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Taxonomy, Diversity and Distribution of the Genus *Cucumis* L. in India

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The eco-geographic distribution and taxonomy of 17 taxa of *Cucumis* L. was investigated based on the study of 978 herbarium sheets in seven major Indian herbaria and germplasm collection of 261 accessions. Distribution map was plotted based on authentic identification of herbarium specimens and field observations under natural conditions. Areas of higher concentration/richness have been worked out for individual taxon. Morphological, ecological, phenological features and economic importance are discussed. The ideal time for collection of germplasm is indicated.

Key Words: *Cucumis*, Crop Wild Relatives, Distribution Map, Germplasm Collection, Herbarium Study, Phenology

Introduction

The two major components of agro-biodiversity that offers the broadest range of diversity for breeders are crop wild relatives (CWR) and landraces (LR), but there is currently a gap between their conservation and use and they remain underexploited by the user community (Maxted and Kell, 2012). In this context, studies on diversity, occurrence and distribution of wild relatives of our crop plants assume high significance. In order to meet the needs of future generations, there are five key areas that need to be addressed: climate change mitigation, limited success of traditional characterization to meet breeders' needs, lack of systematic CWR and LR conservation, threats faced by CWR and LR diversity and lack of plant genetic resource informatics cohesion (Maxted and Kell, 2012), out of which we attempt to address in this paper the last two aspects for the genus *Cucumis* L. in India.

The genus *Cucumis* L. in India as per the earlier concept comprised six species viz., *C. melo* L., *C. sativus* L., *C. prophetarum* L., *C. callosus* (Rottl.) Cogn., *C. setosus* Cogn. and *C. hystrix* Chakrav. (Chakravarty, 1982), of which melon and cucumber (*C. melo* L. and *C. sativus* L.) are commonly cultivated for edible fruits used in salads, pickles, curries and juice. *C. melo* subsp. *agrestis* Naud. var. *agrestis* and *C. sativus* var. *hardwickii* (Royle) W. J de Wilde & Duyfjes are found in disturbed habitats and *C. melo* subsp. *agrestis* var. *agrestis* and *C. callosus* (Rottl.) Cogn. are found almost as a weed in man transformed habitats. Among others, *Cucumis indicus* Ghebret. & Thulin, and *C. silentvalleyi* (Manilal, T Sabu & PJ Mathew) Ghebret & Thulin are endemic to Western Ghats and *C. setosus* Cogn. is an endemic of Deccan region. The genus includes 32 species according to Kirkbride's (1993) treatment in the Monograph of the genus *Cucumis*. Molecular studies undertaken by Schaefer (2007) revealed that the genus *Cucumis* is paraphyletic. In order to make it monophyletic, he merged five genera – *Cucumella chior, Dicoelospermum* C.B. Clarke, *Mukia* Arn, *Myrmecosicyos* C. Jeffrey and *Oreosyce* Hookf under *Cucumis* L., and recircumscribed the subgenera and sections. Out of these, *Mukia* is morphologically very distinct with red ripe fruits adapted to bird dispersal. *Cucumella* has the closest morphological resemblance to subgenus *Melo* with yellow flowers, prostrate habit and leaves with shallowly ovate outline.

This paper is dedicated to late Dr. KS Negi who explored Central Himalayan Agro-biodiversity for about three decades and was responsible for conserving many valuable germplasm and also widening our knowledge of Crop Wild Relatives of Central Himalaya.

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Morphologically, *Mukia* and *Dicoelospermum* do not resemble *Cucumis,* but others resemble to a smaller or greater extent. Moreover, crossability studies do not warrant their inclusion in the genus *Cucumis.*

Recently, Dwivedi *et al.* (2010) reported the distribution, collection, extent of variability, associated indigenous traditional knowledge, conservation status of five different *Cucumis* species and prospects of their utilization in crop improvement. Naveen Garg *et al.* (2007) reviewed intra-specific variation in *C. melo*, inter-specific hybridization in *Cucumis* and sources of disease resistance besides phylogenetic affinities among *Cucumis* species.

While there is unanimous opinion about origin and domestication of cucumber in India, there are two view points on the origin of melon, majority for an African origin, but recent reports support for its Indian origin (Sebastian *et al*., 2010; Joseph John *et al.*, 2013). Identifying gaps in existing *ex situ* germplasm collection is increasingly important as the large scale coarse-grid collecting in the past is to be complemented with a more targeted fine-grid approach. To make the most efficient use of limited resources, germplasm collectors must have a clearly defined set of target taxa and should know where to find species within their target region. A concerted attempt was made to locate, collect, identify and conserve landraces and wild species of *Cucumis* throughout the country and the results are summarized in this paper.

Materials and Methods

As a part of the eco-geographic survey of the genus, the authors visited major herbaria in India during 2008-2011. All the *Cucumis* sheets lodged at Botanical Survey of India, Western Regional Centre, Pune (BSI), Botanical Survey of India, Eastern Regional Centre, Shillong (ASSAM), Central National Herbarium, Howrah (CAL), Calicut University Herbarium, Kozhikode (CALI), The Madras Herbarium, Coimbatore (MH), National Herbarium of Cultivated Plants, New Delhi (NHCP) and ICAR-National Bureau of Plant Genetic Resources Regional Station, Thrissur, Kerala [(NBPGR (T)] were examined. Online herbarium images from Royal Botanic Garden, Edinburgh, Scotland (E), South China Botanical Garden Herbarium, Guangzhou, China (IBSC), Royal Botanic Garden Kew, UK (K), Museum National d' Histoire, Paris, France (P), Chinese National Herbarium, Beijing, China (PE) and North West Agriculture and Forestry University, Shaanxi, China (WUK) were also studied. Based on herbarium data, the entire stretch of Western Ghats was explored extensively, besides specific sites in Deccan Plateau, Central India, Konkan region of Maharashtra, Andaman Islands, Lakshadweep and North East India for collection of germplasm and ecological data. We have observed all the taxa in the field (wild) and augmented several collections through field trips for conservation, characterization and herbarium curation. The seed germplasm is being maintained in the Medium Term Storage (MTS) at ICAR-National Bureau of Plant Genetic Resources Regional Station, Thrissur, Kerala.

Passport data of 261 accessions collected were incorporated into an Exploration Database developed by Indian Council of Agricultural Research-National Bureau of Plant Genetic Resources, India. The GIS software (DIVA-GIS, ver. 5.2 developed by IPGRI) was used to plot individual taxon distribution, areas of greater concentration and for identifying gaps/inadequacies in the existing collections. The eco-geographic and phenological data recorded while collecting germplasm from the original habitat were supplemented with the herbarium observations to find out the natural range, habitat preference, flowering and fruiting periods, etc.

Results and Discussion

Herbarium Representation

Several reports of eco-geographic studies in the wild genepool (Gemeinholzer *et al.,* 2010; Guarino *et al.,* 2002; Kameswara Rao and Bramel, 2000; Maxted *et al.,* 2008) indicate the usefulness of this technique in germplasm collection and conservation. Out of 978 herbarium sheets, the NHCP had the highest number (327) followed by CAL (212), BSI (202), MH (128), NBPGR (T) (98), CALI (7) and ASSAM (4). A total of 83 sheets were found to be labelled under *C. pubescens* and *C. trigonus* of which 56 sheets should be placed under *C. melo* subsp. *agrestis. C. pubescens* is synonym of *C. melo* subsp. *agrestis* and *C. trigonus* is a synonym of *C. callosus. C. melo* has the highest representation among various *Cucumis* species. Herbarium wise representation is given in Table 1.

Herbarium survey indicates prevalence of *Cucumis setosus* in certain pockets of Maharashtra being cultivated for the fruits popularly known as 'meika' and wide distribution of wild and feral forms of *C. melo* subsp. *agrestis* var. *agrestis* and *C. sativus* var. *hardwickii*

Table 1. Representation of *Cucumis* taxa specimens in some major Indian herbaria

S.No.	Taxa	BSI	ASSAM	CAL	CALI	MH	NHCP	NBPGR (T)	Total
1	*C. africanus* L.f.						1		1
2	*C. anguria* L.						3		3
3	*C. callosus* (Rottl.) Cogn.	24		24		28	20	8	104
4	*C. dipsaceus* Ehrenb. ex Spach						2	1	3
5	*C. hystrix* Chakrav.			4			10	2	15
6	*C. indicus* Ghebreti. & Thulin	1		2			7	1	10
7	*C. melo* L. – cultivated	53	2	50		13	76	16	210
8	*C. melo* subsp. *agrestis* (Naud.) Pangalo	31		65		32	35	14	177
9	*C. melo* L. subsp. *agrestis* (Naud.) Pangalo var. *momordica* (Roxb.) Duthie & Fuller						64		64
10	*C. melo* L. subsp. *agrestis* (Naud.) Pangalo var. *utilissimus* (Roxb.) Duthie & Fuller						19		19
11	*C. metuliferus* E. Meyer ex Naudin						2	1	2
12	*C. muriculatus* Chakrav.						2	1	3
13	*C. prophetarum* L.	11		8	1		5	5	30
14	*C. sativus* L. - cultivated	46	2	15		14	27	9	113
15	*C. sativus* L. var. *hardwickii* (Royle) Alef.	16		27	2	36	38	33	152
16	*C. setosus* Cogn.	20		17			9	1	46
17	*C. silentvalleyi* (Manilal, T. Sabu & P. J. Mathew) Ghebret. & Thulin				4	5	2	9	20
18	*Cucumis* spp. (unidentified)						5		5
	Total	202	4	212	7	128	327	98	978

NBPGR (T) = ICAR-NBPGR Regional Station, Thrissur, Kerala

throughout the country with overlapping distribution. *C. hystrix* is under-represented, even though it was spotted from all over Mizoram, parts of Arunachal Pradesh, Nagaland, Manipur and Assam with possible extended distribution in adjoining North East Hill states.

As per the information from herbarium labels and passport data, taxa under the genus *Cucumis* in India are adapted to soil types such as gravelly (Rajasthan), black cotton (Deccan Plateau), sandy loam (Uttar Pradesh), river alluvium and lateritic loam (Kerala), calcareous coral sand (Lakshadweep) and volcanic (Andaman Islands). The low frequency of herbarium collections from the states of Arunachal Pradesh, Nagaland, Tripura, Sikkim and elsewhere in North East (NE) India is rather an indicator of poor botanical exploration undertaken in these states as evidenced from sample survey (nevertheless we made significant cucurbit collections in NE India for the past five years). Very less representation of *Cucumis indicus* and *C. silentvalleyi* in herbaria signifies the niche-specificity of both the species, restricted to a few localities in Western Ghats. Species-specific targeted approach is essential for conservation (*ex situ*) of niche specific/RET taxa.

Species Distribution and Areas of Greater Concentration

Cucumis melo and *C. sativus* are widespread under cultivation throughout the country. Both have wild forms distributed across a long stretch of geographical area in the country. *C. melo* subsp. *agrestis* var. *agrestis* grows in wild habitats throughout the country including Lakshadweep and Andaman and Nicobar Islands where non-bitter types are found. However, it is conspicuously absent in Kerala characterized by high rainfall and acidic soils, except in Attappadi (an area with black cotton soil and less rainfall). The tiny state of Goa offers good scope for collection of variability in snap melon (*C. melo* subsp. *agrestis* var. *momordica*) as original Portuguese introductions still persist in home gardens. Similarly, Kerala state has many selections of oriental pickling melon (*C. melo* subsp. *agrestis* var. *conomon)* by local farmers suited to their ethnic and cultural needs. We have come across three specific named named types; 'Kallanvellari' (IC613488) restricted to Thiruvananthapuram and Kanyakumari districts, 'Kanivellari' – across Kerala, cultivated as a summer vegetable in paddy fallows and 'Ponavellari', now nearly

extinct but a component once prevalent in slash and burn hill agriculture in northern Malabar (Kasaragod/Kannur). *C. silentvalleyi* and *C. indicus* are niche specific; former occurs in specific pockets of southern Western Ghats as ephemeral. It is restricted to Kerala state (Thrissur, Palakkad, Wayanad and Idukki districts) and bordering Tamil Nadu (Coimbatore district). *C. indicus* grows in northern Western Ghats and *C. setosus* is an endemic species restricted to central India including Maharashtra state and border districts of adjoining states *viz*., Dang district in Gujarat; Hoshangabad and Umaria districts in Madhya Pradesh and Belgaum district in Karnataka.

Cucumis hystrix is a wild species indigenous to northeastern India, Myanmar, Thailand and Yunnan province of China. In India, it is found in areas bordering Myanmar and Bangladesh with good population density in Mizoram. It has been classified as a species in the subgenus *Cucumis* based on its morphology (Kirkbride, 1993). It was rediscovered in natural and wild conditions (Chen *et al.,* 1998) and subjected to subsequent genetic characterization. This is the first Asian *Cucumis* species described with chromosome number 2n=24 (Chen *et al*., 1997a). This finding challenges the basic chromosome numbers theory that African *Cucumis* have x=12 and that Asian *Cucumis* have x=7, which has governed the understanding of systematics and phylogenetics in *Cucumis* for decades. Although, *C. hystrix* possess the same number of chromosomes as *C. melo*, yet its fruits have a typical cucumber taste and flavour and has been found to be closer to *C. sativus* (than to *C. melo)* on the basis of isozyme patterns (Chen *et al.,* 1997b), SSR and RAPD marker analysis (Zhuang *et al.,* 2004).

Cucumis muriculatus is a new species record for India (Joseph John *et al*., in preparation). Even though considered synonym with *C. hystrix* (De Wilde and Duyfjes, 2007), it is different from *C. hystrix* for many vegetative, floral and fruit characters. It has been collected from two sites in Mizoram and one site from Nagaland and often with overlapping distribution with *C. hystrix*.

Cucumis prophetarum is localized in Gujarat and Rajasthan and specific regions of Maharashtra and Delhi. *C. callosus* has been found to occur naturally in the wild state in the whole of Deccan Plateau and Indo-Gangetic plains comprising the states of Tamil Nadu, Karnataka (barring coastal and Western Ghats area), Maharashtra, Madhya Pradesh, Uttar Pradesh, Jharkhand, Chhattisgarh, Odisha, West Bengal, Punjab, Haryana, Assam and Himachal Pradesh (Joseph John *et al.,* 2013). *C. sativus* var. *hardwickii* is widely distributed in Khasi hills (Meghalaya), throughout Western Ghats (parts of Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu), Himalayan foothills (parts of Uttarakhand and Himachal Pradesh), Eastern Ghats (parts of Odisha and Chhattisgarh), Chota-Nagpur Plateau in Jharkhand, Central Plateau region (parts of Madhya Pradesh, Chhattisgarh and Maharashtra) besides sporadically in parts of Rajasthan (Aravalli Hills). However, its maximum diversity and distribution is in Western Ghats. The Konkan collections are much like cultivated cucumber but bitter with both truly wild and feral forms. It possesses a multiple fruiting and branching habit not present in the cultivated cucumber (Horst and Lower, 1978). It possesses useful characters such as prolific fruit bearing and high number of laterals (Bisht *et al.,* 2004). Polymorphism in *C. sativus* var. *hardwickii* is higher than in *C. sativus. C. melo* subsp. *agrestis* and *C. callosus* occur as sympatric populations in the Deccan Plateau. Overlapping distribution of *C. sativus* var. *hardwickii* with *C. silentvalleyi* in southern Western Ghats and with *C. indicus* in northern Western Ghats was observed. Species distribution maps based on geographic coordinates generated from herbarium locality information are given in Fig. 1.

Cucumis melo subsp. *agrestis* has wide distribution having many ecotypes (including some cultivated types) adapted to various ecological conditions prevailing in the country. The major distribution areas are Indo-Gangetic plains and Deccan Plateau and rain-shadow areas in the leeward side of Western Ghats. Highly saline tolerant forms growing in calcareous coral sands of Lakshadweep are unique entities. 'Kachuri', a semi-domesticate form of this with fruity flavour is common in arid Central India.

The two exotic introductions, cultivated *C. metuliferus* E. Mey. *ex* Naudin and naturalized *C. dipsaceus* Ehrenb. *ex* Spach have also been collected from peninsular India (Tamil Nadu and Karnataka), the former from farmer's field and the latter as an escape from cultivation. *C. metuliferus* fruits are used as dessert/ substitute for slicing cucumber in tribal area in Sikkim and Darjeeling. Distribution of wild species of *Cucumis* in India is given in Table 2.

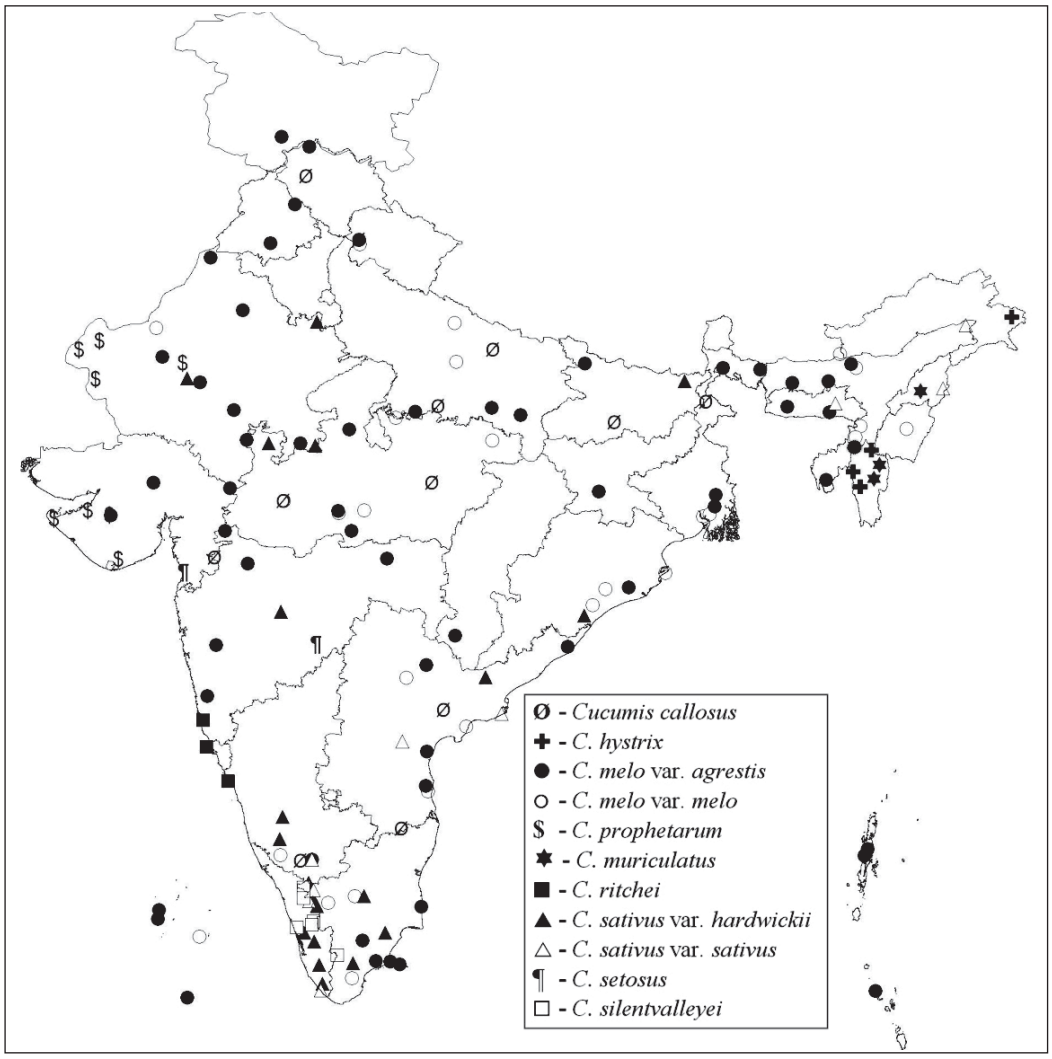

Fig 1. Distributional map of different *Cucumis* species of India based on herbarium records

Morphological Variability

This study has brought out areas of higher concentration of inter and intra-specific diversity in the genus (Table 2). It is difficult to distinguish between cultivated and wild types in case of *Cucumis melo* and *C. sativus* unless live plants are studied. Over-dependence on herbarium data and arriving at conclusions without studying live specimens should be avoided where crop wild relative gene exchange and overlapping distribution/occurrence are common. The difference may be insignificant such as variation in size, shape and colour of the fruit, size of the flower, etc. Smaller size of the fruits and seeds could be observed in the wild taxa of *C. melo* and *C. sativus*. Many workers consider *C. callosus* as the progenitor of melon (Sebastian *et al.,* 2010; Parthasarathy and Sambandam, 1989; Joseph John *et al.,* 2013) and *C. sativus* var. *hardwickii* as the progenitor of *C. sativus* (Nesom, 2011). Morphological variation in wild melon analogous to that in cultivated melon could be located from Eastern Ghats and Deccan Plateau. Some specimens from Lakshadweep and Andaman Islands were non-bitter ones which were with slender branches and profuse bearing. The number of fruits per plant varies from 300-400 in Nicobar collections of *C. melo* subsp. *agrestis*. IC539841, from Nicobar was characterized with miniature fruits that were non-bitter. The plants were highly branched and heavy bearing and adapted to coastal areas with high rainfall and low sunshine hours. Morphologically distinct and unique collection of this wild melon is consumable directly and offer scope for

genetic enhancement. Drought and salinity tolerance could be expected in collections from Lakshadweep which grow prolifically in coastal calcareous soils on beach. Both were found to be easily crossable with all types of cultivated melons and to produce viable fertile progeny (Bhat *et al*., 2014). These materials will be valuable for melon improvement in the context of climate change related abiotic stresses.

Cucumis melo types show considerable variation in leaf lobing, branching habit, size of flower and fruits, etc. and also adapted to various niches/region. Chakravarty (1982) states that leaf characteristics are important in classification of *Cucumis* taxa. Leaf-lobing varies with different entities of *Cucumis viz.* round unlobed (*C. melo* var. *melo*) slightly lobed (subsp. *agrestis*), deeply lobed (*C. callosus* and *C. prophetarum*) and variously angled (*C. sativus*, *C. indicus, C. setosus, C. hystrix* and *C. muriculatus*). Tuberous tap root is a modification for adaptation to extreme temperature stress in *C. callosus,* specimens of the same from Rajasthan state showed extreme drought tolerance, prolific flowering and fruiting under extreme water stress and were resistant to fruit fly. The ovary of *C. sativus*, *C. hystrix, C. muriculatus* and *C. prophetarum* are tubercled or muriculate while that of *C. melo*, *C. indicus*, *C. silentvalleyi* and *C. setosus* are variously pubescent. However, the nature of tubercles varies among the four species in the former case.

Accessions of *Cucumis sativus* from Andaman Islands and North East region were found to produce large number of fruits and showed tolerance to downy mildew. Long fruits ranging from 20-30 cm were observed in accessions IC 613458 and IC 595510 from Mizoram and Tripura respectively. Cucumber with yellow and orange flesh having high carotenoid content was collected from Tripura, Mizoram and Manipur. Ivory white salad cucumber is unique to Hassan district of Karnataka. Large, cooking type cucumber *C. melo* var. *conomon* landraces with high shelf life, namely 'Mulsouthe' and Doppasouthe' were located in coastal Karnataka midlands and also in Vindhyachal part of Madhya Pradesh. The wild taxa such as *C. indicus*, *C. silentvalleyi, C. setosus* and *C. hystrix* bear bitterless fruits and thus have a prospect for direct domestication; they might contribute genes for crop improvement programmes. High rainfall and low sunshine hour tolerance of *C. silentvalleyi* may be a useful trait for incorporation in melon cultivars, especially oriental pickling melon. Distribution and specific traits of melon and cucumber cultivars are given in Table 4.

Phenology

A perusal of phenological data compiled based on herbarium study, revealed a specified period for flowering and fruiting. The actual field study showed slight variation in various localities based on factors such as date of onset of monsoon, soil moisture content, day length, soil and topographic factors. Germination in all the wild species coincide with pre-monsoon rains which is normally in May-July in most part of the country except in Karnataka plains and parts of Deccan Plateau in Tamil Nadu, Andhra Pradesh and Telangana where North East monsoon in October is the normal time for seedling emergence. Seedling morphology is of importance in identifying and locating species for rehabilitation in simulated *in situ* habitats. However, there are no illustrated seedling keys to identify various *Cucumis* species in the juvenile stage. The phenological data is useful to *ex situ* conservationists to plan collection trips in different regions when maximum seed quantities are available. Phenological observations are given in the Table 3. No seed dispersal agents were found. Ripe fruits fall to the ground and disintegrate leaving a soil seed bank for next growth season.

Current Status of Taxonomy

Correct botanical identification of the studied germplasm is paramount to linking it to related information for utilization purpose. The authors consider *Mukia* and *Dicoelospermum* as separate genera and do not favour their merger within *Cucumis* barring *Cucumella*. *Cucumis* L. *sensu stricto* in India comprises only six species (Chakravarty, 1982). A morphological key for field identification of various *Cucumis* species coming under the general pool of cucumber and melon are given below.

Key Diagnostic Characters of Cucumis Species in India

- Prostrate habit, leaves broadly round, fruits smooth or pubescent, ovary softly hairy, not tuberculate, cultivated – *C. melo*
- Climbing, ovary hispidulous, young fruits tuberculate, leaves angular, cultivated – *C. sativus*
- Fruits setose, hairy, wild – *C. setosus*
- Fruits echinate/muriculate, prostrate, leaves round, fruits round, longitudinally white banded and with recurved aculei, wild – *C. prophetarum*

Table 2. Distribution of wild species of *Cucumis* in India

S. No.	Species	Indian distribution and areas of greater concentration
1	*C. callosus* (syn. *C. trigonus* Roxb.)	Andhra Pradesh, Telangana, Tamil Nadu, Karnataka (Deccan areas), Maharashtra, Rajasthan, Gujarat, Odisha, West Bengal, Jharkhand, Chhattisgarh, Uttarakhand, Uttar Pradesh and Madhya Pradesh. Areas of greater concentration: Coimbatore, Salem, Tirunelveli, Ramanathapuram, Chengalpet, Sivagangai and Rajapalayam in Tamil Nadu; Prakasam, Krishna, Chittoor and Nellore in Andhra Pradesh; Rangareddy, Medak and Hyderabad in Telangana; Bellary in Karnataka; Dhule, Thane and Pune in Maharashtra; Ganjam in Odisha; Ranigunj, Jalsuka and Sunderbans in West Bengal; Indore, Jabalpur and Umaria in Madhya Pradesh; Raipur in Chhattisgarh; Dehradun in Uttarakhand; Banda, Gonda, Agra, Bahraich and Saharanpur in Uttar Pradesh; Jodhpur in Rajasthan; Rajgir and Sahibganj in Bihar; Sutlej river bank in Punjab and Palamau and Ranchi in Jharkhand (Joseph John *et al*., 2013).
2	*C. melo* subsp. *agrestis* var. *agrestis*	Occasional as a weed of cultivated fields throughout the country except high rainfall areas of Western Ghats and North-eastern India. Areas of greater concentration: Minicoy and Kavaratti in Lakshadweep; North, South and middle Andaman in Andaman & Nicobar Islands; rain shadow areas of Attappadi in Kerala; Coimbatore, Ramanathapuram and Madurai in Tamil Nadu; Nellore, Prakasam, Krishna and Srikakulam in Andhra Pradesh; Warangal in Telangana; Mysuru in Karnataka; Dhule, Nagpur and Pune in Maharashtra; Churu, Chittaurgarh, Jodhpur, Jaisalmer, Sri Ganganagar and Bhilwara in Rajasthan; Hoshiarpur in Punjab; Doda in Jammu & Kashmir; Hamirpur in Himachal Pradesh; Bastar region in Chhattisgarh; Rewa in Madhya Pradesh; Allahabad, Lakhimpur-Kheri and Mirzapur in Uttar Pradesh; Jalpaiguri, Somra and Kolkata in West Bengal; Goalpara, Kamrup and Darrang in Assam; Dehradun in Uttarakhand and Lohit district in Arunachal Pradesh.
3	*C. melo* subsp. *melo* (cultivated - including varieties)	Cultivated throughout the country as vegetable and as table fruit. Infraspecific variability in cultivated melon is region specific: *C. melo* var. *melo*, *C. melo* var. *conomon*, *C. melo* var. *cantalupensis*, *C. melo* var. *momordica* and *C. melo* var. *utilissimus* are cultivated.
4	*C. sativus* var. *hardwickii*	Common in Western Ghats and occasional in Western Himalayas and rare in Deccan Plateau, Eastern Ghats and Khasi Hills. Areas of greater concentration: Hassan and Chikmagaluru in Karnataka; Alwar and Jhalawar in Rajasthan; Ernakulam, Idukki, Wayanad, Pathanamthitta and Palakkad in Kerala; Nilgiri, Coimbatore, Namakkal and Karaikudi in Tamil Nadu; East Godavari in Andhra Pradesh, Shahdol in Madhya Pradesh and terai region in Uttarakhand.
5	*C. setosus*	Maharashtra state and adjoining districts of the neighbouring states. Areas of greater concentration: Pune, Satara, Nasik, Kolhapur and Khandala in Maharashtra; Dang in Gujarat; Hoshangabad and Umaria in Madhya Pradesh and Belgaum in Karnataka.
6	*C. prophetarum*	Occasional in Rajasthan, Maharashtra, Gujarat, Delhi and bordering areas (as extended distribution from Africa through Arabia and West Asia and Sindh region of Pakistan). Areas of greater concentration: Jodhpur in Rajasthan.
7	*C. hystrix*	Rare in Brahmaputra Valley, occasional in Naga hills (Nagaland); Mishmi hills (Arunachal Pradesh) and Tura mountains (Meghalaya); Lohit district (Arunachal Pradesh); Dampa Wild Life Sanctuary, Champhai, Kolazib and Aizwal districts of Mizoram; Changlang in Arunachal Pradesh and Churachandpur and Jessami (Ukhrul) in Manipur with possible occurrence elsewhere in North-Eastern Hill states.
8	*C. muriculatus*	Very rare in Champhai, Mamit and Kolasib districts of Mizoram and Tuensang district of Nagaland.
9	*C. silentvalleyi*	Endemic to southern Western Ghats of Kerala and Tamil Nadu (Sholayar, Silent Valley, Nelliyampathy, Valparai) on moist rocky crevices. As ephemeral in rainy season, grows on humus rich rocky crevices, near dripping water source. Areas of greater concentration: Kollathirumedu, Anakkayam and Malakkappara Ranges in Sholayar forest, grasslands near Sholayar Dam site (Coimbatore District, Tamil Nadu), Periyar Tiger Reserve in Idukki, Vellarimala, Malabar Wildlife Sanctuary, Wayanad Wildlife Sanctuary, Moozhiyar and Gavi in Pathanamthitta and grasslands in Silent Valley National Park.
10	*C. indicus*	Amboli Ghat (type locality), at two kilometre stretch in Sindhudurg district of Maharashtra and also in Dandeli Wildlife Sanctuary at 250 m near Karwar, Jog Falls and Devarayii in Belgaum district, Karnataka.

- Fruits ovate-oblong with mamillate protuberances, calyx not recurved, climbing, leaves angular, stem scabrid, wild – *C. hystrix*
- Fruits turbinate with hyaline appendages, calyx recurved, climbing, leaves angular, stems soft hairy (brown), wild – *C. muriculatus*
- Retrorse hairs on ovary and fruit; ephemerals – *C. silentvalleyii*
- Antrorse hairs on ovary and fruit; fruit snout like at both ends, ephemerals – *C. indicus*

Further, taxonomy of various cultivar groups of *melo* has been found confusing for which also based on analysis of Indian specimens a key is provided. Cultivated melon is an exceptionally and highly diverse group with at least five cultivar subgroups in India, each with specific morphological characters, typical use and geographic localization. The cultivated melons fall under two subspecies, *C. melo* subsp. *melo* and *C. melo* subsp. *agrestis*. The subsp. *agrestis* comprises var. *conomon* (oriental pickling melon) and var. *momordica* (snap melon) and the subsp. *melo* comprises var. *flexuosus* (snake melon), var. *reticulatus* (netted melon) and var. *maltensis* (Sarda melon).

Morphological Key to the Subspecies of Cucumis melo

- Ovary pilose to villose, hairs long – subsp. *melo*
- Ovary with retrorse or antrorse appressed short hairs – subsp. *agrestis*

Key to the Cultivated Varieties of Cucumis melo subsp. *melo*

- 1a Fruits elongated (snake like), non-sweet, slender, curved, eaten raw (salad) – *flexuosus*
- 1b Fruits globose or oblong-elliptic – 2
- 2a Netted or with longitudinal bands, flesh mildly (melting) sweet, soft, aromatic – *reticulatus*
- 2b Fruits of monocolour, flesh firm, white, mildly sweet – *maltensis*

Key to the Varieties of Cucumis melo subsp. *agrestis*

- 1a Wild or feral, small fruits, inedible or edible – var. *agrestis*
- 1b Cultivated, sweet or non-sweet, non-bitter, edible – 2
- 2a Fruits 20-30×10-15 cm, cylindrical-oval, skin cracks on ripening, flesh granular, mealy, sweet,

Table 3. Phenological traits of various *Cucumis* species helpful in planning exploration

S. No.	Species	Phenology	Best time for collection/seed maturity and locations
1	*C. melo* subsp. *agrestis*	Seedlings emerge with pre-monsoon showers and come to flowering and fruiting within 30 days.	October-December Namakkal (Tamil Nadu), Malacca (Nicobar), Vindhya hills (Madhya Pradesh). May-June Eastern Ghats, Telangana, Andhra Pradesh
2	*C. callosus*	Seedlings emerge with pre-monsoon showers and come to flowering and fruiting within 60-90 days.	September-October (Tamil Nadu plains) October-November (central and western India)
3	*C. melo* subsp. *melo* (cultivated- including varieties)	Germination with monsoon rains.	September-October April-May (var. *conomon* in Kerala) October (Brahmaputra Valley) (*C. melo* var. *acidulus*) April (Andhra Pradesh, Telangana) Snap melon (Goa-Karnataka) - harvested in October. Snake melon (Tamil Nadu) - harvested in March.
4	*C. sativus* var. *hardwickii*	Germination with pre monsoon showers. Flowering in August-September and senescence by December-January.	October-December (Western Ghats) October (Uttarakhand) November (Meghalaya)
5	*C. setosus*	Germination with monsoon rains. Flowering and fruiting in September-October.	October-November (Maharashtra and Madhya Pradesh)
6	*C. prophetarum*	Germination with monsoon rains. Flowering and fruiting in September-October.	September-October (Jodhpur)
7	*C. hystrix*	Germination with pre monsoon rains. Flowering in July-August.	Late October-November (Mizoram), November-December (Manipur, Arunachal Pradesh)
8	*C. muriculatus*	Germination with pre monsoon rains. Flowering in July-August.	November-December (Mizoram)
9	*C. silentvalleyi*	Germination with pre-monsoon showers and flowering and fruiting in July-September (rarely extending to October).	August-October (southern Western Ghats)
10	*C. indicus*	Germination with pre-monsoon showers and flowering and fruiting in July-September (rarely extending to October).	Mid October-November (northern Western Ghats, Konkan)

Table 4. Diversity of cultivated taxa of C*ucumis* in India

S.No.	Common name; Taxa/ Botanical identity	No. of accessions studied	Useful traits	Distribution	Remarks
1	Oriental pickling melon; *C. melo* subsp. *agrestis* var. *conomon*	12	Long fruits, long shelf life	West coast, Kerala; Kanyakumari (Tamil Nadu); Dakshina Kannada (Karnataka); Andhra Pradesh; Dibrugarh (Assam); Lohit (Arunachal Pradesh)	Cooking types 'Dosakka' (Andhra Pradesh) 'Kanivellari' (Kerala) 'Kallanvellari' (South Kerala) 'Ponavellari' (North Malabar)
2	Snap melon; *C. melo* subsp. *agrestis* var. *momordica*	5	Dessert/ summer fruit, refreshing juice, mild sweet taste, carotenoid rich forms, skin cracking during fruit maturity is a typical phenomenon	Goa, Tamil Nadu, Mizoram, Madhya Pradesh, Punjab, Kerala, Tripura, Odisha, West Bengal	'Pottuvellari' (Kerala) 'Phoot' (North India)
3	Musk melon; *C. melo* var. *reticulatus*	5	Dessert, sweet taste, refreshing juice. Thick netted appearance on the fruit and long shelf life.	Uttarakhand, Punjab, Indo-Gangetic plains	'Karbhuj'
4	Winter melon; *C. melo* var. *maltensis*	1	Firm flesh, white, high shelf life, non-cracking skin	North West plains	Zarda
5	Snake melon; *C. melo* var. *flexuosus*	2	Salad, tender fruit for thirst quenching	Rajasthan, Indo-Gangetic plains, Tamil Nadu	Upto 90 cm long fruit
6	'Kachur'/ 'Kachri'; *C. melo* subsp. *agrestis* var. *agrestis* (semi-domesticated)	1	Fresh fruit aromatic	Rajasthan	Bitter and non-bitter (ripe stage) forms
7	'Kheera'/ 'Kakri'/ cucumber; *C. sativus* var. *sativus*	35	Fresh tender fruits used as salad, mature ripe fruits used as vegetable. Long shelf life, fruit weight 1- 6 kg	Andaman, Karnataka, Goa	Carotenoid rich forms collected from Manipur, Tripura and Mizoram, ivory coloured forms from Hassan, Karnataka (Hassan Local) and mildly sweet, good table types from West Bengal

aromatic, soft and melting on ripening, highly perishable – var. *momordica*

- 2b Fruits 15-20×10-12 cm, oblong-ovate, non-sweet, firm white flesh and intact skin, extra long shelf life – var. *conomon*

Adaptability and Habitat Preference

Cucumis silentvalleyii is highly adapted to specific habitats where humus accumulates in shallow soils combined with dripping water source areas during South West monsoon season (Joseph John *et al.,* 2015). *C. sativus* var. *hardwickii* exhibits a clear cut preference for high rainfall and high humidity regions with big fruited forms in eastern Madhya Pradesh and Khasi Hills and small fruited forms in Himachal Pradesh and Uttarakhand. However, all wild cucumbers are bitter and inedible. On the contrary, *C. melo* subsp. *agrestis* var. *agrestis* occurs more in field boundaries, also as weed in field, does not prefer high rainfall prevailing in Western Ghats and thus are mutually exclusive in distribution.

Conclusion

Lack of information on a taxon's precise distribution in different ecosystems is a major constraint to collection and conservation (Arora, 1998). The mega-diversity hotspots in the Indian region – Western Ghats and Eastern Himalayas – represent two mutually exclusive pockets of diversity for these taxa. The findings of the eco-geographical analysis give a clear cut picture of areas of distribution, diversity richness, infraspecific variability and phenology. The distribution maps give a holistic picture of the distribution of component taxa, areas of overlapping distribution and higher concentration that need to be targeted for maximum assemblage of genetic diversity using which a prospective collector can have access to the exact site (location). Comparing the gene bank passport data with distribution map helps to ascertain

area-wise gap in germplasm collection sites. Analysis of species distribution maps based on herbarium survey and locality data of collections currently maintained in Medium Term Storage (MTS) reveal the need for more intensive exploration in diversity rich pockets. Tribal areas in the whole of North East India and Uttara Kannada district for cooking type *C. sativus*; Tamil Nadu and Uttar Pradesh plains for *C. melo* var. *flexuosus* (snake melon); Mizoram, Nagaland and Manipur for *C. hystrix* and *C. muriculatus* are some suggested areas for exploration in the near future. A good representation of diversity in cultivated melon and cucumber has been assembled from Mizoram, Tripura, Nagaland, Manipur, Sikkim-Darjeeling, Meghalaya, Kerala, Karnataka, Goa, Andaman and Lakshadweep. However, other species and areas need extensive coverage. *C. setosus, C. hystrix, C. muriculatus, C. silentvalleyii* and *C. indicus* which are niche specific and endemic, needs to be specially targeted for *ex situ* conservation. *C. silentvalleyii* germplasm is difficult to gather in sufficient quantity due to small clutch size, predation and quick seed dispersal on ripening. Same is the case with *C. indicus,* due to its fragile habit and niche specificity. With the information generated here on rarity, crossability relationship and actual genebank status, prioritization of species for conservation can be planned. A perusal of the long-term storage status of *Cucumis* in the National Genebank indicates that out of the total 1,881 accessions, cultivated melon (1,024) and cucumber (422) together accounts for 76.87% of the holding. Out of the remaining 435 wild accessions (23.13%), 212 are of *C. callosus* (11.27%), 156 are of *C. sativus* var. *harwickii* (8.29%) and 21 are of *C. prophetarum* (1.12%). Endemic and rare taxa like *C. hystrix* (2), *C. muriculatus* (1), *C. setosus* (1) and *C. silentvalleyii* (1) are only meagrely represented. Exotic species like *C. metuliferus* (1) and *C. dipsaceus* (1) and the species falling under tertiary gene pool such as *Mukia javanicus* (2), *M. leiosperma* (2) and *M. maderaspatana* (8) are also under-represented (Source: PGR Portal). Being orthodox and without any apparent issues on cold storage and retrieval of viable plants, *ex situ* conservation of all species is not a problem once sufficient seeds are harvested either directly at source from wild habitats or regenerated *ex situ* in simulated conditions.

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