including *M. charantia*, the commonly cultivated vegetable—bitter gourd. Among the 65 species, only 7 occur in India and 23 in Africa. There is some confusion between *M. dioica and M. cochinchinensis* Spreng. The oil glands on the outer margin of the leaf lamina and petioles are distinctly present only in *M. cochinchinensis*, and both are dioecious and tuberous rooted perennials cultivated in eastern and northeastern India. In the flora of tropical East Africa, Jeffrey (1967) has recognized 23 species under *Momordica*, viz., *sessifolia*, *spinosapetri*, *cissoides*, *multiflora*, *foetida*, *leiocarpa*, *angiosantha*, *pterocarpa*, *friesionium*, *pycnantha*, *glabra*, *boionii*, *cymbalaria*, *kirkii*, *trifoliate*, *rostrata*, *cardiospermoides*, and *calantha*, besides cultivated species, *charantia* and *balsamina*. There is new *M. littorea* with dioecious habit, with succulent foliage leaves. But, Meeuse (1962) identified seven species of *Momordica,* viz., *clematida, welwitschii, repens,* besides *charantia and balsamina* in tropical South Africa. Chakravarty (1982) recorded abundant calcium oxalate and calcium carbonate crystals in the leaves in the form of cystoliths in *M. charantia.*

1.4.4 Tribe-4—Trichosantheae

Trichosanthes is the largest genus and monotypic *Hodgsonia,* an Indo-Malayan genus, is grown for its large edible seed rich in oil and protein in China and Northeast India.

Trichosanthes: *Trichosanthes cucumerina* var. *anguina* L., snake gourd, and *T. dioica* Roxb., parwal or pointed gourd, are the two important vegetable crops belonging to this genus. *Trichosanthes* consists of 44 species of which 22 occur in India. Chakravarty (1982) listed the 22 species of *Trichosanthes* occurring in India. They are *cuspidate, anguina, cucumerina, lobata, horsefieldii, villosa, perrottetiana, truncata, ovata, cordata, wallichiana, majuscula, bracteata, lepiniana, anamalaiensis, himalensis, ovigera, dicaelosperma, dioica, tomentosa, and listeria.*

1.4.5 Tribe-5—Benincaseae

Besides *Citrullus*, *Lagenaria*, *Luffa*, and *Coccinia* there are two monotypic genera, viz., *Benincasa* and *Praecitrullus* which have their species cultivated as vegetables.

1. *Citrullus*: Taxonomic classification of Citrullus consisted of the following four species (Rehm et al., 1957; Shimotsuma, 1965):
   a. *Citrullus lanatus* var. *lanatus*, cultivating watermelon, and *C. lanatus* var. *citroides*, preserving melon

b. *Citrullus colocynthis* compact growth, deeply lobed leaves, and small and hard fruits found in Namibia
c. *C. ecirrhosus* Cogn. Xerophytic perennial, roughly haired vines, tendrils absent, with striped firm rinded, white-fleshed fruits
d. *C. naudinianus* (Sond.) Dioecioue perennial, ligneous xerophyte, roughly and deeply divided leaves, confined to South-West Africa

A fifth species has been identified by Fursa (1985), *C. mucospermus* Fursa, confined to Nigeria and Ghana. It is cultivated for its seeds. Another species *C. rehmii* De Winter from Namibia has been described by De Winter (1990).

2. *Praecitrullus* Pang.: This is a new genus of Russian botanist Pangalo to include Indian squash or "tinda." *Praecitrullus fistulosus* Pang. is the only species recognized, mostly confined to northwestern India and Pakistan. Even though erroneously called round melon or squash melon, it is not related to *Cucumis melo* (melon) or *Citrullus lanatus* (watermelon), and the previous botanical names *Citrullus lanatus* var. *fistulosus* Chakra or *Citrullus fistulosus* stocks are no longer accepted.
3. *Benincasa* Savi: It is of Indo-Malaysian distribution, and the cultivated vegetable crop is *Benincasa hispida* called wax or ash or white gourd. Two botanical forms have been recognized in Japan. One is called typical which is characterized by a velvety testa and marginal band around the seeds, while this characteristic is absent in the other form called *F. marginata*. Decker-Walters and Walters (1989) reevaluated the cultigen, which is morphologically diverse, and their allosyme studies suggest that the species is relatively uniform. Four major cultivar groups were recognized by Herklots (1972), which were redefined by Decker-Walters and Walters (1989).
4. *Coccinia* Wight and Arn: It is reported that there are 30 species, mostly confined to Africa. Only one species *Coccinia grandis* L. (Voigt), called ivy gourd, "kundsru" or "tondli," is cultivated in India as a vegetable from very early times. It is a dioecious perennial having XY chromosome differentiated sex mechanism. Variability in leaf lobation made Cogniaux (Chakravarty, 1982) differentiate three varieties: (1) *genuina,* (2) *wightiaana,* and (3) *Alceafolia*. Meeuse (1962) identified seven species of *Coccinia* in South Africa, viz., *palamata*, *sessifolia*, *quirqueloba*, *varifolia*, *hirtella*, *rehmanii*, and *adoensis*. Calcium carbonate punctuations on the upper surface of the leaves, especially when mature, in similar white scale-like deposition on the lower main veins in *C. indica* are also characteristic (Chakravarty, 1982).
5. *Luffa* Mill.: It is a genus distributed both in Old and New Worlds. *Luffa* includes seven species, three of which are native in the New World and four in the Old World. The Old World species are: (1) *Luffa cylindrica* L. Roem., sponge or smooth gourd, and (2) *L. acutangula* L. Roxb., the ribbed or ridge gourd, usually 10 angled. The two feral species are *L. graveolens* Roxb. and *L. echinata* Roxb. (dioecious perennial). The immature fruits of domesticated species (first two) as well as those of nonbitter selections of the Central and South American *L. operculata* are cooked and eaten also as vegetables. In India, Chakravarty (1982) has recorded *L. tuberosa* Roxb. and *L. umbellata* Roem., the later being endemic in Kerala (southwest India). *Luffa cylindrica* is known as wild populations *Luffa cylindrica* var. *leiocarpa* having small fruits deeply furrowed and bitter fruits, distributed from Myanmar to the Philippines, Australia, and Tahiti.

1.4.6 Tribe-6—Cucurbitae

The cultivated five species of *Cucurbita* and a genus of the New World, *Sicana odorifera* (Vell) Naud. are listed.

Cucurbita L.: Under the genus *Cucurbita*, the five cultivated species are *Cucurbita moschata* Duch. (Lam) Poir. (Pumpkin), *Cucurbita maxima* Duch ex. Lam. (winter squash), *Cucurbita pepo* L.

(summer squash—cooked immature), *Cucurbita mixta* Pang. now named *C. argyrosperma* Huber and *C. ficifolia* Bouche, the latter two principally grown in Latin America. The first three species, especially the first one, is extensively cultivated in India, while the fifth one was later introduced into Meghalaya (Northeast India)

Although as many as 27 species have been described in the New World by Whitaker and Bemis (1975), recent observations of synonyms and taxanomic recognition of subspecies and botanical varieties have reduced to nearly 15. Some of the synonyms are *C. argyrosperma* subsp. *sororia* and *C. argyrosperma* var. *palmeri*; *C. pepo* and *C. pepo* var. *texana*; *C. maxima*; *C. martinezii*, etc.

1.4.7 Tribe-7—Cyclantherae

The cultivated taxon *Cyclantherae pedata* L. (Schrad) is grown in South America and has been introduced in west Himalaya and Nepal. There is one more cultivated species *C. brachystachia* Cogn.

1.4.8 Tribe-8—Sicyoeae

Essentially of the New World and Hawaii, the chow chow or chayote, *Sechium edule* (Jacq) SW, is a vigorous perennial introduced in Northeast India, suited to human situations.

1.5 CHEMOTAXONOMY

Besides cucurbitacins, modern chemotaxonomy treatments include several compounds like protein and enzymes, estimated by starch gel electrophoresis (Mulcahy, 1980). Isoelectric focusing (IEF) electrophoretic seed alubumins (Pichl, 1980), nonprotein amino acids or free amino acids (Fowden, 1990), and fatty acids of seed oils (Hopkins, 1990) are important. Cucurbitacins are the bitter principles of cucurbits and are oxygenated tetracyclic triterpenes (Enslin and Rehm, 1958; Kupchan et al., 1978) having taxonomic significance. Of the known 19 cucurbitacins (A to S), Cucurbitacins B and E constitute the primary components. Most of the African species of *Cucumis* have Cucurbitacins like B and D and traces of G and H. Cucurbitacin C is found in *Cucucmis hardwickii* and *Cucumis sativus,* likewise Rhem et al. (1957) and Rhem (1960) reported that cucurbitacin E was the main bitter principle in *Cucumis vulgaris*, *C. colocynthis,* and *C. ecirrhosus*. *Praecitrullus fistulosus,* the Indian squash or tinda, has only Cucurbitacin B significantly.

1.6 KARYOTAXONOMY

Karyologically, the cucurbits are difficult to study. Varghese (1973) and Roy and his associates (Sinha et al., 1983) have devised some good methods. Basic chromosome numbers for the different taxa vary widely—8, 10, 11, 12, 20 and other numbers 7, 13, and 14 are also known (Jeffrey, 1980). Ayyangar (1967) suggested a karyotaxonomic explanation on the phylogenetic genealogy. The haploid number of 12 was found to have high frequency. Next in order of frequency are 11 and 22. Cytological observations on secondary association of bivalents during meiosis have shown that 3 and 5 are possible primary basic numbers, while 6, 10, and 11 may be considered as secondary basic numbers. All the other numbers might have been evolved through autoploidy, alloploidy, aneuploidy, and secondary polyploids.

1.7 FLOWER DEVELOPMENT

Flowers develop in leaf axils. The flower type varies depending on genetics and other factors. Plants may be monoecious (separate male and female flowers), andromonoecious (separate male and perfect flowers), gynoecious (female flowers only), or hermaphroditic (perfect flowers). The most

TABLE 1.2
Commonly Grown Major Cucurbits in the World

English Name	Scientific Name	Origin	Chromosome Number
Cucumber	*Cucumis sativus*	India	14
Bitter gourd	*Momordica charantia*	Indo-Burma	22
Bottle gourd	*Lagenaria siceraria*	Ethiopia	22
Watermelon	*Citrullus lanatus*	Tropical Africa	22
Melon	*Cucumis melo*	Tropical Africa	24
Long/serpentine melon	*Cucumis melo* var. *flexuosus*	India	24
Melon	*Cucumis melo* var. *momordica*	India	
Ridge gourd	*Luffa acutangula*	India	26
Sponge gourd	*Luffa cylindrica*	India	26
Pumpkin	*Cucurbita moschata*	Peru and Mexico	40
Summer squash	*Cucurbita pepo*	Peru and Mexico	40
Winter squash	*Cucurbita maxima*	Peru and Mexico	40
Ash gourd	*Benincasa hispida*	Southeast Asia	24
Pointed gourd	*Trichosanthes dioica*	India	22
Ivy or scarlet gourd	*Coccinia cordifolia* (syn. *C. indica*)	India	24
Round melon	*Praecitrullus fistulosuos*	Indo-Burma	24
Sweet gourd	*Momordica cochinchinensis*	Southeast Asia	28

Source: Rai, M. et al., IIVR: Fifteen years of accomplishments, Indian Institute of Vegetable Research Publication, Varanasi, India, 2008, pp. 1–45.

common forms for various species are listed in Table 1.2. In monoecious and andromonoecious plants, several male flowers usually open before any pistillate (female or perfect) flowers open. At any one time, there are usually several times more male flowers open than female flowers. Most typically, a stem develops a series of nodes with male flowers, one node with a pistillate flower, another series of nodes with male flowers, a second pistillate flower, and so on. Generally, as the plant develops, the proportion of nodes with female flowers increases. In older plants of cucumbers and summer squash, the distal portion of the stem may have pistillate flowers at every node (Loy, 2004; Wien, 1997). In muskmelons, the pistillate flowers form on short lateral branches either on the main stem or on one of several large basal branches (McGlasson and Pratt, 1963). The first pistillate flower to open on muskmelon is usually on a short lateral of a branch near the base of the plant.

Whether a particular node initiates a male or pistillate flower and whether that flower develops fully to bloom is determined by genetics and the environment. Cool temperatures promote development of pistillate flowers in cucumber, squash, and pumpkin. Under these conditions, the first pistillate flower forms at a node closer to the base of plant, and the ratio of male to pistillate flowers is reduced. For some summer squash, this means the first pistillate flower opens before any male flowers are open, and pollination and hence fruit set does not occur. High temperatures promote male flowers and delay female flower development. For instance, in pumpkins, temperatures of 90°F day/70°F night lead to abortion of female flower buds. Light levels are also important. High light levels promote female flower production, and shade can reduce the number of female flowers. Photoperiod does not appear to play a major role in field production, but under controlled environments, some cucumber cultivars produce more pistillate flowers under short days. Plant nutritional status also plays a role; high nitrogen fertilization can delay production of pistillate flowers (Loy, 2004; Wien, 1997). Sex expression in cucurbits is influenced by hormones produced within the plant as well as synthetic growth regulators applied to the plant. Gibberellins promote male flower development in *Cucumis* and *Cucurbita*. In these genera, ethylene promotes pistillate flower development

and suppresses male flowers. Natural and synthetic auxins promote pistillate flower development in cucumber. Very little work on watermelon has been done in this area, and whether it responds similarly to other genera is not known (Wien, 1997).

1.8 SEX MODIFICATION

A majority of cucurbits are monoecious, and the sex ratio (male:female) ranges from 25–30:1 to 15:1. The sex ratio is influenced by environmental factors. High nitrogen content in the soil, long days, and high temperature favor maleness. Besides environmental factors, endogenous levels of auxins, gibberellins, ethylene, and abscisic acid also determine the sex ratio and sequence of flowering. A primordium can form either a female or a male flower, and it can be manipulated by addition or deletion of auxins. Exogenous application of plant growth regulators can alter sex form, if applied at 2–4 leaf stage. A high ethylene level induces female sex and is suggested to increase female flowers in cucumber, muskmelon, summer squash, and pumpkin. In cucumber, maleic hydrazide (50–100 ppm) GA 3 (5–10 ppm), Ethrel (150–200 ppm), TIBA (25–50 ppm), and boron (3 ppm) also induce female flowers.

Gibberellins promote maleness and are antagonistic to the action of ethylene and abscisic acid. In fact, a gynoecious line of cucumber is maintained by inducing male flowers through spray of GA 3 (1500–2000 ppm). Silver nitrate (300–400 ppm) also induces maleness.

1.9 FLORAL BIOLOGY

Bitter gourd: Bitter gourd is a monoecious annual climber with a duration of 100–120 days. Leaves are palmately 5–9 lobed. Flowers are axillary with long pedicel and are yellow in color. Stamens are five in number, with free filaments and united anthers. Stigma is divided. The fruit is pendulous, fusiform, ribbed with numerous tubercles. The bitterness of the fruit is due to the presence of an alkaloid, Momordicin. Anthesis is from 4:00 to 7:00 a.m. Anther dehiscence takes place between 5:00 and 7:30 a.m. Stigma is receptive 24 h before and after anthesis.

Snake gourd: *T. anguina* is a monoecious annual climber with small white flowers. Female flowers are solitary, sessile with long narrow ovary and fimbriate corolla and are 5-partite. Male flowers appear in clusters on long densely pubescent stalks of 10–20 cm long. Plants flower at early hours of night. Anthesis begins at 5:15 a.m. and continues up to 9:30 a.m. Anther dehiscence occurs before flower opening and is completed by 1 h. Pollen grains remain viable 10 h after anthesis. Stigma is receptive 7 h before and 51 h after opening of flower.

Pumpkin: Pumpkin produces largest flower among cultivated cucurbits with large yellow corolla and large ovary with variable green color. Anthesis occurs between 4:30 and 4:50 a.m. Distinctly visible variation in shape, size, and color of various floral parts like calyx, corolla, anther, stigma, and ovary are noticed. Calyx is always green, but shape and size differ among genotypes. The opened flowers are companulate in shape, measuring 15–20 cm in length. The diameter of the opened flower at the distal end varies from 15 to 25 cm. Pistillate flowers are larger than staminate flowers. Corolla color is yellow, but a tinge of variation in shades of yellow color may be seen among the genotypes. The crop is invariably monoecious, where axillary staminate and pistillate flowers are found on separate nodes of the same plant. Both staminate and pistillate flowers are strictly solitary. In a very few genotypes, in a particular set of climatic conditions at the same location, a transitory trimonoecious (gynomonoecious) condition is also encountered, where a few abnormal, deformed hermaphrodite flowers are formed in some plants of the genotype. Both staminate as well as pistillate flowers have a tendency to convert into abnormal hermaphrodite flowers. The frequency of pistillate flowers turning into hermaphrodite flowers is rather low. Staminate flowers converting into hermaphrodite flowers have superior ovary—an unusual phenomenon in cucurbits. Pistillate flowers converting into hermaphrodite flowers have an usual inferior ovary. The hermaphrodite flowers formed out of either staminate or pistillate flowers never turn into normal, effective fruits.

Ash gourd: This monoecious crop produces large male flowers with long pedicels and female flowers with densely haired ovary and short peduncle on the same plant. Corolla is yellow in colour and large in size. The ratio of staminate to pistillate flowers is 34:1. Anthesis takes place between 4:30 and 7:30 a.m. and anther dehiscence is between 3:00 and 5:00 a.m. Stigma is receptive from 8 h before to 18 h after anthesis.

Bottle gourd: Bottle gourd is commonly monoecious in nature. However, an andromonoecious isolate Andromon-6 has been reported by Singh et al. (1990). Transitory unstable trimonoecious sex form also appears in both monoecious and andromonoecious forms. Generally, solitary staminate, pistillate, or hermaphrodite flowers are present in the leaf axils of separate nodes. However, occasionally, two staminate, one staminate and one pistillate, or even two pistillate flowers are present on the same node in certain genotypes. Very rarely both of the pistillate flowers on a node turn into effective fruits.

Usually, in common genotypes, first staminate flower anthesis takes place earlier at a lower node number, and first pistillate flower anthesis takes place 1–10 days later at a higher node of the vine, but the sequence changes in early/prolific genotypes, where first pistillate flower anthesis occurs 1–2 days earlier at a lower node as compared to first staminate flower anthesis. Anthesis in bottle gourd takes place between 4:30 and 7:00 p.m. In early genotypes, anthesis occurs relatively earlier as compared to late genotypes. In all the genotypes, pistillate flowers open about an hour earlier than staminate flowers on the same plant. In narrow petalled genotypes, opening of petals/corolla of pistillate flower begins early in the day, between 12:00 noon and 2:00 p.m., and staminate flowers also open a bit earlier as compared to normal genotypes. Dehiscence in all the genotypes takes place between 1:00 and 2:00 p.m. Anthesis and dehiscence time is moderately influenced by humidity and temperature conditions.

Cucumber: Cucumber is monoecious, that is, male and female flowers present on the same plant. Flowers are bracteate, pedicellate, unisexual, actinomorphic, pentamerous, and epigynous. The whole developmental process from the initial bud stage to the stage when the flower is detached from the pedicel is divided into eight stages. The opening and closing of the male flowers is mainly influenced by the sunrise and sunset, that is, by light and the time of the day.

Pollination and fruit set: Flowers open at temperatures above 50°F (pumpkins and squash), 60°F (cucumber and watermelon), or 65°F (muskmelon). They remain open for a day in the case of watermelons, muskmelons, and cucumbers or half a day or less for *Cucurbita* spp. In most cases, fruit set requires the activity of pollinators, such as honeybees or native squash bees. Enough viable pollen must be delivered to the stigma so that there is one grain of pollen for each developing seed in the fruit. Once pollen is on the stigma, fertilization is still not guaranteed. The pollen must germinate and grow a pollen tube down the stigma to deliver sperm to the ovule. If there is not enough pollen or conditions are not suitable for pollen tube growth, only the ovules closest to the blossom may be successfully fertilized. Seeds developing close to the blossom end stimulate growth in that part of the fruit, but the rest of the fruit remains small. The result is a misshapen fruit. In the case of triploid watermelon, pollination with viable pollen is necessary to stimulate fruit growth even though seeds do not develop. Triploid plants do not produce enough viable pollen themselves, so a pollenizer variety must be planted nearby. Traditionally, seeded varieties that produce fruit visually different from fruit of the seedless variety are used as pollenizers. More recently, some varieties have been developed that are marketed solely as pollenizers; they do not produce marketable fruit. For successful fruit set in triploid watermelons, it is critical that pollenizer varieties produce viable pollen at the time female flowers are open on the triploid plant. Some gynoecious cucumbers are parthenocarpic (able to set fruit without fertilization of ovules) and so do not require pollinators. Natural parthenocarpy is known to occur in other cucurbits as well, notably summer squash, but is generally not relied upon for commercial production (Wien, 1997). Environmental conditions and the condition of the plant can interfere with pollination and fruit set. Weather conditions influence pollinator activity. For example, honeybees are less active when it is hot and dry. Pesticide applications or

residues can kill or deter bees. Fruit already developing on the plant hinder successful fruit set in younger flowers, especially those on the same branch or stem.

Fruit development: Cucurbit fruit grows exponentially for a period after fruit set and then the growth rate slows. The increase in fruit size after pollination is largely a result of cell expansion rather than an increase in the number of cells. Cucurbits can be divided into two major groups based on whether the fruit are harvested when immature—summer squash and cucumbers—or mature—all types of melons, winter squash, pumpkins, gourds. Cucumbers and summer squash are harvested during the period of rapid growth. They may be ready for harvest as early as 3 days after pollination, depending on the market requirements. In the other crops, fruits typically reach their full size about 2–3 weeks after pollination and take another 3 or more weeks to mature to a harvestable stage. During this time, seeds develop to maturity and sweetness, flavor, and color develop in the fruit. The rind toughens, becomes less permeable to water, and in the case of muskmelon, develops corky netting. A color change may occur, either subtle, as in the change from pale green to yellowish in muskmelon; or just on the portion of the fruit near the ground, as in a yellow ground spot of a watermelon; or across the entire fruit surface, as in pumpkin. Watermelons and muskmelons typically mature 42–46 days after pollination, while winter squash and pumpkins take 50–90 days to reach harvest maturity. Developing fruit places heavy demands on the plant, reducing the growth of new leaves, roots, and any other fruit developing at the same time (Loy, 2004; Wien, 1997). Indicators of harvest maturity vary depending on the crop. Cucumbers and summer squash are usually harvested based on size. Muskmelons form an abscission layer between the peduncle and fruit, so they "slip" from the vine when fully ripe; commercial harvest occurs after the layer begins to form but before the melon falls off the vine. Watermelon harvest maturity is identified by yellowing of the ground spot and wilting of tendrils near the place of fruit attachment. Sugar levels do not increase in muskmelon or watermelon after harvest (Wien, 1997). In winter squash and pumpkin, hardening of the rind and change in rind color at the ground spot or over the entire rind indicate the earliest readiness for harvest. At this stage, seed development may not be complete, and leaving the fruit on the vine for another 10–20 days may improve postharvest quality (Loy, 2004). The size of the mature fruit is influenced by genetics, the environment, and plant conditions during development of the pistillate flower and fruit. Conditions that reduce the amount of assimilate available tend to decrease the size of individual fruit. Increased plant density, greater numbers of fruit per plant, and reduced water supply tend to decrease fruit size. In muskmelon and watermelon, the soluble solids content of the fruit is an important measure of quality. Like fruit size, soluble solids tend to be lower under conditions that reduce assimilate level. High night temperatures, reduced leaf area, increased numbers of fruit per plant, and increased plant density can all reduce soluble solids (Wien, 1997). In contrast to its affect on fruit size, reduced water supply can increase fruit-soluble solids (Bhalla, 1971) (Table 1.3).

1.10 HARVESTING AND POSTHARVESTING

Ash gourd: Ash gourds are mature when the stems connecting the fruit to the vine begin to shrivel. Cut fruits from the vines carefully using pruning shears or a sharp knife leaving 34 in. of stem attached. Snapping the stems from the vines results in many broken or missing "handles." The fruits can be harvested at different stages depending on the purpose for which it will be used. Normally, green fruits are ready for harvest within 45–60 days; matured ones coated with powdery substance are harvested between 80 and 90 days after sowing. The fruit yield can vary depending on variety and crop management. Average marketable yields are 20–25 t/ha. The harvested fruits can be stored for several weeks in ambient conditions. It can be kept for 23 months in temperatures from 10°C to 12°C and 50–75% relative humidity. Avoid cutting and bruising the ash gourds when handling them.

Watermelon: Watermelons do not slip from the vine or emit an odor when ripening, unlike muskmelons. Indicators for picking watermelons include color change (the most reliable), blossom-end conditions, rind roughness, and drying of the nearest tendril to the fruit (less reliable). A sharp

TABLE 1.3
Scientific Names and Typical Sex Expression of Common Cucurbit Vegetables

Crop	Scientific Name	Sex Expression
Cucumber	*Cucumis sativus*	Monoecious[a], gynoecious, hermaphroditic, andromonoecious
Muskmelon	*Cucumis melo*	Andromonoecious[a], monoecious
Pumpkin (most jack-o-lantern and fresh market types)	*Cucurbita pepo*	Monoecious
Pumpkin (processing)	*Cucurbita moschata* or *Cucurbita maxima*	Monoecious
Squash, summer	*Cucurbita pepo*	Monoecious
Squash, winter		
Acorn, sweet dumpling	*Cucurbita pepo*	Monoecious
Buttercup, Kabocha	*Cucurbita maxima*	Monoecious
Butternut	*Cucurbita moschata*	Monoecious
Watermelon	*Citrullus lanatus*	Monoecious[a], andromonoecious

Source: Loy, J.B., *Crit. Rev. Plant Sci*., 23(4), 337, 2004; Wien, H.C., The cucurbits: Cucumber, melon, squash and pumpkin, in: *The Physiology of Vegetable Crops*, Wien, H.C. (ed.), CAB International, New York, 1997, pp. 345–386.

[a] Most common.

knife should be used to cut melons from the vines; melons pulled from the vine may crack open. Harvested fruit is windrowed to nearby roadways, often located 10 beds apart. A pitching crew follows the cutters and pitches the melons from hand to hand, then loads them in trucks to be transported to a shed. Melons should never be stacked on the blossom end as excessive breakage may occur. Loss of foliage covering the melons can increase sunburn. Exposed melons should be covered with vines, straw, or excelsior as they start to mature to prevent sunburn. Each time the field is harvested, the exposed melons must be re-covered. Most fields are picked at least twice. Some fields may be harvested a third or fourth time depending upon field condition and market prices.

1.10.1 Harvest Indexes Could Be Used

- Tapping—A dull or hollow sound is an indication of maturity.
- Color—The fruit part resting on the ground becomes a distinct yellow patch as in sugar baby.
- Tendril right behind each fruit is dried down up to the base.

1.10.2 Sorting and Grading

Seeded melons are sorted and packed in large, sturdy, "tri-wall" fiberboard containers. The melons are sorted according to grade: number 1, 6.4–11.8 kg, and number 2, 3.6–6.4 kg. Inferior melons may be sold at nearby markets; rejects (discolored, misshapen, sugar-cracked, blossom-end rot, and insect-damaged fruit) are discarded. Containers that hold 60–80 melons and weigh 500–545 kg are shipped on flatbed trucks to terminal markets or wholesale receivers. The containers are covered to prevent sunburn in transit. Seedless melons are sorted according to size and packed in cartons containing 3, 4, 5, 6, or 8 fruits. "Fours" and "fives" are preferred to sizes; "sixes" and "eights" are common later in the season after the crown-set melons have been removed from the vine. The rough gross weight of a carton is 18–23 kg. Seedless melons may also be sold in large, bulk containers. Personal, seedless watermelons are sorted by size and packed in single layer boxes containing 6, 8, 9, or 11 fruits. Shipping boxes roughly weigh 15 kg and are arranged 50 boxes/pallet.

1.10.3 Packaging

The seeded melons are sorted and packed in large, sturdy, "tri-wall" fiberboard containers. The melons are sorted according to grade and number. Bins hold 60–80 melons and will weigh 500–550 kg. Two-third bins hold about 360 kg of melons. Discolored, misshapen, sugar-cracked, blossom-end rot, and insect-damaged fruits are regarded as culls but still may be sold to nearby markets.

The containers are loaded on flatbed, 18-wheel trucks destined for terminal market resale. The tops of the containers should be covered to prevent sunburn in transit. Watermelon sales usually are based upon a 1%–2% shrink because of breakage. The buyer is responsible for supplying bins and lids or the shipper will send a bill for the cost of these items. Seedless watermelons are sorted according to size and packed in cartons containing 4, 5, 6, or 8 fruits. "Fours" and "fives" are preferred sizes. "Sixes" and "eights" are common later in the season after the crown-set melons are removed from the vine. The rough weight of a carton is 18–23 kg. Some bins and cartons have high-resolution graphics for logos that may increase overall cost.

1.10.4 Storage

Watermelons are not adapted to long-term storage. Normally, the upper limit of suitable storage is about 3 weeks. However, this will vary from variety to variety. Storage for more than 2 weeks triggers a loss in flesh crispness. Storing melons for several weeks at room temperature will result in poor flavor. However, when a fruit is held just a few days at warmer temperatures, the flesh color tends to intensify. Sugar content does not change after harvest. Watermelons' flesh tends to lose its red color if held too long at temperatures below 10°C.

Watermelons may lose crispness and color in prolonged storage. They should be held at 10°C–15°C and 90% relative humidity. Sugar content does not change after harvest, but flavor may be improved because of a drop in acidity of slightly immature melons. Chilling damage will occur after several days below 5°C. The resulting pits in the rind will be invaded by decay-causing organisms.

1.10.5 Market Preparation

Watermelon: Watermelons usually are sold by the hundred weight at harvest time. The bulk of the commercial crop is shipped out. Many are sold from smaller plantings through temporary or permanent roadside stands or at farmers' markets. Some growers sell their fields to shippers or brokers as harvest time approaches. An important consideration in successful marketing is to have adequate facilities for transporting the crop to market outlets. Although earliness usually results in higher prices, quality and maturity should be of prime importance in marketing watermelons.

Pumpkin: Pumpkins are manually harvested when they have reached maturity. Pumpkins should be picked only when the fruit surface is completely dry. The fruit should be carefully clipped off the vine, leaving about a 2.5 cm (1 in.) stem attached to the fruit. A pair of sharp pruning shears is needed to sever the stem and create an attractive, smooth, clean cut. Do not pick up the pumpkin by the stem as it may separate from the fruit and provide an easy access for decay organisms. A short length of stem should always remain attached to the fruit. Once removed from the vine, the pumpkins should be put in wooden or strong plastic field crates for transport to the collection site or packinghouse. Outgrading is required in the field to remove pumpkins affected by disease, insects, or physical damage. During harvesting, handling, and field transport, every effort should be made to avoid bruising or puncturing the rind. Also, harvested pumpkins should not be exposed to direct sunlight or rainfall. Ideally, pumpkins should not be stacked on top of each other. Stacking is a sure way to create bruises. Padding material, such as grain straw, should be used liberally if fruits have to be stacked during harvest. Spread out a layer of dry straw on the ground and set the pumpkins on this. Keep the fruit dry at all times and never store pumpkins on moist bare ground. If the pumpkins must be stacked for transport, the pile should not be more than 1 m (3 ft) deep.

1.10.6 Sorting/Grading

Pumpkin fruit are quite variable in size, shape, and color; therefore, it is difficult to obtain consistent uniformity of product from a single harvest. However, grading for uniformity of appearance is important to meet market requirements. There are three established size categories (small, medium, and large) for domestic marketing of pumpkins, based on fruit weight. Small-sized pumpkins weigh between 1.4 and 3.2 kg (3 and 7 lb), medium-sized pumpkins weigh between 3.3 and 5.5 kg (7 and 12 lb), and large-sized pumpkins weigh 5.6 kg (12 lb) or more. Export markets accept a range in fruit size, although large-sized fruits weighing between 5.6 and 8 kg (12 and 18 lb) are preferred. Fruit shape may vary from round, to oval, to slightly flat. Similarly, rind color ranges from green, to blue-green, to tan. The striping pattern or mottling of the rind also varies, although the striations are typically white or cream colored. The rind may be smooth or sutured. Domestic consumers and importers prefer uniformly regular-shaped fruits that have a smooth, tough rind.

All fruit should be examined for external maturity characteristics, and only mature pumpkins should be packed. The fruit should be free of noticeable skin blemishes. The rind should not be discolored or have any surface mould growth. Fruit should be free of insect or mechanical damage, and any partially decayed fruit should be discarded. The fruit must have a closed blossom end and be free of cracking in order to avoid serious decay problems. The flesh should be thick and dark orange, since many pumpkins are sold as cut fruit in the market. Randomly selected fruit should occasionally be cut open for assessment of internal color.

1.10.7 Packing

Packages used to market pumpkins vary depending on market destination. Fruit sold in the domestic market and nearby Caribbean export destinations is usually packed in mesh sacks. The sacks typically contain from three to seven fruits and weigh around 23 kg (50 lb). However, mesh sacks provide little or no protection against bruising and physical injury. Variability in fruit size will also cause bulging problems of the mesh sack. Smaller sized pumpkins intended for more distant export markets should be packed in strong, well-ventilated fiberboard cartons containing 19 kg (42 lb) of fruit. The cartons should have a minimal bursting strength of 275 psi and internal dividers should be used to separate and protect the fruit. Large wooden bulk bins holding from 360 to 410 kg (800–900 lb) of fruit may be used for marine transport to export market destinations. Pumpkins packed in cartons and transported by marine containers should include an additional 5% weight to account for moisture and respiratory weight loss that will occur during transport.

1.10.8 Temperature Management

Pumpkin: Pumpkins not intended for immediate sale should be held in a cool, dry, well-ventilated area. The optimum temperature for pumpkin storage is 12°C (54°F). Sound fruit can be stored for up to 3 months at this temperature without a significant loss in quality. Storage at ambient temperature will result in excessive weight loss, loss of surface color intensity, and a decline in culinary quality. Green-skinned cultivars will gradually turn yellow at high temperature, and the flesh will become dry and stringy. The storage life of pumpkins at ambient temperatures is limited to several weeks. On the other hand, the fruit should not be stored at cold temperatures. Pumpkins are susceptible to chilling injury (CI) and should never be stored below 10°C (50°F).

Bitter gourd: Harvesting starts 55–60 days after sowing. Picking is done when fruits are fully grown but still young and tender. Seeds should not be hard at the time of harvest. From a good crop, 15–20 harvests are possible, and harvesting is done twice a week. If fruits are allowed to ripen on vines, further bearing is adversely affected. Fruits after harvest are packed in thin gunny bags or directly packed in trucks and marketed. Since keeping quality of fruits is less, fruits should be

marketed without any delay to nearby markets on the same day itself. Otherwise, tubercles will be dropped and freshness and appearance of fruits will be adversely affected.

Snake gourd: To obtain straight fruits in long and slender-fruited varieties, there is a practice of hanging a weight from the bottom of developing fruits. Fully mature fruits will be fibrous and hard. Hence, fruits are harvested at tender stage. Usually, harvesting is twice a week, and it continues for 2 months. The productivity of snake gourd is more than that of bitter gourd, and it varies with soil and season. The average yield in a well-managed field will be about 30–35 t/ha in Kerala. Fruits, immediately after harvest, are tied into bundles of 15–20 kg and covered with arecanut sheath and marketed to nearby places. Picking should be done once in 2 days. The fruits are to be handled carefully to avoid damage. The fruits are then graded and packed in bamboo baskets or cartons without causing damage. Covering baskets with moistened jute bags will reduce the rate of physiological activities.

Sponge gourd: The crop is ready for harvest in about 60 days after sowing. Both crops are picked at immature tender stage. Fruits attain marketable maturity 5–7 days after anthesis. Overmature fruits will be fibrous and are unfit for consumption. To avoid overmaturity, picking is done at 3–4 days interval. Harvested fruits are packed in baskets to avoid injury and can be kept for 3–4 days in a cool atmosphere.

Bottle gourd: Fruits are harvested at tender stage when they grow to one-third to half. Fruits attain edible maturity 10–12 days after anthesis and are judged by pressing the fruit skin and noting pubescence persisting on the skin. At edible maturity, seeds are soft. Seeds become hard and the flesh turns coarse and dry during aging. Tender fruits with a cylindrical shape are preferred in market. Harvesting starts 55–60 days after sowing and is done at 3–4 days intervals. While harvesting, care should be taken to avoid injury to vines as well as to fruits. Plucking of individual fruits is done with sharp knives by keeping a small part of fruit stalk along with fruit. Average yield is 20–25 t/ha for open-pollinated varieties and 40–50 t/ha for F_1 hybrids.

Fruits can be stored for 3–5 days under cool and moist condition. For export purpose, fruits are packed in polythene bags, and bags are kept in boxes of 50–100 kg capacity.

Muskmelon: Fruits maturing on the vine, without becoming overripe, are superior in quality to those harvested immature or left on the vine after they have become mature. Harvesting at the proper stage is of major importance in marketing good quality produce. The fruits for distant markets should be harvested as they reach the half-slip maturity to avoid losses from the over-ripeness and decay. For local markets, harvesting should be done at "full-slip" stage. Hara Madhu however, never reaches the full-slip stage and color of the rind can be taken as the criteria of maturity. Flavor and texture of the flesh improve for a few days after harvesting and attain highest quality if the fruits are harvested when they have developed their maximum sugar content. Fruits harvested when immature never attain these desirable, characteristics. The soluble solids are considerably affected by the environment, the incidence of diseases and the vigor of the plant.

Round gourd/Tinda: It takes 60–90 days from sowing to first fruit picking, depending upon the cultivar and season. Fruits reach edible maturity 6–8 days after fruit set. Picking should be done when these are still immature and small in size. Large-sized fruits are not liked in the market even if immature and soft. Therefore, picking should be done at every third to fourth day. The first formed one or two fruits at basal nodes should be harvested/nipped early to allow better vine growth so that the plant can bear more number of fruits later.

A good crop can give 80–120 q/ha green, unripe fruits. Plant growth-promoting chemicals also influence the yield. Maleic Hydrazide (50 ppm) aqueous solution sprayed at 2 and 4 leaf stage stimulates vine growth, giving more femaleness, and enhance female flowering at lower nodes. All these factors improve yield by 50%–60%.

Keeping the fruits in a cool environment or under the shade with frequent watering of covering/packing material without causing bruises to their surface could help in storing fruits for 3–4 days.

All deformed and damaged fruits should be sorted out and rejected. Healthy fruits should be graded according to their size. Graded fruits fetch a higher price. The produce is then packed in baskets with some filler, preferable leaves with soft texture and low moisture content. For distant markets, even perforated cardboard boxes with fillers are used. For local market, jumble packing in baskets or gunny bags is done, and water is frequently sprinkled to keep the packing cover wet and cool. Since fruits respire and liberate heat, there should be enough aeration between the fruits and the warm air should go out, otherwise the fruits turn pale and become unmarketable. For transporting, a rack system should be preferred rather than dumping in a truck or heaping in the carriage. Due to high water content, the fruits are likely to get spoiled early, therefore, fast transportation and quick disposal/consumption should be kept in mind.

Cucumber: Fruits of cucumber attain edible maturity within a week from anthesis of female flowers, though variation for edible maturity exists among its varieties. Picking of fruits at the right edible stage depends upon individual varieties and marketing requirement. In salad or slicing cucumber, dark green skin color should not turn brownish-yellow or russet. White spine color is also a useful indication for their edible maturity. Further, overmature fruits show carpel separation in transverse section of the fruits. For commercial purposes, cucumbers are harvested at immature condition 5–7 days after pollination, depending upon the cultivar. If cucumber vines are trained vertically, their fruits reach harvestable size a day or two early. The cucumber should be picked at 2 days intervals. However, their seeds mature 25–30 days after pollination. For seed purpose, pale-yellow and golden-yellow (mature fruit color) cucumbers should be harvested in white and black spine varieties respectively. Its yield varies according to the system of cultivation, cultivar, season, and other factors. Generally, cucumber yields are about 80–120 q/ha.

Cucumber is packed in baskets and transported to markets. The river-bed farmers sell their produce to transport contractors and mandi agents who advance funds to them for cultivation.

Gherkin: The crop is ready for harvest in 30–35 days. As the tender immature fruits are meant for canning, the price of the produce is decided by the stage of maturity. The smallest fruit (stage 1), which will weigh approximately 4.0 g (250 fruits/kg), will fetch the maximum price followed by stage 2 and stage 3. To maintain the grade, the harvesting of fruits should be done every day; a day's break would result in outsized or overgrown gherkin, therefore a loss to the farmer. Avoid sharp sun and high temperature while harvesting. For this, picking of fruits must be done in the very early morning or late evening. Harvest the fruits by retaining the stalk on the plant. Harvested fruits must be collected under the shade. The flower head has to be removed from the fruit. Water should not be sprinkled on harvested fruits at any stage. Even if there is surface water during harvest, it should be dried by aeration. For collection of fruits, jute bags alone have to be used and plastic bags should be totally avoided. The harvested produce should be transported to the factory on the same day before dusk. Leaving the gherkin unprocessed overnight would result in poor quality produce.

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2 Cucurbits

Importance, Botany, Uses, Cultivation, Nutrition, Genetic Resources, Diseases, and Pests

David O. Ojo

CONTENTS

2.1 *CUCUMEROPSIS MANNII* NAUDIN

2.1.1 Introduction

Synonym is *Cucumeropsis edulis* (Hook.f.) Cogn. (1881). Common names are Egusi-itoo (Yoruba), white seed melon, dark egusi (English). Egousi-itoo, égousi, gousi (French). Lipupu (Portuguese) (Schaefer and Renner 2011; Achigan-Dako et al. 2015).

Egusi-itoo occurs wild from Guinea Bissau, east to southern Sudan and Uganda, and south to Angola. It is mostly cultivated in West Africa, especially in Nigeria, but occasionally also elsewhere, for example, in Côte d'Ivoire, Cameroon, and the Central African Republic. Egusi-itoo was very important as a seed vegetable in West Africa and parts of Central Africa at a time when there was plenty of forest to practice shifting cultivation. Now, it is rapidly declining and is replaced by egusi melon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) (Schaefer and Renner 2011; Achigan-Dako et al. 2015).

2.1.2 Uses

Egusi-itoo is mainly grown for its oily seed. The seeds are prepared for consumption by parching and pounding to free the kernels of the seed coat (Sarwar et al. 2013). The kernels are milled into a whitish paste, which is used in soups and stews. The seeds (including seed coat) are also roasted and served as a snack. They resemble groundnut in flavor (Ogunbusola et al. 2012; Onawola et al. 2012).

An expensive semi-drying oil is extracted from the kernel, and the residue is fed to animals or used in the preparation of local snacks. The oil is suitable for cooking, soap making, and, less commonly, illumination. It can readily be refined into superior products for table use. It is of better quality and higher value than cottonseed oil. The flesh of the fruit, though edible, is not commonly eaten (Kapseu and Parmentier 1997; Kamda et al. 2015). In Ghana, the fruit juice mixed with other ingredients is applied to the navel of newborn babies to accelerate the healing process until the cord-relics drop off. Macerated leaves are used in Gabon for purging constipated suckling babies. In Sierra Leone, cattle boys traditionally use the dried fruit-shell of an egusi-itoo type with small elongated fruits as a warning horn (Burkill 1985; Ajuru and Okoli 2013; Kamda et al. 2014).

2.1.3 Production and Trade

Egusi-itoo is regarded as the original indigenous egusi melon in West and Central Africa, and the seed can be found in most markets in the region. In Nigeria, the demand for the seeds, particularly in the towns, led to large-scale planting. Although its production is declining, egusi-itoo still is a common commodity in the markets. The trade is mostly local. Export occurs from Côte d'lvoire to Nigeria, but the quantities involved are not reported.

2.1.4 Nutritional Properties

The nutritional composition of egusi-itoo seed per 100 g is water 8.3 g, energy 2282 kJ (545 kcal), protein 26.2 g, fat 47.3 g, carbohydrate 14.2 g, fiber 4.0 g, and Ca 86 mg. The seeds are rich in niacin (14.3 mg/100 g). The oil content of the kernel is 44% by weight. A sample of egusi-itoo seed oil from Côte d'lvoire consisted of linoleic acid 64.9%, oleic acid 12.4%, stearic acid 11.8%, and palmitic acid 10.9% (Anhwange et al. 2010; John et al. 2014; Kwiri et al. 2014). Egusi-itoo is replaced in many regions by egusi melon (*Citrullus lanatus*) (Burkill 1985).

2.1.5 Botanical Description

It is a monoecious, scandent herb 5–10 m long, climbing by simple tendrils; stem is angular, sparsely hairy. Leaves alternate, simple; stipules absent; petiole 2–15 cm long, initially hairy but glabrescent; blade broadly ovate in outline, 6–21 cm × 7–21 cm, deeply cordate at base, pentagonal to

palmately 3–5-lobed with triangular to ovate lobes, margin sinuate-toothed, sparsely hairy on the veins, scabrid-punctate, palmately veined. Flowers unisexual, regular, five-merous, yellow; calyx campanulate, lobes up to 6 mm × 1.5 mm; corolla with lobes shortly united at base; male flowers in an axillary raceme, often umbel-like, pedicel up to 2 cm long, corolla lobes up to 7 mm × 5 mm, with three free stamens almost lacking filaments; female flowers solitary in leaf axils, pedicel up to 5 cm long, corolla lobes up to 11 mm × 6 mm, with inferior, fusiform, one-celled ovary, style columnar, stigmas three, two-lobed. Fruit, an ellipsoid to obovoid berry 17–25 cm × 8–18 cm, green to pale yellow or creamy white, mottled, glossy, flesh white, many-seeded. Seeds obovate, flattened, 1–2 cm × 0.5–1 cm, smooth, white. Seedling with epigeal germination; cotyledons leafy, elliptical. *Cucumeropsis* comprises a single species. It belongs to the tribe *Melothrieae*, together with *Cucumis* (Schaefer and Renner 2011).

2.1.6 Growth and Development

In West Africa, egusi-itoo is usually planted March–May at the start of the rainy season and harvested 6–8 months later (September–December). The crop requires support and is commonly found at the edge of gardens, climbing into shrubs or trees. When grown in shifting cultivation, debris left after burning serves as support. Egusi-itoo does not do well in the open or on flat land.

2.1.7 Ecology

Egusi-itoo grows in forest, often at the margin or in openings, but also in swamp forest, more humid savanna, and abandoned fields, up to 1150 m altitude.

2.1.8 Cultivation and Management

Egusi-itoo is still mainly collected from wild stands, which are often retained when clearing fields. In cultivation, it requires a soil rich in manure or partially decomposed organic matter. Application of N and K fertilizer can increase yields considerably, but P fertilizer has shown little effect.

At the beginning of the rainy season, three to four seeds per hole are sown. The 1000-seed weight is 150–250 g. Seedlings usually appear within 6–8 days. Egusi-itoo is often grown between other crops, growing on stakes along with yam, or supported by a strong trellis of at least 1 m tall.

2.1.9 Diseases and Pests

In Nigeria, a severe damping-off disease caused by *Macrophomina phaseolina* has been reported. The fruits are sometimes attacked by the fruit fly *Dacus punctifrons*. The larvae develop in the fruit and eventually cause rot. Fruit flies attack fruits at every stage of development and can severely affect production. The pupae are found in the soil, and it is therefore advised not to plant in the same field the following year. The aphid-like flea hopper *Halticus tibialis* may suck sap from the leaves; young leaves become wrinkled, older ones become swollen around the sucking holes and later die. Several other pests that attack cucurbits are also found on egusi-itoo.

Seeds of egusi-itoo stored in open jars may be seriously damaged by beetles within a few weeks of storage; these have been identified as *Triboleum castaneum* and *Lasioderma serricorne*, and are also found in dried okra (*Abelmoschus* spp.) and roselle (*Hibiscus sabdariffa* L.) fruits (Adekunle and Uma 2012).

2.1.10 Harvesting and Yield

Fruits are collected when the stems have dried and fruits have changed color from green to creamy white or yellow.

Under extensive management, where egusi-itoo is planted around the remaining trunks of trees, seed yield is about 300 kg/ha. In more intensive cropping systems, where land has been cleared and burnt before cultivation, it may reach 900 kg/ha. A plant usually produces two to five fruits; each fruit weighs 0.8–1.8 kg and contains 90–400 seeds (up to 100 g) (Nantoume et al. 2012; Yao et al. 2014).

2.1.11 Postharvest Handling

After collection, fruits are cracked or split open; they are then placed in a heap or pit and are left for 14–20 days to let the fruit pulp rot. During this period, a strong pungent smell is produced, and this explains why seed extraction takes place at a distance from the homestead. Then, the seeds are removed and thoroughly washed to remove thick mucilage covering them; next, they are covered with sand or ash to prevent sticking, which would make hulling difficult. The seeds are dried to about 10% moisture content before packing. Packaging must be thorough and packs must be stored away from moisture, as seeds otherwise may germinate. Hulling is facilitated by heating to 60°C. The weight of the decorticated seed is about 60% of the whole dry seed. The kernels are milled and used as a vegetable or for producing vegetable oil for domestic use. Processing the seed of egusi-itoo is time-consuming and labor intensive; this is one of the reasons why it has been partly replaced by egusi melon (Olanrewaju and Moriyike 2013; Touré et al. 2015).

2.1.12 Genetic Resources

Germplasm of several *Cucurbitaceae* species used as seed vegetable, including *C. mannii*, is being maintained at the genebank of the National Centre for Genetic Resources and Biodiversity (NACGRAB), Ibadan, Nigeria (Ladipo et al. 1999).

2.1.13 Prospects

Unless the seed yield of egusi-itoo can be increased and its crop management and seed processing can be simplified, it seems likely that its replacement by cultivars of egusi melon will continue, although specialty markets may develop (Pius et al. 2014; Touré et al. 2015).

2.2 *Cucumis acutangulus* L. (1753)/*Luffa acutangula* (L.) Roxb.

2.2.1 Introduction

Synonym is *Cucumis acutangulus* L. (1753). Common names are ridged gourd, angled loofah, ribbed gourd, Chinese okra, silk squash (En). Papengaye, liane torchon (Fr). *Lufa riscada* (Po). Mdodoki (Sw).

C. acutangulus is believed to have originated in India, where wild types still occur, but has now spread pantropically to all areas with a high rainfall. It is cultivated and locally naturalized in West Africa, from Sierra Leone to Nigeria. It is cultivated from the coastal areas to the semi-dry savanna, for example, in Sierra Leone, Côte d'Ivoire, Ghana, Benin, and Nigeria. In East Africa, ridged gourd is grown on a small scale near the big cities as an exotic vegetable for consumers of Asian origin, and it is also locally cultivated and naturalized in Madagascar, Réunion, and Mauritius. In southern and eastern Asia, it is a widely cultivated vegetable (Robinson and Decker-Walters 1997).

2.2.2 Uses

Immature fruits of less-bitter cultivars of *Luffa acutangula* are used as a vegetable. They are cooked or fried and used in soups and sauces. Occasionally, the stem tops with young leaves and flower buds are used as a leafy vegetable. In Southeast Asia, ridged gourd is a popular vegetable because of the

mildly bitter flavor, the slightly spongy texture, and sweet juiciness. Young fruits of sweet cultivars are also eaten raw and small fruits are sometimes pickled. The seeds yield an edible oil that is, however, sometimes bitter and toxic (Burkill 1985; Lim 2012a,b).

In some parts of West Africa, a leaf extract of ridged gourd is applied on sores caused by guinea worms to kill the parasite. Leaf sap is also used as an eyewash to cure conjunctivitis. The fruits and seeds are used in herbal preparations for the treatment of venereal diseases, particularly gonorrhoea. In Mauritius, the seeds are eaten to expel intestinal worms and the leaf juice is applied to skin affections such as eczema. The plant including the seed is insecticidal. Mature fruits, when harvested dry, are processed into sponges and used for scrubbing the body while bathing or for domestic purposes, such as washing of cooking utensils, and as filters for local drinks such as palm wine. Industrial use is made of these fibers for making hats. However, the sponge gourd (*Luffa cylindrica* (L.) M. Roem., synonym: *Luffa aegyptiaca* Mill.) is preferred for making sponges because its fiber is easier to extract (Adebisi and Ladipo 2000). The trailing stem is used as temporary tying rope for firewood and crops to be carried home. The plant is occasionally used as an ornamental climber for enclosures.

2.2.3 Production and Trade

Ridged gourd is mainly produced as a home garden crop. Thailand exports ridged gourd to western Europe as a vegetable for the Asian communities. Japan and Brazil are the main exporters of loofah sponges, mostly to the United States, but these are mainly from sponge gourd. In West Africa, mature fruits of ridged gourd or sponge gourd are sold as sponges in street markets and supermarkets (Huyskens et al. 1993).

2.2.4 Nutritional Properties

The composition of ridged gourd fruits per 100 g edible portion (tough skin removed, edible portion 62%) is water 94.2 g, energy 70 kJ (17 kcal), protein 0.8 g, fat 0.1 g, carbohydrate 3.3 g, fiber 1.7 g, Ca 12 mg, P 32 mg, Fe 0.3 mg, carotene 26 μg, thiamin 0.07 mg, riboflavin 0.02 mg, niacin 0.4 mg, folate 37 μg, and ascorbic acid 3 mg. The composition of young *Luffa* leaves per 100 g edible portion is water 89 g, protein 5.1 g, carbohydrate 4 g, fiber 1.5 g, Ca 56 mg, Fe 11.5 mg, β-carotene 9.2 mg, and ascorbic acid 95 mg (Holland et al. 1991). The oil content in the seeds is 26%; the fatty acid composition is linoleic acid 34%, oleic acid 24%, palmitic acid 23%, and stearic acid 10% (Uriostegui Arias 2015).

Two trypsin inhibitors and a ribosome-inactivating peptide (luffangulin) have been isolated from ridged gourd seeds. The glycoprotein luffaculin, also isolated from the seeds, exhibits abortifacient, antitumor, ribosome-inactivating and immunomodulatory activities (Fernando and Grün 2001).

Young fruits of sponge gourd (*L. cylindrica*) are used as a substitute for ridged gourd as a vegetable, although much less popular.

2.2.5 Botanical Description

Monoecious, annual, climbing, or trailing herb, with acutely five-angled stem; tendrils up to six-fid, hairy. Leaves alternate, simple; stipules absent; petiole up to 15 cm long; blade broadly ovate to kidney-shaped in outline, 10–25 cm × 10–25 cm, shallowly palmately five to seven-lobed with broadly triangular to broadly rounded lobes, cordate at base, shallowly sinuate-dentate, pale green, scabrous, palmately veined. Male inflorescence racemose with 15–35 cm long peduncle. Flowers unisexual, regular, five-merous, 5–9 cm in diameter; receptacle tube obconic below, expanded above, c. 0.5 cm long, lobes triangular, 1–1.5 cm long; petals free, pale yellow; male flowers with three free stamens inserted on the receptacle tube, connectives broad; female flowers solitary, on pedicels 2–15 cm long, with inferior, densely pubescent, longitudinally ridged ovary, stigma three-lobed.

Fruit a club-shaped, dry and fibrous capsule 15–50 cm × 5–10 cm, acutely 10-ribbed, brownish, dehiscent by an apical operculum, many-seeded. Seeds broadly elliptical in outline, compressed, up to 1.5 cm long, smooth, dull black (Renner and Pandey 2013).

Luffa comprises seven species, four of these native to the Old World tropics and three somewhat more distantly related species indigenous to South America (Heiser and Schilling 1990). In *L. acutangula*, three varieties have been distinguished: var. *acutangula*, the large-fruited cultivated types; var. *amara* (Roxb.) C.B.Clarke, a wild or feral type with extremely bitter fruits and confined to India; and var. *forskalii* (Harms) Heiser & E.E.Schill., confined to Yemen, where it occurs wild or possibly as an escape. *L. acutangula* cultivars grown as vegetables have larger fruits and are less bitter than the wild types. In West Africa, local cultivars are used as vegetables, whereas in East Africa commercial growers use improved cultivars imported from Asian countries for the Asian customers (Robinson and Decker-Walters 1997).

2.2.6 Growth and Development

Spontaneous growth of plants commences with the beginning of the rainy season. Flowering and fruiting take place throughout the rainy season, while fruits mature and seed dispersal commences as the whole plants become dry at the peak of the dry season. In cultivation, seedlings emerge 4–7 days after sowing after soaking the seeds in cold water overnight to soften the hard seed coat. Ridged gourd tends to be day-neutral. Flowering starts 6–10 weeks after sowing. Initially male flowers are produced, later female ones at a ratio of male to female flowers of about 40:1. This ratio can be changed by chemical treatment. The flowers open in the evening and the stigmas have been found to remain receptive from a few hours before to 36–60 h after anthesis. The flowers are cross-pollinated by many insects, including bees, butterflies, and moths (Robinson and Decker-Walters 1997).

2.2.7 Ecology

Ridged gourd may be common as a spontaneous plant on abandoned land and as a fallow crop on garbage heaps. Unlike many other cucurbits, it grows well in tropical lowlands. It prefers seasonal climates because dry-season planting is more successful than wet-season planting. In Africa, it thrives in the dry forest or moist savanna area, around 8°N–10°N. Outside these latitudes, too much rain or excessive dryness often affect the development of the fruits. In humid areas, growth is directed toward the production of leaf biomass, whereas under dry conditions the energy is directed toward abundant flowering. Too much heavy rainfall during flowering and fruiting leads to fruit rot. Frost is not tolerated. Ridged gourd prefers a well-drained soil with a high organic matter content and a pH of 6.5–7.5 (Heiser and Schilling 1990; Robinson and Decker-Walters 1997).

2.2.8 Cultivation Management

In commercial cultivation, the crop needs good care. Planting on raised beds assures good drainage in the rainy season. Irrigation is required during dry conditions at regular intervals, particularly before the flowering period. NPK fertilizer is applied to enhance growth, flowering and fruit formation. A basal dressing of NPK (e.g., 14–14–14) at the rate of 25 g/hill can be given, followed by side dressings of 20 g/hill of urea or NPK at 2-week intervals. Lateral stems are pruned if they grow too abundantly. Some top and leaf pruning may promote flower and fruit development, resulting in a higher yield. For optimal production, the number of fruits per stem may be limited to 20–25. For the spontaneous plants of abandoned farmland or on refuse dumps, hardly any management care is given.

Ridged gourd is normally grown on supports or trellises up to 3 m high. During the dry season, it may also be allowed to trail on the ground, but this practice lowers the yield and quality. The seeds

are sown on mounds or ridges, two to three seeds per hill, 50–60 cm apart in the row, and 200 cm between the rows in a trellized system. Without support, 300 cm between the rows can be practiced, or about one hole per m each way. Alternatively, seedlings may be raised in containers and transplanted. The 1000-seed weight is around 90 g. For direct sowing, 2–3 kg seed is needed per ha for transplanting 1–1.5 kg. In the Philippines, a planting distance of 2 m × 2 m is practiced for a superior F_1 hybrid, with a seed requirement of only 500 g/ha (Huyskens et al. 1993).

2.2.9 Diseases and Pests

Ridged gourd is not very susceptible to diseases and pests. Powdery mildew (*Erysiphe cichoracearum*) and downy mildew (*Pseudoperonospora cubensis*) are reported. Fruits rot easily in contact with wet soil. In Southeast Asia, the larvae of fruit flies (*Dacus* spp.) may damage young fruits; a high infection of thrips may cause stunted growth, and also caterpillars, leaf miners, and aphids are reported as pests.

2.2.10 Harvesting and Yield

Young immature fruits of 300–400 g are picked 12–15 days after fruit set. Fruits can be picked every 3 days throughout the fruiting season, by hand or with a knife. Individual plants may produce 15–20 fruits; yield declines after 8–13 weeks of harvesting. For sponge production, the fruits are left for 2 months on the vines till they turn brown. For seed production, the seeds are shaken out of the completely dry fruits.

Landraces produce 10–15 t/ha. An average yield of 27 t/ha of young fruits is reported for hybrid cultivars in the Philippines under good management.

2.2.11 Postharvest Handling

Immature fruits of ridged gourd are easily damaged. For long-distance transport, the fruits have to be carefully packed. The fruits can be stored for 2–3 weeks at 12°C–16°C. The processing of sponges from the ripe fruits involves immersing the fruit in running water until the rind disintegrates and disappears, then the pulp and seeds are washed out, and the sponges are bleached with hydrogen peroxide and dried in the sun.

2.2.12 Genetic Resources and Breeding

Germplasm collections of *L. acutangula* are kept at genebanks in India and Taiwan, at the Institute for Plant Breeding in the Philippines, and in Nigeria at the National Centre for Genetic Resources and Biotechnology (NACGRAB) at Ibadan (Renner and Pandey 2013).

Many local cultivars are found in the Asian countries and improved cultivars are available from several seed companies. Populations are very variable. F_1 hybrid cultivars are used in several Asian countries. East-West Seed Company in Thailand developed F_1 hybrids for tropical lowland with good market quality, for example, pale or dark green fruits, short (35 cm) to long (50 cm) fruits. Malika F_1 is a hybrid with high disease tolerance and especially suited for the rainy season (Talano et al. 2012).

2.2.13 Prospects

Ridged gourd is a high-yielding and easy-to-cultivate vegetable. Breeding and production technology research combined with market development might give it a chance to develop into a market vegetable of importance in Africa, as in Asian countries (Renner and Pandey 2013). The use of fiber from the mature fruits and the use in agroforestry as a plant for soil rehabilitation with a heavy production of leaf biomass might be investigated.

2.3 *CUCUMIS AFRICANUS* (WILD WATERMELON)

2.3.1 Introduction

Cucumis africanus belongs to the family Cucurbitaceae with the chromosome number 2n = 24. Its origin and geographic distribution occurs in Angola, Namibia, Botswana, and South Africa. It is also found in Madagascar, where it was introduced. *C. africanus* leaves are eaten as a cooked vegetable by many tribes in its area of origin. Its nonbitter fruit types serve as a source of water and are eaten as a vegetable (Kull et al. 2015). The leaves contain per 100 g: water 92.2 g, protein 1.3 g, fat 0.3 g, carbohydrate 3.4 g, fiber 1.2 g, Ca 216 mg, Mg 175 mg, P 11 mg, Fe 12 mg, thiamin 0.02 mg, riboflavin 0.11 mg, niacin 0.34 mg, and ascorbic acid 81 mg. The fruits contain per 100 g: water 88.2 g, protein 2.8 g, fat 1.6 g, carbohydrate 3.3 g, fiber 2.9 g, Ca 13 mg, Mg 29 mg, P 20 mg, Fe 1.1 mg, thiamin 0.2 mg, riboflavin 0.03 mg, niacin 0.84 mg, and ascorbic acid 13 mg (Arnold et al. 1985; Nkgapele and Mphosi 2014, 2015; Mphosi 2015).

C. africanus types with nonbitter, large, and oblong fruits occur wild in Angola, Namibia, and South Africa. The smaller, ellipsoid fruit types found in other *C. africanus* are bitter, could be poisonous, and not used for consumption. A third type, intermediate in taste and shape, seems to exist as well but is not well documented. Medically, the fruit of *C. africanus* contains considerable amounts of cucurbitacin A, B, and D and traces of cucurbitacin G and H. Cucurbitacins, which are known from many *Cucurbitaceae* and various other plant species, exhibit cytotoxicity (including antitumor activity), anti-inflammatory and analgesic activities (Jeffrey 1980).

2.3.2 Botanical Description

C. africanus is an annual, monoecious, prostrate or scandent herb, sometimes with woody, thickened roots, stems up to 1 m long; tendrils simple. Leaves alternate, simple; stipules absent; petiole 1–1.5 cm long; blade ovate, deeply palmately (three to five) lobed, 1.6–8.2 cm × 1.8–7 cm, cordate at base, lobes elliptical, and broadly elliptical to ovate-elliptical. Flowers are unisexual, regular, five-merous; receptacle 3–5 mm long; sepals 1.5–3 mm long; petals bright yellow, 5–11 mm long; male flowers one to five together in small fascicles, with pedicel up to 1 cm long, stamens three; female flowers solitary, with pedicel 1–4 cm long, ovary inferior, densely softly spiny. Fruit an ellipsoid to oblong-ellipsoid berry 3–9 cm × 2–4.5 cm, when ripe strongly longitudinally striped pale greenish-white and purplish-brown, with spines 3–6 mm long; fruit stalk 2–4.5 cm long, slender, not expanded upward. Seeds ellipsoid, compressed, 4–7 mm × 2–3.8 mm × 1–1.2 mm (Kirkbride 1993; Regassa et al. 2015).

The genus *Cucumis* includes about 30 species, 4 of which are economically important: cucumber (*Cucumis sativus* L.), melon and snake cucumber (*Cucumis melo* L.), West Indian gherkin (*Cucumis anguria* L.), and horned melon (*Cucumis metuliferus* Naudin) (Pelinganga et al. 2013). *C. africanus* is placed in the "*anguria*" group of the subgenus *melo*. *C. africanus* flowers from January to June and occurs in dry bushland areas close to habitation (Jeffrey 1980; Kull et al. 2015).

2.3.3 Genetic Resources and Breeding

C. africanus is common in its area of origin, thus is not threatened with genetic erosion or extinction. *C. africanus* germplasm is stored in the United States, the United Kingdom, the Czech Republic, and Spain. Within the "*anguria*" group of about 16 spiny-fruited *Cucumis* species to which *C. anguria* belongs as well, there seem to be no major barriers to gene exchange. Several interspecific crosses have been made in this group. An intermediate response to downy mildew (*P. cubensis*) has been reported for *C. africanus*. In southern Africa, *C. africanus* is considered to have potential for domestication. The variation within the species will allow successful breeding and selection. Breeders' interest will focus on disease resistance within the scope of gene transfer to the economically important *Cucumis* species (Schippers 2000; van Wyk and Gericke 2000; Ojo et al. 2013; Kull et al. 2015).

2.4 *CUCUMIS ANGURIA* L. (GHERKIN)

2.4.1 Introduction

Synonym is *Cucumis longipes* Hook.f. (1871). *C. anguria* vernacular names are gooseberry gourd (English), Concombre antillais, ti-concombre, macissis (French), Pepino das Antilhas, cornichão das Antillas, machiche, maxixé (Portuguese).

C. anguria is synonymous to *C. longipes* Hook.f. (1871) of African origin, and it occurs wild in East and southern Africa. It has bitter fruits, but occasionally nonbitter types occur. Seeds were taken to the Americas with the slave trade, where the cultivated West Indian gherkin was developed. This edible, nonbitter type spread through the Caribbean, parts of Latin America, and the southern United States. It can now be found in a semiwild state as an escape from cultivation, and in some cases, it appears to be an element of the indigenous flora. It is an invasive weed in parts of North America and in Australia and a serious weed in peanut fields of the southern United States. The nonbitter edible form was reintroduced into Africa (e.g., Cape Verde, Senegal, Sierra Leone, DR Congo, Réunion, Madagascar, South Africa), where it is grown for its fruits. In Madagascar, *C. anguria* is probably not originally wild but naturalized because it is localized around human habitations.

2.4.2 Uses

The leaves of bitter forms of *C. anguria* are cooked and eaten in the same manner as pumpkin leaves (*Cucurbita* spp.). In Ruwangwe, Zimbabwe, it is known as "mubvororo" and used to prepare a special dish for the father of the household. In Namibia, it is one of a range of edible wild greens, which are dried into cakes and stored for use during the dry season. Elsewhere in Africa, the nonbitter form is cultivated for its fruits. It is recorded near Thiès (Senegal), where the immature fruits are pickled green. In South Africa, the fruits are eaten both fresh and dried.

In the New World, West Indian gherkin refers to the cultivated nonbitter form, a favorite pickle since the seventeenth century and sometimes eaten fresh. Fruits are also relatively common as a table vegetable, and they are used in soups and stews. In Brazil, the mature fruits are cooked as the main ingredient of a traditional soup called "maxixada." Immature fruit are used as fresh cucumbers.

Bitter forms of *C. anguria* are sometimes used in Zimbabwe as a natural pesticide in stored crops. The juice of the fruit is reportedly used as an antifeedant in granaries. In Matabeleland (Zimbabwe), the fruit is used as a lure in rock and stick traps. Medicinal uses are reported from Tanzania where an enema of the wild plant is used to treat stomach pain. In Zimbabwe, traditional medical practitioners consider the bitter fruit as poisonous and the juice of the fruit is used to treat septic wounds in livestock. In America, medicinal uses are varied, including root decoctions as a remedy for stomach trouble in Mexico, and to reduce oedema in Cuba. The fruit is eaten to treat jaundice in Curaçao, and leaf juice preparations are applied to freckles in Cuba. Kidney problems are treated with a decoction in Colombia, where it is believed that the fruits eaten raw dissolve kidney stones. The fruit is applied to hemorrhoids in Cuba, and the leaves after being steeped in vinegar are used against ringworm (Bates et al. 1990).

2.4.3 Production and Trade

C. anguria as a leafy vegetable is collected from the wild or grown on a small scale in southern Africa, but no data on its production or trade are available. The cultivation of *C. anguria* for nonbitter young fruits is also practiced on a small scale only. In the New World, where it is always cultivated for its immature fruits, it is also of minor importance and in statistics is combined with pickling cucumber (*C. sativus* L.) (Baird and Thieret 1988).

2.4.4 Nutritional Properties

The nutrient composition of the fresh fruit of West Indian gherkin per 100 g edible portion is water 93 g, energy 71 kJ (17 kcal), protein 1.4 g, fat 0.1–0.5 g, total sugar 1.9–2.5 g, starch 0.3–0.4 g, Ca 25–27 mg, P 33–34 mg, Fe 0.6 mg, vitamin A 200–325 IU, thiamin 0.05–0.15 mg, riboflavin 0.40 mg, niacin 0.3–0.5 mg, and ascorbic acid 48–54 mg (Whitaker and Davis 1962). No data are reported on the composition of the leaves, but this is probably similar to other East African dark green leafy vegetables. The seed oil of fruits of the wild bitter form is composed of palmitic, stearic, oleic, linoleic, and linolenic acids.

Many cucurbits have both bitter and nonbitter forms within the same species. In the bitter forms of *C. anguria*, the bitterness increases considerably as the fruit ripens. The bitter principles, known as cucurbitacins, are tetracyclic triterpenoids. Cucurbitacins are among the most bitter substances known and are extremely toxic to mammals. In *C. anguria*, the main bitter principle is cucurbitacin B ($C_{32}H_{48}O_8$) with a much smaller amount of cucurbitacin D ($C_{30}H_{46}O_7$) and traces of cucurbitacins G and H. Toxicity studies showed the juice of the fruits to be highly toxic to rats (LD_{50} 1.6 mg/kg). The toxicity is reported to be reduced more than 100-fold if the juice is first boiled. Studies on the larvicidal activity of aqueous, ethanolic and citric acid extracts from *C. anguria* on *Aedes aegypti*, the yellow fever and dengue fever mosquito, showed that concentrations of 0.5 mg/mL after 24 h exposure caused larval mortalities of up to 40% (Petrus 2014).

2.4.5 Botanical Description

Annual, monoecious herb with trailing or scandent stems, having solitary, simple, setose tendrils 3–6 cm long; stems grooved, with bristle-like hairs. Leaves alternate, simple; stipules absent; petiole (2–)6–13 cm long, hispid to setose; blade broadly ovate in outline, 3–12 cm × 2–12 cm, shallowly to deeply palmately 3–5(–7)-lobed, with punctate to hispidulous hairs on both surfaces. Flowers unisexual, regular, five-merous; sepals narrowly triangular, 1–3 mm long; petals united at base, 4–8 mm long, yellow; male flowers in 2–10-flowered fascicles, with pedicel 0.5–3 cm long, stamens three; female flowers solitary, with pedicel 2–10 cm long, ovary inferior, ellipsoid, 7–9 mm long, softly spiny, stigma three-lobed. Fruit an ellipsoid to subglobose berry 3–4.5 cm × 2–3.5 cm, on a stalk 2.5–21 cm long, beset with soft, thin spines with transparent tips, green, ripening yellow, many-seeded. Seeds ellipsoid, 5–6 mm long, compressed with rounded margins and smooth (Bates et al. 1990; Chen 2011).

The approximately 30 *Cucumis* species are native to Africa, except the cucumber (*C. sativus* L.), which probably originates from India. Wild and cultivated types of *C. anguria* differ in bitterness of the fruits but also in the length of fruit spines (longer in wild forms). Wild types have been distinguished as var. *longipes* (Hook.f.) A. Meeuse or var. *longaculeatus* J.H. Kirkbr, cultivated ones as var. *anguria*. However, plants with short-spined fruits are often naturalized in tropical America and rarely in Africa (Kirkbride 1993).

2.4.6 Growth and Development

In its native habitat in southern Africa, *C. anguria* germinates in a few days during the summer rains when night temperatures are above 12°C and the soil is sufficiently wet. Early growth is upright; the primary stem may reach a height of 20 cm and does not produce flowers. This is followed quickly by several trailing procumbent stems, which branch off from the base, reaching a length of 2–3 m. Male flowers appear first, followed by female ones. Plants are self-fertile and cross-pollination is by insects. Day length plays an important role in flowering. Longer days combined with high temperatures tend to keep plants in the male-flowering phase of development, whereas lower temperatures and shorter days encourage development of female flowers. Fruits may be produced within 60 days from time of planting. They continue to be produced and to ripen over the hot season, giving up to 50 fruits/stem. Fruits remain attached to the withered annual stems long after these have died back at the end of the growing season (Sonnewald 2013).

2.4.7 Ecology and Cultivation Management

Wild *C. anguria* is a common inhabitant of semi-deciduous and deciduous woodland, tree and shrub savanna, grassland and semi-desert, up to 1500 m altitude. Wild and semi-domesticated forms can be found growing near compounds, in woodland and grassland, often on abandoned cultivated land, near cattle kraals, or occasionally as a weed in cultivation.

Plants tolerate a wide range of soil types, including Kalahari sands (regosols), red clays (fersiallitics), and black cotton soils (vertisols). In its southern African habitat, rainfall occurs in summer and varies from less than 400 to over 1000 mm. Temperatures during the growing season range from 15°C to 35°C. *C. anguria* is intolerant of frosts and cold temperatures.

The culture and agronomic requirements are similar to those of the common garden cucumber. In cultivation, the plants should be trailed. The application of organic manure and NPK fertilizer is beneficial. Irrigation can be given in periods of drought. In South Africa, the first fruit of a plant is tasted and if it is bitter, the whole plant is discarded.

2.4.8 Propagation and Planting

West Indian gherkin is propagated by seed, which requires light for germination. Seeds are sown in pockets of three to four at a spacing of 30 cm in the row and 100–150 cm between rows. The seed requirement is 2.5–4.5 kg/ha. In the growing season, the period from seeding to first harvest is 2–2.5 months. Plants continue to flower and set fruit for several months. For leaf production, the same cultural practices can be followed (Fernandes 2011).

2.4.9 Diseases and Pests

West Indian gherkin is quite resistant to pests and diseases. It displays varying degrees of natural resistance to pathogens and insects, such as the cucumber green mottle mosaic virus, root-knot nematodes, powdery mildew, and greenhouse whitefly. The fruits are seldom parasitized by fruit fly larvae, which attack most other cucurbit species in southern Africa.

2.4.10 Harvesting and Yield

As the fruits are preferred for pickling, they are harvested in the immature stage, while still green. If grown for leaves, these can be picked many times during several months. A single plant can produce 50 or more fruits. No statistics on fruit or leaf yield are reported. The yield potential is probably higher than for pickling cucumbers. The fruits can be kept for a few days at room temperature; the leaves should be consumed or marketed within a day.

2.4.11 Genetic Resources and Breeding

C. anguria is not in danger of extinction in its native habitat. The National Plant Germplasm System of the U.S. Department of Agriculture maintains numerous accessions of cultivated types of *C. anguria* at its regional plant introduction station in Ames, IA. Another collection is maintained at the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Turrialba, Costa Rica. Various Western seed companies offer seed of West Indian gherkin, including "African Heirloom," and "West Indian Burr Gherkin" (Sepasal 2003).

C. anguria and related species have been the focus of investigations by plant scientists to identify resistances to the many pests (viruses, bacteria, fungi, insects) attacking cucumber and melon, which might be genetically transferred. *C. anguria* proved to be totally immune to cucumber green mottle mosaic virus (CGMV). Resistance also occurred to root-knot nematodes and powdery mildew. In a study in South Africa, where fungal diseases and fruit parasitization by trypetid larvae is

usually severe in Cucurbitaceae, *C. anguria* showed a high resistance to both fungi and trypetids. Research efforts to transfer resistances into cucumber and melon have been undertaken. Repeated attempts to hybridize different *Cucumis* species have not been entirely successful; some species have never been successfully crossed to produce a fertile F_1 generation, whereas other species have been crossed to a limited extent.

The possibility of using *C. anguria* as a rootstock has been suggested, where scions of desirable crop species are grafted to it. In populations of some cucurbit species that normally produce bitter or toxic fruits, individuals may occasionally arise spontaneously that produce nonbitter, edible fruit. These variants are genetically stable when removed from the bitter gene pool. In *C. anguria*, a single gene distinguishes the bitter from the nonbitter type, the gene producing bitterness being dominant. Multiple factors appear to be involved in controlling bitterness, including various physiological conditions (Schippers 2000; Esteras et al. 2011; Manamohan and Chandra 2011).

2.4.12 Prospects

C. anguria, both as a semi-wild leafy vegetable and as the West Indian gherkin, merits more attention from plant breeders and agronomists. It is an attractive alternative to the common garden cucumber for use as a pickle, with fewer pest and disease problems and a larger fruit production (Sepasal 2003; Fabricante et al. 2015).

2.5 *CUCUMIS HIRSUTUS* SOND. (WILD HIRSUTUS)

2.5.1 Introduction

Synonym is *Cocculus hirsutus* (Linn.). *C. hirsutus* is distributed from Cameroon to Sudan and southwards to South Africa (Cape Province) as well as in Madagascar.

2.5.2 Uses

In Malawi, the leaves are eaten in the same way as pumpkin leaves, that is, sliced and cooked. The raw fruits are eaten as well but are not much appreciated. In South Africa, *C. hirsutus* is considered a poisonous plant. A decoction of the root is used by the Zulu tribe to treat chronic cough (Fand and Suroshe 2015).

2.5.3 Nutritional Properties

There is no information on nutritional values, but the leaf composition is probably comparable to other dark green leaf vegetables and that of the fruits to cucumber. Several cucurbitacins have been isolated from the roots of *C. hirsutus*. Cucurbitacins, which are known from many Cucurbitaceae and various other plant species, exhibit cytotoxicity (including antitumor activity), anti-inflammatory and analgesic activities.

2.5.4 Botanical Description

Dioecious, perennial, prostrate or scandent herb, with simple tendrils; roots fibrous, woody; stems up to 2.5 m long, thickened and woody at base. Leaves alternate, simple; stipules absent; petiole 0.5–5.5 cm long; blade broadly ovate, ovate-triangular or narrowly ovate, 2–15 cm × 1–10 cm, slightly cordate at base, unlobed or variously palmately three to five-lobed, lobes ovate-triangular to linear. Flowers unisexual, regular, five-merous; receptacle 3–9 mm long; sepals 1–9 mm long; petals white, cream or yellow; male flowers 1–12 together in fascicles, pedicel 0.5–7.5 cm long, petals up to 2 cm long; female flowers solitary or paired, pedicel 0.5–2.5 cm long, petals up to

3 cm long, ovary inferior, densely appressed or patent hairy. Fruit a globose to oblong-ellipsoid berry 2.5–7 cm × 1.5–6 cm, brownish-orange when ripe, smooth; fruit stalk 2–6 cm long, slender, not expanded upward. Seeds ovoid, compressed, 6.5–9 mm × 5–6.5 mm × 2–3 mm, white, smooth.

The genus *Cucumis* includes about 30 species, 4 of which are economically important: cucumber (*C. sativus* L.), melon and snake cucumber (*C. melo* L.), West Indian gherkin (*C. anguria* L.), and horned melon (*C. metuliferus* Naudin). *C. hirsutus* is the only species in the "*hirsutus*" group of the subgenus *melo*. In Malawi, the leaves are eaten at the end of the dry and beginning of the rainy season (October–November) (Kirkbride 1993).

2.5.5 Ecology

C. hirsutus is found in woodland, wooded grassland and grassland, and as a weed on formerly cultivated ground, up to 2500 m altitude.

2.5.6 Management

C. hirsutus is exclusively collected from the wild.

2.5.7 Genetic Resources and Breeding

Since *C. hirsutus* is widespread, there is no serious risk of genetic erosion. Only in the United States are a few accessions registered, all originating from South Africa. Breeders' interest in *C. hirsutus* is limited as transfer of genes by conventional breeding techniques to economically important *Cucumis* species is not possible (Sarvalingam et al. 2014; Garad et al. 2015).

2.5.8 Prospects

It is likely that *C. hirsutus* will remain a vegetable of local interest only.

2.6 *Cucumis melo* L. (Muskelon)

2.6.1 Introduction

Vernacular names are melon, muskmelon, cantaloupe (En). Melon (Fr). Melão (Po). Mtango, mtango mungunyana, mmumunye (Sw).

Melon probably originated in East Africa, where wild populations still occur, for example, in Sudan, Ethiopia, Eritrea, Somalia, Uganda, and Tanzania. Possibly, it also occurs wild in southern Africa, but the exact distribution of wild *C. melo* is unclear because of the regular occurrence of plants escaped from cultivation. Melon was domesticated in the eastern Mediterranean region and West Asia at least 4000 years ago and subsequently spread into Asia. During the long period of cultivation, many types developed with many fruit shapes and with either sweet or nonsweet flesh. Important centers of genetic diversity of cultivated melon developed in Iran, Uzbekistan, Afghanistan, China, and India. In Africa, important variations occur in Sudan and Egypt. The name "cantaloupe" derives from a fifteenth-century introduction of melon from Turkish Armenia to the papal residence at Cantalupi near Rome. Melon is now grown worldwide. It is a typical fruit vegetable of subtropical and warm temperate areas.

Melon occurs throughout the warm and dry areas of Africa, where it is grown either for its fruit or for its seeds.

Several nonsweet types of *C. melo* are grown traditionally. The most important one is snake melon, called "ajjur," "faqqus," or "qatta" in Arabic. It is found in many parts of Asia, from Turkey to Japan, and locally in Europe (Italy) and the United States. In Africa, it seems to be restricted

to Sudan and North Africa (Egypt, Morocco, Tunisia), where it is quite important. In Sudan, the immature fruits of a melon type locally known as "tibish" are used in the same way as snake melon. Some other types grown in Africa have bitter flesh and are grown for their edible seeds (Robinson and Decker-Walters 1997; Nonaka and Ezura 2015).

2.6.2 Uses

Mature fruits of sweet melon cultivars are usually consumed fresh for the sweet and juicy pulp. The pulp is also mixed with water and sugar, or sometimes with milk, and served as a refreshing drink or made into ice cream. Immature fruits of nonsweet types, including snake melon, are used as a fresh, cooked, or pickled vegetable; they are also stuffed with meat, rice, and spices and fried in oil. Snake melon is often confused with cucumber and used as such. The seeds are eaten after roasting; they contain edible oil. The Hausa people in Nigeria grind the kernels to a paste and make it into fermented cakes. The young leaves are occasionally consumed as a potherb and in soups. The leafy stems and also the fruit provide good forage for all livestock. In Réunion and Mauritius, a decoction of seeds and roots is used as a diuretic and vermifuge (Robinson and Decker-Walters 1997).

2.6.3 Production and Trade

Annual world production of melon has increased from 9 million t (700,000 ha) in 1992 to 22 million t (1.2 million ha) in 2002. Major producing countries are China with 400,000 ha, West Asia (Turkey, Iran, Iraq) 200,000 ha, the Americas (the United States, Mexico, Central and South American countries) 165,000 ha, northern Africa (Egypt, Morocco, Tunisia) 110,000 ha, southern Asia (India, Pakistan, Bangladesh) 100,000 ha, European Union (Spain, Italy, France, Greece, Portugal) 95,000 ha, Romania 50,000 ha, Japan 13,000 ha, and Korea 11,000 ha.

Each country has its own specific melon cultivars, and most of the crop is sold in local markets. Production for export has developed in the Mediterranean region, the United States, Mexico, Australia, Taiwan, and Japan, using F_1 hybrid cultivars with good shipping and storage characteristics.

In Africa, sweet melon is a luxury crop for urban markets, grown in drier regions and in highlands. Statistics on production are not available for most countries, except Cameroon (3500 ha) and Sudan (1200 ha). Senegal and surrounding countries export melon during the winter to Europe. Snake melon is important in Sudan, where it is grown for home use and local markets. The area grown is about 4000 ha with an annual production of 80,000 t. It is not exported (Jones et al. 2001).

2.6.4 Nutritional Properties

The edible portion of a mature melon fruit is 45%–80%. Fruits (raw, peeled) contain per 100 g edible portion: water 90.2 g, energy 142 kJ (34 kcal), protein 0.8 g, fat 0.2 g, carbohydrate 8.2 g, fiber 0.9 g, Ca 9 mg, Mg 12 mg, P 15 mg, Fe 0.2 mg, Zn 0.2 mg, vitamin A 3382 IU, thiamin 0.04 mg, riboflavin 0.02 mg, niacin 0.7 mg, folate 21 μg, and ascorbic acid 37 mg (USDA 2002).

The nutritional composition of snake melon per 100 g edible portion is water 94.5 g, energy 75 kJ (18 kcal), protein 0.6 g, fat 0.1 g, carbohydrate 4.4 g, fiber 0.3 g, and ascorbic acid 13 mg (Polacchi et al. 1982).

Sugar content and aroma are important factors determining the quality of sweet melon. Esters derived from amino acids are important components of the characteristic flavor; sulfur-containing compounds also play a role. Several C-9 alcohols and aldehydes, including Z-non-6-enal, are characteristic of the melon aroma. To get the best aroma, fruits should be harvested only 2–3 days before they are fully ripe. The edible seed kernel contains approximately 46% of yellow oil and 36% protein (USDA 2014).

2.6.5 Uses

Snake melon for use in salads can be replaced by cucumber (*C. sativus* L.). As a fruit, sweet melon can be replaced by papaya (Wyllie et al. 1995; Falah et al. 2015).

2.6.6 Botanical Description

Monoecious, climbing, creeping, or trailing, annual herb, having simple tendrils; root system large, mostly distributed in the top 30–40 cm of the soil, a few roots descending to 1 m depth; stem up to 3 m long, ridged or striate, hairy. Leaves alternate, simple; stipules absent; petiole 4–10 cm long; blade orbicular or ovate to reniform, 3–20 cm in diameter, angular or shallowly palmately five to seven-lobed, cordate at base, shallowly sinuate-toothed, surfaces hairy. Flowers axillary, unisexual or bisexual, regular, five-merous; pedicel 0.5–3 cm long; sepals linear, 6–8 mm long; corolla campanulate, lobes almost orbicular, up to 2 cm long, yellow; male flowers in two to four-flowered fascicles, with three free stamens; female or bisexual flowers solitary, with inferior, ellipsoid ovary, stigma three-lobed. Fruit a globose, ovoid or oblongoid berry weighing 0.4–2.2 kg, smooth or furrowed, rind smooth to rough and reticulate, white, green, yellowish-green, yellow, yellowish-brown, speckled yellow or orange with green or yellow background, flesh yellow, pink, orange, green or white, many-seeded. Seeds compressed ellipsoid, 5–12 mm × 2–7 mm × 1–1.5 mm, whitish or buff, smooth. Seedling with epigeal germination (Robinson and Decker-Walters 1997).

Most of the about 30 *Cucumis* species are native to Africa. They all have a chromosome number of 2n = 24, except *C. sativus* L. (cucumber) with 2n = 14; probably this species originated from Asia. *C. sativus* fruits are beset with spinous tubercles and warts when young, whereas ovaries of *C. melo* are hairy without tubercles and warts.

C. melo is polymorphic. Wild and weedy plants are often distinguished as subsp. *agrestis* (Naudin) Pangalo, having shortly pubescent ovaries and comparatively small flowers and fruits, whereas the cultivated plants (subsp. *melo*) have villous ovaries and generally larger flowers and fruits.

Cultivated plants belong to many different cultivar groups, of which the most important with sweet fruits for modern market gardening are as follows:

1. *Reticulatus group* (*muskmelon or netted melon*): Fruit globular (1–1.8 kg), rind strongly reticulate, sometimes furrowed, yellowish-green with orange flesh (Italo-American) or finely reticulate to smooth, yellowish-green with pale green flesh (Japanese, Mediterranean, e.g., "Galia"), sugar content high (13%–15%), aromatic, shelf life medium.
2. *Cantaloupe group* (*cantaloupe or muskmelon*): Fruit flattish to globular and often ribbed (1.2–1.8 kg), rind smooth or reticulate, flesh usually orange, carotene and sugar content high, flavor rich, shelf life short, mainly grown in southwestern Europe (e.g., "Charentais") and the Americas.
3. *Inodorus group* (*winter melon*): Fruit ovoid (1.5–2.5 kg), late maturing, rind smooth, wrinkled or slightly reticulate, often striped or splashed, grey, green or yellow, flesh firm, white or pale green, sugar content high but little flavor, shelf life long, mainly grown in Iran, Afghanistan and China, but also in Spain, the United States and Japan; important cultivars are "Casaba," "Honeydew," "Piel de Sapo," "Jaune Canari," and "Chinese Hami."

Examples of groups with nonsweet fruits used as a vegetable in Africa are as follows:

1. *Flexuosus group* (*snake melon or* "*snake cucumber*"): Fruit up to 2 m long, more than six times as long as wide, rind pale green or striped pale and dark green, ribbed or wrinkled, flesh white.
2. *Tibish group*: Fruit small, ovoid to oblate, without ribs, rind smooth, dark green with pale green stripes, flesh firm, white, particularly important in Sudan; a similar type named "seinat" in Sudan is grown for its seed.