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BRIEF REPORT

Reintroduction of *Buchanania barberi*, a critically endangered tree endemic to the south Western Ghats of Kerala, India

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Societal Impact Statement

India is credited with 2603 tree species, and the Global Tree Assessment confirmed that 469 of these species are threatened with extinction. Urgent restoration and conservation efforts are required to prevent the loss of tree diversity. The present study is the first published attempt to reintroduce *Buchanania barberi*, a Critically Endangered tree endemic to the south Western Ghats (UNESCO World Heritage Site) of Kerala, India, which has only two surviving mature individuals. The techniques and approaches applied here may provide guidance for implementing translocation programmes for this rare species and also for other International Union for Conservation of Nature (IUCN) Red Listed species of the genus globally.

KEYWORDS
Buchanania barberi, critically endangered, endemic, germination, global tree assessment, reintroduction, tree conservation, tree establishment

1 | INTRODUCTION

The Global Tree Assessment report has confirmed the presence of 58,497 tree species worldwide. Among these, 30% (17,510) of tree species are threatened with extinction, and at least 142 tree species are already extinct. The study found that there are 2603 tree species in India; 650 of these species are endemic, and 469 are threatened with extinction (BGCI, 2021). Various tree species in India have been used for medicine, food, timber, fuel, fibres, ornamental, cultural and spiritual purposes. Due to overexploitation for timber and other products, habitat loss, forest clearance, disease and climate change, many tree species are facing endangerment. A range of conservation approaches are required to conserve the rare trees of India, that is, in situ conservation, reintroduction, species recovery and ex situ conservation. Furthermore, urgent restoration and conservation efforts are needed to improve the conservation status of tree species on the ground. Reintroduction is a recent development, and an essential step for preventing the extinction of rare and endangered trees (IUCN/SSC, 2013).

Reintroduction is the controlled placement of plant material into a managed ecological or natural area (Godefroid et al., 2011). It has the potential to make substantial contributions to the protection of endangered species, and its effectiveness is further improved when it is integrated with other conservation strategies (Albrecht et al., 2011). The Global Strategy for Plant Conservation (GSPC) has five objectives and 16 targets, which aim to slow the pace of plant extinction around the earth. Target 8 of the GSPC aims to encourage ex situ conservation and the development of recovery plans for threatened plant species, with a goal of reintroducing 20% of these species in natural habitat (CBD, 2012). The recent GSPC progress report highlighted that >50% endemic threatened species have not been conserved ex situ in their country of origin, meaning that they are less accessible for species restoration (Sharrock, 2020). To prevent the extinction of plant species, conservation agencies worldwide are being encouraged

to contribute to the GSPS targets through active participation in ex situ conservation and reintroduction (IUCN/SSC, 2013).

The genus *Buchanania* Spreng. (family Anacardiaceae) comprises 25 species distributed from India to Indo-China, Taiwan, Thailand, Malaysia, Southern China, Australia and the Pacific regions (Chandrasekaran, 2005; Herrera et al., 2018; Sosef et al., 1998). The species have been used for woodwork, that is, making furniture, interior finish, household implements, cigar box and pulp as firewood. Two species (*Buchanania lanzan* and *Buchanania lancifolia*) are used for medicine, and the fruits of some species are edible (Sosef et al., 1998). Anthropogenic pressure (mainly for infrastructure development) has led to habitat loss, and six species have been assessed under different threat categories of the IUCN Red List of Threatened Species. Among these, *Buchanania barberi* is at the highest risk of extinction and is

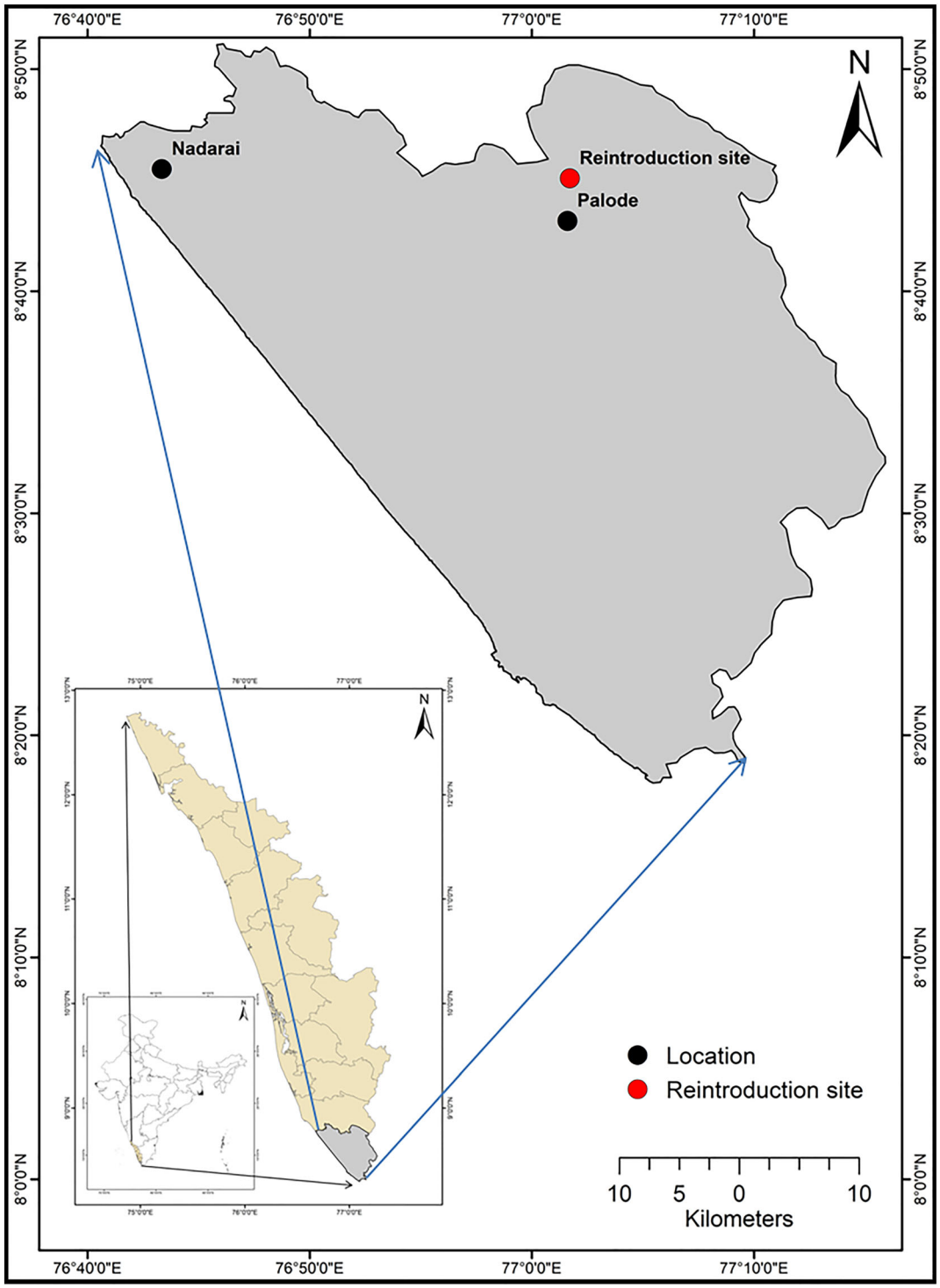

FIGURE 1 Locations of the natural and reintroduction sites of *Buchanania barberi* in Kerala

categorized as Critically Endangered; *Buchanania vitiensis*, *Buchanania lanceolata*, *Buchanania platyneura* are categorized as Vulnerable; and *Buchanania obovata* and *Buchanania insignis* as Least Concern (Dhyani et al., 2022).

B. barberi Gamble, known as *Malamavu*, is endemic to the south Western Ghats of Kerala, India. This evergreen tree reaches up to 15 m in height, has smooth or slightly fissured blaze flesh colour bark, creamy-white flowers, subglobose and slightly compressed drupes, and ovoid seeds. The flowering and fruiting season is from October to January (Santhosh Kumar et al., 2002). *B. barberi* is a terrestrial subtropical/tropical moist lowland tree found at 20–125 m above mean sea level (m.s.l.) (Barstow, 2018; Dhyani & Anilkumar, 2017). The tree grows on the bank of Vamanapuram river, adjacent to the road, in midland slopes (Palode) in association with *Suregada lanceolata* (Wild.) Kuntze, *Chassalia curviflora* (Wall.) Thwaites, *Hydnocarpus pentandrus* (Buch.-Ham.) Oken, *Tabernaemontana alternifolia* L. *Cayratia trifolia* (L.) Domin, *Palaquium thwaitesii* Trimen, *Pothoss scandens* L., *Gnetum ula* Brongn., *Myxopyrum smilacifolium* (Wall.) Blume, *Piper nigrum* L., *Archidendron bigeminum* (L.) I.C.Nielsen, *Ochlandra travancorica* (Bedd.) Gamble, *Scleria lithosperma* (L.) Sw., *Ixora nigricans* R.Br. ex Wight & Arn., *Abrus pulchellus* Thwaites, *Madhuca neriifolia* (Moon) H.J.Lam, *Clidemia hirta* (L.) D. Don, and *Dregea volubilis* (L.f.) Benth. Ex Hook.f.

The natural habitat of *B. barberi* is facing human-induced habitat degradation and loss. Since 1904, much of the coastal vegetation has been cleared for developmental activities, which are responsible for the local extirpation of the species from its type locality, that is, Nadarai (Santhosh Kumar et al., 2002). Recent field visits conducted in the Palode region of Thiruvananthapuram recorded only two reproductive trees and a small population size (Figure 1). Further, low fruit yield, low seed germination, no seedling establishment, and nearby road expansion, all of which are making *B. barberi* more prone to extinction (Dhyani & Anilkumar, 2017). Thus, *B. barberi* is assessed as Critically Endangered based on criteria B2ab(iii,v);D on the IUCN Red List (Barstow, 2018). The Mohamed Bin Zayed Species Conservation Fund, UAE, granted a project for the study and conservation of *B. barberi*. The project comprises ex situ conservation research and experiment activities such as surveys, seed germination, storage and seedling establishment, awareness campaigns and the first documented reintroduction study, which is described here.

2 | MATERIAL AND METHODS

This study was conducted at Jawaharlal Nehru Tropical Botanic Garden and Research Institute (hereafter Tropical Botanic Garden) and Palode in Thiruvananthapuram District, south Western Ghats, India (Figure 1). The two locations exist within the present distribution of *B. barberi*, where the elevation is 20–125 m a.s.l., the average annual precipitation is 3000 mm, the mean annual temperature varying from 19 to 34°C, the soil is laterite and formed by weathering of the gneissic rock, and the vegetation is dominated by evergreen and deciduous forest (Nayar et al., 1986).

A total 774 fruits of *B. barberi* were collected from two trees during March 2017 (364 seeds in Batch 1) and March 2019 (410 seeds in Batch 2) (fruits were not observed due to heavy rainfall during 2018) from the Palode region (74 m a.s.l.) in the Thiruvananthapuram district of Kerala. Seed pulps were removed manually and the seeds were kept in open trays on a laboratory bench-top for a day at ambient room conditions. The seeds (774) were incubated at 30°C (based on preliminary experiments) for germination in the laboratory and monitored for 2 months. During April, after germination, the seedlings were moved into polybags (to the best of our records, no loss was reported in the process of transplanting seedlings from laboratory to polybags) with a sterilized mixture of sand and cow dung (3:1) as a growing medium. These saplings (50 and 70 from batch 1 and batch 2, respectively) were placed in Tropical Botanic Garden nursery for growth and adaptation until September. The saplings were labelled and monitored for growth (plant height was recorded using a millimetre scale), watering, weeding and insect pests every fortnight from April to September (6 months) and no horticulture treatments were adopted.

During October 2017 and 2019, the surviving 40 and 50 plants, were transplanted to near-natural habitats in the Tropical Botanic Garden and Palode area, respectively. After transplantation, the plants were monitored approximately every 2 months for their height and

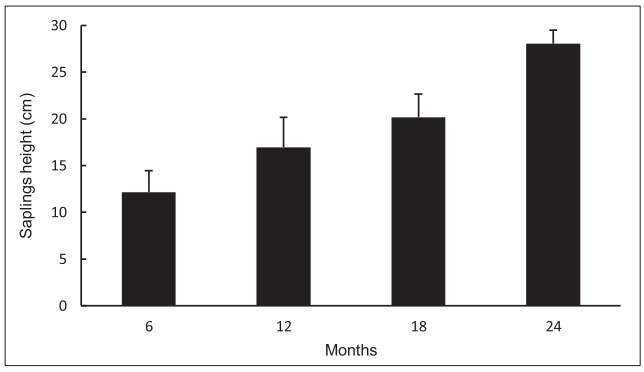

FIGURE 2 Average height of reintroduced individuals of *Buchanania barberi* during 2017 and 2019 at Tropical Botanic Garden. Bars represent standard deviation.

TABLE 1 Propagation for reintroduction. Seed germination and seedlings growth of *Buchanania barberi* during 2017 and 2019

Year	No. of seeds	No. that germinated	Germination (%)	Mean height of 6 months old seedlings (cm)
2017	364	190	52.19	12.16
2019	410	240	58.53	11.64

TABLE 2 Survival rate of transplanted saplings of *Buchanania barberi* at reintroduction sites after 6, 12 and 24 months

Sites	At planting No. of saplings	After 6 months No. of saplings	% survival	After 12 months No. of saplings	% survival	After 24 months No. of saplings	% survival
Tropical Botanic Garden	40	33	82	28	70	22	55
Palode	50	35	70	32	64	20	40[a]

[a]May 2021.

FIGURE 3 *Buchanania barberi* reintroduction, showing (a) a reproductive individual, (b) flowers, (c) fruits, (d) seed germination, (e) seedling, (f) seedlings in nursery, (g) reintroduction site, (h) transplanted individual. Photos by Anurag Dhyani

survival percentage. Monitoring ceased in March 2020 and resumed in August 2020 due to the COVID-19 pandemic.

3 | RESULT AND DISCUSSION

B. barberi seeds took about 15–25 days to germinate. During both years, seed germination success was recorded between 52% and 58%. This low seed germination may have been due to seed dormancy (Dhyani & Anilkumar, 2017), but it needs further detailed study. The saplings (50 and 70 from batch 1 and batch 2, respectively) attained a height of 11–12 cm with seven to nine leaves (7.91 × 2.74 cm) after circa 6 months in the garden nursery before transplantation (Table 1). At this stage, the saplings have well-developed root systems and are ready for transplant. Seedlings of critically endangered and endemic trees, for example, *Madhuca insignis* (Joshi et al., 2019) and *Parakmeria omeiensis* (Yu et al., 2020), were grown in the nursery for 1 year before being planted out in the sites. These saplings require acclimatisation to environmental conditions for successful growth; therefore, hardening is required for propagation. It reduces the planting pressure and increases survival. To decrease the high seedling mortality, several reintroduction guidelines suggest growing plants under controlled environmental conditions before their release to the site (Aguraiuja, 2011; Maschinski & Albrecht, 2017).

Plants in the Tropical Botanic Garden had grown to 16 cm in average height with 70% survival after 1 year of transplantation. In 2019, after 2 years, plants (batch 1) had attained an average height of 28 cm (Figure 2) with a survival rate of 55% (Table 2) (Figure 3). However, during 2020–2021, data collection and monitoring from Palode region was affected due to the global COVID-19 pandemic. Plants of the second batch in Palode region have been growing well, with an average height of 24 cm and a 40% survival rate to date. Comparing sites, the plants' survival rate is higher in the Tropical Botanic Garden than in the Palode region, mainly due to better protection and less human disturbance (e.g., human trampling for firewood collection, seedlings killed by wild and domestic animals and recreational activities). Studies support that reduced human disturbance is one of the key factors in enhancing the survival and growth of transplanted seedlings of rare species (Fenu et al., 2016; Yu et al., 2020). A review of 1001 threatened plant translocation studies revealed a 50% survival rate after 1 year. This is considered a short-term success, but for long-term success, monitoring should be continued for many years (Silcock et al., 2019). Further continuous monitoring programmes help to identify and solve problems in translocation studies. However, it is important to share preliminary results for *B. barberi*, because the first documented trial may guide future conservation efforts not only for this species but also for other IUCN Red Listed species of the genus worldwide.

We observed rat-damaged stored seeds of *B. barberi* in the laboratory. The rats bore a hole in the seed coat and ate embryo and endosperm completely. During seed germination trials in the garden, we observed that seeds were taken and eaten by rats. Later, during the hardening of seedlings for the initial 6 months in the nursery, the rats consumed the cotyledons and hypocotyl of many seedlings. It indicates that rats interacting with the seeds of *B. barberi* in the natural habitat will destroy them. In the nursery, we used metallic rat traps to reduce the pressure on seedlings. Sapling mortality after transplant in Tropical Botanic Garden site was recorded as being due to wild herbivores (may be wild goats) feeding on shoots and leaves, and also due to and a lack of water resulting in dryness and the death of a few plants. Plants growing under a low canopy showed more growth compared with plants under full shade. Here, we focussed only on the survival of seedlings due to the long regeneration period of the species.

Knowledge of focal species' life history, demography, reproductive biology, horticulture and ecology is essential for successful reintroduction (Bajomi et al., 2010; IUCN/SSC, 2013). However, the number of fruitful reintroductions of rare and threatened plants is very small, and it is even smaller for extinct species (Abeli et al., 2020; Godefroid et al., 2011). The poor success rate of reintroductions can be improved by the long-term monitoring of transplanted individuals and by biological and ecological studies of the focal species (Godefroid et al., 2011). Most reintroduction attempts focus on factors, which affect the establishment of the population and those that determine the success or failure of the effort. The success of reintroduction is increased by using propagules taken from multiple populations (Godefroid et al., 2011), but this is not feasible for endemic species with extremely narrow ranges.

4 | CONCLUSION

The reintroduction of *B. barberi* is a low-cost project that involves students, teachers, researchers, local stakeholders and public authorities in a voluntary capacity. Site management was not exhaustive and was easily (approachably) manageable. To improve the survival rate of transplanted plants, planting sites should be covered by fences to sustainably reduce the access of herbivores and humans. Seedlings may be placed in the nursery for a period of more than 6 months before transplantation. Choosing a planting site with low canopy cover (ample sunlight), good watering facilities (nearby stream) and rat traps may improve the establishment of seedlings. After approximately 2 years, conservation indicators for the project remain positive, but long-term care, monitoring and identifying and solving problems will confirm the success of the reintroduction. This is the first published reintroduction of *B. barberi*, which is a substantial landmark in developing planting and reintroduction approaches for the Genus *Buchanania* and for other rare and endemic plants of the Western Ghats of India.

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CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

AUTHOR CONTRIBUTIONS

Conceived and designed the experiments: AD and BS performed the experiments: AD, BS and AKC analysed the data: AD and BS wrote the paper: AD, BS, AKC, CA.

DATA AVAILABILITY STATEMENT

The data that support the findings of the study are available from the corresponding author upon reasonable request.

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