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RESEARCH ARTICLE

Decline in Occurrence and Distribution of *Sesamum prostratum*, a Crop Wild Relative of Sesame, along the Eastern Coastal Region of India

Parimalan Rangan[1,*], Pradheep K[2], Mahalingam Angamuthu[3], Senthilraja G[3] and Justin Mohan J[4, 5]
[1]*ICAR-National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi-110012, India*
[2]*ICAR-National Bureau of Plant Genetic Resources, Regional Station, Thrissur-680656, Kerala, India*
[3]*TNAU-Regional Research Station, Vriddhachalam-606001, Tamil Nadu, India*
[4]*Bharath Institute of Higher Education and Research, Chennai-600073, Tamil Nadu, India*
[5]*National Biodiversity Authority, Chennai-600113, Tamil Nadu, India*

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An exploration was undertaken for collection of the narrow-endemic wild relative of sesame, *Sesamum prostratum* Retz., a potential Critically Endangered (CR) species, specific to the coastal habitats, in the strands between 150-300 m from the sea shore of the east coast. Herbarium specimens, the authentic source for occurrence and distribution, for *S. prostratum* at various herbaria (collected during 1802-1988) are available. A trip was undertaken in Dec. 2020 along the east coast region of Tamil Nadu, between the latitudes 10.29 N to 13.56 N, that covered all previously recorded collection sites. Unfortunately, in 71% of the sites surveyed, *S. prostratum* was absent. All the sites with *S. prostratum* were found to be undisturbed or with minimal human interference. Our preliminary assessment as per the IUCN guidelines suggests for CR category. In sites around the Chennai sea shore, we found *Canavalia rosea*, with *Ipomoea pes-caprae*, while the endemic *S. prostratum* was absent. The loss could be due to two reasons, habitat-based-probable spread of introduced species such as *Ipomoea pes-caprae*, protection afforded to *Spinifex littoreus* (besides severe urbanization, cyclonic storms, and tsunami,where the habitat itself is fragmented and prone to disasters) and the non-competitive nature of the species. Strategies for threat assessment (especially post-disasters) with an action plan, is discussed that could prevent extinction risk, especially of endemic.

Key Words: Climate change, Conservation strategies, Critically endangered, Narrow-endemic, Tsunami.

Introduction

The genus *Sesamum* L. belongs to the family Pedaliaceae, and it includes an important oilseed crop, *S. indicum*, native to India (Bedigian, 2015). The genus *Sesamum*, comprising seven sections viz., *Aptera*, *Ceratotheca*, *Chamaesesamum*, *Dicerocaryum*, *Josephinia*, *Sesamopteris*, and *Sesamum*, occurs mainly in Africa, Australia, India, Malaysia, the Philippines and Indonesia, with 31 species (Ihlenfeldt, 1988; Namiki, 1995; Pradheep *et al*., 2021).

Two of the seven sections of *Sesamum*, namely *Sesamum* and *Chamaesesamum*, are native to the Indian subcontinent (Bedigian, 2015; Pradheep *et al*., 2021). The wild species of the cultivated sesame (sections, *Aptera*, *Chamaesesamum*, *Sesamopteris*, *Sesamum*) is represented in the National Genebank (NGB) of ICAR-NBPGR by a few hundred accessions. However, from the section *Chamaesesamum*, only *S. laciniatum* is collected and conserved (with *S. laciniatum* synonymized to *S. prostratum*, please refer Bedigian, 2015).The habitat for these two taxa are distinct; *S. prostratum*, is a species of the coastal areas of the east coast (Rao, 1971; Rao and Sastry, 1974), and is distributed along the coastal regions of Tamil Nadu, Puducherry and Andhra Pradesh; whereas *S. laciniatum* is documented to occur in hard laterite soil and distributed in the Malabar region and Deccan hills of Peninsular India (Pradheep *et al*., 2021).Our recent studies had shown that the morphological characters of lamina, calyx, stem, and seed are very distinct and worth considering as distinct taxa (Pradheep *et al*., 2021). Furthermore, *S. prostratum* is endemic to certain pockets of India and Sri Lanka (Kumar *et al*., 2019). In Sri Lanka, it is categorized as a critically endangered (CR) species (Wadugodapitiya *et al*., 2013; Weerakoon *et al*., 2020). We undertook an exploration targeted to collect *S. prostratum* material for its conservation, and

**Author for Correspondence: Email- r.parimalan@icar.gov.in*

to map its current distribution pattern, from the eastern coastal areas of Tamil Nadu.

Materials and Methods

A preliminary survey of herbarium collections of *Sesamum* deposited at the Botanical Survey of India (BSI), Coimbatore (MH, the Madras Herbarium) and BSI, Howrah (CAL, the Calcutta Herbarium), and online herbaria was undertaken. The herbarium study provided clues to the possible areas for survey (Table 1) and key morphological features to distinguish *S. prostratum* and *S. laciniatum*. Additionally, habitat features associated with the presence of *S. prostratum*, were noted from earlier reports (Rao, 1971; Matthew, 1981; Irwin *et al*., 2015; Dhaarani *et al*., 2018; IL&FS, 2019).

On the basis of habitat, collection records and phenology of *S. prostratum*, the exploration trip was organized during December 2020. We had started our trip from the southern side Kodiyakkarai (Nagappattinam District) and moved along the northern side in the East Coast till Pulicat Lake (Thiruvallur District), between the latitudes 10.29 N to 13.56 N (Fig. 1). During our trip, we had primarily focused to the narrow strip of coastal tracts adjacent to the sea (up to 700 m from seashore, Rao, 1971), covering nearly 50 km (Fig. 1). Germplasm was collected following standard operating procedures (ICAR-NBPGR, 2016).

A preliminary assessment of the threat status of *S. prostratum* in India was made as per the latest IUCN guidelines (IUCN, 2022). In brief, this species is mainly evaluated to identify the degree of threat of extinction, and to categorize appropriately among the threatened categories, Critically Endangered (CR), Endangered (EN), and Vulnerable (V). IUCN guidelines provide five criteria, A) population size reduction, B) geographic range size, and fragmentation, C) small and declining population, D) very small population, and E) quantitative analysis of extinction risk. In geographic range, the area of occupancy (AOO) has not been calculated as per

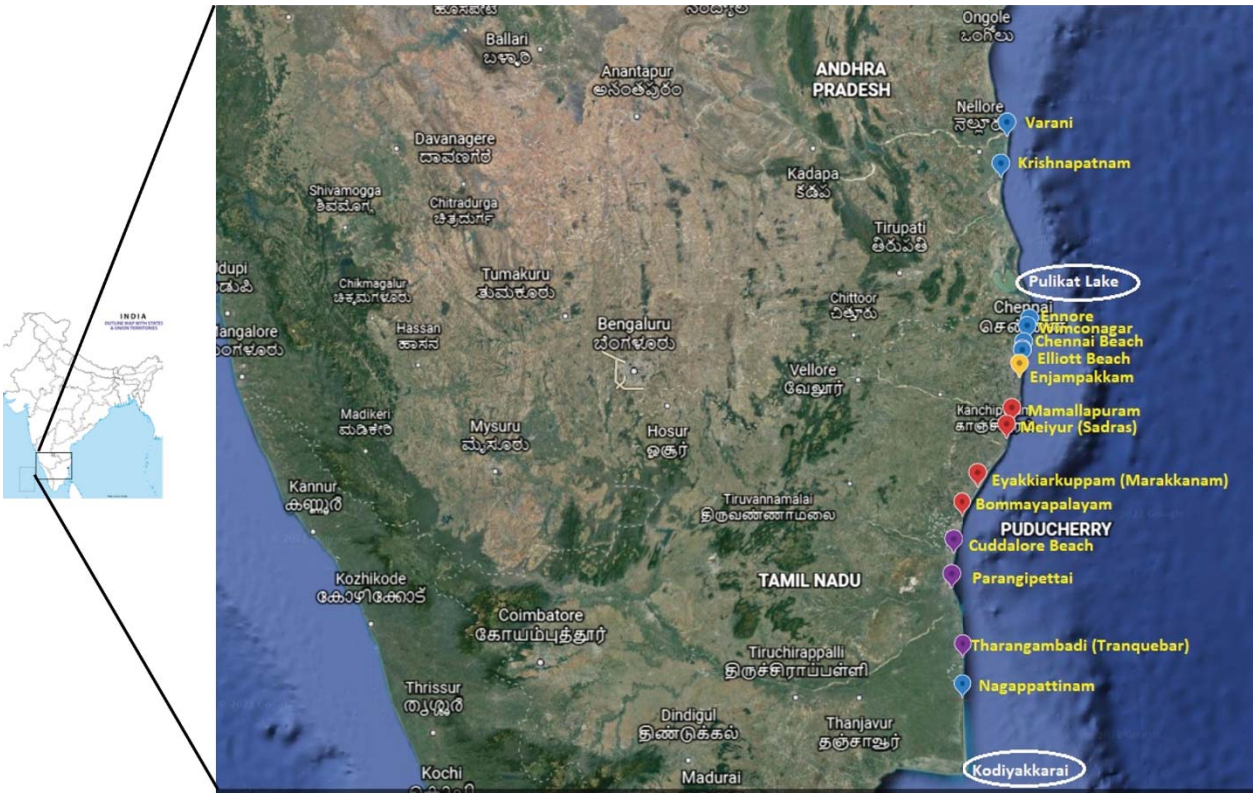

Fig. 1. Areas explored for *Sesamum prostratum* (Kodiyakkarai to Pulicat Lake, cumulative coastal walk of 50 kms at the pinned spots). Blue pinned (Nagappattinam, Elliott beach, Chennai beach, Wimco Nagar, Ennore, *Varani* and *Krishnapatnam*, italicized places not covered during this trip) and violet pinned (Tharangambadi, parangipettai and Cudddalore beach) sites are based on herbarium (#1-14 of Table 1) and literature information (#15-18 of Table 1), respectively. Red pinned (Bommayapalayam, Marakkanam, Meiyur and Mamallapuram) sites are the collection sites and yellow pinned (Enjampakkam) site, indicate only one plant seen in the spot.

the recommended 2 × 2 km grid size, since this is an endemic species exhibiting a linear habitat. The species' biological characteristic features influence the correction factor towards 1, and each site never exceeded the 150 × 500 m area, hence we were unable to quantify the AOO.

Results and Discussion

Augmenting the diversity in crop wild relatives (CWR) is a priority in recent years (Joseph-John and Pradheep, 2018). There are 18 herbarium specimens of *S. prostratum* at the MH, the CAL and other online herbaria (Table 1); in addition, there were few specimens from the inland sites, which were observed to be misidentifications of *S. laciniatum* (Pradheep *et al*., 2021). The earliest herbarium specimen of *S. prostratum* was the one collected in 1802 AD (from India) and the complete list of authentic collections sites for *S. prostratum* over a period between 1802 and 1988 are provided in Table 1 and Fig. 1. Notably, all were documented prior to the 2004 tsunami. The area along the East Coast of Tamil Nadu region, and the collection spots of *S. prostratum*, are provided in Fig. 1. At rare occasions, we observed the presence of a few plants of *S. prostratum* within 50 m from the seashore in Bommayapalayam site and up to 700 m from the seashore in Marakkanam site.

Unnoticed decline in the population of Sesamum prostratum distribution

The prominent sites from where *S. prostratum* had been collected in the past were covered in the current trip (Fig. 1), except for Krishnapatnam, and Varani [from Andhra Pradesh] (Table 1; Fig. 1). However, *S. prostratum* was located only at five locations *viz*., Bommayapalayam (700 m from Auroville Beach), Eyakkiarkuppam (Marakkanam), Meiyur (Sadras), Mamallapuram (earlier Mahaballipuram), and Enjampakkam. Interestingly most of the sites were non-overlapping, with reference to the previous specimen reports, except the last two of the five sites where *S. prostratum* is located during the trip. Seed samples were collected from these five locations except Enjampakkam, where only one plant

Table 1. List of collection spots for *S. prostratum*, as per the herbarium specimens studied at the MH, the CAL, and the other online herbaria.

S. No.	Collector No. / Ref	Place	Year	Herbarium
A. Based on specimens:				
1.	Klein	India	1802	B-W 11614-01 0
2.	Anon.		1818	K001123830
3.	Herb. Hookerianum	Chennai	1825	K00884563
4.	Anon.		1826	K001123829
5.	Anon.		1859	CAL334676
6.	G Bidies.n.	Ennore, Chennai	1879	MH00133781
7.	JS Gamble 12781	Varani, Nellore dt., Andhra Pradesh	1883	CAL, MH
8.	JS Gamble 17140	Near Chennai	1885	CAL, MH
9.	Anon.	Nagappattinam	1886	MH
10.	G Watt 12920	Mahaballipuram (Mamallapuram)	1899	CAL
11.	CA Barber 31	Elliot Beach, Chennai	1899	MH
12.	CEC Fischer 4118	Krishnapatnam, Nellore dt.	1917	CAL
13.	G Davidse & DB Sumithaarachchi 8964	Panama, Sri Lanka	1974	CAL
14.	D Narasimhan 685	ITC Compound, Near Wimco Nagar Railway Station, Chennai	1984	MH
15.	N Parthasarathy & K Ravikumar 85500	Enjampakkam, Chennai	1987	MH
16.	R Rajan 89743	Auroville Beach	1988	MH
17.	Anon.	Chennai Beach		MH00133784
18.	Anon.	Chennai Beach		MH00133782
B. Based on literature studies:				
19.	Matthew, 1981*	Cuddalore beach		-
20.	Irwin et al., 2015*	Adayar Theosophical Society		-
21.	Dhaarani et al., 2018*	Tharangambadi		-
22.	IL&FS, 2019*	Parangipettai		-

* Marked ones are as per the literature information. For details, please refer to the citation list.

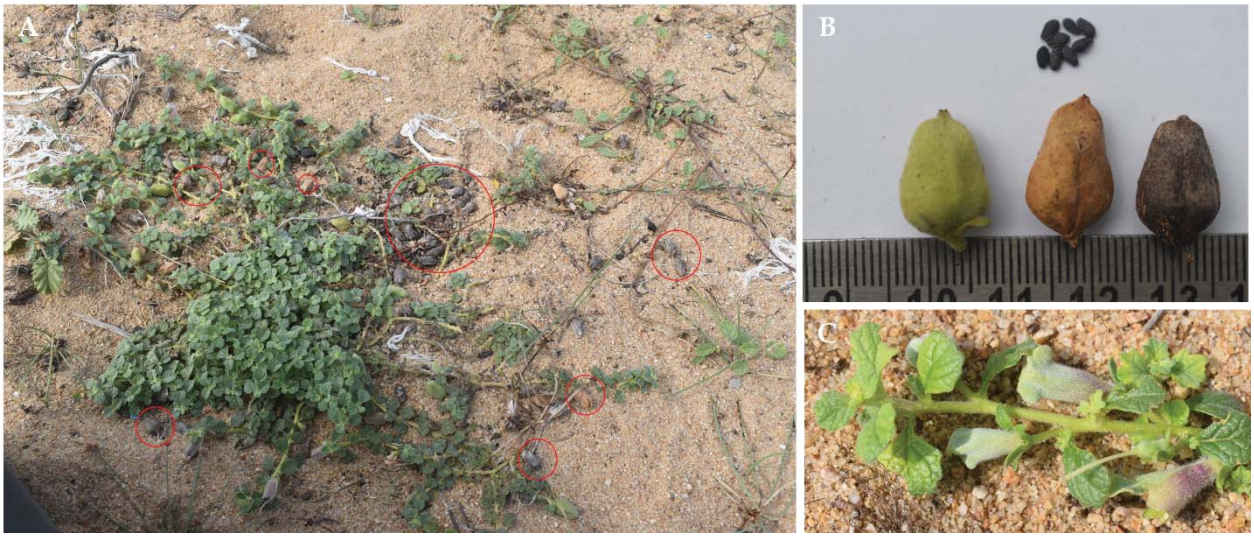

Fig. 2. A: Presence of previous years' capsules (marked as red rings in the figure) lying underneath / adjacent to the plant. B (from L to R): Simultaneous collection of current year maturing capsules (green), matured capsules of previous year (brown), matured capsules relatively older than the previous year' ones (blackish brown). C: Phyllody infection in *S. prostratum*.

was spotted, possibly due to severe urbanization and now being within the city limit. Also, of the four sites, where seeds were collected, only at Bommayapalayam and Eyakkiarkuppam sites, could a large population be located with roughly 1000 plants as a single population. Furthermore, although some reports underscore the potentiality of *S. prostratum* for resistance to phyllody (Thangavelu, 1989; Subramanian, 2003), we noticed phyllody infection in *S. prostratum* plants (upto 5%) at this site (Fig. 2). Detailed resistance reaction studies, in future, in these population would potentially help identify the resistant or tolerant genotypes that could be of potential use in introgression of genes from *S. prostratum* to sesame cultivars to overcome phyllody related yield losses. These plants exhibit a prostrate habit, there would be possibility of additional or newer insect groups responsible for the phyllody infection on the spreading-type plants, that needs detailed research. At the other two sites, Meiyur and Mamallapuram, were represented with a population of less than 100 plants in each. This indicates that *S. prostratum* is absent in roughly 71% of the sites known for previous occurrence. All the sites of location of *S. prostratum* were observed to be in isolated pockets, clearly defining the population, that are undisturbed or with minimal human interference. An independent in-depth study on the phenotypic variability for the various biometric traits, and molecular diversity assessment at intra- and inter-population level is required to understand its variability and diversity patterns. In most of the sites visited (Fig. 1), two species, *Ipomoea pes-caprae* (L.) R.Br. and *Spinifex littoreus* Merr., were dominant. However, a wild relative of jack and sword bean, *Canavalia rosea*, was present in some pockets of seashore around Chennai along with *I. pes-caprae*. Hence, a significant decline in the areas of occurrence is indicated and size of the population of *S. prostratum*, a CR species of Sri Lanka (and probably for India too), and calls for the immediate need to implement conservation strategies for such species that are at risk of severe loss of diversity and even extinction.

Preliminary threat assessment of S. prostratum as per IUCN guidelines

S. prostratum, an endemic species of India and Sri Lanka (Kumar *et al*., 2019 and citations therein; Pradheep *et al*., 2021), is categorized by IUCN as 'CR' in Sri Lanka (Wadugodapitiya *et al*., 2013); along Indian coastal areas too it appears to be under high risk. Based on the IUCN guidelines (IUCN, 2022), we have preliminarily assessed the threat status of *S. prostratum* (Table 2). The annotation as per the IUCN guidelines for *S. prostratum* is: A2ace; B1ab (i,iii)-B2ab (ii,iii); D1 (Table 2). After assessment with maximal number of threat criteria possible, we suggest that the threat assessment level for *S. prostratum* in India falls in critically endangered (CR) category. Being endemic to Indian sub-continent (India and Sri Lanka), and IUCN had already categorized this species as 'CR' in Sri Lanka, our observations and assessment (in line with IUCN guidelines except for AOO) suggest *S. prostratum* for a 'CR' in India

Table 2. Preliminary threat assessment of the *Sesamum prostratum* in India as per the latest IUCN guidelines (IUCN, 2022).

S. No	Criteria	Category			Remarks
		Critically Endangered (CR)	Endangered (EN)	Vulnerable (VU)	
A	Population size reduction (Population with reference to the number of sites)	≥80%	≥50% **A2ace (70.59%)**	≥30%	As per the 22 sites mentioned in the table 1, 8 sites were excluded (2-Andhra Pradesh, 1-SriLanka, 3-unknown, 1-documented location as India, 1- two were from Chennai Beach and probably same location), and the 3 new sites identified were included. Making it to a total of 17 sites (22-8+3), of which in 5 sites it is spotted. Percentage conversion (5/17) makes it to 70.59%.
B	Geographic range* Extent of occurrence (EOO) Area of occupancy (AOO)	B1: <100 km^2 B2: <10 km^2 **B1ab (i, iii) (<55 km^2)** **B2ab (ii, iii) (5 km^2)**	B1: <5000 km^2 B2: <500 km^2	B1: <20000 km^2 B2: <2000 km^2	**B1:** from the first spot, Bommayapalayam, to the last spot, Mamallapuram, it is ca.90 km in length. *S. prostratum* is spotted only within 150 m width (150-300 m from seashore) calculating to 13.5 km^2.Even if this is present in the northern most point (ca. 280 km from Mamallapuram), Varani-Andhra Pradesh, would add 42 km^2 area. Hence, it is roughly55 km^2. **B2:** Total area of each site never exceeded 150 × 500 m, and being 'linear' habitat (coastline) with biological characteristic influence on correction factor nears 1 for this endemic species, unit value of 1 km^2per site was used.
C	Small and declining population size Number of mature individuals (data not available for C1 and C2)	**<250** Categorized based on number of individuals in maximum number of sites with 1, 150-200, and 150-200 individuals.	**<2500**	**<10000**	Three of the five sites spotted were noted with less than 250 mature individuals. One site, Enjampakkam, was identified with only one mature individual; two sites, Mamallapuram and Meiyur were with around 150-200 mature individuals.
D	Very small population or very restricted distribution	**D1 (<50)** Number of mature individuals (**one only**) in smallest population	**<250**	**<1000**	In the smallest population site, only one mature individual has been spotted and in other two sites, Mamallapuram and Meiyur, very restricted distribution pattern was observed.
E	Quantitative analysis of extinction risk	(Data not available)			

***:** The AOO was not calculated as per the recommended 2×2 km grid size (IUCN, 2022) for the four reasons, 1) the total area per site not exceeded 150 × 500 m, 2) linear habitat, 3) biological characteristic features' influence on correction factor approaches 1, and 4) the species being endemic to Indian Sub-continent (India and Sri Lanka).

too. Hence, its high time to act and make appropriate conservation efforts by drafting key strategies and work plan to conserve this species both *in situ* and *ex situ*, to ensure it is free of extinction risk.

The reasons for the reduced number and size of populations at different sites could be due to habit and other morphological features of the species besides climate change: 1) niche-specificity of the species (absent in moist coastal habitat, tsunami affecting beaches), 2) prostrate habit with stem not rooting at nodes, 3) hard capsules, not fully dehiscent and therefore retaining nearly half the seeds in the capsule itself, 4) no seed dispersal through birds or animals, as older capsules of previous years' were found beneath/adjacent to the plant (Fig. 2), 5) around 5-20 per cent germination in *ex situ* conditions may also indicate its non-competitiveness in natural conditions, 6) habitat-based changes in the fragile ecosystem may include severe urbanization around Chennai, cyclonic storms (Kathiresan and Rajendran, 2005a, b; Sandilyan and Kathiresan, 2012; Malik *et al*., 2019). Additionally, industrialization events like thermal power plants (eg. Parangipettai) and ports (eg. Ennore) could be the potential factors for the decline in *S. prostratum* from those sites, where the sample specimens were preserved earlier (IL&FS, 2019; Table 1).

Fig. 3. A: Single plant view of *S. prostratum* from *ex-situ* conservation (stubble transplantation) at Vriddhachalam, of samples collected from Bommayapalayam site; B: flowers; and C: developing capsules from the *ex situ* conserved plant.

Conservation strategies and way forward

Impact assessment of tsunami on biodiversity for territories that are located near the tsunami epicentre, Andaman and Nicobar Islands of India (Porwal *et al*., 2012) and other parts in South-East Asia (Fernando *et al*., 2006; Suppasri *et al*., 2015) are well documented, especially for the mangrove ecosystems (Ayyappan *et al*., 2016). Availability of such assessment reports for coastal strand ecosystems too at state biodiversity level or the appropriate national or global Red List authorities would be of a help in drafting targeted action plan with strategies to include all species (flora or fauna), especially the endemic plants (Mounce *et al*., 2018).

***In situ* conservation measures:** Expanding the protected area is an important key to lock the biodiversity loss and is one of the strategic plans of Aichi Biodiversity Target 11, to conserve biodiversity (Spiliopoulou *et al*., 2021; CBD, 2012). Special need-based conservation drive especially for the non-competitive species is a real concern that requires multiple strategies and action plan. Certain non-competitive species like *S. prostratum* are very niche-specific (Rao and Sastry, 1974), especially in dry coastal strands (if wet, other competitive species dominate). In collaboration with National Biodiversity Authority (NBA), appropriate measures are being taken to earmark the Bommayapalayam site (11.99 N; 79.85 E) as a biodiversity heritage site for *in situ* conservation. This site has been selected for the *in situ* conservation, for the following reasons: 1) largest population among the sites documented with *S. prostratum*; 2) the location being accessible to public, would create a general awareness on the importance of conservation of biodiversity and nurture citizen scientists; 3) its continuity with Auroville beach areas, an important tourist site and prone to trampling damage if proper conservation measures are not taken to protect it; and 4) the site is near academic institutions, and easily accessible for frequent monitoring.

***Ex situ* conservation measures:**The TNAU-Regional Research Station, Vriddhachalam, collected *S.prostratum* accessions from Bommayapalayam and Marakkanam of Villupuram district (Fig. 3), were collected as stubbles along with coastal saline soil in a polythene bag, and with sufficient quantity of sea water to maintain the plant health till transplantation.These were planted in a concrete ring (2.5′ diameter and 1.5′ height) filled with well decomposed farmyard manure (FYM) and coastal saline soil (as cover soil) and irrigated with coastal saline water for initial 2-3days of plant establishment. From 4th day onwards, normally water was provided through drip irrigation.The matured and dried capsules were allowed to perpetuate in the cement rings itself for further successful establishment and maintenance.

Seeds of two *S. prostratum* accessions were soaked in water for 12h followed by 0.3% KNO_3 treatment for 30 min and then sown in the cement rings filled with well decomposed FYM, and drip irrigated for 4-5 h every day. These new plants were established, and flowering and fruiting were initiated during December 2021. Seeds of *S. prostratum* collected from these sites during this collection trip were conserved for the *ex situ* conservation, at the NGB of ICAR-NBPGR, bearing the accession numbers, IC0641138, IC0641140, and IC0641141.

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