Notes on *Luffa* (Cucurbitaceae) Genetic Resources in India: Diversity Distribution, Germplasm Collection, Morphology and Use

Anjula Pandey*, K Pradheep and DP Semwal
Division of Plant Exploration and Germplasm Collection, National Bureau of Plant Genetic Resources, New Delhi-110012

(Received: 29 August 2013; Revised: 31 December 2013; Accepted: 25 January 2014)

Genus *Luffa* has two major cultivated species, namely, ridged gourd and sponge gourd exhibiting rich diversity in the Indian subcontinent. In the present communication data from germplasm collections of cultivated and wild *Luffa* by the National Bureau of Plant Genetic Resources from different phytogeographical regions of India have been used to pinpoint areas for future collection. Fruit and seed morphological characters were studied for developing field identification key. Some less known uses of *Luffa* are discussed in the perspective of genetic resources in India.

Key Words: Cucurbitaceae, Cultivated and wild species, Field identification key, *Luffa,* Morphology, Phytogeographical distribution

Introduction

Genus *Luffa* (Cucurbitaceae) has two cultivated tropical, one American and the other Old World species (Ali *et al*., 2010). Four species namely *Luffa acutangula* Roxb., *L. aegyptiaca* Mill. [*L. cylindrical* (L.) M.J. Roem.], *L. echinata* Roxb., *L. graveolens* Roxb. occur in India (Chakravarty, 1982; Renner and Pandey, 2013). Cultivated species *L. acutangula* (ridged gourd) and *L. aegyptiaca* (sponge gourd) are widely grown whereas a local cultivar 'Satputia' that bears fruits in cluster (trimonoecious form of *L. acutangula* syn. *L. hermaphrodita* Singh & Bhandari) is confined to eastern region (Charkravary, 1990). Among the wild species, bitter-fruited *L. acutangula* var. *amara* (Roxb.) Clarke, *L. graveolens* and *L. echinata* occur in different agro-ecological regions of India. Linguistic support from Sanskrit literature (name *koshataki*) indicates early history of cultivation and use of *Luffa* in India.

Three subspecies are recognized in *L. acutangula; L. acutangula* var. *acutangula* (called angular loofah, Chinese okra, ridged gourd) was probably domesticated in Asia (de Candolle, 1959) or India (Heiser and Schilling 1990), whereas the bitter wild var. *amara* occurs wild throughout India (http://www.efloras.org/florataxon.aspx?flora_id=5&taxon_id=119075; Heiser and Schilling, 1990). Morphological evidences suggest that cultivated *L. acutangula* var. *acutangula* was derived from var. *amara* (Heiser and Schilling, 1988). On the basis of cytogenetical investigations, the two wild species, *L. graveolens* and *L. echinata* have been indicated closer (Dutt and Roy, 1969; 1971). Study based on morphology of leaves, flowers, fruit, reproductive biology and flavonoids has grouped *L. acutangula* and *L. aegyptiaca* into a single clade, apart from the other species (Heiser and Schilling, 1990). Local cultivar of *L. acutangula* 'Satputia' has cross compatibility with *L. acutangula* (Zeven and de Wet, 1982) and has also been included under *L. acutangula* (Marr *et al*., 2005a, b; Ali *et al*., 2010; Prakash *et al*., 2013).

India is one of the diversity rich regions for cultivated and wild *Luffa*. Variability available in different phytogeographical regions needs to be collected for conservation and use, besides utilization in other genetic resource programmes. Therefore, the present work on genetic resources of *Luffa* was envisaged with primary objective to study: 1) diversity distribution *vis-à-vis* germplasm collection for conservation in India, and 2) morphological variability in fruit and seed of cultivated and wild taxa and developing field identification key. Priorities were worked out for future collecting of *Luffa* germplasm from India.

Materials and Methods

The present study was undertaken to identify gaps for future collecting in the genus *Luffa* based on data on germplasm collection from different phytogeographical regions for three decades *vis-à-vis* diversity distribution. The sites of germplasm collections made by the National Bureau of Plant Genetic Resources (NBPGR) were plotted on map using DIVA-GIS version 7.1 software (Hijmans

* *Author for Correspondence: Email:* anjula@nbpgr.ernet.in

et al., 2001). A coarse grid plotting of location (site) data was prepared to pinpoint the sites of germplasm collecting *vis-à-vis* diversity conserved. Information on diversity distribution pattern, use(s)/ potential value of species was drawn from authors' field experience, non-formal interaction with farmers in areas of occurrence and published literature.

Plants of 36 accessions representing major areas of collections including four species (five taxa; accessions used in parenthesis) *viz*. *Luffa aegyptiaca* (16), *L. acutangula* (16), *L. acutangula* var. *amara* (2), *L. echinata* (1) and *L. graveolens* (1) were raised in earthen pots in net house at the Division of Plant Exploration and Germplasm Collection (NBPGR), New Delhi, during the months of May-September 2010-12. Quantitative and qualitative data on fruit and seed morphology were recorded for visual observations and using hand lens (x10 magnification) from five plants each of the representative species and presented as an average value. Most prominent morphological characters were used for preparing a field identification key.

Results and Discussion

Diversity Distribution

Among the cultivated species *L. aegyptiaca* is widely grown throughout India but is less popular in the peninsular region where the other cultivated species *L. acutangula* is more popular. Former species is also reported under semi-wild conditions in disturbed habitats and forest openings. *L. acutangula* is widely cultivated throughout India for tender fruits used as vegetables. Satputia (*L. hermaphrodita*) is widely grown in eastern Uttar Pradesh, Bihar, West Bengal and Rajasthan. This species is characterized by fruits borne in clusters with skin having 8-10 ribs and smooth skin. *L. acutangula* var. *amara,* wild form of ridged gourd, bears small but extremely bitter fruits. It occurs mainly in the lower altitudes of Himachal Pradesh, Rajasthan, Maharashtra, all over the peninsular India and more sporadically in drier habitats of Gujarat and Madhya Pradesh. Of the two wild taxa, *L. echinata* occurs in disturbed habitats of North-western Himalayas, central India and upper-Gangetic to eastern plains whereas *L. graveolens* in Bihar, Maharashtra, Sikkim and West Bengal. Diversity distribution of *Luffa* species is given in Fig. 1a-d.

Germplasm Collection and Conservation

Majority of the germplasm collected represented three cultivated taxa from all over the cultivation range. A total of 2,310 accessions of *Luffa* were collected from diverse habitats all over India during 1976-2013 (Malik and Srivastava, 2006; Plant Germplasm Reporter, 2000-2012; Fig. 1) by National Bureau of Plant Genetic Resources (NBPGR). Status of collected germplasm (cultivated, semi-wild and wild) was recorded based on passport information (collection sites) and herbarium specimens in the National Herbarium of Cultivated Plants (NHCP), NBPGR, New Delhi followed by published literature.

In cultivated *Luffa*, a total of 1,252 accessions in ridged gourd (*Luffa acutangula*), 956 in sponge gourd (*L. aegyptiaca*) and 53 in Satputia (*L. hermaphrodita*) were collected. Major areas of collecting of ridged gourd were Uttar Pradesh (123), Andhra Pradesh (94), Odisha (52) and Assam (56); sporadic collections were also made from Gujarat, Rajasthan, Orissa and Tamil Nadu. In sponge gourd diversity was gathered from eastern Uttar Pradesh (198), Jharkhand (70), Bihar (77) and sporadic representations from Chhattisgarh, Gujarat, Haryana, Madhya Pradesh, Maharashtra and Rajasthan. Collections were made of Satputia from the North-eastern Uttar Pradesh (16), Bihar (14), and Jharkhand (6) and sporadic distribution in other states. During exploration to Uttar Pradesh and Madhya Pradesh, Satputia was also recorded from abandoned (appeared to be escapes from cultivation) habitats. Accessions of *L. acutangula* var. *amara* (8) from Andhra Pradesh (3), Maharashtra (3), Madhya Pradesh (1) and Kerala (1) were collected from dry habitats and road side in Himachal Pradesh, Gujarat, Madhya Pradesh, Maharashtra, Tamil Nadu and Rajasthan. Populations of *L. echinata* were recorded occurring on heaped soil and disturbed/marginal farm areas whereas *L. graveolens* occurred as weedy type in sugarcane fields in Gujarat, Himachal Pradesh, Madhya Pradesh and Uttar Pradesh. In Uttar Pradesh *L. graveolens* locally known as *guslainth* or *guslaria* was often seen along roadsides and as a weed in sugarcane fields.

Sponge gourd collection varied in fruit shape (cylindrical/elongated to globose, oblong, elliptical, tapering, pyriform), ridges (sunken forming bulge between two ridges or not), fruit skin glossiness, shape of blossom end (depressed, flattened, round, pointed), fruit colour (light green, white dotted, blackish), skin (smooth, grayish, finely wrinkled, shallowly wavy, netted, with warts), flesh (white-yellow), taste (sweet, bitter), seed colour (black, grey, brown, white), seed surface (smooth, wrinkled, slightly pitted and scaly). Some significant diversity collected was long fruited

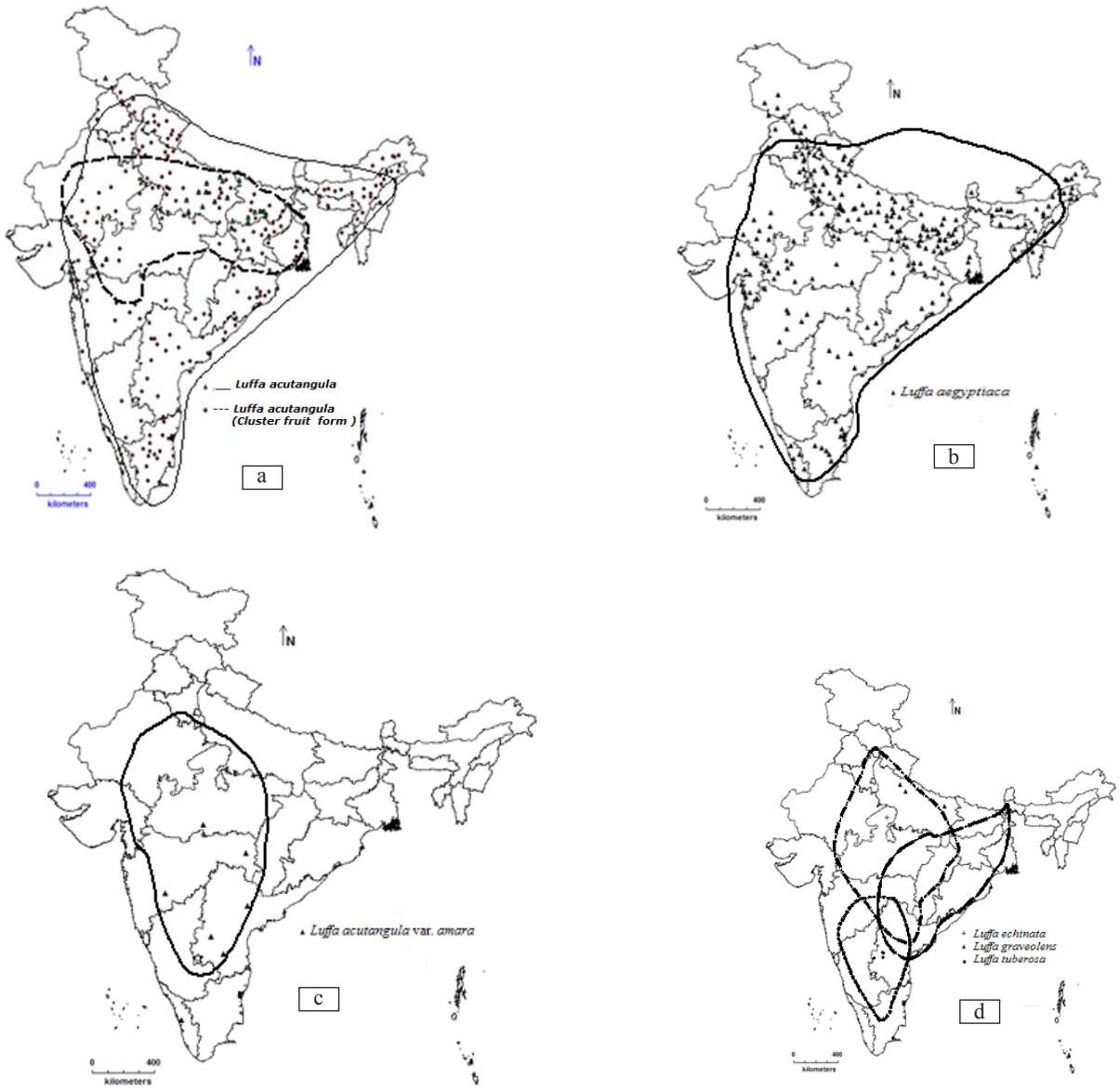

Fig. 1. Diversity distribution (marked with line) in *Luffa* species collected from different states of India: a) *L. acutangula* (monoecious and trimonoecious form); b) *L. aegyptiaca*; c) *L. acutangula* var. *amara*; d) other wild taxa

(over 60 cm) types from southern Uttar Pradesh (Varanasi, Jaunpur, Ghazipur, and Allahabad). Black seeded types were commonly available in the areas of cultivation as compared to grey-white seed types. Germplasm with small (3.2 cm) ball like fruits were collected from Maharashtra. Among the local cultivars/ landraces, namely, *faizabadi, barsati, nenua safed, nenua hara* having adaptability traits to diverse agro-ecological regions, resistance to diseases and pests as well as stress environments including drought, were among the diversity collected.

Ridged gourd and Satputia mainly varied in fruit shape (elliptical, elongated, globose/oblong; straight/ curved, smooth to sharp angled); fruit skin colour (green to pale green), skin with prominent ridges and sunken ribs; fruit skin glossiness (mostly dull) and flesh texture (smooth, grainy/soft). Among the local cultivars/landrace diversity in ridged gourd *Pusa Nasdar* and sponge gourd *Pusa Chikni* are selections from germplasm collected from Neemuch in Madhya Pradesh. Some promising accessions were early types with good bearing. In Satputia some promising types were small fruited types

(5.1-7.5 cm) with profuse bearing and good taste from eastern Uttar Pradesh.

A total of 702 accessions of cultivated and wild *Luffa* were conserved in the National Genebank of NBPGR as seed collection. These included *L. acutangula* (223) mainly from Andhra Pradesh and Uttar Pradesh), *L. aegyptiaca* (387) from Uttar Pradesh, Maharashtra and Andhra Pradesh, *L. echinata* (6) and *L. graveolens* (17) from Uttar Pradesh and *L. acutangula* var. *amara* (69) from Tamil Nadu.

Study on Fruit and Seed Morphology

A total of 37 accessions were shortlisted based on representation from major collection sites of different species assembled from diverse region. Data on morphological characters were recorded for fruit and seed; *L. acutangula* and *L. hermaphrodita* differed in fruit borne singly or borne in cluster and seed testa surface. Fruit was green-pale green, pericarp with prominent lines in *L. aegyptiaca* and *L. hermaphrodita,* prominent longitudinal ridges in *L. acutangula*, prominently ovoid, densely bristled in *L. echinata* and densely tuberculated in *L. graveolens*.

Fruit wall was dry, fibrous at maturity in all species of *Luffa*. However, nature of fibrous wall varied in different species (thickly knitted in *L. aegyptiaca, L. acutangula* and *L. hermaphrodita* and loosely knitted in *L. graveolens* and *L. echinata*). Length of the fruit varied from long in *L. aegyptiaca, L. acutangula* var. *acutangula,* medium in *L. hermaphrodita* and *L. acutangula* var. *amara,* smaller in *L. echinata* and *L. graveolens*. Fruits were generally cylindrical (rarely round) in cultivated species and oval-globose in wild species. The fruits of wild *L. acutangula* var. *amara* were smaller in size than cultivated *L. acutangula* and fruit shape was narrow and pointed at both ends.

Seed shape is a distinguishing character in all species. It varied from elongated-oblong in *L. aegyptiaca*; ovate with prominent beak in *L. actangula*; and oval-ovate in *L. echinata* and *L. graveolens.* Seed surrounded by papery membranous wing in *L. aegyptiaca* was the most distinguishable character.

Comparision of seed characters for qualitative and quantitative characters is given in Tables 1-2. Seed was bigger in *L. aegyptiaca,* medium in *L. actangula* and *L. hermaphrodita,* smaller in *L. echinata* and *L. graveolens.* The seed coat surface was mostly rough but intermediate types were also present in some accessions of the three cultivated species. *L. aegyptiaca* showed variation in seed coat colour-black seeded and white seeded with

Fig. 2. Fibrous sponge obtained from dry fruit wall of *Luffa* species is a characteristic feature of the genus: a) *L. aegyptiaca* (sponge well developed, compact, easy to separate), b) *L. acutangula* var. *acutangula*, c) *L. acutangula* var. *amara* (sponge well developed, difficult to separate), d) *L. graveolens* (sponge poorly developed, not well formed), e) *L. echinata* (sponge soft, loosely knitted, breaks on separation)

Table 1. Quantitative traits recorded in fruit and seed of *Luffa* species

S.No.	Character	*L. aegyptiaca*	*L. acutangula*	*L. graveolens*	*L. echinata*
1.	Length of fruit (cm)	27.15 x 5.71	12.75-22.58 x 3.95-4.85	5.91 x 3.35	3.5 x 3.0
2.	Seed size (mm)	11.53 x 7.50	10.17-10.65 x 5.57-6.02	4.83 x 3.33	4.70 x 3.50
3.	100 seed weight (gm)	11.35	10.58-11.32	3.44	2.83

Table 2. Morphological traits recorded in fruit and seed characters of different species of *Luffa*

S.No.	Character	*L. aegyptiaca*	*L. acutangula*	*L. graveolens*	*L. echinata*
1.	Fruit shape	Elongated, cylindrical	Elongated-cylindrical and spindle shaped (in *amara* type)	Cylindrical-oblong	Spherical-round
2.	Extension on fruit surface	Absent	Ribbed-non ribbed (in satputia)	Tuberculate bristles	Echinate
3.	Fruit skin colour	Green (uniforn or with with specles)	Smooth with continuous lines (in satputia), rugose	Rough	Echinate, long bristles
4.	Flesh colour, taste	White-yellow	White	Yellow	Pale yellow
5.	Fruit borne singly or in cluster	Single	Single, cluster (in satputia)	Single	Single
6.	Seed shape	Oblong-elongated	Ovate	Oblong-ovate	Oblong-ovate
7.	Seed coat colour	Ivory, black, greyish-black	Greyish black-black	Grey	Grey
8.	Seed coat extension	Membranous wing	Apical notch	Absent	Absent
9.	Seed coat surface	Smooth, non-shiny	Smooth, non-shiny	Rough, non-shiny	Rough, non-shiny
10.	Bitter	Sweet (but bitter in wild type)	Sweet (but bitter in wild type)	Bitter	Extremely bitter

smooth wall. Seeds of *L. hermaphrodita* though were similar in shape but had distinctly shiny smooth seed surface as compared to *L. acutangula* which had rugose surface. Accessions of *L. acutangula* var. *amara* had variable degree of roughness in seed coat. However, the seed coat surface of *L. graveolens* and *L. echinata* were rough (finely pitted in former and coarsely pitted in latter species) and greyish-black. In general seeds of cultivated species were bold whereas the wild species were smaller.

Key to species in *Luffa* (using characters of fruit and seed)

While handling germplasm of *Luffa,* characters of mature fruit (fruit wall/pericarp and fibrous wall/ sponge) (Fig. 2) and seed morphology are important especially during collection, sorting, packaging and other activities relevant to plant genetic resource management. The authors have attempted developing key on the basis of fruit and seed morphology for on-spot identification of different species of *Luffa.*

Seed with membranous wing

Fruits solitary, sponge well formed with thickly knitted fibres in mature fruit, seed oval-round, compressed, white, black or gradation of black

---------- *L. aegyptiaca*

Seed with no membranous wing

Fruit wall smooth, borne in clusters, sponge well formed with thinly knitted fibres in mature fruit, seeds dark black and shiny

---------- *L. acutangula* (cluster form/Satputia)

Fruits wall not smooth

Fruit wall prominently ridged, sponge not easily separable

Fruit wall not ridged; fruit with poorly formed sponge at maturity, easy to separate

Cultigen, fruits clavate-oblong, size 22.58x4cm, born singly, pericarp hard on maturity

---------- *L. acutangula*

Fruit pale brown, round-ovoid, wall densely covered with echinate long bristles, seed coat verrucose (coarsely pitted), yellowish-brown to black, seeds extremely bitter (with pungent smell)

---------- *L. echinata*

Fruit grey, ovoid, spasely tuberculate-spinose, seed white- ash, seed coat smooth (finely pitted), bitter (no pungent smell)

---------- *L. graveolens*

Uses

Besides the commonly reported use of sponge gourd as vegetable the sponge from mature fruit wall is also

used as bath sponge, abrasive for glassware and kitchen utensils pot holders, table mats, bathroom mats, etc. We report some lesser known uses of *Luffa* in India. During exploration to Pilibhit-Puranpur region, Uttar Pradesh the second author observed wild population of sponge gourd. Local people use freshly harvested male flower buds from wild plants for use as vegetable and also sell them in markets. Ridged gourd is more popular vegetable in eastern and the peninsular region as compared to sponge gourd. The vegetable prepared from tender fruits of Satputia was the tastiest among all cultivated *Luffa* species; the fruits were very soft and generally cooked without peeling off the fruit (Sh. Krishna Prakash from Bihar; pers. comm.).

In the North-eastern region (Nagaland, Tripura and elsewhere), tender leaves of sponge gourd were reported to be cooked as vegetable (mature leaves are bitter) or used in preparation of soups, quiche, etc. (Sh. Ajit Uchoi from Tripura; pers. comm.). In East Asian regions young leaves of sponge gourd (in Malaysia) and male flowers/ flower buds (in China) are popularly used in curries. In Uttar Pradesh, fruits of *L.* graveolens are used for fever and stomach problems in cattle; they are poisonous if used in high dosage.

Future Thrust

Assessment of diversity of *Luffa* germplasm collected and conserved from different regions of India provides future road map for future collecting besides generating valuable information on less known uses of *Luffa* from India. The following areas have been identified for augmenting more diversity in:

- ridged gourd from drier tracts of western Karnataka and North eastern hill region (Mizoram, Manipur and Nagaland),
- sponge gourd from Karnataka, Chaattisgarh and adjoining Odisha,
- less known cultivated type Satputia from eastern Uttar Pradesh, North Odisha, Bihar and adjoining Nepal region, and
- wild species *L. echinata* and *L. graveolens* from major areas of distribution.

Acknowledgements

Authors express their sincere thanks to the Director, NBPGR, for guidance as well as for rendering help during the course of study. Thanks are also due to NBPGR Regional Station, Hyderabad, for sharing material. Acknowledgements are also due to Dr. E Roshini Nayar and Dr. KC Bhatt for sharing the study material and information; Ms. Rita Gupta and Sh. Shashi K Sharma for their help in various ways.

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