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Diversity and composition of shrubs in Behali Reserve Forest of Biswanath district, Assam, with special emphasis on *Gnetum gnemon* L.

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Abstract. The study is focused to study the diversity and distribution of shrubs in the Behali Reserve Forest. A total of 46 species of shrubs belonging to 40 genera representing 25 families were documented. Rubiaceae and Lamiaceae were the dominant families. *Pycnarrhena pleniflora* has the highest IVI value of (48.25) followed by *Coffea benghalensis* (41.1). Plotting in Raunkiaer's frequency class distribution it was found that the shrub community of BRF is heterogeneous in nature i.e. represents uniform species diversity which does not allow the dominance of a species. Among the recorded shrubs, *Pycnarrhena pleniflora, Coffea benghalensis, Boeica filiformis, Gnetum gnemon* and *Dalhousiea bracteata* has a good population status. *Gnetum gnemon* on the other hand a potential NTFP of BRF has an infrequent distribution which is due to its high economic value and unregulated collection. The market value of *G.gnemon* and its conservation needs are also presented.

Keywords: ecology, Non Timber Forest Product, Northeast India, Species diversity, importance value, dominance, reserve forest.

1. Introduction

Forests can be described as an ecosystem composed of trees along with myriad kinds of biological diversity, a home for indigenous people, a resource for storing carbon, and a source of ecosystem services (Chazdon et al., 2016). The vegetation of the forest plays a major role as a pool of global carbon (C) cycle, accounting a significant fraction of C pool and nutrient stocks. Forest structure and composition are directly influenced by environmental factors, such as climate and topography (Currie, 1991). Plant diversity assessments of these now-left forests can be a valuable tool for studying regional-scale biogeographic patterns (Gordon & Newton, 2006). The semi-evergreen forests of the world are one of the most diverse vegetation types but are also one of the least studied.

Shrub vegetation is an important aspect of forest ecosystem function which includes prevention of soil erosion (Casermeiro et al., 2004); supports regeneration; provides food and habitat for fauna; protects palatable plants against large herbivores (Baraza et al., 2006); influences plant diversity; forest productivity; nutrient cycling (Moore et al., 2007) etc. Their higher species richness and diversity provide an important group of vegetation which facing low attention across the scientific community of the world due to lack of interest of foresters as well as difficulty in the identification systems (Jhariya & Oraon, 2012).

So far, very less studies have been conducted on the diversity of composition of shrubs in natural forests of Northeast India (Bamin et al., 2017). Hence such studies are necessary to understand the structure, and composition

as well as to underpin the role of some particular shrub species to ensure forest protection evaluating the pressure on the forests after harvesting them. The present study aims to study the diversity and composition of shrubs in Behali Reserve Forest and also investigates the distribution of *Gnetum gnemon* L. a shrub species in the reserve along with understanding its association, market demand of this species in the vicinity of the reserve, explaining its role as a potential Non-timber forest resource as well as to explain its availability to hold the promise and demand.

2. Study area

The survey was conducted in Behali Reserve Forest (BRF), the last remaining patch of semi-evergreen forest in the Biswanath district of Assam. The forest is present in the foothills of the Himalayas. Located between 26° 52' 20.08' N and 26° 57' 33.17' N and 93° 11' 30.58' E and 93° 23' 21.09' E, the total geographical area is 140.16 km^2 and the elevation of the area ranges between 90 m a.s.l. and 110 m a.s.l. (Fig. 1). The temperature ranges from 13–37°C and the mean annual rainfall is 1800 mm (Sarma et al., 2009; Upadhaya, 2016–2017). The area is surrounded by Buroi River in the East, Singlijan Reserve Forest in the West, Papum Reserve Forest in the North, Tea Gardens, and human habitations in the South (Sarma et al., 2009). Studies on the tree and herb community structure have been worked out in the forest (Borah et al. 2021a, b). Apart from that, a total list of native plant species (Borah et al., 2020a) and the NTFPs of BRF are also studied (Borah et al., 2020b)

3. Materials and Methodology

Several sampling plots covering almost all the nooks and corners of the forest were established. Forty (5 m × 5 m) quadrats were laid selectively and all the shrub individuals were tagged, measured and collected. The collected samples were later processed following the methods of Jain and Rao (1977). It was then identified using relevant literature and consulting the regional herbaria (ASSAM) and submitted in Herbarium of Rajiv Gandhi University, Arunachal Pradesh. The updated nomenclature of plant species was followed using the database "Plants of the World online" of Royal Botanical Garden, Kew (http://powo.science.kew.org/). Abundance, density, frequency occurrence, species richness were calculated according to Magurran (1988). For

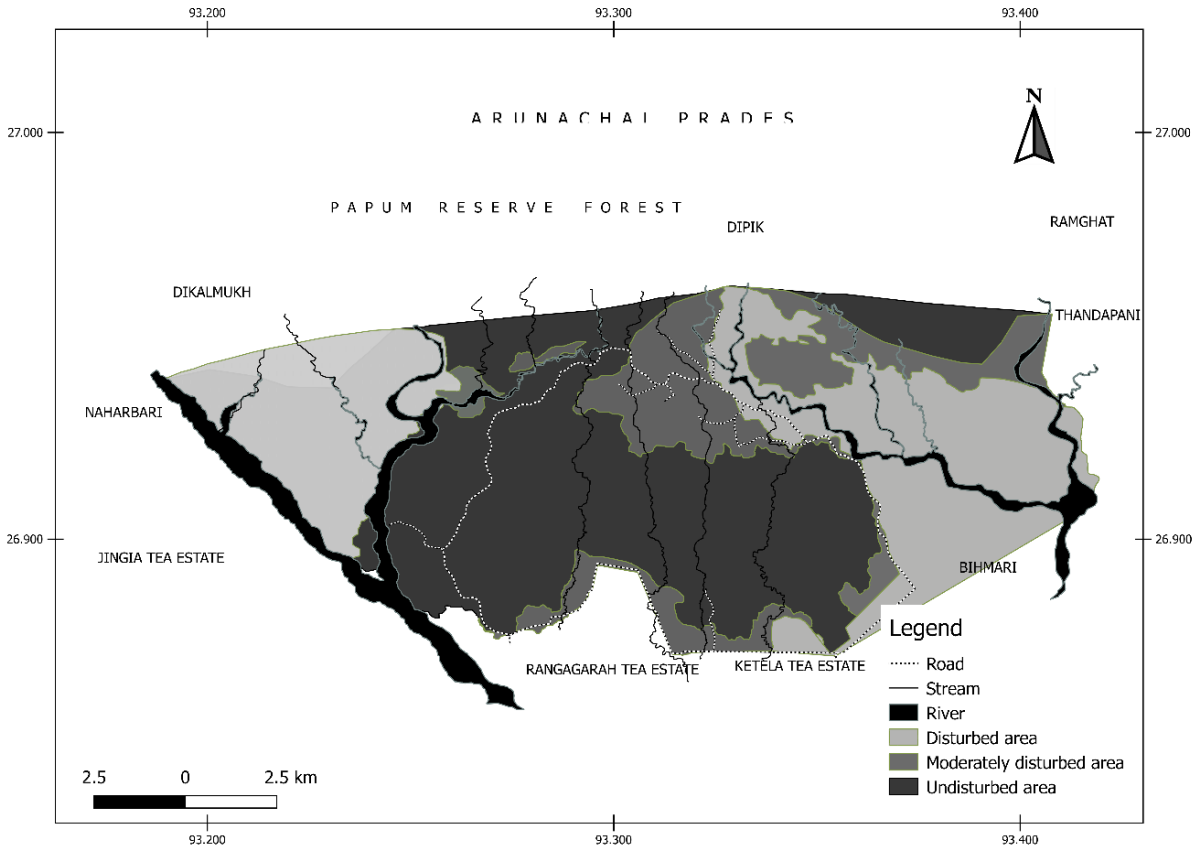

Figure 1. Map of Behali Reserve Forest, Assam, India

each species, Importance Value Index (IVI) was calculated, expressed as the sum of relative density, relative abundance, and relative frequency of species in and among plots (Curtis, 1959; Bhadra & Pattanayak, 2016). All calculations were performed using PAST (Hammer et al., 2001) and Microsoft Excel. Open-ended discussions and questionnaire surveys were also undertaken in the fringe villages and three selected weekly markets, namely Borgang, Ketla, and Tinikhuti involving twelve vendors to study the market value of *Gnetum gnemon* L.

$$\text{Frequency} = \frac{\text{Number of quadrates of species occurrence}}{\text{Total number of quadrates studied}} \times 100\%$$

$$\text{Density} = \frac{\text{Total number of individuals of a species present in all quadrates}}{\text{Total number of quadrates studied}}$$

$$\text{Abundance} = \frac{\text{Total number of individuals of a species present in all quadrates}}{\text{Total number of quadrates of species occurrence}}$$

$$\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Sum of frequency values of all species}} \times 100\%$$

$$\text{Relative density} = \frac{\text{Density of a species}}{\text{Sum of density values of all species}} \times 100\%$$

$$\text{Relative abundance} = \frac{\text{Abundance of a species}}{\text{Sum of abundance values of all species}} \times 100\%$$

IVI (Importance Value Index) = Relative Frequency + Relative density + Relative abundance

4. Results

4.1. Shrub diversity

The forest of BRF is very diverse and rich in terms of species number. The analysis of the randomly laid quadrats indicated an instance of a total of 46 species belonging to 40 genera representing 25 families. A list of taxonomic diversity in terms of family and their occurrence in BRF is provided in Table 1. The following plant families were characterized by the highest number of species: Rubiaceae (6 species), Lamiaceae (5 species), Fabaceae, Primulaceae, Rutaceae and Phyllanthaceae (3 species each), Sapindaceae, Menispermaceae, Lauraceae and Gnetaceae (2 species each). The rest 15 families contain one species each. The genera *Ardisia*, *Psychotria*, *Clerodendrum*, *Litsea, Gnetum* and *Zanthoxylum* included two species each, while the rest genera contained one species only.

4.2. Important value index (IVI)

The relative value of the three qualitative and quantitative parameters like; frequency, density and abundance generate the important value index (IVI). *Pycnarrhena pleniflora* recorded the highest IVI value (48.2) among the reported species followed by *Coffea benghalensis* (41.1), *Boeica filiformis* (23.2), and *Gnetum gnemon* (20.9) (Table 1). *P. pleniflora*, *C. benghalensis, B. filiformis* and *G. gnemon* has good abundance,

Table 1. Overall stand diversity, frequency (%), density, abundance and importance value index of shrub species of BRF, Assam

Species rank	Taxon	Family	Frequency	Density	Abundance	RF %	RD %	RA %	IVI
1	*Pycnarrhena pleniflora* Miers ex Hook.f. & Thomson	Menispermaceae	53.66	5.41	10.09	11.11	29.29	7.86	48.25
2	*Coffea benghalensis* B.Heyne ex Schult.	Rubiaceae	51.22	4.41	8.62	10.61	23.88	6.71	41.20
3	*Boeica filiformis* C.B.Clarke	Gesneriaceae	2.44	0.61	25.00	0.51	3.30	19.47	23.27
4	*Gnetum gnemon* L.	Gnetaceae	58.54	1.32	2.25	12.12	7.12	1.75	21.00
5	*Dalhousiea bracteata* (Roxb.) Graham ex Benth.	Fabaceae	26.83	0.95	3.55	5.56	5.15	2.76	13.46
6	*Mycetia nutans* (R.Br. ex Kurz) Razafim. & B.Bremer	Rubiaceae	19.51	0.63	3.25	4.04	3.43	2.53	10.00
7	*Clerodendrum infortunatum* L.	Lamiaceae	14.63	0.54	3.67	3.03	2.90	2.86	8.79
8	*Lepionurus sylvestris Blume*	Opiliaceae	26.83	0.37	1.36	5.56	1.98	1.06	8.60
9	*Fissistigma bicolor* (Roxb.) Merr.	Annonaceae	21.95	0.32	1.44	4.55	1.72	1.12	7.39
10	*Psychotria* sp.	Rubiaceae	12.20	0.37	3.00	2.53	1.98	2.34	6.84
11	*Psychotria denticulata* Wall.	Rubiaceae	7.32	0.32	4.33	1.52	1.72	3.37	6.60
12	*Dracaena petiolata* Hook.f.	Asparagaceae	14.63	0.32	2.17	3.03	1.72	1.69	6.43
13	*Gomphostemma niveum* Hook.f.	Lamiaceae	12.20	0.29	2.40	2.53	1.58	1.87	5.98
14	*Leea asiatica* (L.) Ridsdale	Vitaceae	12.20	0.29	2.40	2.53	1.58	1.87	5.98

Table 1. cd

Species rank	Taxon	Family	Frequency	Density	Abundance	RF %	RD %	RA %	IVI
15	*Ardisia macrocarpa* Wall.	Primulaceae	2.44	0.15	6.00	0.51	0.79	4.67	5.97
16	*Antidesma roxburghii* Wall. ex Tul.	Phyllanthaceae	17.07	0.24	1.43	3.54	1.32	1.11	5.97
17	*Lepisanthes senegalensis* (Poir.) Leenh.	Sapindaceae	14.63	0.22	1.50	3.03	1.19	1.17	5.39
18	*Ardisia solanacea* Roxb.	Primulaceae	12.20	0.22	1.80	2.53	1.19	1.40	5.11
19	*Ehretia wallichiana* Hook.f. & Thomson ex C.B.Clarke	Boraginaceae	2.44	0.12	5.00	0.51	0.66	3.89	5.06
20	*Glycosmis cyanocarpa var. simpicifolia*	Rutaceae	2.44	0.10	4.00	0.51	0.53	3.11	4.15
21	*Maesa indica* (Roxb.) Sweet	Primulaceae	2.44	0.10	4.00	0.51	0.53	3.11	4.15
22	*Mezoneuron enneaphyllum* (Roxb.) Wight & Arn. ex Voigt	Fabaceae	4.88	0.12	2.50	1.01	0.66	1.95	3.62
23	*Smilax* sp.	Smilacaceae	9.76	0.10	1.00	2.02	0.53	0.78	3.33
24	*Gnetum montanum* Markgr.	Gnetaceae	7.32	0.10	1.33	1.52	0.53	1.04	3.08
25	*Litsea hookeri* (Meisn.) D.G.Long	Lauraceae	7.32	0.10	1.33	1.52	0.53	1.04	3.08
26	*Ayenia grandifolia* (DC.) Christenh. & Byng	Malvaceae	7.32	0.07	1.00	1.52	0.40	0.78	2.69
27	*Dendrocnide sinuata* (Blume) Chew	Urticaceae	4.88	0.07	1.50	1.01	0.40	1.17	2.57
28	*Phanera scandens* (L.) Lour. ex Raf.	Fabaceae	4.88	0.07	1.50	1.01	0.40	1.17	2.57
29	*Bridelia assamica* Hook.f.	Phyllanthaceae	2.44	0.05	2.00	0.51	0.26	1.56	2.33
30	*Ixora polyantha* Wight	Rubiaceae	2.44	0.05	2.00	0.51	0.26	1.56	2.33
31	*Litsea chartacea* Hook.f.	Lauraceae	2.44	0.05	2.00	0.51	0.26	1.56	2.33
32	*Chassalia curviflora* (Wall.) Thwaites	Rubiaceae	4.88	0.05	1.00	1.01	0.26	0.78	2.05
33	*Premna esculenta* Roxb.	Lamiaceae	4.88	0.05	1.00	1.01	0.26	0.78	2.05
34	*Allophylus chartaceus* (Kurz) Radlk.	Sapindaceae	2.44	0.02	1.00	0.51	0.13	0.78	1.42
35	*Aristolochia cathcartii* Hook.f.	Aristolochiaceae	2.44	0.02	1.00	0.51	0.13	0.78	1.42
36	*Breynia androgyna* (L.) Chakrab. & N.P.Balakr.	Phyllanthaceae	2.44	0.02	1.00	0.51	0.13	0.78	1.42
37	*Calamus* sp.	Arecaceae	2.44	0.02	1.00	0.51	0.13	0.78	1.42
38	*Clerodendrum laevifolium* Blume	Lamiaceae	2.44	0.02	1.00	0.51	0.13	0.78	1.42
39	*Ficus subincisa* Buch.-Ham. ex Sm.	Moraceae	2.44	0.02	1.00	0.51	0.13	0.78	1.42
40	*Phlogacanthus curviflorus* (Nees) Nees	Acanthaceae	2.44	0.02	1.00	0.51	0.13	0.78	1.42
41	*Rauvolfia verticillata* (Lour.) Baill.	Apocynaceae	2.44	0.02	1.00	0.51	0.13	0.78	1.42
42	*Rotheca serrata* (L.) Steane & Mabb.	Lamiaceae	2.44	0.02	1.00	0.51	0.13	0.78	1.42
43	*Stephania rotunda* Lour.	Menispermaceae	2.44	0.02	1.00	0.51	0.13	0.78	1.42
44	*Tetracera sarmentosa* (L.) Vahl	Dilleniaceae	2.44	0.02	1.00	0.51	0.13	0.78	1.42
45	*Zanthoxylum asiaticum* (L.) Appelhans, Groppo & J.Wen	Rutaceae	2.44	0.02	1.00	0.51	0.13	0.78	1.42
46	*Zanthoxylum oxyphyllum* Edgew.	Rutaceae	2.44	0.02	1.00	0.51	0.13	0.78	1.42
						100.00	100.00	100.00	300.00

*RF = relative frequency; RD = relative dominance; RA = relative abundance; IVI = important value index.

good distribution pattern which represents its adaptability and establishment in the reserve forest. The lowest IVI values are reported for the species such as *Allophylus chartaceus, Aristolochia cathcartii, Breynia androgyna*, *Calamus* sp., *Clerodendrum laevifolium, Ficus subincisa, Phlogacanthus curviflorus, Rauvolfia verticillata, Rotheca serrata, Stephania rotunda, Tetracera sarmentosa, Zanthoxylum asiaticum* and *Zanthoxylum oxyphyllum*. Similarly, the highest density was reported for *Pycnarrhena pleniflora* followed by *Coffea benghalensis* and *Gnetum gnemon*.

4.3. Shrubby flora characteristics

For the studied flora, we distinguished four species groups in terms of the species abundance: Dominant (species with ≥ 100 individuals), Common (species with 25 to 99 individuals), Rare (species with 3 to 24 individuals) and Very rare species (species with < 3 individuals). 2 species (*Pycnarrhena pleniflora* & *Coffea benghalensis*) are dominant; 3 species (*Gnetum gnemon, Dalhousiea bracteata* & *Mycetia nutans*) are common; 25 species (*Lepionurus sylvestris,*

Fissistigma bicolor, Antidesma roxburghii, Dracaena petiolata, etc.) are rare; 16 species (*Bridelia assamica, Ixora polyantha, Litsea chartacea Aristolochia cathcartii, Zanthoxylum asiaticum, Zanthoxylum oxyphyllum* etc.) are very rare. The abundant species were represented by four species, *Pycnarrhena pleniflora* (222 individuals), *Coffea benghalensis* (181 individuals), *Gnetum gnemon* (54 individuals), and *Dalhousiea bracteata* (39 individuals). The species that are commonly scattered are those that occurred in the most number of quadrats. It included five taxa including *Gnetum gnemon*, *Pycnarrhena pleniflora*, *Coffea benghalensis*, *Dalhousiea bracteata* and *Lepionurus sylvestris.*

Raunkiaer's frequency class distribution (1934) classifies species into five classes: A (1-20%), B (21-40%), C (41-60%), D (61-80%) and E (81-100%). Raunkiaer's normal ratio is A>B>C>=<D<E which stated that if the observed frequency diagram is compared with the Raunkiaer's normal frequency diagram then the particular vegetation is homogeneous, on the other hand, if it does not match then it is heterogeneous. The Raunkiaer's normal frequency distribution revealed a reversed J shape curved.

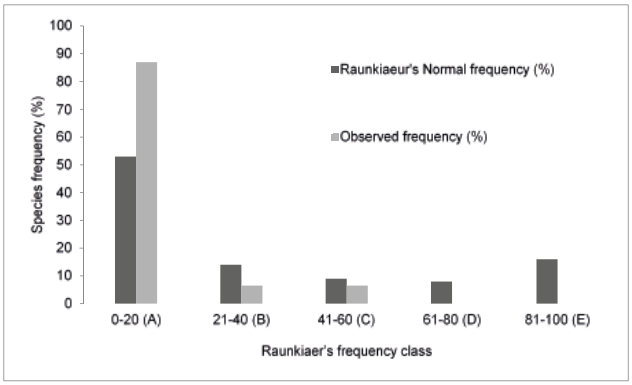

Figure 2. Frequency-distribution pattern of shrub species in BRF, Assam

In this study, the frequency class distribution is observed by grouping the 46 encountered species into 5 classes based on their percentage occurrence. Results revealed that frequency class A constitutes 40 species (86.95%) showing low-frequency dispersion, class B constitute 3 species (6.5%) and C constitutes 3 species (6.5%) that both have moderate frequency dispersion while class D and E have no species that means not showing higher frequency dispersion (Fig. 2). This observed frequency diagram was compared with Raunkiaer's normal frequency diagram and found that it does not match with it and doesn't form a reversed J-shaped curve (Fig. 3). It revealed that the shrub vegetation community found heterogeneous in nature i.e. represents uniform species diversity which does not allow the dominance of a species.

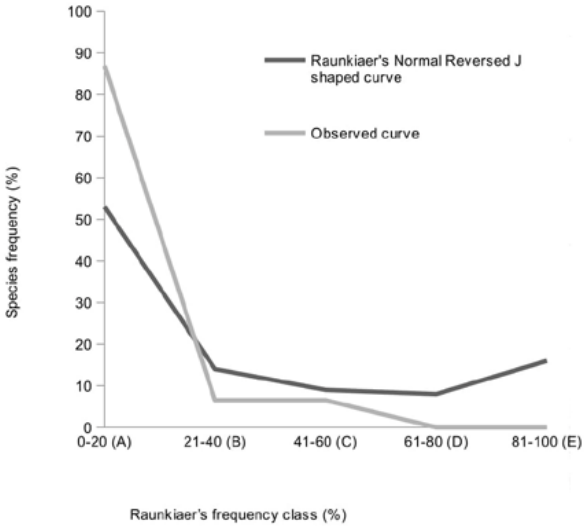

Figure 3. Frequency-distribution curve of shrub species in BRF, Assam

4.4. *Gnetum gnemon*

G. gnemon is one of the most utilized Non-Timber Forest Product of Behali Reserve Forest (Borah et al. 2020a) (Fig. 4). Out of the 40 randomly laid quadrats, *G. gnemon* appeared in only 24 of the quadrats. However other species occurred more rarely but owing to the importance of the former, the species is very infrequent in its occurrence in the forest. The presence of just 54 plants in 40 sampled quadrates reflects the amount of pressure this low population of plants has to face in meeting human's exploitative demands, especially in forest areas near human settlements. This explains why the health of most plants recorded in the study was in bad shape.

The inflorescences collected from the reserve are sold in the local markets from April to June, viz. Borgang, Ketla and Tinikhuti weekly markets by local vendors along with *Dillenia indica* and *Diplazium esculentum*. The price of these cones varies from 350-400 Rs/kg (Table 2). People often have to travel a long distance to collect this species, as most of the plants found nearby in the forest are harvested by those groups of people who search for them early in the flowering season. Leaves are mostly collected for self-consumption; however, some are sold in small bundles in the market but very rarely at the price of 10 Rs/bundle. Although the demand for the product is high, the number of vendors involved in the trade of this species is low. This is due to the very low availability of the species in the forest. The local people, who collect the product from the forest sell them to local vendors. Almost all of the products are amassed by these few groups of vendors who then sell them at higher prices in the nearby market. The demand for the product in the region is so high that almost all of the amount brought

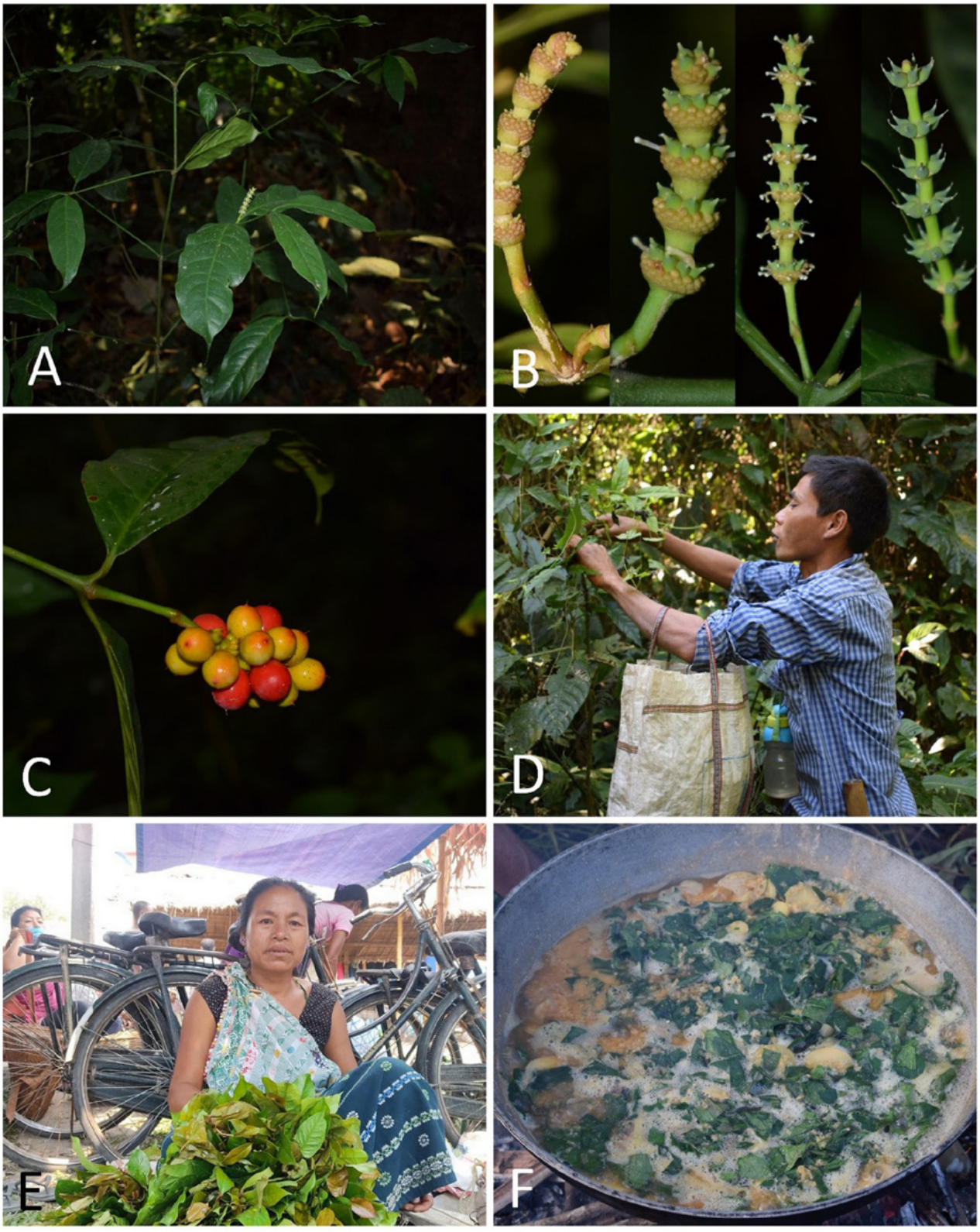

Figure 4. *Gnetum gnemon*: A. habit; B. inflorescences; B. infructescence; D. Collection of leaves and inflorescences; E. Tribal women selling leaves in Tinikhuti market; F. Local dish prepared from *G.gnemon* leaves.

are sold out within a few minutes of the market opening. The only thing that limits the sale of the product is the availability. More and more people therefore recently have engaged in collecting the species from the forest as evident by the increase in the number of vendors from 2018 to 2019 (Table 2). The price of inflorescence hiked by 50 rupees in the year 2021 due to the low availability of the species in the forest and also in the market as local collectors couldn't travel to the forest and market due to restrictions imposed by the Govt. in the face of Covid pandemic (Table 2). Therefore the year 2021 didn't witness any increase in vendor number but saw an increase in the price of the product. The prevalence of this species has drastically decreased in the study area in recent times. As per the respondents/ colleagues interviewed and field observation, the species is unsustainably collected for their inflorescences during the rainy season. Around 10-20 kg of inflorescences is collected daily from the forest, during its peak season. Since the inflorescences are very lightweight, therefore they have to be collected in large quantities to collect just a single kg. Therefore 10-20 kg contains a large quantity of inflorescence that is collected from large numbers of plants. The species is known to flower only once a year and the high market value of the inflorescence has led to overexploitation of this most important organ of the plant, leaving many plants without seed for the whole year. The problem seems so severe that all of the plants recorded during the study were adult plants, no young plants or seedlings were recorded. Careless collection of plant parts also leads to severe damages in surviving plant parts, thereby crippling them for years. This unsustainable exploitation has led to poor fruit setting and also affected its dispersal and germination. Most of the plants recorded during the study were damaged in some or another way. The damage was mostly in form of broken branches. This is of high concern since the species is already infrequent in the forest and the present trend of unsustainable exploitation may further lead to a decrease in their population.

Table 2. Year wise market demands of *G. gnemon* in the near markets of BRF, Assam

Year	Month	Market	Cones Price/ kg	Vendors involved	Leaves price/ bundle	Vendors involved
2018	April	Borgang	350/-	3	-	
2019	April	Tinikhuti, Borgang	350/-	5	10/-	2
2021	April	Ketla, Tinikhuti	400/-	5	10/-	3

5. Discussion

The taxonomic richness (46 species) of shrub plants recorded in the BRF was higher than reported in Namdapha National Park, Arunachal Pradesh, India (45 species) (Nath et al., 2005); Chilapatta Reserve Forest, West Bengal, India (36 species) (Shukla et al., 2014); Lower Dachigam National Park, Kashmir Himalaya, India (35 species) (Yaqoob et al., 2014); Hollongapar Gibbon Wildlife Sanctuary, Assam, India (23 species) (Moumita & Ashalata, 2015); Amchang Wildlife Sanctuary, Assam, India (20 species) (Kar et al., 2015); Lumding Reserve Forest, Assam, India (19 species) (Dutta & Devi, 2013); Doboka reserve forest, Assam, India, (18 species) (Dutta & Devi, 2013); Hojai reserve forest, Assam, India (14 species) (Dutta & Devi, 2013); Kumorakata reserve forest, Assam, India (14 species) (Dutta & Devi, 2013). However, our results were lower than it was reported from some other areas in Northeast India, namely Jeypore Reserve Forest, Assam, India (Rajbonshi & Islam, 2018), Eastern Himalayan forests in Arunachal Pradesh, India (Saikia et al., 2017).

The most dominant species that we obtained from the BRF are not consistent with data from other areas in India. This is because of the unique habitat containing certain ecosystem properties and processes makes unique species interactions provided by BRF.

G. gnemon constitutes one of those few wild plant species which is widely collected by communities residing near forest areas. The species regularly makes an appearance in works of various researches working on ethnobotanical records of various tribes in the northeast state of India such as Yadav et al. (2019), Borah et al. (2020a), Terangpi et al. (2013), Panmei et al. (2016), and Lungphi et al. (2018) just to name a few. Like many regions from nearby nations, *G. gnemon* is a highly preferable plant for cultivation in the homestead gardens of the locals in the study area due to its demand for almost all the plant parts into use. Even in some homegardens, we have noticed its cultivation, however in a small number which is due to reduce the trek to the forest and its return, saving an ample amount of time to devote in other works. The species thus belongs to the group of those few wild plants that have managed to make it into human settlement by virtue of its utility. Its high demand in the market despite the species being very infrequent in the forest reflects the importance and popularity of this species as a much relied upon NTFP from the region. The amount consumed or the market value may however differ among different regions based on demand and availability.

However, *G.gnemon* can be used for rehabilitation and restoration of the degraded areas by the forest department. This species apart from providing an ample source of income for the forest-dependent people will also enrich the soil in

those areas with phosphorus and other micronutrients required for plant growth and development, thus regulating the soil in the forest due to the beneficial association of mycorrhiza with this plant (Manner & Elevitch, 2006; Barua et al., 2015), where exotic species seen to dominate, allowing native species growth.

6. Conclusion

The present study reveals that the BRF comprise moderate diversity of shrub having numerous important NTFPs that support the livelihood of the local communities. The contributions of the NTFPs to the people in various aspects like food security, nutrition, healthcare, income sources etc. are indispensable. A total 46 shrub species were recorded among them, five shrubs viz. *Pycnarrhena pleniflora, Coffea benghalensis, Boeica filiformis, Gnetum gnemon* and *Dalhousiea bracteata* were consisting a good population status but the distribution of *G. gnemon* is so infrequent. This infrequent distribution of *G. gnemon* is due to the high extraction status as its economic demands are so high. This implies that the chance of being rare in the near future is increasing day by day. So that, for the sustainable use of NTFPs, has to prevent the high extraction status from the BRF. Those people who were involved in the extraction, have to find another alternative way of income sources or they can cultivate the species as it's a highly preferable plant for cultivation in the homestead gardens. National or regional governments/Institutes should encourage the local people for value addition of the NTFPs with technical and financial support.

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