J. Orchid Soc. India, 34: 91-99, 2020 *ISSN 0971-5371*

ANALYZING THE CATALOGUE OF *DENDROBIUM* SWARTZ FROM NORTHEASTERN HIMALAYAN STATES AND NORTHERN PART OF WEST BENGAL UTILIZING GIS TECHNIQUES

D Barman, U Parthasarathy[1], and Rampal[2]

ICAR-IARI, RS, Kalimpong- 734 301, West Bengal, India
[1]ICAR-IISR, Chelavoor, Kozhikode- 673 012, Kerala, India
[2]ICAR-NRC for Orchids, Darjeeling Campus, Darjeeling- 734 101, West Bengal, India

Abstract

NorthEastern part of India including Northern part of West Bengal is a hotspot of most of the orchids which represents more than 70% Indian orchid species. Amongst 103 species of *Dendrobium*, 82 are found in this region. As we know, orchid populations are depleting day by day due to the anthropogenic activities and change in climate, a suitable measure is required to predict the current situation and to conserve the valuable species. Realizing the importance of this genus, efforts were presently made in estimating the species richness of *Dendrobium* collected from the different parts of NE Himalayan states and parts of Eastern Himalaya with the help of DIVA GIS (geographic information system) software. Morphological characters of the different species were correlated to the environmental factors. Most of the species of *Dendrobium* (approximately 80%) are available at 1000-2000 m altitude with a suitable temperature variation of 10-25°C and 1000-3000 mm rainfall zone. The species richness is higher in Central Meghalaya, parts of North Bengal, parts of Arunachal Pradesh, and parts of Upper Assam.

Introduction

DENDROBIUM SWARTZ is one of the largest, epiphytic, rarely lithophytic orchid genera with 1556 accepted species (Kew Science, 2017). The genus is widely distributed in the countries like Australia, Burma, China, Japan, India, Malaysia, Philippines, New Guinea, New Zealand, Pacific Island, and SouthEast Asia. The species of genus *Dendrobium* have adapted to a wide variety of habitats ranging from high altitudes in the Himalayan region to lowland tropical forests, and even to the dry climate. The genus is very large, biologically diverse, and taxonomically complex (Misra, 2007). In India, it is the second largest genus after *Bulbophyllum* and is represented by 114 species (Singh *et al.,* 2019) distributed in the Eastern and NorthEastern Himalayas, Western Himalayas, Western Peninsular region, and Andaman and Nicobar Islands. The NorthEast region stretches between 21.57° to 29.30° N latitude and 88.46° to 97.30° E longitude and is bordered by China in the North, Bhutan in the West, Bangladesh in the South, and Myanmar in the East. The NorthEastern India falls under the Eastern Himalayas and comprises of eight states *i.e.*, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura and occupies a total geographical area of 2,62,251 km^2 (9% of the country). This region possesses a great diversity in physiographic and climatic conditions. Similar situation also prevails in Northern part of West Bengal. The region experiences high temperatures combined with high rainfall which stimulates the growth of forest vegetation. The forests have enormous variation in their topography and floral characteristics ranging from tropical ever green at lower altitude; richness of flora at subtropical wet hills, mixed coniferous and coniferous forests at temperate followed by sub-alpines pastures, and Birch, *Rhododendron* at higher levels. The flowers of *Dendrobium* species are very attractive and last for a few days to almost a month. Hybrids last for longer period depending on season and genetic makeup. The long lasting feature of flowers makes the orchids, an important cash crop (Gupta and Saravanan, 2017; Hegde, 2016; Janakiram and Baskaran, 2018; Patnaik *et al.,* 2017). Extracts from *Dendrobium* contain the chemicals like dendrobine, dendroxine, dendramine, and several others. Of these, dendrobine has pharmacologic effects that include analgesic (pain-killing) and antifever effects (http://hprconline.org/dietary-supplements). The principal characteristics of the genus, for example, size, habit, form of stem and leaf, shape, structure, and colour of the flowers vary significantly at inter-specific level. This genus of sympodial orchids develop *pseudobulbs*, which vary in length from under a centimeter (*D. leucocyanum*) to several metres long (*D. discolor*), resembling canes. *Leaves* are strap-shaped or ovate, or sometimes very narrow and grass like, deciduous or persistent. In selected species, the short, ovate leaves grow alternately over the whole length of the stems; in others the leaves are bunched towards the apex of the stem (*D. tetragonum*). *Flowers* are borne on lateral or

Received: November 5, 2020; Accepted: November 28, 2020

terminal branches from the nodes of the *pseudobulb* or cane or in the apical clusters or spikes (Bose *et al.,* 1999). The axillary *inflorescence* vary in length from insignificant to 1 m long, and can carry from a few (1-4) (*D. nobile*) to as many as 100 (*D. speciosum*) *flowers*. Deciduous species carry their *leaves* for one to two years then typically flower on leafless *canes*, while canes of evergreen species usually flower in the second year and can continue to flower for a number of years (*D. densiflorum*).

These orchids grow quickly throughout the summer, but take a rest during winter. Dormant buds erupt into shoots from the base of the pseudobulb mainly in spring and a few species in autumn. This is then followed by rapid growth of new roots. Reproduction is usually through seeds, but a few species reproduce asexually through kiekies produced along the stem, usually after flowering and sometimes as a result of injury to the growing tip. Based on the temperature requirement, *Dendrobium* orchids are grouped in three different classes as species grown in cool temperature (10 to 24°C), intermediate temperature (14 to 26°C), and warm temperature (16 to 30°C). In India, dendrobiums are mostly distributed in tropical and subtropical zone; few in sea level and temperate zone. In general, most of the species require heat and higher humidity with moderate light and air for active vegetative growth. Some species are widely distributed and occur under a variety of environmental conditions and others are narrowly distributed and endemic to small area often at very uniform environmental conditions. GIS habitat models have been demonstrated to be powerful cost-effective methods for identifying potential habitats of plant species (Agee *et al.,* 1989; Clark *et al.,* 1993; Pereira and Itami, 1991). Although GIS models for individual plant species are less common (Cherrill *et al.,* 1995), plant communities have been identified with remotely sensed satellite data and ancillary GIS data layers (Lauver and Whistler, 1993; Schriever, 1992). A geographic information system (GIS) is very useful to facilitate locating potential habitat. The collection survey data could be analysed with GIS software in order to generate a comprehensive map, which will give the information about the climatic conditions required for the species as well as the potential hotspot of species richness and diversity. Barman *et al.* (2012) studied the hotspot of *Cymbidium* in Sikkim with the help of GIS. Parthasarathy *et al.* (2006) identified the species richness and diversity of Black pepper in Western Ghats and predicted the domain of *Piper* species in India.

The aim of this study relates strongly to conservation issues and efforts were made to estimate species richness of *Dendrobium* species collected from the different parts of NE Himalayan states with the help of DIVA GIS software and to predict domain of *Dendrobium,* in India. The morphological characters of the different species were studied and compared to understand the influence of environment, if any.

Material and Methods

Sample Collection

A total of 241 *Dendrobium* plants corresponding to 32 species were collected from NE Himalayan states of India and Northern part of West Bengal from 2011 to 2015. The geographical coordinates of the sample collection sites and altitude were obtained using GPS device at the time of collection.

Morphological Studies

Observations were taken on the 18 variable morphological characters of the collected samples. The morphological traits on plant height, length and width of leaves, inflorescence length, peduncle length, length of ovary, number and size of flowers, size of sepals and petals, size of lip, and number and length of pollinia were recorded.

Cluster Analysis

A phenogram was constructed in NTSys-PC tool using the quantitative data matrix of morphological features. Principal component analysis (PCA) was performed using Past3 tool and calculated variance of Eigen values to determine the morphological traits that had influenced the clustering patterns.

GIS Studies

The geographical coordinates of all the sample collection locations were used to create a data matrix, which was then used to create a 'shape' file in DIVA-GIS. The habitat aspects of *Dendrobium* species such as altitude, total annual rainfall, and the mean annual temperature were analyzed using DIVA-GIS by superimposing the grid maps of altitudes, temperature, and rainfall of NE India. The diversity of *Dendrobium* species in the collection regions were determined using tool DIVA-GIS by Shannon Diversity index method (Shannon and Weaver, 1949). Species richness in the collection areas was determined by Chao (1984) method in DIVA-GIS. In both the studies, circular neighbourhood method was opted with a cell size of 0.5 × 0.5 degree for calculation.

The suitable domains of *Dendrobium* species were predicted using Ecocrop method in DIVA-GIS. The growth parameters considered were as follows, Length of growing season- Gmin (90), Gmax (300), Gused (180);

Table 1. Species collected and number of collections per species of *Dendrobium.*

Species	Number of collections	Species	Number of collections	Species	Number of collections
Dendrobium aduncum Lindl.	3	*D. devonianum* Paxton	7	*D. lituiflorum* Lindl.	8
D. amoenum Wall. ex Lindl.	3	*D. falconeri* Hook.	14	*D. moschatum* (Buch.-Ham.) Sw.	20
D. anceps Sw.	21	*D. farmeri* Paxton	2	*D. nobile* Lindl.	18
D. aphyllum (Roxb.) C.E.C.Fisch.	25	*D. fimbriatum* Hook.	16	*D. parishii* Rchb.f.	2
D. candidum Wall. ex Lindl.	4	*D. formosum* Roxb. ex Lindl.	6	*D. porphyrochilum* Lindl.	1
D. cathcartii Hook.f.	3	*D. heterocarpum* Wall. ex Lindl.	5	*D. primulinum* Lindl.	4
D. chrysanthum Wall. ex Lindl.	13	*D. hookerianum* Lindl.	4	*D. stuposum* Lindl.	1
D. chrysotoxum Lindl.	11	*D. infundibulum* Lindl.	2	*D. sulcatum* Lindl.	5
D. crepidatum Lindl. & Paxton	4	*D. jenkinsii* Wall. ex Lindl.	3	*D. transparens* Wall. ex Lindl.	5
D. cumulatum Lindl.	2	*D. lindleyi* Steud.	2	*D. wardianum* R.Warner	2
D. densiflorum Lindl.	13	*D. longicornu* Lindl.	12		
				Total	241

Temperature variables- KTmp (0), Tmin (10), TOPmn (20), TOP mx (30), Tmax (33); and precipitation variables- Rmin (1500), ROPmin (2500), ROPmax (3500), and Rmax (4700).

Results and Discussion

The different *Dendrobium* species and the number of collections per species are given in Table 1. The collection of *Dendrobium* species was done in NorthEastern part of the country including Northern part of West Bengal. The availability of species is not homogenous and its distribution varies from place to place. Therefore, spatial distribution of a species in different parts of its geographical distribution can be limited by different factors (Brown and Gibson, 1983). The NE region is one of the biodiversity hotspots covering tropical moist deciduous, tropical semi-evergreen, tropical wet evergreen, sub-tropical, temperate, and alpine forests. These forest cover created microclimate which harbor enormous flora and fauna. About 82 species of *Dendrobium* were reported from NE region (Lokho, 2013). *Dendrobium* species of NE region are mainly confined to subtropical and tropical zone and are lesser in plains and temperate zone due to their climatic sustainability (Bose *et al.,* 1999).

Table 2. Eigen value and variance of main characters of *Dendrobium.*

Characters (cm)	Eigen value	% variance
Plant height	3025.1300	90.0300
Length of leaf	230.3950	6.8567
Width of leaf	48.8257	1.4531
Length of inflorescence	33.0874	0.9847
Length of peduncle	10.5250	0.3132
Length of ovary	4.3969	0.1309

Morphological Cluster

The morphological study was done for 18 characters and the Eigen value and variance were studied (Table 2). The maximum Eigen value (3025.13) and variance (90.03%) was recorded in case of plant height. The principal component analysis of the 18 characters of the 32 species indicated that characters like plant height, leaf length and width, inflorescence length, peduncle length, and ovary length are the characters having maximum variations and influenced the morphological cluster (Table 3). These variables, therefore, are predicted to affect the distribution patterns of wild plants.

The dendrogram obtained by using morphological characters in Manhattan's distance analysis is shown in Fig. 1. The dendrogram has separated all 32 *Dendrobium* species into 9 main clusters. The species *D. aduncum, D. amoenum, D. cathcartii,* and *D. cumulatum* grouped into first cluster in which *D. amoenum* and *D. cumulatum* were closely related. The species *D. amoenum* was recorded at higher altitude between 1300-1700 m amsl whereas, *D. cumulatum* was found at altitude of 250-650 m amsl. The remaining two species from the first group were found at lower altitude (250-400 m amsl). The second cluster

comprised of *D. chrysanthum, D. devonianum,* and *D. falconeri* where *D. devonianum* and *D. falconeri* were closely related. All three species were found at subtropical zone at altitude 600-2000 m amsl. The third cluster comprised of *D. formosum, D. infundibulum, D. nobile,* and *D. wardianum*. The species *D. formosum*

Table 3. Species wise morphological characters influenced the cluster.

Species	Plant height (cm)	Length of leaves (cm)	Width of leaves (cm)	Inflorescence length (cm)	Peduncle length (cm)
Dendrobium amoenum Wall. ex Lindl.	45.00	7.50	1.60	1.50	0.25
D. cumulatum Lindl.	42.00	7.50	1.45	1.50	0.82
D. aduncum Lindl.	40.00	7.50	1.10	2.60	0.50
D. cathcartii Hook.f.	50.00	8.50	0.85	1.50	0.30
D. chrysanthum Wall. ex Lindl.	65.00	10.50	2.30	-	0.40
D. devonianum Paxton	60.00	8.50	1.20	2.50	1.20
D. falconeri Hook.	65.00	7.50	0.28	2.50	0.50
D. formosum Roxb. ex Lindl.	35.00	10.20	2.80	4.50	1.60
D. nobile Lindl.	35.00	10.50	2.50	4.20	1.70
D. infundibulum Lindl.	40.00	10.25	1.50	3.50	1.80
D. wardianum R.Warner	45.00	11.25	2.25	3.50	1.25
D. lituiflorum Lindl.	35.00	7.20	1.30	4.50	2.10
D. primulinum Lindl.	35.00	10.50	2.10	5.60	0.50
D. farmeri Paxton	35.00	14.00	4.50	16.00	4.00
D. fimbriatum Hook.	58.00	12.50	2.15	15.50	2.50
D. transparens Wall. ex Lindl.	45.00	8.50	1.90	12.00	0.25
D. anceps Sw.	25.00	2.45	0.75	1.25	0.35
D. candidum Wall. ex Lindl.	15.00	4.50	0.75	1.10	0.65
D. longicornu Lindl.	22.50	4.50	1.20	0.62	0.50
D. crepidatum Lindl. & Paxton	25.00	7.50	1.45	1.30	0.11
D. stuposum Lindl.	26.50	7.50	1.30	2.60	1.50
D. parishii Rchb.f.	15.50	12.50	2.50	0.90	0.25
D. jenkinsii Wall. ex Lindl.	2.50	2.40	1.25	1.10	1.50
D. porphyrochilum Lindl.	2.50	2.80	0.80	7.00	2.20
D. peguanum Lindl.	2.00	5.80	0.70	2.00	0.40
D. chrysotoxum Lindl.	20.50	9.50	1.75	21.50	7.10
D. sulcatum Lindl.	20.00	14.00	4.00	8.00	2.50
D. lindleyi Steud.	7.50	11.00	3.00	26.00	9.50
D. moschatum (Buch.-Ham.) Sw.	1.25	12.50	3.50	26.00	9.50
D. densiflorum Lindl.	30.00	16.60	5.25	19.75	5.25
D. aphyllum (Roxb.) C.E.C.Fisch.	60.00	2.20	1.20	20.00	0.60
D. hookerianum Lindl.	95.00	10.00	3.00	12.00	3.50

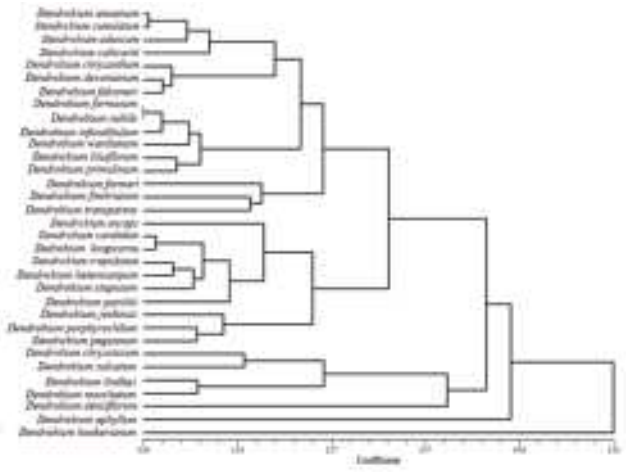

Fig.1. Phenogram of *Dendrobium* spp. based on Manhattan's Distance.

and *D. nobile* were found closely related. *D. formosum* was found at 300-700 m amsl altitude whereas *D. nobile* was available at 300-1500 m amsl altitude; while distantly related species *D. wardianum* occurred in middle altitude 1000-1500 m amsl. Species *D. lituiflorum* and *D. primulinum* made the fourth cluster. In the fifth cluster, *D. fimbriatum* and *D. transparens* were close with a co-efficient value (1.70). However, *D. farmeri,* a very rare species, was little distantly related, occurring at 300-900 m amsl altitude. *D. anceps* which was abundantly available at lower altitude (220-500 m amsl) and *D. parishii* which was available at higher altitude (1500-1800 m amsl) did not form cluster. However, they were distantly related with the species of cluster six. The first pair of cluster six, *D. candidum* and *D. longicornu* was closely related (coefficient 0.79); both were available at middle to higher altitude (1000-2200 m amsl). Similarly, *D. crepidatum* and *D. heterocarpum* of this cluster made a group. Both the species were available at altitude range of 1100-1500 m amsl. The pair of *D. porphyrochilum* and *D. peguanum,* rare orchids of Sikkim of cluster seven was closely associated and formed secondary pairing with *D. jenkinsii. D. porphyrochilum* was a temperate species occurring at altitude 1850-2350 m amsl. *D. chrysotoxum* and *D. sulcatum* form a pair to make cluster eight. *D. chrysotoxum* was available at medium altitude level (1300-1800 m amsl) while *D. sulcatum* was found at little lower level (600-900 m amsl). *D. lindleyi* and *D. moschatum* were closely associated and formed cluster nine. Both were available at middle altitude. *D. aphyllum, D. densiflorum,* and *D. hookerianum* made secondary and tertiary clustering with other species. Similar kind of DNA based correlation was developed amongst 20 species of *Dendrobium* collected from NE hill region of India by Chaudhary *et al.* (2014). Our findings were, however, found to be partially correct with their analysis.

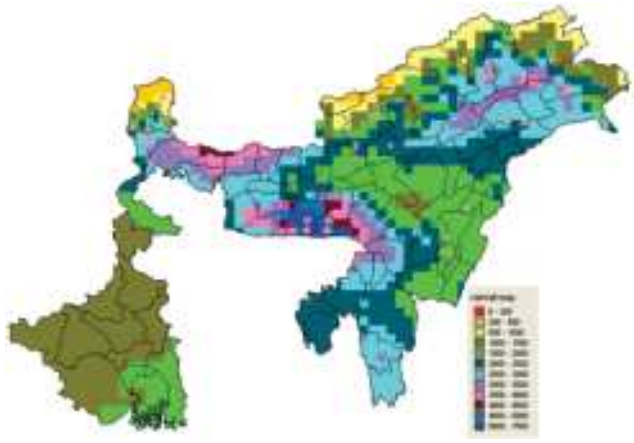

Fig. 2. Total annual rainfall of *Dendrobium* collection locations.

The results indicated that there is a wide range of variation in the plant height, leaf length, and inflorescence length. We further recorded flowering period of different species of *Dendrobium* while surveying and collecting the species. The blooming time of most of the species was in the month of April to May (Table 4). It was further noted that same species flowered earlier in lower altitude than higher altitude which may be due to difference in the temperature and perception of light at two altitudes.

GIS Study

To understand the influence of environment on the variation of the characters, GIS studies were conducted. The study on the annual average rainfall in the areas of availability of *Dendrobium* shows that 1500-5000 mm rainfall zone is suitable to become abode for *Dendrobium* (Fig. 2). Species such as *D. anceps, D. candidum, D. chrysotoxum, D. devonianum, D. eriaeflorum, D. formosum, D. heterocarpum D. longicornu etc.* were found in an area receiving rainfall between 1000-3000 mm. Very rare species of *Dendrobium* (*D.*

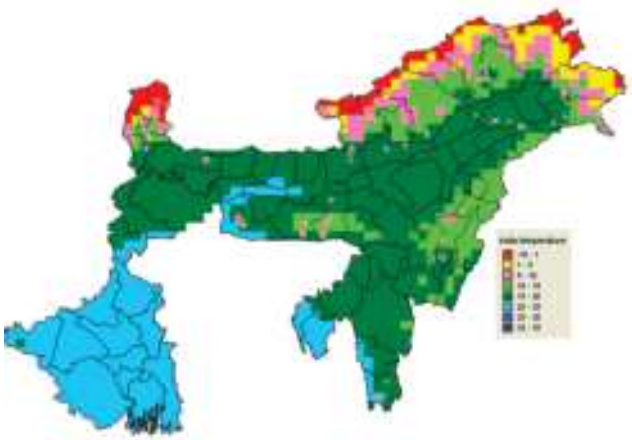

Fig. 3. Average annual temperature of the *Dendrobium* collection locations.

porphyrochilum, D. stuposum) were found in higher rainfall zone of 6000-7000 mm. The temperature conditions of the sites of collection of *Dendrobium* species showed that average 10-25°C is very suitable for most of the species, although some of the species were available at temperate zone (Fig. 3). These

Table 4. Flowering time of *Dendrobium* and range of altitude for availability.

Species	Flowering time		Altitude range (m)
	From	To	
Dendrobium wardianum R.Warner	February	March	425-1255
D. lituiflorum Lindl.	February	April	552-1526
D. devonianum Paxton	February	May	1200-3015
D. falconeri Hook.	February	May	260-3015
D. parishii Rchb.f.	February	May	1350-1620
D. fimbriatum Hook.	March	May	265-2000
D. infundibulum Lindl.	March	May	786-1412
D. lindleyi Steud.	March	May	950-1960
D. aduncum Lindl.	April	May	600-994
D. anceps Sw.	April	May	65-1400
D. aphyllum (Roxb.) C.E.C.Fisch.	April	May	250-1720
D. chrysotoxum Lindl.	April	May	260-3015
D. crepidatum Lindl. & Paxton	April	May	425-1456
D. densiflorum Lindl.	April	May	750-2500
D. farmeri Paxton	April	May	300-425
D. heterocarpum Wall. ex Lindl.	April	May	994-1675
D. nobile Lindl.	April	May	265-2500
D. porphyrochilum Lindl.	April	May	2500
D. primulinum Lindl.	April	May	240-1350
D. sulcatum Lindl.	April	May	240-2640
D. cathcartii Hook.f.	April	September	265-655
D. Wall. ex Lindl.	April	November	450-1485
D. candidum Wall. ex Lindl.	May	June	1412-2640
D. formosum Roxb. ex Lindl.	May	June	950-1526
D. transparens Wall. ex Lindl.	May	June	265-3015
D. moschatum (Buch.-Ham.) Sw.	May	July	400-1960
D. amoenum Wall. ex Lindl.	June	July	260-1720
D. cumulatum Lindl.	June	July	266-655
D. stuposum Lindl.	June	July	1600-3015
D. chrysanthum Wall. ex Lindl.	July	October	265-3015
D. hookerianum Lindl.	September	October	700-3015
D. longicornu Lindl.	September	November	994-1720

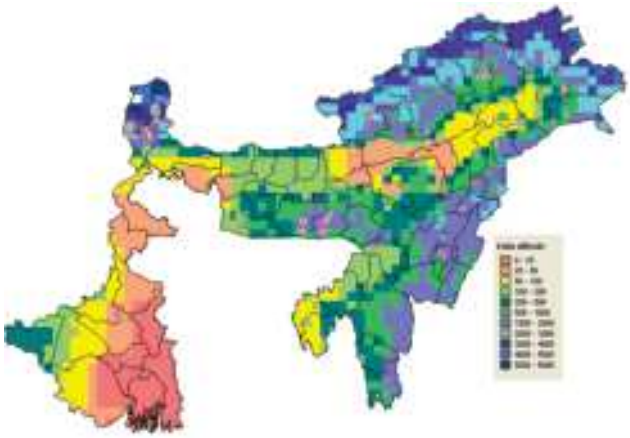

Fig. 4. Altitude (amsl) of *Dendrobium* collection locations.

temperature ranges prevail in subtropical to sub temperate zone. The altitude study indicated that the genus prevails in a large altitudinal variation from 150-3500 m amsl. Altitude is the important factor affecting the appearance of *Dendrobium*. The altitudes of the collection sites of *Dendrobium* in NorthEastern Himalayan region were from 50-4000 m amsl. Most of species were available at 1000-2000 m amsl altitude where temperature was moderately warm (Fig. 4). The species richness map showed that Central Meghalaya and parts of North Bengal are the place where highest richness of the species prevails. But whole of Meghalaya, Sikkim, and parts of Upper Assam and Arunachal may have excellent number of species (Fig. 5). The Shannon diversity index for *Dendrobium* population of collected sites supported the density of population (Fig. 6).

The correlation was made between the collected data of *Dendrobium* species of NE region with the climate and altitude through GIS. Rainfall within the range of 1000-3500 mm was best suited for most of the species. Extreme high or low rainfall reflected the lower distribution of species. Highest number of *Dendrobium* species were found in New Guinea due to high rainfall

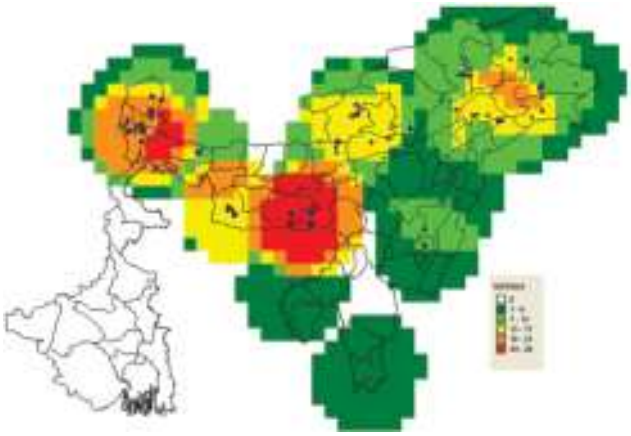

Fig. 5. Species richness of *Dendrobium* in collection domains.

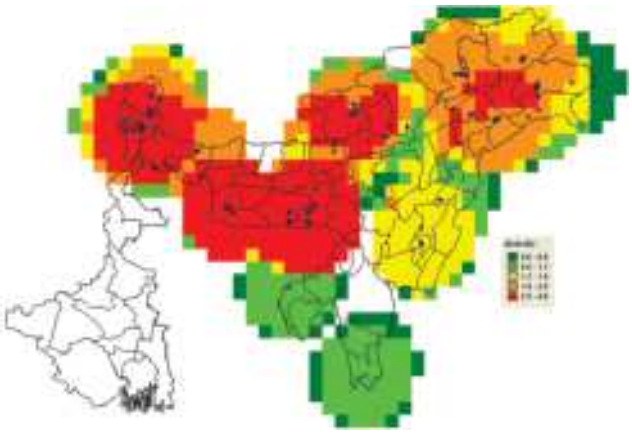

Fig. 6. Shannon diversity index for *Dendrobium* collection locations.

in this region. Most of the *Dendrobium* species prefer moderate to high rainfall and moderate temperature. It implies that forest canopy or vegetation creates a microclimate *i.e.* higher humidity and moderate temperature which is suitable for growth of *Dendrobium* species. It is known that most of the orchids are sensitive to temperature and amount of precipitation for growth and flowering (Janeckova and Kindlmann 2002; Light and MacConaill, 1998; Wells, 1981). Further, altitude was correlated with availability of species. Most of species were available at 1000-2000 m amsl altitude. It is supported by the works of Bose *et al.,* (1999), King and Pantling (1898), Lokho (2013), Mao and Hynniewta (1999), and Sathish Kumar and Manilal (1994).

The species richness was higher in Central Meghalaya, parts of North Bengal, Arunachal Pradesh, Upper Assam because of suitability of congenial climate and vegetation of host trees. Lokho (2013) reported that 82 species of *Dendrobium* are available in NE region of which Arunachal Pradesh alone have 50 species of *Dendrobium*, followed by Manipur (47), Sikkim (41), Mizoram (40), Meghalaya (39), Assam (35), Nagaland (30), and Tripura (5). Vast diversity of *Dendrobium* indicated the climatological suitability of this region. Although richness of species was at 200-2000 m amsl, most of the species of *Dendrobium* were found at wide range of geographical distribution. As for example, *D. falconeri, D. fimbriatum, D. nobile, D. salcutam, D. transparens etc.* are found at lower altitude (250-300 m amsl) to higher altitude (2000-3500 m amsl). It might be due to the wide adaptability of these species. An analysis of co-relation between demographic data and meteorological parameters has shown that the effect of the latter on population of *Dendrobium* species is variable. From the diversity index map, it was found that part of Meghalaya, Assam, Arunachal Pradesh, West Bengal, and Sikkim have the higher diversity index. Richness showed the existence of the species

while diversity index showed the density of the species. The hotspot grid included 32 species under observation. This method is employed for its simplicity, wide adaptation, well versed, and a useful measurement of diversity (Gaston, 1996).

Conclusion

The results of present studies are valuable to the researchers as they may share and employ the data generated during the process, in future studies. The universe continues to evolve at a quicker pace and threats to plants in their native environments rise due to climate change and anthropogenic pressures. Our ability to timely and quickly understand and formulate solutions to these complex issues is essential for plant conservation. In the scenario of climate change, it is important to note that application of GIS approach to germplasm collection can be applied to specific target species as well as to plant diversity as a whole, in a particular zone. Accurate geographical data is essential in order to apply in this method. GIS methodology allows one to predict the presence or absence of genotypes based on its ecological preferences. With appropriate adjustments related to nature of each species, the GIS may prove to be a very useful tool for conservation of genetic resources.

References

Agee, J. K., S. C. F. Stitt, M. Nyquist, and R. Root. 1989. A geographic analysis of historical grizzly bear sightings inthe North Cascades. *Photogramm. Eng. Remote Sens.,* **55**: 1637-42.

Barman, D., R. P. Medhi, U. Parthasarathy, K. Jayarajan, and V. A. Parthasarathy. 2012. A GIS interpretation of diversity of *Cymbidium* Swartz in Sikkim. *MIOS J.,* **12**(10): 8-16.

Bose, T. K., S. K. Bhattacharjee, P. Das, and U. C. Basak. 1999. *Orchids of India* (1st ed.). Naya Prokash, Kolkata, India.

Brown, J. H. and A. C. Gibson. 1983. *Biogeography* (1st ed.). Mosby, St. Louis, Missouri, U.S.A.

Chao, A. 1984. Non-parametric estimation of the number of classes in a population. *Scand. J. Stat.,* **11**: 265-70.

Chaudhary, B., P. Chattopadhyaya, and N. Banerjee. 2014. Modulations in seed micromorphology reveal signature of adaptive species-diversification in *Dendrobium* (Orchidaceae). *Open J. Ecol.,* **4**(2): 33-42.

Cherrill, A. J., C. Watson, P. Mc, K .Tucker, S. P. Rushton, and R. Sanderson. 1995. Predicting the distributions of plant species at the regional scale: A hierarchical matrix model. *Landsc. Ecol.,* **10**: 197-07.

Clark, J. D., J. E. Dunn, and K. G. Smith. 1993. A multivariate model of female black bear habitat use for a geographic information system. *J. Wildl. Manage.,* **57**: 519-26.

Gaston, K. J. 1996. Species richness: Measure and measurement. *In: Biodiversity, A Biology of Numbers and Difference* (ed. K. J. Gaston) pp. 387. Blackwell Science, London, U.K.

Gupta, N. and S. Saravanan. 2017. Effect of different potting media on plant growth and spike yield of *Dendrobium*. *J. Orchid Soc. India,* **31**: 61-64.

Hegde, S. N. 2016. Commercial potential of orchids in India and societal benefits. *J. Orchid. Soc. India*, **30**: 43-49.

Janakiram, T. and V. Baskaran. 2018. Commercialisation and conservation aspects of orchids. *J. Orchid Soc. India*, **32**: 55-61.

Janeckova, P. and P. Kindlmann. 2002. Key factors affecting shoot growth and flowering performance of *Dactylorhiza fuchsia. In: Trends and Fluctuations and Underlying Mechanisms in Terrestrial Orchid Populations* (eds. P. Kindlmann, J. H. Willems, and D. F. Whigham) pp. 99-113. Backhuys Publishers, Leiden, The Netherlands.

Kew Science. 2017. *Dendrobium* Sw. *Plants of the World Online*. Board of Trustees of the Royal Botanic Gardens, Kew, London, U.K.

King, G. and R. Pantling. 1898. The Orchids of the Sikkim Himalaya. *Ann. Royal Bot. Gard.*, **8**: 273-300.

Lauver, C. L. and J. L. Whistler. 1993. A hierarchical classification of Landsat TM imagery to identify natural grassland areas and rare species habitat. *Photogramm. Eng. Remote Sens.,* **59**: 627-34.

Light, M. H. S. and M. MacConaill. 1998. Factors affecting germinable seed yield in *Cypripedium calceolus* var. *pubescens* (Willd.) Correll and *Epipactis helleborine* (L.) Crantz (Orchidaceae). *Bot. J. Linn. Soc.,* **126**: 3-26.

Lokho, A. 2013. Diversity of *Dendrobium* Sw. its distributional patterns and present status in the NorthEast India. *Int. J. Sci. Res. Pub.,* **3**(5): 1-9.

Mao, A. A. and T. M. Hynniewta. 1999. Conservation of threatened plants in North-Eastern India. *In: Biodiversity, North East India Perceptive* (eds. B. Kharbuli, D. Syiem, and H. Kayang) pp. 37-39. NEBRC, NEHU, Shillong, India.

Misra, S. 2007. *Orchids of India, A Glimpse*. Bishen Singh Mahendra Pal Singh, Dehradun, India.

Parthasarathy, U., K. V. Saji, K. Jayarajan, and V. A. Parthasarathy. 2006. Biodiversity of *Piper* in South India-application of GIS and cluster analysis. *Curr. Sci.,* **91**(5): 652-57.

Patnaik, A., M. Kannan, M. Ganga, and S. Vincent. 2017. Studies on influence of nutrient and growth regulator interactions on growth, yield and quality of *Dendrobium* orchid cv. Sonia 17. *J. Orchid Soc. India,* **31**: 9-14.

Pereira, J. M. C. and R. M. Itami. 1991. GIS-based habitat modeling using logistic multiple regression: A study of the Mt. Graham red squirrel. *Photogramm. Eng. Remote Sens.,* **57**: 1475-86.

Sathish Kumar, C. and K. S. Manilal. 1994. *A Catalogue of Indian Orchids*. Bishen Singh Mahendra Pal Singh, Dehradun, India.

Schriever, J. 1992. *Using Multi-Temporal Landsat Thematic Mapper Data to Map Forest Cover-Types in New Hampshire*. M.S. Thesis, University of New Hampshire, Durham, New Hampshire, U.S.A.

Shannon, C. E. and W. Weaver. 1949. *The Mathematical Theory of Communication*. University of Illinois Press, Urbana, U.S.A.

Singh, S. K., D. K. Agrawala, J. S. Jalal, S. S. Dash, A. A. Mao, and P. Singh. 2019. *Orchids of India: A Pictorial Guide.* Botanical Survey of India, Kolkata, India.

Wells, T. C. E. 1981. Population biology of terrestrial orchids. *In: The Biological Aspects of Rare Plant Conservation* (ed. H. Synge) pp. 281-95. Wiley Publisher, Chichester, U.K.