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Floral Diversity Assessment of Forests of Nawada District of Bihar, Eastern India

A. Chandra, H.B. Naithani, P.K. Verma, S. Baig and S. Parajapati

**Systematic Botany Discipline, Forest Botany Division,
ICFRE- Forest Research Institute, New Forest, Dehradun, (Uttarakhand), India**

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ABSTRACT

Phyto-diversity of the forest sites of the Nawada district of Bihar, India was evaluated. A total of 204 species belonging to 171 genera and 63 families were recorded from the district. It includes 55 dicotyledonous families (151 genera, 182 species), 6 monocotyledonous families (18 genera, 20 species) and 2 pteridophyte families (2 genera, 2 species). Different biodiversity indices were used for tree, shrubby and herbaceous layers. On the basis of different biodiversity indices, study reveals that in the tree layer, most diverse site was Pichali Upparisar whereas in shrubby and herbaceous layers Tulsiahari Forest and Pachbahni Forest were the most diverse sites respectively. Varied diversity of tree at different sites may be due to disturbances in the area. Dominance of *Lantana camara* at two sites is a matter of great concern and it may pose heavy problem to other sites in near future. Hence, it is essential to take suitable measures to curb its spread. Findings of study will be useful for conservation and judicious utilization of different components of plant diversity of the Nawada district.

Key words: *Phyto-diversity, Shannon Weiner Index, Species Richness, Invasive Species, Conservation*

Introduction

Biological diversity implies variety and variability of all living organisms on the earth. It also includes diversity within species and of ecosystems. Forests harbor immense biodiversity, sequester carbon dioxide and provide various other tangible and intangible benefits. Change in species diversity and composition in an area is a long duration dynamic process. However, owing to rapid population explosion and industrialization, pressure on forests has increased manifolds resulting in decline in biodiversity. Therefore, for conservation and sustainable utilization of plant resources, inventorization and monitoring of forest biodiversity at regular interval is demand of the time.

Nawada district is one of the districts of Bihar. Its administrative headquarters is Nawada, located at 24°53'2" N latitude & 85°33'2" E longitude. The district has an area of 2,494 km² accounting for 1.43% of the total geographical area of the Bihar State. The Bihar state has forest area of 6,877 km², which accounts for 7.3% of its geographical area. The forest covers in the Nawada district 516.88 km² which is 20.72% of the total geographical area of the state. On the basis of density, 214.68 km² comes under moderately dense forests and 302.20 km² under open forest (FSI, 2021).

Both qualitative and quantitative attributes are essentially required for assessing the diversity of the area. Earlier work on qualitative estimation of different species of the Bihar State was carried out by workers like Haines (1921-24); Mooney, (1950);

Bhattacharya and Sarkar (1998), Singh *et al.* (2001) etc. No work on quantitative assessment of forest vegetation has been reported so far from the region. With view of above in mind, present work was carried out to assess the status of floristic wealth of Nawada District.

The district is bounded in north by Nalanda and Sheikhpura district, in east by Jamui district, in west by Gaya district, while southern half boundary.

Materials and Methods

The study was carried out at forest sites of the Nawada district of Bihar during 2014-15 (Fig.1). The district is bounded in north by Nalanda and Sheikhpura district, in east by Jamui district, in west by Gaya district, while southern half boundary. The climate is usually hot and dry, the winter temperature reaches as low as 4 °C and summer as high as 46°C. The average annual rainfall of the district is 1,037 mm. The maximum rainfall is received from South West monsoon.

Six random forest sites of Nawada district namely 1. Tulsiahari, Nawada Range; 2. Tikwa Baba Jungal, Madhopur, Govindpur Beat, Nawada Range; 3. Pachbahni Forest, Govindpur Beat; 4. Diborup Parisar, Gardibor Beat, Rajoli Range; 5. Rajoli Beat, Pichli Upparisar Range and 6. Jhilar,



Fig. 1. Location map of study area

Mananpur Mohodar Beat, Kawakol Range were selected. Vegetation analysis and field data was collected during 2015-16. GIS cell of the Institute provided random coordinate points for the vegetative data collection. Quadrat number and size were determined by the running mean method (Kershaw, 1973) and species-area curve method (Misra, 1968), respectively. Quantitative analysis of vegetation for frequency, density and dominance was calculated following Misra (1968). Ten quadrats were randomly laid on each site. Quadrat sizes of 10m x 10m, 3m x 3m, and 1m x 1m were laid for trees, shrubs and herbs respectively. In each quadrat, the GBH (girth at breast height at 1.37m above ground level) of each tree was measured and recorded individually. In the case of herbs and shrubs, the collar diameter was measured at 2.5 cm above ground level. Species were identified with the help of concerned floras and matched with specimens housed in DD Herbarium. Plant nomenclature was updated as per Plant of the World Online (POWO, 2023). Values of Relative frequency, density and dominance were summed to get Importance Value Index (IVI). Different biodiversity indices were estimated as given below:

Species richness index was estimated by following (Margalef, 1958):

$$Dmg = S-1/\ln N$$

Where S is the total number of species and N is the total number of individuals

Shannon-Wiener information function (Shannon and Wiener, 1963) was calculated using the formula:

$$H = - \sum p_i \ln p_i$$

Where p_i is (N_i/N) , N_i = Number of individuals of species i and N = Total number of individuals of all the species.

The concentration of dominance (CD) was measured by Simpson Index (Simpson, 1949).

$$CD = \sum (p_i)^2$$

Pielou's evenness index (Pielou, 1966) was calculated using the formula:

$$J = H/\ln (S)$$

Where 'H' is Shannon Wiener diversity index and 'S' is the total number of species

Results and Discussion

A total of 204 species (63 families, 171 genera) were found at forest sites of Nawada forest division. It includes 55 Dicotyledonous families (151 genera, 182 species), 6 monocotyledonous families (18 genera, 20

species) and 2 pteridophytous families (2 genera, 2 species). Largest family recorded from the area is Fabaceae (24 genera, 31 species) followed by Asteraceae (Compositae) (11 genera, 11 species), Poaceae (10 genera, 11 species), Moraceae (3 genera, 11 species), etc. Largest genus is *Ficus* (9 species) followed by *Terminalia* (5 species), *Acacia* (3 species), *Cassia* (3 species), *Dalbergia* (3 species), *Ziziphus* (3 species) etc. On the basis of habit, there were 113 species of trees, 18 shrubs, 22 climber and 51 herbaceous species in the area. Tree species also includes the tree outside the forest areas. A total of 57 species from the dry deciduous forests of Eastern Ghats were reported by Sahu *et al.* (2012). Thakur (2015) reported 36 species of trees, 8 shrubs, and 34 herbs from the Sagar district of Madhya Pradesh. A total of 14 tree species under 10 families were reported from tropical dry deciduous forest of West Bengal (Kumar *et al.*, 2020). Recently, Chandra *et al.* (2021a,b,c; 2022 a, b; 2023) reported 126, 174 156, 129 and 190 species from the forest sites of Aurangabad, Gaya, Banka, Jamui and Kaimur districts of Bihar, respectively. The variations in the number of species in the present work may be due to climatic and edaphic conditions and the extent of the area covered under the study.

Different diversity indices viz., Shannon-Wiener Diversity Index (H), Concentration of Dominance (cd), Evenness (E) and Species Richness (SR) for different growth forms at different sites of Nawada district are presented in Table 4. High diversity is indicated by more number of species in the area. In the tree layer, highest number of species was observed at Rajoli Beat site (39 spp.) followed by Tulsiahari (35 spp.), Jhilar (33 spp.), Diborup Parisar (31 spp.), Diborup Parishar (21 spp.) and Tiwa Baba (18 spp). In case of shrubby layer, highest species value was found in Tulsiahari (35 spp.) and lowest in Jhilar (16 spp). Herbaceous layer had highest species in Tulsiahari (40 spp.) and lowest value was found in Tikwa Baba Jungle (24 spp.). Species Richness was also estimated and similar trend observed.

A greater Diversity Index (H) value implies species diversity and community heterogeneity, whereas a lower value denotes homoge-

Table 1. Top ten dominant species with IVI values of tree layer at different sites

S.N.	Site-I	Site-II	Site-III	Site-IV	Site-V	Site-VI
1	<i>Madhuca longifolia</i> var. <i>latifolia</i> (34.36)	<i>Shorea robusta</i> (56.07)	<i>Shorea robusta</i> (55.61)	<i>Lannea coromandelica</i> (31.13)	<i>Lagerstroemia parviflora</i> (37.87)	<i>Shorea robusta</i> (51.07)
2	<i>Shorea robusta</i> (33.57)	<i>Acacia catechu</i> (37.50)	<i>Anogeissus latifolia</i> (28.10)	<i>Holoptelea integrifolia</i> (21.44)	<i>Terminalia bellirica</i> (22.63)	<i>Boswellia serrata</i> (46.86)
3	<i>Buchanania lanzan</i> (19.89)	<i>Buchanania lanzan</i> (36.27)	<i>Boswellia serrata</i> (27.99)	<i>Bombax ceiba</i> (20.02)	<i>Shorea robusta</i> (18.52)	<i>Lannea coromandelica</i> (20.18)
4	<i>Diospyros peregrina</i> (18.97)	<i>Diospyros melanoxylon</i> (25.45)	<i>Diospyros melanoxylon</i> (20.60)	<i>Madhuca longifolia</i> var. <i>latifolia</i> (19.74)	<i>Aegle marmelos</i> (18.12)	<i>Diospyros melanoxylon</i> (17.34)
5	<i>Terminalia bellirica</i> (18.65)	<i>Phoenix sylvestris</i> (20.69)	<i>Lannea coromandelica</i> (18.89)	<i>Acacia catechu</i> (18.98)	<i>Butea monosperma</i> (16.41)	<i>Anogeissus latifolia</i> (10.84)
6	<i>Ficus racemosa</i> (17.04)	<i>Ficus semicordata</i> (16.83)	<i>Spondias pinnata</i> (17.29)	<i>Terminalia bellirica</i> (15.62)	<i>Bombax ceiba</i> (16.21)	<i>Schleichera oleosa</i> (9.55)
7	<i>Borassus flabellifer</i> (13.11)	<i>Boswellia serrata</i> (12.56)	<i>Lagerstroemia parviflora</i> (16.04)	<i>Boswellia serrata</i> (14.95)	<i>Holarrhena pubescens</i> (10.72)	<i>Terminalia bellirica</i> (9.14)
8	<i>Dalbergia sissoo</i> (11.54)	<i>Cochlospermum religiosum</i> (11.85)	<i>Senecarpus anacardium</i> (13.17)	<i>Ficus mollis</i> (14.13)	<i>Croton roxburghii</i> (10.51)	<i>Buchanania lanzan</i> (9.10)
9	<i>Lannea coromandelica</i> (10.06)	<i>Lannea coromandelica</i> (10.09)	<i>Adina cordifolia</i> (13.17)	<i>Diospyros melanoxylon</i> (13.94)	<i>Cassia fistula</i> (10.22)	<i>Gmelina arborea</i> (8.83)
10	<i>Prosopis juliflora</i> (8.00)	<i>Syzygium cumini</i> (10.09)	<i>Madhuca longifolia</i> var. <i>latifolia</i> (12.09)	<i>Aegle marmelos</i> (11.00)	<i>Terminalia alata</i> (9.41)	<i>Hymenodictyon orixense</i> (8.58)

neity within the community. In the tree layer, highest Diversity Index (H) was estimated for Pichali Upparisar site (3.30) and lowest for Tikwa Baba (2.37). In the shrubby layer, highest Diversity Index (H) value was found for Tulsiahari (3.20) and lowest for Diborup Parisar (1.70). In the herbaceous layer, highest Diversity Index (H) was estimated for Pachbahni Forest (2.70) and lowest for Diborup Parisar, Gardibor Beat (2.02).

Species composition and distribution is mainly affected by the environment which varies from species to species. Important Value Index (IVI) provides information on how dominant is a species in a given forest site. Top ten dominant species of tree, shrubby and herbaceous layers of different forest sites of Nawada districts are given in Tables 1, 2 and 3. In tree layer *Shorea robusta* was dominant species at three sites (II, III, VI) and second most dominated species at site I. *Madhuca longifolia* var. *latifolia*, *Lannea coromandelica* and *Lagerstroemia parviflora* were dominant species at site I, IV and V respectively. In Shrubby layer, *Lantana camara* var. *aculeata* was most dominant species at sites IV and V. In other sites *Combretum roxburghii* (I), *Carissa opaca* (II), *Holarrhena pubescens* (III) and *Diospyros melanoxylon* (VI) were the highest IVI value species. In herbaceous layer, most of the sites were dominated by *Hyptis suaveolens* (IV, V, VI) while *Desmodium triflorum*, *Saccharum bengalense* and *Sida cordata* were at sites I, II and III respectively.

Diversity indices imply to describe properties of communities which are used to compare different regions and taxa. Diversity Indices viz., Shannon-Wiener Diversity Index (H), Concentration of Dominance (cd), Evenness (E) and Species Richness (SR) for different growth forms at different sites of Nawada district is presented in Table. No. 4. The higher value of Diversity Index (H) indicates heterogeneity whereas low value points to homogeneity in the community. In the tree layer, highest Diversity Index (H) was estimated for Pichali Upparisar site (3.30) and lowest for Tikwa Baba (2.37). In the shrubby layer, highest Diversity Index (H) value was estimated for Tulsiahari (3.20) and lowest for Diborup Parisar (1.70). In the herbaceous

Table 2. Top ten dominant species with IVI values of the shrubby layer at different sites

S.N.	Site-I	Site-II	Site-III	Site-IV	Site-V	Site-VI
1	<i>Combretum roxburghii</i> (27.55)	<i>Carissa opaca</i> (32.67)	<i>Holarrhena pubescens</i> (31.64)	<i>Lantana camara</i> var. <i>aculeata</i> (153.00)	<i>Lantana camara</i> var. <i>aculeata</i> (69.74)	<i>Diospyros melanoxylon</i> (54.25)
2	<i>Buchanania lanzan</i> (23.00)	<i>Terminalia bellirica</i> (31.71)	<i>Helicteres isora</i> (30.83)	<i>Holarrhena pubescens</i> (39.73)	<i>Croton roxburghii</i> (49.93)	<i>Woodfordia fruticosa</i> (48.79)
3	<i>Shorea robusta</i> (22.91)	<i>Buchanania lanzan</i> (29.74)	<i>Boswellia serrata</i> (26.19)	<i>Croton roxburghii</i> (11.04)	<i>Casearia tomentosa</i> (21.14)	<i>Holarrhena pubescens</i> (39.67)
4	<i>Croton roxburghii</i> (18.97)	<i>Woodfordia fruticosa</i> (20.42)	<i>Dendrocalamus strictus</i> (24.65)	<i>Eupatorium odoratum</i> (9.48)	<i>Holarrhena pubescens</i> (19.10)	<i>Casearia tomentosa</i> (38.11)
5	<i>Madhuca longifolia</i> var. <i>latifolia</i> (18.97)	<i>Ixora pavetta</i> (18.59)	<i>Diospyros melanoxylon</i> (24.06)	<i>Diospyros melanoxylon</i> (9.39)	<i>Securinega virosa</i> (11.69)	<i>Shorea robusta</i> (29.29)
6	<i>Syzygium cumini</i> (15.94)	<i>Diospyros melanoxylon</i> (18.54)	<i>Woodfordia fruticosa</i> (21.91)	<i>Alangium salviifolium</i> (8.59)	<i>Carissa opaca</i> (11.26)	<i>Croton roxburghii</i> (15.93)
7	<i>Clerodendrum viscosum</i> (12.54)	<i>Streblus asper</i> (17.81)	<i>Aegle marmelos</i> (15.45)	<i>Casearia tomentosa</i> (6.76)	<i>Ziziphus xylopyra</i> (10.78)	<i>Phoenix loureiroi</i> var. <i>pedunculata</i> (10.47)
8	<i>Holarrhena pubescens</i> (11.28)	<i>Terminalia alata</i> (17.36)	<i>Croton roxburghii</i> (14.28)	<i>Clerodendrum viscosum</i> (6.44)	<i>Helicteres isora</i> (9.90)	<i>Ehretia laevis</i> (10.21)
9	<i>Carissa opaca</i> (10.58)	<i>Mimosa himalayana</i> (16.86)	<i>Nyctanthes arbor-tristis</i> (13.76)	<i>Catunaregam spinosa</i> (6.29)	<i>Diospyros melanoxylon</i> (9.08)	<i>Capparis zeylanica</i> (9.91)
10	<i>Ziziphus oenoplia</i> (9.62)	<i>Melastoma malabathricum</i> (12.10)	<i>Buchanania lanzan</i> (12.60)	<i>Gardenia latifolia</i> (4.90)	<i>Woodfordia fruticosa</i> (9.03)	<i>Walsura trifoliolata</i> (7.50)

layer, highest Diversity Index (H) was estimated for Pachbahni Forest (2.70) and lowest for Diborup Parisar, Gardibor Beat (2.02). In our study, the diversity index value ranges from 0.10 to 3.24 as reported in tropical forests of the Indian subcontinent by various workers (Sundarapandian and Swamy 2000, Himanshi and Jakhar 2020; Chandra *et al.* 2021a, b, c; 2022a, b; 2023).

The homogeneous nature of a community increases with Concentration of Dominance (cd) value and vice versa. In the tree layer, Concentration of Dominance (cd) was highest in case of Tikwa Baba Jungle site (0.14) and lowest in Diborup Parisar and Pichali Upparisar (0.05). Shrubby layer had highest value of Concentration of Dominance (cd) at Diborup Parisar and (0.36) and lowest at Tulsiahari (0.05). In the herbaceous layer, highest value of Concentration of Dominance (cd) was estimated for Diborup Parisar (0.25) followed and lowest at Pachbahni Forest (0.12).

High Evenness (E) value of suggests that species are uniformly distributed and vice-versa. In case of tree layer, highest Evenness (E) value was estimated for Diborup Parisar site (0.93) followed and lowest in Tulsiahari (0.81). In case of shrubby layer, highest Evenness (E) value was observed for Tikwa Baba Jungle (0.94) followed and lowest was at Diborup Parisar (0.54). In the herbaceous layer, highest value of Evenness (E) was estimated for Pachbahni Forest (0.80) and lowest for Diborup Parisar (0.62). In our study, Pielou's Evenness Index (E) for the tree, shrubby and herbaceous layers reported similar pattern showed by other tropical Indian forests such as Udaipur, Rajasthan (Kumar *et al.*, 2010), Western Ghats (Sundarapandian and Swamy, 2000), Bundelkhand region of Uttar Pradesh (Verma *et al.*, 2013), South West Haryana (Himanshi and Jakhar, 2020), Nalanda, Aurangabad, Gaya, Banka, Jamui and Kaimur districts of Bihar (Chandra *et al.*, 2021a, b, c; 2022 a, b; 2023).

In the present study, a total of 204 species (63 families, 171 genera) were reported from the forest sites of Nawada forest division. It includes 55 Dicotyledons families (151 genera, 182 species), 6 monocotyledons families (18 genera, 20 species) and 2 pteridophyte families

Table 3. Top ten dominant species with IVI values of the herbaceous layer at different sites

S.N.	Site-I	Site-II	Site-III	Site-IV	Site-V	Site-VI
1	<i>Desmodium triflorum</i> (42.50)	<i>Saccharum bengalense</i> (76.24)	<i>Sida cordata</i> (52.18)	<i>Hyptis suaveolens</i> (97.48)	<i>Hyptis suaveolens</i> (47.21)	<i>Hyptis suaveolens</i> (68.47)
2	<i>Selaginella bryopteris</i> (31.10)	<i>Diospyros melanoxylon</i> (29.25)	<i>Helicteres isora</i> (27.80)	<i>Clerodendrum viscosum</i> (62.55)	<i>Eupatorium odoratum</i> (40.89)	<i>Eupatorium odoratum</i> (43.46)
3	<i>Combretum roxburghii</i> (28.24)	<i>Pogonatherum panicum</i> (24.51)	<i>Diospyros melanoxylon</i> (22.71)	<i>Sida cordata</i> (15.49)	<i>Lantana camara</i> var. <i>aculeata</i> (33.13)	<i>Diospyros melanoxylon</i> (29.34)
4	<i>Polygonum barbatum</i> (22.99)	<i>Carissa opaca</i> (21.55)	<i>Carissa opaca</i> (19.28)	<i>Eragrostis tenella</i> (13.76)	<i>Helicteres isora</i> (29.67)	<i>Selaginella bryopteris</i> (28.64)
5	<i>Sida cordata</i> (18.26)	<i>Aristida adscensionis</i> (21.01)	<i>Cassia tora</i> (18.68)	<i>Lantana camara</i> var. <i>aculeata</i> (11.14)	<i>Croton roxburghii</i> (27.53)	<i>Tephrosia purpurea</i> (14.12)
6	<i>Ichmocarpus frutescens</i> (13.19)	<i>Sida cordata</i> (15.90)	<i>Atylosia scarabaeoides</i> (18.03)	<i>Ichmocarpus frutescens</i> (10.38)	<i>Sida cordata</i> (18.84)	<i>Flemingia bracteata</i> (10.53)
7	<i>Croton roxburghii</i> (10.45)	<i>Bothriochloa pertusa</i> (13.79)	<i>Eragrostiella nardoides</i> (13.08)	<i>Cocculus hirsutus</i> (7.83)	<i>Pueraria tuberosa</i> (8.35)	<i>Spermacoce articularis</i> (9.69)
8	<i>Ziziphus mauritiana</i> var. <i>mauritiana</i> (7.94)	<i>Woodfordia fruticosa</i> (12.16)	<i>Spermacoce articularis</i> (12.51)	<i>Acacia catechu</i> (7.71)	<i>Ziziphus oenoplia</i> (7.71)	<i>Azadirachta indica</i> (8.28)
9	<i>Phoenix loureiroi</i> var. <i>pedunculata</i> (7.61)	<i>Securinea virosa</i> (10.18)	<i>Abrus precatorius</i> (10.35)	<i>Diospyros melanoxylon</i> (7.63)	<i>Ehretia laevis</i> (5.57)	<i>Ichmocarpus frutescens</i> (8.18)
10	<i>Ecoltulus nummularius</i> (7.60)	<i>Atylosia scarabaeoides</i> (8.42)	<i>Woodfordia fruticosa</i> (10.23)	<i>Casearia tomentosa</i> (6.90)	<i>Atylosia scarabaeoides</i> (4.85)	<i>Carissa opaca</i> (7.82)

Table 4. Diversity indices for different growth forms at different sites of Nawada District of Bihar:

Site Stand	Tree Layer			Shrubby Layer			Herbaceous Layer		
	TS	SR	H cd E	TS	SR	H cd E	TS	SR	H cd E
I. Tulsiahari, Nawadas Range	35	4.86	2.90 0.10 0.81	35	3.63	3.19 0.05 0.89	40	3.05	2.43 0.17 0.65
II. Tikwa Baba Jungal, Madhopur, Govindpur Beat, Nawada Range	18	2.45	2.37 0.14 0.82	21	2.16	2.87 0.06 0.94	24	1.86	2.51 0.12 0.79
III. Pachbahni Forest, Govindpur Beat	21	3.21	2.76 0.08 0.90	27	2.67	2.79 0.08 0.84	29	2.31	2.69 0.11 0.80
IV. Diborup Parisar, Gardibor Beat, Rajoli Range	31	4.57	3.20 0.05 0.93	22	2.16	1.69 0.36 0.54	25	1.98	2.01 0.25 0.62
V. Rajoli Beat, Pichli Upparisar Range	39	5.60	3.30 0.05 0.90	28	2.84	2.37 0.18 0.71	36	2.88	2.63 0.12 0.73
VI. Jhilar, Mananpur Mohodar Beat, Kawakol Range	33	4.74	2.99 0.08 0.85	16	1.70	2.33 0.13 0.83	26	2.02	2.27 0.17 0.69

(TS = Total Species ; SR = Species Richness; H = Diversity Index; cd = Concentration of dominance; E = Evenness)

(2 genera, 2 species On the basis of habit, there are 113 tree, 18 shrub, 22 climber and 51 herb species in the area. Species richness was greatly varied in different sites. Highest tree Species Richness (SR) was reported for Rajoli Beat site (39 spp.) followed by Tulsiahari (35 spp.), Jhilar (33 spp.), Diborup Parisar (31 spp.), Diborup Parishar (21 spp.) and Tiwa Baba (18 spp). On the basis of different biodiversity induces, study reveals that in the tree, most diverse site was Diborup Parisar whereas in shrubby and herbaceous layers Tulsiahari Pachbahni Forest and Pachbahni Forest sites were most diverse. Varied diversity of tree in different sites indicates disturbances in the area. Dominance of *Lantana camara* var. *aculeata* at two sites is the indication of heavy invasion of *Lantana* in other sites near future. Hence, it is important to use appropriate management strategies to check the spread of invasive species.

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Conflict of Interest: None

References

- Bhattacharya, P.K. and Sarkar, K. 1998. *Flora of West-Champaran District, Bihar*. Botanical Survey of India, Calcutta.
- Chandra, A., Naithani, H.B., Verma, P.K., Saxena, J., Kishwan, S. and Saini, R. 2021a. Phyto-diversity Assessment of Nalanda Forest Division of Bihar. *Biological Forum – An International Journal*. 13(1): 01-09.
- Chandra, A., Naithani, H.B., Verma, P.K., Saxena, J., Saini, R. and Kishwan, S. 2021b. Assessment of Plant diversity of selected forest sites of Aurangabad district of Bihar. *Int. J. Curr. Microbiol. App. Sci.* 10 (02): 462-468.
- Chandra, A., Naithani, H.B., Verma, P.K., Saxena, J. and Prajapati, S. 2021c. Plant diversity assessment of selected forest sites of Gaya district of Bihar, India. *Journal of Applied and Natural Science*. 13(2):424-432.
- Chandra, A., Naithani, H.B., Verma, P.K. and Saxena, J. 2022a. Floristic Assessment of Forests of Banka District of Bihar, Eastern India. *International Journal of Ecology and Environmental Sciences*. 48: 207-212.

- Chandra, A., Naithani, H.B., Verma, P.K., Saxena, J. and Kishwan, S. 2022b. Floristic Diversity Assessment of Forest areas of Jamui District of Bihar, *Biological Forum – An International Journal*.14(1): 371-378.
- Chandra, A., Naithani, H.B., Verma, P.K. and Sanawar, M. 2023. Phyto-diversity Assessment of Kaimur District of Bihar, Eastern India. *Biological Forum – An International Journal*. 15(2): 493-499.
- Forest Survey of India. 2021. *The State of Forest Report-2021*, Forest Survey of India, Dehradun.
- Haines, H.H. 1921-24. *The Botany of Bihar and Orissa*. Adlard and Sons, London.
- Himanshi, H. and Jakhar, S. 2020. Floristic diversity and vegetation analysis of the community forests of South West Haryana, India. *Current Botany*. 11: 51-59.
- Kershaw, K.A. 1973. *Quantitative and Dynamic Plant Ecology*: 2d Ed. E. Arnold.
- Kumar, N.J.I., Kumar, R.N., Bhoi, R.K. and Sajish, P.R. 2010. Tree species diversity and soil nutrient status of tropical dry deciduous forest of western India. *Tropical Ecology*. 51(2): 273-279.
- Kumar, M.L., Nag, A., Malakar, S. and Joshi, H.G. 2020. Population Structure and Diversity of Trees in Amarkutir, A Tropical Dry Deciduous Forest of West Bengal, India. *Indian Journal of Ecology*. 47(1): 150-154.
- Margalef, R. 1958. Temporal succession and spatial heterogeneity in phytoplankton. In: *Buzzat- Traverso (Ed.). Perspectives in Marine Biology*. University California Press, Berkeley. 323-347.
- Misra, R. 1968. *Ecological Workbook*. Oxford Press, New Delhi.
- Mooney, H.F. 1950. *Supplement to the Botany of Bihar and Orissa*. Catholic Press, Ranchi.
- Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology*. 13: 131-44.
- POWO. 2023. Plants of the World Online. Facilitated by the Royal Botanical Garden, Kew. Published on the Internet: <http://www.plantsoftheworldonline.org/> Retrieved 15 April, 2024.
- Sahu, S.C., Dhal, N.K. and Mohanty, R.C. 2012. Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malyagiri hill range, Eastern India. *Tropical Ecology*. 53(2):163-168.
- Shannon, G.E. and Wiener, W.W. 1963. *The Mathematical Theory of Communities-Urbana*. ILLinois-University of ILLinois press. 117.
- Simpson, E.M. 1949. Measurement of diversity. *Nature*. 163: 688.
- Singh, N.P., Mudgal, V., Khanna, K.K., Srivastava, S.C., Sahoo, A.K., Bandhopadhyay, S., Aziz, N., Das, M., Bhattacharya, R.P. and Hajra, P.K. 2001. *Flora of Bihar- Analysis*. Botanical Survey of India, Calcutta.
- Sundarapandian, S.M. and Swamy, P.S. 2000. Forest ecosystem structure and composition along an altitudinal gradient in the Western Ghats, South India. *Journal of Tropical Forest Science*. 12: 104-123.
- Thakur, A.S. 2015. Floristic composition, life-forms and biological spectrum of tropical dry deciduous forest in Sagar Districts, Madhya Pradesh, India. *Tropical Plant Research*. 2(2): 112-119.
- Verma, M.K., Niranjana, R.K. and Pal, A. 2013. Phytosociological attributes of a tropical dry deciduous forest of Bundelkhand region of Uttar Pradesh, India. *Journal of Biodiversity and Environmental Sciences*. 3 (10):86-89.