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POPULATION STRUCTURE, REGENERATION STATUS AND CONSERVATION MEASURES OF THREATENED *CYATHEA* SPP.

Balkrishna A[1, 2], Arya V[1] & Kushwaha AK[1, *]

[1]*Patanjali Herbal Research Department, Patanjali Research Foundation Trust, Haridwar, Uttarakhand, 249405 India*
[2]*University of Patanjali, Haridwar, Uttarakhand, 249405, India*

**akushwaha072@gmail.com*

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The present study assessed the population structure, regeneration status and conservation of threatened tree ferns *Cyathea,* namely, *C. brunoniana*, *C. gigantea* and *C. henryi* in Seijosha forest, Arunachal Pradesh, north-east, India. Individuals of *C. henryi* had a maximum density of 45 individuals ha^{-1} while *C. brunoniana* and C. *gigantea* had a maximum of 35 individuals ha^{-1}. The population structure showed four general class distribution patterns (i.e. reverse J-shape, Bell shape, irregular shape, and J-shape). Only *C. brunoniana* and *C. henryi* showed reverse J-shaped pattern at two sites, which indicated a stable population. The regeneration status for *C. gigantea* was poor at most of the sites. There were fewer individuals of young, immature and adult plants of *Cyathea*, and some species showed poor or no regeneration at certain sites. The conservation status of young/immature/adult individuals was occasional and infrequent. The study revealed many factors threatening *Cyathea* and suggested some corrective measures which can be helpful for its conservation.

Keywords: Seijosha-Arunachal Pradesh, threatened tree fern, structural analysis, conservation status

INTRODUCTION

Arunachal Pradesh belongs to the moist-temperate subregion of temperate Asia. Rich in fauna and flora, it has been identified as one of the 34 global mega biodiversity hotspots, with numerous endemic, primitive and endangered plant species (Myers et al. 2000). It is situated in the transition zone between the Himalayan and Indo-Burmese regions. The East Kameng district of Arunachal Pradesh has a total area of 861.95 km^2, which accounts for 9.04% of the protected area in the state (Jeri et al. 2011, Tag et al. 2012).

Ferns are an important component of tropical and temperate forests and play a significant role in ecosystem processes in the canopy and forest floor habitats (Hill & Silander 2001). Tree ferns of family Cyatheaceae comprises about 500 species and are found throughout the tropics, subtropics and south-temperate zone of the world (Korall et al. 2007, Lehnert 2012, Korall & Pryer 2014). Many taxonomic studies, classifications and data have been reported on the family Cyatheaceae in the last 50 years that recognise one (*Cyathea*) to many (e.g. *Alsophila*, *Calochlaena*, *Cibotium*, *Culcita*, *Cyathea*, *Dicksonia*) genus. In the last decade, phylogenetic studies of restriction site data and morphology led to the recognition of three or four evolutionary lineages within Cyatheaceae, i.e. *Alsophila, Cyathea, Gymnosphaera* and *Sphaeropteris* (Korall et al. 2007), of which, according to the Red List Category of International Union for Conservation of Nature, 8 species are Endangered (EN), 9 are Vulnerable (VU), 6 are Near Threatened (NT), 90 are Least Concern (LC) and 24 species are Data Deficient (DD) in the world (IUCN 2020).

Plant regeneration is essential for the preservation and maintenance of biodiversity. Several floristic accounts have also been reported on pteridophytes of north-east India (e.g. Kachroo 1953, Bir et al. 1989, Verma et al. 2014). Only a few studies on ecological and conservation aspects of pteridophytes of north-east India were reported (Bhattacharya et al. 2003, Paul et al. 2015), while the Seijosa forest in the East Kameng district of Arunachal Pradesh is still unexplored. Therefore, regeneration and conservation status of the threatened *Cyathea* spp. in the Seijosha forest of Arunachal Pradesh were studied and reported in this paper to provide quantitative data of the tree ferns.

MATERIALS AND METHODS

Study area

The Seijosa forest is located in East Kameng district of Arunachal Pradesh, north-east India (150 to 2000 m asl; 276.0° N, 93.0° E) along the river Pakke, which is part of the lower Siwalik range (Bera et al. 2014) covering an approximate area of 541 km^2 (CBRC 2017), while the study area covered 1263 ha. Six forest sites of the Seijosa forest, viz, Upper Seijosa (site 1), Mobuso (site 2), Dikalmukh (site 3), Lanka (site 4), Passo (site 5) and Khari (site 6) were explored during 2017–2019. The site was categorised as moderately disturbed because of human interference. The Seijosa forest shares its boundaries with Pakke-Kessang, Pizirang and Seppa circles in the north, West Kameng district in the west, Assam in the south and Papum Pare district in the east (Figure 1). During the study, three *Cyathea* species, namely, *C. brunoniana*, *C. gigantea* and *C. henryi* were found and selected for the study. The study area is highly undulating with a gradual slope towards south, rolling plateaus, dissected hills, valleys, plains and experiences about 3742 mm average annual rainfall mostly between June to October (CGWB 2013).

The study area was unexplored and rich in biodiversity due to lack of proper road communication and direct link road, limited human interference, and around the foothills frequent sights of wild animals can be noticed very often (Figure 2). The maximum–minimum temperature recorded at the foothill of the Seijosa varies from 25–14 °C in January to 36–25 °C in June. Soils of the high hills are reddish in colour and acidic in nature and rich in organic matter and clayey alumina type. Soil at the foothills and valleys is alluvial or loamy type (CGWB 2013). The area is covered by dense tropical semi-evergreen forests and is dissected by many small rivers.

Methods

For the vegetational sampling, 10 quadrats were placed randomly at each forest site (for young, immature and adult plants). All the adult tree fern species were sampled in 10 m × 10 m size plots. Immature and young tree ferns were sampled in quadrats of 5 m × 5 m size. The size and number of quadrats were determined using the species–area curve (Misra 1968) and running mean method (Kershaw 1973). For analysis of vegetational parameters, every tree species falling into the sampling quadrat was measured above

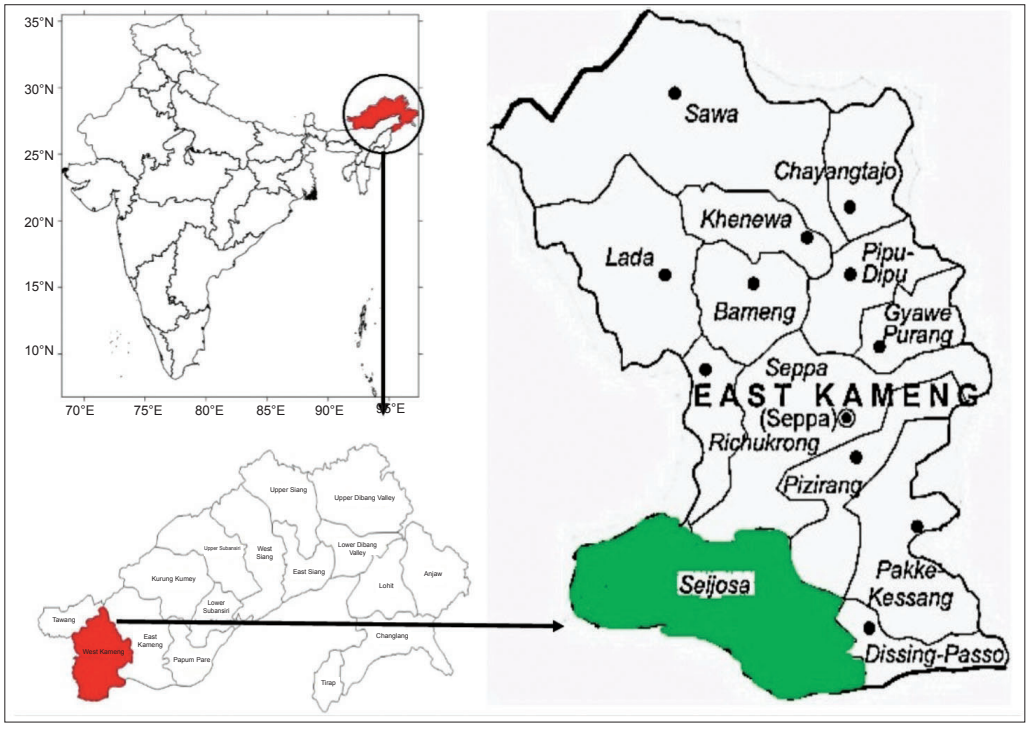

Figure 1 Map of study sites

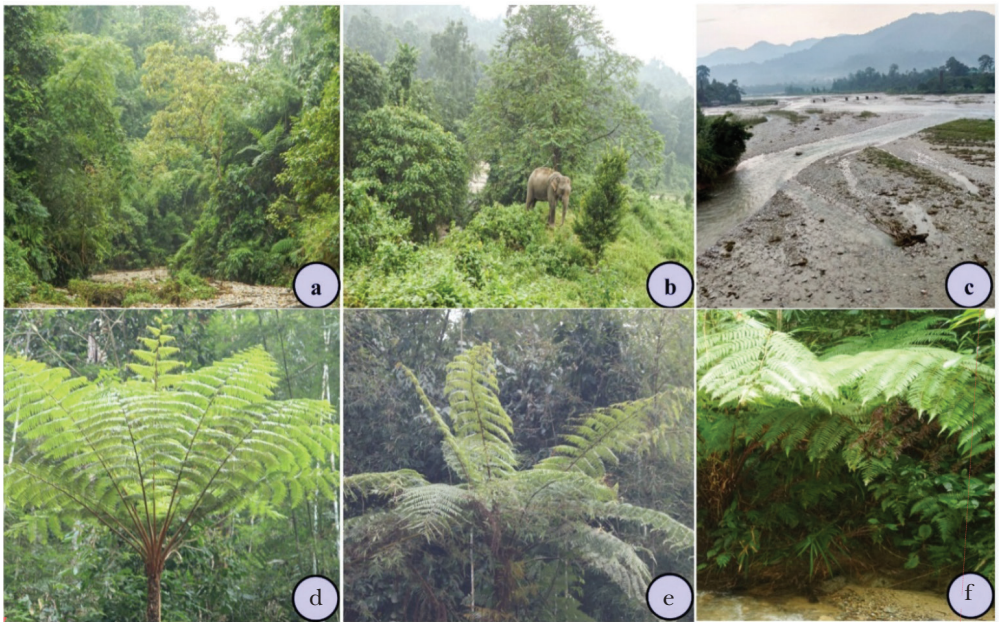

Figure 2 (a–c) An overview of the study area, (d) *C. brunoniana*, (e) *C. gigantea*, and (f) *C. henryi*

the root mantle. Mean basal area was calculated by dividing the square of mean circumference at breast height with 4π. Total basal area of trees was determined by multiplying the mean basal area with density ha^{-1}. Importance value index (IVI) indicates the relative ecological importance of a woody species in each of the sites (Kent & Coker 1992) and is calculated by summing up the relative values of density, dominance, and frequency of each woody species.

Relative density of individuals of each species (y-axis) was categorised into seven diameter classes (x-axis) following Peters (1996), i.e. A = 1–5 cm, B = 6–10 cm, C = 11–15 cm, D = 16–20 cm, E = 21–25 cm, F = 26–30 cm, and G = 31–35 cm. Based on profile represented through population structure, the regeneration status of each species of *Cyathea* was determined following Khan et al. (1987) as:

(1) Good regeneration if number of seedlings > saplings > adults
(2) Fair regeneration if number of seedlings > or ≤ saplings ≤ adults
(3) Poor regeneration if the species survives only in the sapling stage, but no seedlings (number of saplings may be <, > or = adults)
(4) New regeneration if the species has no adults but only seedlings or saplings.

For the present study, the term trees, saplings and seedlings have been replaced with terms adults, immature and young tree fern respectively. The population structure of tree species is expressed in terms of the number of individuals present in each of the definite girth class distribution (Saxena et al. 1984). For the assessment of the local conservation status of the species, criteria defined by Palmer et al. (1995) were adopted in the present study.

RESULTS AND DISCUSSION

Vegetation analysis

A total of three tree fern species of genera *Cyathea* were recorded at the Seijosa forest. Of the three species at all six sites, *C. henryi* had the maximum density (45 individuals ha^{-1}) of adults at Passo (site 5) (Table 1). However, minimum density was recorded for *C. henryi* at site 4 (10 individuals ha^{-1}). The density of immature individuals of tree fern varied between 10 and 192 individuals ha^{-1}. Density values of young individuals at the different sites ranged from 4 to 288 individuals ha^{-1}. Measure of basal area provide a better measure of the relative dominance of woody species in a forest (Cain & Castro 1959). Total basal area of all three species of *Cyathea* varied from 0.0768 (*C. gigantea,* at site 3) to 0.2085 m^2 ha^{-1} (*C. brunoniana* at site 1), indicating poor presence of the tree fern at Seijosa forest.

Population structure and regeneration status

Information on population structure of any species indicates its history of past distribution and its environment, which is very useful in forecast of the future trend of its population (Tamrat 1994, Demel 1997). The population structure and regeneration pattern of all three species of *Cyathea* showed their future potential in the Seijosa forest. The population structure of *Cyathea* species followed four general class distribution patterns (reverse J-shape, bell-shape, irregular-shape, and J-shape) at different sites of the Seijosa forest. A reverse J-shaped pattern was found for *C. brunoniana* at sites 1, 4 and 5 and for *C. henryi* at sites 1, 2 and 5 (Figure 3). At other sites, the different patterns of distribution of species showed the occurrence of irregular-, bell-, and J-shaped density distribution patterns. At sites 2 and 6, *C. brunoniana* showed irregular- (irregular density distribution between different size classes) and J-shaped patterns (higher density of individuals in higher diameter classes) respectively. In contrast *C. henryi* showed irregular- and bell-shaped patterns at sites 3 and 4 respectively (Figure 3). The population structure of *C. gigantea* showed irregular-shaped pattern at all respective sites. All the patterns of distribution of individuals (except reverse J-shape) between the different forest sites indicated that there was an urgent need for protecting the respective species in their particular occurring environment. Reverse J-shaped distribution pattern indicates stable population structure, naturally replacing senesced individuals with seedlings and saplings (Condit et al. 1998, Obiri et al. 2002)

Regeneration status of the *Cyathea* spp. present at Seijosa forest was good for *C. brunoniana* (at sites 4 and 5) and *C. henryi* (at sites 1, 2 and 5) (Table 1). Regeneration was moderate for *C. brunoniana* at site 1, and *C. henryi* at site 3. Poor regeneration status was shown by *C. brunoniana* at site 2 and *C. gigantea* at sites 1, 3, 5 and 6. *Cyathea brunoniana* at site 6, *C. gigantea* at site 2 and *C. henryi* at site 4 showed no regeneration (Table 1). Of the three species, *C. gigantea* had the poorest regeneration at most of the sites. It was completely absent at site 4, while no regeneration for this species was observed at site 2. Hence the analysis clearly indicated an urgent need for conservation of *C. gigantea*.

Conservation status

For the conservation of plant species Palmer et al. (1995) defined six criteria, i.e. abundant, frequent, occasional, infrequent, rare and absent. Adult of *C. brunoniana* plants were found easily in one or more common sites, but it was not dominant at any one site of the forest, while its young plants were frequent and widely scattered between the sites. It was difficult to find adult *C. gigantea* plants in the forest at different sites, while its young plants were occasionally seen. *Cyathea henryi* adult plants were occasional while young plants were abundant and a good number of young plants were recorded in two or more common habitats of the forest. Young plants of *C. henryi* were generally found near parent plant but immature plants were mostly noticed away from adult plants. *Cyathea* spp. were also found mixed with trees, shrubs, and climbers of angiospermic plants. These tree ferns were recorded more towards the forest compared with human habitat. *Cyathea* spp. propagate via spores, stolons or runners or by layering in soil. Large population of this genus mainly grows near moist and moderately shady places. Only a few individuals were observed at dry places, deep shades and disturbed areas of the forest.

The different IVIs of *Cyathea* species shown in Figure 4 can also be used in conservation programmes, where species with low IVIs are prioritised for conservation and those with high IVIs need monitoring management. Overall observations revealed that the percentage of adult tree population was higher than that of immature and young plants at different sites of the forest. Largest young (288 individuals ha^{-1}) and immature (192 individuals ha^{-1}) populations were recorded from site 5 and site 3 respectively. In contrast, the lowest young and immature populations were recorded from sites 1 and 3 respectively. We found fewer individuals of young, immature and adult plants of *Cyathea*. The conservation status of young/immature/adult individuals was found as occasional and infrequent. Some species showed poor to no regeneration at some sites.

CONCLUSIONS AND RECOMMENDATIONS

At majority of the sites, *Cyathea* spp. came under the category of occasional and infrequent

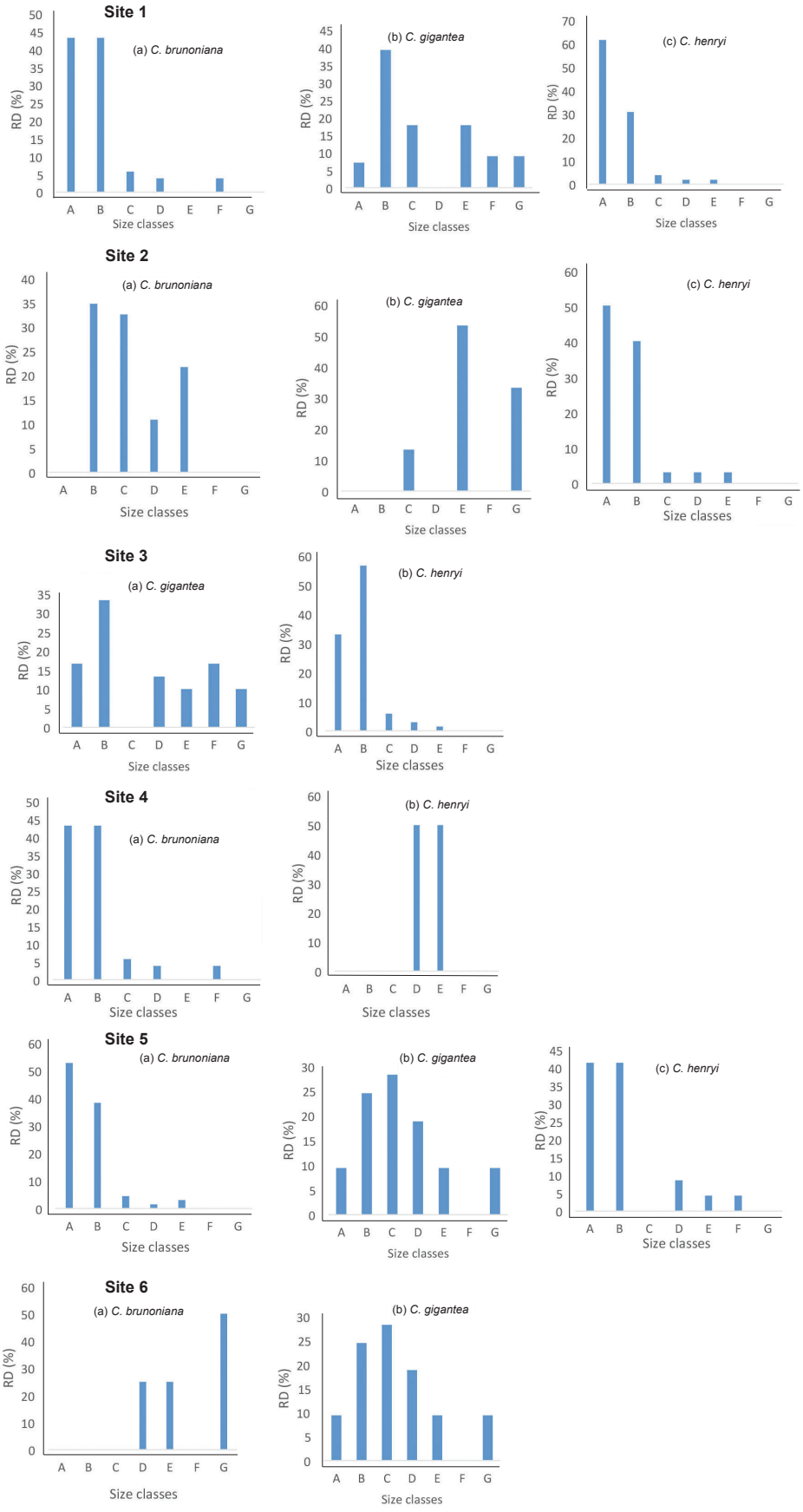

Figure 3 Population structure of three threatened *Cyathea* spp. at six study sites; RD = relative density; size class A = 0–5 cm, B = 6–10 cm, C = 11–15 cm, D = 16–20 cm, E = 21–25 cm, F = 26–30 cm and G = 31–35 cm)

Table 1 Ecological attributes of different species of genera *Cyathea* present at different forest sites

Location	Density (individuals ha^{-1})			TBA	IVI	RS
Site 1	Adult	Immature	Young			
C. brunoniana	35	112	112	0.2085	12.13	Fair
C. gigantea	30	22	4	0.1953	9.18	Poor
C. henryi	20	80	160	0.1163	8.96	Good
Site 2						
C. brunoniana	30	16	0	0.1419	8.64	Poor
C. gigantea	15	0	0	0.2015	7.80	No
C. henryi	15	64	80	0.0899	6.36	Good
Site 3						
C. gigantea	15	10	5	0.0768	2.95	Poor
C. henryi	40	192	112	0.1058	7.36	Fair
Site 4						
C. brunoniana	25	64	128	0.1015	7.87	Good
C. henryi	10	0	0	0.1028	6.73	No
Site 5						
C. brunoniana	30	128	176	0.1032	7.31	Good
C. gigantea	35	13	5	0.1920	7.29	Poor
C. henryi	45	144	288	0.1703	7.88	Good
Site 6						
C. brunoniana	20	0	0	0.0995	5.30	No
C. gigantea	30	16	6	0.1156	7.38	Poor

TBA = total basal area (m^2 ha^{-1}), IVI = importance value index, RS = regeneration status

(following Palmer et al. 1995). All species of *Cyathea* grow on hill slopes and foothills (near streams and rivers). Large numbers of young and immature individuals of *Cyathea* are detached and destroyed every year due to heavy monsoon, cutting of river banks, speedy soil erosion and landslides. Another reason for the loss of their population is that it is more difficult for spores to get favourable environment conditions to germinate than other means of propagation. The unfavourable pH, soil, moisture and shade restrict them from growing on every possible space. Therefore, despite of the large number of spores produced on each tree in every reproductive cycle, only a few plants were observed in the area of the occurrence of the species. It was also observed that the dominant rich angiosperm plants in the forest compete with *Cyathea* spp., and are often responsible for reducing the growth of young *Cyathea* spp. The growth of these young plants was also restricted in the forest due to the movement of wild elephants in large groups. Elephants may destroy not only the tree but also the complete habitat of young plants with their trunks and feet. The local people used tree fern to make houses, softwood or crozier for vegetables and new leaves for fodder; this was also a reason for the exploitation of *Cyathea* spp.

Corrective measures for conservation of these threatened tree ferns are suggested below:

(1) There is an urgent need to educate and increase awareness of the local people about the conservation of *Cyathea* spp.
(2) On a priority basis, continuous monitoring and dynamic protection measures should be carried out to protect the present population of *Cyathea* spp.
(3) An artificial introduction of immature individuals of the species in suitable ecological habitats or secondary forest is necessary to restore the populations.

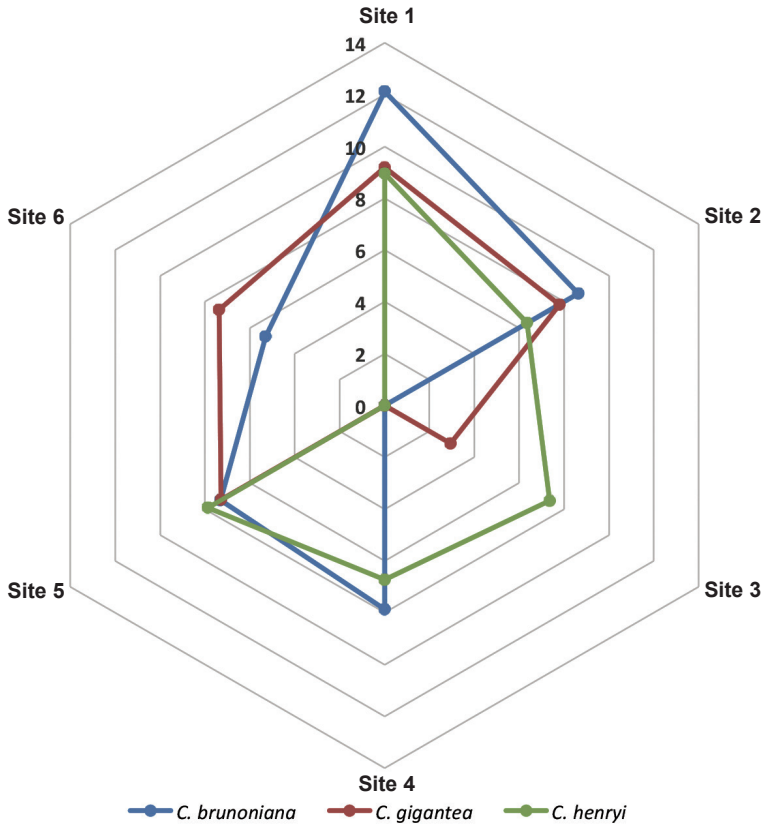

Figure 4 Radar diagram showing importance value indices of different species of *Cyathea*

(4) Those populations which are facing more pressure of competition with other plant species should be planted separately in-vitro or in other natural protective places.

Population generally shrinks and is categorised as endangered when individuals of the population face fragmentation due to less favourable habitat conditions. In the case of *Cyathea*, fragmentation of the population was observed due to unfavourable conditions. However, if proper management strategies are applied, conservation of this species may be possible.

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