CUCURBITS

Biodiversity, Breeding, and Production in Uttar Pradesh

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2013

Published
by
Uttar Pradesh State Biodiversity Board
East Wing, 'A' Block, 3rd Floor, PICUP Bhawan,
Vibhuti Khand, Gomti Nagar, Lucknow-226 010

First Edition- August, 2013

Published by
Uttar Pradesh State Biodiversity Board
East Wing, 'A' Block, 3rd Floor,
PICUP Bhawan, Vibhuti Khand,
Gomti Nagar, Lucknow-226010
Phone No. 0522-2306491, 4006746

Cover page : Biodiversity in shape, size and colour of flowers and fruits of cucurbits
Back page : Cucurbits : Hope of the poor and guardian of the greenery

Printed at: Army Printing Press, 33 Nehru Road, Sadar Cantt., Lucknow . Phone: 0522-481164

Preface

Members belonging to the family Cucurbitaceae, are known as cucurbits. The family is moderately large comprising of 118 genera and 825 species in the world. From India 37 genera and about 100 species of cucurbits, including wild and cultivated, have been reported. China is the world's leading producer of the major cucurbits. India's position in cucurbit production is not clear. Exact statistics of production and area under production of cucurbits are not available for both of these countries. According to 'two and half decades' old Chinese Agricultural Department estimate about 30% of the total land under vegetable production in China was under cucurbit crops. Statistics for area under production in India is not known but in different parts of India 20-25 cucurbit species are cultivated which constitute about 1/3rd of the total number of cultivated vegetables in the country. The major and minor cultivated cucurbits in Uttar Pradesh are: bottle gourd, sponge gourd, ridge gourd, bitter gourd, ash gourd, snake gourd, pumpkin, muskmelon, snapmelon, watermelon, longmelon, roundmelon, cucumber, pointed gourd, ivy gourd, *satputia*, zucchini, spine gourd, sweet gourd etc. Cucurbits are variously used as food, medicine, as well as utilitarian and ornamental items. Some cucurbits possess industrial importance too.

About half of the cucurbits cultivated in the country are indigenous to India or Indian sub-continent itself. Cucurbits are frost sensitive summer season crops. Hence, around the globe cucurbits are generally cultivated in the countries having tropical, sub-tropical, and mildly temperate climatic conditions, unless grown under protected conditions in the temperate countries. It is also a known fact that most of the cucurbits originated in tropical and sub-tropical parts of the world. Therefore, the responsibility of exploration, conservation, characterization, and exploitation through crop improvement of cucurbits lies more on the countries confined to these regions. In particular India's concern, as a role model, must orient to address the problem of detailed description and documentation of landraces of all those cultivated cucurbits which are known to exhibit immense biodiversity in the country, and more so for those cultivated cucurbits which are considered native to India.

Cucurbits constitute an appreciable share of our diet. Nutritive value of cucurbits is although low but they are the first choice for health conscious people and for those who want to lose body weight. Many of the cucurbits like, bottle gourd, bitter gourd, pumpkin, ash gourd, cucumber and pointed gourd are considered medicinally important and health ameliorating vegetables. Cucurbits are although summer season crop but some of them like bottle gourd, bitter gourd, cucumber, and pumpkin are now being cultivated almost round the year in Uttar Pradesh. It has, therefore, become pertinent to focus attention on developing season specific improved varieties with early maturity, high yield, quality, adaptability, and resistance against biotic and abiotic stresses. Cucurbit landraces are expected to play a pivotal role in this effort. Fascinating biodiversity is encountered in landraces of most of the cucurbits cultivated in the state. Detailed precise morphological description and understanding of physiological behaviour of a crop plant is a pre-requisite for any systematic breeding approach. Unfortunately, very vague and general information is available in this respect for most of the cucurbits cultivated in

the state, except for cucumber, pumpkin, muskmelon and watermelon, which have been studied and characterized mainly by scientists of the western countries. Therefore, an earnest effort has been made to describe in brief the morphological biodiversity as well as physiological behaviour with respect to photoperiod sensitivity, wherever possible, of cucurbits of Uttar Pradesh. Within the limited space of the script an attempt has been made to enlist in-brief the breeding objectives of cucurbit relevant to Uttar Pradesh. Breeding methods, and salient breeding achievements made on cucurbit improvement within the state and other parts of the world, along with highlights of production technology, as practised in Uttar Pradesh are also concisely described.

Certainly there have been a large number of motivators in the genesis of this small script on cucurbits and I very humbly extend my cordial gratitudes to all. The author experiences a deep sense of obligation towards his teachers and mentors: Mr. Anwar Ahmad, Dr. V.K. Gupta, Dr. B.D. Agrawal, Dr. D.M. Mukunya, Dr. R.D. Singh, Dr. N.C. Gautam, Dr. S.B. Singh, Dr.V.S. Seshadri, Dr. M.R. Thakur, Dr. Kirti Singh, Dr. U.C. Upadhyay, Dr. B.R. Tripathi, Dr. B.B. Singh, Dr. G.B. Singh, Dr. Chandrika Prasad, and Dr. R.L. Singh, who were the real source of strength and inspiration in the short and yet the thrilling journey on cucurbit research. Here it will be justified to acknowledge my sincere Ph.D. and M.Sc. (Ag.) students, as well as Dr. N.K. Singh (Ex. Senior Technical Assistant), who honestly and wholeheartedly carried out the the task assigned to them in various cucurbit research projects. The author is highly indebted to Uttar Pradesh State Biodiversity Board (UPSBB), Lucknow for sanctioning the budget for publication of this handbook. I am highly grateful to Mr. Pawan Kumar, Secretary, UPSBB; Mrs Pratibha Singh, Conservator of Forests, UPSBB; Mr. Ram Jee Srivastava, Senior Scintist UPSBB; and Mr. R.K. Dubey Asstt. Conservator of Forests, for their direct help, inspiration, and encouragement in the preparation of this handbook. I am especially thankful to my Ph.D. student Mr. Mohd. Meraj Khan for his arduous work in nice computer composition of the manuscript. The genuine hard work of the three daily-wage workers Sri Chandool, Smt. Mangala Devi, and Sri Siyaram Yadav, who were associated in different research projects on cucurbits, deserves a mention. At this juncture I also wish to acknowledge and place on record the forbearance, co-operation and persistent encouragement of my wife Mrs. Kiran Singh.

Within the limited resources and appreciably difficult research conditions whatever 'little' has been achieved by the author as cucurbit researcher, that is totally bestowed by the grace of natural forces and the guidance of 'Sadguru Osho' who teaches *'Work as an unique method of meditation leading to creativity.'* The handbook is expected to be of use to the students and beginners on the cucurbit research, particularly, breeders in basic understanding of cucurbit morphology and in identification of genetic markers in easily observable and relatively stable variations which have become essential for DUS test in modern day breeding. Within the limits of author's ability best efforts have been made to minimize every kind of mistakes and yet there are chances of a few left overs. The generous readers are requested to kindly bear with the errors and forward their valuable suggestions to the author for incorporation in the next edition, if possible.

August, 2013 **Sheo Pujan Singh**

Contents

1 INTRODUCTION AND GENERAL MORPHOLOGY

The family Cucurbitaceae inharbours one of the most diverse groups of plants in the plant kingdom. The term 'Cucurbits' was first coined by Liberty Hyde Bailey of United States of America for cultivated species of the family Cucurbitaceae. Currently the term is used for both cultivated as well as non-cultivated species of the family. Various other names like gourd, melon, cucumber, pumpkin and squash are also used for different species of the Cucurbitaceae. Out of these five names 'gourd' is more commonly used term which means a fruit guarded by hard rind. The term actually fits true to hard shells of mature bottle gourd fruit, but there are other cucurbits which have soft tender rind *viz.* bitter gourd, ivy gourd, pointed gourd, etc. and yet called 'gourd'.

Number and nature of cucurbits

The Cucurbitaceae is a moderately large family comprising of 118 genera and 825 species (Jeffrey, 1990). From India 37 genera and about 100 species have been reported. Some of the largely represented genera of the family along with approximately reported species are *Momordica* (45 species), *Trichosanthes* (44), *Cucumis* (25 species), *Cucurbita* (15 species), *Lagenaria* (6 species), *Luffa* (6 species), and *Echinocystis* (15 species). Robinson and Decker- Walters (1999) enlisted 58 cucurbit species that are cultivated world over. Out of which 34 are cultivated for fruits, 16 for medicinal purposes, 5 for ornamental purposes, and 3 for utilitarian purposes. They observed that many more wild taxa have actual or potential economic value making the Cucurbitaceae one of the most important plant families for human exploitation. They further opined that 'As a family and as individual crops, cucurbits epitomize adaptive differentiation and evolutionary divergence', and stated that, 'Although diverse most cucurbits do share a collection of characteristics (*eg.* rapidly growing vines with tendrils, containing various bioactive compounds) that make them unique, fascinating, and useful family of plants'. In general cucurbits are frost sensitive plants which thrive in tropical, subtropical, and mild temperate climatic conditions around the globe. Cucurbits are trailing or decumbent annual or perennial herbs. In India over 20 cucurbit species are grown for vegetable purposes. The list of cucurbits cultivated in Uttar Pradesh is given in Table 1.

Diverse utility of cucurbits

Tender green fruits of majority of cultivated cucurbits are used as cooked vegetable, besides many of them have multifarious utility in human diet as well as other fascinating day to day activities. Tender green fruits of cucumber, long melon, ivy gourd, zucchini *etc.* are used as salad. Mature fruits of muskmelon, watermelon, and snapmelon are used as dessert fruit. Cucumber, gherkin, ivy gourd, and round melon are used in pickle preparation. Mature fruits of ash gourd are used in sweet candy (*petha*) preparation. Tender fruits of bottle gourd and mature fruits of pumpkin are used in sweet meat or *halwa/barfi* preparation. Full grown fleshy fruits of pointed gourd are used in delicious sweet preparation. Buddha's fruit (*Siraitia grosvenorii*) a cucurbit known as 'luo han

kuo' in China is widely used as non-caloric sweetener in Chinese tonic soups. Buddha's fruit has a glycoside in the fruit called mogrol I-IV which is 150 times sweeter than sucrose. Green, tender fruits of long melon, cucumber, bottle gourd, ash gourd *etc.* are used in *rayata* preparation. Green tender fruits of bottle gourd, cucumber, ash gourd, bitter gourd and mature fruits of water melon and pumpkin are used to extract fruit juice for consumption as healthier drinks. Bottle gourd fruit juice has heart valve blockage and high blood pressure ameliorating properties. Cucumber and bitter gourd fruit juice is used as anti-diabetic drink. Fruit juice of watermelon is fermented to prepare alcoholic beverages. Leaves, tender stem and flowers of bottle gourd, pumpkin, ivy gourd and ash gourd as well as roots of some cucurbits *viz.* chow-chow are cooked and eaten. The dried mature fruit hard-shells of bottle gourd are used to prepare utensils, musical instruments, floats of fishing nets, ornamental items, penis sheath *etc.* Shelled or decorticated seeds of muskmelon, cucumber, watermelon, ash gourd, pumpkin *etc.* are nutritive and used in confectionery. Seed oil of pumpkin, watermelon and other cucurbits is used as cooking oil. Bottle gourd seed oil is used as hair oil by rural folk for cooling head and curing headache. Cucurbit oil is also used as industrial lubricant. Fibrous network of sponge gourd fruits is used as body and utensil scrubber. Fascinating large fruits of *Cucurbita maxima* are used as item of exhibits world over, particularly in Europe and Americas. A fruit weight of 821 kg was recorded in the year 2010 of 'Atlanta Giant' in such an exhibit.

Since ancient times different plant parts of several cultivated as well as wild cucurbits have been used for medicinal purposes. In current years too a large number of cucurbits have been identified as plants for medicinal importance which include antitumour properties (*Momordica*) and treatment against Human Immunodeficiency Virus (*Trichosanthes kirilowii* var. japonica). *Bryonia* and *Colocynth* are famous homeopathic medicines derived from these two cucurbits. A brief account of medicinal properties of cucurbits is described by Robinson and Decker- Walters (1999) and Seshadri and More (2009).

Nutritive value of cucurbits

Except for high β-carotene (provitamin A) contents in orange fleshed *Cucurbita* sp. genotypes and high lycopene content in watermelon, most of the cucurbit fruits are low in nutritive value. Nutritive value of tender leaves and shoots of many of the cucurbits like bottle gourd, pumpkin, etc. are more than their fruits. Cucurbit greens generally contain more calcium, phosphorus, ascorbic acid and iron than the fruits and can be a good source of vitamin A also. Leaves of various cultivated species contain up to 4-6% protein. Seeds are the most nutritious part of the cucurbit plant and they play an important role in the diet of local people in several parts of the world. The development of squash and pumpkin cultivars with 'naked' seeds, devoid of tough seed coats, has increased the popularity of squash seeds for food. Decorticated or shelled seeds are rich in fats (40-60%) and proteins (30-40%), contain few free sugars and lack starch (Robinson and Decker-Walters, 1999).

General morphology and biodiversity of cucurbits

The cucurbits constitute a group of unique creatures among flowering plants characterized by fast growing vines creeping on the ground or climbing the support with the help of strong grip of

Table 1. Cultivated cucurbits of Uttar Pradesh, their Hindi and botanical name, chromosome number, centre of origin and some other common features.

S. No.	Common name	Hindi name	Botanical name	Ch. no. (2n)	Centre of origin	Presence & size of bract	Tendril branching	Tendril length (cm)	Anthesis time	Flower colour	Flower diameter (cm)
1.	Bottle gourd	Lauki	*Lagenaria siceraria*	22	Africa	Rarely seen, Medium	2 branches	20-40	5.00-6.30 p.m.	White	6.50-8.00
2.	Sponge gourd	Turai /Nenua	*Luffa cylindrica*	26	India	Medium	3-7 branches	25-30	4.30-5.00 a.m.	Yellow	9.00-11.0
3.	Ridge gourd	Ara Turai	*Luffa acutangula*	26	India	Medium	4-5 branches	25-30	5.30-6.00 p.m.	Yellow	4.30-6.00
4.	Satputia	Satputia	*Luffa acutangula*	26	India	Medium	4-5 branches	25-30	5.00-5.30 p.m.	Yellow	4.00-4.50
5.	Ash gourd	Petha	*Benincasa hispida*	24	South East Asia (Malaysia)	Large	3 branches	15-25	4.45-5.15 a.m.	Yellow	7.50-10.0
6.	Snake gourd	Chichinda	*Trichosanthes cucumerina*	24	India	Very small	3 branches	25-30	4.30-5.00 a.m.	White	2.50-3.00
7.	Pointed gourd	Parwal	*Trichosanthes dioica*	24	India	Very small	2-3 branches	15-20	7.00-7.30 p.m.	White	5.00-650
8.	Ivy gourd	Kundru	*Coccinia indica*	24	Tropical Africa/India	Medium	Unbranched	20-25	7.30-8.30 a.m.	White	4.50-6.00
9.	Bitter gourd	Karela	*Momordica charantia*	22	Tropical Africa/Indo-Burma	Large	1-2 branches	15-25	4.45-5.15 a.m.	Yellow	3.50-4.00
10.	Spine gourd	Kheksi	*Momordica dioica*	28	Africa/Southern Tropical Asia	Large *	Unbranched	15-25	8.00-8.30 p.m.	Yellow	4.50-6.50
11.	Sweet gourd	Kheksa	*Momordica cochinchinesis*	28	South East Asia/India	Large *	Unbranched	15-20	-	White	5.50-7.50
12.	Roundmelon	Tinda	*Praecitrullus fistulosus*	24	India	Large	2-3 branches	10-13	4.30-5.00 a.m.	Yellow	2.0-2.50
13.	Watermelon	Tarbuz	*Citrullus lanatus*	22	Tropical Africa	Large	3-4 branches	10-15	4.30-5.00 a.m.	Yellow	2.50-3.50
14.	Muskmelon	Kharbuz	*Cucumis melo*	24	Tropical Africa	Very small	Unbranched	15-20	5.30-6.00 a.m.	Yellow	3.50-4.50
15.	Snapmelon	Phoot	*Cucumis melo* var. *momordica*	24	India	Very small	Unbranched	15-20	5.30-6.00 a.m.	Yellow	3.50-4.50
16.	Longmelon	Kakri	*Cucumis melo* var. *utilissimus*	24	India	Very small	Unbranched	15-20	5.30-6.00 a.m.	Yellow	4.50-5.00
17.	Cucumber	Kheera	*Cucumis sativus*	14	India	Absent	Unbranched	20-30	5.30-5.45 a.m.	Yellow	3.50-4.50
18.	-	Pehtul	*Cucumis callosus*	14	India	Very small	Unbranched	10-15	5.30-6.00 a.m.	Yellow	3.00-4.00
19.	Pumpkin	Kashiphal/Kaddu	*Cucurbita moschata*	40	Central Mexico	Absent	3-6 branches	20-25	4.30-4.50 a.m.	Yellow	15.0-25.0
20.	Zucchini	-	*Cucurbita pepo*	40	Northern Mexico	Absent	1-3 branches	10-15	6.15-7.30 a.m.	Yellow	12.0-17.0

spirally coiled long tendrils. In most cucurbits a plant is made up of underground tap root system and aerial shoot, except in an African species aardvark cucumber (*Cucumis humifructus*) having geocarpic fruit, similar to that of the peanut plant. Shoot is comprised of vines which are made up of nodes and internodes. Nodes are of prime importance because they bear all the vital vegetative organs *viz.,* leaves, tendrils, bracts, branches and occasionally adventitious roots; as well as reproductive organs *viz.,* staminate, pistillate, and/or hermaphrodite flowers. Pistillate and hermaphrodite flowers turn into fruits that contain seeds. Typically *Luffa cylindrica* vine nodes are characterized to bear all the seven potential organs *viz.,* **i.** a leaf, **ii.** a tendril, **iii,** a bract, **iv.** a branch, **v.** adventitious root, **vi.** a solitary pistillate flower, and **vii.** a raceme of staminate flowers (Fig. 1a). Leaf, tendril. and bract are the obligatory organs, which are essentially present on all vine nodes while the adventitious root occurs on vine nodes only occasionally when the growing vine touches the ground or hangs in the air (Fig. 5a). Out of the remaining three organs, *viz.,* branch, solitary pistillate flower, and raceme of staminate flowers, various combinations of any one, two or three organ(s) may be seen developing, with the inhibited growth of the others. Whatever may be the relative status of growth of branch, solitary pistillate flower or staminate raceme on a node, all these three and the three obligatory organs i.e. leaf, tendril and bract (keep the adventitious root aside) have a fixed position and sequence on the node. Leaf is the basic nodal organ and occupies

Fig. 1. Typical arrangements of nodal organs in cucurbits: a. sponge gourd vine node -the organs facing leaf (L) from left to right are bract (Brt), staminate flower raceme (SfR), solitary pistillate flower (Pf), branch (Brh) and tendril (T); b. bitter gourd vine node -the organs facing leaf (L) from left to right are tendril (T), branch (Brh), pistillate flower (Pf), and displaced bract (Dsp Brt); c. bottle gourd vine node -the organs facing leaf (L) from left to right are tendril (T), ordinary branch (Ord Brh), staminate flower (Sf), and accessory branch (Acc Brh).

the prime position on the node, facing which the remaining five organs are arranged from left to right as tendril, branch, solitary pistillate flower, raceme of staminate flowers and bract on some nodes; and in reverse order i.e. from left to right as bract, raceme of staminate flowers, solitary pistillate flowers, branch and tendril on other nodes (Fig. 1a). Since leaves are helically arranged on the growing vine, when the leaf is present on the left side the tendril is present towards right and vice-versa when the leaf is present on the right side the tendril is present towards left. When one stands facing the dorsal view of leaf on the growing vine, apparently it appears that raceme of staminate flower arises from the axil of bract within the axil of leaf; and branch appears arising from the axil of tendril. Solitary pistillate flower is always present in between the raceme of staminate flowers and the branch. In monoecious ridge gourd and snake gourd, the arrangement of nodal organs is just like sponge gourd. In hermaphrodite *satputia* solitary pistillate flower is replaced by solitary hermaphrodite flower and staminate raceme is replaced by hermaphrodite raceme. In other cucurbit species having various sex forms, excluding cucumber, pumpkin, zucchini, and bottle gourd, commonly only six nodal organs, *viz.* a leaf, a tendril, a bract, a branch, adventitious root, and solitary/cluster of staminate flower(s) or solitary/cluster of pistillate flower(s) or solitary hermaphrodite flower, are present on vine nodes in reproductive phase. Thus in the vine nodes of these cucurbits, facing leaf only four organs are present. The sequence of the four organs from left to right, on some nodes, remains as tendril, branch, solitary/cluster of flower(s) of one sex, and bract (Fig. 1b). While on other nodes the sequence of organs reverses from left to right as bract, solitary/cluster of flower(s) of one sex, branch, and tendril. Here too flower(s) arise from the axil of bract and branch appears to arise from the axil of tendril. Bottle gourd in reproductive phase have potential to bear seven nodal organs, with a distinct deviation from other monoecious cucurbits, wherein an accessory branch primordium, is added on every vine node in addition to the ordinary branch in its own fixed position (Fig. 1c). The accessory branch primordia sometimes develops into a small branch and very rarely into an effective branch, when ordinary branch is damaged or removed from the node at an early stage. Bract on vine nodes of bottle gourd is a rarely seen organ in some genotypes that too at lower frequency on only few nodes (Fig. 7e). Cucumber, pumpkin and zucchini bear only five nodal organs since bract is absent in these three cucurbits. Development of adventitious roots on vine nodes is an occasional feature, the tendency of which varies among cucurbits (Fig. 5a,b,c) and among the genotypes of the same species (Fig. 5c,d). The number of adventitious roots arising from a node and also their position on the node is not fixed, at least, as observed in case of pumpkin (Fig. 5b) and bottle gourd (Fig. 5c). A brief description of characteristic features of root, stem and the nodal organs is presented below:

Roots: All cultivated cucurbits have strong tap root system which in search of water and nutrients may generally penetrate a depth of 1 m in *Cucumis* and about 2 m in *Cucurbita*, (Weaver and Bruner, 1927). The horizontal spread of lateral roots is quite fast in upper soil depths of about 60 cm. The lateral root extension is usually equal to, and often exceeds that of the shoot and other above ground parts. Mature plants have intricate and intensive root system with the greatest absorbing area in those species that produce the greatest vine growth, (Whitaker and Davis, 1962). Favourable moderate temperature conditions, light soil with optimum moisture and nutrients, crop care, crop

duration, variety and species of the crop are the major determining factors in lateral spread of the roots. The experiments conducted at Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad (NDUAT, Faizabad), have revealed that mid-July sown bottle gourd crop with photoperiod sensitive winter tolerant varieties, *viz.* Narendra Shishir, Narendra Madhuri, and Narendra Shivani, produced lateral roots, extending in different directions from the base of main stem, measuring over 4 m length in eight months old crop in the offing March. The individual plants, trained on trellis of size 36 sq m area were thus found to spread their lateral roots in about 64 sq m area, extending in the underground soil of the neighbouring plots. As described earlier adventitious/ aerial roots originating generally from vine nodes are also observed in many of the cucurbits.

Stem -main vine and branches: Most cucurbits have fast growing herbaceous stems called vines. Typically vines have prostrate growing habit which may trail on the ground or climb the low or high supports, with the help of strong grip of the tendrils. Except for a few variants in *Cucurbita pepo* (zucchini, cocozelle, vegetable marrow, scallop etc.) and *C. maxima*, which possess dwarf sturdy bushy plants with nodes and very short internodes, most of the cucurbits have long tender vines which are usually angular in cross-section. The vines are highly branched and may have 4 to 7 or even more well developed primary branches which in turn also bear secondary and tertiary branches. Commonly the vine length of cucurbits varies from 2 to 10 m. However, a record vine length of 43 m has been reported in *Cucurbita pepo* by Holroyd (1914). As in case of roots, favourable moderate temperature conditions, light soil with optimum moisture and nutrients, crop care, crop duration, variety and species of the crop are the major determining factors in the development of vine growth and branches. At NDUAT, Faizabad a vine length of 29 m was recorded by the author (unpublished data) in a mid-July sown eight months old plant of a photoperiod sensitive cool temperature tolerant bottle gourd variety Narendra Shishir. *Dendrosciyos* is the only tree species of the family Cucurbitaceae.

Leaves: Cucurbits bear usually simple, palmate, cordate, or reniform leaves. The leaves may be completely unlobed or 3 to 5 lobed. Lobes of the leaves may be mild, moderate, deep or acute. Typically acutely lobed leaves are called 'pedate' or 'pinnatifid' (Fig. 7k, 21a, 26b, 27b,). Leaf shape on the same plant may be unlobed or mildly lobed in initial plant growth stage but the same plant develops moderately to deeply lobed leaves in the later stages as in bottle gourd, ash gourd, snake gourd etc. Leaf margins are generally entire but serrated leaves are found in *Momodica* and *Cucumis* species. Formation of serrated leaf margin is also influenced by temperature. In bottle gourd leaf margins are entire in summer and rainy seasons but the leaves of the same plant are serrated during cooler months. Cucurbit leaves are small in some species like pointed gourd, spine gourd, ivy gourd etc.; they are medium in *Luffa* sp., *Cucumis* sp., snake gourd, ash gourd etc.; while they are large in bottle gourd, pumpkin and zucchini. Leaf surface may be soft and glabrous in some while harsh and hirsute in others. The leaf colour within a species may be light green, green or dark green. Typically only one leaf is present per vine node of most cucurbits. However, in exceptional cases the plants producing one leaf per node may produce two to three leaves per node (Fig. 21c,d) in favourable temperature and humidity conditions. The variations in leaf shape, size

and colour among genotypes of the same species can be fruitfully utilized as genetic markers (Singh and Singh, 2012).

Tendrils: Tendrils are thread-like spirally coiled (Fig. 2a,b,h) obligatory and constant organ present on vine nodes of all cucurbits. The tendrils are extra axillary and lateral to the leaves. *Ecballium* is the only genus where tendrils are absent. Tendrils are made up of a little elastic and relatively stronger fibrous tissue that provides tangible strength to the vines to cling with the support, which in turn helps the growing vines to creep on the soil surface or climb on high stakes/trellis. They are sensitive to touch and have tendency to coil around the small objects that come in contact with them. The morphological nature of the tendrils has been much disputed and they have been variously considered as roots, stems, leaves, stipules, shoots, flower, stalks or organs *sui-generis*. May be they have a different origin in different genera.

Tendrils are not present in very young seedlings of cucurbits. In most of the cultivated cucurbits usually the first tendril arises from 4th to 7th node stage of seedling growth (Fig. 38a). However, the first tendrils in watermelon have been noted on 2nd node and in ash gourd they were noted at 10th node (Table 10). Varietal differences for first tendril appearance are also recorded within the species. After appearance of first tendril, the tendrils become regular feature of all vine nodes, except in abnormal cases, as in case of some cucumber genotypes where the tendrils are modified into pistillate flowers on a few nodes (Fig. 2i). Generally cucurbits are characterized by only solitary tendril per node, but there are certain genotypes in some cucurbits like snap melon which bear 2-3 tendrils per node (Fig. 35b). On the other hand there are other cucurbits like bottle gourd and snap melon, usually bearing one tendril per node, but very occasionally bear two tendrils only on a few nodes and again resume the normal tendency of solitary tendril in the successive nodes (Fig. 2h). Tendrils are unbranched in *Cucumis* species (Fig. 2d; 33a,b; 35a,b; 37a,b) ivy gourd, spine gourd (Fig. 29b$_1$) and sweet gourd. In bitter gourd also the tendrils are unbranched (Fig. 27a,b) but there are genotypes which bear unbranched and branched tendril on the same vine (Fig. 2e). In other cucurbits tendrils are variously branched having 2-7 branches per tendril. Some cucurbits have quite stable number of branches per tendril *viz.* bottle gourd has two branches (Fig. 2f), ash gourd has three branches (Fig. 21a), and snake gourd has three branches (Fig. 22b), while there are some cucurbits where number of branches per tendril varies from genotype to genotype and also within the genotype on the same plant, for instance sponge gourd (3-7), ridge gourd (4-5), pumpkin (3-6), watermelon (3-4) (Table 1,7). Sponge gourd has most variable number of branches per tendril varying from 3-7 among different genotypes. Usually branches are unequal in size. Place of branching of tendrils or bifurcation point also differs among cucurbits. In some branching begins near the base at its originating point on the node as in some genotypes of *satputia* (Fig. 2a), zucchini (Fig. 2c), and pointed gourd (Fig. 23b), whereas in other cucurbits the branching begins at a distance from the node.

Tendril length varies among cucurbits (Table 1). It may be very small (10-15 cm) as in zucchini (Fig. 2c), watermelon (Fig. 32b), roundmelon (Fig. 31a) and *pehtul*; small (15-20 cm) as in pointed gourd (Fig. 23b), sweet gourd, muskmelon, snap melon and long melon; medium (20-25 cm) in

Fig. 2. Tendrils of twelve cultivated cucurbits: a. typical spirally coiled *satputia* tendrils, b. a coiled branched tendril of bottle gourd holding a support, c. short and branched tendril of zucchini, d. unbranched tendrils of cucumber, e. unbranched and branched tendrils of bitter gourd, f. branched tendrils of bottle gourd, g. branched tendrils of ridge gourd, h. two tendrils arising from two consecutive vine nodes of bottle gourd, i. a pistillate flower borne in place of tendril in a vine node of cucumber, j. a branch of bottle gourd tendril turning into a real branch, k. a pistillate flower arising from the bifurcation point of sponge gourd tendril, l. tendril arising from a sponge gourd androgynous inflorescence turning into branch.

length as in ash gourd, ivy gourd, bitter gourd, spine gourd and pumpkin; or long (20-40 cm) as in bottle gourd, sponge gourd, ridge gourd, satputia, snake gourd, and cucumber. Great varietal differences are recorded among the genotypes within a species with respect to tendril length, which is again complicated by environmental factors. Tendril length is highly influenced by temperature, humidity and crop growth conditions, for instance a bottle gourd variety with 22-25 cm tendril length during summer may bear 40-50 cm long tendrils during rainy season.

Tendrils of cucurbits signify one of the most adaptive evolutionary organs, which equip the cucurbits for comfortable spread of tender vines in favourable as well as highly adverse conditions available for their growth and development. In fact long tendrils of cucurbits work as tentacles of lower animals like molluscs. The tendrils borne on 2-3 nodes preceding the apical bud of the vine are prominently seen flaunting ahead of the apical portion of the growing vine (Fig. 2d,e,f,g; 23b; 35.a), posing as if they are in search of safe route for guiding/navigating the growth of apical bud – the most tender part of the vine. The longest tendril extension (10-13 cm) beyond apical portion of vine is recorded in snake gourd and sponge gourd, shortest extension is recorded in *kachari* (2.20 cm), while in watermelon the tendrils borne on the preceding nodes are unable to reach the apex and are short by 3.60 cm (Table 10). On the basis of anatomical studies and vascular supply in 24 species of the Cucurbitaceae, Sensharma (1955) interpreted into two categories *viz*., i. tendril as outgrowth of bud axis, and ii. stipule-stem complex. Arsiwal (1981) concluded that tendril belongs to the axillary shoots. Tendrils in most of the cucurbit crops are interpreted as modified shoots. The exceptional abnormal development of leaf in a bottle gourd tendril (Fig. 2j) and development of rudimentary pistillate flower in the axil of bifurcation point of sponge gourd tendril (Fig. 2k) also support the concept of tendril being modified branch. The mechanism of curvature of the tendril in the Cucurbitaceae has been investigated by Dastur and Kapadia (1931). They found that the tendril becomes sensitive when about one-third grown. As the tendril grows in length, the sensitivity will increase. The reaction time varies from twenty seconds to two minutes after the stimulus is applied. Initially the tendrils are slightly curved (Fig. 2d,e,f), and later they become spirally coiled as they grasp the support (Fig. 2b) or without coming in contact of any support (Fig. 2a,h).

Bracts: Bracts are the modified special leaves from the axil of which one or more flowers arise. Bracts vary in size, shape, colour and duration. Like leaves and tendrils, bracts are obligatory organ and characteristic feature in both vegetative and reproductive phases of vine nodes of majority of the cultivated cucurbits. The size of the bract may be very small, small, medium, or large in various cucurbits (Fig. 3, Table 1). In Bottle gourd bracts are rarely seen in some genotypes, that too at a very low frequency on few vine nodes. They are absent in cucumber (Fig. 2i), and pumpkin (Fig. 3a). Bracts of both staminate and pistillate flowers are displaced from the vine nodes in bitter gourd (Fig. 3h), sweet gourd (Fig. 3i,j), and spine gourd (Fig. 3k,l) and they are present in the varying positions along the peduncles. Bracts of staminate flowers in sweet gourd (Fig. 3i) and spine gourd (Fig. 3k) are conspicuously large, while they are small and scaly in their respective pistillate flowers (Fig. 3j,k). Except for ivy gourd, bracts are invariably green in colour in all the cultivated cucurbits of Uttar Pradesh. In most of the ivy gourd genotypes the proximal or basal part of the bract is green, while the distal end of the bract is slightly pinkish (Fig. 3b) or brownish in colour.

Fig. 3. Bracts in cultivated cucurbits: a. pumpkin- bract absent, b. ivy gourd- small bract with half distinct violet colour towards distal end, c. watermelon -a staminate node bearing boat shaped medium size bract, d. watermelon- a pistillate node bearing boat shaped large bract, e. a common sponge gourd genotype -a small bract, f. ash gourd -a staminate node bearing large bract, g. ash gourd -a pistillate node bearing medium size bract, h. bitter gourd -a staminate flower peduncle bearing conspicuously large bract and a pistillate flower peduncle bearing large bract, i. sweet gourd -a staminate flower bearing conspicuously large bract at its base, j. sweet gourd -a pistillate flower peduncle bearing scaly bract, k. spine gourd -a staminate flower bearing conspicuously large bract at its base, l. spine gourd -a pistillate flower peduncle bearing scaly bract.

Flower size, shape and colour

Pistillate flowers have large inferior ovary. Flowers are generally large and showy which attract insects for pollination. Distinct intraspecific and interspecific flower shape variations are recorded with respect to petal structure. There are size variations with respect to flower diameter among the cucurbits (Table 10). The flowers of *Cucumis* species, snake gourd, bitter gourd, and ridge gourd are relatively smaller in size, whereas the flowers of bottle gourd, sponge gourd, pointed gourd, sweet gourd and spine gourd are medium in size. Pumpkin and zucchini bear the largest flowers (Table 1). Flower colour is yellow in majority of cucurbits with minor but distinct variations in shades of yellow colour (Front page). Bottle gourd, snake gourd, pointed gourd, and sweet gourd bear white flowers. Ivy gourd flowers are also prominently white but some genotypes have brownish (Fig. 26j) or pinkish (Fig. 26k) petal terminal ends. Corolla shape and size distinctly vary among genotypes of the same species. Staminate flowers are larger than pistillate flowers with respect to floral diameter (Table 1) and petal dimensions, on the same plants, in some species while reverse is true for other species. Sepals are usually green in all the cultivated cucurbits, except for ivy gourd where half basal portion of sepals is green and the distal end is invariably brownish or pinkish in all the genotypes (Fig. 26i,j,k). Distinct sepal size variations are recorded in pumpkin genotypes. Penduncle length of flowers varies to a great extent among genotypes.

Sex forms and floral arrangements: Different cucurbit species bear staminate, pistillate and/or hermaphrodite flowers in various combinations on different plants or on the same plant. There are eight sex forms in cucurbits *viz*. **i.** monoecious, **ii.** andromonoecious, **iii.** gynomonoecious, **iv.** gynoandromonoecious (trimonoecious), **v.** hermaphrodite, **vi.** androecious, **vii.** gynoecious, and **viii.** dioecious i.e. androecious and gynoecious combine. Staminate, pistillate, and hermaphrodite flowers of different sex forms are arranged in following patterns:

i. Solitary or cluster of 2-4 staminate flowers on vine nodes of stable androecious lines of dioecious cucurbits like pointed gourd, ivy gourd, spine gourd and sweet gourd. This arrangement may occasionally be found in segregant genotypes of some cucurbits. **ii.** Generally solitary or occasionally 2-4 cluster of only pistillate flowers on vine nodes of stable gynoecious lines of dioecious cucurbits *viz*. pointed gourd (Fig. 23e), ivy gourd (Fig. 3b), spine gourd and sweet gourd and stable gynoecious lines of monoecious cucurbits like cucumber bitter gourd etc. **iii.** Generally solitary staminate and solitary pistillate flowers on separate vine nodes of monoecious bottle gourd (Fig. 7g), bitter gourd (Fig. 27c), watermelon (Fig. 3c,d), ash gourd (Fig. 3f,g), pumpkin, zucchini (Fig. 41c) etc. **iv.** Occasionally cluster of staminate (Fig. 4c) and cluster of pistillate (Fig. 4d) flowers or staminate pistillate combination (Fig. 4c) in transitory form on separate vine nodes and usual solitary staminate and pistillate flowers on other nodes of monoecious bottle gourd (Fig. 7g). **v.** Occasionally cluster of 2-3 staminate (Fig. 4e) and cluster of 2-3 pistillate (Fig. 4f) flowers on the branched peduncle at some nodes and usual solitary staminate and pistillate flowers on other nodes of monoecious bottle gourd. **vi.** Solitary staminate and solitary hermaphrodite flowers on separate vine nodes in stable andromonoecious genotypes of muskmelon, watermelon and bottle gourd. **vii.** Solitary staminate, solitary pistillate, and occasionally solitary hermaphrodite flowers on

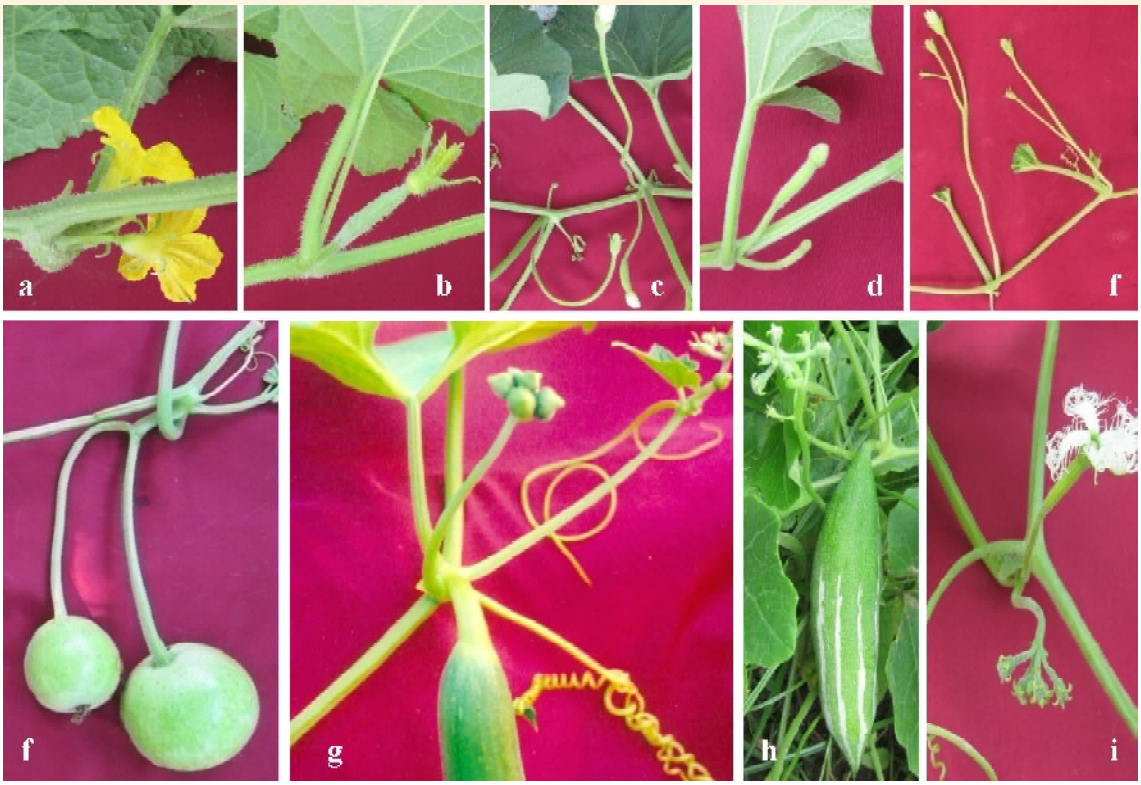


Fig. 4. Typical as well as unusual floral arrangements in some cultivated cucurbits: a. a cluster of staminate flower in cucumber, b. solitary pistillate flower in cucumber, c. two staminate flowers at a node (left) a staminate and a pistillate flower at another node (right) of a monoecious bottle gourd genotype, d. two pistillate flowers at a vine node of bottle gourd genotype, e. a bottle gourd genotype bearing 2-3 staminate flowers on the branched peduncles at each node, f. two pistillate flowers, borne on a branched peduncle, turning into effective fruits, g. an androecious raceme and a solitary pistillate flower present on one node in sponge gourd, h. an androecious raceme and a solitary pistillate flower present on one node in snake gourd, i. an androecious raceme and a solitary staminate flower on a node in snake gourd.

separate vine nodes of unstable/transitional trimonoecious lines of bottle gourd (Fig. 7h) and pumpkin (Fig. 39c). **viii.** Solitary staminate, solitary hermaphrodite and very occasionally solitary pistillate flowers on separate vine nodes as in andromonoecious line Andromon-6 (Fig. 7i) of bottle gourd producing transitional androgynomonoecious condition. **ix.** Cluster of 2-7 staminate flowers and solitary pistillate flower on separate vine nodes of monoecious cucumber (Fig. 4a,b), long melon (Fig. 37a,b), snapmelon (Fig. 35c,d), muskmelon, *pehtul* (Fig. 36b) *etc.* **x.** Cluster of 2-7 staminate flowers, solitary pistillate and occasional cluster of 2-3 pistillate flowers on separate nodes of monoecious cucumber (Fig. 38g,h). **xi.** Raceme inflorescence of staminate flowers (androecious raceme) along with solitary pistillate flower on the same node as in typical monoecious sponge gourd (Fig. 4g), monoecious ridge gourd (Fig. 18a), and snake gourd (Fig. 4h). **xii.** Transitory androgynous racemes (raceme inflorescence of staminate and pistillate flowers) along with solitary pistillate flower, on a few nodes in the vines of typical monoecious sponge gourd. **xiii.** Usual

androecious raceme and solitary pistillate flower on most of the nodes along with unusual transitory androecious raceme and solitary staminate flower only on few of the nodes as in sponge gourd, ridge gourd (Fig. 18b), and snake gourd (Fig. 4i) **xiv.** Androecious inflorescence without pistillate flower on some nodes, and androgynous inflorescence without solitary pistillate flower on other nodes, as in androgynous monoecious genotypes Androgyne-1 (Fig. 17a), Androgyne-4 (Fig. 17b) and Androgyne-7 (Fig. 17c) of sponge gourd. **xv.** Androgynous inflorescence and solitary pistillate flower on the same node of naturally occurring stable androgynous monoecious genotypes of sponge gourd. **xvi.** Raceme of hermaphrodite flowers along with solitary hermaphrodite flower on the same node, as found in hermaphrodite *satputia* genotype (Fig. 19a). **xvii.** Raceme of staminate flowers and solitary hermaphrodite flower on the same node, as found in andromonoecious genotypes of *satputia* (Fig. 19b). **xviii.** Androgynous inflorescence and solitary staminate flower, on the same node as recorded in a wild *Luffa* species located in Azamgarh and Barabanki districts of Uttar Pradesh.

Detailed information on sex genetics, regulation of sex, sex modification, pollination, and fruit set has been described by Robinson and Decker-Walters (1999) and Seshadri and More (2009).

Fruits: Fruits of cultivated cucurbits exhibit immense diversity in their fruit characters including shape, size and colour. Some cucurbits produce very small fruits while the others produce very large fruits. The largest fruit of the plant kingdom is produced by *Cucurbita maxima*, as described earlier in this chapter. Among the cultivated cucurbits of Uttar Pradesh, spine gourd produces the smallest fruits of about 5 g while among the largest fruit producers are pumpkin, ash gourd, and bottle gourd, where fruits of over 30 kg weight are usually brought to state level exhibit at Raj

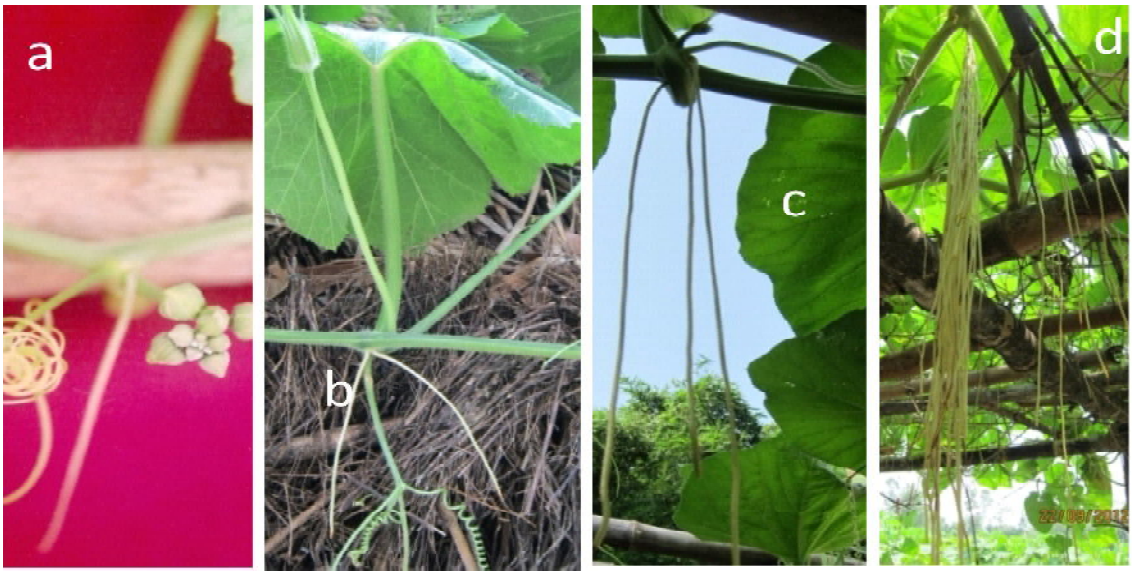


Fig. 5. Aerial and adventitious roots of some cucurbits: a. an aerial root arising from sponge gourd vine node, b. aerial roots arising from pumpkin vine node, c. aerial roots arising from a vine node of a bottle gourd, d. a highly branched aerial root arising from a bottle gourd variety Narendra Shivani.

Fig. 6. Variability in seed shape, size and colour of one wild and eighteen cultivated cucurbits: a. *pehtul*, b. cucumber, c. longmelon, d. muskmelon, e. snapmelon, f. ivy gourd, g. round melon, h. bitter gourd, i. bottle gourd, j. snake gourd, k. ash gourd, l. spine gourd, m. pointed gourd, n. sponge gourd, o. ridge gourd, p. watermelon, q. pumpkin, r. *satputia*, s. sweet gourd.

Bhawan in Lucknow. There is extreme diversity in fruit shape of cucurbits but usually the fruits are categorized as long, oblong, or round. Fruit colour of tender fruits of most cucurbits is generally green, patchy green, or striped green. At maturity fruits of different cucurbit species may remain green or acquire whitish green, brown, almond, light yellow, yellow, red, scarlet or other colours.

Seeds: Great variability is recorded in seed size, shape and colour (Fig. 6). Smaller seeds are found in *Cucumis* species (Fig. 6a,b,c,d,e) and ivy gourd (Fig. 6f). Medium size seeds are recorded in ash gourd, sponge gourd, ridge gourd, watermelon, round melon etc. while large seeds are found in bottle gourd, bitter gourd, snake gourd, and pumpkin. Seeds are elongated, flat in all the cucurbits, except in spine gourd and pointed gourd. The seed colour of *Cucumis* species, ivy gourd, ash gourd, pumpkin and some genotypes of sponge gourd are white, whereas other species have brown or black seeds (Fig. 6). Anatomical structural details of cucurbit seeds have been described by Whitaker and Davis (1962), Robinson and Decker-Walters (1999), and Seshadri and More (2009).

2 BOTTLE GOURD

Origin, history, and use

Bottle gourd [*Lagenaria siceraria* (Molina) Standley syn. *L. vulgaris* Ser., *L. leucantha* Rusby] is an annual monoecious species with five wild perennial dioecious species, the later confined to Africa, Madagascar and Comero islands. The dioecious species are *L. sphaerica* (Sond.) Naud., *L. breviflora* (Benth.) Roberty, *L. abyssinica* Hook, C. Jeffrey, *L. guineensis* (G. Dow), and *L. rufa* Gilg., (Zeven and de Wet, 1982). Morphological differences have been recorded between the land races of African and New World origin from those of Asian origin and they are classified, respectively, as *L. siceraria* ssp. *siceraria* and *L. siceraria* ssp. *asiatica* (Kobiakova) Heiser. An andromonoecious isolate Andromon-6 has also been reported by Singh *et al.* (1996). Bottle gourd is one of the oldest cultivated plants in the tropics (Purseglove, 1974). Harris, (1967) suggested a pan tropical distribution of *Lagenaria* with the possibility of independent domestication in Old and New World. On the basis of occurrence of wild *Lagenaria* in West Africa, Chakravarty, (1982) clearly indicated its African origin. Some estimate that human utilization of *Lagenaria* whether as a vegetable, water receptacle, musical instrument or medicinal plant, was at least 15,000 years old in New World and 12,000 years in Old World (Richardson, 1972). Flowers are vitalizer to men. Seeds are nutritious to all and stimulant to females. Heiser (1980) gave a fascinating account of different uses of cups, barrels, ladles, floats, pipes, musical instruments, penis sheaths, carvings, etc. Irrespective of centre of origin of bottle gourd, India is considered to possess greatest biodiversity in the world. Existence of several names in the Sanskrit language for bottle gourd suggests its long history of cultivation on the Indian sub-continent. In Sanskrit bottle gourd is known by various names like *alabu*, *tumbi*, *ikshvaku* and *mahaphala*. *Mahaphala* (meaning a great-fruit) is particularly used for bitter type bottle gourd because of its considerably high medicinal values. Application of bottle gourd leaf juice has been found instant antidote in poisonous insect stings, if applied quickly after sting (Singh, 2006).

General morphology and biodiversity

Nodal organs: In reproductive phase the bottle gourd vine nodes have potential of bearing seven organs (Fig. 7e) *viz.* i. leaf, ii. ordinary branch, iii. accessory branch, iv. tendril, v. bract (rarely seen only on some nodes in a few genotypes), vi. adventitious root (Fig. 5c), and vii. staminate or pistillate flower. In vegetative phase flowers are not present. Except adventitious roots the remaining five organs are located at fixed position on the node. Leaf occupies the prominent position on every node facing which, from left to right, are present tendril, ordinary branch, staminate or pistillate flower, and easily visible accessory branch primordium. The adventitious roots neither originate from a fixed position on the node nor have a fixed number. They may originate from anywhere in the available space in the circumference of the vine, encircling the leaf. The number of adventitious roots on a node has been recorded to vary from 1 to 5. Easily observable morphological biodiversity is recorded in leaf, vine, flower, adventitious root formation, fruit, and seed characters.

Leaves and bracts: Presence of one leaf on each node is a constant phenomenon, only in rare cases on abnormal nodes the leaf may remain absent. Very rarely some abnormal nodes may bear two to four leaves also. The common normal leaf shape is simple-cordate or palmate. The simple leaves may be unlobed (Fig. 7a), mildly lobed (Fig. 7b) or moderately lobed (Fig. 7c). In contrast to the normal leaf shape certain land races found in eastern Uttar Pradesh districts of Azamgarh, Ballia, Kushinagar etc. and adjoining Bihar possess acutely lobed or pinnatifid leaves technically called as pedate leaf shape (Fig. 7d). In genotypes having unlobed leaf shape, the leaves are generally unlobed in initial plant growth stage and later at 25th-30th node stage of main vine the leaves become mildly to moderately lobed in the same plant. The unlobed leaf shape in some genotypes like Pusa Naveen may remain stable throughout the life span. The pinnatifid or pedate leaf shape, as in case of Narendra Shishir, exhibits monogenic intermediate dominance over normal unlobed leaf shape (Singh and Singh, 2012). All leaves have two distinct glands on the petiole near lamina base (Fig. 7l). The leaf size may be small, medium or large. Leaf size of the same plant also varies depending upon the growth stage and agro-climatic conditions (temperature and humidity). Observations under eastern Uttar Pradesh condition have revealed that the July sown bottle gourd crop produces normal size leaves up to September, the same plants produce largest leaves during October-November and thereafter leaf size decreases in offing cooler months of December-January. Bracts are rarely seen in some genotypes, that too at a very low frequency on only few vine nodes of bottle gourd (Fig. 7e).

Ordinary and accessory branches: Close observations by the author have revealed that each node has two branch primordia, *viz*. an ordinary branch primordium and an accessory branch primordium, which have potential to develop into full length branches. This is in distinct contrast to the other cucurbits, where only one branch primordium is present on a node. The ordinary branch primordium is present at its usual location, like other cucurbits, in the axil of tendril on one side of the node which usually develops into an ordinary full length branch or may exhibit inhibited/rudimentary growth. The accessory branch primordium is located on the other extreme of the node (Fig. 7e) which appears arising from the axil of the bract, if bract is present. The accessory branch primordial usually remains inhibited/rudimentary on most of the nodes. On very few nodes the accessory branch primordium is found to develop into short length branch of few nodes and it is termed as accessory branch in addition to the commonly found ordinary-branch. The frequency of development of accessory branches into short length branches increases when the ordinary branch primordia and flower buds were nipped off, in the initial stages of their growth, from the vine nodes leaving only the accessory branch primordium, leaf, and tendril on the node. Some of the accessory branches developing on the trimmed nodes, devoid of ordinary branch primordia, develop into full length effective branches.

Tendrils: Bottle gourd vine nodes usually bear single extra axillary long tendrils (with 20-40 cm length) having two unequal branches (Fig. 2f) on the ordinary branches. However, unusual two tendrils per node are also occasionally noticed at the initial nodes in the ordinary branches, and the later nodes on these branches bear only usual single tendrils (Fig. 7f). The presence of two tendrils, at the initial one, two, three, or four nodes, is an essential feature of the accessory branches.

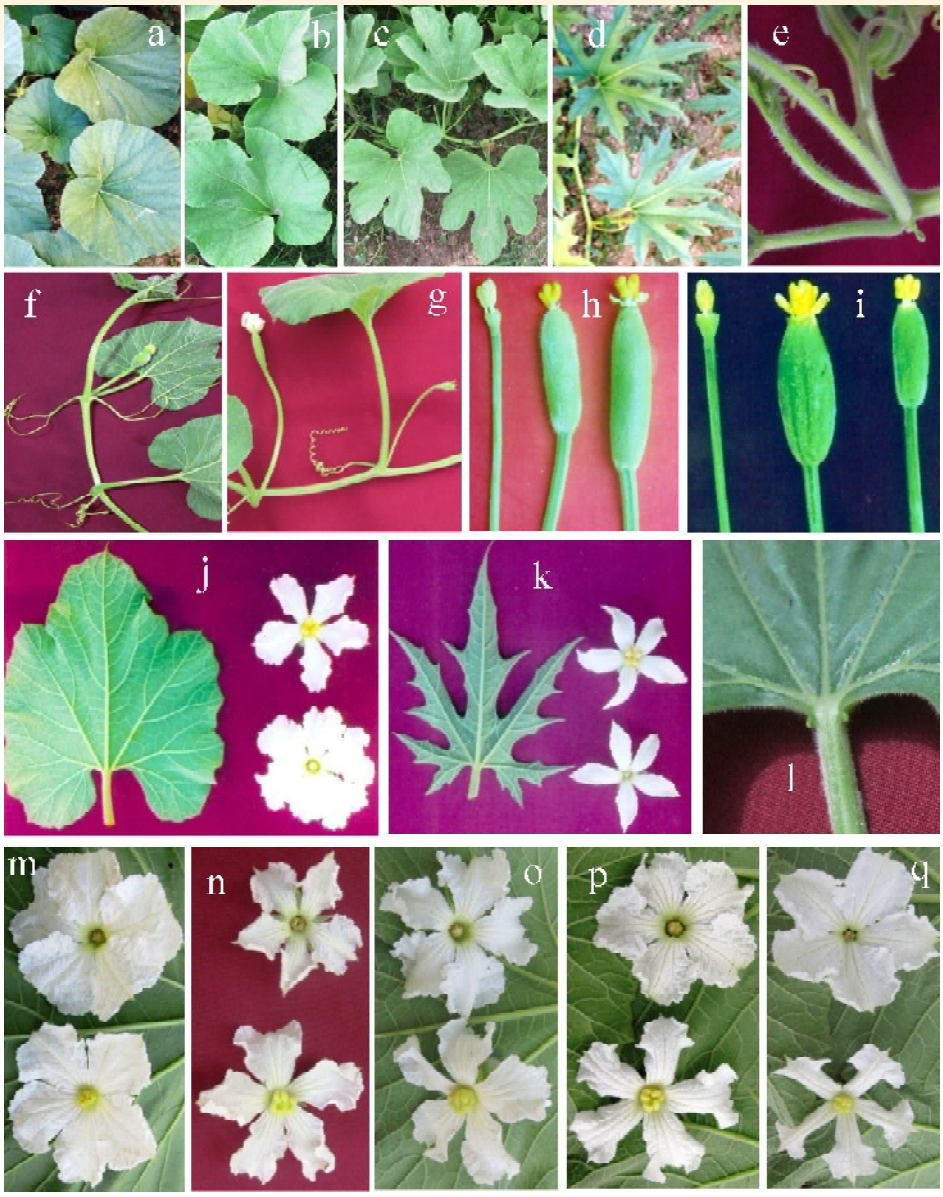


Fig. 7. Variability in leaf, sex form, and floral characters of bottle gourd: a. unlobed leaves, b. mildly lobed leaves, c. moderately lobed leaves, d. pinnatifid or pedate leaves, e. a node with leaf, tendril, ordinary branch, accessory branch primordium, a small bract and staminate flower, f. a branch bearing unusual two tendrils at its initial two nodes and usual one tendril on third node, g. monoecious sex form, h. trimonoecious sex form in a monoecious genotype, i. trimonoecious sex form in an andromonoecious genotype, j. normal leaf and broad petalled large pistillate (upper) and staminate (lower) flowers, k. pedate leaf and narrow petalled small staminate (lower) and pistillate (upper) flowers, l. two oil glands on the petiole near lamina base, m, n, o, p, q. variability in shape and size of staminate (upper) and pistillate (lower) flowers in different normal genotypes having broad petalled large flowers.

Adventitious roots: Formation and development of adventitious roots is a common feature in bottle gourd as in other cucurbits. In the vines that creep on the ground the adventitious roots may arise usually from the nodes which penetrate the moist soil and perform the function of absorption. The adventitious roots mainly arise during highly humid August-September months, and hang as aerial roots (Fig. 5c,d) from the vines that grow on trellis and stakes above the ground. The genotypes differ in the tendency of formation of aerial roots.

Sex forms: Bottle gourd is commonly monoecious (Fig. 7g) in nature. However, an andromonoecious isolate Andromon-6 has been reported by Singh *et al.* (1996). Transitory unstable trimonoecious sex form also appears in both monoecious (Fig. 7h) and andromonoecious (Fig. 7i) forms. Generally solitary staminate, pistillate or hermaphrodite flowers are present in the leaf axils of separate nodes (Fig. 7g). However, occasionally two staminate (Fig. 8a), one staminate and one pistillate (Fig. 4c) or even two pistillate flowers are present on the same node (Fig. 4d) in certain genotypes. Very rarely both of the pistillate flowers on a node turn into effective fruits.

Flower colour, size and shape: The flowers of bottle gourd are invariably white in colour with insignificant minor variations. Variations are recorded in flower shape and size (Fig. 7j,k,m,n,o,p,q). Flower size of the genotypes bearing normal unlobed and lobed leaves bear broad petalled large flowers (Fig. 7j), the size and shape of which varies among the genotypes (Fig. 7m,n,o,p,q). In these genotypes normally the staminate flowers are distinctly larger on the same plant as compared to the pistillate flowers (Fig. 7j). Bottle gourd genotypes, with pedate or pinnatifid leaves, bear small flowers with narrow petals (Fig. 7k). Contrary to the normal genotypes the staminate flower size in pedate leaf genotypes is relatively smaller as compared to the pistillate flower size on the same plant. All the bottle gourd genotypes produce smaller petal/corolla size under cool temperature conditions in comparison to the petal/corolla size produced in warmer/moderate temperature conditions.

Sex ratio and anthesis time: Biodiversity is recorded among the genotypes with respect to staminate and pistillate flower sex ratio which varies from 10 staminate:1 pistillate to 30 staminate:1pistillate. In cooler months of December, January and February, sex ratio reverses in the same genotype and a sex ratio of 1 staminate : 1 pistillate or even 1 staminate : 20 pistillate ratio may also be recorded. Usually in common genotypes first staminate flower anthesis takes place earlier at lower node number and first pistillate flower anthesis takes place 1-10 days later at higher node of the vine but the sequence changes in early/prolific genotypes where first pistillate flower anthesis occurs 1-2 days earlier at lower node as compared to first staminate flower anthesis. Anthesis in bottle gourd takes place in 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 in 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 in between 1:00 and 2:00 p.m. Anthesis and dehiscence time is moderately influenced by humidity and temperature conditions.

Unique bottle gourd variant NDBG-713 with branched flower peduncles: A unique bottle gourd variant NDBG-713, is isolated at NDUAT, Faizabad which bear branched flower peduncles with otherwise normal flowering behaviour. As usual NDBG-713 bears solitary staminate and pistillate flowers on majority of the branches, but there are certain deviations in the flowering behaviour *viz*. i. some of the branches bear two staminate flowers on several consecutive nodes (Fig. 8a), ii. a few branches bear two to three staminate flowers on branched staminate flower peduncle (Fig. 8b), an unusual flowering behaviour in bottle gourd, iii. some of the nodes possess two pistillate flowers on branched pistillate flower peduncle –with branching initiating at the proximal end (Fig. 8c), these two pistillate flowers generally develop into effective fruits, and iv. some pistillate flowers have branched peduncle at distal end (Fig. 8e). These deviations are recorded in July sown crop, only from late September to whole of October, after which the genotype resumes normal flowering behaviour as found in common bottle gourd genotypes. NDBG-713 has flat round fruit shape till late October (Fig. 8f). With advancing cooler temperature the fruits on the same plant become round (Fig. 8g) or even slightly oblong, indicating influence of temperature on fruit shape development. The genotype has patchy green fruit skin colour (Fig. 8f). NDBG-713 is a

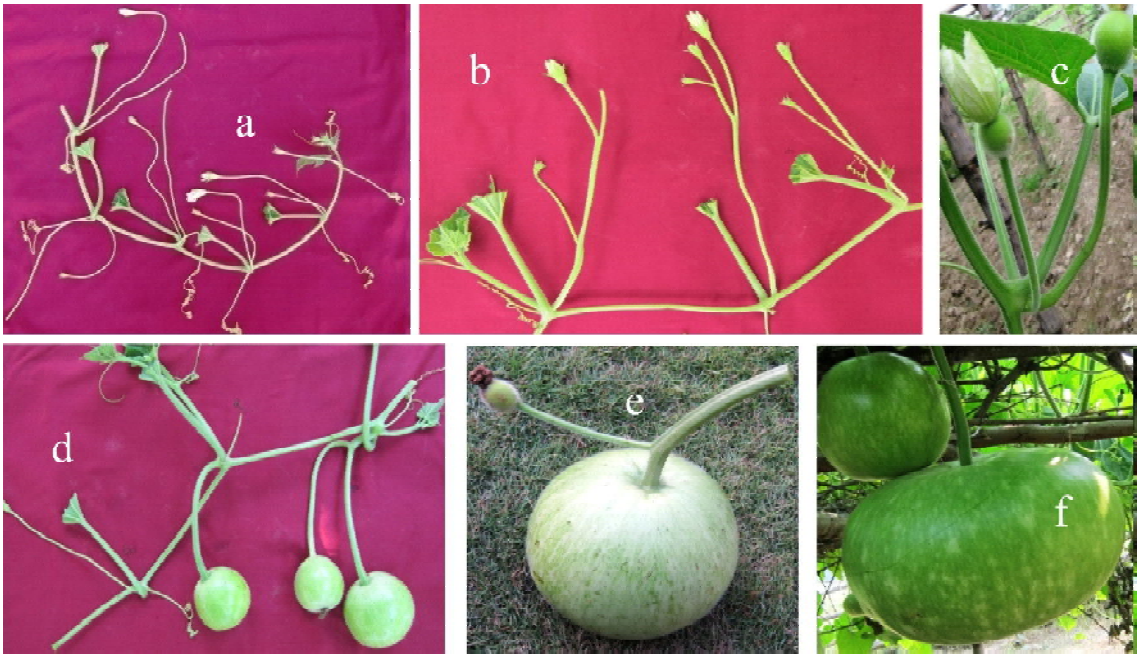


Fig. 8. Floral arrangement and fruit bearing habit of a photoperiod sensitive short day type bottle gourd genotype NDBG-713: a. vine bearing two staminate flowers on five consecutive nodes and the sixth node bearing solitary staminate flower, b. vine bearing two to three staminate flowers on the branched peduncles at three consecutive nodes, c. a node bearing two pistillate flowers on a branched peduncle at base, d. a vine bearing two fruits at a node borne out of two pistillate flowers of a branched peduncle and the consecutive node bearing single fruit borne out of solitary pistillate flower and the third node bearing solitary staminate flower, e. an effective fruit and a decaying pistillate flower borne out of two pistillate flowers on a branched peduncle at the distal end, f. a typical full grown flat round patchy green fruit developed in mid-October, g. a round patchy green tender fruit developed in mid-November.

photoperiod sensitive genotype with prolific fruit bearing, with yield level of 1034.16 q/ha in July sown winter season crop having short days (Table 2), and very shy fruit bearing (10.37 q/ha) in April sown summer crop having long days (Table 3). Branched flower peduncles and multiple staminate and pistillate flowers on a node in NDBG-713 are indicative of advancing speciation in bottle gourd. Multiple fruit bearing on a node of this genotype can be utilized in future breeding programme.

Vines: The vines of different bottle gourd genotypes may be small, moderately long or very long. The vine lengths may vary from 5.0-25.0 m. The number of primary and secondary branches also varies to a great extent. The colour of the vine may be pale green, green or dark green.

Fruit characters: Enormous variability is recorded in bottle gourd fruit characters, particularly in fruit shape. Although the fruit shape can broadly be categorized as long (Fig. 9a, $10a_1$-a_{11}), oblong (Fig. $10.b_1$-b_8) and round (Fig. 9b,c,d and $10c_1$-c_5), a great deviation is noticed within each of the three broad categories. The long fruits may be bottle shaped (Fig. $10a_3$,a_9), cylindrical (Fig. $10a_1$, a_5), slender (Fig. $10a_2$, a_6), club shaped (Fig. $10a_{11}$), necked (Fig. $10a_3$, a_9), headed (Fig. $10a_4$), straight (Fig. $10a_1$), curved (Fig. $10a_8$) etc. Round fruits may be exactly round (Fig. $10c_1$, c_3), near round (Fig. $10c_2$), globe shaped, pear shaped (Fig. $10c_4$), flat round (Fig. $10c_5$) pitcher shaped (Fig. $10d_2$), broader towards head and narrow towards base, small headed (Fig. $10d_1$), big headed (Fig. $10d_4$), conical or beaked (Fig. $10d_3$) towards head. Similarly large variations are also recorded within oblong fruit shape. The fruits at maturity may be smooth (Fig. $10a_1$-a_8), mildly ridged (Fig. $10a_{11}$, $10.b_8$) or deeply ridged (Fig. $10c_4$). Blossom scar present at the distal end of the fruit may be small, medium or large in size. The observations recorded on fruit shape indicate that numerous shape genes are at work, which are responsible for amusing minor and major modifications of bottle gourd fruit shape. Stable variations in fruit peduncle lengths are recorded among genotypes.

Fig. 9. Full grown fruit dimensions of bottle gourd genotypes: a. Narendra Shivani, b. Narendra Madhuri, c. NDBG-713, d. Narendra Bow-Wonder.

The length of full grown fruits of common long fruited genotypes generally varies from 50-70 cm. However, the extremes of fruit length recorded range from 25 cm to 245 cm. The longest fruit length (245 cm) of the bottle gourd variety Narendra Shivani, developed at NDUAT, Faizabad, was recorded in July, 2012 sown winter crop at Sirsa in Haryana. The recorded weights of full grown round fruited genotypes at NDUAT, Faizabad, have ranged from 1.5 kg to 18 kg. Fruit length and weight dimensions of the same genotype are greatly influenced by environmental and crop management conditions. The fruit colour of bottle gourd can broadly be identified as

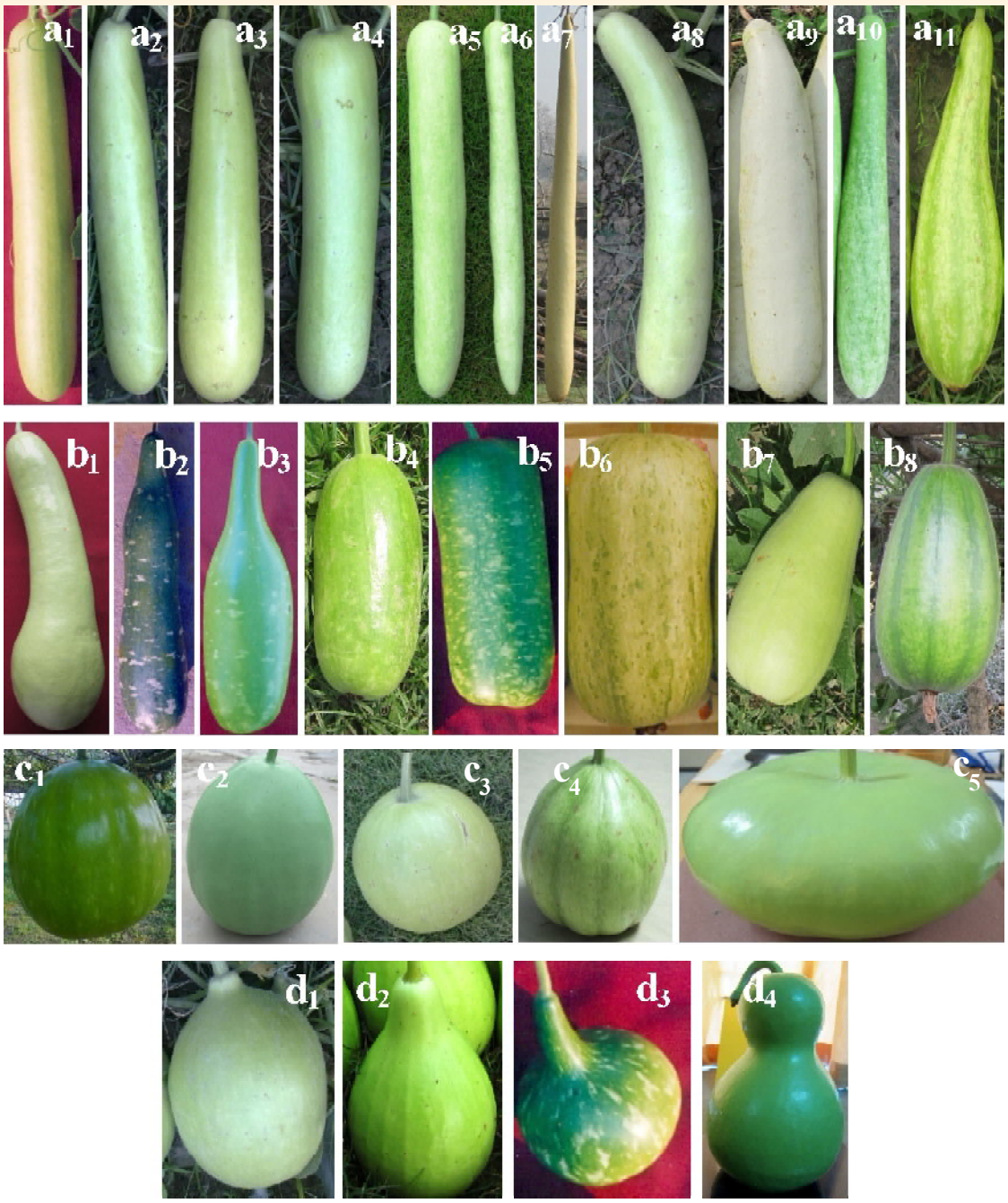


Fig. 10. Variability in fruit shape, size and colour of bottle gourd: a_1-a_{11} : variability in long fruited genotypes, b_1-b_8 : variability in oblong fruited genotypes, c_1-c_5 : variability in round fruited genotypes, d_1-d_4: variability in round fruited genotypes having head and beaks.

patchy green and striped green. The patchy green types can further be divided into three categories as pale green patchy (Fig. 9b), light green patchy (Fig. 9c) and dark green patchy (Fig. 9d). White patches of pale green patchy genotypes are clearly visible in the fruits when they grow under shade and at mild cool temperature. In sunny hot days patches are invisible in patchy pale green genotypes and fruits appear simply plain pale green in colour. In striped green fruits ten well marked green stripes are formed alternating to lighter green base colour (Fig. $10a_{11}$, $10b_{8}$, $10c_{4}$). With the increasing fruit size ten grooves and ten ridges are formed corresponding to the stripes and base colour, respectively. The colours of stripe and base as well as depths of grooves are found to vary among genotypes.

Palatability and bitterness: Fruits may be sweet/non-bitter or bitter in taste. Only sweet types are used for consumption mainly through cooked vegetable. Palatability of cooked vegetable varies among non-bitter genotypes. Narendra Madhuri and Narendra Shivani the two improved bottle gourd cultivars are rated to possess very high palatability with distinct taste of cooked vegetable. Bitter types are distracting in taste which cause vomiting and nausea when eaten in lower quantities but may prove deadly poisonous when eaten in moderate and higher quantities. However, bitter type bottle gourd is of greater medicinal importance as compared to the sweet types. Rind thickness of mature fruits among genotypes is recorded to vary from 2.0-25.0 mm. Flesh thickness and textures of the genotypes also differ.

Seed characters: Invariably bottle gourd seeds are flat and the common shape is rectangular with rough and ridged seed coat, the proximal end of which is slightly pointed and the distal end is slightly broader (Fig. 11a,b,c,e,g). Distal end is variously grooved in these normal seeds. Some of the genotypes with normal seed possess additional stable structural abnormality which may be used as morphological genetic marker of the genotype. For instance, the variety Narendra Rashmi possesses 15-20% hooded seeds (Fig. 11e) on one side and Narendra Shivani possesses about 20% crooked and curved seeds (Fig. 11h). In normal category seeds with rough ridged seed coat some genotypes possess triangular seed shape, the proximal end of which is conical and distal end is remarkably

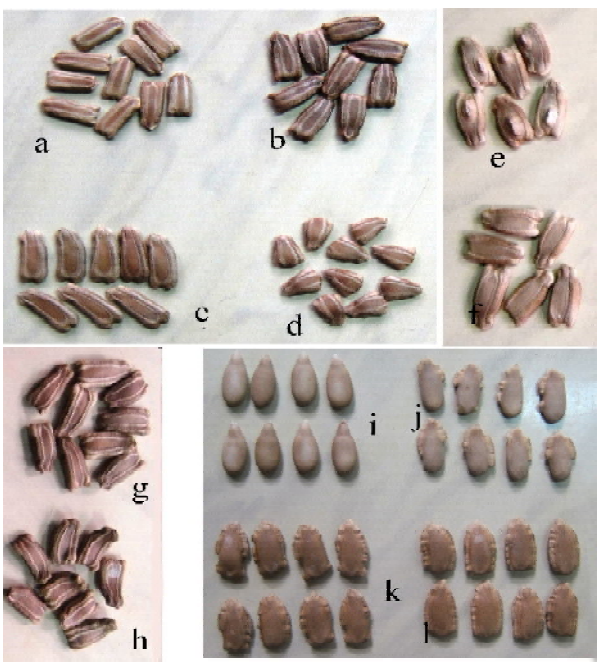


Fig. 11. Variability in seed shape, size and colour of bottle gourd: a. and b. normal rectangular seeds of bottle gourd as in Narendra Madhuri and Narendra Bow-Wonder, respectively, c. curved headed seeds of Narendra Shishir, d. triangular seeds of NDBG-619, e. normal seeds of Narendra Rashmi, f. hooded seeds of Narendra Rashmi, g. normal seeds of Narendra Shivani, h. crooked seeds of Narendra Shivani, i. smooth seeds of NDML-SS-4, j, k and l. variously winged smooth seeds of bottle gourd genotypes.

broad (Fig. 11d). Apart from the rough and ridged seed coat category there is an entirely different category with smooth seed coat (Fig. 11i,j,k,l). In smooth seed category the seed of some genotypes may be simple with acutely pointed proximal end and broad concave distal end (Fig. 11i) while the other genotypes may possess variously winged seeds (Fig. 11j,k,l). Mature and dried seeds of both rough and smooth coated seeds may be scaly or non-scaly. Scaly genotypes possess translucent very fine layer of scale cover on the mature seeds, which loosens and wear off as the seeds dry. Majority of genotypes have scaly seeds and a few have non-scaly seeds. Pusa Naveen, Narendra Jyoti, NDBG-619, Narendra Shivani, and Narendra Bow-Wonder have highly scaly seeds, whereas, Narendra Rashmi, Narendra Shishir, and Narendra Madhuri possess non-scaly seeds. Scaly and non-scaly traits can be used as stable genetic marker of the genotypes.

Earliness and yield: Remarkable variability is recorded among bottle gourd genotypes with respect to earliness. Node number to first staminate flower anthesis among genotypes varies from 6th to 50th node and node number to first pistillate flower anthesis varies from 10th to 55th node. Days to first staminate flower anthesis generally varies from 40 to 70 days whereas for first pistillate flower anthesis it varies from 40 to 90 days. Node number and days to first staminate and first pistillate flower anthesis for the same genotype are highly influenced by season of planting, soil type and other environmental factors. Bottle gourd is a widely grown crop in Uttar Pradesh. Fruit yield levels

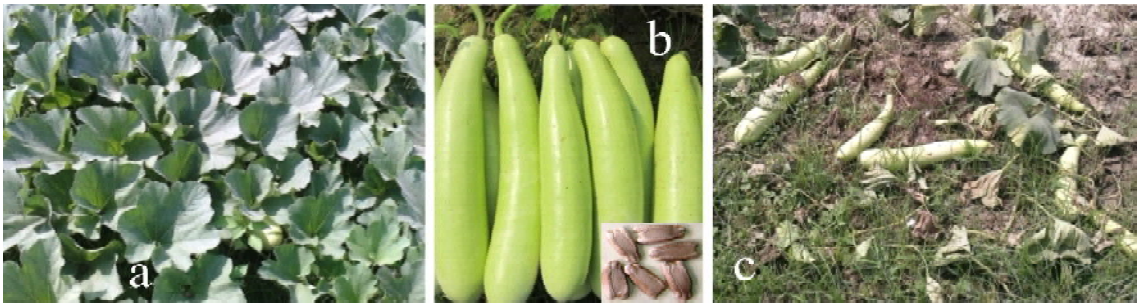


Fig. 12. Narendra Rashmi a bottle gourd variety with field resistance against Fusarium wilt: a. field view of seed crop at 85 days stage, b. a heap of tender fruits of Narendra Rashmi and normal seed in the inset, c. seed crop of susceptible control Narendra Jyoti at 85 days stage.

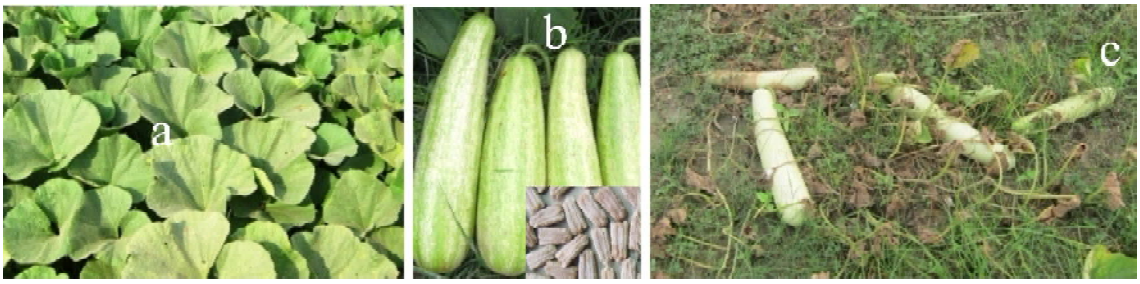


Fig. 13. Narendra Dharidar a bottle gourd variety with field resistance against fusarium wilt: a. field view of seed crop at 85 days stage, b. a heap of tender fruits of Narendra Dharidar and normal seed in the inset, c. seed crop of susceptible control NDBG-619 at 85 days stage.

of bottle gourd open pollinated and hybrid varieties generally vary from 200 to 700 q/ha. The fruit yield is influenced by the yield potential of the variety, season of planting, method of cultivation, crop care, etc. July-August sown winter crop of photoperiod sensitive bottle gourd genotypes have

Fig. 14. NDML-SS-4 a round striped fruited bottle gourd genotype with field resistance against fusarium wilt: a. field view of seed crop at 85 days stage, b. a heap of tender fruits of NDML-SS-4 and smooth seed in the inset, c. seed crop of susceptible control NDBG-613 at 85 days stage.

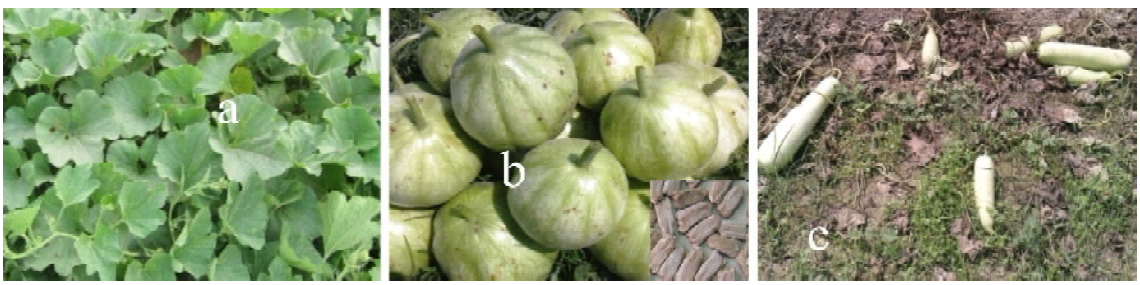


Fig. 15. NDML-NS- 7 a round striped fruited bottle gourd genotype with field resistance against fusarium wilt: a. field view of seed crop at 85 days stage, b. a heap of tender fruits of NDML-NS-7 and normal seed in the inset, c. seed crop of susceptible control Pusa Naveen at 85 days crop stage.

shown maximum yield potential on trellis system of cultivation as compared to summer type genotypes grown during summer and rainy season crops. Singh (2008) recorded an yield potential of 1900 q/ha in a photoperiod sensitive bottle gourd hybrid Narendra Madhushree in mid-July sown winter crop.

Resistance: Bottle gourd genotypes exhibit variability in resistance against important biotic and abiotic stresses. Bottle gourd cultivar Renshi from Taiwan is reported to be highly resistant against fusarium wilt (Matsuo *et al.*, 1985). The varieties Narendra Rashmi (Fig. 12) and Narendra Dharidar (Fig. 13) as well as striped round fruited genotypes NDML-SS-4 (Fig. 14) and NDML-NS-7 (Fig. 15) developed at NDUAT, Faizabad, have been found to exhibit field resistance against fusarium wilt. Sources of resistance to viruses in bottle gourd have been reported by Provvidenti, (1981). A bottle gourd variety Cow leg grown in Taiwan has multi-viral resistance (Provvidenti, 1995). The winter type bottle gourd variety Narendra Shishir developed at NDUAT, Faizabad has also shown high degree of field resistance against viral diseases of bottle gourd. Narendra Shishir is a multiple disease resistant genotype against Anthracnose, downy mildew, powdery mildew, and viral disease complex (Singh, 2008). Powdery mildew resistance of Narendra Shishir in a cross combination

with a powdery mildew susceptible genotype was recorded to be recessive in F_1 hybrid (Singh *et al.,* 2008). Nath (1964), and Vashishtha and Chaudhary (1972) have reported resistance against red pumpkin beetle in NB 28 and Sl 28, respectively. NB 29 has been found resistant against both red pumpkin beetle and fruit fly (Nath, 1964).

Photoperiod insensitive and sensitive genotypes in bottle gourd

With respect to photoperiod sensitivity, bottle gourd land races/varieties can broadly be categorized as i. photoperiod insensitive or summer type genotypes *viz.* Pusa Naveen, Narendra Rashmi (Fig. 12a,b), Narendra Dharidar (Fig. 13a,b), Narendra Jyoti etc. and ii. photoperiod sensitive or winter type genotypes *viz*. Narendra Madhuri (Fig. 9b), Narendra Shivani (Fig. 9a), NDBG-713 (Fig. 9c), Narendra Bow-Wonder (Fig. 9d), NDBG-712, and Narendra Shishir (Table 2). Phatoperiod sensitivity is short day type and the degree of sensitivity differs among photoperiod sensitive genotypes. The data in Table 2, indicate that Narendra Madhuri, Narendra Shivani, Narendra Bow-Wonder and NDBG-713 are moderately photoperiod sensitive genotypes, requiring in between 12 hr 24 minutes to 12 hr 12 minutes day length for pistillate flower anthesis, whereas, NDBG-712 and Narendra Shishir are highly photoperiod sensitive which require 11 hr 50 minutes short day length for pistillate flower production. Photoperiod insensitive genotypes can be planted in any month of the year for different cropping periods. Whereas, photoperiod sensitive genotypes should be planted in July-August months, for proper flowering and fruiting in the offing months having short days. The flowering and fruiting behaviour of photoperiod sensitive and insensitive genotypes can be demonstrated with the results of experiments conducted under different cropping periods having distinct photoperiods. The performance of six winter type (photoperiod sensitive) genotypes in 4th July, 2012 sown winter crop, having short days, is given in Table 2. In this cropping period all the potoperiod sensitive genotypes produced high yield levels in the range of 867.36 q/ha (Narendra Madhuri) to1189.64 q/ha (Narendra Bow-Wonder). To evaluate the yield and yield attributes performance during long summer days the four photoperiod sensitive genotypes, five photoperiod insensitive genotypes, and six cross combinations of photoperiod sensitive × photoperiod insensitive genotypes, were planted on 5th April, 2013 for summer crop (Table 3). The yield performance of photoperiod insensitive genotypes produced satisfactory fruit yield ranging from 249.42 q/ha

Table 2. Yield and yield attributes data on 4th July, 2012 sown winter type bottle gourd genotypes.

S. No.	Genotype	Node to first staminate flower anthesis	Node to first pistillate flower anthesis	Days to first staminate flower anthesis	Days to first pistillate flower anthesis	Date of first pistillate flower anthesis	Day length for first pistillate flower anthesis	Yield (q./ha.)
1.	Narendra Madhuri	25	34	56	65	07.09.2012	12 hr 24 min	867.36
2.	Narendra Shivani	52	50	62	66	08.09.2012	12 hr 24 min	945.20
3.	Narendra Bow- Wonder	27	54	58	70	12.09.2012	12 hr 16 min	1189.84
4.	NDBG-713	38	37	60	72	14.09.2012	12 hr 12 min	1034.16
5.	Narendra Shishir	50	61	75	86	28.09.2012	11 hr 50 min	1056.40
6.	NDBG-712	41	74	60	86	28.09.2012	11 hr 50 min	1000.80

(Narendra Jyoti) to 326.63 q/ha (NDBG-619), whereas, photoperiod sensitive genotypes produced sporadic staminate flowers and scarcely a few pistillate flowers in only one or few plants, which produced only very low yield levels ranging from 4.0 q/ha (NDBG-713) to 38.55 q/ha (Narendra Bow-Wonder).

The cross combinations *viz.,* NS × NR, NBW × NR, NBW × PN and NDBG-713 × PN, produced moderate fruit yield and behaved more or less like photoperiod insensitive genotypes,

Table 3. Comparative performance of photoperiod insensitive, photoperiod sensitive and their cross combinations during long summer season crop in 5th April, 2013, sown crop.

S.No.	Genotypes	Node to first male flower	Node to first female flower	Days to first staminate flower	Days to first pistillate flower	Days to first picking	Fruit yield (q/ha)	Vine length (m)
Photoperiod insensitive genotypes								
1.	Narendra Rashmi (NR)	10.50	14.09	40.67	43.33	51.67	321.08	5.17
2.	Pusa Naveen (PN)	8.67	10.33	40.67	42.33	49.33	252.53	5.69
3.	Narendra Jyoti (NJ)	12.16	13.17	43.67	42.67	52.67	249.42	6.23
4.	Narendra Dharidar	15.06	13.44	48.00	45.33	54.00	292.86	5.78
5.	NDBG-619	9.61	14.00	40.33	41.33	52.00	326.63	6.62
Photoperiod sensitive genotypes								
6.	Narendra Shishir (NS)	28.39*	28.39*	57.33*	62.33*	69.33*	14.77	7.50
7.	Narendra Bow- Wonder (NBW)	23.06*	36.33*	57.33*	60.67*	69.33*	38.55	8.90
8.	NDBG-712	17.11*	28.39*	50.67*	54.00*	67.33*	04.00	9.07
9.	NDBG-713	26.33*	32.67*	52.67*	57.33*	72.50*	10.37	9.92
Photoperiod sensitive x photoperiod insensitive cross combinations								
10.	NS x NR	15.83	18.89	49.00	49.00	55.33	177.43	7.37
11.	NBW x NR	13.26	17.56	47.33	50.00	58.00	135.76	7.07
12.	NBW x PN	12.83	19.11	47.33	51.00	57.00	164.76	6.72
13.	NBW x NJ	21.89	33.96	55.67	60.33*	72.67*	10.67*	10.31
14.	NDBG-712 x PN	12.81	18.13	45.67	52.33	60.33	45.21	8.34
15.	NDBG- 713 x PN	13.98	20.24	45.67	47.33	55.33	122.99	8.14

*Observations based on one or few plant(s) of the plot

while the cross combinations NBW × NJ and NDBG-712 × PN behaved like photoperiod sensitive genotypes. Thus flowering and fruiting behaviour of photoperiod sensitive × photoperiod insensitive cross combinations revealed that photoperiod insensitivity was fairly dominant over photoperiod sensitivity in four cross combinations, while in the remaining two cross combinations photoperiod sensitivity was dominant over insensitivity. This observation is of practical significance in the sense that for summer season cultivation desirable attributes like biotic and abiotic resistance of photoperiod sensitive genotypes can be fruitfully exploited in those cross combinations where insensitivity is dominant over sensitivity. It is important to record that in general photoperiod sensitive genotypes and their cross combinations with photoperiod insensitive genotypes produce longer vines.

3 SPONGE GOURD

Origin, history, and use

Sponge gourd [*Luffa cylindrica* Roem. syn. *L. aegyptica* Mill.] known as *ghia tori* or *torai* in Hindi, is an annual monoecious species. 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 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 an Arabic origin because of sponge characteristic in Egyptian writing. *Kosataki* and *dharmaragava* are the equivalent name in Sanskrit for luffa. Immature tender fruits of non-bitter varieties are of major economic importance and used as cooked vegetable. The fibrous spongy network of mature dried fruits, after extraction of seeds, are used as body and utensil scrubber, insulating material, shoe soles, pillow stuffs, industrial filter etc. Various parts of bitter and non-bitter sponge gourd have medicinal properties.

General morphology and biodiversity

Nodal organs in 'typical monoecious' genotypes: *Luffa* is usually monoecious in nature in which staminate and pistillate flowers are found on the same node. In reproductive phase the sponge gourd vine nodes have potential of bearing seven organs *viz.* leaf, tendril, branch, bract, solitary pistillate flower, androecious raceme (Fig. 4g) and adventitious root (Fig. 5a). The bracts of sponge gourd are glandular which is frequently visited by ants. Except adventitious root the remaining six organs are present in fixed position on the node (Fig. 4g). Position of leaf and other nodal organs have been described in chapter 1.

Nodal organs in 'androgynous monoecious' genotypes: In few land races it is recorded that androecious racemes are stably replaced by androgynous racemes i.e. a raceme bearing both staminate and pistillate flowers. Presence of the remaining six organs, *viz.* leaf, tendril, branch, bract, solitary pistillate flower, and adventitious root, is as usual. Singh *et al*. (2012) isolated yet other variants 'androgynous monoecious' genotypes of sponge gourd, *viz.* Androgyne-1, Androgyne-4, and Androgyne-7, which were basically monoecious in nature but had a distinctly different floral arrangement, along with deviations in some other nodal organs. In these variants the true branch, bract and solitary pistillate flower were conspicuously absent from every vine node (Fig. 17a) . In place of androecious racemes of typical monoecious genotypes, these variants had androecious or androgynous racemes on different nodes. Thus these variants had only four nodal organs potential

Fig.16. Variability in leaf, flower, fruit and seed characters of sponge gourd: a. and b. mildly lobed leaves, c. and d. moderately lobed leaves, e, f, g, h. acutely lobed leaves, i, j, k, l. variation in corolla shape, size and colour, m, n, o. variation in fruit shape, size and colour, p. deep black seeds, q. light black seeds, r. light brown seeds, s. white seeds.

viz. a leaf, a tendril, an androecious or androgynous raceme, and an adventitious root. In these genotypes some of the androecious and androgynous racemes got converted into full length branches. The three androgynous lines differed in their behaviour of expression of androecious and androgynous racemes as well as conversion of androecious and androgynous racemes into full length branches. A small frequency of the androecious as well as androgynous racemes of Androgyne-1 and Androgyne-4 got converted into full length branches (Fig. 17f,g). Androecious racemes more frequently converted into branches than androgynous racemes in Androgyne-1 and Androgyne-4, whereas none of the androecious and androgynous racemes of Androgyne-7 converted into a branch. Androgyne-1 bore only one pistillate flower in its androgynous raceme, which was constantly at first position in the raceme (Fig. 17a,b). Androgyne-4 had two to seven pistillate flowers, generally placed at initial position in the androgynous racemes (Fig. 17c). Androgyne-7 had seven to ten pistillate flowers in androgynous racemes (Fig. 17.d). At lower temperature of December and January, Androgyne-7 bore only gynoecious racemes with 15 to 20 pistillate flowers (Fig. 17e). Fruits developing on androgynous racemes were sessile (Fig. 16i,j) and dissimilar in shape and size (Fig. 17k). All the three androgynous lines produced quite low yield with poor marketable quality.

Genetics of 'typical monoecious' and 'androgynous monoecious' floral arrangements: Homozygous 'androgynous monoecious' line Androgyne-4 with 'four organs node potential' was crossed with another homozygous 'typical monoecious' genotype NDSG-5, having 'seven organs node potential'. All the F_1 plants had 'androgynous inflorescence' with 'four organs node potential', indicating dominance of 'androgynous monoecious' trait with 'four organs node potential' over 'typical monoecious' trait with 'seven organs node potential'. A gene symbol 'A^{dgn}' is proposed for the mutant gene determining androgynous inflorescence in the 'androgynous monoecious' lines, and the counterpart allele' 'a^{dgn}' for expression of typical monoecious genotypes. The F_2 and BC_1 segregation data very vividly revealed monogenic dominance of allele 'A^{dgn}' over that of normal allele 'a^{dgn}'. The 'four organs node potential' associated with androgynous inflorescence inherited together. It is concluded that the 'A^{dgn}' has the pleiotropic effect on the expression of morphological organs on the node and several other unusual behaviour. Distinct variations in androgynous monoecious lines Androgyne-1, Androgyne-4 and Androgyne-7 suggested that the expression of the gene 'A^{dgn}' is influenced by background minor genes. The occurrence of advanced form of androgynous inflorescence as compared to androecious inflorescence is a direct evidence of advancing speciation in *L. cylindrica* (Singh *et al*., 2012).

Leaves and vines: Presence of one leaf on each node is a constant feature. Leaves are simple in shape but may be variously lobed (Fig. 16a to h). Sponge gourd genotypes may possess mildly lobed leaves (Fig. 16.a,b), moderately lobed leaves (Fig. 16c,d) or deeply lobed leaves (Fig. 16e,f,g,h) in varying dimensions. The leaf size may be small, medium or large. The leaf shape and size on the same plant also varies depending upon the plant growth stage and agro-climatic conditions (temperature and humidity) through which the plant advances to complete its life cycle. The leaf colour may be light green, green or dark green. The vines of different sponge gourd genotypes may be short, moderately long or very long. The number of primary and secondary branches also varies to a great extent. The colour of the vine may be pale green, green or dark green. The colour of vine

Fig. 17. Floral arrangements and fruiting behaviour of androgynous lines Androgyne-1, Androgyne-4 and Androgyne-7: a. a vine bearing an androecious raceme on one node (left) and androgynous raceme (right) on another node in Androgyne-1, b. a typical androgynous raceme of Androgyne-1, c. a typical androgynous raceme of Androgyne-4, d. a typical androgynous raceme of Androgyne-7, e. a gynoecious raceme of Androgyne-7, f. an androecious raceme of Androgyne-4 converting into full length branch, g. an androgynous raceme of Androgyne-4 converting into a full length branch, h. a fruit with peduncle of a normal sponge gourd genotype, i. a sessile fruit developing in androgynous raceme of Androgyne-1, j. two sessile fruits developing in androgynous raceme of Androgyne-4, k. fruits of Androgyne-7 with dissimilar shape and size.

is linked with the leaf and fruit colour. Genotypes with the pale green fruit colour have pale green vine and those having dark green fruit colour have dark green vine.

Tendrils, bracts, and adventitious roots: Sponge gourd vine nodes usually bear single extra axillary long tendrils measuring 25-30 cm. The first tendrils are formed at 6th to 8th node of seedling growth stage. The genotypes may possess 3-7 unequal tendril branches, which may be used as

genetic marker of the genotype. The same plant of a genotype may differ in number of tendril branches by 1 or rarely by 2. For instance a genotype may bear 3 or 4 tendril branches on different vine nodes of the same plant and another genotype may have 4 or 5 tendril branches on different nodes. An unusual occurrence of underdeveloped pistillate flower in the axil of a branched tendril (Fig. 2k) suggested that tendril in sponge gourd is a modified branch. Bracts are constant feature of all sponge gourd genotypes, except in Androgyne isolates reported by Singh *et al.* (2012). Minor variations in bract size are also recorded among genotypes. Formation and development of adventitious roots is a common feature in sponge gourd as in other cucurbits.

Sex form and floral biology: As described earlier sponge gourd is typically monoecious. Flowers in sponge gourd are conspicuously large and bright yellow in colour, the size and shape of which varies among the genotypes (Fig. 16i,j,k,l). Commonly the staminate flower size is distinctly smaller on the same plant as compared to the pistillate flower size. Noticeable variability is recorded among the genotypes with respect to staminate and pistillate flower sex ratio. It is a common observation that some genotypes produce high frequency of well developed solitary pistillate flowers on the consecutive nodes accompanied with the tendency of formation of underdeveloped androecious racemes. Usually in common genotypes first staminate flower anthesis takes place earlier at lower node number and first pistillate flower anthesis takes place a few days later at higher node of the vine but the sequence changes in early/prolific genotypes. During summer anthesis and dehiscence takes place at around 4:45 a.m.

Fruit characters: Great variability is recorded in sponge gourd fruit shape, size and colour (Fig. 16m,n,o). The fruit shape may be categorized as very long, long, oblong, or short. The fruits at maturity may have ridges and grooves of varying intensity. The length of full grown fruits commonly varies from 15 to 40 cm. The fruit colour of sponge gourd may be patchy pale green, patchy green or patchy dark green. Patches of whitish green colour are generally arranged in ten straight lines corresponding to very mildly grooved stripes formed on the surface of the tender fruits.

Palatability and bitterness: Fruits of cultivated genotypes are generally non-bitter or sweet. Palatability of cooked vegetable varies among non-bitter genotypes. Occasionally bitter genotypes are also encountered and they should never be used for consumption because they are poisonous. Non-bitter genotypes are found to produce mildly bitter fruits on the same plant under cool temperature conditions.

Seed characters: Great variability is recorded in shape, size and colour of seeds. Invariably sponge gourd seeds are flat and oblong round in shape (Fig. 16p,q,r,s) but minor variations are recorded in size. The seeds of different genotypes may be variously winged. The seed colour of sponge gourd varies from bright white to deep black (Fig. 16p,q,r,s). Seeds of all genotypes are highly scaly.

Earliness, yield, and resistance: Sponge gourd genotypes are recorded to vary with respect to their earliness. In July sown crop first staminate flower anthesis is recorded from 7th to 25th node and first pistillate flower anthesis occurs from 15th to 30th node. The range of days to first staminate and first pistillate flower anthesis are recorded from '30 to 60 days' and '35 to 85 days', respectively. Fruit yield and resistance against biotic and abiotic stresses also vary to a great extent.

Photoperiod insensitive and sensitive genotypes in sponge gourd

The experiments conducted over the years and seasons at NDUAT, Faizabad, have vividly revealed that their exist two distinct groups of sponge gourd genotypes, *viz.* **i.** summer type - photoperiod insensitive genotypes and **ii.** rainy season/winter type -photoperiod sensitive genotypes. Photoperiod sensitivity in sponge gourd is short day type, like that of bottle gourd. After attaining a minimum vegetative growth, the photoperiod sensitive genotypes have different short day length requirements for flowering, particularly for normal pistillate flower production. Thus, the photoperiod sensitive genotypes may be subdivided into three categories. Some genotypes are mildly photoperiod sensitive (requiring only about 12 hrs 30 minutes critical short day length), some are moderately sensitive (requiring about 12 hrs 10 minutes critical short day length), while others are highly photoperiod sensitive (requiring about 11 hrs 50 minutes critical short day length), for normal pistillate flower production. Photoperiod sensitive genotypes if ignorantly planted in Feb-March, for summer season crop, they exhibit only luxuriant growth and produce shy staminate and very sporadic pistillate flower during long days of summer months (ranging in between 12 hrs 36 minutes to 13 hrs 34

Table 4. Varying short day length requirements of photoperiod sensitive sponge gourd genotypes in 31st July, 2011 sown crop

S. No.	Genotypes	Node to first staminate flower anthesis	Node to first pistillate flower anthesis	Days to first staminate flower anthesis	Days to first pistillate flower anthesis	Date of first pistillate flower anthesis	Day length required for first pistillate flower anthesis	Days to first fruit harvest	Fruit yield (q/ha)
Photoperiod insensitive genotypes									
1.	NDSG-1	7	15	31	36	05.09.2011	12 hr 26 min *	39	96
2.	NDSG-2	10	17	33	38	08.09.201	12 hr 24 min *	42	110
Mildly photoperiod sensitive genotypes									
3.	Androgyne-7	11	14	31	30	30.08.2011	12 hr 36 min	41	67
4.	Androgyne-1	11	21	32	34	03.09.2011	12 hr 28 min	42	111
5.	NDSG-4B	11	23	36	38	07.09.2011	12 hr 24 min	42	240
Moderately photoperiod sensitive genotypes									
6.	NDSG-10	16	24	40	42	11.09.2011	12 hr 18 min	47	270
7.	NDSG-7	16	25	45	46	15.09.2011	12 hr 10 min	60	223
8.	NDSG-5	12	23	44	48	17.09.2011	12 hr 08 min	56	163
Highly photoperiod sensitive genotypes									
9.	NDSG-128	20	28	53	59	28.09.2011	11 hr 50 min	67	187
10.	NDSG-127	22	29	54	60	29.09.2011	11 hr 50 min	67	196

*specific photoperiod not required for photoperiod insensitive genotypes

minutes). The sporadically formed pistillate flowers are generally rudimentary which wither and die and only a few of them are normal and scarcely turn into fruits. Normal staminate and pistillate flowering and fruiting in February-March sown photoperiod sensitive genotypes begin 6 to 7 months after planting, depending upon the degree of photoperiod sensitivity, when the day length drops to 12 hrs 36 minutes or lower. When planted in last week of July the mildly and moderately photoperiod sensitive genotypes receive short day photoperiod requirements to produce first pistillate flowers in about 30 to 45 days, while highly photoperiod sensitive genotypes produce first pistillate flowers in about 60 days after planting (Table 4).

4 RIDGE GOURD

Origin, history, and use

Ridge gourd or ribbed gourd [*L. acutangula* (L.) Roxb.] known as *kali tori* or *ara tori* in Hindi, is an annual monoecious species of Indian origin. Immature tender fruits of non-bitter varieties are of major economic importance and used as cooked vegetable. Like sponge gourd the fibrous spongy network of mature dried fruits is used in several ways. In ancient Sanskrit scripts it has been called as '*ervaruka*' and '*kratavedhana*' and various plant parts of the species have been reported to be useful in asthma, conjunctivitis, emetic, diuretic, laxative, leprosy and leprous ulcers, purgative, dysentery, haemorrhoids and eruption, cathartic etc.

General morphology and biodiversity

Ridge gourd is strictly monoecious in nature where staminate and pistillate flowers are found on the same node. In reproductive phase the ridge gourd vine nodes have potential of bearing seven organs *viz.* leaf, tendril, branch, bract, solitary pistillate flower, androecious raceme (Fig. 18a) and adventitious root. The bracts of ridge gourd are glandular which are frequently visited by ants. In vegetative phase flowers are not present. Except adventitious root the remaining six organs are present in fixed position on the node like that of sponge gourd. Some of the nodes are found to bear solitary axillary staminate flowers in place of solitary pistillate flowers, along with androecious raceme (Fig. 18b). Easily observable morphological biodiversity is recorded in leaf, tendril, vine, flower and fruit characters. Leaves are simple in shape (Fig. 18c) but may be variously lobed (Fig. 18d). The leaf size and colour varies among genotypes. Ridge gourd vine nodes usually bear single extra axillary long tendrils measuring 25-30 cm in length. The first tendrils are formed at 6^{th} to 8^{th} nodes of seedling growth stage. The genotypes may possess 4-5 unequal tendril branches (Fig. 2g), which may be used as genetic marker of the genotypes. The same plant of a genotype frequently differs in number of tendril branches.

Ridge gourd flowers are about half of the size (Fig. 18d) of sponge gourd flowers, which measure 4.30 - 6.00 cm in diameter. They are light yellow in colour. Generally the staminate flower size is smaller on the same plant as compared to the pistillate flower size. Noticeable variability is recorded among the genotypes with respect to staminate and pistillate flower sex ratio, in the sense that genotypes differ in tendency of production of solitary pistillate flowers and raceme of androecious flowers. Dehiscence in staminate flower occurs at around 4:30 p.m. and anthesis in both staminate and pistillate flowers takes place an hour later i.e. at around 5:30 p.m. Great variability is recorded in ridge gourd fruit shape, size and colour (Fig. 18e,f). The fruit shape may be categorized as very long, long, oblong, or short as that of sponge gourd. Very long fruits get curved unless they hang. The longest full grown fruits measure about 150 cm. For marketable purpose straight tender fruits are preferred (Fig. 18e,f). The fruits at tender as well as full grown stage are marked by ten sharp

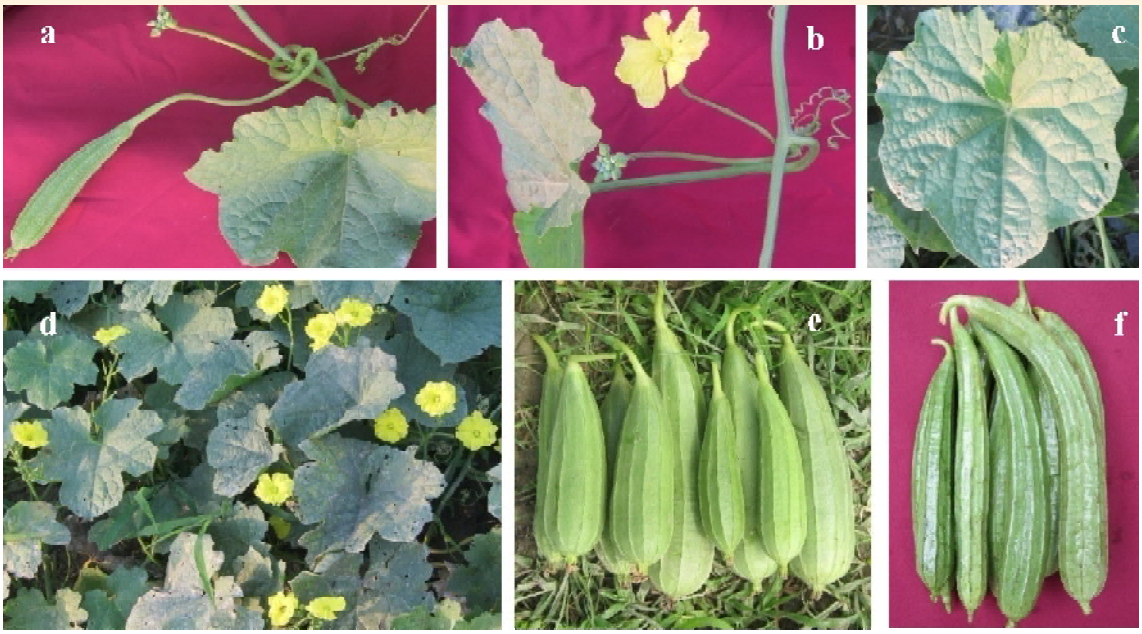


Fig. 18. Floral arrangement and variability in leaf and fruit characters of ridge gourd: a. a node showing androecious raceme and a solitary pistillate flower turning into a fruit, b. an unusual node with an androecious raceme and a solitary staminate flower, c. very mildly lobed leaf, d. moderately lobed leaves and bloom in the evening, e. and f. variability in fruit shape, size and colour of tender fruits.

straight mildly raised ridges alternating to ten grooves. The intensity of ridges and grooves varies among genotypes. The fruit colour of ridge gourd may be pale green (Fig. 18e) or green (Fig. 18f). Fruits of cultivated genotypes are generally non-bitter or sweet. The palatability of cooked vegetable varies among genotypes. The seeds are flat oblong in shape and black in colour (Fig. 6o). Seed surface is slightly rough as compared to sponge gourd seeds. Very little variability is recorded in shape, size and colour of seeds. Ridge gourd genotypes vary with respect to their earliness, fruit bearing capacity, and the degree of resistance against biotic and abiotic stresses.

Surveys of the farmers' field and availability of the fruits in the local vegetable markets in Uttar Pradesh suggest that ridge gourd is a hardy crop as compared to sponge gourd. Ridge gourd fruits arrive in bigger heaps to the market and they are relatively less damaged by insects during rainy season as compared to sponge gourd fruits. The market sale rates of ridge gourd are generally lower compared to sponge gourd, although ridge gourd is considered to be sweeter and tastier than sponge gourd. All the apparent drawbacks of ridge gourd lie in its rough and ridged surface as compared to smooth surface of sponge gourd. Whether ridge gourd genotypes differ with respect to photoperiod sensitivity is a matter of study. It is interesting to note that ridge gourd is never recorded growing in wild on roadsides like sponge gourd.

5 SATPUTIA

Origin, history, and use

Satputia once identified as *Luffa hermaphrodita* by Singh and Bhandari (1963) is still recognized as botanical variety of [*L. acutangula* (L.) Roxb.]. It is commonly considered as hermaphrodite in its sex form, however, several stable and unstable sex forms, *viz.* hermaphrodite, andromonoecious, monoecious, and gynoecious, were reported by Singh, *et al*. (1948). *Satputia* has religious significance in eastern Uttar Pradesh and neighbouring Bihar, where ladies break their 24 hours' fast of a local festival '*jiutiya'* by eating cooked vegetable of *satputia*.

General morphology and biodiversity

The hermaphrodite genotypes of *satputia* vine nodes in its reproductive phase have 'seven organs potential' (Fig. 19a) like sponge gourd and ridge gourd. The seven nodal organs are a leaf, a tendril, a bract, a branch, a solitary hermaphrodite flower, a raceme of hermaphrodite flowers and an adventitious root. These organs are arranged exactly in similar ways as that of sponge gourd or ridge gourd, except that solitary flower or the flowers in raceme are all hermaphrodite. Leaf, tendril and bract are the obligatory organs of every vine node, whereas, out of the remaining four nodal organs a varying combination of organs are formed on the growing vine nodes, as per the growing condition of preceding and succeeding nodes. For instance a vine node may bear a branch and a solitary pistillate flower combination (Fig. 19b) or it may have developed raceme of hermaphrodite flower and an inhibited branch growth (Fig. 19c).

Size of leaf, flower, fruit and seed are generally smaller than ridge gourd. Leaves are mildly to moderately lobed and differ in size and colour. Tendrils are long (25-30 cm) and have four to five branches like ridge gourd (Fig. 2a). Nature of tendril branching differs. Generally the genotypes have branching initiation at a distance from the node but in some genotypes branching may initiate just near the node (Fig. 2a). Flowers of *satputia* are light yellow (Fig. 19j) like ridge gourd but flower size is slightly smaller with a flower diameter of 4.00 to 4.50 cm. Anthesis and dehiscence occurs at around 5:00 p.m. during summer. The fruits may be elongated, oblong or round (Fig. 19e,f,g,h,i). The fruit skin may be smooth (Fig. 19e) or ridged (Fig. 19f). *Satputia* seeds are smaller in size as compared to ridge gourd and shining deep black in colour. The seeds are highly scaly and vary in size among genotypes (Fig. 6r). The farmers use local land races of *satputia* for cultivation. The cultivation of *satputia* is generally limited to poor farmers with small holdings. It is generally grown as intercrop with maize or trained on the fences of the borders of the fields. The produce that reaches the market contains mixtures of all kinds of fruit shape, size and skin structures. It is a popular vegetable in eastern Uttar Pradesh, generally cultivated during rainy season and very occasionally during summer season. Differences occur in fruiting and yield potential of land races. Selection of genotypes with high yield and uniformity will prove a boon to the farmers.

Fig.19. Floral arrangement and variability in leaf and fruit characters of *satputia*: a. raceme of hermaphrodite flowers and a solitary hermaphrodite flower on a node of hermaphrodite *satputia*, b. a node with only solitary hermaphrodite flower turning into fruit, c. a node with only raceme of hermaphrodite flowers turning into fruits, d. a node of andromonoecious satputia with a raceme of staminate flower and a solitary hermaphrodite flower turning into fruit, e. a heap of smooth skin tender fruits of a satputia genotype, f. a heap of ridged skin tender fruits of a satputia genotype, g. a bunch of oblong fruited satputia, h. a bunch of round fruited satputia, i. variability in fruit shape of satputia, j. a satputia plant in bloom in the evening.

The surveys of *satputia* cultivation in eastern Uttar Pradesh have revealed that it is not only hermaphrodite in sex form, but andromonoecious land races (Fig. 19d) are frequently grown by villagers in districts of Faizabad, Azamgarh, Mau, Kushinagar etc. In these land races solitary hermaphrodite flower is present in the axil of leaf and staminate flowers are present in the androecious inflorescence. The full grown fruit length varies from 7 to 20 cm whereas circumference varies from 10 to 18 cm. The *satputia* fruits born out of solitary axillary hermaphrodite flowers are in general bigger than fruits born in the cluster of raceme of hermaphrodite flowers.

6 ASH GOURD

Origin, history, and use

Ash gourd [*Benincasa hispida* (Thunb.) Cogn.] also known as wax gourd, white gourd, white pumpkin and winter melon is most probably indigenous to south east Asia. It is a monotypic species of the genus *Benincasa* and unknown in wild conditions. The ash and wax names refer to the thick waxy cuticle which develops on maturing fruits. The term *hispida* refers to the hirsute pubescence on the foliage and immature fruit. Once removed after washing in stored fruits the wax layer reappears. Full of nutritive and medicinal values ash gourd is called '*kusmand'* in Sanskrit. In Hindi ash gourd is known by various names like *petha*, *bhatua* etc. The mature fruits can be stored for 6-12 months at ambient temperature. The waxy coat preserves moisture content of fruits and protects the fruits from insects and pathogen damage. The genotypes vary in keeping quality. In eastern Uttar Pradesh the crop has got religious significance, where ash gourd fruits are used in certain worship rituals, and hence it is locally called as *pujau kohara* (worship gourd) i.e. a gourd worth worshipping. In some parts of the country as a token of vitality an ash gourd fruit is presented to the bride and groom on the wedding day. Immature green fruits are used for preparing cooked vegetable whereas mature fruits are used in candy and *badi*. *Petha* (ash gourd candy) is the commercial product of ash gourd. Tender leaves, vine tips and flower buds are also cooked as vegetable. Seeds are fried and consumed. Ash gourd is considered vitalizer to nervous system and the fruit juice is used in several nervous system illnesses like arthritis, epilepsy and madness. It is aphrodisiac to men and useful in venereal diseases of women. It has blood sugar lowering principle. Application of leaf extract ameliorates muscular pain on wound site as well as arthritic pain.

General morphology and biodiversity

Ash gourd is strictly monoecious crop where axillary solitary large showy yellow staminate and pistillate flowers are present on different nodes. Pistillate flowers are distinctly larger than staminate flowers on the same plant. Anthesis occurs before sunrise in between 4:45 and 5:15 a.m. In reproductive phase ash gourd vine nodes have potential of bearing six organs *viz.* i. leaf, ii. tendril, iii. branch, iv. bract, v. staminate or pistillate flower, and vi. adventitious root (Fig. 3f,g). The adventitious root on node originates under favourable soil moisture conditions. Presence of one leaf on each node is a common feature; however, an unusual behaviour of the presence of two to three leaves on nodes has been recorded (Fig. 21c,d) in the genotype NDWG-1 during August-September months in early March sown crop. The nodes bearing two leaves had two tendrils and two bracts (Fig. 21c) and those nodes bearing three leaves had three tendrils and three bracts (Fig. 21d). These abnormal nodes had also potential of developing extra flowers and branches also but due to crowded space on the node their expression was suppressed and only occasionally two flowers were seen on these nodes. The leaves are mildly lobed (Fig. 20a), moderately lobed (Fig. 20b) or deeply lobed (Fig. 20c,d). The plants bearing moderately lobed leaves in initial plant growth stage

Fig. 20. Variability in leaf and fruit characters, and cultivation of ash gourd: a. mildly lobed leaf, b. moderately lobed leaf, c. and d. deeply lobed leaves, e. round fruit shape, f and g. oblong fruit shape, h. flesh thickness, i and j. field view of ash gourd cultivation.

generally bear deeply lobed leaves in the later stages. The tendrils are medium long and have two to three unequal branches (Fig. 21a,b). Bracts are conspicuously large and may vary in size among the genotypes. The fruit shape may be round (Fig. 20e) or oblong (Fig. 20f,g) and the fruit weight may vary from 2-40 kg. Flesh thickness (Fig. 20h) is an important feature of this crop because mostly mature fruits are used for sweet preparation after scooping out the seed portion from the centre. Seeds are white in colour with rough surface (Fig. 6k) and vary in size among genotypes.

It is hardy and high yielding crop that grows in even abandoned places on huts and house tops, apart from its organized commercial cultivation in different parts of Uttar Pradesh. The cultivation of ash gourd is done during rainy season, generally on ground in specific pockets/regions from where it is transported to distant places. In the vicinity of Bareilly farmers grow ash gourd on trellis.

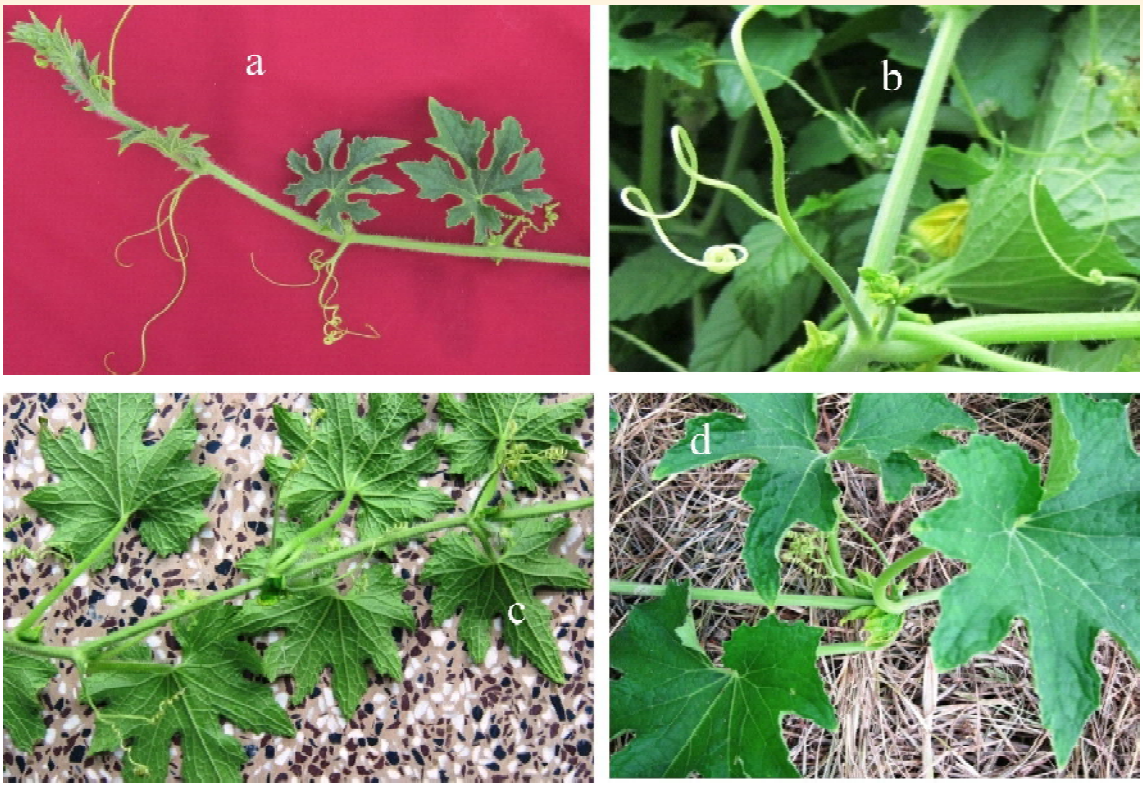


Fig. 21. Leaf and tendril arrangement in ash gourd: a. normal single leaf and single tendril arrangement on an ash gourd vine node, b. two unequal branches of a tendril, c. single leaf and single tendril on first two nodes (left), and two leaves and two tendrils on the other two nodes (right) of a vine, d. a vine node with three leaves, three tendrils and three bracts.

Kamalanathan (1972) reported that short-day length (5.7 to 6.1 hr), low maximum temperatures (29.4 to 29.9 ºC), low minimum temperatures (18.2-18.9 ºC), high relative humidity and cloudiness favoured femaleness in ash gourd.

Experiment conducted in 6th March, 2012 sown summer crop indicated that ash gourd genotype NDWG-1 continued to grow and produce fruit yield till mid-November, 2012 (Fig. 20i), while the other cucurbits like bottle gourd, pumpkin, sponge gourd, cucumber and long melon withered and died before the end of July. This observation revealed that ash gourd is relatively resistant to common biotic and abiotic stresses. A plot of size, 12 sq m produced 106 kg green fruit yield (76 fruits). The equivalent fruit yield was 883 q/ha. At the time of last picking on 16th November, 2012, average vine length was 11.50 m, with 13 branches per plant. The vine weight of single plant was 13 kg. The 16th July, 2012 sown crop of NDWG-1 produced 28 fruits weighing 40 kg fruit yield in 9 sq m size plot (Fig. 20J).

7 SNAKE GOURD

Origin, history, and use

Snake gourd [*Trichosanthes cucumerina* var. *anguina* (L.) Haines] is a cucurbit of Indian origin. It is called *chichinda* in Hindi. Because of prominent and undesirable smell of green fruits, it is normally a less preferred cucurbit at least in Uttar Pradesh, even though there remains no trace of smell in cooked vegetable. For vegetable preparation immature fruits are fried or boiled in curries. Plant parts of snake gourd are used as vermifuge, antipyretic, bilious disorder, boils and carbuncles, cardiac tonic, cathartic, emetic, febrifuge, skin eruption, laxative tonic etc. (Seshadri and More, 2009).

General morphology and biodiversity

The crop is strictly monoecious where solitary pistillate flower and raceme of staminate flowers occur on the same node. However, solitary pistillate flower may remain rudimentary on many of the nodes and many a times it is replaced by solitary staminate flower. Floral arrangement is similar to that of common genotypes of sponge gourd. Flowers are small and white in colour. Anthesis takes place around 4:30 a.m. The tendrils are long and have three unequal branches (Fig. 22b). Bracts on the node are very small. Easily observable biodiversity is recorded in shape, size and colour of leaf and fruit. The leaves may be mildly lobed or deeply lobed (Fig. 22a). Deeply lobed leaf shape was found to exhibit near complete dominance over mildly lobed leaves. The fruit length may vary from 15-150 cm (Fig. 22d). Short and medium length fruits are easy for transportation and generally medium fruit length of 25 to 30 cm is preferred over very long fruits. Fruit colour may vary from near white (whitish green) (Fig. 22e) to dark green with conspicuous white stripes (Fig. 22f). Consumers' preference for colour varies from place to place and person to person. Palatability of cooked vegetable has been recorded to differ among genotypes. The mature fruits turn into orange or red which contain seeds wrapped with bright red sheath. The seed sheath is sweet and edible. Seeds are large and have ridged undulating seed coat (Fig. 6j). Genetic study on inheritance of leaf shape revealed that deeply lobed leaf shape is monogenically dominant over mildly lobed leaf shape (Fig. 22a). The two characters segregate in the monogenic ratio of 3 deeply lobed : 1 mildly lobed.

Cultivation in Uttar Pradesh: In Uttar Pradesh, the growers generally cultivate snake gourd in June-July sown rainy season crop. Because of shy and late flowering (particularly of pistillate flowers) and fruiting, February-March sown crop is least preferred in Uttar Pradesh. To study the flowering and fruiting behaviour of snake gourd in July sown rainy season crop and March sown summer crop, the experiments were conducted on a prolific bearer snake gourd genotype Narendra Snake Gourd-1 (NDSNG-1). The observations revealed that there was early flowering and heavy fruiting in 16th July, 2012 sown rainy season crop and very late and shy bearing in 16th March, 2013

Fig. 22. Leaf, tendril, and fruit characters, and floral arrangement in snake gourd: a. deeply lobed (upper left) and mildly lobed leaves (upper right) and F_1 of the two (lower middle), b. long branched tendrils, c. an usual flowering node bearing a raceme of staminate flowers and a solitary pistillate flower turning into fruit, d. a full grown long curved fruit and a full grown fruit of very short length, e. white fruited snake gourd, f. dark green striped fruits.

Table 5. Maturity and yield data of NDSNG-1 in 16.07.2012 sown rainy season crop and 16.3.2013 sown summer season crop.

S. No.	Name of characters	Mid July, 2012 sown rainy season crop on trellis	Mid March, 2013 sown summer crop on ground
1.	Days to first male flower anthesis	37	54
2.	Days to first female flower anthesis	43	60
3.	Days to first picking	55	70
4.	Fruit yield (q/ha)	310.0	67.0

sown summer crop. The results of the experiments are presented in the Table 5. It was therefore inferred that short days with moderate temperature favour pistillate flower formation and fruiting whereas long and hot summer days play an inhibitory role in pistillate flower formation and fruiting. Venkatram (1967) also reported that shorter photoperiods (6 or 9 hrs) encouraged female phase in snake gourd.

8 POINTED GOURD

Origin, history, and use

Pointed gourd (*Trichosanthes dioica* Roxb.) is a cucurbit of Indian origin. The genus *Trichosanthes* has about 44 species of which 22 are reported from India (Chakravarthy, 1982). In Hindi pointed gourd is called as *parwal*, *patar*, and in Sanskrit it is known as *patola*. The green fruits are generally used in various preparations of cooked vegetable which is highly palatable and easily digestible. Fruits are also used in delicious sweet preparations. They become red at maturity. The fruits are diuretic. The extract of tender leaves and roots is antipyretic. Bitter fruits are non-edible but they are recommended in fever treatment in Ayurvedic system of medicine.

General morphology and biodiversity

Pointed gourd is dioecious in nature where staminate and pistillate flowers are borne on separate male and female clones. The vine nodes have potential to bear six nodal organs *viz.* a leaf, a tendril, a branch, a bract, a staminate (in male clone) or a pistillate flower (in female clone) and adventitious root. The nodal organs are typically arranged like bottle gourd. The variability is recorded in leaf shape, size and colour. The leaves are generally unlobed which may be round, palmate, cordate or elongated in shape (Fig. 23a). Moderate or deeply lobed leaves have not been recorded in any of the clones surveyed in Uttar Pradesh. The tendrils may be unbranched or may have two to three unequal branches (Fig. 23b). Unbranched and branched tendrils may be found in the same vine. In branched tendrils bifurcation takes place at the base of the tendril near the node. Bracts are small and appear undifferentiated (Fig. 23c). The flowers are white in colour and commonly solitary but cluster of two to four staminate (Fig. 23d) as well as pistillate flowers (Fig. 23e) are also recorded in staminate and pistillate clones, respectively. The anthesis of both staminate and pistillate flowers takes place in the evening in between 7:30 and 8:00 p.m. Staminate flowers open a few minutes earlier than pistillate flowers.

Most fascinating biodiversity is recorded in fruit shape, size and colour. Fruits may be round (Fig. 24a), oblong (Fig. 24b), highly elongated (Fig. 24c), spindle shaped (Fig. 24d) etc. Fruit weight may vary from 15 to 70 g and length may vary from 5 to 15 cm. The fruits may be stripeless whitish green (Fig. 24c) or conspicuously striped in various shades of green background (Fig. 24a,b,d). On maturity the fruit colour becomes bright red without distinction of stripes (Fig. 23f). The mature fruits contain 15-20 round seeds which are brown or black in colour (Fig. 6m). There are local preferences and variable market demand depending upon fruit shape, size and colour. In Varanasi and vicinity whitish stripeless fruits are preferred over striped green fruits. Flesh thickness of fruits also varies among clones. Generally thick flesh varieties are preferred. In particular large spindle shaped fruits with thick flesh are preferred in sweet preparations. Differences in cooking quality and palatability are also found. The clones are found to vary with respect to yield and yield attributes *viz.* earliness, fruit bearing capacity, vine length and thickness, insect pests and disease resistance

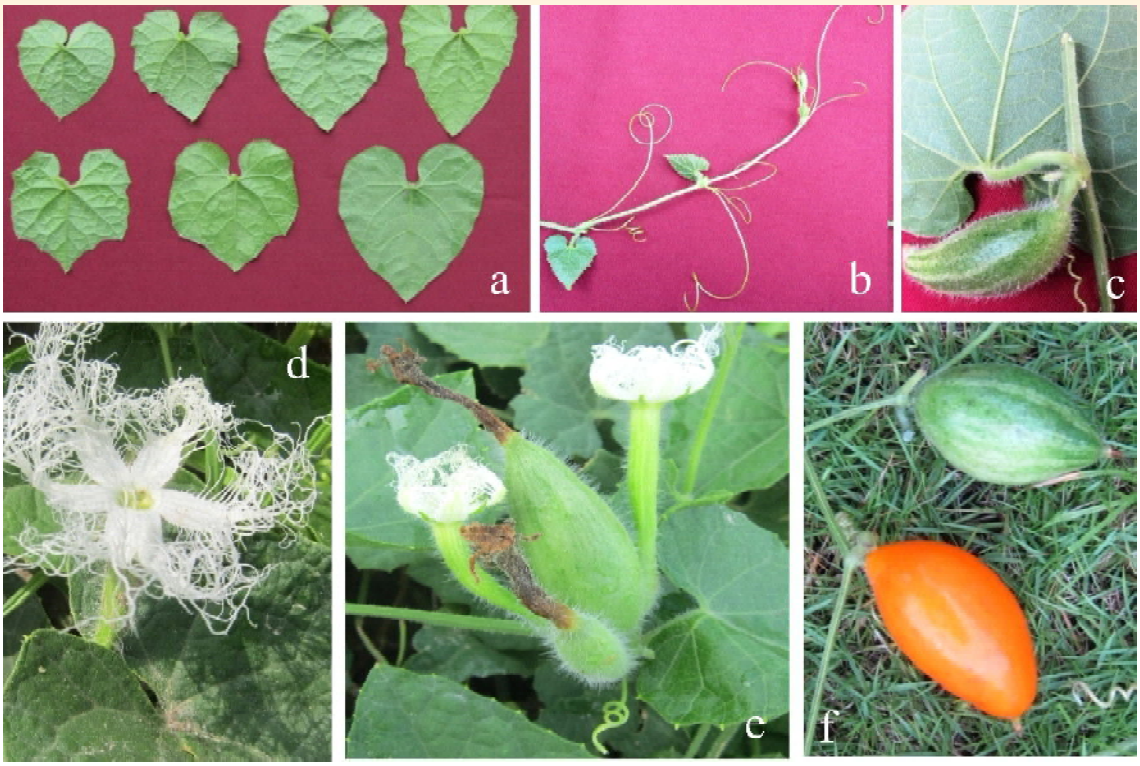


Fig. 23. Variability in leaf shape, floral arrangement, and fruit characters of pointed gourd: a. unlobed and very mildly lobed leaves, b. branched tendrils, c. very small bract at the base of pistillate flower turned into fruit, d. staminate flower in a male/androecious clone, e. pistillate flower in a female/ gynoecious clone, f. a tender green (upper) and a mature fruit (lower).

etc. Depending upon bearing capacity and crop management fruit yield of pointed gourd may vary from 100-350 q/ha. Pointed gourd is an under worked vegetable crop largely left to the brilliant skill of poor progressive farmers for its crop improvement through clonal selection.

Fig. 24. Variability in fruit shape, size and colour of pointed gourd: a. Narendra Parwal-307, b. Narendra Parwal-602, c. Narendra Parwal-601, d. Narendra Parwal-520.

Fig. 25. Variability in shelf life of pointed gourd genotypes at ambient temperature at 10 days stage: a. IVPG-1, b. Narendra Parwal-307, c. Narendra Parwal-260, d. Narendra Parwal-504.

Shelf life of fruits : Shelf life of edible green fruits varies among genotypes. In an experiment conducted at NDUAT, Faizabad, out of eight clones the fruits of IVPG-1(Fig. 25a) had best shelf life, whereas Narendra Parwal-504 (Fig. 25d) exhibited the poorest keeping quality when stored for 10 days at ambient temperature. The shelf life of Narendra Parwal-307 (Fig. 25b) was only next to IVPG-1.

Cultivation in Uttar Pradesh: Pointed gourd is extensively cultivated in eastern Uttar Pradesh, particularly in Ganga river basins in districts of Varanasi, Ghazipur, and Ballia. In upland conditions the major growing districts are Jaunpur, Bahraich, Basti, Balrampur and Ambedkarnagar. To meet out the local market demands it is also cultivated in small to moderate scale in other districts of eastern Uttar Pradesh. In basins of river pointed gourd is cultivated on flat sloppy lands near river banks. In upland conditions, cultivation of pointed gourd is done both in flat land as well as on trellis system. Trellises are made variously as per the convenience of the farmers. It is perennial, dioecious and cross pollinated cucurbit, which is propagated both by seed as well as vine cuttings. Sometimes root cuttings with small portion of stem are also used which should be avoided because such vegetative parts have chances of nematode infestation. In upland the planting can be done from July to Mid October and also in February through vine cuttings by maintaining a ratio of 90-95% female clone and 5-10% male clone in the field. It is the crop that remains in fruiting for 6 to 8 months extending over summer and rainy seasons from March to October. The produce is supplied to different parts of the state and also transported to neighbouring states like Uttarakhand, Delhi etc.

9 IVY GOURD

Origin, history, and use

Ivy gourd, (*Coccinia indica* syn. *C. grandis*) i.e. evergreen gourd, is also called as scarlet gourd because of its red ripe fruits. In Hindi it is called as *kundsru*. In Sanskrit it is known as *vimba* or *vimb*. Africa is considered as centre of origin by some, whereas India is considered as centre of origin by other group of scientists. The fruits may be non-bitter (sweet) or bitter. The non-bitter types are cultivated while the bitter types are found growing wild in abandoned places near human habitation, on the bushes and trees along the roadsides or other uncared for places. The bitter types are poisonous and must never be eaten. The green fruits of cultivated sweet types are variously used as salad, cooked vegetable, *rayata* and pickle preparations. Ivy gourd has several medicinal values. Green leaf extract cures scorpion sting, dry leaf powder is reported to be antidiabetic, and fruits are aphrodisiac. Leaves too are vitalizer for men. In Ayurvedic system of medicine, ivy gourd is considered palatable, appetizer, warm and ameliorator of *vat, cough*, and *pitt* problems. Fruits are helpful to leprosy, breathing problems, fever, cardiac pain etc. Considering the multifarious health improving and medicinal properties the myth that it is inhibitory to intellect appears misleading.

General morphology and biodiversity

Nodal organs: Ivy gourd is a perennial, dioecious and cross pollinated cucurbit, which is propagated by both seed as well as vine cuttings. Ivy gourd vines have potential to bear six nodal organs as in pointed gourd. Easily observable fascinating biodiversity is recorded in leaf, flower and fruit shape, size and colour.

Leaves: The leaf shape may be unlobed (Fig. 26b-left) mildly lobed (Fig. 26a,e) or acutely lobed (Fig. 26b-right,d). The leaf shape may remain uniform on whole of the vines of a clone (Fig. 26c). However, in some clones the leaves in the same vine may acquire remarkably distinct shapes in varying plant growth stages and weather conditions (Fig. 26d,e). In majority of the clones the leaf size is generally small and medium but large leaves may also be found in some clones. Commonly leaves are 5-7 cm in length and 4-6 cm in width. Leaves of many clones have several pink glandular structure on the margins at the major vein ends (Fig. 26f). The intensity of pink colour varies from clone to clone. In some clones the pink glandular structure is not clearly visible. Thus, this trait may be used as genetic marker of ivy gourd genotypes.

Tendrils and bracts: Ivy gourd nodes bear unbranched long tendrils measuring 20-25 cm in length. Bracts are small but well marked (Fig. 26a). The clones differ in bract size and colour. Some clones have uniformly green bract while the others have bracts with basal half portion green and distal half portion pinkish in colour.

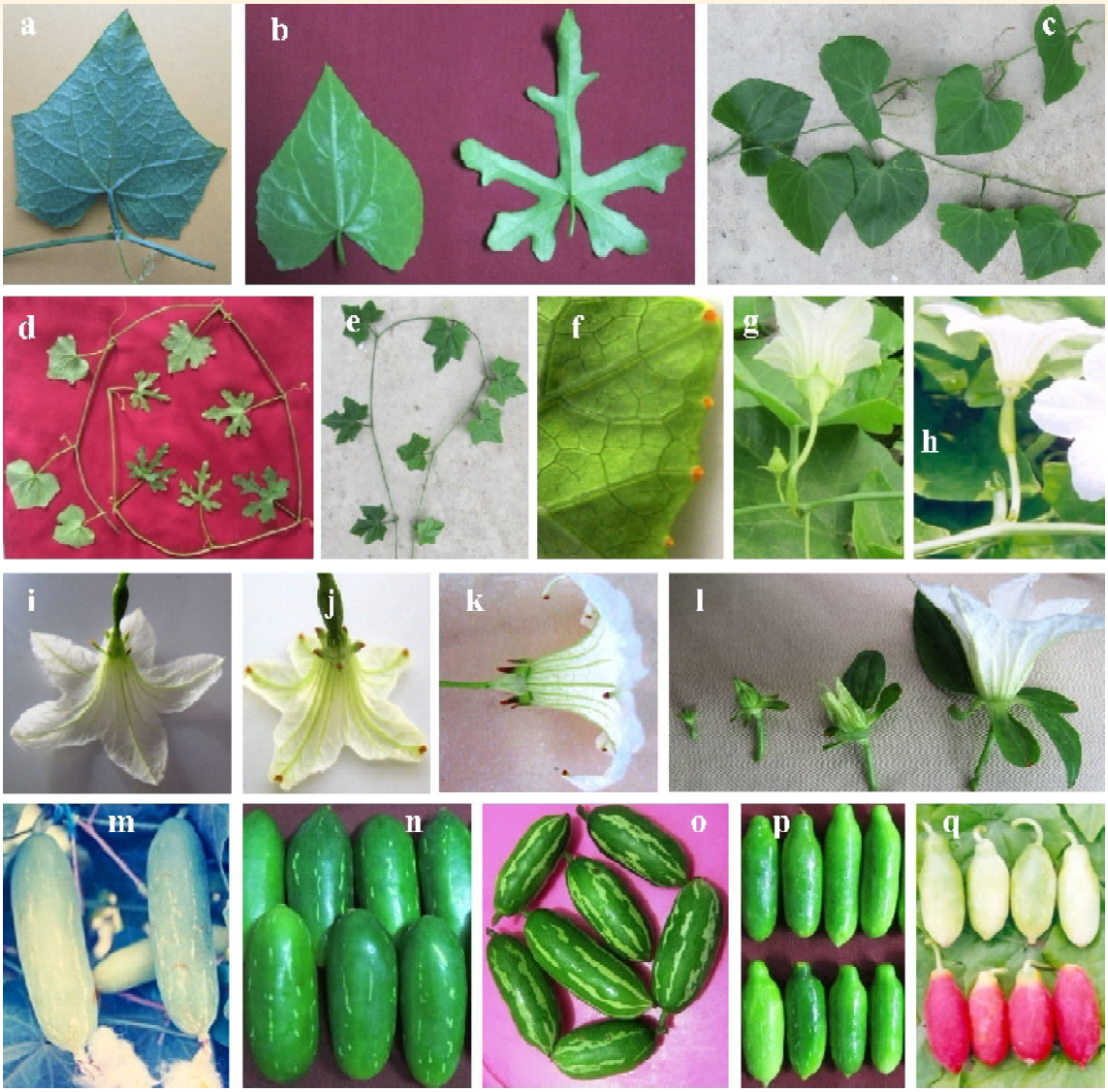


Fig.26. Variability in leaf, flower and fruit characters of ivy gourd: a. typical mildly lobed leaf, b. unlobed leaf (left) and acutely lobed leaf (right), c.uniformly unlobed leaves on whole vine, d. unlobed leaves in initial stage of vine growth and moderately to acutely lobed leaves on subsequent nodes, e. mildly lobed leaves in intial vine growth stage and moderately leaves on subsequent nodes, f. pink glandular structures on the leaf margin of a genotype, g. cluster of staminate flowers on a vine node in male plant, h. solitary pistillate flower on a vine node of female plant, i. a pistillate flower having pink colour half distal end of sepals and petals without pink end, j. a pistillate flower having pink colour half distal end of sepals and petals with pink end, k. a staminate flower having distinctly pink colour half distal end of sepals and petals with pink end, l. conspicuously large winged sepals of unequal size in a male clone, m. parthenocarpic fruit set, n, o, p. variability in fruit shape, size and colour, q. light green tender fruits (upper) and scarlet colour mature fruits (lower) of a female clone.

Floral Biology: The flowers are axillary, large and bright white. The flowers of ivy gourd are characterized by a few distinct markers. Generally the calyx is small, the distal end of which is pinkish in colour in almost all clones (Fig. 26i,j,k). A variant male clone was recorded having conspicuously large winged sepals of unequal size (Fig. 26l). The flowers of ivy gourd clones also differ in possessing a distinct pointed pinkish distal end colouration of petals. Some of the clones possess distinct pointed pinkish distal end of petals (Fig. 26j,k), while in others the petals are uniformly white without pinkish end (Fig. 26i,l). In male clones staminate flowers may be one, two (Fig. 26g) or in bunch of three to five per axil, whereas in female clones pistillate flowers are usually solitary (Fig. 26h) but rarely two in one axil. The anthesis takes place in the morning in between 7:00 and 8:00 a.m. Pollens are required for fertilization and fruit development, however, parthenocarpic fruit set is common in ivy gourd.

Fruit characters: The fruits may be elongated (Fig. 26m) or oblong (Fig. 26n,o). The fruits may have a neck at proximal end (Fig. 26p,q). Fruit weight may vary from 20 to 50 g and length may vary from 4-7 cm. The fruit colour may be light green or dark green with shining and smooth skin, which is invariably characterized by fine white discontinuous stripes (Fig. 26n) or sometimes well marked near continuous stripes (Fig. 26o). The fruits at maturity become scarlet red in colour (Fig. 26q) non-bitter, and contain numerous very small white seeds (Fig. 6f). The palatability of raw fruits as well as cooked vegetable varies from clone to clone.

Hardy crop: During the surveys and explorations, it has been recorded that ivy gourd (bitter type) is the only cucurbit which is found surviving almost round the year in difficult wild conditions. This growth behaviour of ivy gourd really speaks of its hardy/resistant behaviour against abiotic and biotic stresses. It is in fact the most hardy crop among the four dioecious and vegetatively propagated cucurbits in Uttar Pradesh *viz.* pointed gourd, ivy gourd, spine gourd, and (very sporadically grown) sweet gourd. With the help of long unbranched tendrils the thin and fast growing vines spread over low bushy plants/structures or climb to the high tree-tops, sometimes measuring up to 25 m in length. A ten-year-old such hardy plant climbing on a *Neem* tree was recorded in a village during a survey, bearing non-bitter fruits even during cool month of December.

Cultivation in Uttar Pradesh: Eastern Uttar Pradesh, Gorakhpur and Maharajganj are the major producer districts from where ivy gourd produce is transported to distant markets of Maharashtra and Andhra Pradesh. In other parts of the state it is also produced to meet out the local market demands. Cultivation is commonly done on trellis system. Since improved varieties are not available, growers depend mainly on locally available clones of the area. In Uttar Pradesh ivy gourd generally remains available in the market from March to November where it is sold at cheaper half rate as compared to pointed gourd. Commercial cultivation is done mainly through vegetative propagation, by using 100 % female plant cuttings in the field.

10 BITTER GOURD

Origin, history, and use

Bitter gourd (*Momordica charantia* L.) is considered to be originated either in Tropical Africa or Indo-Burma region. It is known as *karela* in Hindi and *karavellika* in Sanskrit. Richer in Vitamin C, compared to other cucurbits, bitter gourd is mainly consumed as cooked vegetable. Green fruits are also sliced, dehydrated and stored for later use. Bitter gourd has several medicinal properties, including as antidote to snake poison (Seshadri and More, 2009). In recent years bitter gourd has assumed importance because of its antidiabetic property. Other medicinal values like HIV multiplication inhibitor are under investigation.

General morphology and biodiversity

In reproductive phase bitter gourd vine have potential to bear six nodal organs as in typical monoecious bottle gourd genotypes. Bitter gourd is commonly a monoecious cucurbit but gynoecious lines are also found. Gynoecious sex form is monogenic recessive in nature. In monoecious genotypes both pistillate and staminate flowers are solitary in the axils of leaves (Fig. 27c), whereas in gynoecious lines the pistillate flowers may be either solitary or two in number on each node (Fig. 27e). Invariably bitter gourd genotypes possess highly pinnatifid leaves (Fig. 27b), except for the first two true leaves which are unlobed and appear simultaneously in the seedlings on the same node (Fig. 27a). The leaf size may be small or big. The colour of leaves may be green or dark green. Tendrils are long (15-25 cm in length) which may be unbranched or may have two branches. There are also genotypes which bear unbranched and branched tendrils on the same vine (Fig. 2e). In gynoecious lines nodes bearing two pistillate flowers usually also bear two tendrils (Fig. 27e). The bracts in bitter gourd are conspicuously large. The bracts are displaced from the nodes and are present on flower peduncles at a distance from the node (Fig. 27d). Bracts of staminate flowers are larger and located at higher position on the peduncle while bracts of pistillate flower are smaller and present nearer to the node. Flowers are yellow and small, and have pleasant fragrance. Staminate flowers are slightly bigger than pistillate flowers (Fig. 27d). Flower size differs among genotypes. Anthesis of flowers occurs in between 4:45 and 5:15 a.m. Great variations are recorded in fruit shape, size and colour. The fruits may be short (Fig. 27.i,k), medium (Fig. 27g,j) or very long (Fig. 27h) and they may be slender or thick. Fruit weight may vary from 20 to 150 g. Colour may be white (Fig. 27f), light green (Fig. 27.k,m), green (Fig. 27i,j) or dark green (Fig. 27g,h). Fruit bitterness varies from genotype to genotype. Moderate bitterness is preferred by all. Fruit surface of bitter gourd is characterized by presence of several kinds of protuberances which may be small or big, may be continuous or discontinuous/broken. Genotypes differ in earliness and fruit bearing capacity. The early genotypes bear first fruit within 50 days while late genotypes produce first fruits in 60 to 70 days. Variations in seed size, shape and colour are fascinating.

Fig. 27. Leaf character, sex forms and variability in fruit shape, size, and colour of bitter gourd: a. a young plant bearing first two true unlobed leaves and the rest acutely lobed leaves, b. typical acutely lobed leaves in vines showing tendril out growth, c. pistillate and staminate flowers on two consecutive vine nodes of a monoecious genotype, d. conspicuously large bracts in staminate and pistillate flower peduncles, e. two pistillate flowers and two tendrils on each of the two consecutive nodes of a gynoecious genotype, f, g, h, i, j, k, l, m, n. variability in fruit shape, size, colour and rind surface of different bitter gourd genotypes.

Fig. 28. Morphological features of a wild bitter gourd isolate: a. a lush green wild bitter gourd plant growing over a bushy plant on roadside in district Barabanki in April, 2013, b. a vine node bearing two small ripe fruits, c. a heap of tender and full grown fruits, d. very small seed size (upper) of wild isolate in comparison to big seed size (lower) of cultivated bitter gourd genotype.

Cultivation in Uttar Pradesh: In Uttar Pradesh bitter gourd is cultivated during summer and rainy seasons. Like bottle gourd and sponge gourd there are two groups of varieties in bitter gourd too, which are popularly known as summer season type (photoperiod insensitive) and rainy season type. Rainy season type genotypes are also locally called as Barahmasi type because of their prolonged life period. Preliminary observations have revealed that summer type genotypes are photoperiod insensitive and can be sown any time in between mid-January and mid-July, whereas rainy season type genotypes are photoperiod sensitive and should be planted from mid-June to whole of July. Since rainy season type bitter gourd genotypes are photoperiod sensitive they exhibit shy flowering and fruiting when grown during summer season.

Small fruited wild land race of bitter gourd: A peculiar very small fruited land race growing in wild has been located growing on bushes along the roadsides in Sitapur districts of Sultanpur, Gonda, Bahraich, Lucknow and Barabanki. The land race bears very small leaves, flowers (Fig. 28a) and fruits (Fig. 28b,c). The mature fruits contain 3 to 4 very small seeds (Fig. 28d) per fruit. The land race grows in lush green condition on the bushes and other abandoned structures during summer months and continues flowering and fruiting from March to late November. It is perennial in nature. During March the race produces predominantly pistillate flowers. The sex ratio later changes with high proportion of staminate flowers. It is expected to possess built-in genetic potential for drought resistance and prolonged fruiting period facing adverse conditions of summer, rainy season and even early winter. The green fruits produce crisp, tastier and moderately bitter fried vegetable. The valuable features of the land race can be utilized in breeding programme for developing improved desirable cultivars.

11 SPINE GOURD

Origin, history, and use

Spine gourd (*Momordica dioica* Roxb.) called *kheksi* in Hindi and *karkotaka* in Sanskrit has got its centre of origin in Africa/ Southern Tropical Asia. The green fruits are used to prepare fried/cooked vegetable like bitter gourd. The cooked vegetable is non-bitter and palatable but, a tinge of acceptable pleasing bitterness is also recorded in certain clones. Roots, vines and leaves are reported to be of medicinal significance in treatment of diabetes, skin diseases and asthma. It acts as antiseptic in piles and sedative to high fever with delirium. It is useful in painful micturation and other urinary complaints (Seshadri and More, 2009).

General morphology and biodiversity

It is perennial, dioecious and cross-pollinated cucurbit, which is propagated both by seed and vine cuttings. The vines in reproductive phase have potential to possess six nodal organs as in pointed gourd and ivy gourd. The easily observable biodiversity is particularly recorded in shape, size and colour of leaves (Fig. 29a.), flowers (Fig. 29b,c,d) and fruits (Fig. 29f,g,h). The leaf may be small, medium or large. They may be nearly unlobed, mildly lobed or moderately lobed (Fig. 29a). Some clones have serrated leaf margins. Tendrils are long (15-25 cm) and unbranched (Fig. $29b_2$). Bracts of staminate and pistillate flowers differ in size and shape. They are displaced from the node. The bracts of staminate flowers are conspicuously large and creamy green. The staminate flower bud is completely enclosed within the cup shaped bract before anthesis. The petals emerge from the 'bract-cover' at the time of anthesis, where the basal part of the flower still remains closely enveloped by the bract (Fig. $29b_1$,b_2). In pistillate flowers bracts are very small and scaly and they are present in the middle of the peduncle quite below the base of ovary (Fig. 29c).The staminate and pistillate flowers are borne separately in male and female plants, respectively. Both staminate and pistillate flowers are solitary, axillary and light yellow in colour. In general staminate flowers are larger than pistillate flowers, while pistillate flowers in some clones may be as big as that of the largest staminate flowers. The girth of the opened flowers varies from 3.5 cm to 4.5 cm. The anthesis of both staminate and pistillate flowers takes place in the evening/night in between 7:30 p.m. and 9:00 p.m. Both male and female clones genetically differ in their time of anthesis, in some anthesis takes place at around 7:30 p.m. while in others it extends up to 9:00 p.m. in the night. The flowers are visited by colourful insect pollinators during night. The petals of the flowers loosen and start turning inwards generally before 4:00 am and loosening and closing of petals continues in some clones till 6:00 a.m. and beyond. It was recorded that the clones in which anthesis took place late at 9:00 p.m. their petals loosened late in the morning at 6:00 a.m. The fruits are spiny with slight colour variations. The fruits may be exactly round or slightly oblong (Fig. 29f,g). Fruit weight varies from 5.0 to 15.0 g. Some clones may bear small tails towards the distal end of the fruit. Fruits turn

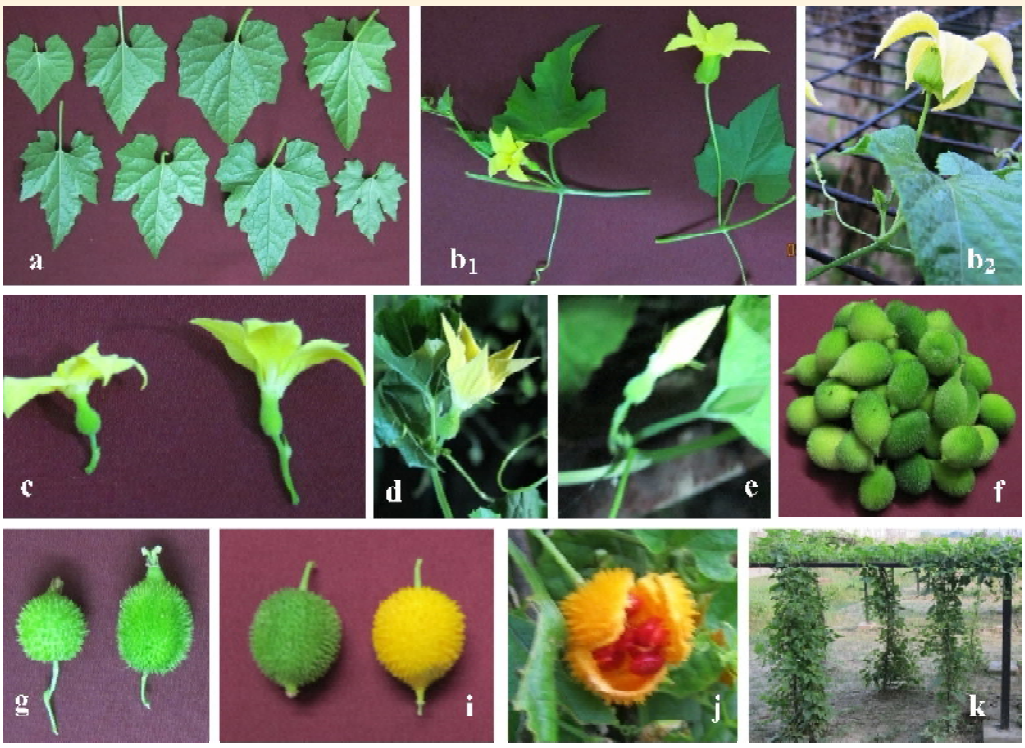


Fig.29. Variability in leaf shape, sex form and floral arrangement, fruit dimensions and method of cultivation of spine gourd,: a. mildly lobed, moderately lobed and deeply lobed leaves, b_1. a vine bearing pistillate flower (left) in a gynoecious clone and a vine node bearing staminate flower (right), b_2. a large staminate flower in anthesis, c. variability in flower dimension of the two gynoecious clones, d. a pistillate flower opening early in the evening, e. a pistillate flower still closed late in the evening, f. a heap of tender spine gourd fruits, g. fruit shape, size and colour dimensions of tender fruits of two female clones, h. a tender (left) and a mature fruit (right), i. a burst opened mature fruit. j. cultivation of spine gourd on trellis system.

yellow in colour (Fig. 29h), and burst open to expose seeds covered with bright red sticky sheath (Fig. 29i). The seeds are near round (Fig. 6i) and the number of seeds per fruit may vary from 25 to 30.

Limited cultivation in Uttar Pradesh: Spine gourd is planted in months of May-June by using seeds. The growing vines are trained on trellis (Fig. 29j), stakes or border fencing of the farm. Fifty per cent of such plants are expected to be female and rest male. The numbers of male plants so developed are heavily reduced to a mere 10% level of total plants. Vine cuttings are also used for vegetative propagation of spine gourd where a ratio of 9 female:1 male planting is maintained. Insect pollination is helpful in satisfactory fruit set. It is also found growing in wild conditions in some bushy, shady places and the fruits are harvested by poor villagers. The spine gourd fruits remain available in the market from late July to early October. Spine gourd fetches the double price of bitter gourd in the market. Crop improvement through clonal selection for high yielding female clones may enhance the cultivator's option for spine gourd as commercial crop.

12 SWEET GOURD

Origin, history, and use

Sweet gourd [(*Momordica cochinchinensis* (Lour.) Spreng.] is considered to be indigenous to south east Asia/India. In Hindi sweet gourd is called as *kheksa,* because of its bigger fruits as against *kheksi* (spine gourd). In Sanskrit it is called as *karkataki*. Green edible fruits are fried to prepare highly palatable non-bitter cooked vegetable. Apart from other medicinal values in Ayurvedic system of medicine tubers of male plants are reported to be beneficial as antidote to poisonous snake bite.

General morphology and biodiversity

It is perennial dioecious and vegetatively propagated crop. Seed propagated population contains 50% female and 50% male plants, where fruits borne on female plants are heterogeneous in shape and size. Therefore, vegetative propagation is preferred over seed propagation method. Vegetative propagation is done through tubers, formed underground in the spreading roots. In reproductive phase vine nodes have potential to bear six nodal organs like pointed gourd and ivy gourd. Much variability in sweet gourd could not be recorded in Uttar Pradesh because of the least cultivated area and popularity of the crop. The two clones, one male and another female of sweet gourd, which were observed in Sultanpur district; had cordate, unlobed, serrated leaves (Fig. 30b). The tendrils are unbranched (Fig. 30b) measuring 15-20 cm in length. Like spine gourd the staminate flowers of sweet gourd possess conspicuously large bracts which are green in colour and closely attached in the base of the flower (Fig. 30c). On the other hand the bract in the pistillate flower is very small and located in the middle of the peduncle at a distance from its origin on vine node (Fig. 30b). The large staminate and pistillate flowers are borne separately in male and female plants, respectively. Both staminate and pistillate flowers are solitary, axillary and creamy white in colour. In general staminate flowers are larger than pistillate flowers. The diameter of the opened flowers varies from 5.0 cm to 6.0 cm. The anthesis of both staminate and pistillate flowers takes place in the morning. Natural fruit set is very nominal in the female plants. There might be two probable speculations about this observation i) insect pollinators do not visit the flowers, and ii) even if the insects visit it is ineffective in pollination. The interior of the opened staminate and pistillate flowers is marked by three big and black spots (Fig. 30d,e), posing scaring view of the flower, at least to human eye, which may be a distracting factor for insect visit. Other natural inhibitory factors may also be at work. The detailed in-depth research is required in this matter. The pistillate flowers turn into fruits only when they are individually hand pollinated. Hand pollination of pistillate flowers is a common practice for producing fruits of sweet gourd in North East States of the country, where it is cultivated in larger areas. The fruits that arrive in local markets of the state from North East States exhibit variability in shape, size and colour. The fruits are generally oblong (Fig. 30f). The fruit weight varies from 30 to 40 g. On maturity the fruits turn reddish yellow in colour, and burst

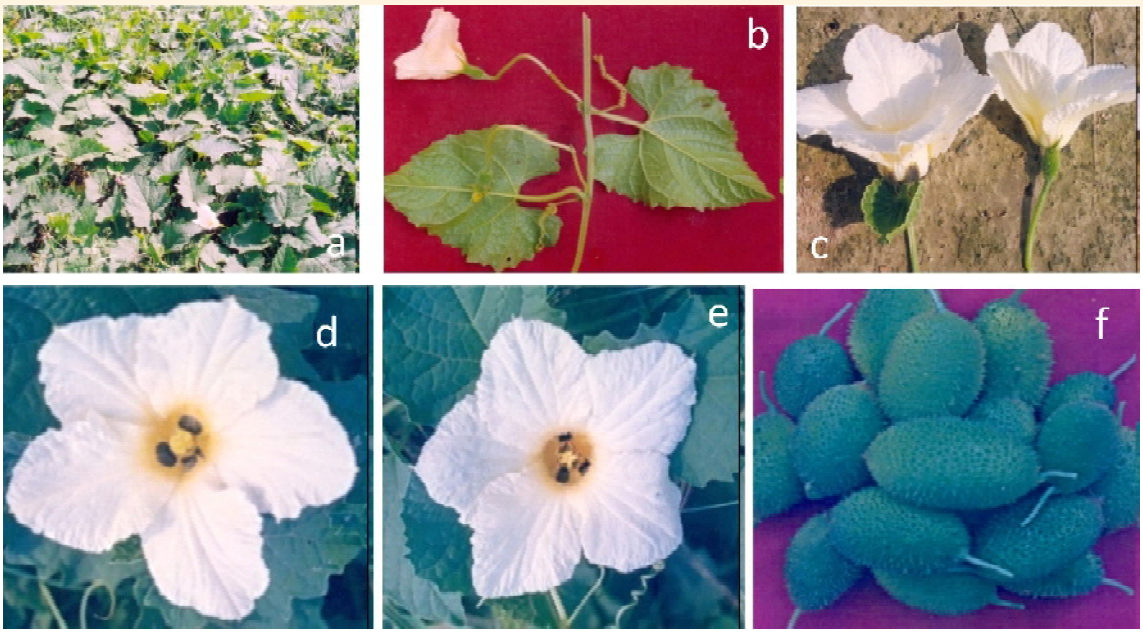


Fig. 30. Method of cultivation, sex form, and dimensions of leaf, flower fruit and seed characters of sweet gourd: a. cultivation on flat land, b. unlobed cordate leaf shape, c. a staminate flower with large bract (left) and a pistillate flower with small scaly bract (right), d. interior of a staminate flower, e. interior of a pistillate flower, f. a heap of tender fruits.

open to expose the seeds which are covered with dark red soft sheath like that of bitter gourd and spine gourd. There are 20-25 seeds per fruit. The seeds are black, large, thick, and oval in shape with astral projections on the margins (Fig. 6s).

Rare cultivation in Uttar Pradesh

Cultivation of sweet gourd is very rare in Uttar Pradesh. Non-fruit set in the female plants under natural conditions appear to be a major limiting factor in the least popularity of this valuable cucurbit crop. The root tubers of both male and female clones are planted for vegetative propagation in months of January- February. After germination the vines grow fast and produce enough number of staminate and pistillate flowers. The cultivation can be done either on trellis system or on raised beds (Fig. 30a). A farmer of the village Muralinagar in the vicinity of Sultanpur city started cultivation of sweet gourd looking into its highly remunerative market price, but got discouraged for further cultivation because of very low yield levels due to non-fruit set in female plants. The farmer was unaware of the fact of hand pollination necessary for fruit set in sweet gourd.

13 ROUNDMELON

Origin, history, use, biodiversity and cultivation

Roundmelon [*Praecitrullus fistulosus* (Stocks) Pang.] is also known as Indian gourd or round gourd. In Hindi it is called as *tinda*. It is considered to be originated in North-West India adjoining Pakistan. *Praecitrullus fistulosus* is the monotypic species of the genus *Praecitrullus*. Immature tender fruits are mainly used in various vegetable preparations and to a very limited extent in *rayata* and pickle preparation. Round melon is popular vegetable of Rajasthan, Punjab, Haryana, and western Uttar Pradesh. It is only sporadically grown in eastern Uttar Pradesh, Bihar and other neighbouring states. Distinct morphological variations are found in leaf, flower, fruit and seed characters. The leaves are moderately to deeply lobed (Fig. 31a). Tendrils may have two to three branches (Fig. 31a) in the same plant, which measure 10-13 cm in length. Bracts are conspicuously large and boat shaped (Fig. 31b) like watermelon, from the axils of which staminate and pistillate flowers arise. The genotypes differ in shape and size of bracts which may be used as genetic marker of the genotypes. The vines are relatively shorter in length. The crop is strictly monoecious, where solitary axillary staminate and pistillate flowers are present on separate vine nodes (Fig. 31b). The round or flat round fruits at immature tender stage are green in colour (Fig. 31c). At maturity the fruit colour fades and becomes pale green or whitish green. The seeds are flat round in shape, medium in size and black in colour (Fig. 6g). The seeds have ridged border. In Uttar Pradesh the crop is planted in February-March for summer season crop and in May-June for rainy season crop.

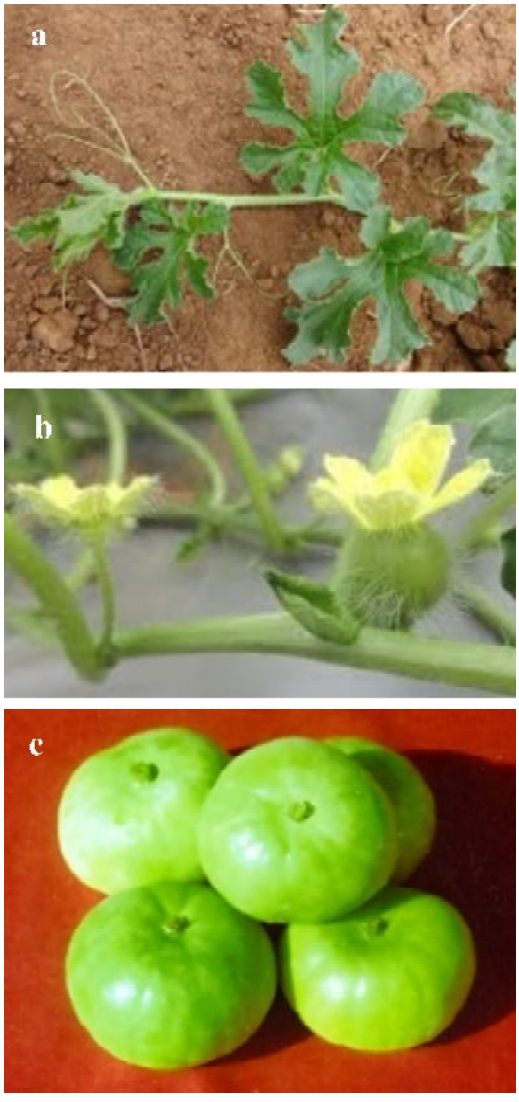


Fig. 31 Salient morphological features of roundmelon: a. deeply lobed leaves along with tendrils having three branches, b. staminate and pistillate flowers originating from the axils of large bracts at different vine nodes, c. a heap of tender green fruits.

14 WATERMELON

Origin, history, and use

Watermelon (*Citrullus lanatus* Mats. & Nakai), known as *tarbuz* in Hindi, is indigenous to South Africa. It is truly wild or native in Kalahari Desert of South Africa. Mature fruits of watermelon are chiefly used as delicious dessert fruit. Mature fruits are also used to prepare juice. Watermelon is considered relatively poor in nutritive value but recent studies have revealed that it is richer in lycopene and it contains 40-50% higher lycopene content as compared to tomato. In some parts of the country immature tender fruits are cooked into vegetable. Watermelon seeds are edible and nutritious and they are used as additive in confectionery items. Watermelon seeds are also used to extract edible oil.

General morphology and biodiversity

In reproductive phase watermelon vine nodes have potential of bearing six organs *viz.* i. leaf, ii. tendril, iii. branch, iv. bract, v. staminate, pistillate, or hermaphrodite flower, and vi. adventitious root. Watermelon exhibits distinctly observable diversity in its leaf, flower, fruit, and seed characters. Commonly watermelon leaves are acutely lobed (Fig. 32a) but unlobed or mildly lobed leaves are also found (Fig. 32c). Acutely lobed leaf shape is dominant over unlobed leaf shape (Fig. 32c). Leaf size and colour variations among watermelon genotypes are common which may be used in genetic characterization of genotypes. Tendrils of watermelon are short in length (10-15cm). Each tendril has 3-4 unequal branches (Fig. 32b). Each vine node bears conspicuously large boat-shaped bract from the axil of which any one out of staminate, pistillate or hermaphrodite flower arise (Fig. 32a,b). Potential for the development of a branch and an adventitious root on nodes exists as in other cucurbits. Flowers are bright yellow in colour and genotypes exhibit minor distinguishable variations in shape and size. Both monoecious and andromonoecious sex forms are found in watermelon. In monoecious/andromonoecious lines solitary staminate and solitary pistillate/ hermaphrodite flowers are found on separate nodes (Fig. 32a,b). The solitary flowers arise from the axils of the bracts within the axils of leaves. Staminate flowers are larger in size than pistillate flowers. Anthesis of both staminate and pistillate flowers takes place at around 4:30 a.m.

Fascinating diversity is observed in fruit shape, size and colour of watermelon. Fruits may be exactly round (Fig. 32f,g), oblong (Fig. 32d), or elongated (Fig. 32e) in shape. The fruit size may vary from 1.5 kg to 30.0 kg in weight. Watermelon exhibits a great range of variation in its fruit colour. The fruit colour may be pale green, light green, green, or deep green. The fruits may be striped or non-striped (Fig. 32d,e,f,g). The flesh colour of mature fruits is usually red but some genotypes also possess golden yellow colour flesh, where red colour is dominant over golden yellow flesh colour in F_1 (Fig. 32h). The fruit markets during summer in Uttar Pradesh in current years have been found flooded with striped green oblong fruit having 5-8 kg weight. Amazing variations

Fig. 32. Leaf shape; sex form; fruit shape, size and colour; and flesh colour of watermelon: a. acutely lobed leaves, boat shaped bract and staminate flowers, b. an unopened solitary staminate flower and an opened solitary pistillate flower on two consecutive nodes of a monoecious watermelon genotype, c. acutely lobed leaf shape (left lower) showing dominance over mildly lobed leaf shape (left upper) in F_1 (right centre), d. a heap of striped dark green oblong fruits, e. a heap of striped light green oblong fruits, f. a heap of striped light green round fruits, g. a heap of dark green round fruits, h. red colour flesh (upper left) showing dominance over golden colour flesh (upper right) in F_1 (lower centre).

are observed in rind thickness, crispness of the flesh, flesh colour, T.S.S. content, seed size and colour. The desirable fruit quality traits may be enumerated as thin rind, deep red flesh colour of mature fruits, crisp flesh with above 10% T.S.S. content, lesser number of seeds with very small size. A small dark green fruited variety of watermelon with thin rind, deep red flesh, very small seeds and high T.S.S., transported from Southern states, remains available round the year, in the fruit markets of small and big cities of Uttar Pradesh. Variability in earliness, fruit yield, fruit quality and resistance against biotic and abiotic stresses are also reported.

15 MUSKMELON

Origin, history, and use

Muskmelon (*Cucumis melo* L.), known as *kharbuz* in Hindi and *panduphal* or *karkaru* in Sanskrit, is indigenous to Tropical Africa. India is credited secondary centre of diversity and diversification of *Cucumis melo*. Indian germplasm of muskmelon is unique that it comprises both dessert or sweet varieties and non-dessert or non-sweet forms (Seshadri and More, 2009). It is mainly used as delicious dessert fruit. For majority of consumers it is preferred over watermelon because it is easier to eat, has desirable musk-flavour flesh, and comparatively higher T.S.S. content. Immature fruits of some varieties are used for cooking vegetable. Muskmelon has curative effect in urinary disorder. Seed kernel is vitalizer and it is used as a nutritive additive in sweets and other confectionery items. Seeds contain 50 % oil. Seed oil is recommended as diuretic.

General morphology and biodiversity

Muskmelon is probably the most colourful cucurbit cultivated in the country. In reproductive phase muskmelon vine nodes have potential to bear six organs *viz.* i. leaf, ii. tendril, iii. branch, iv. bract, v. staminate, pistillate, or hermaphrodite flower, and vi. adventitious root. Distinct biodiversity is recorded in leaf, flower, fruit and seed characters. The leaves of muskmelon genotypes are simple which may be mildly to deeply lobed (Fig. 33a,b). Size and colour variations are also found. Single, unbranched tendril is constant feature of every vine node (Fig. 33a,b) after 4th to 6th node seedling growth stage. The tendrils are fairly long and vary 15-20 cm in length. Nodes bear very small bracts. Majority of muskmelon genotypes are andromonoecious in nature but monoecious sex form is also found in some genotypes. In andromonoecious/monoecious sex forms, staminate and hermaphrodite/pistillate flowers are borne on separate nodes in the same plant (Fig. 33a,b). Staminate flowers are found in cluster of 2-5 in the axils of leaves whereas hermaphrodite/pistillate flowers are solitary. Staminate flowers are smaller than hermaphrodite/pistillate flowers. Anthesis in staminate and pistillate flowers takes place at around 5:45 a.m. Among morphological characters of muskmelon distinct biodiversity is observed in fruit characters. Fruit shape may be flat round (Fig. 34a), round (Fig. 33c,i,j,k,l) or oblong (Fig. 33h). Full grown mature fruit size varies from 1.0 kg to 8.0 kg. The most fascinating diversity is recorded in skin colour (Fig. 33d,e,f). Striped or stripeless immature fruits are green in various shades (Fig. 33c). At maturity the fruits acquire diverse colours *viz.* greenish yellow, light yellow, bright yellow, brown, almond or reddish brown. The skin colour of Jaunpuri local is brown with ten prominent well marked stripes (Fig. 33j), and it is stripeless reddish brown in Lucknow Batti (Fig. 34a). Noticeable diversity is also found in rind thickness; flesh thickness and colour (Fig. 34n,o,p); flesh texture, flavour/aroma and T.S.S. content; and cavity diameter and compactness.

T.S.S. content among genotypes found in Uttar Pradesh varies from 6-16%. Most of the central Asian varieties like those of Afghanistan, Turkmenistan, Kyrgyzstan, Kazakhstan, Uzbekistan,

Fig.33. Sex form, and dimensions of fruit characters in muskmelon: a. cluster of staminate flower on two consecutive vine nodes, b. solitary hermaphrodite flower on a vine node, c, d, e, f, g, h, i, j, k, l. fruit shape, size and colour dimensions, m, n, o, p. variability in flesh thickness, flesh colour and seed cavity size.

Fig. 34. Current status of cultivation and variability in Lucknow-Batti muskmelon: a. a heap of homogeneous flat round golden-red mature fruits, b. an unusual striped mature fruit in a heap of Lucknow-Batti, c. a heap of muskmelon fruit showing an alarming out crossing effect of other muskmelon genotypes on Lucknow-Batti fruit shape, size and colour.

etc. are very sweet with 15 to 17% T.S.S. 'Gulyaby' recorded 21% T.S.S. in Turkmenistan. In fact muskmelons of central Asia are the sweetest melons of the world produced under sub-tropical climatic conditions. 'Sarda' melon of Afghanistan whose fruits are available in north Indian cities during October-November is one such variety (Seshadri and More, 2009). Seshadri and More (2009) observed that it is not uncommon that all the fruits of the same vine could not record the same T.S.S. percentage. There will always be range of ±2%. Fruit characters determine the market demand, fruit quality and shelf life of a genotype. Seshadri and More (2009) described in brief the differences between cantaloupe and muskmelon. They stated that muskmelon and cantaloupe (of USA) differ somewhat in physical characteristics and regional adaptations. Today the cantaloupe signifies to those varieties, with uniform netting on the outer skin (corky tissue on the rind) with relatively distinct ribs or vein tracts and internal dry flesh is very thick, salmon orange in colour, with characteristic flavour and moderate sweetness and seed cavity very small and dry. The cantaloupe varieties of USA have an additional attribute of withstanding long distance haulage by packing in crates and also ripening during transit. Muskmelon cultivars on the other hand have a stronger aroma, juicy flesh and large seed cavity.

The surveys revealed that Uttar Pradesh inharbours rich biodiversity among muskmelon land races found in the state. Jaunpuri Kharbuza, Faizabadi Kharbuza, Mau Local, Lucknow Batti (Fig. 34a) etc. are among the famous land races across the country. However, these land races have been affected by introgression of genes from other muskmelon genotypes cultivated by farmers (Fig. 34b). A close observation of heaps of Lucknow Batti in Lucknow and Barabanki markets and also in the farmers' field indicate a lot of mixtures of fruit shape, size and colour (Fig. 34b,c). Even if, the fruit skin, shape and size are uniform in a heap, variations are recorded in flesh colour, flesh thickness (Fig. 33n), and flesh sweetness. Thus these observations suggest that there is an urgent need to protect the identity of valuable muskmelon land races of Uttar Pradesh, and to breed pure uniform genotypes out of these potential materials.

A great variability is also recorded with respect to earliness, fruit bearing capacity, resistance against biotic and abiotic stresses. The crop is cultivated only during summer in Uttar Pradesh, for which sowing is done in between mid-February and mid-March for main season crop.

16 SNAPMELON

Origin, history, and use

Snapmelon, (*Cucumis melo* var. *momordica* Duthie & Fullar) called *phoot* in Hindi, is considered as 'poor man's muskmelon'. It is a crop grown by poor and also mainly eaten by poor. This is a valuable cucurbit of Indian origin. The mature fruits are eaten as dessert fruit like musk melon. Since mature fruits have a low sweetness, the consumers add jaggery or sugar to enhance palatability. It is considered to possess cooling effect.

General morphology and biodiversity

The crop is strictly monoecious in nature where staminate and pistillate flowers are found on different nodes (Fig. 35c,d). Vine nodes of snapmelon in reproductive phase have potential to develop six organs like muskmelon. Leaves may be mildly to moderately lobed (Fig. 35a,b,c,d). Commonly one unbranched long tendril is present on each vine node (Fig. 35a). However, there are certain genotypes which bear 2-3 tendrils per node (Fig. 35b). Genotypes possessing single tendril per node are frequently noticed to bear two tendrils on the node bearing pistillate flowers. Bract is present but very small in size. Flowers are small and bright yellow in colour. Pistillate flowers are slightly larger than staminate flowers (Table 1). Staminate flowers are found in bunch of two to four whereas; pistillate flowers are solitary in nature. Anthesis occurs in between 5:30 and 6:00 a.m. Great variability is particularly noticed in fruit shape, size, colour and quality. Fruit shape may be exactly round like muskmelon, oblong round (Fig. 35f,g,i) or elongated drum shaped (Fig. 35e). Fruit weight may vary from 1 to 5 kg. There are also colour variations at maturity stage, the fruit surface may be smooth, mildly or deeply ridged (Fig. 35i). The TSS of mature fruits varies from 4-7%. There is also a variation in the texture of mature fruit flesh that adds to the taste and palatability. Seeds are white and small in size (Fig. 6e).

High yield potential compared to closely related species

Snapmelon has a hidden wealth of variability ready for sensible exploration, exploitation and crop improvement. The small heap of snapmelon (Fig. 35e) speaks of the large variability latent in the crop. No two fruits are similar with respect to one single visible morphological character. Selection for desirable fruit shape, size, colour, sweetness of flesh and toughness of skin may lead to revolutionary changes in the utilization and marketability of the crop. In Uttar Pradesh snapmelon is mainly cultivated as mixed crop during rainy season; however a few farmers also grow pure crop of snapmelon during summer. The land races differ in earliness, yield, quality and resistance. Snapmelon is reported to carry resistance against powdery mildew, downy mildew and cucumber green mottle mosaic virus (Seshadri and More, 2009). Pottu vellari is an improved variety of snapmelon in Kerala, whereas two improved varieties of snapmelon, *viz.* AHS-10 and AHS-2, have been released by Central Institute of Arid Horticulture, located at Bikaner in Rajasthan. The

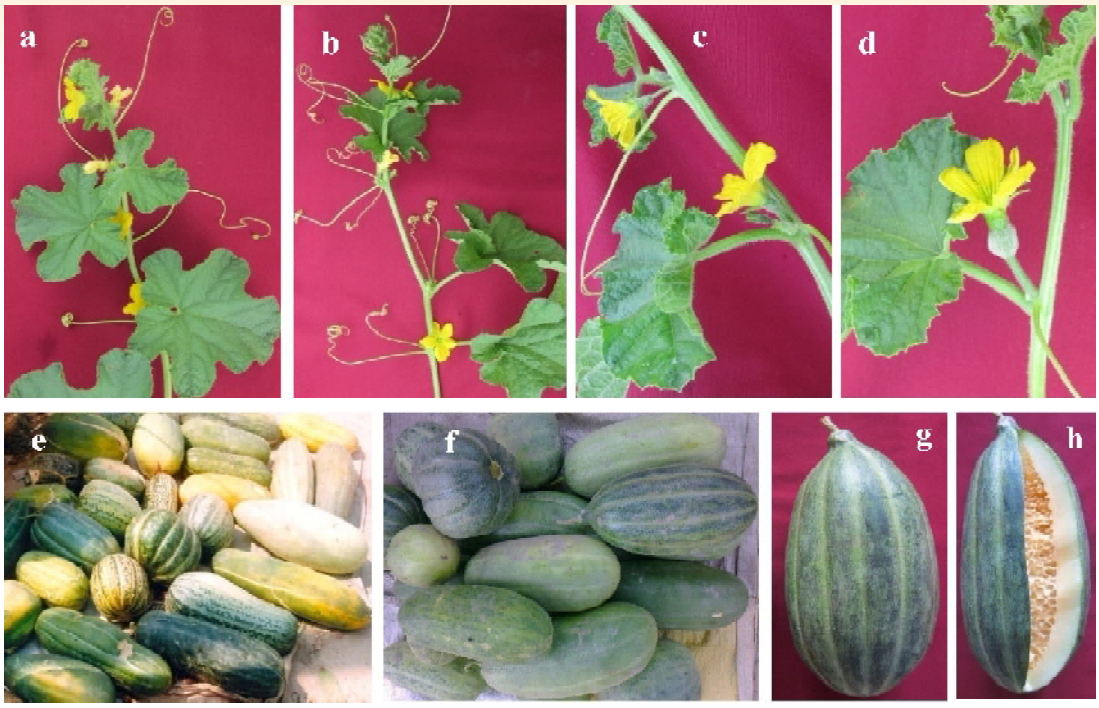


Fig. 35. Leaf and tendril characters; sex form and floral arrangement; and variability in fruit shape, size, colour, and quality of snapmelon: a. moderately lobed leaves and unbranched single flaunting tendrils present on the vine nodes, b. 2-3 unbranched tendrils present on each vine node of a genotype, c. cluster of staminate flowers on the vine nodes, d. solitary pistillate flower on a vine node, e. a heap of mature snapmelon fruits showing diverse fruit shape, size, colour and skin surface dimensions, f. a heap of fully grown maturing fruits harvested before cracks and ready for marketing, g. a ridged skinned fruit, and h. maturing fruit ready to eat before cracking.

experiment conducted on fourteen annual cucurbits, including snapmelon, has exhibited snapmelon as relatively hardy and a heavy yielder cucurbit (245.71 q/ha), like watermelon (304.75 q/ha), pumpkin (253.75 q/ha) and bottle gourd (251.08 q/ha) (Table 7). A promising land race of snapmelon NDSM-1 was found to out yield its sister species cucumber (150.20 q/ha), long melon (191.65 q/ha), muskmelon (193.31 q/ha), and *kachari* (94.80 q/ha).

Pre-burst harvest of fruits

At full maturity the fruits burst open while they are still attached with the plant, this is why snapmelon is locally called *phoot*. The transportation of burst fruits from the field to the market place becomes problem for growers. It has been observed that even if the fully developed fruits are harvested 2-3 days earlier before bursting they exhibit similar sweetness and taste even better as that of burst open fruits. Harvesting at pre-bursting stage facilitates easy transportation of fruits from field to the market (Fig. 35g,h). There are land races which have very little tendency of bursting at maturity. In crop improvement programme attention should be focused for selecting non-bursting type genotypes possessing desirable flesh texture and sweetness.

17 PEHTUL

Origin, history, and use

Pehtul (*Cucumis callosus* syn. *Cucumis trigonus and C. melo* var. *agrestis*) is a cucurbit of Indian origin that grows mainly in wild and as weed in the cultivated fields during summer and rainy seasons along with other cucurbits and field crops. *Pehtul* or *pehta* is the neglected cucurbit weed of eastern Uttar Pradesh. In western Uttar Pradesh it is called *kacharia* and known as *kachari* in Rajasthan. In western Uttar Pradesh mature fruits of *kacharia* are called as *sendh*. *Kachari* is a fairly popular cucurbit in Rajasthan, where semi-mature and mature fruits are used to prepare cooked vegetable, chutney and several other cuisines.

General morphology and biodiversity

All the six potential nodal organs *viz*. leaf, tendril, bract, branch, adventitious root and flower are found in *pehtul*. Leaves are relatively small in size, palmate and mildly to moderately lobed. Leaf size and shape varies among genotypes. Tendrils are short and unbranched (Fig. 36b). Bracts are very small in size. *Pehtul* is monoecious in nature, where small, bright yellow staminate and pistillate flowers are borne on short peduncles on different nodes. Pistillate flowers are solitary, while staminate flowers may be solitary or in bunch of 2-4 (Fig. 36b). Anthesis takes place early in the morning at around 4:30 a.m. Most fascinating diversity is observed in fruit shape, size, and colour. The fruit shape may be exactly round, oblong or long (Fig. 36d). Fruit weight varies from 15 g (Fig. 36c) to 100 g (Fig. 36f). Big fruited *kachari* is called *kachara* in Rajasthan (Fig. 36e). The colour may be white or variously striped, mottled in variable shades of green base colour (Fig. 36c). The mature fruits acquire various shades of yellowish or pinkish colour depending upon the immature fruit colour. Earliness, fruit bearing capacity (Fig. 36a), edible quality at maturity and resistance to abiotic and biotic stresses differ among genotypes. *Cucumis callosus* possesses genes for resistance to fruit fly and leaf eating caterpillars. The resistance of this semi domesticated and under exploited cucurbit may be transferred to muskmelon with which the earlier is crossable.The immature fruits of most of the *pehtul* genotypes are bitter and non-edible which turn sweet and sour at maturity and become edible. The mature fruits have thin flesh and large number of seeds (Fig. 36g). The main reason for non-acceptability and neglect of this valuable and hardy cucurbit is its bitterness in immature fruits. Fruits of some genotypes growing in wild are non-bitter and edible even at immature stage. Such genotypes possess special significance in future crop improvement programme and popularization of *pehtul*.

Fig. 36. Prolific fruit bearing; sex form and variability in fruit characters of pehtul/kachari: a. prolific bearer wild pehtul plant bearing 70 fruits, b. cluster of staminate flowers on a vine node (lower) and solitary pistillate flower (upper) on the consecutive node, c. variability in immature fruit shape, size and colour of a few wild pehtul genotypes of Uttar Pradesh, d. variability in mature fruit shape, size and colour of kachari of Rajasthan, e. a heap of big fruited kachari known as *kachara* in Rajasthan, f. a heap of uniform fruit shape, size and colour of maturing fruits of kachari produced at NDUAT, Faizabad, g. variability in flesh thickness and seed cavity of mature kachari fruits.

18 LONGMELON

Origin, history, and use

Longmelon, (*Cucumis melo* var. *utilissimus*) also known as serpent melon is called *kakri* in Hindi. The English names longmelon or serpent melon signify the slender, long, curved and coiled nature of fruits of this under exploited and underexplored summer thirst quencher cucurbit. It is eaten raw as salad. India is the centre of origin of longmelon.

General morphology and biodiversity

Longmelon is monoecious in nature. Bright yellow solitary axillary staminate and pistillate flowers are born on separate nodes of a vine. Flowers are small in size of about 4 cm girth at full bloom stage. Anthesis takes place at around 4:30 a.m. before sunrise. The flowers are bright yellow and slightly larger than muskmelon, cucumber, and snapmelon. Pistillate flower-diameter is higher than staminate flower-diameter (Table 7). Longmelon vine nodes also have six organ potential in reproductive phase like watermelon. The major observable variability in longmelon is recorded with respect to leaf and fruit characters. Leaves may be unlobed (Fig. 37b) or mildly lobed (Fig. 37c), they may be small or big in size, and may be green or dark green in colour. Leaves of some genotypes have serrated margins. Tendrils are long and unbranched (Fig. 37a,b). Bracts are very small (Fig. 37d). Fruits are generally curved or coiled because of soft, slender and long length. The immature soft fruit length varies from 30 cm (Fig. 37g,i) to 150 cm (Fig. 37f). Short fruits have natural tendency to remain straight while they are still tender. Short straight fruits have advantage in packing and transportation over long curved fruits. Since the cultivation of longmelon is done on flat lands, the curving/coiling tendency of the fruits increases as the fruit length increases. The fruit colour is generally pale green (Fig. 37e) to light green but distinct colour variations may be noticed in certain genotypes which are darker in shade (Fig. 37g).

Variation in fruit quality with respect to crispness, sweetness, flesh thickness etc. is also recorded. Some genotypes have bitter fruits and they should not be consumed. Variations are also recorded with respect to earliness, fruit bearing capacity, disease and insect pest resistance etc. In crop improvement programme of longmelon attention should be focused on early, high yielding genotypes having short, straight, slender, and soft fruits with crispy texture and sweet taste. The cultivation of longmelon in Uttar Pradesh is mostly done under river-bed conditions and to a limited extent in upland conditions. All cultivation is done on flat land.

Fig. 37. Floral arrangement and variability in leaf and fruit characters of longmelon: a. cluster of staminate flowers in two consecutive vine nodes, b. solitary pistillate flower in the axil of unlobed leaf, c. mildly lobed leaves and a long curved fruit, d. a vine node showing a very small bract towards left side of the node, e. curved medium long light green fruits, f. a very long curved edible fruit measuring 130 cm., g. a heap of straight tender green fruits, h. a heap of medium long slender curved green tender fruits, i. a heap of short thick light green straight fruits, j. a heap of slender light green near straight fruits.

19 CUCUMBER

Origin, history, and use

Cucumber (*Cucumis sativus* L.) is a cucurbit of Indian origin. It is known as *kheera* in Hindi. The tender, immature fruits are primarily consumed as salad. Use of cucumber fruit juice is beneficial to diabetic and jaundice patients. Immature fruits are also cooked into vegetable and used to prepare *rayata* and pickles. It is rich in Vitamin B and C, and contains calcium, phosphorus, iron and potassium. Dehusked cucumber seed is edible and used as nutritive additive in sweets and confectionery items.

General morphology and biodiversity

Nodal organs: Only five organs, *viz.* leaf, tendril, branch primordium, adventions root and staminate or pistillate flower, are present on cucumber vine nodes in the reproductive phase. Bracts are absent. The distinct observable biodiversity is recorded in leaf, vine length, sex expression, flower, fruit, and seed characters. Leaf shape is commonly palmate or cordate, generally pentangular and mildly to moderately lobed (Fig. 38b,c,d,g). Stable variations in leaf shape, size and colour are observed, which can be used as marker of the genotype. Single unbranched, long tendril is present on each node. Minor genotypic differences are observed in tendril length (Fig. 38a,f) . Branch primordium is present on each node which may develop into effective branch as decided by particular vine node conditions. Adventitious roots develop from the vine nodes when they come in contact with the moist soil. Depending upon vine growth cucumber genotype could broadly be categorized into two groups *viz.* i. genotypes with determinate vine growth, and ii. genotypes with indeterminate vine growth. Very early genotypes of cucumber are prolific bearer and have short vines of 1.5-2.5 m in length. The genotypes with medium and late maturity bear moderately long vines (4-6 m) and continue to bear fruits for longer duration. Ghosh and Bose (1969) reported that cucumber plants receiving 16 hr. day length did not flower, 8 hr. treatment favoured female flower, with four times the number produced in 12 hr. treatment.

Sex forms and floral arrangements: Commonly cucumber is monoecious in nature, however stable gynoecious lines also occur (Fig. 38h). A Korean cultivar 'Sogoin' has gynomonoecious sex form. In monoecious lines both staminate and pistillate flowers are found on separate nodes in the axils of leaves (Fig. 38e,f). Anthesis of both staminate and pistillate flowers takes place at around 5:30 a.m. Pistillate flowers are larger in size than staminate flowers. Staminate flowers are found in bunch of two to four or more in number, whereas pistillate flowers are normally solitary. Occasionally two to three pistillate flowers are also found on one node (Fig. 38g,h). On nodes having two pistillate flowers, the tendril conspicuously disappears (Fig. 38g), which indicates that second pistillate flower on the node is modification of tendril. Flowers are considered modified branch which alternatively indicates that tendril is modified branch in cucumber. In gynoecious lines of cucumber

Fig. 38. Leaf characters; floral arrangement; fruiting behaviour; variability in fruit shape, size and colour; and flesh thickness and seed cavity size in cucumber: a. a cucumber seedling with a long unbranched first tendril originating from 7th node, b. moderately lobed leaves, c, d. mildly lobed leaves, e. cluster of staminate flowers on the two consecutive nodes, f. usual solitary pistillate flowers on the two consecutive nodes, g. an unusual vine node bearing two pistillate flowers (left) and the consecutive node bearing usual solitary pistillate flower (right), h. a prolific bearer gynoecious cucumber genotype bearing one fruit per node (towards the basal nodes) and two fruits on the succeeding node, i, j, k, l, m. heaps of cucumber fruits showing variability in shape, size and colour, n. thick flesh and small compact seed cavity in a cucumber genotype (left); and thin flesh and big hollow triangular seed cavity (right) in another genotype.

only pistillate flowers are present on each node. The number of pistillate flowers on nodes varies from 1 to 3.

Fruit characters: Cucumber exhibits great biodiversity for its fruit shape, size, and colour (Fig. 38i,j,k,l,m). Flesh thickness, seed cavity diameter, and compactness of seed cavity also vary (Fig. 38n). The fruit shape is generally cylindrical but variations in fruit shape do occur. Fruits are usually straight but may be mildly curved in some genotypes. Length of immature fruits at appropriate edible stage may vary from 10 cm as in Faizabadi Muthia Kheera (Fig. 38m) to 30 cm in improved F_1 hybrids (Fig. 38k). Fruit colour varies from light striped green (Fig. 38k) to deep striped green (Fig. 38m) or non-striped dark green (Fig. 38h). At maturity the fruit skin colour becomes light almond to deep almond in colour depending upon fruit colour dimension of immature fruit. Flesh thickness and seed cavity diameter are important attributes in determination of fruit quality of cucumber. Desirable variations are observed in these two traits. As far as seed cavity diameter is concerned, whether it is small or big, it should be fully packed with seed and associated mass and it should never have triangular hollow space (Fig. 38n). The Chinese scientists Qi *et al*. (1983) identified *C. sativus* var. *xishuangbannesis*, with orange flesh and high carotene content. Differences observed in seed shape and size among genotypes can be used as marker of a genotype.

Bitter and non-bitter fruits: The most important among edible quality attributes is non-bitter characteristic of fruits. All other good features of cucumber genotypes become useless if the fruits are bitter. The extent of bitterness also varies among the varieties. Since cucumber is mainly used as salad the fruits of improved varieties should be free from bitterness from tip to tail and must possess other desirable attributes such as acceptable level of T.S.S. content, crispness etc. Bitterness in cucumber is influenced by environmental factors. A single plant may bear bitter and non-bitter fruits under different weather conditions. Some cucumber varieties have bitter foliage but never have bitter fruits; others have bitter foliage and may have bitter or non-bitter fruits, depending on environmental conditions. Therefore, it becomes difficult to distinguish between these types in a breeding programme because of the environmentally-induced variability (Robinson and Decker-Walters, 1999). Andeweg and Bruyn (1958), reasoned that if they could find a cucumber mutant with non-bitter foliage, it would have non-bitter fruits regardless of the environment and growing conditions. In fact, they were able to isolate one non-bitter spontaneous mutant plant after tasting the cotyledons of 15,000 cucumber seedlings. This seedling when grew, produced non-bitter fruit under all growing conditions. The single recessive gene of the spontaneous mutant prevents biosynthesis of Cucurbitacin-C and is involved in the development of non-bitter improved cultivars.

Growth habit and yield: Cucumber genotypes greatly differ in vine growth habit, earliness, fruit bearing capacity and resistance against biotic and abiotic stresses. Lower and Nienhuis (1990) developed cucumber cultivar with short internodes, compact plant habit and profuse lateral branches by transferring genes to cucumber from *Cucumis hardwickii*. There were successful in producing multiple pistillate flowers in the axil in contrast to single pistillate flowers found on vine nodes. Yield levels in common variety varies from 200 to 400 q/ha under open field conditions. However, under microprocessor system, with controlled conditions of temperature, humidity, light and CO_2; having extended crop growth period of cucumber plants, Sheard (1981) recorded a high yield level of 300 t/ha.

20 PUMPKIN

Origin, history, and use

Pumpkin (*Cucurbita moschata* Dutch. ex. Poir.) called *kashiphal*, *sitaphal, kaddu* or *kohara* in Hindi, is considered to be indigenous to Mexico. There are five cultivated species of genus *Cucurbita viz. C. argyrosperma* (earlier *C. mixta*), *C. pepo*, *C. maxima*, *C. moschata* and *C. ficifolia*. However, *C. moschata* is the most popular throughout India because it is amenable to hotter climates more than other cultivated *Cucurbita* species. Both immature tender and mature fruits of pumpkin are primarily used as cooked vegetable. Preferences for use of immature and mature fruits for cooking into vegetable vary from place to place in the country. Here it may be noted that carotenoids, particularly β-carotene content, the precursor of vitamin A, is higher in mature fruits in comparison to immature fruits. Tender shoots and flowers are also fried and consumed as vegetable. The mature fruits of pumpkin are also variously used to prepare *halwa/barfi*, confectionery items, tomato ketchup etc. Pumpkin seeds contain omega-3 and 6 essential fatty acid, an essential nutrient for normal mental health. The seeds have several medicinal properties also and are reported to be useful as protectant of prostate gland enlargement in men. Seeds are also considered vitalizer for men and used in confectionery. The pumpkin seed oil is edible and can be used for cooking. The charred pumpkin peduncle powder in hot mustard oil prepared into ointment has been found an effective treatment of gangrene (Singh and Singh, 2009).

General morphology and biodiversity

Nodal organs: Pumpkin vines in reproductive phase possess potential to bear five nodal organs *viz.* leaf, tendril, branch, adventitious root, and flower (Fig. 5b). The bracts are constantly absent from vine nodes of all the pumpkin genotypes. The distinct observable morphological biodiversity is recorded in leaf, vine length, flower, fruit and seed characters of pumpkin. Leaf shape is commonly palmate or cordate, generally pentangular or mildly lobed (Fig. 39a,b). Leaf margin is entire. Leaf size may be small, medium or big. Colour variation in pumpkin leaf occurs in two respects *viz.* variation in background base colour and variation in silvery splashing pattern. Background base colour of leaf may be light green, moderate green or dark green. Remarkable variations are recorded in silvery splashing patterns on leaves of different genotypes. The leaves may be highly splashed, moderately splashed (Fig. 39a), mildly splashed or non-splashed (Fig. 39b). Leaf splashing patterns are highly influenced by temperature, humidity and cloudy weather conditions. High temperature and sunny days favour full expression of splashing while, low temperature and cloudy weather diminishes the splashing to a great extent. The same plant may bear splashed and non-splashed leaves as it passes through transitory climatic conditions. Pumpkin leaves are borne on long petiole which may vary in size in different genotypes. Single tendril is a constant feature of every vine node starting from 6^{th}-7^{th} node after seedlings growth. Each tendril has 4 to 5 unequal branches originating from a single point at a distance from its emergence on the node. Variations in tendril length are also

recorded among the genotypes. Single branch potential is common feature of all the pumpkin genotypes which develops at certain nodes as per the need of the growing vines. One to four or even more adventitious roots may arise from the nodes which come in contact of soil having favourable moisture condition. During rainy season in favourable high humid and moderate temperature conditions one to several aerial roots may also arise on some of the nodes of vines growing on trellis, which are not even in contact of the soil (Fig. 5b). The tendency of adventitious and aerial root formation differs from genotype to genotype.

Sex forms and floral biology: Pumpkin produces largest flower among cultivated cucurbits with large yellow corolla and large ovary with variable green colour. Anthesis occurs in between 4:30 and 4:50 a.m. (Table 1). Distinctly visible variation in shape, size, and colour of various floral parts like calyx, corolla, anther, stigma, and ovary are noticed (Fig. 39e). Calyx is always green but shape and size differ among genotypes. The opened flowers are companulate in shape which measure 15 to 20 cm in length. The diameter of the opened flower at distal end varies from 15 to 25 cm. Pistillate flowers are larger than the staminate flowers. Corolla colour is yellow, but a tinge of variation in shades of yellow colour may be seen among the genotypes. The crop is invariably monoecious, where axillary staminate and pistillate (Fig. 3a) flowers are found on separate nodes of the same plant. Both staminate and pistillate flowers are strictly solitary. In a very few genotypes, in particular set of climatic conditions at the same location, transitory trimonoecious (gynandromonoecious) condition is also encountered, where a few abnormal, deformed hermaphrodite flowers are formed in some plants of the genotype. Both staminate (Fig. 39d) as well as pistillate (Fig. 39c) flowers have tendency to convert into abnormal hermaphrodite flowers. The frequency of pistillate flowers turning into hermaphrodite flower is rather low. The staminate flowers converting into hermaphrodite flowers have superior ovary-an unusual phenomenon in cucurbits. Pistillate flowers converting into hermaphrodite flower have usual inferior ovary. The hermaphrodite flowers formed out of either staminate or pistillate flowers never turn into normal effective fruits.

Fruit characters: Most fascinating diversity is encountered in fruit shape, size, and colour (Fig. 39f to p). Commonly pumpkin fruits are round in shape (Fig. 39l,m,n,o), but they may be globular, flat round, oblong (Fig. 39g to j), near cylindrical (Fig. 39f) or in other shapes. Full grown fruit size may vary from 1 to 25 kg weight. The immature fruit colour may be dark green (Fig. 39n), striped dark green (Fig. 39j,m), pale green or even white (Fig. 39g). At maturity the fruits acquire varying shades of almond, orange and yellowish colour (Fig. 39p) depending upon the immature fruit colour of the genotypes. The fruit surface may be near smooth or mildly to moderately ridged and grooved. The number of ridges generally varies from 10 to 15. Rind at maturity may be papery, as in Narendra Amrit, or mildly to moderately thick. The texture of rind at maturity may be soft/weak or hard/ strong. Full grown fruits of pumpkin genotypes vary to a great extent with respect to flesh thickness and seed cavity. The genotypes may have three alternative combinations of relative flesh thickness and seed cavity *viz.* i. thin flesh and big seed cavity, ii. thick flesh and big seed cavity, and iii. thick flesh and small seed cavity (Fig. 39q). The third combination of thick flesh and small seed cavity is considered desirable. In an ideal flesh thickness and seed cavity proportion, in a transversely cut fruit from the centre, the flesh thickness of both sides of the cavity added together and the diameter

Fig. 39. Variability in leaf; flower; sex form; fruit shape, size, and colour; flesh thickness and cavity diameter; and seed shape, size and colour of pumpkin: a. unlobed and moderately splashed leaves, b. unlobed and non-splashed leaves, c. staminate, pistillate and hermaphrodite flowers in transitory trimonoecious sex form of a pumpkin genotype, d. an unusual staminate flower with eight petals (upper) and a staminate flower turned into hermaphrodite flower having unusual superior ovary, e. a pistillate flower with dark green ovary and brown colour stigma (left) and another pistillate with pale green striped ovary with yellow stigma, f, g, h, i, j. oblong fruits in different shape, size and colour, k, l, m, n, o. round fruits in various shape, size and colour, p. a heap of pumpkin fruits in different shap, size and colour, q. thin flesh large cavity (left upper) thick flesh small cavity (left lower) and thick flesh large cavity (right), r. small seed size (upper), medium seed size (middle) and large seed size (lower).

of the seed cavity should be close to 1:1 ratio. For instance if the flesh thickness added together of both sides of the seed cavity of the cut fruit is 10 cm (5 cm + 5 cm) and the seed cavity diameter is also about 10 cm, it makes an ideal flesh thickness and seed cavity proportion. The flesh colour of mature fruits of different pumpkin genotypes may be creamish, light orange, orange or deep orange in colour. Since flesh colour in pumpkin is associated with carotenoid content, deeper the flesh colour higher will be the carotenoids and hance higher will be the nutritive value. Variation in palatability of the cooked vegetable of pumpkin fruit is determined by the flesh texture and odour of the flesh.

Fruit quality: Fruit quality is an important aspect of any improved variety, which covers a large number of traits in pumpkin *viz.* i. fruit skin colour of immature as well as mature fruits for which consumers' preferences vary, ii. presence of ridges and grooves which in combination with rind thickness and texture determine the transportation quality as well as flesh recovery of fruits, iii. non-cracking of maturing fruits on the plants, iv. rind thickness and texture are associated with keeping quality *i.e.* shelf life of fruits, v. flesh thickness which is associated with flesh recovery of fruit, vi. diameter of seed cavity, vii. flesh colour/β carotene content, viii. T.S.S. content, ix. palatability of cooked vegetable, and x. flesh texture –a desirable factor for cooking quality *barfi/halwa* and confectionery item preparations. Sufficient variability is recorded in the above mentioned traits of pumpkin genotypes found in Uttar Pradesh.

Seed characters: Like in other morphological features observable differences are recorded, particularly in seed shape and size. The seed shape may be round, broad, elongated or narrow. The size may be small, medium or big (Fig. 39r). With minor colour variations seed colour is generally white or creamy. The variations in seed shape, size and colour are independent of fruit shape, size and colour.

Earliness and yield: Great variability is encountered among pumpkin genotypes with respect to earliness. The anthesis of first staminate and pistillate flowers in early genotypes takes place at lower node numbers near the base of the vine in lower number of days as compared to late genotypes. Generally anthesis of first staminate flower occurs in lower number of days as compared to anthesis of first pistillate flowers. But it has been recorded that in early homozygous lines of pumpkin like Narendra Agrim and Narendra Amrit, anthesis of first pistillate flower occurs 4-6 days earlier than anthesis of first staminate flower. First pistillate flower anthesis in lower number of days as compared to first staminate flower anthesis in a genotype can be used as criterion for selection of early genotypes in pumpkin. Days to first picking in late February to early March sown summer type varieties varies from 55-75 days. Fruit yield potential of improved open pollinated varieties as well as land races in terms of fruit bearing capacity varies to a great extent (250-500 q/ha). In pumpkin hybrid Narendra Abhooshan the recorded potential fruit yield is 700 q/ha. Fruit yield is determined by fruit weight and number of fruits per plant, which in turn is a function of existent source-sink relationship of the genotypes.

Resistance: Resistance against biotic and abiotic stresses is an essential requisite trait of any crop which also holds true for pumpkin. Pumpkin is rated as a hardy crop that withstands relatively

better against certain common biotic and abiotic stresses in comparison to some other cultivated cucurbits. However, the crop does get adversely affected by certain stresses, important among which are several viral diseases and some major insect-pests like red pumpkin beetle, thrips, fruit fly etc. Surveys and explorations of pumpkin land races in Uttar Pradesh have revealed variability with respect to resistance against some viral diseases like pumpkin yellow mosaic disease (cucumis mosaic virus), watermelon mosaic virus etc. These valuable resistant land races require intensive evaluation, purification, selection, maintenance conservation and commercial exploitation. One such land race possessing resistance against pumpkin yellow mosaic disease was collected from district Rae Bareli, which was purified and developed into resistant cultivar Narendra Upcar (Fig. 40b) at

Fig. 40. Pumpkin mosaic disease incidence and intensity in 21st June, 2012 sown crop of pumpkin: a. stunted and withering plants showing severe PMV and WMV disease complex symptom in a common susceptible pumpkin genotype at 23rd days stage, b. PMV and WMV disease free plants of the field resistant variety Narendra Upcar at 23rd days stage.

NDUAT, Faizabad. A great wealth of variability, for resistance against biotic and abiotic stresses, is available with the farmers of Uttar Pradesh.

Photoperiod insensitive and sensitive genotypes in pumpkin

In North India improved and local land races are grouped into summer type and rainy season types. Villagers in Uttar Pradesh classify these two types as *Jethau Kohara* (summer season type) and *Bhadavaha Kohara* or *Barsati Kohara* (rainy season type). The *Jethau Kohara* is named after the month of Hindi calendar year Jyeshtha (the summer month corresponding to late May to early June months of English calendar year, possessing the longest days of about 13 hrs 30 minutes), and the *Bhadavaha Kohara* is named after the Bhadrapada or Bhado month of Hindi calendar year (the rainy season month generally corresponding to late August to early September months of English calendar year, possessing the period when the day length becomes moderately shorter of about 12 hrs 30 minutes). Generally the cultivators are not aware of distinctive behaviour of these two groups of pumpkin with respect to the photoperiod sensitivity. Only they know that *Jethau Kohara* produces satisfactory yield during summer and *Bhadavaha Kohara* produces satisfactory yield during rainy season, extending to early winter months. Here it may be noted that so far authentic and specific information is not available regarding photoperiod sensitivity of these two groups of pumpkin varieties. To assess the existence of nature of photoperiod sensitivity

among nine summer type (*Jethau Kohara*) and six rainy season/winter type (*Bhadavaha Kohara*) pumpkin genotypes, the experiments were conducted at NDUAT, Faizabad; with four distinct dates of planting, *viz*. 6th March, 21st June, 26th July, and 25th September, 2012. The four cropping periods had distinctly variable day lengths.

The flowering and fruiting behaviour of the 15 genotypes, as presented in Table 6, indicated that all the nine summer type genotypes produced normal pistillate flowers in all the cropping seasons, and therefore categorized as photoperiod insensitive genotypes. In the 6th March, 2012, sown crop out of six rainy season type genotypes four *viz*. NDPK-12-1, NDPK-12-2, NDPK-12-3, NDPK-12-4, although produced sporadic staminate flowers, late in the season, but could not produce even a single pistillate flower up to 100 days stage (Table 6). Therefore, they were considered strictly photoperiod sensitive, whereas the other two rainy season type genotypes NDPK-12-5 and NDPK-12-6 were quite late and shy in pistillate flower bearing in 6th March, 2012 sown crop and they produced very low fruit yield. These two genotypes were categorized as mildly photoperiod sensitive genotypes. The crop was terminated on 14th June, 2012, because it was withering due to ageing and various diseases. It may be noted that May-June are the months which are characterized by having longer days in between 13 hrs 11 minutes and 13 hrs 34 minutes.

The 21st June, 2012 sown crop was severely damaged by pumpkin mosaic disease complex where the plants of all the genotypes withered and showed stunted growth much before flowering stage (Fig. 40a), except for summer type genotype Narendra Upcar (Fig. 40b), which had very low severity of the disease complex even at later stages of the crop and the rainy season type genotype NDPK-12-2 which had low disease severity. The rainy season genotype NDPK-12-1 also had severe disease but a few plants escaped disease and produced pistillate flowers as well as fruits (Table 6). In Narendra Upcar first pistillate flowers opened in 55 days in more or less similar number of days (53.08) as required in 6th March, 2012 sown crop. The rainy season type genotypes NDPK-12-1 and NDPK-12-2 produced first pistillate flowers in 76 and 73 days, respectively, in first week of September characterized by 12 hrs 20 minutes day length.

The 26th July, 2012 sown crop had very low to moderate degree of severity due to pumpkin mosaic disease complex. This crop was although affected by adverse water logging conditions but all the genotypes produced normal staminate and pistillate flowers. Pistillate flowers were produced in lower number of days in all the mildly photoperiod sensitive and photoperiod insensitive genotypes as compared to 6th March, 2012 sown crop, except for Narendra Agrim (Table 6). The photoperiod sensitive genotypes NDPK-12-1, NDPK-12-2, NDPK-12-3, and NDPK-12-4, which could not produce pistillate flowers till 100 days stage of crop growth in 6th March sown crop produced first pistillate flowers within 62 days stage in 26th July, sown crop. These four genotypes were although in general five to ten days late in first pistillate flower anthesis as compared to summer type photoperiod insensitive genotypes but produced the comparable yield to the latter (photoperiod insensitive genotypes). The 25th September, 2012 sown crop was characterized by slow growth due to cool weather conditions of the winter but all the genotypes produced first pistillate flowers in slightly higher number of days, because of slow vegetative growth. None of the genotypes could

Table 6. Mean performance of 15 pumpkin genotypes for 13 economic characters in different dates of planting.

S. No.	Characters / Genotypes	6th March, 2012 sown crop				21st June, 2012 sown crop			26th July, 2012 sown crop			25th Sept., 2012 sown crop		
		Days to first staminate flower anthesis	Days to first pistillate flower anthesis	Yield (q /ha)	Rating of PMV disease at 100 days	Days to first pistillate flower anthesis	Yield (q /ha)	Rating of PMV disease at 23 days	Days to first pistillate flower anthesis	Yield (q /ha)	Rating of PMV disease at 100 days	Days to first pistillate flower anthesis	Yield* (q /ha)	Rating of PMV disease at 100 days
Rainy season type -photoperiod sensitive genotypes														
1.	NDPK-12-1	72.53	@	@	Low	76.0	20.3	Very high	61	112.21	Moderate	69.50	0.0	Low
2.	NDPK-12-2	64.80	@	@	Moderate	73.0	51.4	Low	62	106.98	Low	63.00	0.0	Low
3.	NDPK-12-3	69.40	@	@	Low	@@	0.0	V high	58	200.64	Very low	81.00	0.0	Low
4.	NDPK-12-4	65.42	@	@	Moderate	@@	0.0	V high	61	89.54	Moderate	68.25	0.0	Moderate
Rainy season type -mildly photoperiod sensitive genotypes														
5.	NDPK-12-5	63.49	84.59	150.2	Very low	@@	0.0	High	62	126.20	Moderate	80.50	0.0	Low
6.	NDPK-12-6	65.89	73.06	83.9	Symptom free	@@	0.0	V high	62	130.65	Low	71.50	0.0	Low
Summer season type -photoperiod insensitive genotypes														
7.	NDPK-12-7	62.00	63.08	391.5	Very low	@@	0.0	V high	56	101.76	Low	71.00	0.0	Low
8.	NDPK-12-8	56.37	58.00	417.2	Symptom free	@@	0.0	V high	55	226.19	Very low	63.50	0.0	Low
9.	NDPK-12-9	58.61	55.11	342.6	High	@@	0.0	V high	52	166.98	Low	59.50	0.0	Low
10.	NDPK-12-10	57.60	52.55	375.0	High	@@	0.0	V high	51	142.20	Low	59.00	0.0	Low
11.	NDPK-12-11	56.29	53.39	396.8	Very low	@@	0.0	V high	52	104.43	Low	60.50	0.0	Low
12.	NDPK-12-12	55.50	56.00	343.0	Moderate	@@	0.0	V high	52	91.10	Low	60.50	0.0	Low
13.	NDPK-2409	56.43	50.43	416.8	Very low	@@	0.0	V high	49	111.00	Low	46.50	0.0	Moderate
14.	Narendra Upcar (Check)	55.54	53.08	453.7	Symptom free	55.0	155.20	Very low	52	228.86	Very low	51.50	0.0	Very low
15.	Narendra Agrim (Check)	52.83	48.10	522.6	Very low	@@	0.0	V high	52	162.20	Low	52.40	0.0	Low

@these characters were not expressed till 100 days stage of plant growth in photoperiod sensitive genotypes *viz*., NDPK-12-1, NDPK-12-2, NDPK-12-3 and NDPK-12-4.

@@All plants in these genotypes withered and died before flowering and fruiting due to high pumpkin mosaic disease severity in 21st June, 2012, sown crop.

*The plants in all the genotypes in 26th September, 2012, sown crop, could not attain sufficient vegetative growth; therefore, the pistillate flowers produced could not turn into fruits.

produce any fruit yield because pistillate flowers could not turn into fruits due to very poor vegetative growth.

Based on the preliminary observations recorded on non-formation of pistillate flowers in NDPK-12-1, NDPK-12-2, NDPK-12-3, and NDPK-12-4, during long summer days (with more than 13 hrs day length) in 6th March, 2012 sown crop and normal production of pistillate flowers in rest of the later three crops, growing in months having shorter day lengths, it was inferred that these four pumpkin genotypes were photoperiod sensitive for pistillate flower formation and fruiting. First pistillate flower formation in NDPK-12-1 and NDPK-12-2 in 21st June, 2012 sown crop during first week of September, having 12 hrs 20 minutes day length, is indicative of the critical day length of 12 hrs 20 minutes required for pistillate flower production in photoperiod sensitive pumpkin genotypes. Since all the four photoperiod sensitive genotypes could produce pistillate flowers normally in the other two crops in the later months after September having shorter day lengths, pumpkin should be considered as short day type plant with respect to photoperiod sensitivity. Based on the pistillate flowering and fruiting behaviour over different dates of planting it is recommended that summer type photoperiod insensitive genotypes can be planted in any period of the year as per the requirement of the produce, whereas rainy season type photoperiod sensitive genotypes should be planted during June-July or even later upto first week of September.

Kamalanathan and Thamburaj (1970a,b) recorded that under south Indian conditions, pre-flowering and flowering phases in pumpkin were influenced, mainly by day length and temperature. Humidity and rainfall did not show significant effect on flowering. Seshadri and More (2009) observed that in North India, pumpkin varieties flower under long day conditions (April-May) in December-January sown crop. But in South India, August-September sown crop flowers under short day conditions in November-December.

21 ZUCCHINI

Origin, history, and use

Zucchini (*Cucurbita pepo* L.) is considered to be originated in northern Mexico and eastern United States. Zucchini is a vine less cucurbit, little known and little grown in Uttar Pradesh (Fig. 41a,c,d,e). However, it has big potential for wide cultivation in whole of Uttar Pradesh. It is one of the six variant groups of summer squash (*Cucurbita pepo* L.*) viz.* straight neck, crooked neck, cocozelly, zucchini, ornamental type, and scallop. Among these summer squash variants zucchini has become most popular world over. Unlike pumpkin only immature tender fruits are used in various vegetable preparations. It can also be used to produce delicious preparations like *pulau*, curry, sandwich, salad *etc.* Zucchini seeds have nutritive and medicinal value similar to pumpkin.

General morphology and biodiversity

Zucchini plants are bushy in nature having single culm unbranched short erect stems with very short internodes. Stem of some genotypes may get branched into two or three. Stem length varies from 40-100 cm. The crop bears deeply lobed very large leaf lamina with 30-35 cm length, which varies in shape, size, colour, and pattern of silvery splashing. Leaf petiole is also very long and the length varies among genotypes from 30 to 40 cm in length. The leaves may be highly splashed (Fig. 41a) or plain green (Fig. 41b).The bushy plants have underdeveloped, short, curved or spirally coiled and basically non-functional tendrils (Fig. 41c), mainly because tendril support is not required for sturdy erect stem of zucchini. Tendrils have two to three unequal branches arising from the place of its origin on the nodes. Few genotypes also have unbranched tendrils. Bracts are absent. Branches or even branch primordia are usually not visible, except in few genotypes. Vestigial branch primordia are rarely seen in some nodes of certain genotypes. Aerial roots arising from the stem nodes have never been seen in agro-climatic conditions prevailing at Faizabad. The crop is strictly monoecious in nature where staminate and pistillate flowers are borne on separate nodes (Fig. 41c). Pistillate flowers are larger (17 cm diameter) and open at 6:15 a.m., whereas staminate flowers are smaller (12 cm diameter) and open around at 6:30 a.m. in December. In improved cultivars, particularly F_1 hybrids, the anthesis of first pistillate flower take place a few days earlier at lower node number as compared to staminate flower anthesis. Improved varieties differ in earliness. In mid-October sown crop first harvest becomes available in 50-60 days and the total fruiting period extends from 40-60 days depending upon variety, crop care, and prevailing climatic conditions –particularly temperature. Parthenocarpic fruit set is a common observation in this crop. Great variability is recorded in fruit shape, size, and colour of zucchini (Fig. 41c,d). Mostly the varieties are cylindrical in shape and dark green in colour (Fig. 41c). Some genotypes are club shaped and light green in colour. A few genotypes are bright yellow in colour (Fig. 41d). Stable genetic variations in seed shape and size are also found.

A crop suitable for winter season cultivation in Uttar Pradesh

Fig. 41. Leaf characters; sex form and floral arrangement; fruiting behaviour and variability in fruit characters; cultivation methods; common cultivation problems; and comparative growth rate of zucchini compared to pumpkin in winter months: a. highly spalashed leaves, b. non-splashed leaves, c. solitary axillary staminate and pistillate flowers, d. bright yellow cylindrical fruits of zucchini, e. zucchini planting on raised bed, f. fruit cracking due to boron deficiency, g. a plant and fruits affected by viral disease complex, h.a frost damaged plant of the zucchini.

Zucchini is an easy-to-grow crop which thrives well under cool weather conditions of Uttar Pradesh. It is planted sporadically in October-November months in the vicinity of moderate to big cities like Lucknow, Varanasi, Jaunpur, Barabanki, Faizabad etc., to catch up the market demand as substitute of pumpkin from early December to mid-February. Pumpkin exhibits inhibited/dormant growth during this period. The cultivation is based mainly on the seed supplied by multinational or well established national seed companies of the country. Although it is a new crop, zucchini is getting fast popularity among the farmers because of its easy to grow nature and remunerative premium price during winter months. The overweight fruits of zucchini above 1.0 kg weight lose tenderness and taste; therefore, they should be harvested at 400 to 700 g fruit weight. Overgrown and mature fruits become hard and fibrous, and are useless for consumption. Zucchini is the one cucurbit which is most suitable for pot cultivation in the kitchen gardens as well as on the roof tops.

The results of experiments conducted over the years at NDUAT, Faizabad, have revealed that zucchini can successfully be cultivated by planting from early October to first week of November. Both earlier and later plantings result in viral diseases incidence and poor yield. Usually the yield levels vary from 300 to 400 q/ha with normal planting dates. The experiments have revealed that F_1 hybrids Cheongma Zucchini, Champion, Sunny House, Angelica, etc. supplied by private sector seed companies, produce remunerative yields in Faizabad conditions. The crop is prone to fruit cracking (Fig. 41f) which can be satisfactorily controlled by fortnightly spray of 0.4% borax or other micronutrients containing boron, starting from second true leaf stage of seedlings. The diseased plants suffering from viral diseases (Fig. 41g) should be removed from the field as and when they appear. Time to time removal of old diseased withering leaves is beneficial for enhancing yield. The crop is also damaged by frost (Fig. 41h). Varieties differ in respect to frost damage. The variety Cheongma Zucchini has been found relatively tolerant to frost.

22 COMPARATIVE STUDY OF ANNUAL CUCURBITS

Out of twenty-one common cucurbits *viz.* cucumber, longmelon, muskmelon, snapmelon, snake gourd, bottle gourd, ash gourd, ridge gourd, sponge gourd, bitter gourd, *satputia*, watermelon, roundmelon, pumpkin, zucchini, ivy gourd, pointed gourd, spine gourd, sweet gourd, chow-chow, and *kachari*, grown in India, 18 cucurbits (excluding the last three, sweet gourd, chow-chow and *kachari*) are cultivated in Uttar Pradesh in different months of the year. *Kachari* of Rajasthan is known as *pehtul* or *pehta* in eastern Uttar Pradesh and *kacharia* in western Uttar Pradesh. Pehtul commonly grows in wild or as volunteer crop in summer or rainy season. Pointed gourd, ivy gourd and spine gourd are vegetatively propagated and perennial in nature, while the remaining cucurbits are annual and propagated through seed, mainly during summer. In Uttar Pradesh zucchini is cultivated during winter.

An experiment was planted at NDUAT, Faizabad on 16th March, 2013, incorporating all the fourteen common annual cucurbits of Uttar Pradesh, to study the inherent biodiversity and comparative performance with respect to a few important morphological and economic traits. *Kachari (pehtul)* a popular cucurbit of Rajasthan was also incorporated in the study to assess its performance and acceptability in Uttar Pradesh. The name of fourteen crops, their varieties/land-races and the traits on which observations were made are given in Table 7. Tendrils were the constant feature of all the cucurbits. The average node number at which the first tendril appeared greatly varied from crop to crop. The results revealed that first tendril was born on the lowest average node number in watermelon (2.71). Ash gourd bore the first tendril at the highest average node number (10.76). Tendril length and their branching behaviour also varied among cucurbits. Presence and size of bracts were the variable features among the cucurbits (Table 7). The largest flowers, as observed in terms of male flower diameter (14.33 cm) and female flower diameter (20.93 cm), were produced in pumpkin followed by sponge gourd and ash gourd, while smallest flowers were recorded in watermelon followed by bitter gourd. In bottle gourd, bitter gourd and watermelon male flower size was larger than female flower size of the same plant/genotype, whereas, in other cucurbits female flower size was larger than male flower size. First green fruit picking was done in lowest number of days in cucumber (44.66 days) and longmelon (45.33 days), while ash gourd produced first green fruits in highest number of days (82.00 days) followed by snake gourd (67.33 days). Muskmelon, snapmelon, *kachari* and watermelon produced first mature fruits in more or less in similar number of days (ranging in between 66.33 and 69.66 days). With respect to fruit yield (q/ha) *satputia* (46.88 q/ha), snake gourd (66.55 q/ha) and *kachari* (94.80 q/ha) were among the lowest yielders in 16th March, 2013 sown crop, while watermelon (304.7 q/ha), pumpkin (253.75 q/ha), bottle gourd (251.08 q/ha) and snapmelon (245.71 q/ha) were among the highest yielder cucurbits. Among the *Cucumis spp*. snapmelon had the highest fruit yield (245.71q/ha) followed by muskmelon (193.31 q/ha), longmelon (191.65 q/ha), cucumber (150.20 q/ha) and kachari (94.80 q/ha).

Table 7. Biodiversity and comparative performance of distinct morphological and economic traits of fourteen common cucurbits.

S. No.	Name of Crop	Variety/ Genotype	Node No. to first tendril appearance	Tendril length (cm)	Tendril extension from apex (cm)	Branching Nature of tendril	Bract size	Staminate flower diameter (cm)	Pistillate flower diameter (cm)	Vine length (cm)	No. of branches
1.	Cucumber	NDCU6-4	5.83	26.53	9.06	Single	Absent	3.63	4.33	213	5.25
2.	Longmelon	NDLM-1	4.67	17.00	2.36	Single	Very small	4.23	4.83	382	7.91
3.	Muskmelon	NDMM-7	4.88	16.70	6.23	Single	Very Small	3.50	4.40	283	7.05
4.	Snapmelon	NDSM-1	5.29	15.43	5.16	Single	Very Small	3.50	3.93	253	10.33
5.	Kachari	Pushkar Local	5.00	13.43	2.20	Single	Very Small	3.10	3.43	345	11.66
6.	Snake gourd	NDSNG-1	6.98	25.56	12.93	3	Very Small	2.83	3.03	512	9.44
7.	Bottle gourd	Narendra Rashmi	5.88	19.83	6.63	2	Absent	7.70	6.96	327	9.77
8.	Ridge gourd	NDRG-1	6.17	26.01	11.70	4-5	Medium	4.53	5.56	418	9.41
9.	Sponge gourd	NDSG-1	5.19	25.23	10.60	3-4	Medium	9.23	10.50	417	8.00
10.	Ash gourd	NDWG-1	10.76	17.20	4.96	3	Large	7.4	9.86	371	7.88
11.	Bitter gourd	Faizabadi	7.36	19.83	8.73	1-2	Large	3.66	3.40	335	15.58
12.	Satputiya	Narendra Satputia-1	6.50	23.80	11.43	4-5	Medium	3.96*	3.96*	409	9.88
13.	Watermelon	Lal Pasand	2.71	10.63	-3.60	3-4	Large	3.53	2.73	388	10.08
14.	Pumpkin	Narendra Upcar	5.40	18.56	10.1	3-4	Absent	14.33	20.93	455	14.94

*Hermaphrodite flower diameter

Table 7. continued…..

S. No.	Name of Crop	Variety/ Genotype	Node to first staminate flower anthesis	Node to first pistillate flower anthesis	Days to first staminate flower anthesis	Days to first pistillate flower anthesis	Days to first harvest	Average fruit length (cm)	Average fruit Circum-ference (cm)	Average fruit weight (g)	Fruit yield (q/ ha)
1.	Cucumber	NDCU6-4	3.05	6.10	31.50	35.49	44.56	21.08	12.33	171	150.20
2.	Longmelon	NDLM-1	3.79	6.96	31.38	41.48	45.33	45.30	8.90	206	191.65
3.	Muskmelon	NDMM-7	6.57	9.78	35.87	42.75	69.00	24.41	34.13	728	193.31
4.	Snapmelon	NDSM-1	3.57	5.99	32.75	39.88	68.33	33.66	49.25	1600	245.71
5.	Kachari	Pushkar Local	3.27	4.44	31.81	34.30	66.33	13.08	15.20	110	94.80
6.	Snake gourd	NDSNG-1	10.61	20.79	53.73	59.57	70.00	38.25	15.25	677	66.55
7.	Bottle gourd	Narendra Rashmi	9.80	12.13	45.54	45.92	54.33	38.87	22.79	1000	251.08
8.	Ridge gourd	NDRG-1	3.94	11.13	34.26	43.21	50.00	19.29	12.50	120	65.33
9.	Sponge gourd	NDSG-1	5.18	11.04	43.04	40.18	50.00	25.74	12.50	130	184.42
10.	Ash gourd	NDWG-1	19.44	24.83	61.45	64.27	82.00	20.79	38.76	1067	120.21
11.	Bitter gourd	Faizabadi	6.47	11.55	41.84	46.66	56.33	15.30	11.87	98	104.43
12.	Satputiya	Narendra Satputia-3	7.35	7.35	49.20	49.20	55.33	12.77	11.07	42	46.88
13.	Watermelon	Lal Pasand	5.80	13.71	32.94	37.42	69.66	44.75	65.70	5683	304.75
14.	Pumpkin	Narendra Upcar	6.16	15.38	45.83	46.38	54.33	23.72	54.40	1522	253.75

23 BREEDING OBJECTIVES

Breeding objectives of cucurbits can broadly be grouped into five general categories, *viz.* earliness, yield, quality, resistance against biotic and abiotic stresses, and breeding for special purposes. A general description of these five major objectives as it pertains to different cucurbit crops is discussed in brief as under:

Earliness, sex ratio, growth habit, and sensitivity to photoperiod

Earliness in cucurbits implies to first picking of edible tender fruits of majority of cucurbits which are used as cooked vegetable, and implies to first picking of mature fruits, in case of dessert fruit cucurbits. Days to first picking is primarily determined by days to anthesis of first pistillate (in gynoecious or monoecious crops) or first hermaphrodite flowers (in hermaphrodite and andromonoecious crops). Since fruits are formed from pistillate or hermaphrodite flowers, first flower anthesis in these flowers are considered to be more important than first staminate flower anthesis. Days taken to first staminate/pistillate/hermaphrodite flower anthesis as well as node number to first anthesis of these three types of flowers are treated as criteria for earliness of a cultivar. Generally node number at which first staminate/pistillate flower anthesis occurs is taken as more stable criteria than days to first flower anthesis. Studies conducted by Kumar (2000) on 55 bottle gourd genotypes with four dates of planting over a period of year at NDUAT, Faizabad revealed that node numbers at which first staminate and first pistillate flower antheses took place were as much vulnerable to change over different climatic conditions as that of days to first flower anthesis (Table 8). In fact, except for the off season planting on 16th November, 1997 for the offing early summer crop (which passed through cool temperature condition and dormant/ slow growth period of about 90 days), the other three crops planted on 15th March, 25th June, and 15th September, 1998 exhibited more stable number of days for first staminate and pistillate flower antheses than node numbers to first staminate and pistillate flower antheses. The data revealed that node numbers to first staminate/pistillate flower antheses during normal growth period of the crop were more influenced by temperature, humidity and photoperiod conditions than days to first flower anthesis. In most cucurbit crops, commonly the first staminate flower anthesis occurs in lower number of days and at lower node number as compared to first pistillate flower anthesis (Table 7). However, there are certain genotypes in different cucurbits where first pistillate flower anthesis does occur a few days earlier than pistillate flower anthesis as in case of pumpkin varieties Narendra Agrim and Narendra Amrit (Table 9). It also holds true both for node number as well as days to first pistillate and staminate flower antheses in very early genotypes of bottle gourd and sponge gourd.

Cucurbit genotypes producing first pistillate flowers earlier than first staminate flowers, have also the tendency to produce a high pistillate : staminate flower ratio, a desirable attribute for enhancing fruit yield. Apart from genetic factors sex ratio is highly influenced by temperature,

photoperiod, nitrogen application, and plant growth regulators. Low temperature and short day length favour pistillate flower production while high temperature, long photoperiod, and high nitrogen application favour staminate flower production.

Genotypes with short vines generally flower earlier than those having long vine growth. But the short vines may become a limiting factor for fruit yield in terms of fruit weight and number of fruits per vine. Therefore, a balance of medium vine length and earliness is necessary for optimum fruit yield. Bushy cucurbits like zucchini (*Cucurbita pepo*) (Fig. 42) are early and prolific bearer. Bushy genetic stocks are also available in *Cucurbita maxima* (Robinson and Decker-Walters, 1999), muskmelon, and watermelon (Seshadri and More, 2009), but they are not yet commercially exploited.

Table 8. Effect of planting dates on grand means of maturity traits studied over 55 bottle gourd genotypes

S. No.	Date of planting	Days to first staminate flower anthesis	Days to first pistillate flower anthesis	Nodes to first staminate flower anthesis	Nodes to first pistillate flower anthesis
1.	16th November, 1997	104.10	112.96	7.37	10.42
2.	10th March, 1998	48.75	51.73	10.73	14.41
3.	25th June, 1998	49.93	55.92	20.85	28.88
4.	15th September, 1998	43.83	46.98	14.07	17.50

It is a common conception among cucurbit scientists that cucurbits are generally day neutral plants. Seshadri and More, (2009) observed that cucurbits are generally day neutral plants with some variations and exceptions. However, close observations in the experiments conducted at NDUAT, Faizabad on bottle gourd (Chapter 2), sponge gourd (Chapter 3), bitter gourd (Chapter 10) and pumpkin (Chapter 20); the author is of the view that many of the cucurbit species have both photoperiod insensitive and sensitive genotypes. The experimental results on bottle gourd, sponge gourd, and pumpkin are indicative of short day type photoperiod sensitivity in these crops. In general the critical day length for initiation of pistillate flower formation in photoperiod sensitive bottle gourd genotypes appears to be somewhere in between 12 hr 20 minutes (in the first week of September in Uttar Pradesh) and 11 hr 50 minutes (in the last week of September in Uttar Pradesh). The critical day length requirements among photoperiod sensitive sponge gourd genotypes are recorded to be in between 12 hr 36 minutes and 11 hr 50 minutes. Thus, the requirements of critical short day length have been observed to vary among the photoperiod sensitive genotypes. Below the critical day length pistillate flower formation is accelerated. A large number of studies have already been conducted on various cucurbits on this subject. In Malabar gourd (*Cucurbita ficiflolia*) and Chayote (*Sechium edule*), long days inhibit flower production altogether (Robinson and Decker-Walters, 1999). Temperate region growers wanting to produce fruits from short day plants like Chayote during the summer need to control the photoperiod of young plants. Vines can be allowed to grow under natural day lengths after flowering has begun (Aung *et al.* 1990). The effect of long and short photoperiods on the production of staminate and pistillate flowers is complicated by the temperature regimes prevailing in summer and winter, respectively. The experiments conducted over the years at NDUAT, Faizabad on summer type photoperiod insensitive and winter type photoperiod sensitive genotypes of bottle gourd and sponge gourd, have revealed that photoperiod sensitive genotypes of

these two crops are relatively hardy to cool temperature and have long fruiting period as compared to photoperiod insensitive genotypes, when planted during July-August, for off-season winter crop. On the other hand the winter type photoperiod sensitive genotypes if planted in March-April for summer season crop, these genotypes scarcely produce pistillate flowers with very small number of staminate flowers. Thus, there is a need to breed for improved photoperiod insensitive genotypes for summer season cultivation and photoperiod sensitive genotypes for winter season cultivation at least in those crops where the two distinct groups of genotypes with distinctive flowering and fruiting behaviour are in existence.

Fruit yield

The most complex character-fruit yield-is the top priority breeding objective of every crop improvement programme, which is mainly governed by fruit weight and number of (marketable) fruits per plant. Number of fruits per plant and bulking of fruits are influenced by efficient source-sink relationship within a crop variety, apart from other related factors like pistillate:staminate flower sex ratio, vine length, number of branches per vine, length of fruiting period etc.

Fruit quality

Quality pertains to fruit characters of cucurbits. A variety of criteria are used to define quality in different cucurbits. Many of the quality factors may be common to a number of cucurbits and yet a few of them differ to a great extent when it comes to specific description of quality of a particular crop. Some important quality factors are **i.** Fruit shape, **ii.** Fruit surface, **iii.** Fruit colour, **iv.** Fruit size, **v.** Flesh thickness, **vi.** Flesh colour, sweetness and palatability, **vii.** Bitter and non-bitter fruits, **viii.** Number and size of seeds, **ix.** Shelf life and transportation quality, and **x.** Processing quality.

Resistance against stresses

Cucurbits are grown in diverse agro-climatic conditions of soil, nutrient, temperature, water, humidity, photoperiod, pollutants etc. They are cultivated in the riverbeds and uplands as well as in the vicinity of huts and houses. Some of the cucurbits are grown almost round the year in Uttar Pradesh. Therefore, they are expected to face a variety of biotic and abiotic stresses. In form of biotic stresses they are prone to several kinds of insect-pests, *viz.* red pumpkin beetle, thrips, cut worm, white fly, fruit fly, epilachna beetle, aphids, vine borer, bottle gourd bug, nematodes etc.; and diseases, major of which are damping off, downy mildew, powdery mildew, anthracnose, fusarium wilt, alternaria leaf blight, and several viral diseases. Resistance in a cultivar against a disease or pest provides permanent solution by reducing input cost and it is also safer to health. Therefore, attempt should be made to develop resistant cultivars of cucurbits. Wherever, possible preference should be given to develop multiple resistance against diseases and pests (Peterson *et al.,* 1982; Provvindenti, 1990). Sources of resistance against several diseases and pests of different cucurbits have been given by Seshadri and More (2009). Considering the diverse agro-climatic conditions for round the year cucurbit cultivation, covering main season and off-season crops, and also other prevailing soil, water and air factors, the breeding objectives should also be focused to develop resistant varieties against the major abiotic stresses.

Breeding for special purposes

Apart from their use as salad, vegetable, and dessert fruits the cucurbit plant parts have various utilitarian uses. The hard shells of mature fruits of bottle gourd have multifarious use in preparation of utensils, containers, rattles, floats for fish nets and musical instruments like sitar, ektara etc. The author (Sheo Pujan Singh) has designed and constructed pipes/sirens of different sizes and shapes using dried hard shells of variety Narendra Shivani. Blowing of the sirens creates sound like conch and it works as a good breathing exercise (Fig. 44). Bottle gourd varieties to be used for such items should have specific fruit shape, size and thickness of shell to fit the specific requirements for the specific purposes. The fibro-vascular network of sponge gourd dried mature fruits after removing fruit cover and seeds are used as filters and scrubber of body and utensils. The varieties used for these purposes should have specific density and strength of fibre. The seeds of several cucurbits are used in confectionery items and to extract oil. The improved varieties of these cucurbits should possess attributes like soft and thin seed coat, high palatability, and high fat content and quality. The pumpkin and squash cultivars with 'naked' seeds, have increased the popularity of seeds for food in several countries (Robinson and Decker-Walters, 1999). In China and Iran watermelon seed is the main product and valued more than flesh and hence large seeded varieties are common. Attractive award winning competitive exhibits are displayed every year in Europe and Americas to promote, production of heavier fruits of *Cucurbita maxima*. In Uttar Pradesh at Raj Bhawan, Lucknow state level exhibition is organized every year, where large size pumpkin, ash gourd and bottle gourd fruits are the interesting exhibits. The bottle gourd variety Narendra Shivani attracts large crowds for its very long fruits of over 6 feet length in such exhibits (Fig. 43). Therefore, attempt should also be made to develop larger and longer size fruits for exhibition purposes.

Fig. 43. Uttar Pradesh Governor Mr. B. L. Joshi looks at the fascinating fruit length of bottle gourd variety Narendra Shivani, measuring 200 cm, in an exhibit at Raj Bhawan, Lucknow, in February, 2011.

Fig. 44. Bottle gourd conch blow by Professor Sheo Pujan Singh in an U.P. Science Congress exhibit at Gorakhpur in March, 2012. A bottle gourd painted conch is in the inset.

24 BREEDING METHODS

Cucurbits are, broadly, classified as cross pollinated crops and the cross pollination is entomophillous. The extent of cross pollination varies among cucurbits, depending upon the eight types of diverse sex forms, *viz.* androecious, gynoecious, dioecious, monoecious, hermaphrodite, andromonoecious, gynomonoecious, and gynandromonoecious. In dioecious cucurbits self pollination is excluded and cross pollination is 100%. The monoecious sex form also favours cross pollination and the extent of cross pollination in such populations may vary from 60 to 80%, depending upon the environmental conditions and availability of insect pollinators (Seshadri and More, 2009). But the single monoecious plants which grow in distinct range of isolation, without any possibility of cross pollination through insects, only self pollination prevails. The remaining four sex forms, *viz.* hermaphrodite, andromonoecious, gynomonoecious, and gynandromonoecious, are characterized by the presence of hermaphrodite flowers, having both sex organs. Since all cucurbits are self-compatible; there are higher possibilities of self pollination in all those cucurbit genotypes which bear hermaphrodite flowers in various sex forms. Nugent and Hoffman (1981) studied natural cross pollination in four andromonoecious seedling marker lines of muskmelon in replicated design for three years. The average out crossing in these genetic stocks was less than 10 %. One line exhibited only 0.5% natural out crossing in a specific year. This natural tendency of cross and self pollination mode among cucurbits over the millennia have placed cucurbits in an unique group of cross pollinated plants, which withstands the adverse effect of inbreeding depression even after several generations of inbreeding. Bushnell (1922) was able to isolate uniform high quality lines with desirable economic attributes in *Cucurbita maxima* through inbreeding. Cumming and Jenkins (1928) experimented with Hubbard group of *C. maxima* over a period of 10 years and concluded that pure line studies in relation to vigour of the plant and reproduction, seemed to show that degeneration or pauperization were not necessary concomitants, arising from continuous self pollination. Jenkins (1942) developed inbred lines of cucumber without loss of vigour. Allard (1960) stated that cucurbits, although monoecious and cross-pollinated, do not suffer inbreeding depression and in many ways their population structure is more similar to that of in-breeders than out-breeders. He pointed out, the cucurbits may have existed in small colonies in nature and under cultivation, and this restriction of population size may have produced inbreeding despite the floral mechanism favouring out crossing. Thus, the presence of insignificant or no-inbreeding depression in cucurbits provides an opportunity for developing improved varieties with high degree of uniformity in the morphological traits as well as economic attributes. Therefore, all the breeding methods applicable to self pollinated crops can easily be adopted for crop improvement of cucurbits.

Since genes are at work behind all the characters the knowledge of genes and genetics of the characters under improvement is paramount for successful crop improvement. In some of the cucurbits genetic studies have been conducted and the comprehensive gene lists have been published from time to time by Cucurbit Gene List Committee in the years 1979, 1982, 1985 and 1986. Apart

from this Robinson *et al*. (1976), Robinson and Hutton (1996), Rhodes and Dane (1999), Robinson and Paris (2000), Xie and Wehner (2001), Pitrat (2002), also reported gene list of some important cucurbits. A brief review of cucurbit genetics have been presented by Seshadri and More (2009). To achieve the different breeding objectives the important breeding methods used in cucurbit improvement are described here in brief.

Pure line breeding

Pure line breeding has been the most popular method of crop improvement of cucurbits world over and it continues to be so even today, particularly in the Indian context. Although the simplest among breeding methods, pure line breeding requires careful scrutiny of the segregating population after selfing in the promising and potential indigenous or other base materials. Cucurbits are characterized by numerous easily observable, stable, distinct and large morphological features, *viz*. size, shape, and colour of vine, leaf, tendril, bract, flower and floral arrangement, fruit, and seed. Node number and days to first staminate and pistillate flower anthesis and fruiting behaviour are also reasonably stable genetic characters within the given limits of temperature, humidity, photoperiod, and growth conditions of the crop. In India majority of open pollinated cucurbit varieties have been developed through pure line breeding.

Mass selection

No doubt pure line breeding method leads to uniformity of characters, mass selection has its own strength in developing populations of broad genetic base with better adaptability and stability, having limited acceptable heterogeneity. Somehow the method has not received much acceptability among breeders.

Pedigree method

Pedigree method provides opportunity for selection of desirable transgressive segregant(s) as well as reconstituted genotypes having desirable traits of both the parents. Bottle gourd variety Narendra Dharidar (Fig. 47) developed by NDUAT of Faizabad has been developed using pedigree method of selection. The striped round fruited bottle gourd genotypes NDML-SS-4 (Fig. 14) and NDML-NS-7 (Fig. 15), possessing field resistance against fusarium wilt are also the derivative of pedigree method selection. The quality pumpkin genotype Narendra Amrit-4 (Fig. 49), selected through pedigree method of breeding, has the reconstituted desirable traits of both of its parents Narendra Amrit and Narendra Agrim (Fig. 48). Kashi Harit a pumpkin variety developed at IIVR, Varanasi is a product of cross between NDPK-24 (Narendra Agrim) and PKM produced through pedigree method.

Backcross breeding

The term backcross usually applies to a cross between a F_1 hybrid and to either of its parents, but in backcross breeding system the F_1 hybrid and the progenies in the subsequent generations are repeatedly backcrossed to one of the parents of the hybrid, which is accompanied by selection for one or a few desirable characters. The backcross breeding is used to transfer simply inherited

monogenic, oligogenic or highly heritable traits from a donor parent to an otherwise superior and adapted variety of an area. Generally 6-7 generations of backcrossing, by recurrent parent and selections are required to recover a reconstituted genotype with almost identical genetic base of the recurrent parent and one or few desirable traits from the donor parent. For transfer of trait controlled by a dominant gene and that controlled by a recessive gene, the schemes of backcrossing slightly differ. Backcross breeding is commonly used to transfer disease resistance from one variety to another; however, it can also be used for transferring other desirable characters, as described by Singh (2001).

Heterosis breeding

Cucurbits are highly amenable for heterosis breeding because of the following favourable features of these crops: **i.** Cucurbits are generally monoecious in nature, therefore emasculation is not required in manual crossing procedures for producing F_1 hybrid seed, **ii.** Except for few, most of the cucurbits have large flowers, easy to handle in controlled pollination, **iii.** There is relatively a high success rate of fruit development in attempted self, sib, and cross pollinations, **iv.** Number of seeds per fruit is generally quite high which reduces hybrid seed production cost even if hand pollination is the option, **v.** Seed rate per unit area is quite low, which makes hybrid seed production more practical and acceptable, **vi.** Highly uniform inbreds for fruit characters, maturity traits, and disease resistance can be developed without significant loss of vigour, **vii.** With the use of uniform inbreds highly uniform hybrids are attained and **viii.** High level of exploitable heterosis is reported in most cucurbits. Therefore, cucurbit hybrids are widely cultivated world over and they are getting fast popularity in India too. The F_1 heterotic hybrids provide unique opportunity for combined expression of the desirable traits like earliness, yield, quality, and resistance of both the parents. The typical examples of bottle and pumpkin hybrids developed at NDUAT, Faizabad, are presented as follows:

Narendra Sankar Lauki-4 (NDBGH-4): Narendra Sankar Lauki-4 is a bottle gourd hybrid developed by using Narendra Jyoti (NDBG-104) (Fig. 47) and Pusa Naveen as the two parental lines. NDBGH-4 has exhibited 22.92 % superiority over Pusa Naveen in the coordinated trials. In the F_1 hybrid the desirable traits like longer vine length, higher number of branches per plant, longer and attractive fruits, higher fruit weight of Narendra Jyoti are combined with the desirable traits like earliness and prolific bearing of Pusa Naveen. The yield attributes of NDBGH-4 (Fig. 47) has been described in Chapter 25.

Narendra Abhooshan (NDPKH-1): Narendra Abhooshan is a pumpkin hybrid developed by using Narendra Agrim and Narendra Amrit as parental lines. The recorded potential yield of Narendra Abhooshan is above 700 q/ha. The important characteristic features of the parental lines and Narendra Abhooshan are shown in Fig. 45, 46 and presented in Table 9.

Gynoecious hybrids of cucumber are reported to produce a fruit yield of 300 t/ha, under protected cultivation in U.K. (Sheard, 1981), and nearly 500 t/ha under Netherlands conditions. Describing prospects of adoption of hybrid technology for cucurbits in India Seshadri and More (2009), opined that cucurbit hybrids can penetrate in garden land cultivation, if disease resistance to

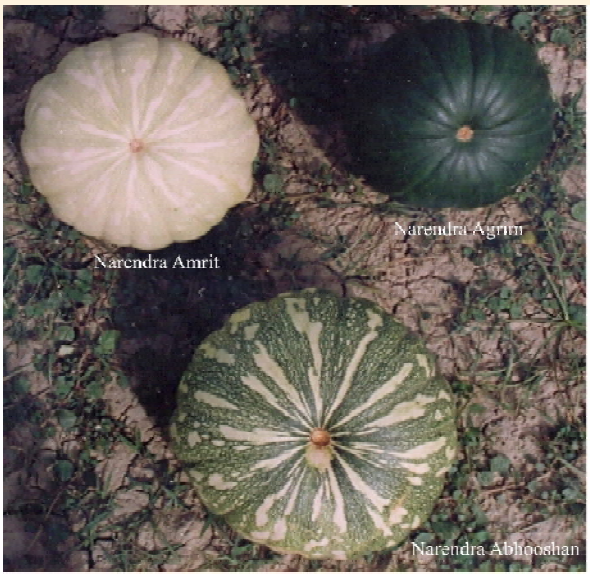


Fig. 45. Fruit shape, size and colour of parental lines and Narendra Abhooshan

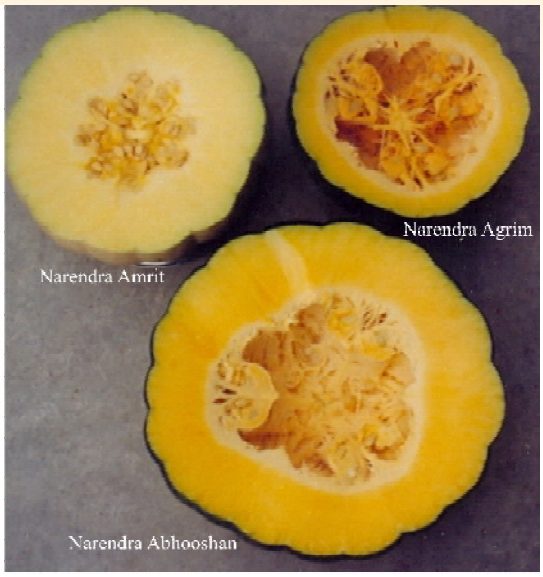


Fig. 46. Flesh thickness, flesh colour and cavity size of parental lines and Narendra Abhooshan

Table 9. Salient characteristic features of F_1 hybrid Narendra Abhooshan and its parental lines Narendra Agrim and Narendra Amrit.

S. No.	Characteristic features	Narendra Agrim	Narendra Amrit	F_1 Narendra Abhooshan
1.	Node number to first staminate flower anthesis	3.90	5.20	4.80
2.	Node number to first pistillate flower anthesis	12.00	16.30	13.30
3.	Days to anthesis of first staminate flower	50.50	57.90	49.00
4.	Days to anthesis of first pistillate flower	46.70	53.30	55.10
5.	Days to first green fruit harvest	58.00	64.00	56.00
6.	Number of green fruits per plant	2.80	1.90	2.50
7.	Average weight of green fruit (kg)	2.00	3.00	3.10
8.	Yield of green fruits per plant (kg)	5.60	5.70	7.76
9.	Main vine length (m)	4.90	5.80	6.70
10.	Mature fruit weight (kg)	3.00	6.00	6.50
11.	Flesh thickness of mature fruits (cm)	3.10	5.60	4.60
12.	Potential fruit yield (q/ha)	520	430	700
13.	Fruit shape	Round	Round	Round
14.	Tender fruit colour	Stripeless dark green	Striped pale green	Striped dark green
15.	Flesh colour of mature fruit	Deep orange	Cream	Orange
16.	Leaf colour	Highly splashed	Mildly splashed	Highly splashed

mildews and viruses are incorporated. In fact F_1 hybrids offer an unique opportunity for multiple disease resistance provided resistance is governed by dominant genes.

Mutation breeding

Although mutation breeding is not directional breeding, to produce expected results and yet this technique has been successfully used in some cucurbits with desirable results. Japanese scientists Sugiyama and Morishita (2002) were successful in producing diploid plants yielding seedless watermelon fruits, by using soft X-ray irradiated pollen. Watermelons that are produced from pollination with pollen irradiated with 800 Gy or more, contained only empty seeds. Rajasekaran and Shanmugavelu (1984), irradiated the seeds of a local bitter gourd cultivar MC-103 with gamma rays (15-20 kR) and isolated a superior line having early flowering and high yield (32 t/ha) which was later released as MDU-1. Datta (1987) obtained a mutant with yellow striped fruits in M_2 generation following treatment with 18 kR X-rays of seeds of snake gourd (*Trichosanthes anguina*), which had white stripes and white fruits.

Polyploidy breeding

Like mutations polyploids have a great potential to bring about sudden changes in the phenotypes of organisms. Some of them may have practical application in plant breeding programme. Production of triploid seedless watermelon is a classic and single example of direct application of autotetraploidy in cucurbit crop improvement Kihara (1951). The seed of triploid cultivar is produced every year by crossing autotetraploid (4x=44) as female parent with the diploid (2x=22) as male parent. Stable tetraploid lines *viz.* Tetra-1, Tetra-2, Tetra-3, and Tetra-4 were developed by Vegetable Breeding Laboratory of USDA at Charleston, (South Carolina) USA. Tetra-2 has been used at Indian Agricultural Research Institute, New Delhi for production of seedless watermelon variety 'Pusa Bedana' (Seshadri *et al.*, 1972). Crimson Jewel and Genesis are some other seedless varieties of watermelon; developed as a result of the discovery by Kihara. Attempts have been made to develop tetraploids in other cucurbits *viz.* muskmelon (Batra, 1952; Rajsekaran and Ganesan, 1971), bitter gourd (Kadir and Zahoor, 1965), and snake gourd (Singh and Roy, 1975) but no headway has been achieved for their practical utility. Efforts of researchers to develop homozygous lines (by developing haploids), dihaploids, and aneuploids in some cucurbits are briefly reviewed by Seshadri and More (2009).

Clonal selection

Clonal selection is of major significance for production of uniform fruit shape, size and colour, along with other important morphological features in highly heterozygous vegetatively propagated cucurbits like pointed gourd, ivy gourd, spine gourd, and sweet gourd. Since all these cucurbits are dioecious in nature, their purification through inbreeding is doubly complicated, rather unlikely. The potential female clones can be selected, after extensive evaluation, out of the existing variable clones available with the farmers. Alternatively new female clones can be produced from seed generated heterogeneous population and clonal selections made thereafter. Vigorous male clones producing prolific staminate flowers and abundant pollen grains can also be selected, to be used as male parents in minimum recommended ratio along with female clones, in the commercial production

plots. Pointed gourd varieties Narendra Parwal-260, Narendra Parwal-307, and Narendra Parwal-604 (Fig. 50) have been developed through clonal selection.

Interspecific hybridization

Interspecific hybridizations between any two related species of a genus are attempted when it is considered necessary to transfer some desirable traits like resistance against biotic and abiotic stresses or otherwise. Interspecific hybridizations are also made to study the relationships among the species of a genus. Generally the interspecific crosses are incompatible and if crosses are successful, the progenies so produced are usually sterile. Among cucurbits interspecific hybridizations have been tried in several genera such as *Cucumis*, *Citrullus*, *Cucurbita*, *Lagenaria*, *Momordica*, *Luffa*, *Trichosanthes* etc. (Seshadri and More, 2009). Except for, interspecific hybridizations among *Cucurbita* species the results with other genera have been of little consequence or of academic interest only. Interestingly the F_1 hybrids of *Cucurbita maxima* × *C. moschata* have been directly utilized as cultivars of winter squash without further breeding. Both parental species are monoecious, with proportionately large number of male than female flowers, but the interspecific hybrid is gynoecious or predominantly female in sex expression. The interspecific hybrid is usually very productive if a monoecious cultivar is grown nearby to provide pollen. The interspecific hybrid combined the desirable traits like good quality flesh from *C. maxima* and resistance to squash bug and squash vine borer from *C. moschata* to which *C. maxima* is susceptible (Pearson *et al*. 1951). The Japanese seedsmen have perfected the technique of seed production of the interspecific hybrid *C. maxima* × *C. moschata*. Seed production has been found to be prolific when *C. maxima* is used as maternal parent. The gynoecious hybrid is also produced by crossing two monoecious species *C. pepo* × *C. ecuadorensis* (Robinson and Decker-Walters, 1999). Similarly *C. pepo* and *C. moschata* are also crossable. The bush gene of *C. pepo* has been introgressed into *C. moschata* to incorporate compact plant habit, whereas ZYMV resistance from 'Nigerian local' (*C. moschata*) has been transferred to Tigress and Jaguar cultivars of *C. pepo*. Gene transfers have been made for viral disease resistance from *C. ecuadorensis* and *C. foetidissima* to cultivated species of *Cucurbita* (Provvidenti, 1990).

Genetic engineering

Genetic engineering can be of great help in improvement of cucurbits by incorporating specific desirable genes in the chosen genetic backgrounds. Of particular interest are the attempts by the scientists to develop transgenic cucurbit plants having resistance against viral diseases. In the USA the first commercially available transgenic viral disease resistant cucurbit 'Freedom-II' has been developed in yellow summer squash of crookneck type (*Cucurbita pepo)*. This cultivar has resistance to WMV and ZYMV.

25 BIODIVERSITY AND CROP IMPROVEMENT

In Uttar Pradesh the two state agricultural universities, *viz.* Narendra Deva University of Agriculture and Technology (NDUAT), Kumarganj, Faizabad and Chandra Shekhar Azad University of Agriculture and Technology (CSAUAT), Kanpur; and one central government institution *viz.* Indian Institute of Vegetable Research (IIVR), Jakhini, Varanasi are actively engaged in the development of improved varieties of various cucurbits. The names of the cucurbit varieties developed by these three institutions are given in Table 10. Majority of these varieties have been developed through pure line breeding by directly utilizing indigenous land races collected from within the state of Uttar Pradesh. Bottle gourd variety Narendra Dharidar and pumpkin variety Kashi Harit are the derivatives of pedigree method of breeding. The two hybrids, *viz.* Narendra Sankar Lauki-4 (NDBGH-4) and Narendra Abhooshan (NDPKH-1) developed in bottle gourd and pumpkin, respectively, are the product of two promising parents in each hybrid. Characteristic features of varieties along with unique and promising genetic stocks developed at NDUAT, Faizabad are briefly described in the offing pages.

Table 10. Crop-wise list of names of cucurbit varieties developed at NDUAT, Faizabad; CSAUAT, Kanpur; and IIVR, Varanasi.

S.No.	Crop	Varieties Developed		
		NDUAT, Faizabad	CSAUAT, Kanpur	IIVR, Varanasi
1.	Bottle gourd	Narendra Rashmi, Narendra Jyoti, Narendra Dharidar, Narendra Prabha, Narendra Sankar Lauki-4 (F_1 hybrid), NDBG-132, Narendra Pooja, Narendra Shishir, Narendra Madhuri, Narendra Shivani,	Kalyanpur long green, Azad Harit, Azad Nutan, Azad Sankar Lauki-1	Kashi Ganga, Kashi Bahar
2.	Pumpkin	Narendra Agrim, Narendra Amrit, Narendra Upcar, Narendra Abhooshan (F_1 hybrid)	Azad Pumpkin-1	Kashi Harit
3.	Pointed gourd	Narendra Parwal-260, Narendra Parwal-307, Narendra Parwal-604	-	Kashi Alankar
4.	Muskmelon	Narendra Kharbuja-1, Narendra Kharbuja-2	-	Kashi Madhu
5.	Bitter gourd	Narendra Barahmasi Karela-1, Narendra Barahmasi Karela-2	Kalyanpur Barahmasi, Kalyan Sona	-
6.	Sponge gourd	-	Kalyanpur Hari Chikni, Azad Torai Chikni-1, Azad Torai-2	Kashi Divya
7.	Ash gourd	-	KAG-1	Kashi Dhawal, Kashi Ujwal
8.	Cucumber	-	Kalyanpur Green	-

Bottle gourd

Narendra Rashmi (NDBG-1, IC-470159, Notification No. 597(E) 25.4.2006): The variety Narendra Rashmi is an indigenous collection improved through pure line breeding. It is a summer type photoperiod insensitive variety of bottle gourd suitable for cultivation in summer and rainy

seasons. It requires 60 days for first fruit picking. Fruits are attractive long bottle shaped (Fig. 47). Fruit yield varies from 300-400 q/ha. It is released and notified for cultivation in Uttar Pradesh. Narendra Rashmi exhibits high degree of field resistance again fusarium wilt. The variety is highly popular among farmers of Uttar Pradesh, Bihar and other parts of the country.

Narendra Jyoti (NDBG-104, IC-418245, Notification No. 597(E) 25.4.2006): The variety Narendra Jyoti is an indigenous collection improved through pure line breeding. It is an early maturing variety which requires about 60 days for first picking. Fruits are long, slender and attractive (Fig. 47). The average fruit yield during summer is 400 q/ha. The July-August sown rainy season crop,when trained on bowers, produces fruit yield of about 600 q/ha. It is released and notified for cultivation in Uttar Pradesh.

Narendra Prabha (NDBG-619, IC-566639): The variety was identified for release in the year, 2009 and recommended for release in 2014. It bears long attractive cylindrical fruits (Fig. 47). The variety is endowed with stable genetic marker of small triangular seeds, in contrast to rectangular seeds of common bottle gourd varieties. It is an early variety which requires 60 days for first picking in early March, sown crop. With an average yield of about 309 q/ha, over different testing centers in the country, Narendra Prabha has exhibited yield potential of 635 q/ha.

Narendra Dharidar (NDBG-208-1, IC-470160, Notification No. 597(E) 25.4.2006): Narendra Dharidar is derivative of a cross between a striped fruited genotype NDBG-208 and NDBG-1. Narendra Dharidar is an early variety that bears long bottle shaped striped green fruits (Fig. 47). Fruits produce highly palatable cooked vegetable. It is suitable for cultivation during summer and gives an average fruit yield of 350 q/ha. The variety is released and notified for cultivation in Uttar Pradesh. Narendra Dharidar exhibits high degree of field resistance again fusarium wilt.

Narendra Sankar Lauki-4 (NDBGH-4, IC-470857, Notification No. 597(E) 25.4.2006): Narendra Sankar Lauki-4 is a F_1 hybrid of Narendra Jyoti × Pusa Naveen. Summer type bottle gourd; suitable for cultivation in summer, rainy season and early winter crop in northern Indian plains. Fruits are near cylindrical, uniform and attractive (Fig. 47). It is an early variety, produces first fruits in 50-55 days. It is a prolific bearer bottle gourd hybrid, with fruit yield potential of 700q/ha in February-March sown summer crop and 1000 q/ha in July– August sown rainy season/early winter crop on bower system. The variety is released and notified for cultivation in Uttar Pradesh, Bihar, Punjab, Rajasthan and Haryana.

Narendra Shishir (NDBG-202, IC-527921): An indigenous collection improved through pure line breeding. It is a photoperiod sensitive winter type round fruited variety (Fig. 47). It has peculiar multifid/pedate leaf shape and small narrow petals. Variety is good for kitchen garden as well as commercial cultivation purposes. Appropriate time of planting is mid-July to mid- August. With proper plant care and nutrient management the plants trained on trellis remain in fruiting for about six months. It has an average fruit yield of 850 q/ha. Single plant produces about 200 fruits of 1.0 kg size. Narendra Shishir has shown multiple disease field resistance against anthracnose, downy-mildew, powdery-mildew and viral disease complex. It was recommended for release in Uttar Pradesh in the year 2001.

Narendra Madhuri(NDBG-505, IC-418253): An indigenous collection, improved through pure line breeding, recommended for release in the year 2007. It is a moderately photoperiod sensitive winter type bottle gourd which can produce moderate yield in summer also. Fruits are attractive round (Fig. 47). Appropriate time of planting is mid-July to mid-August. With proper plant care and nutrient management, the plants trained on bowers remain in fruiting for about six months. It has yield potential of more than 1000 q/ha. It produces highly palatable cooked vegetable.

Narendra Shivani (NDBG-403, IC-418252): Narendra Shivani is an indigenous collection improved through pure line breeding. It was recommended for release in Uttar Pradesh in the year 2007. Narendra Shivani is a photoperiod sensitive winter-type prolific bearer, very long, slender fruited variety of bottle gourd, fit for kitchen garden purpose. Full grown fruits exceed the length of 2.0 metres (Fig. 9a). It remains in fruiting for 5-6 months when sown in July-August and trained on bowers, in frost free areas of Uttar Pradesh. It has an yield potential of 1,300 q/ha. With proper plant care and nutrient management single plant produces more than 200 fruits on bowers. It is released for cultivation in Uttar Pradesh and has become popular among growers and consumers for its fascinating extraordinary fruit length and fruit yield.

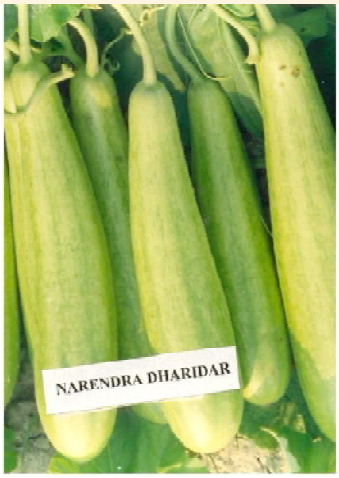
Narendra Bow-Wonder: Narendra Bow-Wonder is an unique promising genetic stock of bottle gourd, developed at NDUAT, Faizabad. It is a winter type photoperiod sensitive genotype with dark-green-patchy round fruits (Fig. 47). The genotype was developed through pure line breeding utilizing indigenous collection. Appropriate time of planting is mid-July to mid-August. With proper plant care and nutrient management, the plants trained on trellis remain in fruiting for five to six months. It has yield potential of about 1000 q/ha. The weight of mature fruits varies from 8 to 10 kg (Fig. 9d). The genotype is under testing.

NDBG-713: NDBG-713 is an unique round fruited winter type photoperiod insensitive genotype of bottle gourd with fruit yield level of 1,034 q/ha. It produces sweet and highly palatable cooked vegetable. The unique flowering behaviour (Fig. 8) of this genotype has been described in Chapter 2.

Andromon-6: (A near seedless genotype of bottle gourd): Andromon-6 is an unique contribution of NDUAT, Faizabad, to the bottle gourd world (Singh *et al.* 1996). Andromon-6 is an andromonoecious genotype, which bears staminate and hermaphrodite flowers (Fig. 7i) on separate vine nodes, in contrast to the commonly found monoecious sex form in bottle gourd. The fruits are drum shaped (Fig. 47) and bear no seeds or 1-20 seeds per fruit near the blossom end. It is summer type photoperiod insensitive genotype. Andromon-6 has been registered with National Bureau of Plant Genetic Resources, New Delhi with Registration number –IGNR-99009.

Narendra Madhu Lata-Smooth Seeded-4(NDML-SS-4): NDML-SS-4 is a striped round fruited bottle gourd genotype (Fig. 14) developed at NDUAT, Faizabad, through hybridization technique involving Narendra Lattoo, Narendra Dharidar, and Narendra Madhuri as parents. The genotype is endowed with smooth seed coat which is stable character and can be used as genetic marker of NDML-SS-4. It is an early, summer type, photoperiod insensitive, and prolific bearer genotype. The average fruit weight is 870 g and average fruit yield is 396 q/ha. It produces highly palatable cooked vegetable. The genotype exhibits field resistance against fusarium wilt.

Narendra Rashmi



Narendra Dharidar

Narendra Sankar Lauki-4

Narendra Jyoti

Narendra Prabha

Andromon-6

Narendra Shishir

Narendra Madhuri

Narendra Bow-Wonder

NDML-SS-4

Fig. 47. Improved varieties and unique genotypes of bottle gourd developed at NDUAT, Faizabad.

Narendra Madhu Lata-Normal Seeded-7(NDML-NS-7): NDML-NS-7 is also a striped round fruited bottle gourd genotype (Fig. 15) developed at NDUAT, Faizabad, through hybridization technique involving Narendra Lattoo, Narendra Dharidar, and Narendra Madhuri as parents. NDML-NS-7 mainly differs from NDML-SS-4 in seed coat character. The earlier has normal rough coated seed as compared to smooth coated seed of the latter. It is also an early, summer type, photoperiod insensitive, and prolific bearer genotype. The average fruit weight is 910 g and average fruit yield is 376 q/ha. It produces highly palatable cooked vegetable. The genotype exhibits field resistance against fusarium wilt.

Pumpkin

Narendra Agrim (NDPK-24, IC-470161, Notification No. 597(E) 25.4.2006): An indigenous collection improved through pure line breeding. Narendra Agrim is a short vined very early variety of pumpkin. First picking of tender fruits is done in 55 days. Green fruit weight is about 2.0 kg and mature fruit weight 3.0 kg. It is suitable for February-March sown summer crop. The fruits are small, round and stripeless dark green (Fig. 48). The fruit yield range from 300-400 q/ha. Narendra Agrim is released and notified for cultivation in Uttar Pradesh, Delhi, Punjab, Bihar, Haryana and Gujarat.

Narendra Amrit (NDPK-130, IC-470162, Notification No. 597(E) 25.4.2006): An indigenous collection developed through pure line breeding. Narendra Amrit is medium maturing variety which gives its first picking in about 65 days. It is suitable for February-March sown summer crop. The green fruits are of 3.0 kg average weight. Fruits are near round in shape and light green mottled in colour (Fig. 48). Mature fruits weigh 5-7 kg, they have papery skin, 5-6 cm thick flesh and small seed cavity. Average fruit yield of the variety is 350 q/ha. Green as well as mature fruits possess negligible level of peculiar odour of common pumpkin varieties, therefore, they are good for highly palatable vegetable preparations. Mature fruits are suitable for sweet meat (*Halwa*/*Burfi*) preparation. It is released and notified for cultivation in Uttar Pradesh.

Narendra Abhooshan (NDPKH-1, IC-527922, Notification No. 597(E) 25.4.2006): Narendra Abhooshan is F_1 hybrid between Narendra Agrim and Narendra Amrit. It is suitable for February-March sown summer crop. It bears near round, dark green striped and highly attractive fruits (Fig. 48). It is an early, prolific bearer hybrid with an yield potential of about 700 q/ha in mid-February sown summer crop. The fruits have thick flesh and deep orange colour at maturity. The fruits produce highly palatable cooked vegetable.

Narendra Upcar (NDPK-421-1, IC-566642): An indigenous collection improved through pure line breeding. Narendra Upcar was recommended for release in eastern Uttar Pradesh in the year 2007. It is an early variety of pumpkin which gives its first fruits in about 55 days. Fruits are small, round and striped dark-green (Fig. 48). It has shown high degree of field resistance against pumpkin mosaic disease. Therefore, it can successfully be grown in summer as well as rainy seasons. Average fruit yield is 400 q/ha.

Narendra Amrit-4: Narendra Amrit is a quality variety of pumpkin, but in boron deficient soils the variety has an undesirable attribute of fruit cracking after 22-25 days of fruit development on the plant. Although fruits harvested at an early stage, when kept in the storage, turn into mature fruits and produce normal mature seeds after 40-50 days of storage. To get rid of this drawback of Narendra Amrit, the variety was crossed with Narendra Agrim –a genotype having non-cracking fruit habit in fully grown mature fruits in the field. By adopting pedigree method of selection the segregating plants bearing desirable traits like Narendra Amrit along with non-cracking fruit habit of Narendra Agrim in the maturing fruits were selected in segregating generations. In F_5 generation the isolate Narendra Amrit-4 was selected, which bore fruits that did not crack even after 40 days stage of fruit development on the plants. Narendra Amrit-4 produces first staminate and pistillate flowers at 6th node and 18th node, respectively. In March sown crop during summer it produces its first pistillate flowers at about 62 days stage of the crop, one to three days earlier than first staminate flower. The tender fruits are striped yellowish green (Fig. 49a) and mature fruits are attractive, creamy, almond in colour (Fig. 49b). The average mature fruit yield of Narendra Amrit-4 was 430 q/ha as against 400 q/ha of Narendra Amrit. Narendra Amrit-4 has 6.5 kg average full grown fruit weight, papery skin, thick flesh of about 6 cm (Fig. 49c), small seed cavity, light orange flesh colour at maturity, very high palatability of cooked vegetable, and 4-6 months shelf life of mature fruits at ambient temperature.

Fig. 48. Improved pumpkin varieties developed at NDUAT, Faizabad.

Pointed gourd

Narendra Parwal-260: Narendra Parwal – 260 is a big fruited variety of pointed gourd. Fruits measure 10-15 cm in length and 40-60 g in weight. Fruits are spindle shaped, striped-light-green (Fig. 50), and have thick flesh. Fruits are suitable both for vegetable and sweet-making. It is tolerant to vine borer and wilt disease complex. Average fruit yield is 225 q/ha. It is recommended for release in Uttar Pradesh in the year 2001.

Fig. 49. Fruit character dimensions of Narendra Amrit-4: a. striped yellowish tender immature fruits, b. creamy, almond colour mature fruits, c. thick flesh and small seed cavity.

Narendra Parwal-307: An indigenous female clone, Narendra Parwal is a small fruited variety of pointed gourd. Fruits are round, striped-dark-green (Fig. 50). It has thin vine, dark green small leaves and short inter-node. The average fruit weight is 15g. It is prolific bearer with average fruit yield of 230 q/ha. It is recommended for release in Uttar Pradesh in the year 2001.

Narendra Parwal-604: The fruits are stripeless light green with medium size fruits (Fig. 50). The average fruit yield is 225 q/ha. It is recommended for release in Uttar Pradesh in the year 2001.

Narendra Karela Barahmasi-1: An indigenous collection was improved through pure line breeding. Narendra Karela Barahmasi-1 is a green, long fruited variety of bitter gourd (Fig. 50). Average fruit length of edible fruits is 40 cm. First fruits are harvested after 60 days of sowing. It is rainy season type bitter gourd with suitable time of planting in between mid-June and mid-July. Average fruit yield is 230 q/ha. It is recommended for release in Uttar Pradesh in the year 2007.

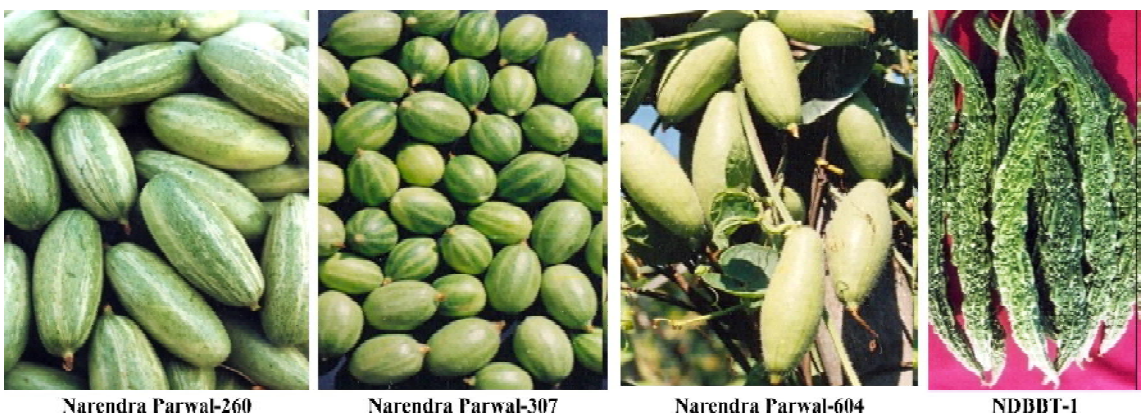


Fig. 50. Pointed gourd and Bitter gourd varieties developed at NDUAT, Faizabad.

Comprehensive lists of improved cucurbit varieties developed by state agricultural universities and ICAR institutes as well as private sector organizations are given by Seshadri and More (2009).

26 PRODUCTION TECHNOLOGY

Cucurbits are classified as warm season vegetables because they thrive well under warm and humid climatic conditions. However, they are cultivated in varying climatic conditions of tropical, sub-tropical, and mildly temperate parts of the world, from near the sea shore to the reasonable heights of mountains. Sandy-loam light soil is suitable for cucurbit growth but they can be grown in sandy soil of riverbeds and sandy-loam or loam soil of uplands by applying appropriate quantity of organic manures and fertilizers. They are the most adoptable and adaptable crop for the kitchen gardens which are allowed to creep on ground and abandoned spaces or trained on bushes, garbage heaps, huts, houses, and tree tops (back page). They are also trained on variety of systematically erected bowers and trellises (Fig. 51). A comprehensive aspect of cucurbit production technology in India is described by Seshadri and More (2009). A brief description of salient features of cucurbit production as applicable to Uttar Pradesh is summarized here as under:

Fig. 51. Winter type very long fruited bottle gourd variety Narendra Shivani, trained on high trellis. There lies a low trellis behind it.

Planting time

In central and southern India cucurbits are cultivated throughout the year. In Uttar Pradesh there are three distinct climatic seasons, *viz.* summer, rainy and winter season. Although majority of the cucurbits are grown mainly during summer and rainy seasons, but a few cucurbits like bottle gourd, sponge gourd, bitter gourd and cucumber are harvested almost round the year, except for the coolest period extending from mid-December and mid-February. Bottle gourd is the one crop which continues to produce fruits even during this period, if saved by frost. A relatively cool weather loving crop zucchini, has emerged as winter season crop for Uttar Pradesh. It can be sown in whole of October and harvested from December to mid-March by using moderately frost hardy varieties. Considering the climatic suitability and market demand different cucurbits can be planted in the following six periods of the year:

i. **Mid-January to mid-March:** This is period of planting for early and main summer season crop of most of the cucurbits. Only sprouted seeds should be planted from mid-January and

mid-February. First fruits of this crop are harvested within 55 to 75 days depending upon the time of planting. January-February planting requires longer period for first picking compared to March sown crop.

ii. **Mid-May to mid-July:** This is planting time for rainy season crop of most of the annual cucurbits, except watermelon and muskmelon. In rainy season crop the first fruits are harvested within 50 to 60 days. The fruit yield levels of bottle gourd, bitter gourd, sponge gourd and pumpkin are lower as compared to summer season crop but the produce fetches higher market price. In June- July spine gourd tubers or seeds are also planted.

iii. **Mid-July to mid-August:** In this period summer type bottle gourd, bitter gourd, rainy season type bitter gourd, pumpkin, cucumber, round melon, sponge gourd, snake gourd etc. are planted for late rainy season and early winter season crop. Except for pumpkin other cucurbits are cultivated on bower system. Seeds are sown on hills and growing vines are trained on trellis. First fruit of this crop is also harvested within 50 to 60 days. Higher yields are harvested in this crop which receive better market price. This is also the planting time of winter type photoperiod sensitive genotypes of bottle gourd, sponge gourd and pumpkin. Winter type bottle gourd produces first fruits within 70-90 days if planted in mid-July and if they are planted in August the first fruits are harvested within 65 to 75 days.

iv. **Mid-August to mid-September:** For early and main season winter crops, this is period of planting for both summer type photoperiod insensitive and winter type photoperiod sensitive varieties of bottle gourd. The crop can be trained on trellis or allowed to creep on the ground. The produce of this crop is lower but it fetches higher market price. This is also planting time for pointed gourd and ivy gourd vine cuttings.

v. **Mid-October to mid-November:** This is main period of planting of cucurbits in riverbeds for early summer season crop. In upland conditions bottle gourd, pumpkin, bitter gourd, sponge gourd etc. are planted as relay-inter crop with short canopy vegetable crops like potato, cabbage, cauliflower, early pea etc. Care is taken that other crops are harvested by mid-February so as to provide enough space for cucurbit crop care and growth. The first fruiting in this crop begins by mid-March and the produce fetches maximum market price of the year. The whole October month is suitable for planting of zucchini crop by using suitable varieties. First fruits of this crop are harvested within 50 to 60 days and fruiting continues from December to mid-March.

vi. **Mid-December to mid-January:** In this period nursery is raised under low tunnel poly-house. The sprouted seeds are planted in small poly bags and they are placed under the tightly closed low tunnel poly house of appropriate height. The seedlings become ready for transplanting in about 20-25 days, when they attain two -four true leaf stage.

Manures and fertilizers

All cucurbits respond very well to the application of manures and fertilizers. Manure and fertilizer rates vary depending upon soil type, planting system, and also on the growth behaviour of

a cucurbit crop. In general per hectare FYM requirement varies from 250 to 300 q, nitrogen requirement varies from 60-100 kg, phosphorus requirement varies from 40-60 kg, and potash requirement varies from 40-60 kg. Whole quantity of FYM, half amount of nitrogen, full quantity of phosphorus and potash should be homogeneously mixed in the soil before sowing, near the expected root growth zone of plants, instead of its application in the whole field. Half of the remaining quantity of nitrogen is applied at the time of earthing at about 25 days stage. The rest quantity of nitrogen is given at about 40 days stage as top-dressing near the plants at flowering stage. Apart from this application of zinc, boron and other micronutrients have been found beneficial. Spraying of micronutrients at appropriate stage and at required intervals should be done instead of basal application.

Seed rate and planting method

Commonly for large seeded cucurbits 3 to 4 kg seed of open pollinated varieties and 2.5 to 3.0 kg seed of hybrid varieties is sufficient for one hectare land area in flat system of planting. For small seeded cucurbits like longmelon, muskmelon, cucumber, snapmelon etc. only about half of the above quantity is enough. Seed rate and spacing of various cucurbits is given in Table 11. Depending upon planting season and nature of crop, planting is done in the trenches, along the ridges of channels, on raised beds or on hills/mounds. In summer, vines are allowed to creep on flat land, while in rainy season and early winter crop the planting should be done on hills/mounds and the

Table 11. Seed rate and spacing of annual and perennial cucurbits

Annual cucurbits				
S. No.	**Crop**	**Seed rate (kg/ha)**	**Row to row distance (m)**	**Plant to plant distance (cm)**
1.	Bottle gourd	2.5-3.0	2.8-3.0	50-60
2.	Pumpkin	3.0-3.5	2.8-3.0	50-60
3.	Zucchini	1.5-2.0	0.9-1.0	80-100
4.	Cucumber	1.5-2.0	2.0-2.5	40-50
5.	Long melon	1.5-2.0	2.5-2.8	50-60
6.	Snapmelon	1.5-2.0	2.8-3.0	50-60
7.	Muskmelon	1.5-2.0	2.0-2.5	50-60
8.	Watermelon	2.0-3.0	2.8-3.0	50-60
9.	Bitter gourd	4.0-5.0	2.0-2.8	40-50
10.	Sponge gourd	2.0-2.5	2.8-3.0	50-60
11.	Ridge gourd	2.0-2.5	2.8-3.0	50-60
12.	Satputia	1.0-1.3	1.5-2.0	150-200
13.	Round melon	2.5-3.0	2.5-2.8	40-50
14.	Ash gourd	2.0-3.0	2.5-3.0	50-60
15.	Snake gourd	3.0-3.5	2.0-2.5	150-200
Perennial cucurbits				
S. No.	**Crops**	**Numbers of cuttings or tubers per ha**	**Row to row distance (m)**	**Hill to hill distance (cm)**
1.	Pointed gourd	2500-4500	1.5-2.0	1.5-2.0
2.	Ivy gourd	2500-4500	1.5-2.0	1.5-2.0
3.	Sweet gourd	2500-4500	1.5-2.0	1.5-2.0
4.	Spine gourd	2500-4500	1.5-2.0	1.5-2.0

growing vines are trained on trellis or bowers. Generally seeds are planted at 15 to 20 cm distance at closer spacing on the ridges along the sowing channels to ensure required plant stand. At 20 days stage of seedling growth, healthy and vigorous plants are retained at required spacing of 40 to 60 cm and the rest are thinned out.

Irrigation, weeding, and intercultural operations

First two to three irrigations are given at short intervals of 2-3 days with full care so that there is no overflow of water over the sown seeds before germination. Rest irrigations are given at 4 to 6 days interval as per the requirement. During summer light flooding of plots is also done. In rainy season, there should be proper drainage arrangement for water. In the initial stages of crop two to three weedings are required to keep the neighbouring space of plants free from weeds. The earthing is done 25-30 days after sowing. Straw mulching below growing vines conserves soil moisture, controls weed growth, and is helpful in protecting the tender apical portion of vines from hot soil during sunny days of summer.

Harvesting, fruit yield, and marketing

Dessert fruits, *viz.* watermelon, muskmelon and snapmelon as well as ash gourd (unless harvested for cooking vegetable) are harvested at maturity. Pumpkin is harvested both at tender and mature fruit stage. Rests of the cucurbits are harvested at tender green fruit stage. Whether mature or tender, harvesting of all cucurbits should be done at appropriate stage. It is recommended that tender zucchini fruits should be harvested at 400 to 700 g weight. The over-grown fruits lose taste and palatability. As far as possible, tender fruits of all cucurbits should be harvested in uniform size at regular interval. The yield levels of cucurbits may vary from 200 to 1500 q/ha depending upon crop variety, crop management and season of cultivation. Record yield of 1,900 q/ha has been observed with a round fruited winter type photoperiod sensitive bottle gourd hybrid at NDUAT, Faizabad, in July sown winter crop on trellis system. The growers should be well aware about the local and distant marketing demand of the produce, particularly before initiating the largescale production of any cucurbit crop. Organized farming by a large group of farmers is helpful in transportation of the produce to distant markets.

Management of major insect-pests

Red pumpkin beetle: Red pumpkin beetle is the first and most devastative insect pest that damages the young seedlings of almost all cucurbits except bitter gourd. However, incidence and intensity of damage varies with crops and cropping seasons. Spraying of solution of Carbaryl 50 WP 2 g or Fenvalerate 20 EC 0.75 ml per litre water has been found effective.

Thrips: Thrips is another insect pest that sucks the leaf sap and damages the young seedlings of all cucurbits. Leaf puckering is the typical damaging symptom of thrips. The insect can be effectively controlled by spraying Malathion 50 EC 2 ml or Methyl-o-demeton 20 EC 1.0 ml or Dimethoate 30 EC 1.0 ml per litre of water.

Mites: Spider like tiny arthropod colonize on the under surface of leaves of muskmelon, cucumber

and watermelon, during hot and humid weather condition above 35-39 °C. The nymph and adults suck the leaf sap and destroy chlorophyll. Consequently the leaves get curved resulting in stunted plant growth and lower yield. Spraying of dicophal 1 ml or dimethoate 30 EC 1 ml per litre of water effectively controls the insect.

Bottle gourd bug: This greenish colour small insect damages the young plants of bottle gourd at 20-40 days stage of plant growth, by sucking leaf sap of apical tender leaves which leads to sieve like leaf appearance and adversely affects the plant growth. The insect pest can be effectively controlled by spraying 2 ml Dimethoate or 1 ml imidachlopride per litre of water at 10 days' interval.

Epilachna beetle: The pest is more damaging during rainy season. The insect damages bitter gourd, sponge gourd, ridge gourd, snake gourd etc. It can be effectively controlled by spraying 2 ml of dimethoate 30 EC.

White fly: This small white insect mainly damages pointed gourd crop from April to October by sucking the leaf sap of tender leaves. The flies also suck the sap of fruit skin and make the fruit skin rough leading to deshaped fruits. The damaged leaves develop secondary infection of black shooty mould, on honey dew excreted by the insect, inhibiting photosynthesis. Spraying of Dimethoate 1.0 ml or imidachlopride per litre of water before flowering and Malathion 2 ml per litre of water at fruiting stage effectively controls the insect.

Management of major diseases

Downy mildew: Downy mildew is a problem of places having hot and high humid weather. This fungus attacks only leaves. Yellow spots are seen on the upper surface of leaves and on the lower surface light purplish white spores appear. In advanced disease stage leaves dry. The disease affects all cucurbits. Spraying Blitox or Metalaxyl + Mancozeb 2.5 g per litre of water at 10 days' interval effectively controls the disease. Affected leaves should be removed from plants. Crop rotation should also be adopted.

Powdery mildew: In the initial stages of the disease white powdery spots are formed on the upper surface of the leaves, which later spread on whole of leaves, stem and other plant parts. Seriously affected leaves become brown and get shrinked. Spraying of Calixin or Karathane 1 ml per litre of water at 10 days interval effectively controls the disease. In bottle gourd spraying of Sulphex 2.5 g per litre of water has also been found effective.

Anthracnose: This is a seed-borne fungal disease of several cucurbits. First symptoms of the disease are seen on leaves in form of light coloured angular spots, which turn black later. The disease spreads fast and symptoms are seen on stems and fruits also. Plant dies if disease is not managed. As a preventive measure treatment of seed with Bavistin 2.5 g per kg of seeds is useful. For controlling the disease Blitox or Dithane M-45 3 g per litre of water or Bavistin 2 g per litre of water has been found effective.

Fusarium wilt: This is soil-borne fungal disease mainly affecting watermelon, muskmelon, cucumber, and bottle gourd. The disease can be damaging in any plant growth stage. In younger plants symptoms

include damping off, cortical rot, and stunting, while in grown up plants the symptoms begin with wilting of leaves and later on whole plant wilts and dies. Many a times the disease becomes devastative, destroying the whole crop (Fig. 12c, 13c, 14c and 15c). Seed should be treated before sowing with Bavistin 2.5 g or Trichoderma (jowar formula) 10 g/kg of seed. The infected plants should be sprayed with solution of Trichoderma (jowar formula) 10 g or Bavistin 2 g per litre of water; and the same solution should be used for drenching soil near the root zone of the plants. It may be noted that the disease cannot be controlled effectively by any chemical in large area. Use of resistant varieties and crop rotation are the only preventive measures.

Viral diseases: There are several viruses infecting one or the other cucurbits. It is usually noted that cucurbits in temperate countries are infected by a set of viruses, while in tropical countries like India, larger number of cucurbits have been reported to suffer from a different set of wider range of viral diseases. Complete control measures are not possible for viral diseases. Use of disease free seeds of the seed-borne viruses and chemical control of vectors are helpful in mitigating the spread of viral diseases. Resistant varieties appear to be temporary reliable solution against viruses, because resistance too is not durable and it is liable to be broken by new virulent strains and pathotypes. Singh (2012), identified escape period of planting for watermelon mosaic virus (WMV) disease in bottle gourd and pumpkin; and pumpkin mosaic disease in pumpkin in eastern Uttar Pradesh. Singh observed that in general there is high incidence of WMV in off season early summer crop of bottle gourd and pumpkin, when planted in November, December and January. The incidence of this disease progressively decreases with delayed sowing after mid-February with increase of temperature. The incidence of this disease decreases sharply when the planting is done in March and April months. For pumpkin mosaic disease planting of pumpkin from mid-February to mid-March was the safest period for summer season crop in eastern Uttar Pradesh. The incidence of pumpkin mosaic virus disease increases in April to June sown crop of pumpkin and it declines in July and onwards sown crop. It was, therefore, recommended that the planting of pumpkin between April and June for rainy season crop in eastern Uttar Pradesh should be avoided with the use of common susceptible varieties. However, rainy season crop can be planted any time using resistant varieties like Narendra Upcar.

Seed production

Planting of seed crop is done as per field and isolation requirements. In Uttar Pradesh the appropriate time of seed crop planting for annual cucurbits is from last week of February to first week of March. Delaying in planting dates after mid March adversely affects seed yield and quality. For seed production of snake gourd, ash gourd, and photoperiod sensitive genotypes of bottle gourd, sponge gourd, bitter gourd, and pumpkin the planting should be done in mid-July. Except for ash gourd and pumpkin, as far as possible, July sown crop should be trained on trellis for quality seed production. In summer crop the seeds in the fruits mature within 40-60 days after fruit set, depending upon the crop. The July sown seed crops require longer period for seed maturity within the fruit, because of cool temperature in the offing winter months.

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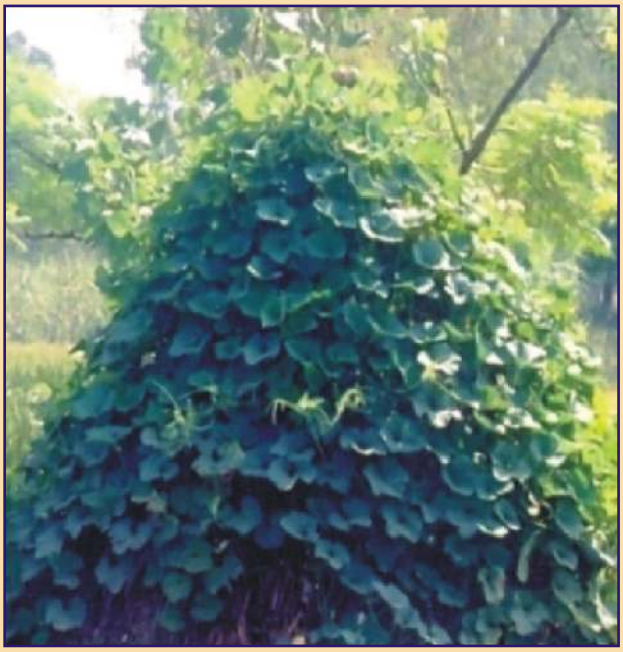

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