Genet Resour Crop Evol (2014) 61:345–355
DOI 10.1007/s10722-013-0038-5

RESEARCH ARTICLE

On the occurrence, distribution and taxonomy of *Cucumis setosus* Cogn., an endemic wild edible vegetable from India

K. Joseph John · R. Khedasana · V. A. Muhammed Nissar · Sheen Scariah · Shrikant Sutar · S. R. Rao · M. Abdul Nizar · M. Latha · S. R. Yadav · K. V. Bhat

Received: 26 January 2013 / Accepted: 15 August 2013 / Published online: 7 September 2013

Abstract *Cucumis setosus* Cogn. is a rare, endemic, wild gathered or semi-domesticated vegetable restricted to Maharashtra state and border districts of adjoining states in India. Herbarium and literature survey shows that it is poorly collected and inadequately studied. Morphological characters, basic chromosome number and crossability barriers indicate that *Cucumis setosus* is a valid species, distinct from *C. sativus* and endemic to western India. Its morphology, basic cytology, crossability relationship with other *Cucumis* species, taxonomy, distribution, ecology, conservation, economic importance and viability under cultivation are discussed. Besides, a key to distinguish it from *C. sativus* var. *hardwickii* (wild and feral form of *C. sativus*) and other species having sympatric distribution in the area is also presented. Absence of bitter principle in the fruits makes it a potential germplasm for melon and cucumber improvement as well as direct domestication as a future crop.

Keywords *Cucumis setosus* · Genetic resources · Gene pool relationship · Wild *Cucumis*

K. J. John (✉) · V. A. M. Nissar · S. Scariah · M. Latha
NBPGR Regional Station, KAU PO, Thrissur 680656, Kerala, India
e-mail: josephjohnk@rediffmail.com

R. Khedasana · S. R. Rao
North Eastern Hill University, Shillong 793022, India

S. Sutar · S. R. Yadav
Department of Botany, Shivaji University, Kolhapur 416004, India

M. A. Nizar
NBPGR Regional Station, Dr. PDKV Campus, Akola 444104, Maharashtra, India

K. V. Bhat
NBPGR, Pusa Campus, New Delhi 110012, India

Introduction

The genus *Cucumis* L. is taxonomically complex and in its latest revision, Kirkbride (1993) has included 32 species under *Cucumis.* However, this traditional circumscription is not fully agreed upon by all (Sebastian et al. 2010). Based on nuclear and chloroplast DNA data of *Cucumis* and a few related genera, Ghebretinsae et al. (2007a) and Renner et al. (2007) argued that *Cucumis* as circumscribed by Kirkbride (1993) is paraphyletic and proposed for merger of *Cucumella* Chiov., *Dicoelospermum* C.B.Clarke, *Mukia* Arn., *Myrmecosicyos* C.Jeffrey and *Oreosyce* Hook.f. with *Cucumis* to make the genera monophyletic. Relying on nuclear and DNA studies, Ghebretinsae et al. (2007b) and Schaefer (2007) recircumscribed the genera and published nomenclatural changes, the former having precedence over the latter.

In India, Chakravarthy (1959, 1982) recognised 6 species in *Cucumis* with *C. melo* L. and *Cucumis sativus* L. being cultivated and C. *prophetarum* L., *C. callosus* (Rottler) Cogn. et Harms, *C. hystrix* Chakrav. and *C. setosus* Cogn. as truly wild. Both melon and cucumber are represented by wild and weedy forms in their distribution range, the former represented by *C. melo* subsp. *agrestis* (Naud.) Pangalo and the latter by *C. sativus* var. *hardwickii* (Royle) Gabaev. (Jeffrey 2001). However, in the most quoted and recent world revision of *Cucumis* L. (Kirkbride 1993) and *Cucumella* Chiov. (Kirkbride 1994), the Indian wild taxa of *Cucumis setosus* is treated as a synonym of *C. sativus* and is not even accorded an infraspecific status. While revising the genus for south-east Asia, de Wilde and Duyfjes (2007) suggests that further studies are needed for bringing about clarity on synonymy of *C. setosus* "with its habit strongly deviating from *C. sativus*". *C. setosus* is also accepted as a distinct species by Jeffrey (1980).

Sebastian et al. (2010) based on nuclear and chloroplast DNA studies argue for the retention of C. *setosus* as a distinct species, allied to the southern/western Indian *Cucumis silentvalleyi* (Manilal, T. Sabu et P.J. Mathew) Ghebret. et Thulin (*Cucumella silentvalleyi* Manilal, T. Sabu et P. Mathew) and *Cucumis indicus* Ghebret. et Thulin (*Cucumella ritchiei* (Chakrav.) C.Jeffrey). It is in this context that an investigation was carried out to find out the status of this taxon in the field, herbarium and genebank.

Materials and methods

Herbarium survey was carried out at Central National Herbarium, Kolkota (CAL), Botanical Survey of India (BSI), Pune, Botanical Survey of India (BSISH), Eastern circle, Shillong and Madras Herbarium (MH), Coimbatore and Calicut University Herbarium (CALI), Kozhikode, wherein a total of 175 sheets of *Cucumis* including twenty five sheets of *C. setosus* were examined.

Seeds of *Cucumis setosus* (IC583551 and SUC 1) was obtained from NBPGR Regional Station, Akola and Shivaji University, Kolhapur respectively and raised in pots along with all other *Cucumis* taxa of Indian occurrence under insect proof net house and also in open field during 2008–2009, 2009–2010 and 2010–2011 monsoon (June–October) seasons. All the accessions were morphologically characterised using the descriptor and descriptor states developed by NBPGR (Mahajan et al. 2001) and modified following Kirkbride (1993) and Kirstkova et al. (2003).

The crosses were made using conventional pollination techniques for cucurbits (Robinson and Decker-Walters 1997; Whitaker and Davis 1962). Direct and reciprocal crosses were attempted with *C. melo* var. *conomon* Thunb. (IC255374, IC256242 and IC278542), *C. melo* var. *momordica* Roxb. (IC536705, IC373556), *C. melo* subsp. *agrestis* (IC550176 and W 59) besides *C. sativus* var. *hardwickii* (IC256248, IC256260 and IC421736), *C. sativus* var. *sativus* (IC248274, IC469522, IC469517 and IC541367), *C. prophetarum* (IC550188, IC550179 and SUC 2), *C. silentvalleyi* (JRN 09-1, JRN 09-2 and JRN 09-15), *C. indicus* (JMP 09-26 and JMP 09-32) *C. melo* subsp. *callosus* (IC550180 and IC550203) and *C. hystrix* (KVB/10-1 and KVB/10-2). Hybrid fruit set and growth were monitored and seeds were raised for germination in petri plates. Reaction to various biotic and abiotic stresses was recorded under natural epiphytotic conditions in the characterisation plot.

For cytological studies, flower buds of appropriate size were collected from mature plants of *Cucumis* species and fixed on the spot in freshly prepared 1:3 glacial acetic acid: 95 % ethanol mixture for a minimum of 24 h at room temperature and later stored in 70 % ethanol at 10 °C. Anthers were squashed in 1 % acetocarmine solution with ferric chloride solution as mordant (Jahier et al. 1996).

Results and discussion

A sound knowledge of the natural geographic range of target species is important for germplasm collection and conservation. A perusal of the herbarium label information and passport data of available limited collections indicate that *C. setosus* is an endemic restricted to Maharashtra state and adjoining districts of the neighbouring states (Dang forest in Gujarat, Hosangabad district in Madhya Pradesh and Belgaum district in Karnataka) (Fig. 1).

Altogether, there were five herbarium sheets at CAL in which four sheets were properly identified (two with incomplete locality details) and one wrongly identified and placed under *C. melo,* besides twenty sheets at BSI. Being a rare taxon, the typical

Fig. 1 Distribution of *Cucumis setosus* in India (based on ecogeographical survey data)

specimens examined are cited below for the use of future researchers.

Specimen examined

B. Venkata Reddy, 99427 (CAL), 29.10.1964, Tiskari forest, Mubi, Ambaine, Maharashtra; Hemadri K, 85177 (CAL), 18.03.1970, Bhoma Hills, Tata's Power Station, Khandala, Maharashtra; G Panigrahi & Singh VN, 4315 (CAL), 21.07.1964, Kothalakinal, Hoshangabad District, Madhya Pradesh.

The sheet B. Venkata Reddy, 99427 (CAL) 29.10.1964 was examined by Kirkbride for his revision of *Cucumis* but wrote determinant slip as *C. sativus*, ignoring its unique morphological features. However, the specimen is clearly distinct from *C. sativus* in its slender plant body, female flowers and fruits developing on slender lateral branches and bristly setose ovary and fruit without any tubercle (Figs. 2, 3).

Chakravarthy (1959) notes that only two sheets are available and that Cogniaux (1924) described the species based on Ritchie, No 321, Edinburgh which is

Fig. 2 *C. setosus* Cogn.: herbarium sheet 99427 (CAL) (*reproduced with permission from BSI)

without precise locality, but presumed to be from Eastern India. However, our observations on its distribution based on herbarium survey indicate that rather than Eastern India, Western India comprises its home range (Fig. 1). A second sheet, which was originally labelled as *Mukia leiosperma* Thw., has been identified by Chakravarthy as *C. setosus*. As the available descriptions are based on these two sheets only, it is incomplete and hence a detailed technical description based on our observations of live plants is given.

Taxonomic description

Annual, climbing, monoecious, setose herb, stem herbaceous, weak, branched, pubescent, internodes c.5 cm long. Leaves simple, alternate, exstipulate, petiolate. Petiole 1.5–3 cm long, green, pubescent. Leaf blade 4.5–8 × 4–7 cm, 3–5 angular, both surfaces setose hairy, base cordate, apex acute, broadly triangular, lateral lobes acute-acuminate, margins dentate. Tendril simple, solitary sparsely hispid up to half portion. Male flowers borne in clusters of 4–6 in fascicles at nodes, pedicel up to 1.4 cm long, flowers with a diameter of 1.5–2 cm, actinomorphic, hypanthium infundibular, 5 mm long, hairy. Calyx: Sepals 5, gamosepalous forming hypanthium tube; tube 0.5 cm long, infundibular, hairy on either sides; calyx lobes 0.3 cm. Corolla yellow, petals 8–12 × 5–7 mm, ovate or oblong, hairy on both sides, apex acute. Stamens 3, one monothecous, two bithecous, inserted, adnate to hypanthium, coherent to each other; anther thecae 2 mm, straight, apically shortly duplicate, ciliate. Female flowers—yellow, calyx and corolla same as in male flower. Pedicel 10–15 mm long, hairy. Ovary 7–8 × 2–3 mm long, setose, oblong, trilocular with many horizontal ovules. Style up to 1 mm, single, glabrous. Stigma 2 mm, trifid each part bilobed, papillate, yellow. Fruit 2–2.8 × 1.5–1.8 cm, indehiscent, many seeded, stalk end and distal end rounded, covered with white hairs as on ovary, stalk up to 2 cm, pendant. Seeds ovate oblong often mucronate 4.3–5.5 × 2.1–2.7 mm, compressed, emarginate, straw coloured.

Comparative morphology, crossability relationship, cytology and taxonomy

A comparison of the morphological features of the taxa with *C. sativus* indicates that delicate, slender, bristly hairy plant body, setose hairy ovary and cylindrical-elliptic fruits with round stalk and distal end are specific to *C. setosus* (Table 1; Fig. 3). This is in agreement with the recent molecular phylogenetic study by Sebastian et al. (2010), by far the most comprehensive in terms of number of species covered especially the Asian taxa compared to the previous studies (Ghebretinsae et al. 2007a; Renner et al. 2007; Schaefer et al. 2009), which showed it to be more allied to *C. indicus* and *C. silentvalleyi*. However, the bristly setose, non rostrate fruits and non-fragile habit of *C. setosus* distinguish it from *C. indicus* and *C. silentvalleyi.* Besides, both these entities are clearly outside the range of its distribution.

Direct and reciprocal crosses of *C. setosus* with *C. silentvalleyi* and *C. indicus* resulted in fruit set (29 and 36 % respectively with *C. silentvalleyi* and 22 and 30 % with *C. indicus*). Fruit set was absent in all other combinations except with *C. melo* (40 %) as pollen parent (Fig. 4). Even though there was fruit set apparently looking normal and retained on the mother plant until maturity, more than 50 % of the seeds were

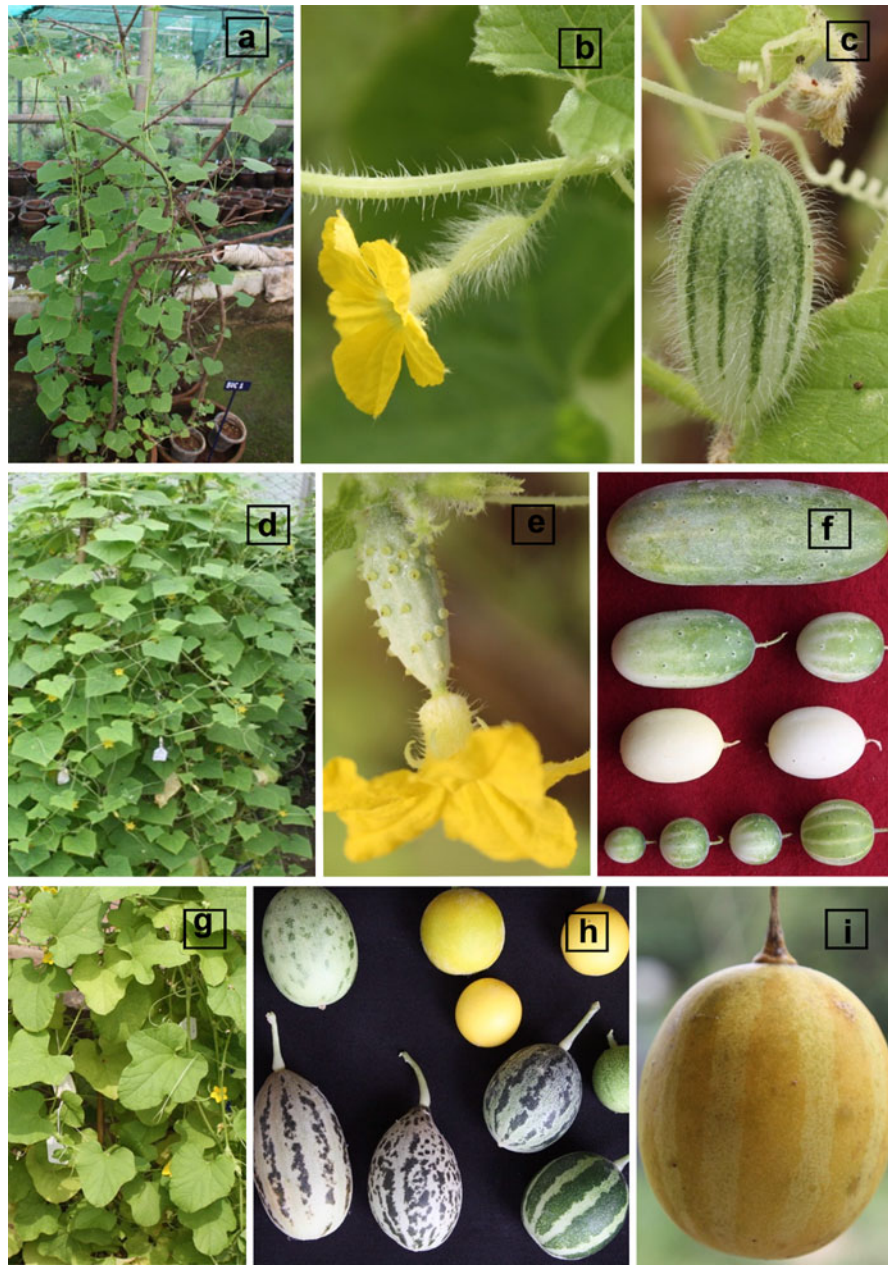

Fig. 3 Comparative morphology: **a–c** habit, female flower and fruit of *C. setosus;* **d–f** habit, female flower and fruit variability of *C. sativus* var. *hardwickii;* **g–h** habit and fruit of *C. melo* subsp. *agrestis*; (i) fruit of *C. melo* subsp. *callosus*

found to be chaffy. Absence of fruit set in direct and reciprocal crosses involving *C. sativus* (4 accessions) and *C. sativus* var. *hardwickii* (3 accessions) proves its distinct species status from *Cucumis sativus*, contrary to the observations of Kirkbride (1993). Normally *C. sativus* sets fruits on pollination with *C. melo* pollen, even though mature fruits are with chaffy seeds. Fruit set in direct and reciprocal crosses with *C. silentvalleyi* support the position of Sebastian et al. (2010) that it is more related to southern/western Indian (erstwhile) *Cucumella* species than *C. sativus*. Retention of crossed fruit until maturity in the case of crosses with *C. melo* and *C. silentvalleyi* offer scope for recovery of hybrids by embryo rescue.

Table 1 Comparative morphology of *C. setosus* and other wild and feral *Cucumis* forms with sympatric distribution

S.No.	Character	*C. setosus*	*C. sativus* var. *hardwickii*	*C. melo* subsp. *callosus*	*C. melo* subsp. *agrestis*
Qualitative characters					
1	Life span	Annual	Annual	Perennial	Annual
2	Tap root	Non tuberous	Non tuberous	Tuberous	Non tuberous
3	Stem type	Delicate, thin setose hairy	Thick pubescent	Rough and hard, pubescent	Delicate, puberulent
4	Laterals	Similar to main stem	Slender than main stem (easily distinguishable)	Almost similar to main stem	Slender than main stem (easily distinguishable)
4	Leaf lamina	Membraneous	Thick	Thick	Thick
5	Leaf margin	Denticulate	Dentate	Serrate	Serrate−dentate
6	Leaf lobing	3 -angular	3–5 angular	Deeply lobed	Unlobed
7	Leaf lamina shape	Ovate	Broadly cordate- ovate	Sub orbicular	Sub orbicular
8	Male flowers	Fascicles of 7 (−9)	Fascicles of 4–6	Solitary	Fascicles of 3–5
9	Anther thecae	Apically shortly duplicate	Apically shortly triplicate	Apically shortly triplicate	Apically shortly triplicate
10	Corolla base	Cup shaped	Saucer shaped	Funnel shaped	Saucer shaped
11	Female flower pedicel	Straight	Straight	Looped, U shaped	Slightly curved
12	Fruit shape	Oblong	Ovate–oblong	Round/obovoid	Oblong or turbinate
13	Ovary pubescence	Bristly setose	Tubercled	Tomentose	Pubescent
14	Seed funicle	Acute	Acute	Mucronate	Acute
15	Fruit colour on ripening	Pale green/ whitish green	Yellow/brown	Yellow with prominent white stripes	Whitish green/bright yellow/ mottled green
16	Shelf life of fruits	Very short (3–5 days)	Longer duration (up to 12 months)	Longer duration (12 months or more)	Short to medium duration (varying)
17	Epicarp	Peeling easily on ripening	Non peeling	Non peeling	Non peeling
18	Mesocarp (ripe fruits)	Granular/ crystaline	Thick and firm	Thick and firm	More or less thick and firm
19	Fruit pulp taste	Non bitter	Bitter	Bitter	Bitter/Sour
Quantitative characters					
1	Leaf length	4.5–8 cm	10–13 cm	6.0–7.5 cm	6–7.5 cm
2	Flower diameter	1.5–2.5 cm	2.3–2.7 cm	1.8 -2.2 cm	2.0–4.0 cm
3	Pedicel length	0.8–1.4 cm	1.5–3.5 cm	0.5–1 cm	0.5–1 cm
4	Calyx tube	4.5–5.3 mm	4–6 mm	2–4 mm	3–5 mm
5	Anther length	±2 mm	±3 mm	±2 mm	±3 mm
6	Fruit length	2–2.8 cm	4–9 (−12) cm	3.5–5 cm	2.5–6 cm
7	Fruit diameter	1–1.5 cm	3.9–7.4 cm	3–5.2 cm	2.8–4.5 cm
8	Fruit circumference	±7 cm	14–18.6 cm	12.4–13.2 cm	8–11.3 cm
9	Single fruit weight	5–7 g	25–90 g	13–21 g	10–30 g

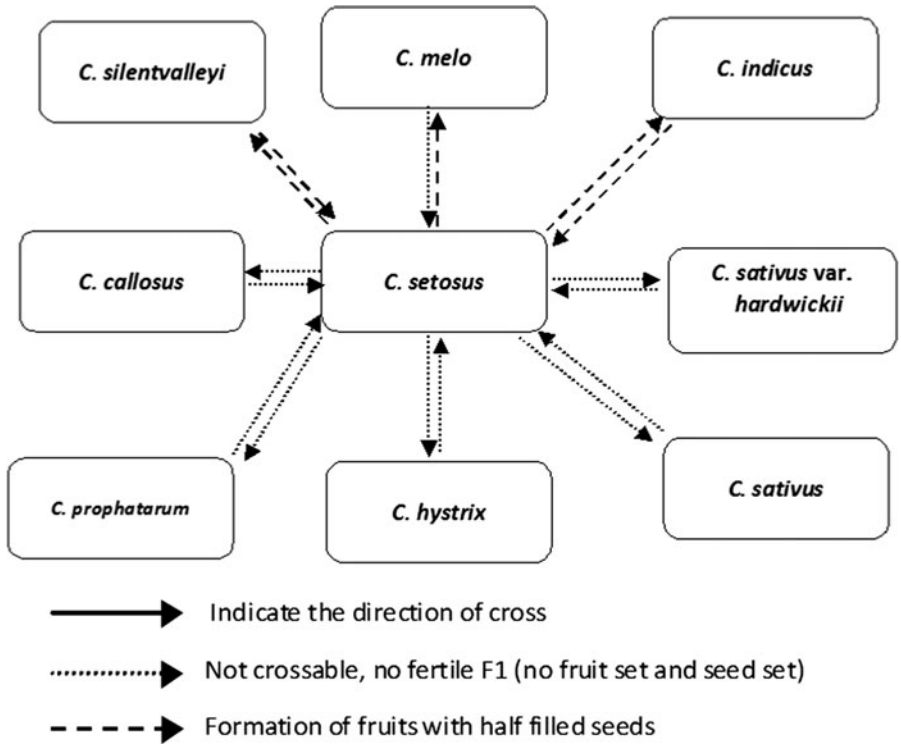

Fig. 4 Crossability polygon of *C. setosus* with other taxa

Contrasting cytological characters that distinguish it from *C. sativus* are given in Table 2. Further, the somatic chromosome number for *C. setosus* is 2n = 24, which is quite divergent from *C. sativus* (2n = 14) (Fig. 5). The basic differences in somatic chromosome number of these two taxa, evidence traditionally adopted in plant systematics (Kumar and Rao 2002; Verma and Raina 1983), also do not support clubbing of these two species.

Morphological characters, somatic chromosome number and crossability barriers indicate that *Cucumis setosus* is a valid species endemic to central India, quite distinct from *C. sativus*. It is more related to *C. silentvalleyi* and *C. indicus* than *Cucumis melo*, but distant from *C. sativus* and all other *Cucumis* taxa. It has overlapping distribution with *C. melo* subsp. *agrestis* and *Cucumis sativus* var. *hardwickii* in the whole range of its distribution. In the light of the fact that in the recent revision of *Cucumis* L. (Kirkbride 1993) it was considered only as a synonym of *C. sativus,* a key to distinguish it from *C. sativus* var. *hardwickii* (wild and feral form of *C. sativus*) and other species having sympatric distribution in the area is also presented.

Leaves broadly round deeply or shallowly lobed, tender fruits puberulent	
Male flowers solitary, roots tuberous, perennials	*C. melo* subsp. *callosus*
Male flowers in fascicles, roots non-tuberous, annuals	*C. melo* subsp. *agrestis*
Leaves 3-5 angular, tender fruits tomentose hairy or tubercled	
Vines delicate, ovary and fruits bristly setose, hairs persistent, mesocarp granular, disintegrating quickly on ripening, fruits non bitter, cylindrical—elongate, between 5 and 7 g	*C. setosus*
Vines robust, ovary and fruit distantly tuberculate, tubercles caducous, mesocarp firm, non disintegrating, fruits bitter, round to elongate, between 25 and 90 g	*C. sativus* var. *hardwickii*

Ecology

The plant is a natural component of grasslands especially in farm borders trailing to fences, bushes

Table 2 Comparative cyto-morphology of *C. setosus* and *C. sativus*

S.N.	*C. setosus*	*C. sativus*
Mitosis		
1	The chromosome count in root tip cells was recorded as 2n = 24	14 chromosomes were observed in root tip cells (2n = 14) which were resolved into seven homologous pairs and forming a series from the longest to shortest pair within the complement
2	Four median, five submedian and three subterminal centromeric chromosome pairs were present.	All the seven pairs were median-centromeric chromosomes
3	The centromeric position on chromosomes was quite diverged, reflecting the range of arm ratio index from 1.26 to 5.03.	Arm ratio index ranged from 1.17 to 1.57
4	The fourth chromosome pair was heteromorphic in nature.	No heteromorphic pairs were recorded.
5	The ratio of longest to shortest chromosome length was 1.81	The ratio of the longest to shortest chromosome in the complement was 1.66
6	Karyotypic formula was resolved as 4 m + 5sm + 3st	Karyotypic formula was recorded as 7 m
Meiosis		
1	All the PMC analyzed had shown both univalent and bivalents association with characteristic 12 bivalents at diplotene/diakinesis/metaphase I	All the PMC analyzed had shown both univalent and bivalents with characteristic 7 bivalents at diplotene/diakinesis/ metaphase I
2	The mean value of total number of bivalents and univalent per PMC was 11.95 and 0.48	The mean value of total number of bivalents and univalent per PMC was 6.75 and 0.27
3	Each PMC had 21.53 chiasmata on an average, out of which 15.93 were terminalized and 5.48 were unterminalized chiasmata showing a terminalisation coefficient of 0.73	On an average, there were 5.2 ring and 1.55 rod bivalent. Each PMC had 11.97 chiasmata on an average, out of which 9.15 were terminalized and 2.82 were unterminalized chiasmata showing a terminalisation coefficient of 0.76.nts
4	All the PMCs analyzed at anaphase I/II had shown equal distribution of chromosomes (12:12)	All PMCs analyzed at anaphase I/II had shown equal distribution of chromosomes (7:7)

and other supports. It grows well in hot semi arid regions on gentle slopes during the rainy season at an altitude of 1,050–2,340 m. The soil type in its natural home range is 'Warkas' (light laterites of reddish brown to black colour) and soil pH ranges from 6 to 8. The habitat is characterised by a maximum temperature of 29–39 °C and minimum temperature of 13–20 °C and 2,600–3,000 mm rainfall, received mostly from southwest monsoon. Germination of seeds starts with pre-monsoon showers in May–June and seedlings come to flowering by late July to early August. Fruits take about 30–32 days for ripening. Within a month of withdrawal of monsoon (early December), the vines start drying up. The soft pericarp disintegrates quickly leaving the dormant seeds in the soil.

Conservation

This species, being rare and endemic, has not attracted the attention of agriculturists and conservationists alike. There is no information available on its genetic erosion and threats in natural habitats. As the taxa is a component of grasslands in the rolling hill slopes, impact of open grazing by cattle needs to be investigated. Conservation efforts are very meagre as the taxon is little known. As more and more wild areas are being destroyed for developmental activities, especially mining, there is an urgent need for its conservation both *in situ* and *ex situ*. Two accessions of wild populations collected from Maharashtra state are maintained in the medium term genebank of NBPGR at Thrissur and Akola in India. Tribes residing in its

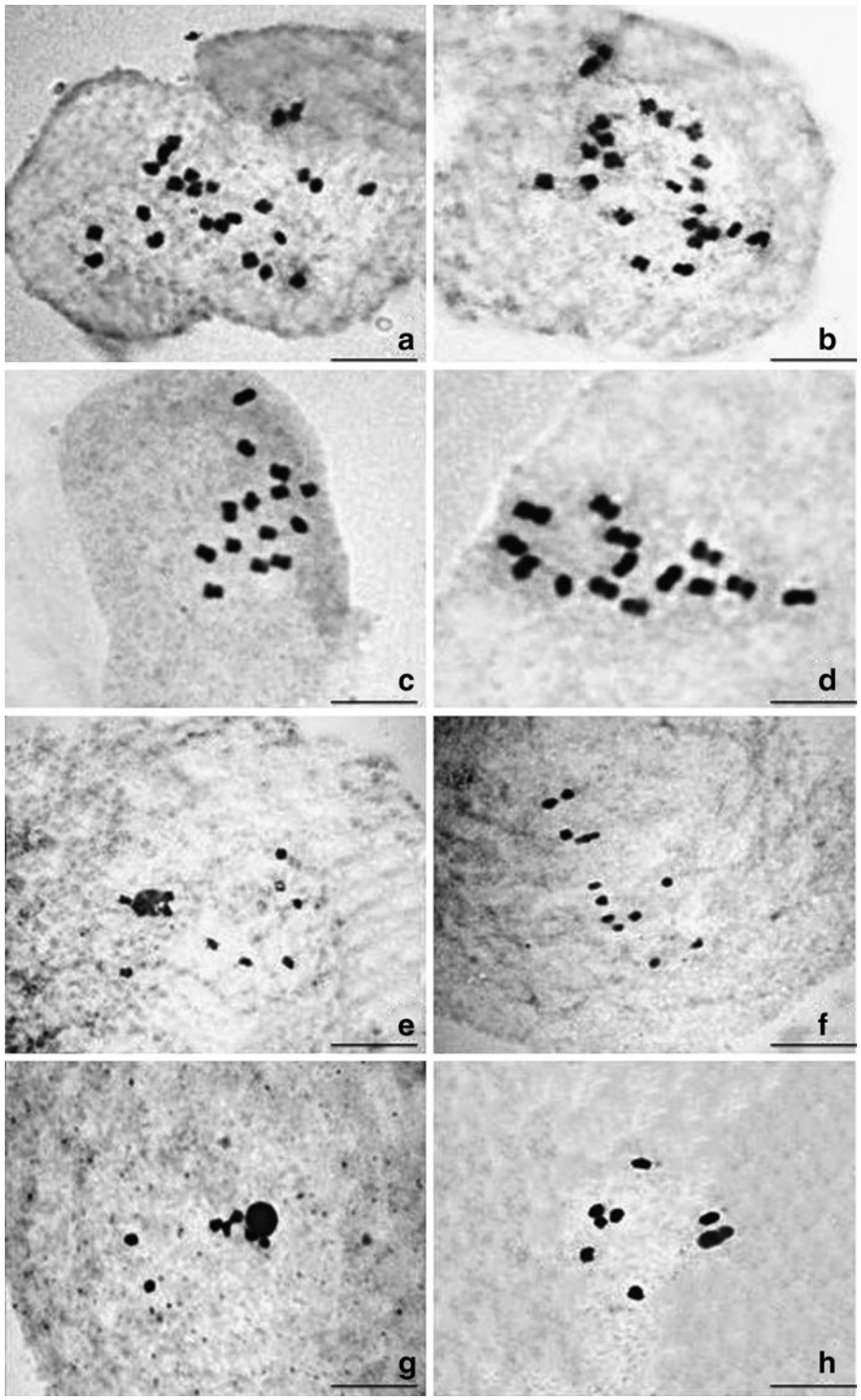

Fig. 5 Mitotic and meiotic chromosomes in *C. setosus* and *C. sativus.* **a–b** Mitotic pro-metaphase and metaphase chromosome of *C. setosus*; **c–d** Mitotic pro-metaphase and metaphase chromosomes of *C. sativus*; **e–f** Meiotic chromosomes (12II) at diplotene and metaphase I of *C. setosus* respectively; **g–h** Meiotic chromosomes (7II) at diplotene and metaphase I of *C. sativus* (scale bar −5 μm)

distribution range namely, Berad, Bhamta (Uchala), Bhil, Chodhara, Gamit, Gond, Kaikadi, Kangari, Kathodi, Katkari, Kokna, Kolidhor, Koli Mahadev, Naikda, Pardhi, Ramoshi, Thakur, Vadar, Vaidu, Vanjari and Varli can be entrusted the task of producing sufficient seeds of representative populations for gene bank.

Prospects for cultivation

Natural regeneration is through seeds which are orthodox in nature. Prostrate vines root at nodes which can be separated out and grown. Rooting of cutting by application of rooting hormones under mist house conditions was found to give 30 % success.

For seed regeneration, plants can be raised either in pots or in the field. Seed sown plants come to flowering by July end. Even though, prolific vine growth, branching and flowering was noticed, fruit set was very low outside its home range. Compared to an average yield of 300 fruits per well-spread vine in its home range, an average of 40 fruits per plant only was obtained under *ex situ* pot culture in rain-proof net house. Hand pollination resulted in 10 % increase in fruit set and absence of pollinators may be one of the reasons for reduced fruit set.

Leaf area damage due to pumpkin caterpillar (*Diaphania indica*) was severe both in open field and pot culture.

Recently, Maharashtra Forest Department has taken initiative for its cultivation for augmenting the income of forest-dwelling communities. Mature fruits are consumed as vegetable by the 'Korku' tribe of Amravati district of Maharashtra. Some of the 'Korku' tribals were trained by the Medicinal Plant Conservation Centre—Rural Communes, Pune, Maharashtra, for adopting cultivation of *Cucumis setosus* as a livelihood option.

Economic importance

Tender fruits are esteemed as vegetable eaten directly as salad, fried or pickled. Locally called 'Meika' in Maharashtra, surplus produce from wild gathered harvest is sold in the local vegetable market. Raw fruit taste like 'Gerkin' and tender cucumber and doesn't have any bitterness at all. The flesh is non-fibrous having the same taste and crispness of salad cucumber. Absence of bitter cucurbitacin in the fruit may contribute to its use in improvement of cucumber and melon. It has direct potential for domestication as a promising vegetable crop also.

Conclusions

Morphological characters, somatic chromosome number and crossability barriers indicate that *Cucumis setosus* is a valid species distinct from *C. sativus* and endemic to western India. It is more related to *C. silentvalleyi* and *C. indicus* than *Cucumis melo*, but distant from *C. sativus* and all other *Cucumis* taxa. Absence of the bitter principle, cucurbitacins and good edible quality of fruits make it a potential candidate for direct domestication as a crop and also in cucumber and melon improvement.

Acknowledgments The work was carried out with the funding from National Agricultural Innovation Project on "Biosystematics of the genera *Vigna, Cucumis* and *Abelmoschus*". We profusely thank Dr. N. K. Dwivedi, Principal Scientist and Officer in charge, NBPGR Regional Station, Thrissur, Dr. M. Dutta, Head, Germplasm Evaluation Division and Dr. K. C. Bansal, Director, National Bureau of Plant Genetic Resources, New Delhi for the support and encouragement. The facility extended by authorities of CNH and BSI for herbarium consultation and photography of a few sheets is gratefully acknowledged.

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