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Distribution and Phenology of *Syzygium stocksii* (Duthie) Gamble an Endangered Tree Species in South Konkan

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Abstract**:** *Syzygium stocksii* (Duthie) Gamble is an endangered, evergreen tree species, endemic to southwestern states of India. An assessment was conducted on distribution and phenology of *S. stocksii* in South Konkan viz. Ratnagiri and Sindhudurg districts. A snowball sampling was used in the study to identify the primary database on location of these species. Tree density and population structure were accessed by laying a quadrat of 10 x10 m around the individual tree and minimum 3 similar quadrats were laid around mature trees for the population. At each site, 3 adult individuals of these species were marked permanently for recording phenological observations. General BBCH (Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie) was used to record phenophase of the selected trees. Total 78 individual trees were recorded in which maximum number of mature stems was recorded from the study area. Present study revealed that good sized populations of *S. stocksii* were is present in the study area. In total, seven principal stages - *i.e*., bud development, leaf development, inflorescence emergence, flowering, fruit development, fruit maturity, senescence and beginning of dormancy are described with respect to their seasonal progression and relative dominant.

Keywords: Endangered, Endemic, Distribution, Phenology

Syzygium is the largest woody genus of flowering plants, with 1200-1800 species found throughout the Old World tropics and subtropics (Ahmad et al 2016). The genus is found naturally in subtropical and tropical regions of Africa and Madagascar, Asia, and Oceania and the Pacific region. The majority of *Syzygium* species range from medium to large evergreen trees. The forests of the Western Ghats, particularly tropical wet evergreen, and high-altitude Shola peaks, are ideal habitats for the *Syzygium* (Sreekumar et al 2020). It was reported that many species in this area have not yet received the proper taxonomic classification, and it is likely that new species will be classified in the future (Ahmed et al 2016). *S. stocksii* is a tall, evergreen tree which belongs to the family Myrtaceae. It is an eendangered tree species (WCMC 1998), endemic to southwestern states of India. Page (2017) reported the species as rare along forest streams and swamps within 40-80 m elevation range and put it into Data Deficient category. It was published by Duthie as *Eugenia stocksii* based on plant collection of J. E. stocks from Konkan region of Maharashtra in 1879. Despite being first described from Konkan region, this species is a less-known rarity in Maharashtra. This species is found only in few localities of Konkan region of Maharashtra, Uttara Kannada in Karnataka, Wayanad district of Kerala and Tamil Nadu (Hooker 1880, Cooke 1905). It is classified as endangered in IUCN red list category (IUCN 1998). There have been no attempts to document phenological growth stages in this species so far. The study was therefore conducted to study the distribution and phenology of *S. stocksii* in Ratnagiri and Sindhudurg districts in south Konkan region of Maharashtra. This study also attempts to provide photographic phenophases charts for the *S. stocksii* for the first time.

MATERIAL AND METHODS

Study site: The present investigation was conducted in the southern Konkan region, comprising Ratnagiri and Sindhudurg districts, located between 15°36' N to 18°50' N latitude, and 74°36' E to 75°50' E longitudes. The areas of Ratnagiri and Sindhudurg districts are 8208 and 5207 km^2, respectively. The South Konkan is bounded in the west by the Arabian Sea, in the east, it shares boundary of the Sahyadri escarpment, in the north by the river Savitri and in the south by the Union Territory of Goa and the Terekhol estuary. South Konkan experiences tropical warm, humid or maritime climate throughout the year. Atmospheric temperature of South Konkan varies from 25 to 35°C with the average humidity ranging between 60 and 90 %. As the districts (Sindhudurg and Ratnagiri) of South Konkan belong to coastal region, the variation in temperature during the day and through the seasons is not large (Dhawal et al 2013).

Collection of data and field survey: Rare tree species are distributed sparsely and the knowledge of existence of individual trees or populations of such species is often with the researchers, forest department officials and some local

people. There are no databases of locations of this species. Hence, snowball sampling or chain referral sampling was used in the study (David 2008). The initial small pool of informants included some known researchers and forest department personnel. They were contacted over phone and email and a simple questionnaire following Tantiado (2012) was provided to them to get the locations of the study species. They were also requested to nominate further sources of information for finding more populations/individuals of the study species. Once, the information on a few sites was obtained, the sites were visited personally and the claim of existence of the species were verified. Trees were identified in the field as much as possible, with the help of local people or departmental persons. Interactions were also conducted with local people to identify any more nearby trees/populations. For the unidentified plants, photos and sample parts were collected and identification was done with the help of experts or books like Flowers of Sahyadri (Ingalhalikar 2001) and Further Flowers of Sahyadri (Ingalhalikar 2007), Endemic Woody plants of the Western Ghats (Page 2017), Flora of Maharashtra (Singh et al 2001).

Tree density and ppopulation sstructure: At some sites, there were single individuals while at others, there were populations. Wherever single individuals occurred, a quadrat of 10 m x10 m was laid around the individual tree. For all mature trees taken at the centre of the quadrat, location parameters (village, lat-long, elevation, slope, aspect), physical parameters (height, GBH), social parameters (ownership) and population/stand parameters (total number of individuals in a population) were recorded. Ravi altimeter was used for measuring top height of tree and ordinary measuring tape was used for measuring girth and crown spread. Photographs of trees and its phenophases were also taken. Girth at Breast Height (GBH) was taken for all the stems of *S. stocksii*. Based on the girth class, populations were grouped into three classes. Stems <30 cm gbh were classified as saplings. Stems between 30-60 cm gbh were treated as sub adults. Stems >60 cm gbh were classified as mature trees (Irwin et al. 2013).

Mapping: Precise locations of *S. stocksii* in South Konkan were mapped using Garmin eTrex 10 Global Positioning System (GPS) handheld receiver. The GPS data were plotted using QGIS software and a distribution map was prepared.

Phenology of *S. stocksii:* Three adult individuals of *S. stocksii* were marked permanently at each site for recording phenological observations. On each marked individual, 20 branches (five in each direction) were selected and tagged. General BBCH scale for phenology of tree and woody species was used to record phenophase of the selected trees (Finn et al 2017). The General BBCH scale modified for woody species uses eight of the ten principle stages, beginning with sprouting/bud development (stage 0) and ending with dormancy (stage 9). Stage 2 and Stage 4 were excluded as they were irrelevant to woody species. Secondary stages were numbered 0 to 9 and correspond to ordinal or percentile growth stages. Appropriate corresponding photographs were taken to develop a pictorial guide to phenophases of the selected species. On every visit, the predominant phenophase was recorded for each of the tagged branch. The observation interval was approximately 30 days. Secondary information and photographs of phenological events was collected from the informants. The duration of phenological events such as leaf fall, completion of leaf fall, leaf initiation, beginning of flowers, completion of flowering, beginning of fruiting and completion of fruiting of the selected species were recorded.

RESULTS AND DISCUSSION

Locations were sought from experts in snowball sampling method. Initially two experts were contacted and later the number increased to fifteen. From them, total 5 locations for *S. stocksii* were received *viz*. Aavere, Barsu, Dhamapur, Medhe, and Parule in the study area. It is seen growing between 7-84 m altitude, exclusively in 50-100 m vicinity of streams. The tree grows to a height of about 22 m, attains maximum girth of 425 cm and maximum crown spread of 19.5 m. The trees were observed as the fastest growing tree as the 6 months old tree in study site shows the 22 cm girth and approximately 3 m height. It was also observed as a good coppicer tree species. Total 78 trees were enumerated from five different locations in study areas. Among all 5 locations, highest number of individuals was found at the study site Parule followed by Barsu, Dhamapur and least was found at Medhe. Among all identified sites an individual tree was recorded at the study site Aavere. Average girth of trees at different locations revealed that in Kalse, Dhamapur comparatively higher GBH were recorded followed Rajapur and least was recorded in Medhe and Parule (Table 1). On the other hand, average height of trees at different locations revealed that study area in Barsu recorded highest average height followed by Dhamapur while least was recorded Parule followed by Medhe. Both highest average GBH and height values were recorded for a single tree in Aavere (Table 1). This species is found growing in association with *Cocos nuciifera, Caryota urens, Areca catechu, Mangifera indica, Callophyllum inophyllum, Macaranga peltata, Hydnocarpus pentandrus, Artocarpus heterophyllus, Holigarna arnottiana, Vitex negundo, Tabernaemontana alternifolia, Tectona*

grandis, Mammea suriga, Garcinia indica and *Strychnos-nux-vomica*. The species is threatened in the study area due to harvesting of trees for the timber, clearance for the agricultural lands and farms. It was reported earlier as rare in the evergreen forest of Konkan (Cooke 1905), whereas Page (2017) also reported it as rare along forest streams and swamps within 40-80 m elevation range. Recently Sathish et al (2020) reported it as critically endangered in two locations of the *Kaanu* forests in Karnataka having perennial stream. But observations showed that large populations of this species are scattered along the streams over Sindhudurg and Ratnagiri districts.

Among all five locations, five adults were recorded from the study area in Medhe while only a single stem was recorded from Aavere. Of the five locations, population sites which were highly disturbed due to anthropogenic interference show very poor number of saplings and sub-adults (Fig. 2). Saplings were completely absent at the study area in Barsu and Dhamapur. The absence of saplings, despite good adult population, indicates poor germination of seeds and establishment of seedlings. The reasons for this phenomenon need to be explored through more intensive field studies. In Parule site, good number of sapling (10), sub-adult (13) and mature stems (15) were recorded. Occurrence of more saplings in this site proves that if an area is left undisturbed, regeneration of species is promoted naturally, especially of endemic species. On the other hand, occurrence of more saplings may be due to the high rate of seed germination. Similar observations have been made for *Elaeocarpus venustus* in Agastyamalai Biosphere Reserve, Kanyakumari District (Irwin et al 2013).

Phenology of *S. stocksii*: Phenological data for *S. stocksii* was collected from January to June 2022 in all the 3 sites viz. Barsu, Dhamapur and Parule. Throughout the season, trees at all the three sites showed similar progression of phenophases. Overall, the trees remained in the vegetative flush phenophases till Meteorological Week (MW) 9. Inflorescence emergence phenophases started during MW 10 and peaked during MW 14. Flowering phenophases prevailed dominantly during MW 18 along with simultaneous fruit development. Fruit maturity was maximum during MW 23. Despite the large distance between Barsu, Dhamapur, and Parule sites, no obvious delay in inflorescence emergence was observed. In *Syzygium caryophyllatum*, Nadarajan and Pujari (2018) found that flowering occurred during the summer season (second week of March to May) with massive flowering in the month of April (peak photoperiod). Synchronous flowering was observed in this species. In the present study, similar observations regarding flower emergence and peak flowering were recorded. Further, there was synchronous flowering even in very distant populations. A pictorial depiction of phenophases in

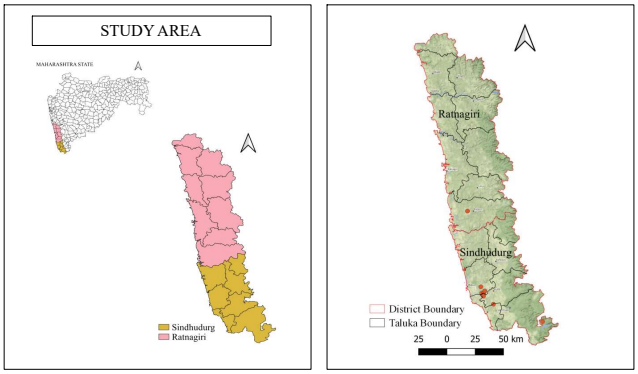

Fig. 1. Population sites of *S. stocksii* in Ratnagiri and Sindhudurg districts

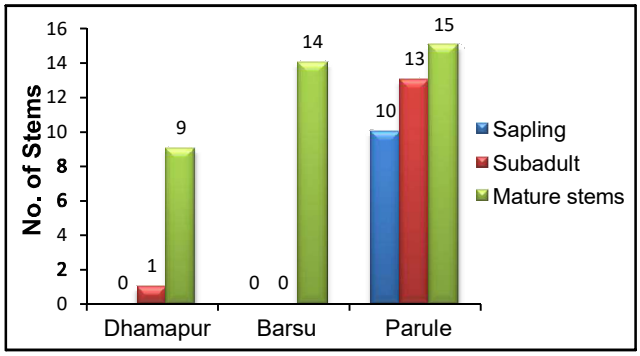

Fig. 2. Population structure of *S. stocksii* in Ratnagiri and Sindhudurg districts

Table 1. Current population status of *S. stocksii* in Ratnagiri and Sindhudurg districts

Village	Taluka, District	No. of trees	Av. GBH (cm)	Av. Height (m)
Aavere	Vengurla, Sindhudurg	1	270.00	19.0
Barsu	Rajapur, Ratnagiri	14	213.02	9.9
Dhamapur	Malvan, Sindhudurg	10	86.00	7.5
Medhe	Dodamarg, Sindhudurg	5	89.91	8.1
Parule	Vengurla, Sindhudurg	48	199.23	12.3
Total		78	143.57	9.6

Fig. 3. a– Habit and Habitat of tree, b– Quadrangular branches of *S. stocksii*, c- 6 months old *S. stocksii* growing in study area, d– Coppicing shoots of *S. stocksii*

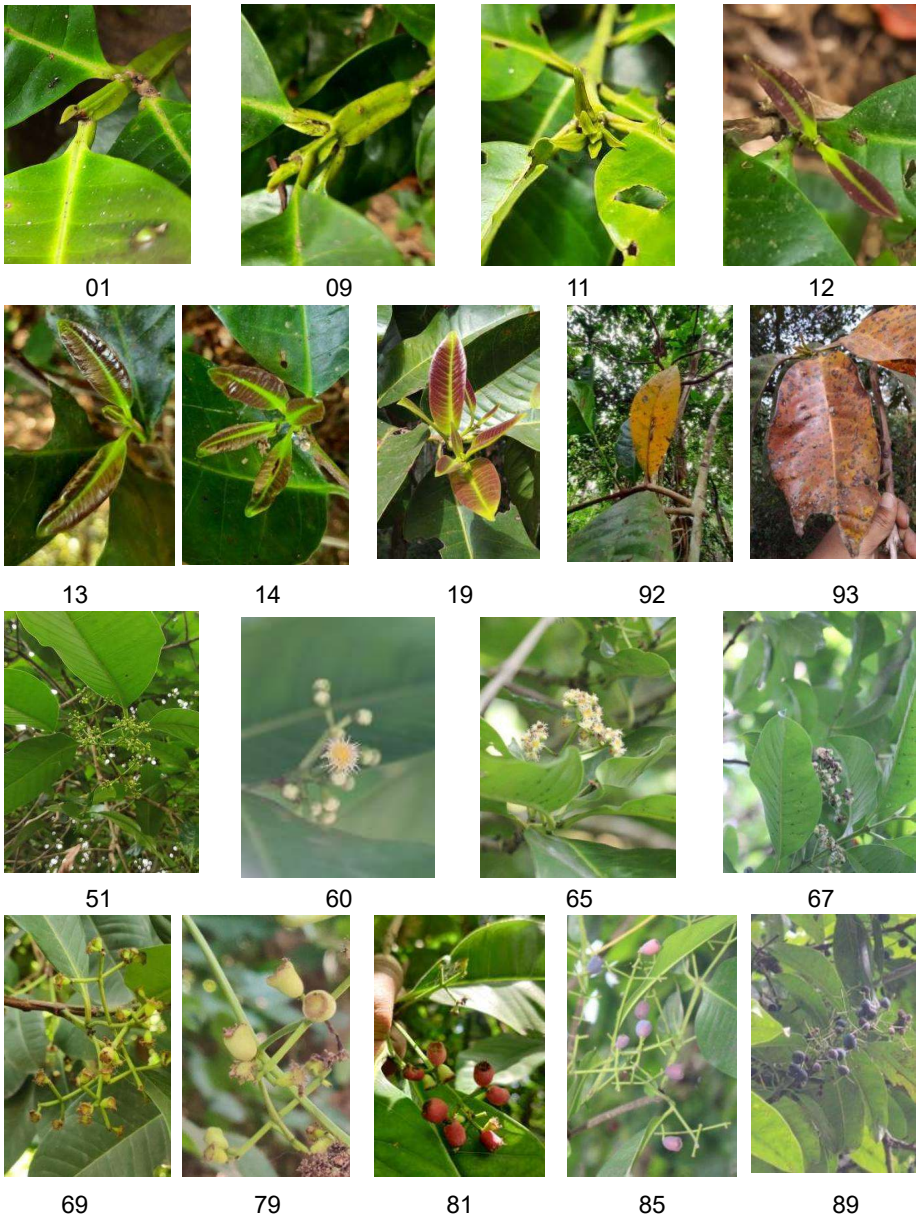

Fig. 4. Phenological growth stages of *S. stocksii* according to the BBCH scale

Table 2. BBCH scale developed for phenological growth stages of *S. stocksii*

Code	Stage/ sub-stages and description/ timing of occurrence
Principal growth stage 0: Bud development	
00	Dormancy: Buds closed and covered by green scale
01	Beginning of bud swelling
03	End of bud swelling
07	Beginning of sprouting or bud breaking
09	Bud shows green tips
10	First leaves separated
Principal growth stage 1: Leaf development	
11	First leaves unfolded
12	2 true leaves unfolded
13	3 true leaves unfolded
14	4 true leaves unfolded
15	5 true leaves unfolded
16	6 true leaves unfolded
17	7 true leaves unfolded
18	8 true leaves unfolded
19	more true leaves unfolded and expanded
Principal growth stage 5: Inflorescence emergence	
51	Inflorescence or green flower buds visible
55	First individual flowers visible (still closed)
59	First flower petals visible (in petalled forms)
Principal growth stage 6: Flowering	
60	First flowers open (sporadically), A tiny white color flower open
61	Beginning of flowering: 10% of flowers open
62	20% of flowers open
63	30% of flowers open
64	40% of flowers open
65	Full flowering: 50% of flowers open
67	Flowering finishing: majority of petals fallen or dry
69	End of flowering: fruit set visible
Principal growth stage 7: Development of fruit	
72	20% of fruits have reached final size
75	50% of fruits have reached final size
78	80% of fruits have reached final size
79	Fruit final size. The small light green fruits are seen
Principal growth stage 8: Maturity of fruits and seeds	
81	Beginning of ripening or fruit coloration, pericarp turns into pinkish red
85	Advanced ripening or fruit coloration, pericarp turns into pinkish purple
87	Fruit begins to soften
89	Fruit fully ripe, pericarp turns into dark purple
Principal growth stage 9: Leaf senescence and beginning of dormancy	
91	Shoot growth completed; foliage still green and terminal bud developed
92	Beginning of leaf discoloration, majority of leaves turn yellow
93	Beginning of leaf-fall, majority of leaves turn brown
95	50% of leaves fallen
	End of leaf fall

S. stocksii is presented in Fig. 4 and description of these phenophases is provided in Table 2.

CONCLUSION

S. stocksii is confined to riparian habitat which is a specialized ecological niche and is assessed as Endangered in the IUCN Red List of Threatened Species (WCMC 1998). The species were having good natural populations whereas some were sparsely distributed as individuals. This study provides a unified standard for describing the phenology of *S. stocksii.* In contrast to other procedures, application of the extended BBCH scale allows for more accurate and scientific description of the morphological characteristics of *S. stocksii* in different developmental stages. Detailed stand structure and regeneration studies need to be conducted for this species in future.

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