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Research article

# A preponderance of alien species in Delhi NCR of western Uttar Pradesh: possible impacts on ecosystem

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**Abstract:** The present study catalogued the alien species of parts of Delhi NCR, western Uttar Pradesh, India concerning their possible impacts on biodiversity and ecosystem. Altogether 93 alien plant species belonging to 69 genera and 28 families were identified including two new species record to this region. Of the 93 alien species, about 94% (87 species) have been enlisted as invasive species in Uttar Pradesh and Delhi NCR by different authors. Surprisingly, the study enlisted more than 50% aliens invasive of entire Uttar Pradesh and 90% of the total alien flora of Delhi. Among the alien species, dicots comprised of 83 species and 10 species to monocots. Asteraceae was the most dominant family with 14 alien species followed by Amaranthaceae and Fabaceae (10 species each), Malvaceae (8 species), Convolvulaceae and Euphorbiaceae (7 species each), Solanaceae (6 species) and Poaceae (5 species). Genera such as *Alternanthera*, *Euphorbia*, and *Ipomoea* had the highest number of alien species (4 species each) followed by *Corchorus* and *Indigofera* (3 species each). The largest number of species (72%) were of American origin, followed by African (14%), European (5%), Mediterranean (4%) and Asian (2%). The herbaceous plants dominated with 78 alien species whereas trees were least dominant with only two alien species. Being herbaceous, numerous plant species showed seasonality in their occurrence and were recorded in a specific season. Besides their harmful impacts on local biodiversity and ecosystem in general, several alien species were found to have potent medicinal properties and used in folk medicines. A high degree of disturbances due to several developmental activities including land use/land cover changes in the recent past could be one of the reasons for the preponderance of alien species in the study area. A discrepancy in reporting the nativity of some alien species are also highlighted.

**Keywords:** Alien plants - Nativity - Invasive species - Biodiversity - Seasonality.

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## INTRODUCTION

An alien plant is an exotic and non-indigenous species that have been introduced intentionally or otherwise through human agency or accidentally from one region/country to another. From an ecological perspective, when an alien plant species spread and establishes in larger populations in an ecosystem beyond their natural distribution limits, they become invasive (Mack *et al.* 2000). A naturalized species is an introduced species that can consistently reproduce and sustain the population over many generations without direct intervention by humans (Richardson *et al.* 2000). Invasive weeds, considered as a primary cause of global biodiversity loss, usually have faster rates of growth and biomass production, high competitive ability, high reproductive efficiency including the production of a large number of seeds, efficient dispersal, easy vegetative reproduction, rapid establishment and other traits as compared to native species that help them adapt to newly introduced habitats within a short period (Sharma *et al.* 2005, Simberloff *et al.* 2005, Huang *et al.* 2009, Rastogi *et al.* 2015).

International Union for Conservation of Nature and Natural Resources (IUCN) defines alien invasive species as an alien species which becomes established in natural or seminatural ecosystems or habitat as agent of


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change, and threatens native biological diversity. Invasion of alien plants may be either human-introduced or through natural means such as water, winds, birds, and animals (Dogra *et al.* 2010). The invasion of alien species leads to substantial ecological damage to native biodiversity and accelerate the disappearance of endemic and threatened taxa (Reddy 2008, Yadav *et al*. 2016). Due to an enormous number of possible ways for alien species to enter the country, the list of alien species is increasing each year. It has been observed that about 25 percent of the introduced species became invasive in India within a short period of 50–100 years (Murphy *et al*. 2001).

Invasive aliens are responsible for serious ecological and economic impacts on native flora worldwide. At least 10% of the world's vascular plants (300,000) have the potential to become invasive in other ecosystems and affect native vegetation in direct or indirect ways (Singh *et al*. 2006). Ecosystem services are largely affected by invasive plant species and an invader may have positive effects on some services and negative effects on others (Eviner *et al.* 2012). Non-native species are responsible for changes in the ecosystems (Jeschke *et al.* 2014), however, their major effects in different ecosystems are still unclear and also which ecosystem services are most affected (Vila *et al.* 1994).

In the past, several studies have been conducted and focused on different aspects of alien invasive species in India (Pandey & Parmar 1994, Raghubanshi *et al.* 2005, Tripathi *et al.* 2006, Negi & Hajra 2007, Reddy 2008, Dogra *et al.* 2010, Rastogi *et al*. 2015, Yadav *et al*. 2016). Spatial distribution of alien species can be seen across landscapes of Uttar Pradesh (Khanna 2009, Singh *et al.* 2010, Srivastava *et al.* 2014, Kumari *et al.* 2016) and Delhi NCR (Mishra *et al.* 2015). While studying the flora of the study area, a large percentage of species were identified as alien species. Though the alien plants contributed significantly to enhance the local plant diversity, the results are examined from the ecological perspective on possible reasons for the occurrence of a high percentage of invasive alien species in a small geographical area and their probable impacts on biodiversity and the ecosystem.

## MATERIAL AND METHODS

### *Study area*

The study area Chithara Village Panchayat including the campus of Shiv Nadar University comes under the Gautam Buddha Nagar District in western Uttar Pradesh is situated in the eastern part of Delhi NCR. Geographically, it lies between latitude 28° 31′ N to 28° 33′ N and longitude 77° 33′ E to 77° 35′ E, under Dadri Block Panchayat/Tehsil and covers an area of approx. 7.70 $km^2$. The study area witnessed several developmental activities including land use/land cover changes in the recent past.

The climate of the study area is typically monsoon with three distinct seasons, namely, summer (March to mid-June), rainy (mid-June to September), and winter (October to February). The study area experiences the hottest weather in June with an average mean temperature of 32.85ºC followed by May with 31.9ºC. The coldest month is January with an average mean temperature of 14.2ºC followed by December with 15.4ºC (Joshi 2008–2009).

The soil of the study area is fertile alluvial soil characteristic of soils represented in Wheat–Rice agriculture system in the southwestern plain of Upper Gangetic Plain. The soil pH ranges from 7.64 to 9.38 with reasonably good maximum water holding capacity. Nutrient-wise the soil contained OC (0.299–0.400%) which is within the desirable range of soils of Upper Gangetic Plain.

### *Methodology*

The extensive floristic survey to document flora of the study area was carried out during 2015–2018. Field survey covered different types of habitat such as agricultural fields, canal bunds, roadsides, village streets, wild date palm groves, wetlands, wastelands, grasslands, etc. The aquatic and terrestrial vegetation of area was surveyed frequently throughout the year covering different seasons. The plants were identified following regional floras and herbaria of Botanical Survey of India (BSI), Dehradun. The taxonomic identity of the plant specimens were verified from WFO (2021). A specimen of identified plants were deposited in BSI herbarium, Northern Regional Centre, Dehradun.

To ascertain the nativity of each plant species, an exhaustive literature search was made (Pandey & Parmar 1994, Reddy 2008, Khanna 2009, Dogra *et al.* 2010, Singh *et al.* 2010, Sekar *et al.* 2012, Srivastava *et al.* 2014, Mishra *et al.* 2015, Rastogi *et al*. 2015, Kumari *et al.* 2016, Jakhar *et al.* 2018) and list of alien species prepared. The species were also searched in CABI (Invasive Species Compendium) for their nativity. Seasonality in the occurrence of particular alien species were confirmed in the fields in different seasons.

## RESULTS AND DISCUSSION

The study area recorded a total of 93 wild alien plant species from 69 genera and 28 families (Table 1). The majority of species were Dicotyledons (83 species) represented about 90% of total alien flora while monocots only 10 species. Of the 93 alien species, 87 (approx. 94%) are reported to be invasive in several landscapes of Uttar Pradesh by various researchers (Khanna 2009, Singh *et al.* 2010, Srivastava *et al.* 2014, Kumari *et al.* 2016). Overall, 173 plants were enlisted as alien invasive in India (Reddy 2008) which are invading various landscapes of the country. Earlier, Singh *et al.* (2010) reported a total of 152 invasive alien plants belonging to 109 genera and 44 families from entire Uttar Pradesh whereas Mishra *et al.* (2015) enlisted 102 alien plant species from 69 genera and 33 families in Delhi flora (Table 2). In comparison to all these studies, the present study reported 93 alien plants (87 invasives; Table 1) which is a very high proportion of occurrence of alien species in such a small geographical area (7.7 $km^2$) when compared with large geographical area of Uttar Pradesh (2,40,928 $km^2$) and NCT of Delhi (1,483 $km^2$). It constitutes more than 50% of invasive plants of entire Uttar Pradesh (152 invasive alien plants; Singh *et al.* 2010) and 90% of the total alien flora of Delhi (102 alien plant species; Mishra *et al.* 2015) (Table 2). This probably indicates a high degree of disturbance in the study area ecosystem due to various anthropogenic factors resulting in extensive land use and land cover changes, and consequently large scale invasion of alien species. The study area witnessed a number of habitats including agricultural fields, canal bunds, roadsides, village streets, wild date palm groves, wetlands, shallow water bodies, grasslands and wastelands. The presence of several kinds of habitats also responsible for the high species richness of alien species in the area. The area witnessed a number of wetlands and wild date palm [*Phoenix sylvestris* (L.) Roxb.] groves which are highly threatened due to manmade anthropogenic disturbances. A number of alien species in present study were recorded from open and wastelands. In disturbed habitats alien plant species are ready colonizers (Reddy 2008) and wastelands are preferred place for invasion of alien species (Singh *et al*. 2010). In disturbed communities, invasive alien species pose a threat to native/indigenous plant diversity worldwide whereas only a few alien plants have the potential to invade undisturbed plant communities (Rejmanek 1989). A global meta-analysis of 199 research articles on invasive species including 1041 field studies that in total describe the impacts of 135 alien plants on resident species, communities, and ecosystems and reported that abundance and diversity of the resident species reduced in invaded sites, while primary production and numerous ecosystem processes were enhanced (Vila *et al.* 2011). Globally, the Global Invasive Species Database (GISD 2021) focuses on invasive alien species of the world that have serious impacts on native biodiversity. Among the species recorded in the present study, four species namely, *Eichhornia crassipes* (Mart.) Solms, *Imperata cylindrica* (L.) Raeusch., *Lantana camara* L. and *Leucaena leucocephala* (Lam.) de Wit are listed among 100 of the world's worst invasive alien species (GISD 2021). All these species are known for their aggressive nature and threaten native vegetation world-wide in many countries including India.

**Table 1**. Wild alien plants with their nativity in Delhi NCR, western Uttar Pradesh.

| S.N. | Name of plant species | Family | Nativity | Habit | Seasonal occurrence |
|---|---|---|---|---|---|
| 1 | *Ageratum conyzoides* (L.) L.* | Asteraceae | America (Trop. America) | H | W |
| 2 | *Ageratum houstonianum* Mill.* | Asteraceae | America (Trop. America) | H | W |
| 3 | *Alternanthera paronychioides* A.St.-Hil.* | Amaranthaceae | America (Trop. America) | H | R |
| 4 | *Alternanthera philoxeroides* (Mart.) Griseb.* | Amaranthaceae | America (Trop. America) | H | TY |
| 5 | *Alternanthera pungens*Kunth* | Amaranthaceae | America (Trop. America) | H | S |
| 6 | *Alternanthera sessilis* (L.) R.Br. ex DC.* | Amaranthaceae | America (Trop. America) | H | TY |
| 7 | *Anagallis arvensis* L.* | Primulaceae | Europe | H | W |
| 8 | *Argemone mexicana* L.* | Papaveraceae | America (South America) | H | W |
| 9 | *Biden spilosa* L.* | Asteraceae | America (Trop. America) | H | S |
| 10 | *Blainvillea acmella* (L.) Philipson* | Asteraceae | America (Trop. America) | H | R |
| 11 | *Blumea obliqua* (L.) Druce* | Asteraceae | America (Trop. America) | H | W |

| | | | | | |
|---|---|---|---|---|---|
| 12 | *Calotropis gigantea* (L.) Dryand.* | Apocynaceae | Africa (Trop. Africa) | SH | PV |
| 13 | *Calotropis procera* (Aiton) Dryand.* | Apocynaceae | Africa (Trop. Africa) | H | TY |
| 14 | *Cardamine hirsuta* L.* | Brassicaceae | America (Trop. America) | H | W |
| 15 | *Celosia argentea* L.* | Amaranthaceae | Africa (Trop. Africa) | H | R |
| 16 | *Chenopodium album* L.* | Amaranthaceae | Europe | H | W |
| 17 | *Chenopodium murale* L.* | Amaranthaceae | America (Trop. America) | H | W |
| 18 | *Chloris barbata* Sw.* | Poaceae | America (Trop. America) | H | R |
| 19 | *Cleome viscosa* L.* | Cleomaceae | America (Trop. America) | H | R |
| 20 | *Corchorus aestuans* L.* | Malvaceae | America (Trop. America) | H | R |
| 21 | *Corchorus olitorius* L.* | Malvaceae | Africa (Trop. Africa) | H | R |
| 22 | *Corchorus tridens* L.* | Malvaceae | Africa (Trop. Africa) | H | R |
| 23 | *Croton bonplandianus* Baill.* | Euphorbiaceae | America (South America) | H | TY |
| 24 | *Cuscuta chinensis* Lam.* | Convolvulaceae | Mediterranean | CL/CR | TY |
| 25 | *Cuscuta reflexa* Roxb.* | Convolvulaceae | Mediterranean | CL/CR | TY |
| 26 | *Cyperus difformis* L.* | Cyperaceae | America (Trop. America) | H | R |
| 27 | *Cyperus iria* L.* | Cyperaceae | America (Trop. America) | H | R |
| 28 | *Datura innoxia* Mill.* | Solanaceae | America (Trop. America) | H | TY |
| 29 | *Digera muricata* (L.) Mart.* | Amaranthaceae | Asia (South West Asia) | H | R |
| 30 | *Dysphania ambrosioides* (L.) Mosyakin & Clemants* | Amaranthaceae | America (Trop. America) | H | R |
| 31 | *Echinochloa colona* (L.) Link* | Poaceae | America (Trop. America) | H | R |
| 32 | *Echinochloa crus-galli* (L.) P. Beauv.* | Poaceae | America (South America) | H | R |
| 33 | *Eclipta prostrata* (L.) L.* | Asteraceae | America (Trop. America) | H | TY |
| 34 | *Eichhornia crassipes* (Mart.) Solms* | Pontederiaceae | America (Trop. America) | H | TY |
| 35 | *Emex australis* Steinh.[#] | Polygonaceae | Africa (South Africa) | H | W-S |
| 36 | *Erigeron bonariensis* L.* | Asteraceae | America (South America) | H | S |
| 37 | *Euphorbia heterophylla* L.* | Euphorbiaceae | America (Trop. America) | H | R |
| 38 | *Euphorbia hirta* L.* | Euphorbiaceae | America (Trop. America) | H | TY |
| 39 | *Euphorbia hypericifolia* L. | Euphorbiaceae | America (Trop. America) | H | R |
| 40 | *Euphorbia serpens* Kunth | Euphorbiaceae | America (South America) | H | R |
| 41 | *Evolvulus nummularius* (L.) L.* | Convolvulaceae | America (Trop. America) | H | R |
| 42 | *Gnaphalium purpureum* L. | Asteraceae | America (Trop. America) | H | W |
| 43 | *Gomphrena celosioides* Mart.* | Amaranthaceae | America (Trop. America) | H | R |

| | | | | | |
|---|---|---|---|---|---|
| 44 | *Grangea maderaspatana* (L.) Poir.* | Asteraceae | America (Trop. South America) | H | TY |
| 45 | *Hyptis suaveolens* (L.) Poit.* | Lamiaceae | America (Trop. America) | H | R |
| 46 | *Imperata cylindrica* (L.) Raeusch.* | Poaceae | America (Trop. America) | H | R |
| 47 | *Indigofera astragalina* DC.* | Fabaceae | America (Trop. America) | H | R |
| 48 | *Indigofera linifolia* (L.f.) Retz.* | Fabaceae | America (Trop. South America) | H | R |
| 49 | *Indigofera linnaei* Ali* | Fabaceae | Africa (Trop. Africa) | H | S |
| 50 | *Ipomoea carnea* Jacq.* | Convolvulaceae | America (Trop. America) | SH | PV |
| 51 | *Ipomoea eriocarpa* R. Br.* | Convolvulaceae | Africa (Trop. Africa) | CL/CR | R |
| 52 | *Ipomoea obscura* (L.) Ker Gawl.* | Convolvulaceae | Africa (Trop. Africa) | CL/CR | W |
| 53 | *Ipomoea pes-tigridis* L.* | Convolvulaceae | Africa (Trop. Africa) | CL/CR | R |
| 54 | *Jatropha gossypiifolia* L.* | Euphorbiaceae | America (Brazil-South America) | SH | PV |
| 55 | *Lantana camara* L.* | Verbenaceae | America (Trop. America) | SH | PV |
| 56 | *Lathyrus aphaca* L. | Fabaceae | Mediterranean | H | W |
| 57 | *Lepidium didymum* L.* | Brassicaceae | America (Trop. America) | H | W |
| 58 | *Leucaena leucocephala* (Lam.) de Wit* | Fabaceae | America (Trop. America) | T | PV |
| 59 | *Ludwigia octovalvis* (Jacq.) P.H. Raven* | Onagraceae | Africa (Trop. Africa) | H | R |
| 60 | *Malvastrum coromandelianum* (L.) Garcke* | Malvaceae | America (Trop. America) | H | R |
| 61 | *Mecardonia procumbens* (Mill.) Small* | Plantaginaceae | America (Trop. America) | H | R |
| 62 | *Melilotus albus* Medik.* | Fabaceae | Europe | H | W |
| 63 | *Melochia corchorifolia* L.* | Malvaceae | America (Trop. America) | H | R |
| 64 | *Nicotiana plumbaginifolia* Viv.* | Solanaceae | America (Trop. America) | H | TY |
| 65 | *Oxalis corniculata* L.* | Oxalidaceae | Europe | H | W |
| 66 | *Oxalis debilis* var. *corymbosa* (DC.) Lourteig* | Oxalidaceae | America (Trop. South America) | H | W |
| 67 | *Parthenium hysterophorus* L.* | Asteraceae | America (Trop. North America) | H | TY |
| 68 | *Phyllanthus tenellus* Roxb.* | Phyllanthaceae | Mascarene Islands (Indian Ocean) | H | S |
| 69 | *Physalis angulata* L.* | Solanaceae | America (Trop. America) | H | R |
| 70 | *Physalis peruviana* L.* | Solanaceae | America (Trop. America) | H | R |
| 71 | *Pistia stratiotes* L.* | Araceae | America (Trop. America) | H | S-R |
| 72 | *Portulaca oleracea* L.* | Portulacaceae | America (South America) | H | S-R |
| 73 | *Portulaca quadrifida* L.* | Portulacaceae | America (Trop. America) | H | S-R |
| 74 | *Prosopis juliflora* (Sw.) DC.* | Fabaceae | America (Mexico-Central America) | T | PV |
| 75 | *Ricinus communis* L.* | Euphorbiaceae | Africa | SH | PV |
| 76 | *Saccharum spontaneum* L.* | Poaceae | Asia (Trop. West Asia) | H | TY |

| | | | | | |
|---|---|---|---|---|---|
| 77 | *Scoparia dulcis* L.* | Plantaginaceae | America (Trop. America) | H | TY |
| 78 | *Senna obtusifolia* (L.) H.S. Irwin & Barneby* | Fabaceae | America (Trop. America) | H | R |
| 79 | *Senna occidentalis* (L.) Link* | Fabaceae | America (Trop. South America) | H | R |
| 80 | *Sesbania bispinosa* (Jacq.) W. Wight* | Fabaceae | America (Trop. America) | SH | R |
| 81 | *Sida acuta* Burm.f.* | Malvaceae | America (Trop. America) | H | R |
| 82 | *Solanum americanum* Mill.* | Solanaceae | America (Trop. America) | H | TY |
| 83 | *Solanum torvum* Sw.* | Solanaceae | West Indies | SH | PV |
| 84 | *Sonchusasper* (L.) Hill* | Asteraceae | Mediterranean | H | W |
| 85 | *Spermacocearticularis* L.f.* | Rubiaceae | America (Trop. America) | H | R |
| 86 | *Stellaria media* (L.) Vill. | Caryophyllaceae | Europe | H | W |
| 87 | *Symphyotrichum squamatum* (Spreng.) G.L. Nesom[#] | Asteraceae | America (South America) | H | W |
| 88 | *Tribulus terrestris* L.* | Zygophyllaceae | America (Trop. America) | H | R |
| 89 | *Tridax procumbens* (L.) L.* | Asteraceae | America (Trop. Central America) | H | S |
| 90 | *Triumfetta rhomboidea* Jacq.* | Malvaceae | America (Trop. America) | H | R |
| 91 | *Typha domingensis* Pers. | Typhaceae | America (Trop. America) | H | PV |
| 92 | *Urena lobata* L.* | Malvaceae | Africa (Trop. Africa) | SH | R |
| 93 | *Xanthium strumarium* L.* | Asteraceae | America (Trop. America) | H | R |

**Note:** H - Herb, SH - Shrub, CL/CR - Climber/Creeper, T - Tree; Trop. - Tropical; W - Winter, S - Summer, R - Rainy, TY - Throughout year, PV - Permanent vegetation, W-S - Winter & Summer, S-R - Summer & Rain.

* Species recorded as invasive in Uttar Pradesh by several authors (Khanna 2009, Singh *et al.* 2010, Srivastava *et al.* 2014, Kumari *et al.* 2016); [#] Newly recorded alien invasive species in study area.

**Table 2.** A comparison of alien species recorded in present study with other studies done in Uttar Pradesh, NCT of Delhi and in India.

| S.N. | Study area | Alien species recorded | Number of Genera | Number of Families | Source |
|---|---|---|---|---|---|
| 1 | Chithara (Delhi NCR, Western Uttar Pradesh) | 93 | 69 | 28 | Present study |
| 2 | India | 173 | 117 | 44 | Reddy (2008) |
| 3 | Uttar Pradesh | 153 | 107 | 45 | Khanna (2009) |
| 4 | Uttar Pradesh | 152 | 109 | 44 | Singh *et al*. (2010) |
| 5 | North-Eastern Uttar Pradesh | 149 | 100 | 41 | Srivastava *et al*. (2014) |
| 6 | NCT of Delhi | 102 | 69 | 33 | Mishra *et al*. (2015) |
| 7 | North-Western Uttar Pradesh (Rohilkhand region) | 79 | 64 | 29 | Kumari *et al*. (2016) |

*Nativity of alien plants*

The largest number of species (67; 72%) were native to America followed by Africa (13 species; 14%), Europe (5 species; 6%), Mediterranean (4 species; 4%) and Asia (2 species; 2%) (Fig. 1). There was a single species *i.e.*, *Phyllanthus tenellus* Roxb. originated from Mascarene Islands (Indian Ocean) and one species, *Solanum torvum* Sw. from West Indies. Altogether, a large number of species (91%) were of African, American, and European origin (Table 1). In a study of invasive flora of whole Uttar Pradesh, Singh *et al.* (2010) stated 73% of species from American nativity and Srivastava *et al.* (2014) reported 70.5% invaders of American nativity in north-eastern Uttar Pradesh. While studying invasive alien flora of India, authors enlisted 74% species native to America (Reddy 2008). All these studies confirm the finding of the present study which reports 73% of alien plants as American nativity. A similar trend of results was obtained in a study of the alien flora of

Delhi which demonstrated that the maximum number of alien species was introduced from tropical America followed by Africa (Mishra *et al.* 2015).

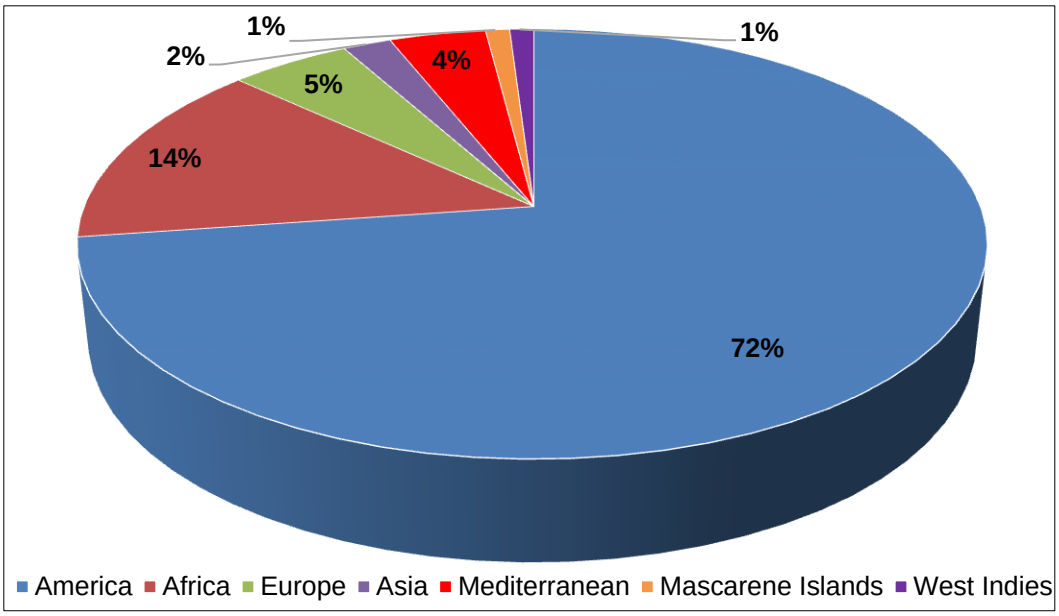


**Figure 1.** Contribution of different geographical regions to the alien flora.

*Discrepancy in reporting nativity of species*

The authenticity of the nativity of certain species ascribed by various authors appears to be questionable since discrepancies have been observed in reporting their nativity. Singh *et al.* (2010) reported that the nativity of *Saccharum spontaneum* L. is Malaysia while other authors (Srivastava *et al.* 2014, Mishra *et al.* 2015, Kumari *et al.* 2016) listed it as native to tropical west Asia. Similarly, *Urena lobata* L. has been enlisted as native to tropical America (Khanna 2009, Singh *et al.* 2010, Kumari *et al.* 2016) whereas several researchers have referred its nativity to tropical Africa (Negi & Hajra 2007, Reddy 2008, Srivastava *et al.* 2014, Mishra *et al.* 2015).

Another point that emerges through literature analysis is reporting certain invasive species by some authors while others have not included that particular plant in their studies for the same geographical area. There are several such instances which were encountered while referring to various publications on alien invasive. For example, *Ricinus communis* L., a plant of Euphorbiaceae family is said to be native to Africa by some researchers (Negi & Hajra 2007, Srivastava *et al.* 2014) while its alien status was not included in another research of Uttar Pradesh (Singh *et al.* 2010). Similarly, in a study of Uttar Pradesh, *Saccharum spontaneum* was not included as one of the alien invasive species (Khanna 2009) while another study referred to it as an invasive alien (Singh *et al.* 2010). The nativity of *Cannabis sativa* L. (Marijuana) is still unclear. Besides this, it was enlisted as alien invasive in one study (Srivastava *et al.* 2014). *Cannabis sativa* has become a potentially serious invasive weed in this part of Uttar Pradesh like any other noxious alien weeds. In the present study, we found that it is growing gregariously along roadsides, railway lines, waste places, fallow lands, edges of wetlands, and even in cultivated wheat fields. It has invaded all types of ecosystems in this region. Another species, *Ceratophyllum demersum* L., an aquatic plant is considered an invasive alien in Uttar Pradesh (Khanna 2009, Singh *et al.* 2010), however, it was not included in invasive alien flora of India (Reddy 2008).

*Family and genera dominance*

Concerning families, Asteraceae was the most dominant with 14 alien species followed by Amaranthaceae and Fabaceae (10 species each), Malvaceae (8 species), Convolvulaceae and Euphorbiaceae (7 species each), Solanaceae (6 species) and Poaceae (5 species). These families contributed approx. 37% of the total alien plants. The dominance of the family Asteraceae, Amaranthaceae, and Fabaceae were also reported in alien flora of Delhi (Mishra *et al.* 2015) and Uttar Pradesh (Singh *et al.* 2010, Srivastava *et al.* 2014, Kumari *et al.* 2016). Fourteen families had a single species each while six families had 2 species each (Fig. 2).

Genera such as *Alternanthera*, *Euphorbia*, and *Ipomoea* had the highest number of alien species (4 species each) followed by *Corchorus* and *Indigofera* (3 species each). The dominance of Genera like *Alternanthera*, *Ipomoea*, *Corchorus*, and *Indigofera* were also reported in alien flora of Delhi (Mishra *et al*. 2015). Eleven genera had two species each and all the rest of the genera (53) were represented by a single species (Fig. 3).

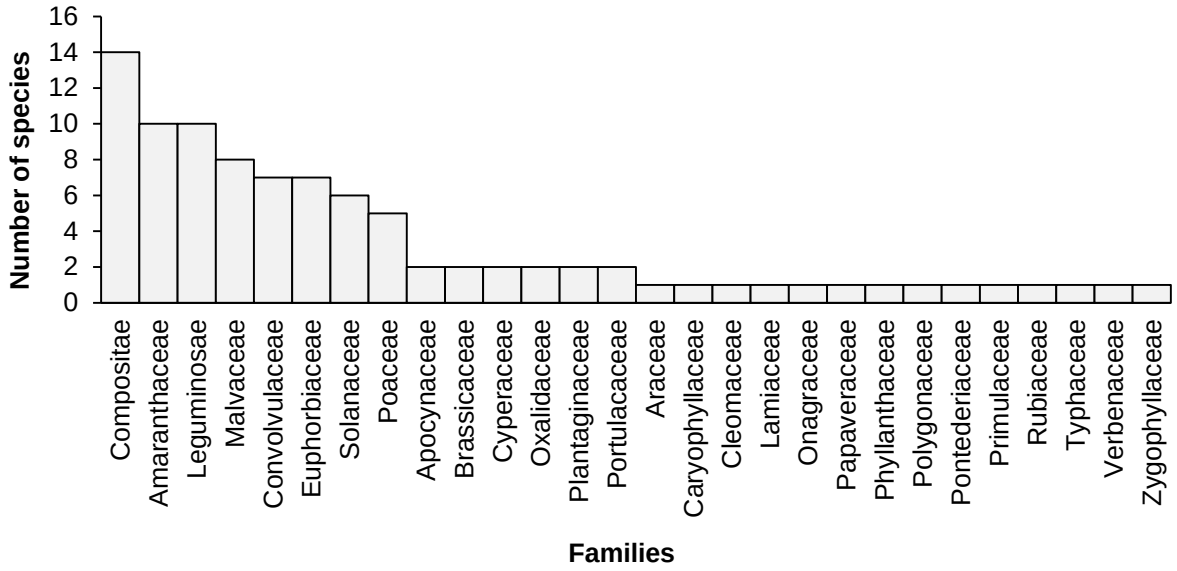


**Figure 2.** Distribution of number of alien species in various families.

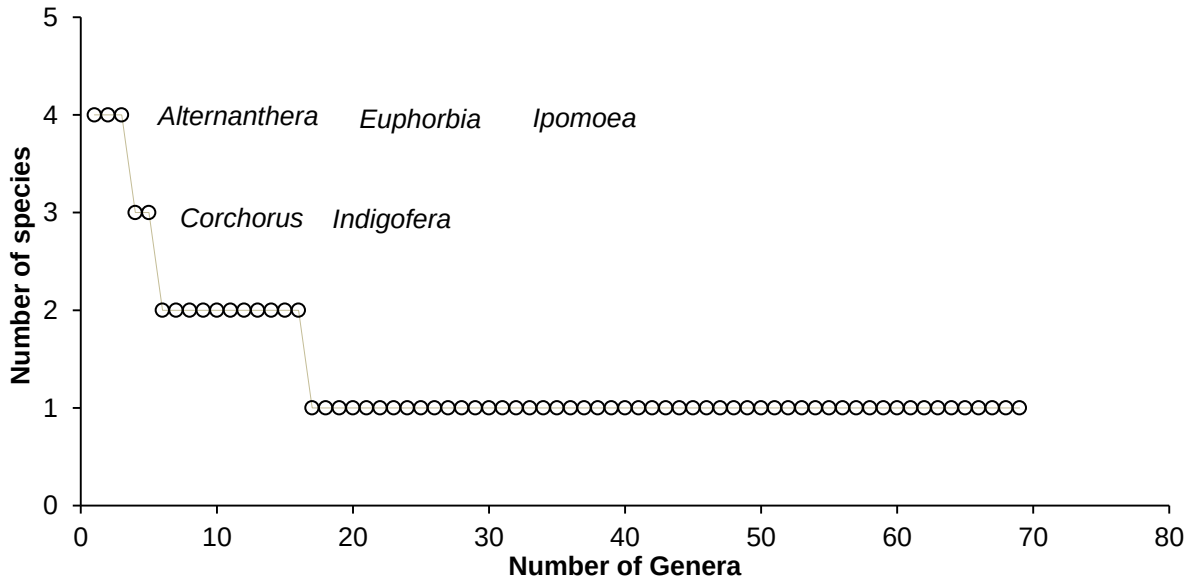


**Figure 3.** Distribution of number of alien species in various genera.

*Habit of plants*

The exotic herb species were greater in numbers than other life forms. Herbs with 78 species contributed maximum percentage (approx. 84%) of alien species followed by shrubs (9%), and climbers/creepers (5%). Trees were least dominant with 2 alien species *i.e.*, *Prosopis juliflora* (Sw.) DC. and *Leucaena leucocephala* (Table 1; Fig. 4). The dominance of herbaceous alien flora also confirms findings of various authors in Uttar Pradesh (Singh *et al.* 2010, Srivastava *et al.* 2014, Kumari *et al.* 2016) and Delhi (Mishra *et al.* 2015); also these authors reported a very few numbers of tree species as aliens in their studies. Habit-wise analysis of the entire Indian flora of invasive alien species also shows that herbs with 87.3% predominate followed by shrubs, climbers, and trees (Reddy 2008).

*Seasonality in the occurrence of species*

The annual herbs, grasses, and sedges, etc. showed seasonality in their occurrence. A large number of species (40) start germinating in rainy seasons towards the end of June and early July when the monsoon starts followed by winter (18). However, 16 alien species were observed growing throughout the year. Nine species were present as the permanent vegetation being shrubs or trees and six species occurred in the summer season. Interestingly, *Emex australis* Steinh. was recorded both during winter and summer seasons whereas three species continued to grow during summer and rainy seasons (Table 1). In comparison to species occurring in a specific season, the species found throughout the year such as *Alternanthera philoxeroides* (Mart.) Griseb., *Cuscuta chinensis* Lam., *Eichhornia crassipes*, etc. are most dangerous to the different ecosystems.

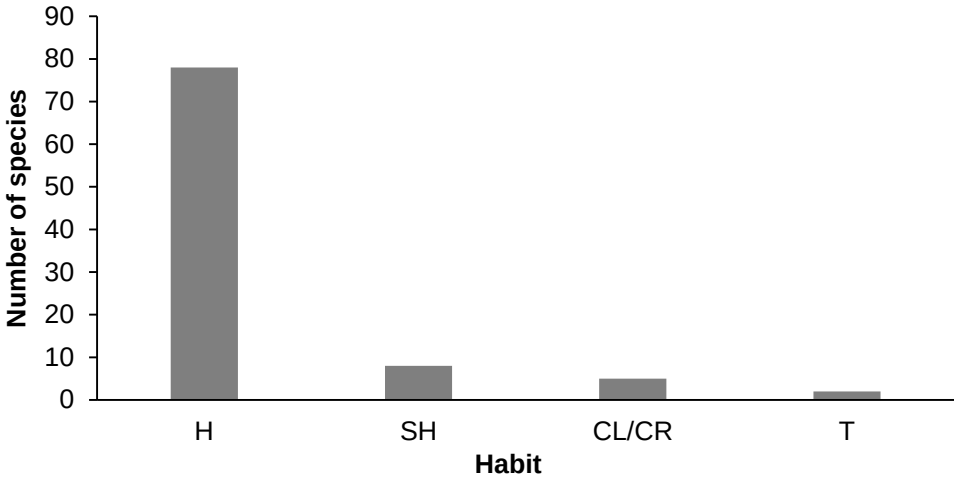


**Figure 4.** Habit wise distribution of alien species. [H – Herb, SH – Shrub, CL/CR - Climber/Creeper, T - Tree]

*Medicinally important alien plants*

Alien plants have both beneficial and harmful impacts but invasion ecology has mostly highlighted harmful impacts (Goodenough 2010). Several alien species recorded in the flora were found to have potent medicinal properties and used in folk medicines. Alien species like *Euphorbia hirta* L., *Solanum americanum* Mill., *Eclipta prostrata* (L.) L., *Tribulus terrestris* L., *Hyptis suaveolens* (L.) Poit. were rated to have outstanding medicinal properties as they are used for the cure of a large number of diseases, both in traditional and folklore medicines in India and elsewhere (Sharma *et al.* 2018). A study confirms the presence of a large number of alien plant species in Uttar Pradesh which are medicinally useful and being utilized by local people for medicinal purposes (Singh *et al.* 2010). Therefore, sustainable utilization of these species for medicinal purposes is also required as it will not only provide a livelihood to people, and augment dwindling herbal resources in the country but will also help to manage the invasive population of alien species (Mandal 2011).

*Possible impacts of alien species on ecosystem*

A large number of alien invasive species have been reported from Uttar Pradesh by different authors *viz*; 102 (Singh *et al.* 2010), 149 (Srivastava *et al.* 2014), 79 (Kumari *et al.* 2016), however, our field investigations indicated that not all species as reported by these authors were invasive in this part of Delhi NCR in western Uttar Pradesh. Further, our field observations suggest that a species could be invasive in a particular region of Uttar Pradesh but not necessarily to the entire part of Uttar Pradesh. *Ageratum conyzoides* (L.) L., *Parthenium hysterophorus* L., *Lantana camara* and *Ageratina adenophora* (Spreng.) R.M.King & H.Rob. are major invaders and causing huge loss to indigenous species diversity in North West Himalaya of India (Dogra *et al.* 2010). *Ageratum conyzoides*, *Parthenium hysterophorus*, and *Lantana camara* were also recorded in the present study but except *Parthenium hysterophorus*, the other two species were not found aggressive.

Our field observation and interaction with local inhabitants during the present study suggest that major noxious invasive species in this region are *Alternanthera philoxeroides* (Alligator Weed), *Calotropis procera* (Aiton) Dryand. (Sodom Apple, Aak), *Chenopodium album* L. (Goosefoot, Bathua), *Eichhornia crassipes* (Water Hyacinth), *Parthenium hysterophorus* (Carrot Grass), *Pistia stratiotes* L. (Water Cabbage), *Prosopis juliflora* (Algaroba, Junglee Kikar), *Saccharum spontaneum* (Kans Grass), *Tribulus terrestris* (Puncture Vine, Gokhru) and *Typha domingensis* Pers. (narrow-leaf cattail, Patera). These species are major invaders of a number of habitats throughout the study area and surroundings. Among these, the species namely *Alternanthera philoxeroides*, *Eichhornia crassipes* and *Pistia stratiotes* were found most serious invasive of aquatic habitats (Fig. 5A, C, D). These species have adversely affected several wetlands and other aquatic habitats in the area and they have become a major threat to water bodies and their native aquatic flora. *Tribulus terrestris* (Fig. 5B) was recorded to grow gregariously in the study area and its large populations occupy waste and fallow lands (Tripathi *et al.* 2019). *Chenopodium album* (Fig. 5F), is one of the most aggressive noxious alien invasives in this region affecting the local biodiversity to a great extent as it does not allow any other species to grow in its habitat similar to *Parthenium hysterophorus*. Its pure growth was observed in fallow lands, wastelands, boundaries of agricultural fields and roadsides, and railway tracks. Growing most vigorously, it has greatly impacted cultivated and non-cultivated fields. The fertile upper Gangetic Plain's alluvial soil rich in nitrogen seems to favour the growth of this plant. *Chenopodium album* is one of the most dangerous weeds in Europe, and in India, Mexico, New Zealand, Pakistan, and South Africa and ranked amongst the six most serious weeds

(CABI). However, the qualitative and quantitative impact of all these weed species on terrestrial and aquatic ecosystems is yet to be studied in detail.


**Figure 5.** Alien invasives in Delhi NCR, western Uttar Pradesh: **A**, *Alternanthera philoxeroides* (Mart.) Griseb.; **B**, *Tribulus terrestris* L.; **C**, *Eichhornia crassipes* (Mart.) Solms; **D**, *Pistia stratiotes* L.; **E**, *Saccharum spontaneum* L.; **F**, *Chenopodium album* L.; **G**, *Emex australis* Steinh.; **H**, *Symphyotrichum squamatum* (Spreng.) G.L. Nesom [**A** to **F** - Highly invasive; **G** & **H** - Newly reported alien species]

With regards to trees, two alien species namely *Prosopis juliflora* and *Leucaena leucocephala* were recorded in the present study. *Prosopis juliflora* is one of the most aggressive and fast-growing tree species in this region. The species is known for its allelopathic effects retarding the growth of other native species. Also, *Leucaena leucocephala*, another alien fast-growing invasive tree species introduced in India for raising fast-growing plantations has spread vigorously in various habitats and resulted in significant biodiversity loss. This is due to the production of a huge quantity of seeds that germinate after the rains without any dormant period producing an innumerable number of seedlings.

Two invasive alien species namely *Emex australis* (Three corner jack) and *Symphyotrichum squamatum* (Spreng.) G.L.Nesom (Annual saltmarsh aster) were recorded for the first time in the study area and were new additions to the flora of Upper Gangetic Plains and flora of India respectively (Tripathi *et al.* 2018, Tripathi & Sharma 2019). These two species are known to produce a large number of seeds and spread rapidly and may become aggressive invasive weeds in India. *Emex australis* (Fig. 5G) is already an aggressive serious weed in Australia and South Africa (Cairns *et al.* 1979, Gilbey & Weiss 1980, Parsons & Cuthbertson 1992) while *Symphyotrichum squamatum* (Fig. 5H) is also reported as alien invasive in different parts of the world (Arianoutsou *et al.* 2010, Uludağ *et al.* 2017, Mokni & Iamonico 2018). The extensive floristic surveys are required in India for early detection and reporting of infestation and spread of new and naturalized populations of *Emex australis* and *Symphyotrichum squamatum* before they become a potential threat to the ecosystem. The newly introduced species in the balanced ecosystems can affect the natural process which leads to the loss of biodiversity (Louda *et al*. 2003).

## CONCLUSION

While there is considerable research on the characteristics and traits which allow a species to become invasive, the reasons in individual cases are not very clear. Probably the likelihood of an alien species becoming invasive is increased if it is introduced in a geographic area with conducive climatic conditions which will help to establish and spread to become invasive (CBD 2009).

At present, the impact of invasion is seen in current global change and there is no single opinion about the impact and scale of changes caused by invasive alien species by concerned stakeholders and scientists (Richardson & Ricciardi 2013). The shifting environmental conditions may not help native species in some ecosystems and invasive species may be serious contributors to the resilience of ecosystem services (Eviner *et al.* 2012). There should be a standardized approach for detecting and quantifying the impacts of alien plants (Kumschick *et al.* 2015). Coordinated planning is needed for early detection and reporting of infestation and spread of new and naturalized weeds in India by the establishment of plant detection network in prominent research institutions, mainly all the regional stations of Botanical Survey of India through communication links between taxonomists, ecologists, and foresters to monitor and timely eradication/control of alien species. This is important as it will probably be easier to manage the invasion of alien species in the initial stages of introduction rather than when it has already spread in a larger geographic area. To document truly alien invasive species, and their impact on ecosystem a long term biodiversity inventory needed at the village panchayat level in India.

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