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Cover: *Minervarya cepfi* & *Nyctibatrachus petraeus*—mix media. © P Kritika



Distribution, population status, associations, and biotic challenges of *Sanjappa cynometroides*, an endemic legume tree (Leguminosae: Caesalpinioideae) in the southern Western Ghats, Kerala, India

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Abstract: *Sanjappa cynometroides* (Bedd.) E.R.Souza & Krishnaraj, an unique species indigenous to the lush environs of the southern Western Ghats, India, epitomises the intricate interplay between flora, fauna, and conservation challenges. This tree was earlier categorized as Critically Endangered; however, no updated status is available. Extensive field surveys resulted in locating two new populations in Kathipara and Kambimood parts of the southern Western Ghats, Kerala and these population consist of about 20 and 70 mature trees respectively. The Kambimood population is distinct with epicormic branching, cauliflory, and stem galls. This study also offers a meticulous examination of its associations with other taxa, like epiphyllous lichens, such as *Racoplaca subtilissima* Fée, *Byssoloma chlorinum* (Vain) Zahlbr, *Tricharia vainioi* R. Sant; Corticolous lichens, *Hemithecium* sp., and *Trichothelium* sp.; leafy liverwort, *Cololejeunea lanciloba* Steph.; Corticolous bryophytes including *Meteoriopsis squarrosa* (Hook. ex Harv.) M.Fleisch and *Actinodontium raphidostegum* (Müll.Hal.) Bosch & Sande Lac.; a snail belonging to the *Beddomea* genus; and a preying mantis *Indomenella indica* Ghate & Mukherjee. In addition to restricted seedling regeneration in their natural habitat, they also suffer from leaf infestations caused by whiteflies, flower bud infestations by mealybugs & aphids, and fruit & seed predation by Bonnet Macaques. Moreover, the downward-growing branches of the tree touch the soil and subsequently form roots, facilitating vegetative propagation; even fallen trees do the same. This natural vegetative propagation is observed in the wild as a survival strategy in their natural habitat.

Keywords: Cauliflory, epicormic branching, fabaceae, new populations, phenology, plant-animal interactions, restricted seedling establishment, riparian, threats, vegetative propagation.

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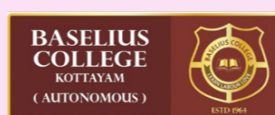
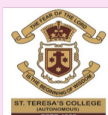
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INTRODUCTION

Leguminosae is the third largest angiosperm family after Asteraceae and Orchidaceae with 796 genera and 22,450 species, and the recent Legume Phylogeny Working Group re-classified the family to six monophyletic subfamilies, viz., Caesalpinioideae DC. (Including Mimosoideae DC.), Cercidoideae LPWG, Detarioideae Burmeister., Dialioideae LPWG, Duparquetioideae LPWG, and Papilionoideae DC. (<https://www.legumedata.org/>; LPWG 2017). In India, the family is represented with 273 genera and 1510 species (Sanjappa & Pusalkar 2024). Kerala harbours 115 genera and 449 species, of which 17 species are strictly endemic to the state (Vajravelu & Kabeer 2016; Balan & Predeep 2021).

Sanjappa cynometroides (Image 1) is an endemic tree legume in the southern Western Ghats, Kerala, India. Beddome (1873) described the species, *Calliandra cynometroides* based on his collection from Tinnevely and Travancore mountains at an elevation of about 760 m. Although Benth (1875), while revising the suborder Mimoseae, treated it under *Calliandra* Benth., Baker (1878) and Kuntze (1891) transferred it to the genus *Inga* Mill. (*Inga cynometroides* (Bedd.) Baker), and *Feuillea* Kuntze (*Feuillea cynometroides* (Bedd.) Kuntze) respectively. After thorough morphological and molecular phylogenetic studies by de Souza et al. (2016), the taxonomic identity of this enigmatic taxon, previously placed in the genera *Calliandra*, *Inga*, and *Feuillea* was clarified, and a new genus *Sanjappa* E.R. Souza & Krishnaraj was erected to accommodate the same. Recently, Thulin (2023) expanded the genus by adding two more species, viz., *Sanjappa umbrosa* (Wall.) Thulin and *Sanjappa vietnamica* Thulin. However, Sanjappa & Pusalkar (2024) described a new genus *Kanjilalia* Sanjappa & Pusalkar comprising two species viz., *Kanjilalia griffithii* (Baker ex Benth.) Sanjappa & Pusalkar and *Kanjilalia umbrosa* (Wall.) Sanjappa & Pusalkar, based on the characters of flowers, stipular spines, and distribution pattern. Hence, presently the genus *Sanjappa* E.R. Souza & Krishnaraj comprises only two species.

In the present work, apart from the discovery of two new populations of *Sanjappa cynometroides*, provided an overview of the current population status, floral-faunal associations, and the threats in its natural habitat.

MATERIALS AND METHODS

Field exploration was conducted during 2022–2024 in parts of the Agasthyamalai Biosphere Reserve. Continuous field surveys and the collection of various plant parts, including leaves, inflorescences with flower buds & flowers, fruits, and seeds, were made in populations located at Rosemala (part of Shendurney Wildlife Sanctuary), Kallar, Kathipara, and Kambimood (part of Agasthyamalai Biosphere Reserve), southern Western Ghats, Kerala. Preliminary morphological observations of the vegetative and reproductive parts for floral, faunal associations and infestations were examined using a 15x hand lens in the field. Unidentified biological specimens were later identified with the help of experts in the respective fields. The epiphyllous lichen specimens and bryophytes were deposited at Kerala Forest Research Institute (KFRI) Herbarium and Herbarium of the Department of Botany, Calicut University (CALI), respectively. Photographs of the specimens were taken using a stereo microscope MSZ-Tr LED with Magcam DC10MP camera, manufactured by Magnus Opto Systems, India, and a macro lens (SKYVIK Signi 15x macro lens). The geographic coordinates of study sites were recorded using a handheld device of Garmin eTrex 10.

RESULTS AND DISCUSSION

Population status

Sanjappa cynometroides is an endemic species to the southern Western Ghats and was thought to be extinct until Sasidharan (1998) rediscovered it after a lapse of 125 years from Rosemala (Kollam District, Kerala). After almost 20 years, Somen et al. (2017) found another population of this species in Kallar (Thiruvananthapuram district, Kerala). Diminishing to less than 40 mature individuals and restricted seedling regeneration in Rosemala, present a bleak picture of it in the wild and earlier was categorized under Critically Endangered (IUCN 2012). While the present study was going on, six new seedlings were found in the Rosemala population in July 2024, however, only three out of the six survived (50%). The Kallar population has 4–10 mature trees, but no seedlings could be traced. Both populations have an area of occupancy of less than 1 km² each, and they inhabit areas close to streams (Image 2). During this field study, we found two new populations in the wild, Kathipara and Kambimood (Image 2). The population at Kathipara (8.6922° N, 77.1353° E, at an altitude of

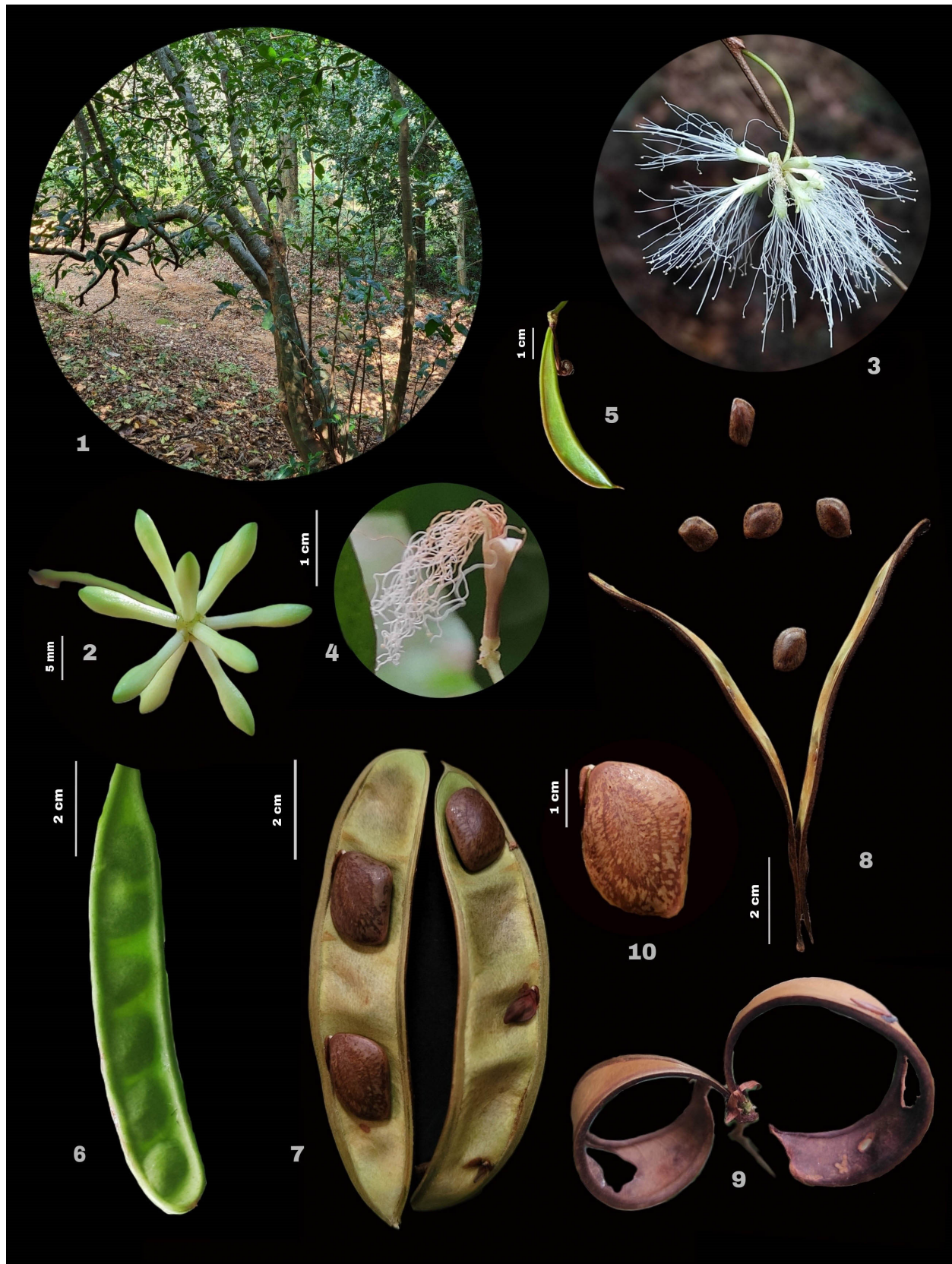


Image 1. *Sanjappa cynometroides* (Bedd.) E.R. Souza & Krishnaraj: 1—Habit | 2–3—Inflorescence Pre-anthesis & Post-anthesis stage | 4—Post-pollination change | 5—Immature fruit | 6—Mature fruit | 7—Pod with seeds | 8–9—Stages of fruit dehiscence | 10—Seed. © Gopika Suresh.

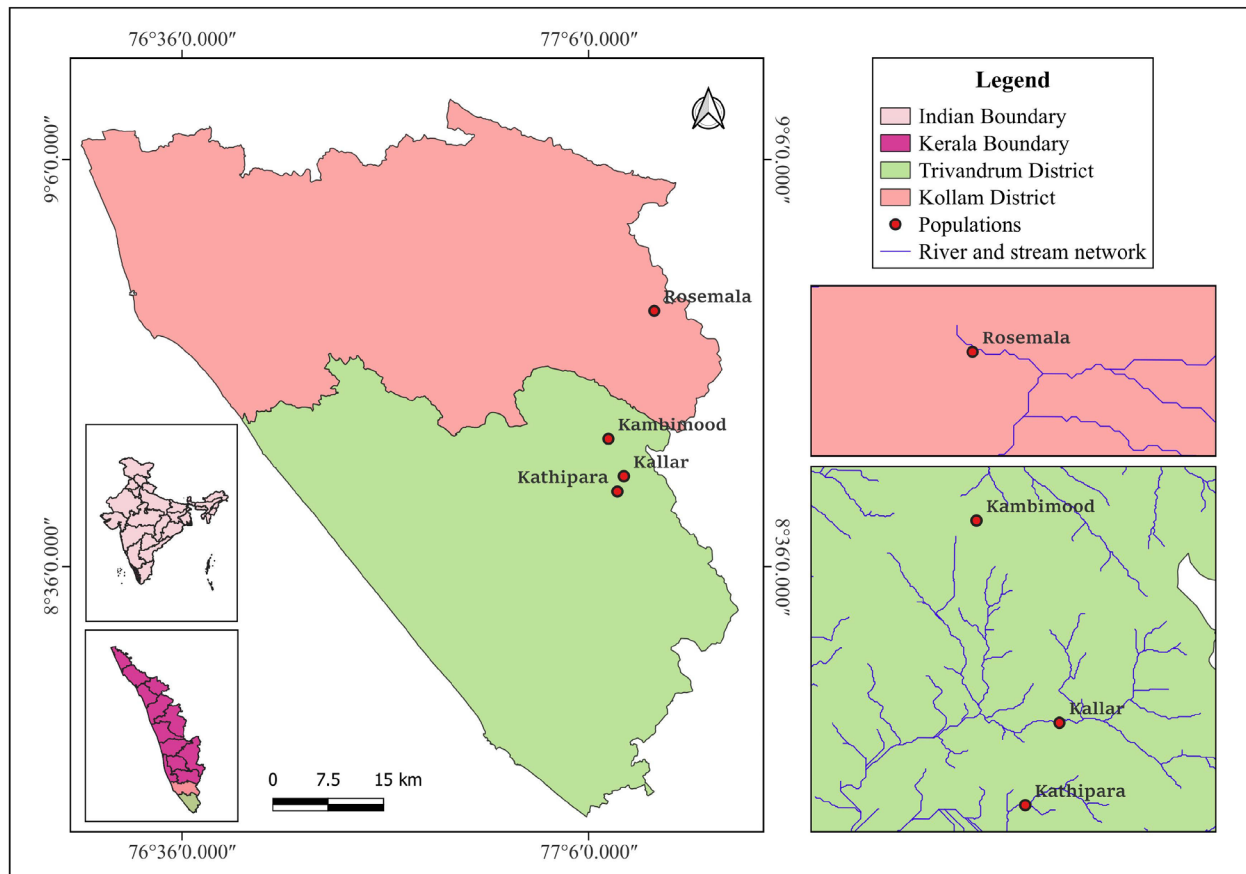


Image 2. Map showing the geographic locations of the presently known populations of *Sanjappa cynometroides* and associated river and stream networks. (Map prepared by using QGIS software).

114 m) (Image 3A) is riparian and 2–3 km farther from the Kallar population, with lesser exposure to human habitation. In this population, *S. cynometroides* survives with seedlings, saplings, and mature trees. Seedlings and saplings range from 4–5, and mature individuals are 20–25 in number, including fallen trees. However, the fallen trees are successfully alive through vegetative propagation (Image 3B). The second population is at Kambimood (8.757011° N, 77.124298° E) (Image 3C), near the Ponnudi hilltop, Thiruvananthapuram. This population is found near to tea plantation at an altitude of 770 m, and interestingly, this is the only one not inhabited close to a stream (see Image 2). This one is the largest population comprising 70–80 mature trees and a few saplings without any seedlings. Moreover, the morphology of the tree trunk is much more varied than that of the other three populations and shows epicormic branching throughout (Image 3D). The plant's epicormic branching is a survival mechanism against environmental disturbances to recover its damaged shoot system (de Campos et al. 2021). Anthropogenic disruption is low in

this population, and forest fire activities are not reported in this area. So, further investigation is essential to find the reason behind epicormic branching.

The bud bank is a collection of buds that includes axillary and adventitious buds in dormant form, which act as a reserve and play a crucial role in the regeneration of the shoot system. When any disturbance (like injury) happens, these buds are actively grown, leading to vegetative regeneration (Klimes'ová & Klimeš 2007). In the Kambimood population, we have noticed bud growth in the main trunk, even though the tree was completely damaged (Image 3E). Cauliflory, an intimately related phenomenon to epicormic branching, is reported for the first time in *S. cynometroides* (Image 3F); here, the number of cauliflorous inflorescences is more than axillary inflorescences in the branches. In the Rosemala population, one tree showed an epicormic branching-like pattern, and another showed cauliflory.

Phenology

The phenological behaviour of the species in the



Image 3. New Population and its characteristics: A—Population at Kathipara | B—Fallen trees showing vegetative propagation at Kathipara | C—Population at Kambimood | D—Epicormic branching at Kambimood | E—New bud proliferation from the completely damaged tree | F—Cauliflory at Kambimood tree. © Gopika Suresh.

Rosemala population shows relatively narrow variation. Floral bud initiation occurs during July–August, followed by peak flowering between late August and early October. Although the flowering period of individual trees is brief (4–5 days), flowering is highly synchronous within the population. Fruiting commences in November,

with fruits maturing in December and January.

Floral-Faunal associations

In the Kallar population, the adaxial surface of the leaf is intensely colonized with epiphyllous lichens such as *Racoplaca subtilissima* Fée (Image 4A), *Byssoloma*

chlorinum (Vain) Zahlbr (Image 4B) and *Tricharia vainioi* R. Sant (Image 4C). This is the first report of epiphyllous lichens from *Sanjappa cynometroides*. As per the study of Randive et al. (2017), the abundant proliferation of lichens on foliage indicates minimal human disturbances. Despite the high level of human interference, the epiphyllous lichens are growing abundantly on trees in the Kallar population. Additionally, we found two corticolous lichens, *Hemithecium* sp. (Graphidaceae) and *Trichothelium* sp. (Porinaceae), associated with the twigs of *Sanjappa cynometroides* from the Kambimood population.

It is also observed that *S. cynometroides* as a host plant of an epiphyllous liverwort called *Cololejeunea lanciloba* Steph. of the family Lejeuneaceae (Image 4D). Leafy liverworts exhibit sensitivity to changes in moisture and temperature levels, making them reliable indicators of climate change and forest fragmentation (Jiang et al. 2018). The trees growing at the Kambimood population are home to Corticolous bryophytes, *Meteoriopsis squarrosa* (Hook. ex Harv.) M.Fleisch (Meteoriaceae) (Image 4E) and *Actinodontium raphidostegum* (Müll. Hal.) Bosch & Sande Lac. (Hookeriaceae) (Image 4F). During the field surveys, observed a snail belonging to the genus *Beddomea* of the family Camaenidae (Image 4G) found attached to the leaves of *Sanjappa cynometroides*. Due to the lack of studies on arboreal snails in the Western Ghats, not able to identify it up to the species level. It would be interesting to study the interaction between the snails and the trees. In addition, the Ootheca (egg mass) of the praying mantis, *Indomenella indica* Ghate & Mukherjee was observed, which is attached to the lower surface of many leaves, even on stems (Images 4H,I), and also spotted the nymphs and mature ones frequently in the Rosemala population. Additionally, it was interesting to notice *I. indica* displayed egg mass guarding behaviour that lasts for 5–10 days. The researchers in this field did not observe any plant-specific egg-laying mechanisms. However, the site selection for capturing prey and the deposition of ootheca are essential for their reproduction and survival. Habitat selection is also influenced by camouflaging dense foliage, prey availability, predators, microclimatic conditions, and various other elements (Balakrishnan 2012). A wide range of butterflies, moths, beetles, bees, flies, and ants were also observed on the tree across flowering and non-flowering seasons. However, we have not found any pollination-like behaviour during the daytime so far.

Natural threats in the wild

Natural threats that have a negative impact on the population of *Sanjappa cynometroides* are infestation and predation of leaves, flower buds, fruits, and seeds. In Rosemala and Kallar, severe leaf infestation is caused by the Whiteflies (Image 5A). Whiteflies are highly invasive, exotic, phytophagous insect species belonging to Hemiptera: Aleyrodidae. It is infested on the lower surface of the leaves and causes damage to the host plants by sucking the plant sap and interfering the normal growth. Furthermore, the whiteflies cause indirect damage by excreting honeydew and producing wax (Selvaraj et al. 2024). Sundararaj et al. (2021) assessed the intensity of damage caused by whiteflies using the following parameters: “Low (less than ten live egg spirals or adults/leaflet), Medium (11–20 live egg spirals or adults/leaflet), and Severe (more than 20 live egg spirals or adults/leaflet)”. In the case of *S. cynometroides*, the whitefly population and intensity of damage are low in the Kallar population. However, it was observed more than 20 adults/leaflets at Rosemala in January, indicating a severe population and damage caused by whiteflies. Although the tree showed signs of recovery through leaf flushing, this process was not immediate. Also observed empty pupa shells hidden under the leaves, which seem to be either a butterfly or moth pupa; more evidence is needed to confirm this.

The Kambimood population is distinctive due to the numerous stem galls on the trees (Image 5B). Usually, galls are formed due to abnormal tissue growth caused by biological agents such as viruses, bacteria, nematodes, and insects. The interaction between gall-inducing insects and their host plant species is highly species-specific (Silva & Urso-Guimarães 2021). The causative organism for the stem galls in *S. cynometroides* has not been studied. Additionally, within the same population spotted the nymph of the treehopper (Membracidae, Hemiptera) associated with the stem gall (Image 5C). Treehoppers are phytophagous insects that cause damage to host plants by sucking large amounts of plant sap, and the honeydew they excrete is an alternative nectar to other organisms such as ants, bees, wasps, and even to butterflies (Bartlett et al. 2018).

Interestingly, a prey-predator (mealybug-apefly) relationship as part of flower bud infestation in *S. cynometroides* in the Kallar population is an interesting to record. Mealybugs are pests that feed on plant sap and reduce plant vigour. Here, it attacks the flower bud, causing stunted growth, leading to the malformation of the flower (Image 5D). The butterfly larvae of *Spalgis epeus* (Apefly) (Image 5E) were also found within the

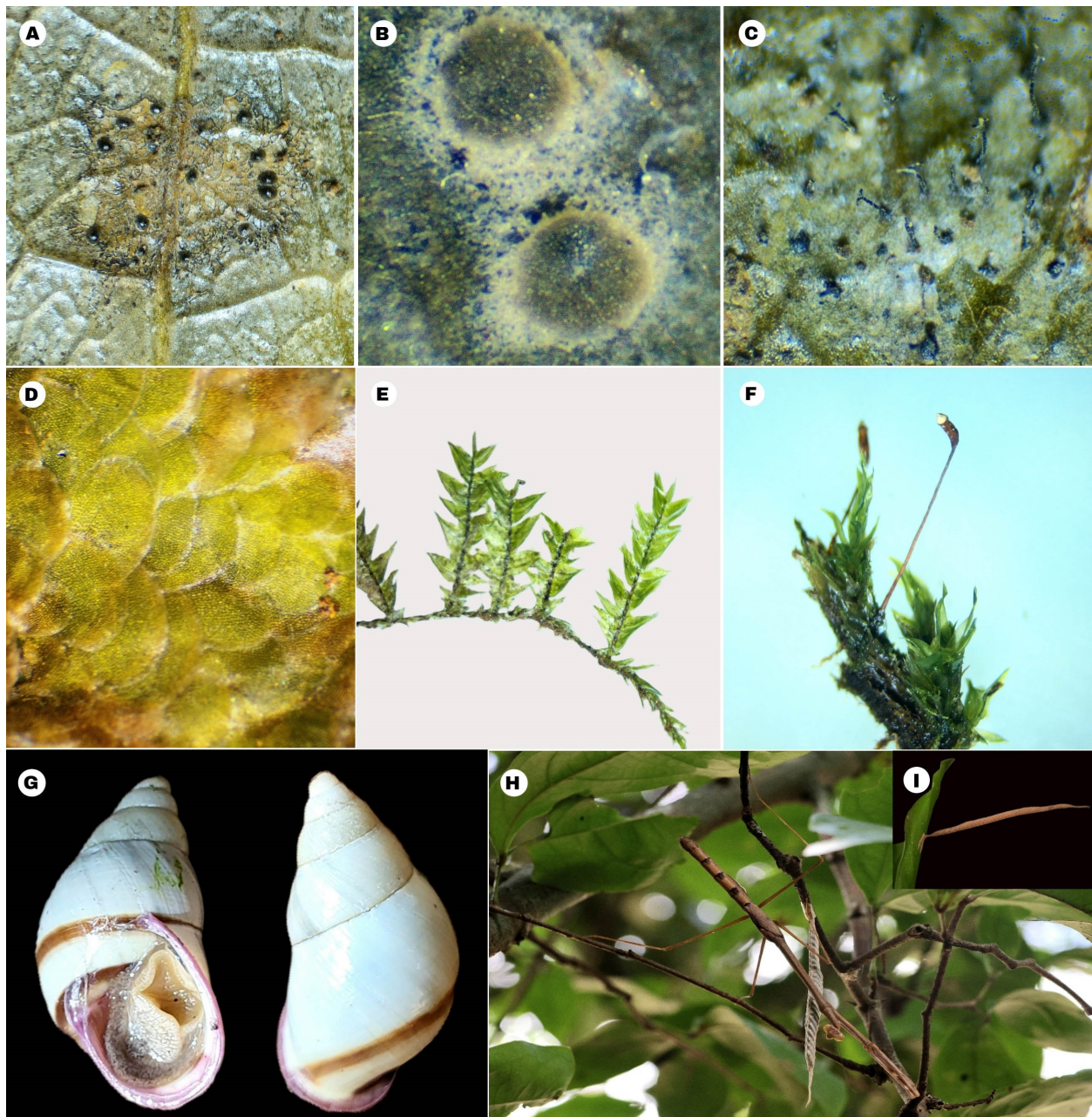


Image 4. Floral-faunal associations found in *Sanjappa cynometroides*: A—*Racoplaca subtilissima* Fée | B—*Byssoloma chlorinum* (Vain) Zahlbr | C—*Tricharia vainioi* R.Sant | D—*Cololejeunea lanciloba* Steph. | E—*Meteoriopsis squarrosa* (Hook. ex Harv.) M.Fleisch | F—*Actinodontium raphidostegum* (Müll.Hal.) Bosch & Sande Lac | G—A snail species of *Beddomea* | H—*Indomenella indica* Ghate & Mukherjee with ootheca | I—*Ootheca*. © Gopika Suresh.

same inflorescence. Apefly larvae are recognized as predators of mealybugs (Saengyot & Burikam 2012).

In Rosemala population, aphids (Aphidoidea, Hemiptera) exclusively attack flower buds in the late monsoon and post-monsoon periods (usually August–November). This significantly affects the reproductive mechanisms of the plant, resulting in a limited number of healthy flower buds and flowers suitable for

pollination and fruit development. It was also observed that an ant-aphid mutualistic relationship associated with *Sanjappa cynometroides* (Image 5F) in the same population. Aphids ingest the phloem sap using stylets and excrete sugary honeydew. Ants use this honeydew as food; in return, they protect the aphids from predation, parasitism, and fungal infections (Phillips & Willis 2005). As the infestation progresses, the host



Image 5. Natural and anthropogenic threats: A—Leaf infestation by whiteflies | B—Stem gall | C—Nymph of treehopper associated with stem gall | D—Flower bud infestation by mealybug | E—Larvae of *Spalgis epeus* (Apefly) associated with mealybug infected flower bud | F—Ant-aphid mutualistic relationship leading to flower bud infestation | G—Predation-like act on immature, mature and dried pods | H—Fully consumed seed condition by unknown organism | I—Vegetative propagation at Rosemala | J—Vegetative propagation at Kathipara | K—Seedling growing in stream bed at Kathipara | L—Sapling growing on the rock within the stream bed at Kathipara. © Gopika Suresh.

plant may develop a morphological barrier or attract natural enemies of aphids. Meanwhile, natural enemies have started to use honeydew produced by the aphids as food (Guerrieri & Digilio 2008). So, this mutualistic relationship has a negative impact on the plants' health.

Some notable infestations on fruits include reddish patches on immature fruit surfaces. Moreover, infestation, the signs of the predation-like act, are seen on immature, mature, and even dried fruit surfaces at Rosemala (Image 5G). Additionally, part of the fruit wall, where the seeds occur, appears as an ample vacant space with fully consumed empty seeds (Image 5H); nevertheless, the dehiscence mechanism is carried out without fail at maturity. The infestations are more prominent on the trees near the stream at Rosemala.

Ramachandran (1995) recorded 23 feeding plants of Bonnet Macaque *Macaca radiata* from Shendurney Wildlife Sanctuary and observed monthly variations in the diet. During this study it is observed that Bonnet macaques consume young fruits of *Sanjappa cynometroides* and themselves serve as seed dispersers after fruit maturity. Their movement across the tree branches, coupled with the elastically dehiscent character of fruits from the apex downwards, favours effective seed dispersal. However, only a few seeds were found on the forest floor, indicating further predation.

Apart from infestation and predation, some trees were washed out during the flood at the Kallar River. In Rosemala, strong winds cause large woody trees to fall onto *S. cynometroides*. In the new Kathipara population, more fallen trees are observed due to flooding in the stream. However, roots are formed from the fallen branches of *S. cynometroides*, indicating a change in their reproductive strategy towards vegetative propagation in reaction to difficulties encountered in their natural environment. This changing reproductive strategy is more prominent at Rosemala (Image 5I) and Kathipara (Image 5J). Moreover, at Kathipara, because tree branches extend over the stream, seeds can fall directly into the water. Under low streamflow conditions, the seeds may be deposited in the sandy streambed, where they can germinate and grow into seedlings (Image 5K), even on large rocks within the streambed as saplings (Image 5L). As a result, seedlings are more likely to be washed out during the rainy season or periods of heavy streamflow; conversely, this flow may help the seeds spread farther.

Anthropogenic threats

The populations at Rosemala and Kallar are concentrated around the pedestrian routes, and they

are popular tourist destinations in southern Kerala. In Rosemala, the trail acts as a path for vehicles, mostly Jeeps used by the local people and tourists. Consequently, to prevent travelling issues, the branches of *Sanjappa cynometroides* along the path are chopped down. The neighbouring local community uses the branches of this tree to produce domestic items like handles of pick-axes, etc., without having enough awareness of its taxonomic or conservation significance, which negatively affects the population. In Ponmudi, the local people called *S. cynometroides* as 'Penarakam' in their mother tongue, Malayalam. According to them, in earlier times, the leaves were boiled in water along with leaves of other medicinal plants (not revealed their exact local names), and bathing in this decoction was believed to alleviate arthritic problems.

CONCLUSION

Through continuous field surveys, two new populations in the wild and expanded distribution of *Sanjappa cynometroides* were reported in this work and believe that this new reports will have an impact on their IUCN threat status. The field surveys indicate that all the populations have restricted seedling regeneration, and the species is undergoing considerable risks including natural calamities and man-made disasters. It is also witnessed that the plant adopt vegetative propagation to survive in its natural environment. The reason for the shift in reproductive strategy is currently under study. The stem cuttings were directly planted in the humus-rich soil of the population at Rosemala, as a trial, resulting in the successful regeneration of the plant. To conclude, this species grapples with various challenges despite its taxonomic novelty and ecological significance, underscoring the necessity for comprehensive conservation strategies.

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Articles

Bat assemblages at two contrasting agricultural sites in northern Algeria: a preliminary conservation assessment

– Saida Meghezzi, Fatima Zohra Bissad, Farid Bounaceur, Afaf Boukhari, Moncef Ait-Abdesselam & Leila Benfekih, Pp. 29375–29389

Linear power infrastructure and vulture electrocution risk: mitigation through carcass dump relocation in Sudhauwala, Dehradun, India

– Javed Anver, Yash Vardhan Singh Sengar, Bikash Ghimire, Vonchano Ngullie, Hemam Rama Nanda, Tashi P. Dorji, Ankit Sharma, Akshay Jain, Sas Biswas, Arun Kumar & M. Muzahed, Pp. 29390–29400

Avifaunal diversity of the central Western Ghats in Uttara Kannada, Karnataka, India

– Rounak Patra, Nonita Rana, S.J.D. Frank & Govindan Veeraswami Gopi, Pp. 29401–29417

A study on the avifaunal diversity and community dynamics of Karanji Lake, Mysuru, Karnataka, India

– S. Sushanth & K.S. Raghunandan, Pp. 29418–29429

A preliminary checklist and seasonal diversity of wetland-associated birds in Bajali District, Assam, India

– Bidyut Kumar Das, Pp. 29430–29446

Fish diversity and conservation status across habitat guilds in the river Rupnarayan, West Bengal, India

– Mridul Kanti Kar, Mohd Shahnawaz Khan, Anamitra Anurag Danda & Kripal Datt Joshi, Pp. 29447–29458

Community structure and environmental determinants of amphibians in the Western Ghats watersheds of eastern Goa, India

– Mayur M. Gawas, Sharan S. Sawal & Nitin S. Sawant, Pp. 29459–29469

Microhabitat associations and seasonal dynamics of amphibians in the lateritic rocky outcrops along the western coast of Goa, India

– Dipak Yashawant Bowalkar & Nitin Savlo Sawant, Pp. 29470–29482

Distribution, population status, associations, and biotic challenges of *Sanjappa cynometroides*, an endemic legume tree (Leguminosae: Caesalpinoideae) in the southern Western Ghats, Kerala, India

– Suresh Gopika & Moothedathu Venugopalan Nair Krishnaraj, Pp. 29483–29492

Lichen diversity of Churdhar Wildlife Sanctuary and adjacent areas of Himachal Pradesh, India

– Anupma Devi, Gaurav K. Mishra & Manjoosha Srivastava, Pp. 29493–29506

Communications

New record of the Malayan Porcupine (Rodentia: Hystricidae: *Hystrix brachyura* Linnaeus, 1758) in Tripura, India

– Omkar Patil, Ashutosh Joshi & Rutuja Digaskar, Pp. 29507–29514

Fishermen-led documentation of bycatch of sea snakes (Serpentes: Elapidae: Hydrophiinae) on the Malabar coast of southwestern India

– R. Sree Vishnu & S.R. Ganesh, Pp. 29515–29520

Checklist of the plants of Radhabai Kale Mahila Mahavidyalaya Campus, Ahilyanagar, Maharashtra, India

– Manjushree Gokul Bhagwat & Sharad Suresh Kambale, Pp. 29521–29531

Review

Exploring the agarwood trade in India and its promising horizon

– H.V. Girisha, Ajay Maletha, S.P. Goyal, Miatcha Tangjang, Avishek Bhattacharjee, Sayan Chakraborty, M.R. Ranjith Layola, Sudipta Sardar, Shabnam Bandyopadhyay, Bidisha Mallick, Oindrila Chakraborty, Sanchayita Sengupta, Tanay Shil, Sayak Chakraborty, Ranjan Shaw & Farheen Banu, Pp. 29532–29543

Short Communications

Nesting of Shikra *Accipiter badius* on *Gliricidia sepium* (Jacq.) Kunth (Leguminosae)

– Sunil M. Gaikwad & Manoj M. Lekhak, Pp. 29544–29547

New addition to the Odonata fauna of India: *Gynacantha basiguttata* Selys, 1882 (Odonata: Aeshnidae) from Arunachal Pradesh – a rectification

– R. Mahesh, Rajesh Gopinath, Dattaprasad Sawant, Gaurav Joshi & Roshan Upadhaya, Pp. 29548–29551

Notes

Breeding tern colonies in Valinokkam Lagoon, Tamil Nadu, India: additional records from the Gulf of Mannar region

– H. Maitreyi, H. Byju, N. Raveendran & S. Ravichandran, Pp. 29552–29554

Addition of *Athyrium rhachidosorum* (Hand.-Mazz.) Ching, 1934 (Polypodiales: Woodsiaceae) to the pteridophyte diversity of India

– Chhandam Chanda & Christopher Roy Fraser-Jenkins, Pp. 29555–29558

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