

Original Research Article

DIVERSITY OF INVASIVE ALIEN DICOT SPECIES IN PANTNAGAR, UTTARAKHAND, INDIA

ABSTRACT

Invasive alien species are considered one of the major threats to native plant diversity. Regular assessment of invasive species is essential to understand the status of flora in any area. The current study is the result of a floristic survey of wild dicotyledonous angiospermic plants of Pantnagar. Pantnagar is a small town and University campus located in Udham Singh Nagar district of Uttarakhand. Anthropogenic stresses on the vegetation are on high in the area in the form of intensive agricultural farming, industrial activities, university campus activities, roads and traffic, parks and playgrounds and continuous removal of natural wild vegetation. The natural tarai vegetation of the region is nearly lost or found in patches while a major portion of the vegetation is composed of invasive alien plant species (IAPS). Two assessments of invasive alien angiosperm species have been carried out in the area during the last decade in 2011 and 2015. These assessments reported the presence of 52 species (Joshi and Rawat, 2011) and 85 species (Rastogi *et al.*, 2015) of invasive alien dicot plants. The current study, however, reveals the presence of 105 invasive alien dicot species (IADS) from the study region. This large increment of more than 23 % in the IADS in such a short span of time reflects the poor state of natural vegetation and high degree of anthropogenic activities in the area. The nativity analysis revealed the

dominance of South American elements (53.33%) in the invasive alien dicot flora of the study region, followed by Tropical American, African and North American elements.

Keywords: Wild flora; Dicots; Invasive alien dicot species; Pantnagar; Taxonomy.

1. INTRODUCTION

Floristic explorations, identification and documentation of flora of any small region is an important step to ascertain the biodiversity wealth of a larger landmass [1]. In the Holocene epoch, a high degree of anthropogenic activities have already marked humans influenced time period- 'anthropocene' in the geological time scale. Biological invasions in the form of invasive alien plant species (IAPS) constitute a significant element of environmental change driven by anthropogenic activities [2, 3, 4]. "Invasive alien plants are non-native or non-indigenous species that invade an ecosystem, acclimatize for survival and nutrition, and ultimately manipulate the local environment creating a negative pressure for native plants" [5]. With globalization in transport, trade and commerce, the problem of biological invasion by IAPS is expected to increase rapidly with serious repercussions in ecological and economic fields [6, 4]. A Strategic Plan for Biodiversity (2011-2020) was formulated in October 2010 by The Convention on Biological Diversity (CBD) in which invasive alien species and their pathways were to be traced, aggressive priority species were to be controlled and measures were to be taken to prevent their further introduction and establishment, all by the year 2020 [7]. There is substantial data of alien flora available at both regional and continental level [7, 8, 4], however there is data gap due to over representation of data from developed countries and under - representation of data from developing countries [7, 9, 4]. Apart from this, the data concerning distribution of invasive alien plant species is fragmented and deficient which is however required to be complete and up to date [9, 10, 4].

There are numerous studies on invasion of plants throughout India by various researchers. These studies signify the distribution and proliferation of alien species in India and their effects in alteration of native floral composition. In a study conducted by Khuroo *et al.*, (2012) on invasive alien flora of India, a compelling introduction of the non-native species

was observed. The study reported the presence of 1,599 non native species, belonging to 842 genera under 161 families contributing 8.5% to the total Indian vascular flora. Sekar (2012) reported the presence of 190 invasive alien species under 112 genera, and 47 families from the Indian Himalayan Region [11]. Sekar *et al.*, (2012) conducted a study in Uttarakhand, where a total of 163 invasive alien species under 105 genera, belonging to 46 families were documented [12]. Negi and Hajra (2014) compiled a checklist of 436 alien species from Doon valley of North-West Himalaya, comprising 308 woody (45.69%) and 128 (19.4%) non- native herbaceous species [13]. Pathak *et al.*, (2019) reported 297 naturalized alien plant species belonging to 65 families from the Indian Himalayan Region [14]. Khuroo *et al.*, (2021) compiled an inventory of invasive alien flora of India. The study was based on an extensive review of scientific literature in the form of regional and state floras, regional weed floras, research papers, books, field guides, and flower manuals published between the year 1934 and 2018. In the study, a total of 145 invasive plant species belonging to 101 genera in 40 families were documented. The 5 dominant families in terms of number of invasive species were Asteraceae (27 species), Fabaceae (20 species), Solanaceae (12 species), Amaranthaceae (11 species), and Euphorbiaceae (8 species). With respect to nativity of the invasive alien species, the study reported the dominance of Southern American elements (60%) followed by Northern America (13%), Africa (9%), Asia-Temperate (5.5%) and Europe (5.5%) [4].

During the floristic study of dicot plants of Pantnagar region from the year 2016 – 2022, the major portion of the flora was found to be composed of IADS. Invasive alien species can be considered as a scale to measure the loss of native vegetation of a region. These are the species that can survive on their own without any human interference. Pantnagar region is a highly disturbed habitat devoid of native vegetation with a high rate of anthropogenic activities. The increasing diversity of IAPS is a matter of serious concern since invasive species along with the loss of native vegetation are also responsible for extinction of native species and altered hydrology and ecosystem function [15]. The current study has tried to give an insight to the current status of invasive alien elements in the dicot flora of Pantnagar while comparing the data from the previous studies by Joshi and Rawat (2011) and Rastogi *et al.* (2015) [16, 17].

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY

The study area Pantnagar is a university campus and a small town located in District Udham Singh Nagar in Uttarakhand. The town cradles the campus of Govind Ballabh Pant University of Agriculture and Technology (also known as Pantnagar University), the first

agricultural university of India which was formerly known as Uttar Pradesh Agricultural University (UPAU). The climate of Pantnagar is distinctly humid-subtropical. Precipitation in the form of rainfall is dominated by the monsoon, which accounts for the maximum rainfall during the months of June to September. In the present research work, IAPS of dicots were collected from different localities of Pantnagar for herbarium preparation and their photographs were taken to record their habit and other morphological features. Regular field trips were made for the collection of plant specimens in different seasons and to observe habit, habitat, flowering and fruiting of these plant species in different seasons. Usually the places accessed for collection were the wastelands, roadsides, marshy areas, partial forest area and agricultural fields in different localities

The collected specimens were identified with the help of various floras and by verification with the specimens housed at Botanical Survey of India - Northern Circle (BSD). The collected specimens have been submitted in G.B. Pant University Herbarium (GBPUH). For nativity analysis of the invasive alien plant species, various published literatures have been followed. The pertinent reference for nativity is also listed in the table 1.

3. RESULTS AND DISCUSSION

Plant collections during 2016-2022 have resulted in the occurrence of 450 species under 311 genera of 79 families of dicotyledonous angiosperms in the Pantnagar area. Nature and activity of the species revealed that 105 are invasive alien species. These species with their families, nativity, habit, flowering and fruiting season are listed in the table 1. These species belong to 79 genera, 30 families and 17 orders.

In the previous reports by Joshi and Rawat (2011) 52 species of invasive alien dicotyledonous angiosperms were found present in the Pantnagar area [16]. Later, after four years another report by Rastogi *et al.* (2015) demonstrated presence of 85 Invasive Alien Dicot Species (IADS) under 65 genera and 28 families [17]. However, the current study proves presence of 105 IADS from the region, belonging to 79 genera and 30 families. The results of present study are compared with earlier reports in the Figure 1. This comparison shows that the number of invasive alien species has increase clearly during last one decade. Though, this increase may partially be attributed to more intensive plant collection in the area.

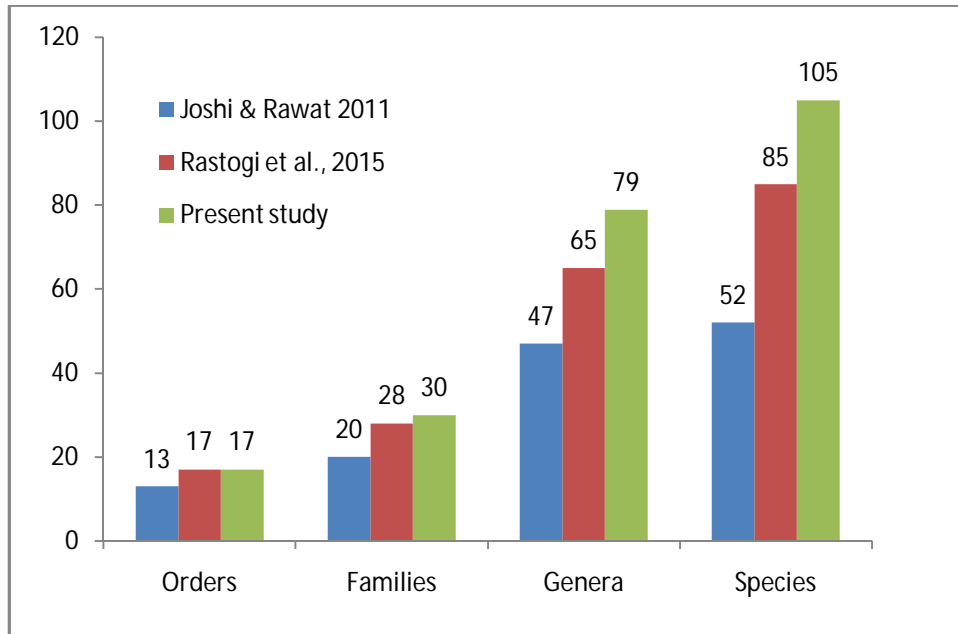


Figure 1. Invasive Alien Dicot Species in Flora of Pantnagar

Amongst the 30 families contributing to the invasive dicot flora, family Asteraceae dominates with 21 species under 18 genera constituting 20% of the total invasive flora, followed by Fabaceae (13 species under 19 genera, 12.38%), Amaranthaceae (11 species under 7 genera, 10.47%), Solanaceae (9 species under 4 genera, 8.57%), Convolvulaceae (8 species under 4 genera, 7.61%), Malvaceae (7 species under 6 genera, 6.66%) and Euphorbiaceae (5 species under 4 genera, 4.76%) (Figure 2). 16 families of invasive alien dicot flora are represented by single species.

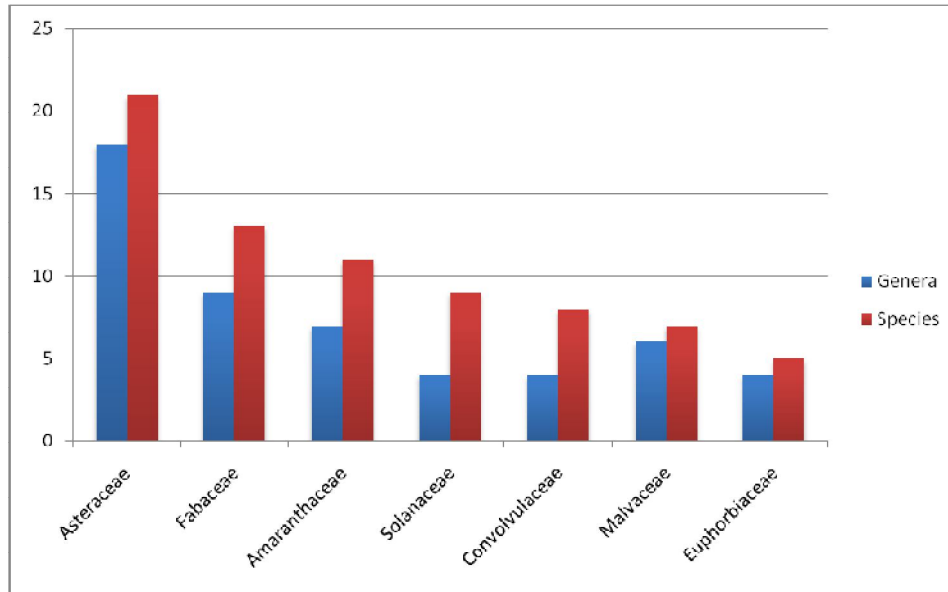


Figure 2. Dominant invasive alien dicot families of Pantnagar, Uttarakhand

Habit wise analysis of invasive flora shows dominance of herbaceous form over other life forms. Herbs with 75 species constitute 71.43% of the total invasive dicot flora of Pantnagar, followed by Shrubs (16 species; 15.24%), Climbers (9 species; 8.57%) and Trees (5 species; 4.76%) (Figure 3). These results indicate dominance of herbs as also shown by Reddy (2008), Singh *et al.*, (2010), Sekar *et al.*, (2012) [18, 19, 12]. Since, herbaceous species can survive better than other growth forms in disturbed habitat, therefore in the present study they are seen to dominate the habit of invasive alien flora. The herbaceous species were found abundantly along the roads, wastelands, parks, crop fields and gardens. The other life forms were often found in the wastelands and along forest margins.

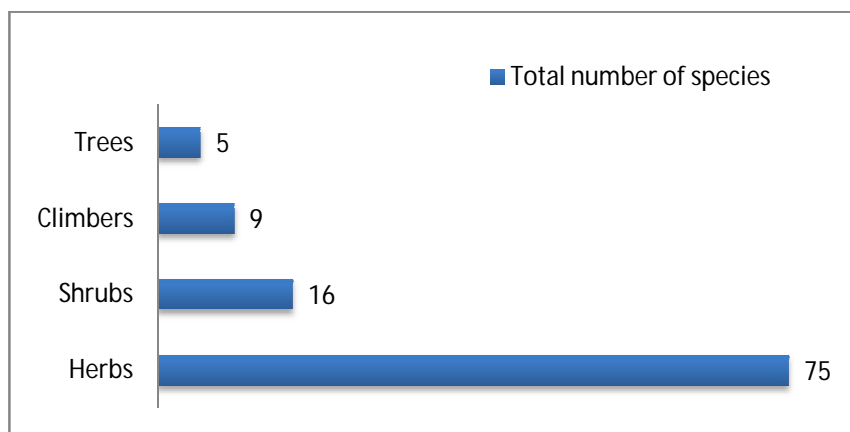


Figure 3. Total number of species representing growth forms in invasive alien dicot flora of Pantnagar

A total of 7 different geographic regions are recorded in terms of nativity in the present study. These geographic regions are Africa, Asia, Europe, Mediterranean, North America, South America and Tropical America. On the basis of nativity, IADS of South American nativity with 56 species are found to dominate the invasive alien flora of Pantnagar, contributing a total of 53.33 %, followed by Tropical American (13 species; 12.38 %), African (12 species; 11.43 %), North American (11 species; 10.48 %), Asian (8 species; 7.62 %), European (5 species; 4.76 %) and Mediterranean (3 species; 2.86 %). The results reveal the dominance of American continents contributing 76.19 % to the invasive alien dicot flora of Pantnagar (Figure 4). These results resonates with Reddy (2008), Singh *et al.*, (2010), Sekar *et al.*, (2012) where Tropical American elements are recorded as the dominant part of invasive alien flora [18, 19, 12]. Pantnagar is a hot and moist subtropical habitat where, tropical American plants have found climatic conditions similar to their native habitats and thus flourish well.

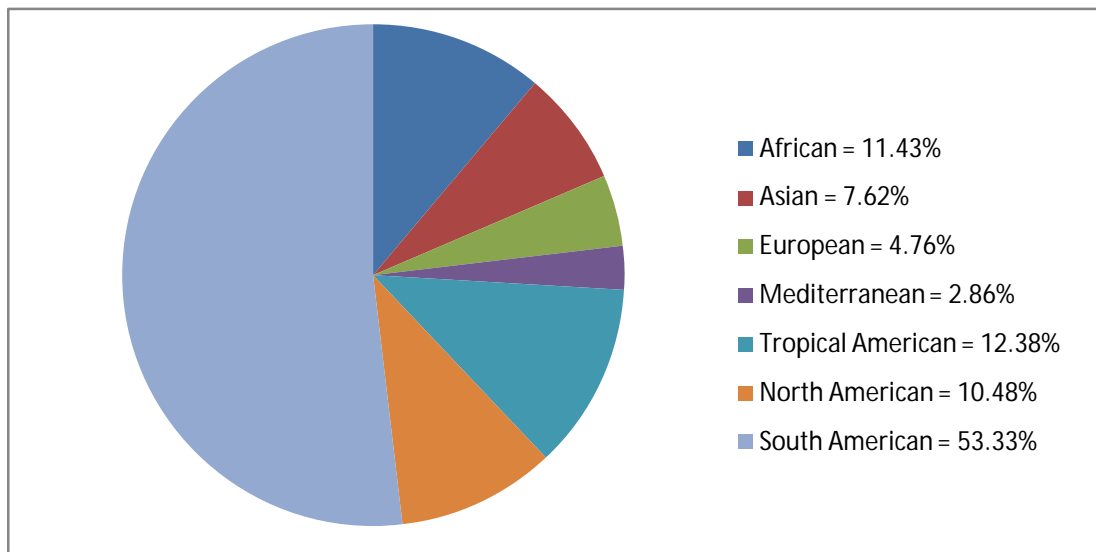


Figure 4. Percent contribution of different geographic regions to the invasive alien dicot flora of Pantnagar.

Table 1. Checklist of IADS of Pantnagar region of Uttarakhand.

| S. No. | Plant Name, Family | Nativity | Habit | Flowering & Fruiting Time | Reference |
|--------|--------------------------------------------------------------------|---------------|-------|---------------------------|-----------|
| 1 | <i>Acanthospermum hispidum</i> DC. (Asteraceae) | South America | Herb | March - April | [4] |
| 2 | <i>Ageratum conyzoides</i> L. (Asteraceae) | South America | Herb | Throughout the year | [4] |
| 3 | <i>Ageratum houstonianum</i> Mill. (Asteraceae) | North America | Herb | Throughout the year | [4] |
| 4 | <i>Alternanthera ficoidea</i> (L.) P.Beauv. (Amaranthaceae) | South America | Herb | March - December | [4] |
| 5 | <i>Alternanthera paronychioides</i> A. St-Hil. (Amaranthaceae) | South America | Herb | March - January | [4] |
| 6 | <i>Alternanthera philoxeroides</i> (Mart.) Griseb. (Amaranthaceae) | South America | Herb | Throughout the year | [4] |
| 7 | <i>Alternanthera pungens</i> Kunth | South America | Herb | May - August | [4] |

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|----|-----------------------------------------------------------------|-------------------------|---------|---------------------|-----|
| | (Amaranthaceae) | | | | |
| 8 | <i>Alternanthera sessilis</i> (L.) R.Br. ex DC. (Amaranthaceae) | Tropical America | Herb | Throughout the year | [5] |
| 9 | <i>Amaranthus spinosus</i> L. (Amaranthaceae) | South America | Herb | July - December | [4] |
| 10 | <i>Antigonon leptopus</i> Hook. & Arn. (Polygonaceae) | South America | Climber | February - July | [4] |
| 11 | <i>Argemone mexicana</i> L. (Papaveraceae) | South America | Herb | February - June | [4] |
| 12 | <i>Argemone ochroleuca</i> Sweet. (Papaveraceae) | North America | Herb | March- May | [4] |
| 13 | <i>Asclepias curassavica</i> L. (Apocynaceae) | South America | Shrub | February - June | [4] |
| 14 | <i>Bidens pilosa</i> L. (Asteraceae) | South America | Herb | March - October | [4] |
| 15 | <i>Blumea lacera</i> (Burm. f.) DC. (Asteraceae) | Tropical America | Herb | April - June | [5] |
| 16 | <i>Calotropis gigantea</i> (L.) W.T.Aiton (Apocynaceae) | Tropical Africa | Shrub | February - June | [5] |
| 17 | <i>Calotropis procera</i> (Aiton) W.T.Aiton (Apocynaceae) | Tropical Africa | Shrub | December - June | [5] |
| 18 | <i>Cannabis sativa</i> L. (Cannabaceae) | Asia temperate | Herb | March - October | [4] |
| 19 | <i>Celosia argentea</i> L. (Amaranthaceae) | South America | Herb | September - January | [4] |
| 20 | <i>Chenopodium album</i> L. (Amaranthaceae) | Africa, Asia - tropical | Herb | July - December | [4] |
| 21 | <i>Cissampelos pareira</i> L. (Menispermaceae) | South America | Herb | March - October | [4] |
| 22 | <i>Cleome viscosa</i> L. (Cleomaceae) | South America | Herb | March - September | [4] |
| 23 | <i>Convolvulus arvensis</i> L. (Convolvulaceae) | Europe | Climber | September - October | [5] |
| 24 | <i>Corchorus aestuans</i> L. (Malvaceae) | South America | Herb | April- October | [4] |
| 25 | <i>Corchorus olitorius</i> L. (Malvaceae) | Tropical America | Herb | July- October | [5] |

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|----|------------------------------------------------------------------------------------|------------------|---------|---------------------|-----|
| 26 | <i>Crassocephalum crepidioides</i> (Benth.) S. Moore (Asteraceae) | Africa | Herb | January-March | [4] |
| 27 | <i>Crotalaria pallida</i> Aiton. (Fabaceae) | Tropical America | Herb | February - April | [5] |
| 28 | <i>Croton bonplandianus</i> Baill. (Euphorbiaceae) | South America | Herb | April - June | [4] |
| 29 | <i>Cuscuta reflexa</i> Roxb. (Convolvulaceae) | Mediterranean | Climber | June - November | [5] |
| 30 | <i>Cyclospermum leptophyllum</i> (Pers.) Sprague ex Britton & P. Wilson (Apiaceae) | South America | Herb | March-May | [4] |
| 31 | <i>Datura metel</i> L. (Solanaceae) | South America | Herb | April - October | [4] |
| 32 | <i>Datura stramonium</i> L. (Solanaceae) | South America | Herb | April - September | [4] |
| 33 | <i>Digera muricata</i> (L.) Mart. (Amaranthaceae) | Asia | Herb | July - November | [5] |
| 34 | <i>Dysphania ambrosioides</i> (L.) Mosyakin & Clemants (Amaranthaceae) | South America | Herb | January - April | [4] |
| 35 | <i>Eclipta prostrata</i> (L.) L. (Asteraceae) | South America | Herb | Throughout the year | [4] |
| 36 | <i>Emilia sonchifolia</i> (L.) DC. (Asteraceae) | Tropical Africa | Herb | Throughout the year | [5] |
| 37 | <i>Erigeron bonariensis</i> L. (Asteraceae) | Asia temperate | Herb | March - September | [4] |
| 38 | <i>Erigeron 10anadensis</i> L. (Asteraceae) | North America | Herb | May-August | [4] |
| 39 | <i>Euphorbia heterophylla</i> L. (Euphorbiaceae) | North America | Herb | February - August | [4] |
| 40 | <i>Euphorbia hirta</i> L. (Euphorbiaceae) | South America | Herb | Throughout the year | [4] |
| 41 | <i>Evolvulus nummularius</i> (L.) L. (Convolvulaceae) | South America | Herb | August-November | [4] |
| 42 | <i>Galinsoga parviflora</i> Cav. (Asteraceae) | South America | Herb | January-March | [4] |

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|----|---------------------------------------------------------------|------------------|---------|----------------------|------|
| 43 | <i>Gamochaeta pensylvanica</i> (Willd.) Cabrera (Asteraceae) | Tropical America | Herb | January-March | [5] |
| 44 | <i>Gomphrena celosioides</i> Mart. (Amaranthaceae) | South America | Herb | January – April | [5] |
| 45 | <i>Grangea maderaspatana</i> (L.) Poir. (Asteraceae) | South America | Herb | March-June | [5] |
| 46 | <i>Impatiens balsamina</i> L. (Balsaminaceae) | Tropical America | Herb | March-September | [5] |
| 47 | <i>Indigofera linifolia</i> (L.f.) Retz. (Fabaceae) | South America | Herb | May – October | [5] |
| 48 | <i>Indigofera linnaei</i> Ali. (Fabaceae) | Tropical America | Herb | February-March | [5] |
| 49 | <i>Ipomoea carnea</i> Jacq. (Convolvulaceae) | South America | Shrub | July - November | [4] |
| 50 | <i>Ipomoea hederifolia</i> L. (Convolvulaceae) | South America | Climber | September - December | [4] |
| 51 | <i>Ipomoea nil</i> (L.) Roth. (Convolvulaceae) | North America | Climber | March - December | [5] |
| 52 | <i>Ipomoea pes-tigridis</i> L. (Convolvulaceae) | Tropical Africa | Climber | July-September | [5] |
| 53 | <i>Ipomoea quamoclit</i> L. (Convolvulaceae) | South America | Climber | July - September | [4] |
| 54 | <i>Lagascea mollis</i> Cav. (Asteraceae) | North America | Herb | March- April | [4] |
| 55 | <i>Lantana camara</i> L. (Verbenaceae) | South America | Shrub | Throughout the year | [4] |
| 56 | <i>Lepidium didymum</i> L. (Brassicaceae) | South America | Herb | January - May | [4] |
| 57 | <i>Leucaena leucocephala</i> (Lam.) de Wit. (Fabaceae) | Tropical America | Tree | March - May | [26] |
| 58 | <i>Ludwigia octovalvis</i> (Jacq.)P.H. Raven (Onagraceae) | Tropical Africa | Herb | April - October | [5] |
| 59 | <i>Ludwigia perennis</i> L. (Onagraceae) | Tropical Africa | Herb | April - October | [5] |
| 60 | <i>Lysimachia arvensis</i> (L.) U.Manns&Anderb. (Primulaceae) | Europe | Herb | February - May | [5] |
| 61 | <i>Malvastrum coromandelianum</i> (L.) Garcke | South America | Herb | March - December | [4] |

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|----|-------------------------------------------------------------------|---------------------------------|---------|------------------------|-----|
| | (Malvaceae) | | | | |
| 62 | <i>Martynia annua</i> L. (Martyniaceae) | South America | Shrub | July- October | [4] |
| 63 | <i>Mecardonia procumbens</i> (Mill.) Small (Plantaginaceae) | South America | Herb | Throughout the year | [4] |
| 64 | <i>Melilotus albus</i> Medik. (Fabaceae) | Europe | Herb | March - May | [5] |
| 65 | <i>Melochia corchorifolia</i> L. (Malvaceae) | Tropical America | Herb | June- December | [5] |
| 66 | <i>Mesosphaerum suaveolens</i> (L.) Kuntze (Lamiaceae) | South America | Herb | March- May | [4] |
| 67 | <i>Mikania micrantha</i> Kunth (Asteraceae) | South America | Climber | January- February | [4] |
| 68 | <i>Mimosa pudica</i> L. (Fabaceae) | South America | Herb | January - April | [4] |
| 69 | <i>Mirabilis jalapa</i> L. (Nyctaginaceae) | South America | Shrub | April- September | [4] |
| 70 | <i>Nicotiana plumbaginifolia</i> Viv. (Solanaceae) | South America | Herb | March - September | [4] |
| 71 | <i>Oxalis corniculata</i> L. (Oxalidaceae) | Europe | Herb | April- September | [4] |
| 72 | <i>Oxalis debilis</i> Kunth (Oxalidaceae) | South America | Herb | February - April | [4] |
| 73 | <i>Parthenium hysterophorus</i> L. (Asteraceae) | South America | Herb | Throughout the year | [4] |
| 74 | <i>Passiflora foetida</i> L. (Passifloraceae) | South America | Climber | July - December | [4] |
| 75 | <i>Peperomia pellucida</i> (L.) Kunth (Piperaceae) | South America | Herb | August- September | [4] |
| 76 | <i>Physalis angulata</i> L. (Solanaceae) | North America, South America | Herb | July - September | [4] |
| 77 | <i>Physalis pruinosa</i> L. (Solanaceae) | North America | Herb | July- September | [4] |
| 78 | <i>Pilea microphylla</i> (L.) Liebm. (Urticaceae) | South America | Herb | August- October | [4] |
| 79 | <i>Pithecellobium dulce</i> (Rox.) Benth. (Fabaceae) | South America | Tree | March - June | [4] |
| 80 | <i>Portulaca oleracea</i> L. (Portulacaceae) | Africa, Europe | Herb | March - September | [4] |

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|-----|-------------------------------------------------------------|-------------------------------------------------|-------|---------------------|------|
| 81 | <i>Portulaca quadrifida</i> L. (Portulacaceae) | Africa, Asiatropical, Pacific, Southern America | Herb | Throughout the year | [4] |
| 82 | <i>Prosopis juliflora</i> (Sw.) DC. (Fabaceae) | North America, South America | Tree | April - January | [4] |
| 83 | <i>Ricinus communis</i> L. (Euphorbiaceae) | Africa | Shrub | Throughout the year | [4] |
| 84 | <i>Rorippa indica</i> (L.) Hiern (Brassicaceae) | Asia | Herb | February - August | [27] |
| 85 | <i>Scoparia dulcis</i> L. (Plantaginaceae) | South America | Herb | March- May | [4] |
| 86 | <i>Senna alata</i> (L.) Roxb. (Fabaceae) | South America | Shrub | March- June | [4] |
| 87 | <i>Senna occidentalis</i> (L.) Link (Fabaceae) | South America | Shrub | August- October | [4] |
| 88 | <i>Senna tora</i> (L.) Roxb. (Fabaceae) | South America | Shrub | July - November | [12] |
| 89 | <i>Sesbania bispinosa</i> (Jacq.) W. Wight (Fabaceae) | Tropical America | Shrub | November - December | [12] |
| 90 | <i>Sida acuta</i> Burm. f. (Malvaceae) | South America | Shrub | August - November | [27] |
| 91 | <i>Solanum americanum</i> Mill. (Solanaceae) | North America South America | Herb | December - April | [4] |
| 92 | <i>Solanum nigrum</i> L. (Solanaceae) | South America | Herb | Throughout the year | [27] |
| 93 | <i>Solanum pseudocapsicum</i> L. (Solanaceae) | Tropical America | Herb | October - November | [12] |
| 94 | <i>Solanum viarum</i> Dunal (Solanaceae) | South America | Herb | October - December | [4] |
| 95 | <i>Sonchus asper</i> (L.) Hill (Asteraceae) | Mediterranean | Herb | February - April | [12] |
| 96 | <i>Sonchus oleraceus</i> L. (Asteraceae) | Mediterranean | Herb | February - April | [12] |
| 97 | <i>Torenia fournieri</i> Linden ex E.Fourn. (Linderniaceae) | Asia temperate | Herb | July- October | [4] |
| 98 | <i>Triadica sebifera</i> (L.) Small (Euphorbiaceae) | Asia temperate | Tree | May - December | [4] |
| 99 | <i>Tribulus terrestris</i> L. (Zygophyllaceae) | Tropical America | Herb | May – June | [5] |
| 100 | <i>Tridax procumbens</i> (L.) L. (Asteraceae) | North America | Herb | Throughout the year | [4] |

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|-----|-----------------------------------------------------------|------------------|-------|------------------|------|
| 101 | <i>Triumfetta rhomboidea</i> Jacq. (Malvaceae) | South America | Shrub | May - August | [4] |
| 102 | <i>Urena lobata</i> L. (Malvaceae) | Tropical Africa | Shrub | June - September | [12] |
| 103 | <i>Vachellia farnesiana</i> (L.)Wight & Am. (Fabaceae) | South America | Tree | November - March | [4] |
| 104 | <i>Xanthium strumarium</i> L. (Asteraceae) | Tropical America | Shrub | July - December | [4] |
| 105 | <i>Youngia japonica</i> (L.) DC (Asteraceae) | South America | Herb | March - June | [4] |

39 of the species are found to have flowering and fruiting season of up to 6 months and more which facilitates regular seed production resulting in high proliferation of the species in the habitat. It is also found that maximum number of species flower during the month of February – April which make them early germinating species and potential for early germination has been considered as an important trait for invasiveness [20]. Early germinating species benefit early access to the resources like space and have lesser competition in terms of establishment which leads to substantial increase in their size before other species [21]. Pre-emption of resources by early germinating species significantly affect establishment of other late germinating species by exercising founder control over later germinating species [22].

4. CONCLUSION

The current study revealed the presence of 105 species of IADS under 79 genera belonging to 30 families. Asteraceae was found to be the dominant family of IADS from the region. 16 of the families of IADS were represented by single species. Herbs were found to be the dominant life form. Since their life cycle is short, they have better and easier proliferation which might contribute to the dominance of herbs [17]. In the study, species of South American nativity dominated the invasive alien dicot flora of the region. Since Pantnagar is a hot and humid habitat resembling the climatic conditions of South American region, therefore the alien species of South American nativity have proliferated the area abundantly [17]. At global level invasive alien species constitute about 3.9% of global vascular flora [23] and at national level, invasive alien dicot species constitute about 1.23 % of

total flora of India [24, 25], but in Pantnagar area their share is too high being above 23% showing the poor state of native dicot angiosperm flora. Although invasive plant species are abused for massive local impacts by reducing native plant diversity, changing fire regimes and nutrient cycling [26], their longer-term impacts on regional and global plant diversity are still elusive. In Pantnagar these 105 species are considered as a threat to native flora although there are hardly any evidences of plant extinction by invasive alien species in the world [27]. At present these species are contributing to the greenery of the campus.

REFERENCES

1. Singh KP, Sinha GP, Khanna KK. Flora of Uttar Pradesh: Volume-I. Kolkata, Botanical Survey of India. 2016.
2. Anton A, Geraldi NR, Lovelock CE, Apostolaki ET, Bennett S, Cebrian J et al. Global ecological impacts of marine exotic species. *Nat Ecol Evol.* 2019; 3(5): 787-800. <https://doi.org/10.1038/s41559-019-0851-0>
3. Brondizio ES, Settele J, Diaz S, Ngo HT. Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. *IPBES Secretariat*, Bonn, Germany. 2019.
4. Khuroo AA., Ahmad R, Hamid M, Rather ZA, Malik AH, Rashid I. An annotated inventory of invasive alien flora of India. In: Pullaiah T, Lelmini MR, editors. *Invasive alien species: observations and issues from around the world.* John Wiley & Sons Ltd. 2021. <https://doi.org/10.1002/9781119607045.ch14>
5. Das M, Sharma R, Nath N. Invasive alien herbaceous species in terrestrial and swampland habitats in India: A review. *Int. J. Botany Stud.* 2021; 6(2): 661 – 668.
6. van Kleunen M, Pysek P, Dawson W, Kreft H, Pergl J, Weigelt P. et al. The global naturalized alien Flora (GloNAF) database. *Ecology* 2019; 100: 1 [10.1002/ecy.2542](https://doi.org/10.1002/ecy.2542)

7. Khuroo AA, Reshi ZA, Malik AH, Weber E, Rashid I, Dar GH. Alien flora of India: Taxonomic composition, invasion status and biogeographic affiliations. *Biol. Invasions*. 2012; 14: 99-113. <https://doi.org/10.1007/s10530-011-9981-2>
8. Ansong M, Pergl J, Essl F, Hejda M, van Kleunen M, Randall R, Pysek P. Naturalized and invasive alien flora of Ghana. *Biol Invasions*. 2019; 21: 669–683. <https://doi.org/10.1007/s10530-018-1860-7>
9. Pysek P, Pergl J, Essl F, Lenzner B, Dawson W, Kreft H. *et al.* Naturalized alien flora of the world: species diversity, taxonomic and phylogenetic patterns, geographic distribution and global hotspots of plant invasion. *Preslia* 2017; 89: 203–274. <http://dx.doi.org/10.23855/preslia.2017.203>
10. Vinogradova Y, Pergl J, Essl F, Hejda M, van Kleunen M, Pysek P. Invasive alien plants of Russia: insights from regional inventories. *Biological Invasions* 2018; 20: 1931–1943. <https://doi.org/10.1007/s10530-018-1686-3>
11. Sekar KC. Invasive Alien Plants of Indian Himalayan Region—Diversity and Implication. *Am. J. Plant Sci*, 2012; 3:177-184. <http://www.scirp.org/journal/PaperInformation.aspx?PaperID=17533>
12. Sekar KC, Manikandan R, Srivastava SK. Invasive alien plants of Uttarakhand Himalaya. *Proc. Natl. Acad. Sci. India Sect. B - Biol. Sci.* 2012; 82: 375-383. <https://doi.org/10.1007/s40011-012-0040-2>
13. Negi PS, Hajra PK. Alien flora of Doon Valley, Northwest Himalaya. 2007. *Curr. Sci.* 92: 968-978. <https://www.jstor.org/stable/24097678>
14. Pathak R, Negi VS, Rawal RS, Bhatt ID. Alien plant invasion in the Indian Himalayan Region: state of knowledge and research priorities. *Biodivers. Conserv.* 2019; 28: 3073-3102. <https://doi.org/10.1007/s10531-019-01829-1>
15. McGeoch MA, Butchart SH, Spear D, Marais E, Kleynhans EJ, Symes A, Chanson J, Hoffmann M. Global indicators of biological invasion: species numbers, biodiversity impact and policy responses. *Divers. Distrib.* 2010; 16(1): 95-108. <https://doi.org/10.1111/j.1472-4642.2009.00633.x>
16. Joshi K, Rawat DS. A preliminary investigation on alien and native elements in flora of Pantnagar, Uttarakhand, India. *J. Indian Bot. Soc.* 2011; 90(1&2): 66-74.

17. Rastogi J, Rawat DS, Chandra S. Diversity of Invasive alien species in Pantnagar flora. *Tropical Pl. Res.* 2015; 2(3): 282-287
18. Reddy CS. Catalogue of invasive alien flora of India. *Life Sci. J.* 2008; 5(2): 84–89
19. Singh KP, Shukla AN & Singh JS. State-Level Inventory of Invasive Alien Plants, Their Source Regions and Use Potential. *Curr. Sci.* 2010; 99(1): 107–114.
20. Pysek P, Richardson DM. Traits associated with invasiveness in alien plants: where do we stand? *Biol. Invasions.* 2007; 193: 97–125.
https://doi.org/10.1007/978-3-540-36920-2_7
21. Gioria M, Pysek P, Osborne BA. Timing is everything: does early and late germination favor invasions by herbaceous alien plants? *J. Plant Ecol.* 2018; 11(1): 4–16. <https://doi.org/10.1093/jpe/rtw105>
22. Korner C, Stocklin J, Reuther-Thiebaud L, Pelaez-Riedl S. Small differences in arrival time influence composition and productivity of plant communities. *New Phytol.* 2008. 177(3): 698–705. <https://doi.org/10.1111/j.1469-8137.2007.02287.x>
23. van Kleunen M, Dawson W, Essl F, Pergl J, Winter M, Weber E. *et al.* Global exchange and accumulation of non-native plants. *Nature* 2015; 525: 100 - 103. <https://doi.org/10.1038/nature14910>
24. Reddy C S, Bagyanarayana G, Reddy KN, Vatsavaya SR. Invasive Alien Flora of India. National Biological Information Infrastructure, Usgs, USA. 2008.
25. Mao AA, Dash SS. Flowering plants of India An annotated checklist (Dicotyledons) volume 1. Botanical Survey of India, Kolkata. 2020.
26. . Pysek P, Jarosík V, Hulme PE, Pergl J, Hejda M, Schaffner U, Vila M. A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of impact measures, invading species' traits and environment. *Glob. Change Biol.* 2012. 18(5): 1725-1737.
<https://doi.org/10.1111/j.1365-2486.2011.02636.x>

27. Thomas CD, Palmer G. Non-native plants add to the British flora without negative consequences for native diversity. *P. Natl. Acad. Sci.* 2015: 4387 - 4392. <https://doi.org/10.1073/pnas.1423995112>
28. Debnath A, Debnath B. Diversity, invasion status and usages of alien plant species in northeastern hilly state of Tripura: a confluence of Indo-Barman hotspot. *Am. J. Plant Sci.*, 2017: 8(02): 212.
29. Wani ZA, Pant S, Sharma V. Diversity, Distribution, and Status of Weed Species of Northwest Himalaya. In: Pant D, Bhatia SK, Patel AK, Giri A, editors. *Bioremediation using weeds* Singapore: Springer; 2021.

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