Indian J. Applied & Pure Bio. Vol. 39(1), 424-434 (2024). **ISSN: 0970-2091**
A Web of Science Journal

Impact of elevation on distribution of pitcher plant, *Nepenthes khasiana* Hook. f. and its threats in Meghalaya, India

[a]Sarah G. Momin, [a]Anindita Bhattacharya, and [b*]Prabal Sarkar

[a]Department of Earth Science
[b]Department of Zoology, University of Science & Technology
Meghalaya-793101 (India)
[*]Corresponding author: Prabal Sarkar (prabalsarkarindia@gmail.com)

Abstract

Literature is available on the distribution of pitcher plants, *Nepenthes khasiana* Hook. f., an endangered and highly endemic species, in Meghalaya and Assam states of India. However, the study of the landscape features on its distribution is scarce. Hence, the present field-based survey was conducted between 2018 and 2022 to find out the impact of elevation on the distribution of pitcher plants, and threat perspectives in Meghalaya. The study found that all the locations where pitcher plants flourish are mostly found on the hill slope. The pitcher plant prefers the open canopy irrespective of the study hills of Meghalaya. Large-scale deforestation for jhum and mining along with enormous growth of built-up areas and forest fire are some of the landscape-level threats identified for the loss of pitcher plant population in Meghalaya. Hence, the threats prevailing for pitcher plants need urgent attention as the conservation of these plants is not only needed for ecological and economic benefits but also for safeguarding the cultural values of the inhabitants of Meghalaya.

Key words : Pitcher plant, *Nepenthes khasiana,* elevation, slope direction, distribution, threats.

Nepenthes khasiana is a scandent evergreen insectivorous shrub (Fig. 1) found to be preyed on 74 numbers of species[34]. Like other insectivorous plants, they also develop some kind of prey-trapping mechanism in the form of pitcher which arises from the terminal part of the leaves. This pitcher is filled with liquid known which acts as a pitfall trap. This contains a copious amount of liquid (a mixture of deposited rainwater and dew drops as well as enzyme and acidic secretions). The inner surface of the pitcher is very slippery. Hence, once the insect gets inside fails to come out of the pitcher.

N. khasiana is endemic to India[29,33]

with an area of occupancy of 250 km^2 [48], and found only in the "Indo-Burma" biodiversity hot spot of the world. They inhabit tropical and subtropical climatic regions. It is categorized as the Endangered Species in Red Data Book by SSC-IUCN[48], as Appendix-I category by CITES, and under the Negative List of Export by the Govt. of India[50].

There is scattered information about the distribution of *N. khasiana* from isolated forest patches in Jarain, Jowai, and Umtra areas of the Jaintia Hills, the Baghmara, Balpakram, and Maheskhola areas of the Garo Hills and Lawboh and Mawlynnong region of the East Khasi Hills of Meghalaya[8,14,21,24]. Very recently, the presence of this species was discovered in the Dima Hasao area of Assam[5]. Unfortunately, the study on the habitat selection pattern is scarce. This is because; the topography plays an important role in influencing the abundance, distribution, and diversity of vegetation[7,9]. In mountain areas, landscape parameters like elevation and slope aspect also affect the vegetation diversity and distribution patterns[16,26]. Hence this study aimed to find out some landscape parameters like elevation that ultimately act as suitable habitats for this insectivorous plant. An attempt was also made to record the threats to the pitcher plant in all three hills of Meghalaya, India.

Study area :

The study was conducted within the Meghalaya state of India (Fig. 1). It is located between latitude 24º 58'N & 26º 07'N and longitude 89º 48'E & 92º 51'E. The state is bounded on the north by Goalpara, Kamrup, and Nawgong districts of Assam, on the east by Karbi Anglong and North Cachar Hills District of Assam, and on the south and west by Bangladesh. The total area covered by the state is 22,429 sq. km and the total forest area is 8510 sq. km. The elevation of the plateau ranges from 150m to 1961m.

Meghalaya is mostly a forested terrain covered with one-third of forests. The state has eco-region and sub-tropical forests with mountainous forests and lowland tropical forests. The various types of forests like Tropical moist and dry deciduous forests, Tropical forests, Tropical Evergreen forests, Tropical semi-evergreen forests, Grass and Savannas, Temperate forests, and Sacred Groves are the types of forest found in Meghalaya. The forests are home to a large variety of mammals, birds, and plants.

The climate of Meghalaya is moderate but humid. The average annual rainfall in Meghalaya is 1200 in some areas. The climate in Meghalaya changes with the augment of monsoon. The average yearly rainfall is around 2600 millimetres in the western part of the northeastern state while the northern Meghalaya receives an annual rainfall between 2500 to 3000 millimetres.

The Khasis, Jaintia, and Garos are the chief inhabitants of the state of Meghalaya. The Khasi people form the majority of the population of the eastern part of Meghalaya. The Garo people are the second-largest tribe in Meghalaya.

(a) Elevation :

Both the primary and secondary data were gathered and probable distribution areas of the pitcher plant in Meghalaya were identified. The trail survey method[10,11] was

followed in the field to locate the distribution of pitcher plants in each identified area. Wherever there was a sighting of the pitcher plant, the GPS coordinate, as well as elevation data of the site, was recorded with the help of a GPS Garmin Etrex 10 device. For cross-verification of the elevation, we also used an altimeter device.

(b) Threats :

The prevalence of threats within a 50 m radius of the pitcher plant area was ascertained to record the landscape-level threat perspective. Habitat degradation and conversion into a human settlement, mining, forest fire overexploitation of the species, etc. have a major impact on population viability[13]. Data on these parameters were collected from the field sites which then were cross-verified with the land use map. As the major source of livelihood of this region is jhum cultivation which is done by slash-and-burn shifting cultivation that causes severe loss of habitat, a GIS-based map was also prepared to identify the areas prone to forest fire.

Status of the habitat :

Pitcher plants are growing in hilly areas and are mostly found at the hill slope and cliff (Table-1). Occasionally, they were found at the roadside slope and steep river bed. These slopes varied from moderate to very steep. They occur in both primary as well as secondary forests. But most of them were found in open canopy forest habitats with sunlight intensity or partially shaded areas. Except for some protected areas (national parks and wildlife sanctuary) and non-protected areas (reserved forests) belonging to the forest department, the majority of the pitcher plant distribution sites are located on private land. In very few cases, they were also found close to agricultural plots.

Elevation :

In Jaintia Hills (East and West Jaintia Hill Districts) of Meghalaya, the pitcher plants were found in and around Tuber Kmaishnong, Rymbai, Bataw, Umtasai, Ladwah Wapung, Ksietphare, Tuber Kmaishnong, Dain Satlang, Pynurleba, Umsang, Ipmala, Suchen Shnong, Suchen mulieh, Moonpun Falls, Stone bridge, Lechka Dam site, Suchen Dhana, Deinsalalu, Mukkjai, Jarain, Shken Pyrsit, Thluamvi, Skhentalang, Jarain Pitcher Plant Lake, Thangbuli Road, Amsarim and Mustem. All these locations where the pitcher plants were found had an altitude between 650 and 1400 m above M.S.L. (Table-1; Fig. 1). These plants were mostly found either on the hill slope or on hill cliffs. Some of them were also found at the road cliff.

In Garo Hills, locations (Baghmara Pitcher Plant Sanctuary, Balsri Gittim, Baghmara, Bhawanipur, Dilsa Jarek/ Abri, Matcha-Nokpante Community Conserve Pitcher Plant Reserve, Bandarigre Community Reserve and Nokrek Biosphere) where the pitcher plants occurred at an altitude between 565 and 1430 m above M.S.L. (Table-1; Fig. 1).

In Khasi Hills (East, West, and South Khasi Hill districts), the pitcher plants were found in and around Ranikor, Lawbah, Pynursla, Mawsynram, Nonglang, Phlangdilion, and Santi Pahar areas at about 800-1200 m altitude above M.S.L. (Table-1; Fig. 1). However, no pitcher plant was found in Ri-Bhoi district area of Meghalaya.

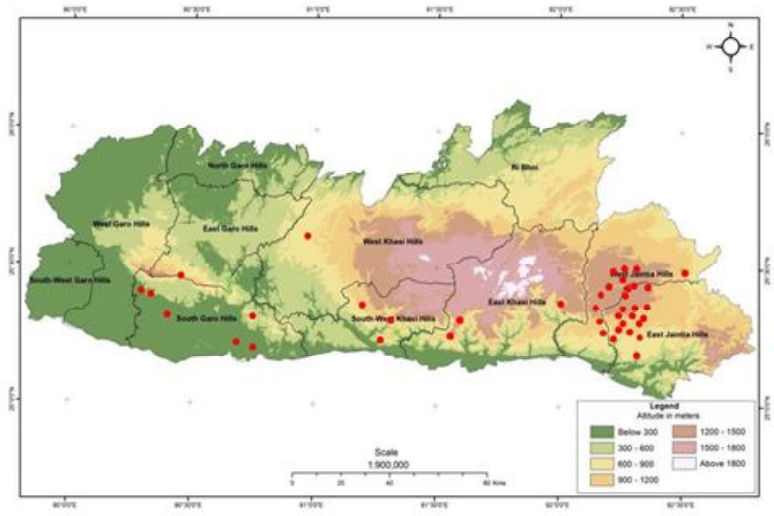

Fig. 1. Impact of elevation on the distribution of pitcher plant, *N. khasiana* in Meghalaya

Table-1. Landscape parameter and altitudinal variation in the distribution of pitcher plant, *Nepenthes khasiana* in Meghalaya

Hills	Distribution	Elevation	Locations†	Canopy	Land status†
Jaintia Hills	Ksietphare	1330	Hill slope	Open	Private land
	Tuber Sohshrich	1400	Hill slope	Open	Private land
	Moonpun Falls	1300	Hill slope near river bad	Open	Private land
	Stone bridge	1310	Hill slope	Open	Private land
	Tuber Kmaishnong	1390	Hill slope near river bad	Open	Private land
	Rymbai	1200	Hill slope	Open	Private land
	Bataw	1080	Hill slope	Open	Private land
	Umtasai	960	Hill slope	Open	Private land
	Ladwah Wapung	970	Hill slope	Open	Private land
	Dain Satlang	970	Hill slope	Open	Private land
	Pynurleba	930	Hill slope	Open	Private land
	Umsang	1150	Hill slope	Open	Private land
	Ipmala	1090	Hill slope	Open	Private land
	Suchen Shnong	1070	Hill slope	Open	Private land
	Suchen mulieh	960	Hill slope	Open	Private land
	Lechka Dam site	930	Hill slope	Open	Private land
	Suchen Dhana	940	Hill slope	Open	Private land

	Deinsalalu	1180	Hill slope	Open	Private land
	Mukkjai	680	Hill slope	Open	Private land
	Jarain	650	Roadside slope	Open	Private land
	Shken Pyrsit	680	Plain	Open	Private land
	Thluamvi	690	Hill cliff	Open	Private land
	Skhentalang	720	Road side slope	Open	Private land
	Jarain Pitcher Plant Lake	680	Plain	Open	Private land
	Thangbuli Road	670	Road side slope	Open	Private land
	Amsarim	660	Hill slope	Open	Private land
	Mustem	680	Hill cliff	Open	Private land
Garo Hills	Balsri Gittim	610	Roadside slope	Open	Reserved Forest
	Baghmara Pitcher Plant Sanctuary and Baghmara	630	Hill slope	Open	Wildlife Sanctuary
	Bhawanipur	590	Hill slope	Open	Reserved Forest
	Dilsa Jarek/ Abri	690	Hill slope	Open	Reserved Forest
	Matcha-Nokpante Community Conserve Pitcher Plant Reserve	565	Hill slope	Open	Community Reserve
	Bandarigre Community Reserve	640	Hill slope	Open	Community Reserve
	Nokrek Biosphere	1430	Hill slope	Open	National Park
Khasi Hills	Mawsynram	1200	Hill slope	Open	Private land
	Nonglang	1080	Hill slope	Open	Private land
	Phlangdilion	940	Hill slope near river bad	Open	Private land
	Ranikor	830	Hill slope near river bad	Open	Private land
	Lawbah	800	Hill slope	Open	Private land
	Pynursla	1050	Hill slope	Open	Private land
	Santi Pahar	870	Hill slope	Open	Private land

Threats :

Being a hilly state, shifting cultivation is the traditional way of agriculture by the tribal people of Meghalaya[6,38,39]. For this, people cut and burned the forest land and then practiced agriculture. After the final crop is harvested, the area becomes fallow land. Next year, people select another plot and follow the same slash and burned technique to prepare the land for agriculture. Recent data indicates that the Meghalaya state lost about 112 sq. km. area in the last two years of which Jaintia Hills lost a total of 64 sq km of forest cover followed by West Garo Hills which lost 27 sq. km and West Khasi Hills with a total loss of

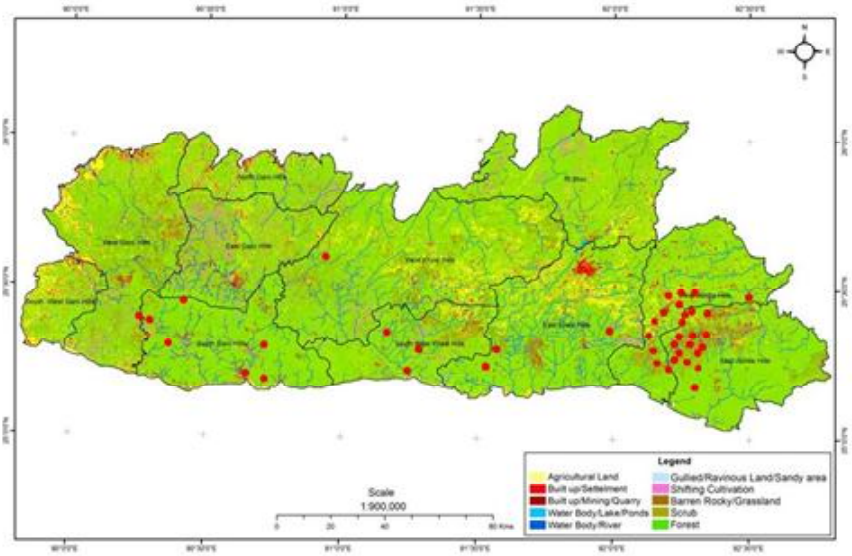

Fig. 2. Land use map showing the destruction of prime pitcher plant habitat into settlement and mining. The present distribution of pitcher plants is depicted as dots.

26 sq. km. Other districts lost a total of 5 sq. km[27]. The Geospatial study indicated a loss of about 64.18 to 158.8 sq. km. between 1999 and 2013 in Garo Hill alone[45]. The land use map of 2021 prepared for this study further indicates that a large chunk of primary forest which was once a habitat of pitcher plants is lost due to shifting cultivation and expansion of settlement area (built-up area), (Fig. 2).

As Meghalaya state is rich with large deposits of several minerals such as coal, limestone, kaolin, clay, granite, glass-sand, and uranium, uncontrolled and unscientific mining of minerals results in reduction of the forest cover and loss of biodiversity apart from other environmental problems. The land use map prepared for 2021 (Fig. 2) for this study also indicates a drastic change in the loss of prime pitcher plant habitat in the entire state. A previous study conducted in Jaintia Hills of Meghalaya also reported that there was 13.76 sq. km. area under mining at the time when there was 95.12 sq. km. dense forest in 1975. The total area under mining increased to 45.24 sq. km. when the dense forest area decreased to 51.52 sq. km. in 2001[42,43]. He also reported that there was 57.05 sq. km area under high fragmentation in the year 1975 which increased to 68.23 sq. km. in 2001. A similar study was conducted in the Nokrek Biosphere Reserve in the Garo Hills of Meghalaya, India where an adverse effect was reported on the vegetation and the density of trees, shrubs, and herbs in coal-mined areas[44]. All these studies further reported not only the shrinkage of forest cover but also the fragmentation of forest which ultimately resulted in the loss of valuable plant species like *N. khasiana.*

The primitive and unscientific 'rat-hole" method of mining adopted by private

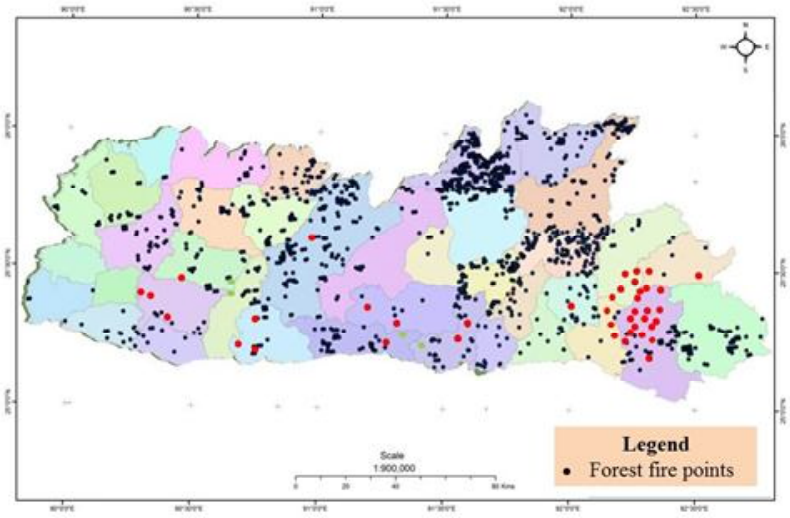

Fig. 3. Map of Meghalaya showing a wide abundance of forest fire. The dots indicate the occurrences of forest burning.

operators and related activities has been causing large-scale environmental degradation and severe ecosystem destruction in Meghalaya. This mining practice is an open cast or surface mining that is causing severe loss of the prime habitat of pitcher plants (Fig. 2).

Forest fire is also identified as another major cause of threats in Meghalaya which is causing the death of pitcher plants. The GIS map prepared for 2021 further depicted that the majority of the forest patch is under threat of forest fire (Fig. 3). This detrimental factor not only dominates the soil structure and composition but also adversely hinders the growth of pitcher plants in their natural habitat. As a result, the population of pitcher plants was wiped out from many areas where there was a distributional record till a few decades.

N. khasiana has great ethno-medicinal importance among the local communities of Meghalaya. The various parts of this plant are traditionally used by different indigenous communities for treatment of various diseases[14,30]. Besides this, modern allopathic use of pitcher plant extract is well established[40]. In addition to its medicinal value, *N. khasiana* is also in great demand for its ornamental value on account of the fascinating beauty of the pitchers[35]. Therefore, unsustainable collection from the wild and subsequently trading of pitcher plants in the local market under the name "*Tiew rako*" were reported[33,4]. These contribute to a large chunk loss of the pitcher plants population that leads to local trade.

The majority of the *Nepenthes* plants grow well in open or exposed habitats among the shrub, and very rarely occur within lowland dipterocarp and other forest. Holttum[23] also reported that Nepenthes plants are only found in open places, never in shady primitive forests. He also reported that some species are highly adapted and exposed to mountain ridges. Hotta and Tamin[25] found that Sumatran *Nepenthes*

in lowland and montane areas grow in exposed habitats such as secondary scrub or bush, roadside clearing, and montane mossy forest. Green[19] observed a similar situation for Nepenthes in Singapore. Hidayat *et al.*[22] reported open canopy and watery as well as relative fertile soil to be the habitats of *Nepenthes* in Sampit Botanic Gardens, Central Kalimantan, Indonesia. Our finding about the distribution of *N. khasiana* mostly in hilly terrain with open forest canopy of Garo, Khasi, and Jaintia Hills of Meghalaya further matches with the previous studies on the distribution of most of the *Nepenthes* species.

Our study found that the pitcher plant is distributed between 500 and 1500 m elevation above the M.S.L. irrespective of hills in Meghalaya. Previous studies conducted by Mao and Khurbuli[33] reported that *N. khasiana* in West Khasi Hills to East Khasi Hills, Jaintia Hills, East to West, and South Garo Hills occurred at 1000 to 1500 m altitude. A similar phenomenon was also reported in other species of pitcher where four new species of Nepenthes were reported from the central mountains of Mindanao, Philippines growing in a lower montane forest around 1000 m of elevation[20]. Lagunday *et al.*[32] found two new Nepenthes species from the mountains of central Mindanao, Philippines at 1,000 – 1020 m elevation. Lagunday and Amoroso[31] again discovered another new species of Nepenthes from the central mountains of Mindanao, Philippines at 1,020-1,050 meters of elevation on Mt. Pantaron range. Ghazalli *et al.*[18] found two new species of *Nepenthes* from Terengganu, Peninsular Malaysia, and observed that they were found between 850-1100 meter elevations in hilly terrain. However, Adam *et al.*[1] reported the distribution of 31 Bornean Nepenthes at an elevation of 3400 m above M.S.L. which is slightly higher than our present study. On the contrary, Rizqiani *et al.*[41] reported the presence of seven species of *Nepenthes* and two natural hybrids in lowland habitats from Bangka Belitung Island at 0-1000 m elevation. These pitcher plants occur in heath forests, secondary forests, swamps, lowland forests, and post-mining land.

It is already established that landscape features, identical habitat conditions, and climatic factors have some role in the species distribution. This is because landscape features affect the variation of the micro-climatic condition of an area. Therefore, some plant species grow in areas with high humidity and frequent rainfall; sometimes, they grow in the sandy ground and even up cliff faces where the soil needs to be light, airy, and mildly acidic. Some species prefer the margins of the forest and secondary vegetation areas[2,15,28]. The morphological characteristics of the plant species also differed between sunny and shady slopes[3]. Previous studies reported that southern slopes exhibit higher shrub species diversity while northern slopes show higher herb species diversity. This variation might be because of spatial redistribution of sunlight, heat, water, and soil nutrients, resulting in the development of micro-climatic conditions with different soil texture and nutrient distributions[17,36,49].

Once the pitcher plants were widely distributed in Meghalaya, their population declined sharply, and about 40% of their total population was lost within their distribution

range[48]. It was observed that the pitcher plants in Garo Hills are threatened due to traffic, road construction, jhum cultivation, human pressure, and tourism. Various threat factors identified for pitcher plants in Jaintia Hills are road construction, human pressure, paddy fields, and tourism. These findings are consistent with Rizqiani *et al.*[41] who stated that habitat destruction and over-exploitation are the factors found to be responsible for its population decline. The primitive and unscientific 'rat-hole" mining method[42-44,46-47] adopted which are an open cast or surface mining that alters the nature of groundwater-surface water interactions and also alters the air, soil, and water pollution. Hence most coal mining districts in India have been declared as critically polluted areas (CPAs) by MoEF&CC in 2009[12]. Prasad and Jeeva[37] indicated the presence of toxicity symptoms (necrotic spot on the leaf merging and pitcher) on the pitcher plant.

Though *N. khasiana* is an endemic species and falls under the endangered species category (SSC-IUCN), special emphasis is required to conserve them in their native area. Meghalaya harbors about 76.33% of the forest cover of the total geographical area[27], but only 4.58% of the total geographical area of the state is under the control of the Meghalaya Forest Department. The remaining area is either private or clan/community-owned and is under the indirect control and management of the Autonomous District Councils. Hence the conservation of pitcher plants needs an urgent policy-level intervention to safeguard their habitat which is outside the protected area network.

The lack of conservation awareness for pitcher plants among the local people of this region is putting the species at the edge of extinction from their primary habitat in Meghalaya and Assam states as well as in India. Until local communities of this region feel proud of being the native owner of this species, conservation goals cannot be achieved.

However, the threats prevailing for pitcher plants need urgent attention as the conservation of these plants is not only needed for ecological and economic benefits but also for safeguarding the cultural values of the inhabitants of Meghalaya.

The authors are thankful to the local people of Meghalaya for providing necessary help during this study. Authorities of the University of Science & Technology Meghalaya are also acknowledged.

References :

1. Adam J.H., C.C. Wilcock and M.D. Swaine (1991). *Journal of Tropical Forest Science, 5*(1): 13-25.
2. Albert V.A., E. Williams and M.W. Chase (1992). *Science, 257:* 1491–1495.
3. Aprill W. and R.C. Sims (1990). *Chemosphere*, *20:* 253-265.
4. Banu G.S., G. Kumar and A.G. Murugesan (2009). *Food and Chemical Toxicology*, *47:* 490–495.
5. Betlu A.L.S. (2016). *Current Science, 111*(8): 1311.
6. Bhatt B.P., A. Pattanayak and P. Tondon (2007). Shifting cultivation: Issues and strategies in the NEH Region. *In:* Tondon P, Abrol YP, Kumaria S. (Eds.), Biodiversity and its Significance. IK International, New

Delhi, 262-273.
7. Cantlon J.E. (1953). *Ecological Monographs, 232:* 41-270.
8. Choudhury A. (2000). *Journal of the Bombay Natural History Society, 97*(1): 166–167.
9. Coblentz D.D. and K.H. Riitters (2004). *Journal of Biogeography*, *31:* 1125-1138.
10. Cole D.N. (1983). Assessing and monitoring backcountry trail conditions. Research paper INT–303, US Dept of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT, USA.
11. Coleman R.A. (1977). *Environmental Conservation, 4:* 145–8.
12. CSE (Centre for Science and Environment). (2012). Coal mining, 1–5. http://www.cseindia.org/userfiles/fsheet2.pdf. Accessed September 03, 2023.
13. Daszak P., A.A. Cunningham and A.D. Hyatt (2000). *Science, 287:* 443–449.
14. Devi R. and N. Venugopal (2006). *Journal of the Swamy Botanical Club, 23*(l-4): 75-80.
15. Ellison A.M. and N.J. Gotelli (2002). Nitrogen availability alters the expression of carnivory in the northern pitcher plant, *Sarracenia purpurea*. Proceedings of the National Academy of Sciences of USA, *99:* 4409–4412.
16. Fang J.Y., Z.H. Shen and H.T. Cui (2004). *Chinese Biodiversity*, *12:* 10-19.
17. Feng Y., K.M. Ma, Y.X. Zhang and Q.R. Guo (2011). *Chinese Journal of Ecology*, *30:* 2137-2144.
18. Ghazalli M.N., A.A. Tamizi, D. Nikong, E.E. Besi, M.I.M. Esa, A.R.M. Nordin, A. Latiff, A.Z. Zaini and M.A. Shakri (2020). *Webbia Journal of Plant Taxonomy and Geography, 75*(1): 5-28. https://doi.org/10.36253/jopt-7950
19. Green S. (1967). *The Gardens' Bulletin Singapore, 22:* 53-65.
20. Gronemeyer T., F. Coritico, A. Wistuba, D. Marwinski, T. Gieray, M. Micheler, F.S. Mey and V. Amoroso (2014). *Plants, 3:* 284-303.
21. Haridasan K. and R.R. Rao (1987). Forest flora of Meghalaya. 2 vols. Dehra Dun, India: Bishen Singh Mahendrapal Singh.
22. Hidayat S., H. Helmanto, D.W. Purnomo and I. Supriyatna (2018). *Biodiversitas, 19*(4): 1258-1265. https://doi.org/10.13057/biodiv/d190411
23. Holttum R.E. (1940). *Malayan Nature Journal*, *1:* 35-44.
24. Hooker J.D. (1886). *The Flora of British India*, Vol. *5:* Kent.
25. Hotta M. and R. Tamin (1986). Nepenthes di Sumatra. *In:* Hotta M. (Ed.), Diversity and dynamics of plant life in Sumatra. Forest ecosystem and speciation in Wet Tropical Environments. Part 1. Report and collection of papers. Sumatra Nature Study (Botany). Kyoto University, 75-113.
26. Huang K.Y. (2002). *International Journal of Remote Sensing, 23:* 2051-2069.
27. ISFR (Indian State of Forest Report). (2019). A report by Forest Survey of India. Ministry of Environment, Forest & Climate Change, Govt. of India.
28. Juniper B.E., R.J. Robbins and D.M. Joel (1989). The carnivorous plants. London: Academic Press.
29. Kanjilal U.N., P.C. Kanjilal, A. Das, R.N. De and N.L. Bor (1936). Flora of Assam, Government Press, Shillong.
30. Kharkhongor P. and J. Joseph (1981). Folklore, medico-botany of rural Khasi and

Jaintia tribes in Meghalaya. *In:* Jain SK (Ed.), Glimpses of Indian ethnobotany. Oxford and IBH, New Delhi, 124–136.

31. Lagunday N.E. and V.B. Amoroso (2019). *Journal of Systematic Biology, 13*(1): 39-45. https://doi.org/10.26757/pjsb2019a13005
32. Lagunday N.E., F.M. Acma, V.G. Cabana, N.M. Sabas and V.B. Amoroso (2017). *Philippine Journal of Science, 146*(2): 159-165.
33. Mao A.A. and P. Kharbuli (2002). *Phytotaxonomy, 2:* 77–83.
34. Momin S.G., M. Pale, P. Sarkar, G. Ahmed and A. Bhattacharya (2023). *Uttar Pradesh Journal of Zoology*, *44*(13): 115-130. https://doi.org/10.56557/UPJOZ/2023/v44i133550
35. Mukerjee A., D.P. Dam and N. Dam (1984). *Indian Journal of Horticulture, 1:* 6–18.
36. Parker A.J. and J.C. Branner (1982). *Physical Geography*, *3:* 160-168.
37. Prasad M.N.V. and S. Jeeva (2009). *Biological Diversity and Conservation*, *2*(3): 29-33.
38. Rai R.N. (1986). Land use under shifting cultivation *In:* Dutta BB (Ed.), Land use pattern of North-East India. Gagan Publishers, Ludhiana, India, 29-40.
39. Ramakrishnan P.S. (1993). Shifting agriculture and sustainable development: An interdisciplinary study from North-Eastern India. New Delhi: Oxford University Press.
40. Reynolds E.H. (1987). *Epilepsia*, *28:* 97–106. https://doi.org/10.1111/j.1528-1157.1987.tb03633.x
41. Rizqiani S., N.S. Ariyanti and Sulistijorini. (2018). *Earth and Environmental Science, 197:* 012021. https://doi.org/10.1088/1755-1315/197/1/012021
42. Sarma K. (2005a). Impact of coal mining on vegetation: a case study in Jaintia Hills district of Meghalaya, India. M.Sc. dissertation, International Institute for Geoinformation Science and Earth Observation (ITC), Enschede, the Netherlands.
43. Sarma K. (2005b). Impact of Coal Mining on Vegetation: A case study in Jaintia Hills district of Meghalaya, India. M.Sc. Thesis. International Institute for Geo-information Science and Earth Observation, the Netherlands and Indian Institute of Remote Sensing (IIRS), India.
44. Sarma K. and S.K. Barik (2011). *Biodiversity*, *12:* 154–164.
45. Sarma P.K., Al Huda E., B. Baruah, B.S. Mipun and B.K. Talukdar (2015). *International Research Journal of Environment Sciences*, *4*(11): 1-7.
46. Swer S. and O.P. Singh (2003). *ENVIS Bulletin on Himalayan Ecology*, *11:* 26–33.
47. Swer S. and O.P. Singh (2004). Status of water quality in coal mining areas of Meghalaya, India. In: National seminar on environmental engineering with special emphasis on mining environment. *NSEEME*, 19–20 March, Dhanbad, India, 26–33.
48. Ved D., D. Saha, K. Haridsan and K. Ravikumar (2015). *Nepenthes Khasiana.* The IUCN Red List of Threatened Species 2015: e.T48992883A49009685. Accessed September 03: 2023. http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T48992883A49009685.en
49. Yang Y.C., L.J. Da and W.H. You (2005). *Acta Ecologica Sinica*, *25:* 2830-2840.
50. Ziemer B. (2010). *Carnivorous Plant Newsletter, 39*(3): 67.