Eco. Env. & Cons. 29 (May Suppl. Issue) : 2023; pp. (S379-S394)
Copyright@ EM International
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i03s.067

An Invasive Ecological Study on the Flora of Soil Seed Bank and Standing Vegetation Across Diverse Anthropo-ecosystems in Indian Dry Tropics

***Chandan Yadav and Rup Narayan**

Department of Botany, Chaudhary Charan Singh University, Meerut 250 004, (U.P), India

(Received 10 December, 2022; Accepted 20 February, 2023)

ABSTRACT

Plant invasions in tropical ecosystems are being increasingly realized particularly in highly dynamic but fragile dry tropical ecosystems, where there is generally little ecological information on invasions in subterranean vegetation. The present study was carried out to understand the floristic composition of both seed bank and standing vegetation across a range of five diverse anthropo-ecosystems in an urban region in Indian dry tropics. A total of one hundred soil samples (each of size of 25cm×25cm from 0-5 cm and 5-10 cm depth) from five anthropic sites (vegetation of University campus, polluted Kali River bank, Brick kiln, Waste land and Road side) were analyzed for their taxonomic position, life form and bio-geographic origin of the seedling emergents in relation to the flora in standing vegetation. A total of 221 plant species (58% aliens, 34% of aliens of American origin, 75% weedy herbs) in standing vegetation spread over 54 families were recorded in standing vegetation of the study sites with more than 55% representation from eight dominant families led by Fabaceae, Poaceae and Asteraceae followed by Malvaceae, Amaranthaceae and Solanaceae. In contrast, a total of 81 seed bank flora (10 unidentified, 62% aliens, 43% of American origin, 87% herbs) distributed over 32 angiospermic families were recorded. While none of the seed bank vegetation at any site showed significant similarity with its standing vegetation indicating the minor role of seed bank flora in the regeneration of the standing plant communities above ground. However, a considerable similarity among seed banks and standing vegetation at other sites indicated a significant possible role of anthropogenic activities in the urban regions of Indian dry tropics, evinced by the largest proportion of grasses and herbs dominated by exotics, especially of American origin. These aliens through successful naturalization via seed banks may cause homogenization of floristic structure. In conclusion, the present study revealed a heavy scale of intrusion by the alien plants dominated by American elements into not only standing vegetation but also in seed banks across the anthropic sites in urban regions in Indian dry tropics which is likely to alter the standing vegetation floristic structure with a larger abundance of alien flora.

Key words : *Alien species, Tropical ecosystems, Plant invasions, Species diversity, Urban sprawl, Land use*

Introduction

Understanding the diversity and density level of Seed bank (SB) is important for designing conservation and restoration programs in degraded ecosystems, especially in arid ecosystems. SBs are considered an essential constituent of plant communities since the potential to reclaim communities after disturbances are believed to lie mainly in the buried seed populations (Song *et al*., 2017). Their studies facilitate an understanding of secondary succession and assume the first step for the design of ecological restoration plans, as SBs contribute to the diversity and dynamics of most plant communities (Singhal, 2014). Consequently, SB characteristics elucidate seed dynamics in various vegetation types. The scientific knowledge of SB is used for land use planning and policy formulation for conservation or restoration programs (Shiferaw *et al*., 2018). For dry tropical anthropo-ecosystems, it is an important ecosystem resilience component and represents a stock of regeneration potential in many plant assemblages. These SBs have the capacity to survive for a long period in the soil and overcome the poor establishment stress and low survival rates of seedlings during drier years (Santos *et al*., 2018) and contribute significantly to the re-establishment of plant species lost from the original plant community. The seeds in such anthropo-ecosystems remain dormant till exposed to favorable germination conditions such as increased light, temperature, or moisture conditions which are inadvertently associated with disturbances and ecosystem perturbations (Weerasinghe *et al.*, 2019). In fact, SBs may be considered as species reservoirs consisting of transient, short-term persistent, and persistent seeds (Gioria *et al.,* 2012). This reservoir basically corresponds to the non-germinated seeds but is potentially capable of replacing the annual adult plants, which had disappeared by natural death or and perennial plants that are susceptible to plant diseases, disturbances and animal consumption including man (Taiwo *et al.,* 2018). It commonly acts as a reserve out of which new recruitment may occur under favorable environmental conditions (Kolodziejek and Patykowski, 2015).

Tropical ecosystems are considered highly dynamic and rich in biodiversity but due to immense developmental activities here in dry tropics, in particular, its fragility is being increasingly reported, especially in and around urban and peri-urban ecosystems. The delicate balance of ecological processes in these ecosystems in dry tropics is inadequately investigated with respect to the surface vegetation and seed bank potential. While it is widely acknowledged that biological invasion is the second largest threat to biodiversity (Pauchard and Shea, 2006; Pimentel *et al.,* 2001) there has been little attempt to investigate invasion into seed banks and standing vegetation with respect to the success of alien intrusion into SBs. The present study aimed to examine how the nativity and life form of plant species in standing vegetation and seed banks across diverse anthropo-ecosystems in Indian dry tropics.

Materials and Methods

Study area

Location and topography

The study area was located at Meerut (28°57' and 29°02' N lat. and 77°40' and 77°45' E long.), at 237.4 m above MSL (mean sea level) which falls in the upper doab of the Ganges and Yamuna rivers, which is mainly composed of Pleistocene and subrecent alluvial sediments transported and deposited by river action from the Himalayan region. This

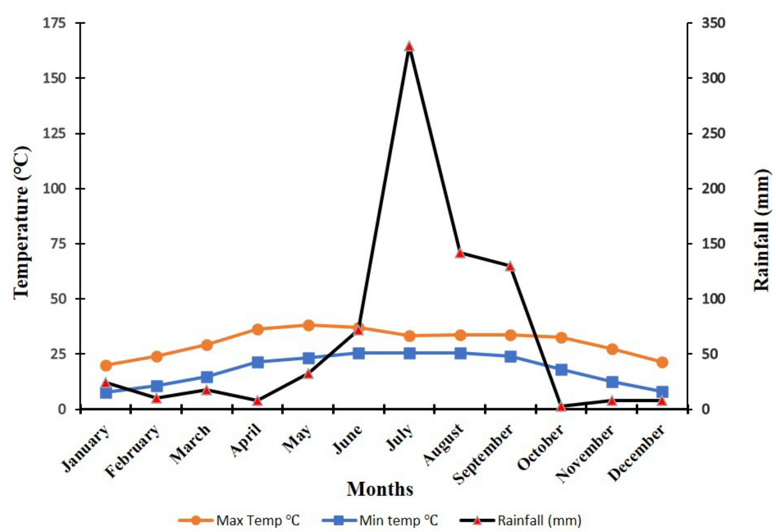

Fig. 1. Ombrothermic diagram indicating total rainfall distribution over different months and mean monthly minimum and maximum temperature of the study area in Meerut.

metropolitan city at a distance of 72 km from the national capital Delhi, occupies an area of about 142 km^2 and it is the fifth-largest town (population-wise) in Uttar Pradesh after Kanpur, Lucknow, Agra and Varanasi. It is basically the major agricultural region of western U.P. where sugarcane, wheat, maize, paddy, vegetables and fruit orchards are cultivated in abundance. Some of the prominent industries in the city are textile, tyres, sugar, transformer, chemicals, pharmaceutical, distillery, paper, engineering, sports goods and publishing.

Climatic condition

Meerut has a moderate type of climate. The study area has three major seasons: rainy (Jul-Oct), winter (Nov-Feb) and summer (Mar-Jun). The mean maximum and minimum temperatures were in the month of May (38.2 °C) and January (7.8 °C) respectively (Fig. 1). The daily relative humidity varied from 9 to 100%. Annual mean rainfall was 784.8 mm received mostly during monsoon (Jul-Oct). This climate data is based on data from five years(2016-2020) obtained from the records of the meteorological office, Meerut (Chaudhary Charan Singh University Campus Meerut).

Study Sites

Five permanent study sites representing diverse habitat conditions were selected for investigation in this study.

i). University campus (UC): Chaudhary Charan Singh University (formerly, Meerut University) established in 1965, is one of the premier and largest state universities in Uttar Pradesh with a vast, beautiful and lush green campus with a large number of planted trees spread over 222 acres of land. The campus is covered with a variety of weeds and ruderals. A total of over half-million students from over one thousand affiliated colleges are enrolled here who are frequently seen moving in large numbers into the campus for one purpose or the other.

ii). River bank (RB): Kali River, a tributary of Ganga, originates from Muzaffarnagar (U.P) and after a long journey through the Muzaffarnagar, Meerut, Bulandshahr and Aligarh finally merges with Ganga near Mahdurpur village at Kannauj in Farrukhabad district. Kali river, passing through the eastern edge of Meerut city, is a sink of untreated and partially treated industrial effluents, domestic sewage and urban waste. The study site was located along the banks of Kali River near Gokalpur village on the state highway (SH-14 Meerut to Garhmukteshwar).

iii). Brick kiln (BK): Bricks are one of the most important construction materials that fulfill the growing demand of urban expansion in India. Our country is the second-largest producer of bricks in the world after China. There are about 70 brick kiln industries in the Meerut district. The brick kiln site was located at SH-14 (Meerut to Garhmukteshwar) near Hasanpur Kaddim village, working continuously for the last 4-5 decades. More than five hundred people have been employed who are local residents and migrants from the state of Bihar and Bengal.

iv). Waste land (WL): This site is located at National Highway (NH-334 Meerut to Hapur) called 'Lohiya Nagar dumping ground'. It receives waste byproducts of human activities such as households, public places, hospitals, commercial centers, construction sites and various industries across the Meerut region.

v). Road side (RS): This region has witnessed a rapid upsurge in transportation due to developmental activities in the last 4-5 decades. There are two expressways, six NHs and five SHs in the sub-region of western Uttar Pradesh. Meerut is the second-largest city after Delhi in the National Capital Region (NCR) of India. It is well connected with roads to highly advanced urban centers e.g., Delhi, Noida, Ghaziabad, Gurugram and Dehradun lying in the vicinity.

Species composition

Standing Vegetation

Floristic composition of study sites was recorded seasonally from April 2018 to March, 2021. Plant species were identified according to Sharma, (1980); Gaur, (1999) and according to the available flora of Duthie, (1960). They were listed alphabetically in tabular form with family, life form, bio-geographical origin and site-wise distribution in standing vegetation and underground flora (Table A). Nomenclature and families of listed plant species were updated using the taxonomic on-line POWO (https://powo.science.kew.org) database. Bio-geographical origin of the plants was recorded from the published literature (Reddy, 2008; Khanna, 2009; Sekar, 2012; Joshi and Rawat, 2011; Khuroo *et al*., 2007; Agrawal

Table A List of plant diversity (species count) recorded in standing and seed bank vegetation across five different anthropic habitats in a dry tropical urban region of Meerut, India.

S. N.	Name of the Plant	Family	Life form	Bio-geographical origin range	Occurrence of plant species at selected sites across Meerut region. UC		RB		BK		WL		RS	
					SV	SB	SV	SB	SV	SB	SV	SB	SV	SB
1.	*Abutilon indicum* (L.) Sweet	Malvaceae	H	India	-	-	+	-	-	-	+	-	+	+
2.	*Acalypha indica* L.	Euphorbiaceae	H	India	-	-	-	-	-	-	-	-	+	+
3.	*Achyranthes aspera* L.	Amaranthaceae	H	North America	+	+	+	+	+	+	+	+	+	-
4.	*Aegle marmelos* (L.) Correa	Rutaceae	T	India	-	-	+	-	-	-	-	-	-	-
5.	*Ageratum conyzoides* L.	Asteraceae	H	Tropical America	+	-	-	-	-	-	-	-	-	-
6.	*Ageratum houstonianum* Mill.	Asteraceae	H	Tropical America	-	-	-	-	-	-	-	-	+	-
7.	*Albizia lebbeck* (L.) Benth.	Fabaceae	T	India	-	-	-	-	-	-	-	-	+	-
8.	*Alstonia scholaris* (L.) R.Br.	Apocynaceae	T	India	-	-	-	-	-	-	-	-	+	-
9.	*Alternanthera ficoidea* (L.) P. Beauv.	Amaranthaceae	H	South America	-	-	-	-	-	-	+	-	-	-
10.	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae	H	Tropical America	+	-	+	-	+	-	-	-	-	-
11.	*Alternanthera pungens* Kunth	Amaranthaceae	H	Tropical America	+	-	+	-	+	-	+	-	-	-
12.	*Alternanthera sessilis* (L.) DC.	Amaranthaceae	H	Tropical America	-	-	+	+	+	-	+	-	-	-
13.	*Alysicarpus longifolius* (Rottler ex Spreng.) Wight & Arn.	Fabaceae	H	India	+	-	-	-	+	-	+	-	-	-
14.	*Amaranthus spinosus* L.	Amaranthaceae	H	South America	-	-	+	-	-	-	+	-	+	+
15.	*Amaranthus viridis* L.	Amaranthaceae	H	Tropical America	+	-	+	+	+	-	+	+	+	+
16.	*Ammannia baccifera* L.	Lythraceae	H	Asia	-	-	-	-	+	-	-	-	-	-
17.	*Anisomeles indica* (L.) Kuntze	Lamiaceae	H	India	+	-	-	-	+	-	-	-	-	-
18.	*Antigonon leptopus* Hook. & Arn.	Polygonaceae	C	Tropical America	-	-	-	-	-	-	-	-	+	-
19.	*Argemone mexicana* L.	Papaveraceae	H	South America	+	-	+	+	-	-	-	-	-	-
20.	*Artemisia capillaris* Thunb.	Asteraceae	H	India	+	+	-	-	-	-	-	-	-	-
21.	*Avena sativa* L.	Poaceae	H	Asia	+	-	-	-	-	-	-	-	+	-
22.	*Azadirachta indica* A. Juss.	Meliaceae	T	India	+	-	+	-	+	-	-	-	-	-
23.	*Basella alba* L.	Basellaceae	C	India	-	-	-	-	-	-	+	-	-	-
24.	*Benincasa hispida* (Thunb.) Cogn.	Cucurbitaceae	C	Asia	-	-	-	-	-	-	+	-	-	-
25.	*Bidens pilosa* L.	Asteraceae	H	Tropical America	-	-	-	-	+	-	-	-	-	-
26.	*Blumea lacera* (Burm.f.) DC.	Asteraceae	H	Tropical America	-	-	-	-	-	-	+	-	+	-
27.	*Boerhavia diffusa* L.	Nyctaginaceae	H	India	+	-	+	-	+	-	-	-	-	-
28.	*Bombax ceiba* L.	Malvaceae	T	India	+	-	-	-	-	-	-	-	-	-
29.	*Bonnaya ciliata* (Colsm.) Spreng.	Linderniaceae	H	India	+	-	-	-	+	+	-	-	-	-
30.	*Bouffordiadichotoma* (Willd.) H. Ohashi & K. Ohashi	Fabaceae	H	India	+	-	-	-	-	-	+	-	-	-
31.	*Brassica rapa* L.	Brassicaceae	H	Eurasia, Africa	-	-	+	-	-	-	+	-	-	-
32.	*Butea monosperma* (Lam.) Kuntze	Fabaceae	T	India	-	-	-	-	+	-	-	-	-	-
33.	*Calotropis gigantea* (L.) W.T. Aiton	Apocynaceae	S	Africa	+	-	-	-	-	-	-	-	-	-
34.	*Calotropis procera* (Aiton) W.T. Aiton	Apocynaceae	S	Africa	+	-	+	-	+	-	+	-	+	-
35.	*Cannabis sativa* L.	Cannabaceae	H	Asia	+	-	+	+	+	+	-	-	+	+

Table A. *Continued ...*

S. N.	Name of the Plant	Family	Life form	Bio-geographical origin range	Occurrence of plant species at selected sites across Meerut region.									
					UC		RB		BK		WL		RS	
					SV	SB	SV	SB	SV	SB	SV	SB	SV	SB
36.	*Carissa macrocarpa* (Eckl.) A.DC.	Apocynaceae	S	Africa	-	-	+	-	-	-	-	-	-	-
37.	*Cassia fistula* L.	Fabaceae	T	India	+	-	+	-	-	-	+	-	-	-
38.	*Causonis trifolia* (L.) Mabb. & J. Wen	Vitaceae	C	India	-	-	-	-	-	-	+	-	+	-
39.	*Celosia argentea* L.	Amaranthaceae	H	Africa	-	-	+	-	-	-	-	-	-	-
40.	*Cenchrus ciliaris* L.	Poaceae	H	India	+	-	-	-	-	-	-	-	-	-
41.	*Cenchrus setiger* Vahl	Poaceae	H	India	+	-	-	-	-	-	-	-	-	-
42.	*Centella asiatica* (L.) Urb.	Apiaceae	H	India	-	-	+	+	-	-	-	-	-	-
43.	*Chamaecrista pumila* (Lam.) V. Singh	Fabaceae	H	Tropical America	+	-	-	-	-	-	-	-	-	-
44.	*Chenopodium album* L.	Amaranthaceae	H	Europe	+	+	+	+	+	+	+	+	+	+
45.	*Chenopodiastrum murale* (L.) S. Fuents, Uotila & Borsch	Amaranthaceae	H	Tropical America	-	-	-	-	+	-	-	-	-	-
46.	*Chloris barbata* Sw.	Poaceae	H	Tropical America	-	-	-	-	-	-	+	-	-	-
47.	*Cirsium arvense* (L.) Scop.	Asteraceae	H	Europe	-	-	-	-	-	-	-	-	+	-
48.	*Cissampelos pareira* L.	Menispermaceae	C	India	+	-	-	-	-	-	-	-	+	+
49.	*Cleome viscosa* L.	Cleomaceae	H	Tropical America	-	-	+	-	+	-	+	-	-	-
50.	*Coccinia grandiflora* Cogn. ex Engl.	Cucurbitaceae	C	Africa	+	-	+	-	+	-		-	+	-
51.	*Cocculus hirsutus* (L.) W. Theob.	Menispermaceae	C	India	-	-	+	-	-	-	+	-	+	-
52.	*Coixlacryma jobi* L.	Poaceae	H	India	-	-	-	-	+	-	-	-	-	-
53.	*Commelina benghalensis* L.	Commelinaceae	H	India	+	-	+	-	+	-	+	-	+	-
54.	*Commicarpus chinensis* (L.) Heimerl	Nyctaginaceae	H	India	-	-	-	-	-	-	-	-	+	-
55.	*Corchorus aestuans* L.	Malvaceae	H	Tropical America	+	+	+	-	-	-	+	-	-	-
56.	*Corchorus olitorius* L.	Malvaceae	H	Africa	+	+	+	-	+	+	+	-		-
57.	*Cordia myxa* L.	Boraginaceae	T	India	-	-	-	-	-	-	-	-	+	-
58.	*Coriandrum sativum* L.	Apiaceae	H	Europe	-	-	-	-	-	-	+	-	-	-
59.	*Croton bonplandianus* Baill.	Euphorbiaceae	H	South America	+	-	+	-	+	+	+	+		-
60.	*Cucumis melo* L.	Cucurbitaceae	C	India	-	-	+	-	-	-	+	-	-	-
61.	*Cyanotis axillaris* (L.) D. Don ex Sweet	Commelinaceae	H	India	+	-	-	-	-	-	-	-	+	-
62.	*Cyanthillium cinereum* (L.) H. Rob.	Asteraceae	H	India	-	-	-	-	-	-	+	-	+	+
63.	*Cynodon dactylon* (L.) Pers.	Poaceae	H	India	+	-	+	-	+	-	+	-	+	-
64.	*Cynoglossum lanceolatum* Forssk.	Boraginaceae	H	India	-	-	-	-	+	-	-	-	-	-
65.	*Cyperus alopecuroides* Rottb.	Cyperaceae	H	Africa	-	-	+	-	-	-	+	-	-	-
66.	*Cyperus compressus* L.	Cyperaceae	H	India	+	-	+	-	+	-	+	+	-	-
67.	*Cyperus difformis* L.	Cyperaceae	H	Tropical America	-	-	-	-	+	-	+	-	-	-
68.	*Cyperus iria* L.	Cyperaceae	H	Tropical America	-	-	+	-	+	-	-	-	-	-
69.	*Cyperus rotundus* L.	Cyperaceae	H	Europe		-	+	-	+	-	+	-	+	-
70.	*Dactyloctenium aegyptium* (L.) Willd.	Poaceae	H	India	+	-	+	-	+	+	+	+	+	-
71.	*Dalbergia sissoo* Roxb. ex DC	Fabaceae	T	India	+	-	+	-	+	-	-	-	+	-
72.	*Datura stramonium* L.	Solanaceae	H	South America	-	-	+	-	-	-	-	-	+	-
73.	*Delonix regia* (Bojer ex Hook.) Raf.	Fabaceae	T	Africa	-	-	+	-	+	-	+	-	+	-

Table A. *Continued ...*

S. N.	Name of the Plant	Family	Life form	Bio-geographical origin range	Occurrence of plant species at selected sites across Meerut region.									
					UC		RB		BK		WL		RS	
					SV	SB	SV	SB	SV	SB	SV	SB	SV	SB
74.	*Desmostachya bipinnata* (L.) Stapf	Poaceae	H	India	+	-	-	-	+	-	-	-	+	-
75.	*Dichanthium annulatum* (Forssk.) Starf	Poaceae	H	India	+	-	-	-	+	-	-	-	-	-
76.	*Dicliptera paniculata* (Forssk.) I. Darbysh.	Acanthaceae	H	Tropical America	+	+	+	-	+	-	+	-	+	+
77.	*Digera muricata* (L.) Mart.	Amaranthaceae	H	Asia	+	-	+	-	+	-	-	-	+	-
78.	*Digitaria sanguinalis* (L.) Scop.	Poaceae	H	India	+	-	+	-	+	+	+	-	+	-
79.	*Dysphania ambrosiodes* (L.) Mosyakin & Clements	Amaranthaceae	H	Tropical America	-	-	+	+	-	-	-	-	-	-
80.	*Echinochloa colonum* (L.) Link	Poaceae	H	South America	+	-	+	-	+	-	+	+	-	-
81.	*Eclipta prostrata* (L.) L.	Asteraceae	H	Tropical America	-	-	+	+	+	-	+	+	-	-
82.	*Eleusine indica* (L.) Gaertn.	Poaceae	H	India	+	-	+	-	+	-	+	+	+	-
83.	*Eragrostis tenella* (L.) P. Beauv. Ex Roem. & Schult.	Poaceae	H	India	+	-	+	-	+	-	+	-	-	-
84.	*Erigeron bonariensis* L.	Asteraceae	H	South America	-	-	-	-	+	-	-	-	+	-
85.	*Erigeron canadensis* (L.)	Asteraceae	H	North America	-	-	-	-	+	-	-	-	+	-
86.	*Eucalyptus globulus* Labill.	Myrtaceae	T	Australia	-	-	+	+	+	-	-	+	+	+
87.	*Euphorbia hirta* L.	Euphorbiaceae	H	Tropical America	+	+	+	-	+	+	+	+	-	-
88.	*Euphorbia prostrata* Ailton	Euphorbiaceae	H	Tropical America	-	-	-	-	-	-	+	-	-	
89.	*Evolvulus alsinoides* (L.) L.	Convolvulaceae	H	India	+	+	-	-	-	-	-	-	-	-
90.	*Evolvulus nummularius* (L.) L.	Convolvulaceae	H	Tropical America	+	+	-	-	-	-	-	-	-	-
91.	*Ficus benghalensis* L.	Moraceae	T	India.	-	-	+	+	-	-	-	-	-	+
92.	*Ficus religiosa* L.	Moraceae	T	India	+	+	+	+	+	-	-	+	+	+
93.	*Ficus virens* Aiton	Moraceae	T	India	-	-	+	+	-	-	-	+	+	+
94.	*Fumaria indica* (Hausskn.) Pugsley	Papaveraceae	H	India	-	-	-	-	-	-	-	-	+	-
95.	*Gamochaeta pensylvanica* (Willd.) Cabrera	Asteraceae	H	Tropical America	+	+	+	+	+	+	-	-	+	+
96.	*Glinus lotoides* L.	Molluginaceae	H	India	-	-	-	-	-	-	+	-	-	-
97.	*Gomphrena celosioides* Mart.	Amaranthaceae	H	South America	+	-	-	-	+	-	-	-	-	+
98.	*Grona triflora* (L.) H. Ohashi & K.Ohashi	Fabaceae	H	India	+	+	-	+	-	-	-	-	-	-
99.	*Hibiscus panduriformis* Burm.f.	Malvaceae	H	India	-	-	-	-	-	-	+	-	-	-
100.	*Holoptelea integrifolia* (Roxb.) Planch	Ulmaceae	T	India	+	-	+	-	+	-	-	-	+	-
101.	*Hygrophila ringens* (L.) R.Br. ex Spreng.	Acanthaceae	H	India	-	-	-	-	-	-	+	-	-	-
102.	*Imperata cylindrica* (L.) P.Beauv.	Poaceae	H	Tropical America	+	-	-	-	+	-	-	-	+	-
103.	*Indigofera linnaei* Ali	Fabaceae	H	Africa	+	-	-	-	+	-	-	-	-	-
104.	*Indigofera tinctoria* L.	Fabaceae	H	India	-	-	+	-	-	-	-	-	-	-
105.	*Ipomoea aquatica* Forssk.	Convolvulaceae	H	Asia	-	-	-	-	-	-	+	-	-	-
106.	*Ipomoea indica* (Burm.) Merr.	Convolvulaceae	C	Tropical America	+	+	+	+	+	-	-	-	+	-
107.	*Ipomoea nil* (L.) Roth	Convolvulaceae	C	North America	-	-	-	-	-	-	-	-	+	-
108.	*Ipomea obscura* (L.) Ker Gawl.	Convolvulaceae	H	Africa	-	-	-	-	-	-	+	-	-	-
109.	*Ipomoea pestigridis* L.	Convolvulaceae	H	Africa	-	-	-	-	-	-	+	-	-	-
110.	*Juncus bufonius* L.	Juncaceae	H	Europe	-	-	-	-	+	+	-	-	-	-

Table A. *Continued ...*

S. N.	Name of the Plant	Family	Life form	Bio-geographical origin range	Occurrence of plant species at selected sites across Meerut region.									
					UC		RB		BK		WL		RS	
					SV	SB	SV	SB	SV	SB	SV	SB	SV	SB
111.	*Lagenaria siceraria* (Molina) Standl.	Cucurbitaceae	C	Africa	-	-	-	-	-	-	-	-	+	-
112.	*Lantana camara* L.	Verbenaceae	S	Tropical America	+	-	-	-	-	-	-	-	+	-
113.	*Lathyrus oleraceus* Lam.	Fabaceae	H	Eurasia, Africa	-	-	-	-	-	-	+	-	-	-
114.	*Launaea procumbens* (Roxb.) Ramayya & Rajagopal	Asteraceae	H	India	+	-	-	-	+	-	-	-	-	-
115.	*Lepidium didymum* L.	Brassicaceae	H	South America	+	-	+	-	+	-	-	-	+	+
116.	*Leucaena leucocephala* (Lam.) de Wit	Fabaceae	T	Tropical America	-	-	-	-	-	-	-	-	+	-
117.	*Ludwigia perennis* L.	Onagraceae	H	Africa	-	+	+	+	-	-	+	+	-	+
118.	*Lysimachia arvensis* (L.) U.Manns & Anderb.	Primulaceae	H	Europe	-	-	+	-	+	+	-	-	+	+
119.	*Madhuca longifolia* (J. Koenig ex L.) J.F. Macbr.	Sapotaceae	T	India.	-	-	-	-	-	-	-	-	+	-
120.	*Malva parviflora* L.	Malvaceae	H	Eurasia, Africa	-	-	-	-	-	-	+	-	-	-
121.	*Malvastrum coromandelianum* (L.) Garcke	Malvaceae	H	Tropical America	-	-	+	-	+	-	-	-	+	+
122.	*Mangifera indica* L.	Anacardiaceae	T	India	+	-	-	-	-	-	-	-	-	-
123.	*Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs	Poaceae	H	Asia, Africa	+	-	+	+	+	-	+	+	+	+
124.	*Melia azedarach* L.	Meliaceae	T	India	-	-	+	-	-	+	+	+	-	+
125.	*Melilotus indicus* (L.) All.	Fabaceae	H	India	+	-	-	-	+	+	+	+	+	-
126.	*Melochia corchorifolia* L.	Malvaceae	H	Tropical America	-	-	-	-	-	-	+	-	-	-
127.	*Mesosphaerum suaveolens* (L.) Kuntze	Lamiaceae	H	Tropical America	-	-	+	-	+	-	-	-	-	-
128.	*Morus alba* L.	Moraceae	T	Asia	-	-	+	-	+	-	+	+	-	-
129.	*Murraya koenigii* (L.) Sperg.	Rutaceae	T	India	-	-	-	-	-	-	-	-	+	-
130.	*Nerium oleander* L.	Apocynaceae	S	India	+	-	-	-	-	-	-	-	-	-
131.	*Nicotiana plumbaginifolia* Viv.	Solanaceae	H	Tropical America	-	-	+	+	+	+	-	+	+	+
132.	*Ocimum americanum* L.	Lamiaceae	H	Tropical America	+	-	-	-	-	-	-	-	-	-
133.	*Ocimum tenuiflorum* L.	Lamiaceae	H	India	+	-	+	-	+	-	-	-	-	-
134.	*Oenothera laciniata* Hill	Onagraceae	H	North America	-	-	-	-	-	-	-	-	+	-
135.	*Oldenlandia corymbosa* L.	Rubiaceae	H	India	+	+	+	+	+	+	-	-	-	+
136.	*Oplismenus undulatifolius* (Ard.) P. Beauv.	Poaceae	H	India	+	-	-	-	-	-	-	-	-	-
137.	*Origanum majorana* L.	Lamiaceae	H	Eurasia	-	-	-	-	-	-	+	-	-	-
138.	*Oxalis corniculata* L.	Oxalidaceae	H	Europe	-	+	+	+	+	+	-	+	+	+
139.	*Parthenium hysterophorus* L.	Asteraceae	H	North America	+	+	+	+	+	+	+	+	+	-
140.	*Phalaris minor* Retz.	Poaceae	H	India	-	-	-	+	-	+	+	-	+	-
141.	*Phoenix dactylifera* L.	Arecaceae	T	Asia	-	-	-	-	-	-	-	-	+	-
142.	*Phyla nodiflora* (L.) Greene	Verbenaceae	H	South America	-	-	-	-	+	-	-	-	-	-
143.	*Phyllanthus amarus* Schumach. & Thonn.	Phyllanthaceae	H	Tropical America	+	+	+	-	+	+	+	+	+	-
144.	*Phyllanthus reticulatus* Poir.	Phyllanthaceae	S	India	-	-	-	-	-	-	-	-	+	-
145.	*Physalis angulata* L.	Solanaceae	H	Tropical America	-	-	+	+	+	-	+	-	+	+
146.	*Pithecellobium dulce* (Roxb.) Benth.	Fabaceae	T	Tropical America	-	-	+	-	-	-	-	-	-	-

Table A. *Continued ...*

S. N.	Name of the Plant	Family	Life form	Bio-geographical origin range	Occurrence of plant species at selected sites across Meerut region.									
					UC		RB		BK		WL		RS	
					SV	SB	SV	SB	SV	SB	SV	SB	SV	SB
147.	*Pluchea ovalis* (Pers.) DC.	Asteraceae	S	India	-	-	-	-	+	-	-	-	-	-
148.	*Plumbago zeylanica* L.	Plumbaginaceae	S	India	-	-	-	-	-	-	-	-	+	-
149.	*Polygala erioptera* DC.	Polygalaceae	H	India	+	-	-	-	-	-	-	-	-	-
150.	*Polygonum plebeium* R. Br.	Polygonaceae	H	North America	+	-	-	-	+	-	-	-	-	-
151.	*Pongamia pinnata* (L.) Pierre	Fabaceae	T	India	+	-	-	-	-	-	-	-	+	-
152.	*Populus deltoides* W. Bartram ex Marshall	Salicaceae	T	North America	-	-	+	-	-	-	-	-	-	-
153.	*Portulaca oleracea* L.	Portulacaceae	H	South America	-	-	+	-	-	-	+	+	-	-
154.	*Portulaca quadrifida* L.	Portulacaceae	H	Tropical America	-	-	-	-	-	-	+	-	-	-
155.	*Prosopis glandulosa* Torr.	Fabaceae	T	South America	-	-	-	-	+	-	+	-	+	-
156.	*Prosopis juliflora* (Sw.) DC.	Fabaceae	T	North America	-	-	+	-	-	-	+	-	+	-
157.	*Psidium guajava* L.	Myrtaceae	T	Tropical America	-	-	+	-	-	-	-	-	-	-
158.	*Ranunculus sceleratus* L.	Ranunculaceae	H	Asia	-	-	+	+	-	-	+	-	-	-
159.	*Rhynchosia minima* (L.) DC	Fabaceae	H	India	-	-	-	-	+	-	-	-	-	-
160.	*Ricinus communis* L.	Euphorbiaceae	S	Africa	-	-	+	-	+		+		+	-
161.	*Rumex dentatus* L.	Polygonaceae	H	Europe	-	-	+	+	+	-	+	+	+	-
162.	*Rungia pectinata* (L.) Nees	Acanthaceae	H	India	-	-	-	-	-	-	-	-	+	-
163.	*Saccharum spontaneum* L.	Poaceae	H	Asia	+	-	+	-	-	-	-	-	-	-
164.	*Salvia plebeia* R.Br.	Lamiaceae	H	Asia, Australia	-	-	-	-	-	-	-	-	+	-
165.	*Scleromitrion diffusum* (Willd.) R.J. Wang	Rubiaceae	H	India	+	-	-	-	-	-	-	-	-	-
166.	*Scoparia dulcis* L.	ýPlantaginaceaeý	H	Tropical America	-	-	-	-	+	-	+	-	-	-
167.	*Senna obtusifolia* (L.) H.S. Irwin & Barneby	Fabaceae	H	Tropical America	+	-	-	-	-	-	-	-	-	-
168.	*Senna occidentalis* (L.) Link.	Fabaceae	H	South America	+	+	+	--	+	+	+	-	+	-
169.	*Senna siamea* (Lam.) H.S. Irwin & Barneby	Fabaceae	T	Asia	+	-	-	-	-	-	-	-	+	-
170.	*Senna tora* (L.) Roxb.	Fabaceae	H	South America	+	-	-	+	+	-	-	-	-	-
171.	*Sesamum indicum* L.	Pedaliaceae	H	India	+	-	-	-	+	-	-	-	-	-
172.	*Sesbania sesban* (L.) Merr.	Fabaceae	S	India	-	-	+	-	-	-	+	+	-	-
173.	*Setaria pumila* (Poir.) Roem. & Schult.	Poaceae	H	India	+	-	-	-	-	-	-	-	-	-
174.	*Setaria verticillata* (L.) P. Beauv.	Poaceae	H	India	+	-	+	+	+	-	+	-	+	+
175.	*Sida acuta* Burm.f.	Malvaceae	H	Tropical America	+	+	+	+	+	+	+	-	+	+
176.	*Sida cordata* (Burm.f.) Borss. Waalk.	Malvaceae	H	South America	+	-	-	-	-	-	-	-	-	-
177.	*Sida cordifolia* L.	Malvaceae	H	South America	+	-	+	+	-	-	-	-	-	-
178.	*Sida rhombifolia* L.	Malvaceae	H	India	+	+	-	-	+	+	+	-	+	+
179.	*Sida spinosa* L.	Malvaceae	H	India	-	-	-	-	+	-	-	-	-	-
180.	*Sisymbrium irio* L.	Brassicaceae	H	Eurasia, Africa	+	-	+	-	-	-	-	-	+	-
181.	*Solanum americanum* Mill.	Solanaceae	H	Tropical America	+	-	-	-	+	-	+	-	+	-
182.	*Solanum lycopersicum* L.	Solanaceae	H	South America	-	-	-	-	+	-	+	-	-	-
183.	*Solanum melongena* L.	Solanaceae	H	Asia	-	-	+	-	-	-	+	-	-	-
184.	*Solanum nigrum* L.	Solanaceae	H	Tropical America	-	-	+	-	-	-	+	+	+	-
185.	*Solanum villosum* Mill.	Solanaceae	H	India	-	-	-	-	+	+	+	+	-	-

Table A. *Continued ...*

S. N.	Name of the Plant	Family	Life form	Bio-geographical origin range	Occurrence of plant species at selected sites across Meerut region.									
					UC		RB		BK		WL		RS	
					SV	SB	SV	SB	SV	SB	SV	SB	SV	SB
186.	*Sonchus asper* (L.) Hill	Asteraceae	H	Europe	-	-	-	-	-	-	+	-	-	-
187.	*Sonchus oleraceus* (L.) L.	Asteraceae	H	Europe	-	-	-	-	-	-	-	-	+	-
188.	*Spergula arvensis* L.	Caryophyllaceae	H	India	+	+	+	+	+	-	-	-	+	-
189.	*Stellaria media* (L.) Vill.	Caryophyllaceae	H	India	-	-	-	-	+	-	-	-	-	-
190.	*Streblus asper* Lour.	Moraceae	T	India.	+	-	-	-	-	-	-	-	-	-
191.	*Strobilanthes hirta* (Vahl) Blume	Acanthaceae	H	India.	-	-	-	-	-	-	-	-	+	-
192.	*Tagetes erecta* L.	Asteraceae	H	South America	-	-	+	-	-	-	+	-	-	-
193.	*Tamarindus indica* L	Fabaceae	T	Africa	-	-	-	-	-	-	+	-	-	
194.	*Taraxacum mongolicum* Hand. -Mazz.	Asteraceae	H	Asia	-	-	-	-	+	-	-	-	-	-
195.	*Tectona grandis* L.f.	Lamiaceae	T	India	+	-	-	-	-	-	-	-	-	-
196.	*Tephrosia purpurea* (L.) Pers.	Fabaceae	H	India	-	-	-	-	+	-	+	-	-	-
197.	*Torenia crustacea* (L.) Cham. & Schltdl.	Linderniaceae	H	Asia	+	+	+	+	+	+	-	+	-	+
198.	*Trianthema portulacastrum* L.	Aizoaceae	H	Tropical America	-	-	+	+	+	-	+	+	-	+
199.	*Tribulus terrestris* L.	Zygophyllaceae	H	Tropical America	+	-	-	-	+	-	+	-	-	-
200.	*Trichodesma indicum* (L.) Sm.	Boraginaceae	H	India	+	-		-	-	-	-	-	-	-
201.	*Tridax procumbens* L.	Asteraceae	H	Tropical America	+	-		-	-	-	+	-	-	-
202.	*Trifolium hybridum* L.	Fabaceae	H	Eurasia, Africa	-	-	+	-	-	-		-	-	-
203.	*Trifolium resupinatum* L.	Fabaceae	H	Eurasia, Africa	-	-		-	+	-	+	-	+	-
204.	*Triticum aestivum* L.	Poaceae	H	India	-	-		-	-	-	+	-	-	-
205.	*Triumfetta rhomboidea* Jacq.	Malvaceae	H	Tropical America	+	+	+	+	+	-	-	-	+	-
206.	*Typha angustifolia* L.	Typhaceae	H	Tropical America	-	-	+	-	-	-	-	-	-	-
207.	*Urena lobata* L.	Malvaceae	H	Africa	+	-	+	-	+	-	+	-	+	-
208.	*Urochloa eminii* (Mez) Davidse	Poaceae	H	Africa	-	-	+	-	-	-	+	-	-	-
209.	*Urochloa lata* (Schumach.) C.E. Hubb.	Poaceae	H	India	-	-	+	-	-	-	-	-	-	-
210.	*Urochloa ramosa* (L.) T.Q. Nguyen	Poaceae	H	India	+	+	+	+	+	+	+	+	+	-
211.	*Urochloa reptans* (L.) Stapf	Poaceae	H	India	-	-	+	-	-	-	-	-	-	-
212.	*Vachellia nilotica* (L.) P.J.H. Hurter & Mabb.	Fabaceae	T	India	-	-	-	-	-	-	+	-	-	-
213.	*Veronica anagallis aquatica* L.	Plantaginaceae	H	Asia	-	-	-	-	-	-	-	-	+	+
214.	*Vicia sativa* L.	Fabaceae	H	India	-	-	-	-	+	-	-	-	-	-
215.	*Vigna radiata* (L.) R. Wilczek	Fabaceae	H	India	-	-	-	-	-	-	-	-	+	-
216.	*Vigna unguiculata* (L.) Walp.	Fabaceae	H	Africa	-	-	+	-	+	-	-	-	+	-
217.	*Withania somnifera* (L.) Dunal	Solanaceae	H	India	-	-	-	-	-	-	+	+	+	-
218.	*Xanthium strumarium* L.	Asteraceae	H	Tropical America	-	-	+	-	+	-	+	-	-	-
219.	*Ziziphus jujuba* Mill.	Rhamnaceae	T	Asia	+	-	-	-	-	-	-	-	-	-
220.	*Ziziphus mauritiana* Lam.	Rhamnaceae	T	India	-	-	+	-	+	-	+	-	-	-
221.	*Zornia gibbosa* Span.	Fabaceae	H	India	+	-	-	-	-	-	+	-	-	-

*India category includes all those plants whose origin is in India as well as in any other country/continent at the same time.
SV represents Standing vegetation; and SB Seed bank.
Life form: H - Herb; S - Shrub; C - Climber; T - Tree.
Site code: UC-University campus; RB-River bank; BK-Brick kiln; WL-Waste land; RS-Road side.

and Narayan, 2017; Singh *et al*., 2010; Kumar and Bihari, 2015; Negi and Hajra, 2007) and online available database (https://powo.science.kew.org; https://www.cabi.org).

Soil seed bank

Seed bank samples were collected in two seasons (March, 2019, Summer; November 2019, Winter) to determine the taxonomic position of the emergent seedlings. Five seasonal soil samples (each of the size of 25cm×25cm) at two depths (0-5 cm) and (5-10cm) were collected from each of the five study sites with the help of knife and spoon. The seed was taxonomically analyzed following seedling emergence method. This technique is considered effective for assessing both the transient and persistent components of seed banks (Thomson and Grime, 1979). Before the collection of soil samples, the surface of the soil was cleared off the existing live plant parts, litter, debris etc. The soil was air-dried and sieved through 2 mm sieve to remove the vegetative fragments. The soil was then spread uniformly in round earthen pots (size 29 cm upper diameter, 25 cm bottom diameter and 9 cm deep). Pots were placed in a shade-house with transparent roof and fiber walls. The pots were watered regularly. The seedling emergence was investigated for eleven months to record the late emergents too. The seedlings were allowed to grow to the identifiable stage and then eliminated.

Data analysis

Similarity Coefficient

Sorensen similarity coefficient (Southwood, 1978) was estimated according to the following formula to calculate the similarity among the standing vegetation and soil seed bank across five selected study sites.

$$SC = \frac{2\ jN}{aN + bN}$$

aN = total number of species in a vegetation 'a'
bN = total number of species in a vegetation 'b'
jN = the number of common species in both standing vegetation and soil seed bank sites.

Results

Floristics

Standing vegetation and seed bank

In the present study, a total of 221 angiospermic plant species (186 dicots and 35 monocots) distributed over 178 genera and 54 families (48 dicots and 6 monocots) were recorded in the standing vegetation across five different study sites (UC, RB, BK, WL and RS) in the dry tropical region of Meerut (Table A). The top eight dominant families accounted for (58.4%) flora recorded in standing vegetation (Fig. 2).

On the other hand, in the seed bank a total of 71

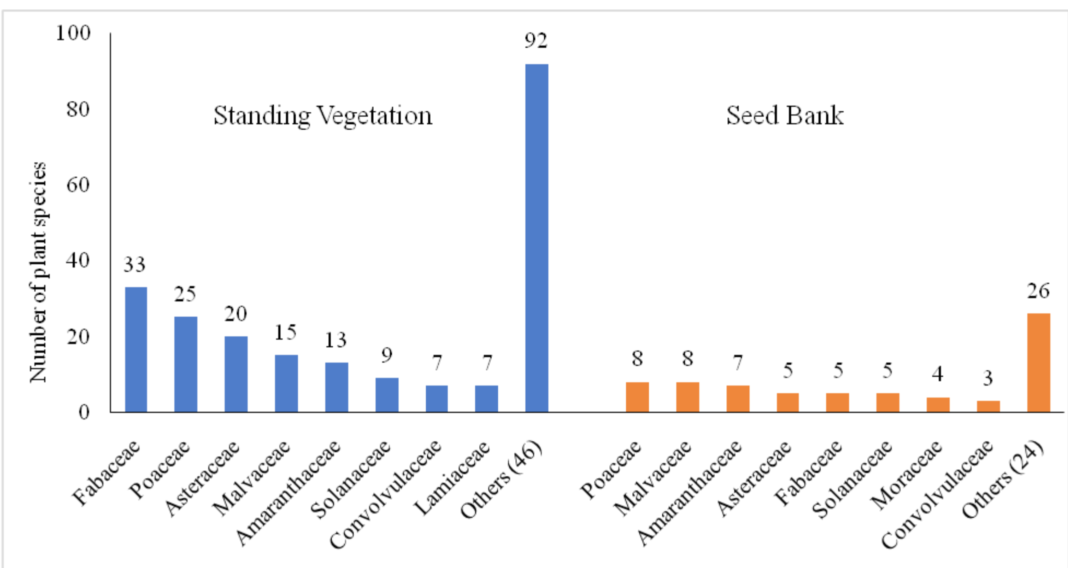

Fig. 2. Number of species across dominant angiospermic families in the standing vegetation and seed bank in adry tropical urban region at Meerut.

Table 1. Diversity (species count) in standing and seed bank vegetation across five different anthropic sites in a dry tropical urban region at Meerut, India.

Sl. No.	Vegetation	Species count at different study sites.				
		UC	RB	BK	WL	RS
1	Standing vegetation	96	100	101	96	92
2	Soil seed bank	25	35	27	32	31
		23*	32*	25*	25*	24*

*Represents the number of species common to both standing vegetation and seed bank.
Site code: UC - University campus; RB - River bank; BK - Brick kiln; WL - Waste land; RS - Road side.

angiospemic flora were recorded (Table A), the top eight dominant families were Malvaceae, Poaceae, Amaranthaceae, Asteraceae, Fabaceae, Solanaceae, Moraceae and Convolvulaceae which accounted for 45 species (55.6%) of total SB flora (81) recorded in our study. A total of 81 angiospermic plant species (71 identified and 10 unidentified) distributed over 62 genera and 32 families were recorded from diverse seed banks under diverse anthropic sites. Much lower number of flora were recorded in SB vegetation (81) compared to that in standing vegetation (221).

Diversity and life form

The number of flora in SV at all the investigated five sites (92-101) was generally more than three times the no. of flora in their corresponding SBs (25-35). It was noteworthy that out of eight top dominant angiospemic families recorded, seven were common to both SV and SB vegetation. The number of plant species common to both SV and SB varied between 23 and 32 at these studied sites and the number of SB species uncommon to their corresponding SV was much lower 2-3 at UC, RB, and Bk sites and 7 at WL and RS sites (Table 1).

Among the different life forms (Table A) while herb flora dominated both the SV and SB, tree flora was also recorded in both vegetation types, albeit the SV tree flora was about 6 times the SB tree flora. Climbers and shrub species were much lower in SB vegetation (Table 2).

Table 2. Life form of plant taxa in standing vegetation and soil seed bank from diverse anthropogenic sites in a dry tropical region of Meerut, India

S. No.	Life form	Number of plant species	
		Standing vegetation	Seed Bank
1	Tree	35	6
2	Shrub	10	1
3	Climber	11	2
4	Herb	165	62
5	Unknown (UK)	-	10
	Total number of species	221	81

Similarity analysis

The analysis of the similarity of SV and SB of the five anthropic sites indicated that no SV at any site had > 50% similarity (Sorensen index > 0.50) with any SB vegetation studied, although some SV sites showed > 50% similarity with SV at other sites (Table 3) *viz.* SV of UC with that of RB and BK sites; SV of RB with WL, BK and RS sites; SV of BK with WL and RS. SBs of these study sites also showed the varying scale of inter-site SB similarity. SB of UC showed > 0.50 similarity coefficient with that at RB and BK sites. SB of RB site showed similar relation with SBs at WL and RS sites. Higher similarity was recorded between SBs of BK and WL sites and comparable similarity was also exhibited by SBs at RS and RB sites.

Species nativity analysis

In this study, the recorded angiospermic flora in terms of nativity belonged to twelve different biogeographic regions (Table 4). Among these, seven major geographical regions contributed about 96% in SV and 97% in SB. The American continent contributed the largest number (34% in SV and 42% SB) of exotic plants. The native species were only 42% in SV and 38% in SB.

Discussion

Alien flora in seed bank and standing vegetation

The present study revealed a large scale of intrusion by alien flora not only in the standing vegetation of dry tropical urban regions in India but also in its soil seed banks. This intrusion by exotic flora was evidently comparable in both standing vegetation (58%) as well as seed bank (62%), reflective of the

Table 3. Similarity coefficient (Sorensen Index) of standing and seed bank vegetation at five anthropic habitats in dry tropical urban region of Meerut, India.

		UC		RB		BK		WL		RS	
		SV	SB	SV	SB	SV	SB	SV	SB	SV	SB
UC	SV	1									
	SB	0.38	1								
RB	SV	0.49	0.32	1							
	SB	0.31	0.51	0.47	1						
BK	SV	0.59	0.30	0.61	0.37	1					
	SB	0.31	0.54	0.33	0.39	0.39	1				
WL	SV	0.36	0.21	0.56	0.24	0.50	0.26	1			
	SB	0.27	0.39	0.44	0.51	0.38	0.51	0.39	1		
RS	SV	0.44	0.26	0.50	0.33	0.51	0.30	0.41	0.31	1	
	SB	0.24	0.36	0.38	0.55	0.32	0.41	0.22	0.41	0.39	1

SV represents Standing vegetation; and SB Seed bank.
Site code: UC-University campus; RB-River bank; BK-Brick kiln; WL-Waste land; RS-Road side.

Table 4. Bio-geographical analysis of flora in standing and seed bank vegetation in a dry tropical anthropic urban region in India.

Sl. No.	Bio-geographical origin	Standing vegetation	Seed Bank
1	India	93	27
2	Tropical America	48	18
3	South America	18	10
4	Africa	18	2
5	Asia	16	5
6	Europe	10	5
7	North America	8	2
8	Eurasia, Africa	6	-
9	Australia	1	1
10	Asia, Australia	1	-
11	Asia, Africa	1	1
12	Eurasia	1	-
	Total	221	71

*India category includes all those plants whose origin is in India as well as in any other country/continent at the same time.

high vulnerability of urban ecosystems in Indian dry tropics, reportedly resulting into altered vegetation structure in diverse anthropic ecosystems after elimination of the native plant species (Gupta and Narayan, 2010; 2011). Higher intrusion into seed banks reflected the progressive naturalizing ability of these aliens in these ecosystems where they may later turn invasives with higher phenotypic plasticity, as suggested for *Chenopodium murale* in these dry tropical anthropic ecosystems (Gupta and Narayan, 2012) resulting into further reduction of native biodiversity. Majority of the alien flora were of American origin that alone contributed 34% to the standing vegetation and 43% to the seed banks in this study. These alien species have evidently established themselves in the Indian tropics successfully over the last 4-6 decades (Table 5) and are likely to impact dominant vegetation structure above ground in future. At the scale of India, some workers (Nayar, 1977; Reddy, 2008) had reported only 18% alien flora out of 16809 recorded flora by them. This representation of alien flora varied at regional levels of study. The dry tropical Allahabad region in India was reported to have 38% alien intrusion (Sharma and Pandey, 1984), Rajasthan region showed only 11% exotics (Pandey and Panwar, 1994). The relatively cooler regions of Pantnagar had 44.5% alien flora (Joshi and Rawat, 2011) and Kashmir 29% (Khuroo *et al.*, 2007). Maheshwari (1963) reported the occurrence of 27% alien flora in the Delhi region. However, a much higher degree of exotic plant intrusion in dry tropical peri-urban vegetation in the National capital region of Delhi (89%) that included largest of American origin (39%) was reported by Agrawal and Narayan, (2017). In contrast, only 15% and 19% aliens were reported in Barda Hills, Gujrat (Nagar *et al.*, 2004) and Doon valley, Uttarakhand respectively (Negi and Hajra, 2007; Babu, 1977). Of the 4700 recorded species the invasive aliens in Uttarakhand were reported to be only 3% in 2007 (Uniyal *et al.*, 2007).

Seed bank flora recorded in this study (81) was much lower than that recorded in standing vegetation (221). However, the top most eight dominant families were considerably common, albeit varying in order (Fig. 2). While Fabaceae and Poaceae were the top two dominants in standing vegetation followed by Asteraceae, Malvaceae, Amaranthaceae and Solanaceae, in the subterranean vegetation, Poaceae and Malvaceae were two most equally dominant families, closely followed by Amaranthaceae, Asteraceae, Fabaceae and Solanaceae. A comparable dominance of these angiospermic families *viz* Asteraceae, Fabaceae, Amaranthaceae and Malvaceae in the standing vegetation in Asian regions (Wu *et al.,* 2004a, b; Zerbe *et al.,* 2004) and also in other parts of the world has been reported (Pysek, 1998).

Grasses belonging to Poaceae have been generally suggested to predominate in areas under heavy disturbance, as found in the presently investigated study sites. While predominance of leguminous members in the vegetation reflected adaptive significance under nutrient-poor dry tropical conditions here (Narayan, 1992; Gupta and Narayan, 2006), the increasing dominance of the family Asteraceae (20 in SV and 5 in SBs) reflected the increasing prevalence of weeds in particular. Asteraceae is considered a dominant invasive family not only of the Indian Himalayan Region (Sekar, 2012) but also of Uttar Pradesh (Singh *et al.,* 2010) and the whole of India (Reddy, 2008). One of this family's members *Parthenium hysterophorus* is one of the world's leading worst invasive weeds. It completes 3-4 life cycles in a year and has occupied nearly all diverse habitats across the whole of India (Gupta and Narayan, 2006; 2010; Chaudhary *et al*., 2015). Other Asteraceae members found in this study included *Ageratum conyzoides, Erigeron* spp., *Gamochaeta pensylvanica* and *Xanthium strumarium.* Besides these, the other most dominant invasive alien weeds in this dry tropical region were *Lantana camara, Cannabis sativa, Chenopodium album, Dysphania ambrosiodes, Echinochloa colonum, Nicotiana plumbaginifolia, Oxalis corniculata, Malvastrum coromandelianum, Croton bonplandianum, Argemone mexicana, Alternanthera philoxeroides* and *Alternanthera pungens* which are reported to adversely affect human health and agricultural productivity in this region.

Amongst the different life forms in SV and SBs, the herbs formed the most dominant component (75%) followed by tree, climber and shrub (Table 2). Higher number of herbaceous species could be attributed to increased anthropogenic activities in the studied urban ecosystems, as increased disturbance intensity is suggested to favor invasion by herbaceous flora (Gurarni *et al.,* 2010). In fact, at such ecologically disturbed sites, herbaceous species have been often opined to have a far better chance of recovery from the seed banks compared to the woody species (Teketay, 2005; Sanou *et al.,* 2018). The annual life forms, here at these anthropic sites, are usually more than the perennial species, more forbs than grasses, and more weed than non-weed species (Sternberg *et al.,* 2003). The annual plant communities commonly produced seeds lying in the seed bank that easily germinate which could be used as alternate germination strategy (Pekas and Schupp, 2013; Hongyuan *et al.*, 2018). Occurrence of only 42% native flora in SV and 38% in SBs could be attributed to greater viability and tolerance to harsh conditions by alien flora especially the most dominant herbaceous ones.

Table 5. Comparative flora in the standing vegetation in different regions of India

Study area	Total flora				Aliens		Invasive aliens	
	Reference	Spp.	Gen.	Fam.	Spp.	%	Spp.	%
Delhi	(Maheshwari, 1963)	531	326	92	-	27	-	-
India	(Nayar, 1977, Reddy, 2008)	16809	-	-	-	18	173	1
Allahabad	(Sharma and Pandey, 1984)	-	-	-	458	38	-	-
Rajasthan	(Pandey and Panwar, 1994)	-	-	-	206	11	-	-
Barda Hills, Gujrat	(Nagar *et al.,* 2004)	-	-	-	154	15	-	-
Kashmir	(Khuroo *et al.,* 2007)	-	-	-	571	29	93	5
Doon-Valley, Uttarakhand	(Negi and Hajra, 2007, Babu, 1977)	1230	624	115	436	19	-	-
Uttarakhand	(Uniyal *et al.,* 2007)	4700	1503	231	-	-	129	3
Uttar Pradesh	(Singh *et al*., 2010)	-	-	-	-	-	152	-
Pantnagar	(Joshi and Rawat, 2011)	360	259	76	160	44	60	19
Bulandshahr	(Agrawal and Narayan, 2017)	87	78	28	77	89	37	48
Meerut	Present study	221	78	54	128	58	36	16

Similarity analysis of seed bank and standing vegetation

Analysis of floristic similarity between SV and SBs at five anthropic sites indicated the occurrence of 92-101 species in SV and 25-35 species in SBs at these sites, and the number of species common to both SV and SB at a site varied between 23 and 32 species (Table 1). However, the comparison of Sorensen's similarity coefficient estimates between standing vegetation and seed bank at none of the investigated five anthropic sites showed > 0.5 value reflective of poor similarity between SV and SB at any study site, thus, clearly indicating the minor role of seed bank in regenerating the standing plant communities, and a crucial role of seeds dispersed from the surrounding plant communities (Ssali *et al*., 2018). However, some sites; SV exhibited> 50% similarity with other SV at other sites. Interestingly, even the SV of the UC site, which could be considered relatively protected, exhibited > 50% similarity with highly disturbed SV at RB and BK sites. This appears to be on account of high mobility of humans and transport vehicles in the university campus which caters to the educational interest of several thousands of students in the most populous state of Uttar Pradesh, situated in close vicinity of the capital city Delhi. Heavy road transportation and associated commercial activities in and around this rapidly expanding urban sprawl of Meerut could be the major reason behind the similarities recorded here. Highways and roads are suggested to favor the transport and dispersal of invasive plants by increasing disturbance intensity (Pollnac *et al.,* 2012) or by facilitating seed dispersion of invasive species (Thiele *et al.,* 2008; Delnatte *et al.,* 2012). Vehicular transport-mediated seed dispersal possibly explains the significantly high similarity in SV of RB with that of WL and BK and similarity in SV of BK with that of WL and RS anthropic sites. Accordingly, it is noteworthy that similarity between both SV and SB of RS when respectively compared with that at the RB site is over 50%. Similar is the cases of considerable similarity recorded among SV and SBs at WL, RB and BK sites, and between BK and UC site (Table 3). Both SV and SB of UC site also shared respectively significant similarity with that of highly anthropic sites RB and BK. Thus, disturbance appears to have a homogenization impact on both SV and SBs. But, none of the sites showed over 50% similarity between their individual site's SB and SV composition. This is explicable in terms of random transport-mediated seed-propagule dispersal as well as the variability of seed viability and harshness of the host environment.

Conclusion

The results show a heavy scale of intrusion of alien flora predominated by American floristic elements in a dry tropical region, which via successful naturalization in seed banks may cause homogenization of floristic structure above and below ground.

Acknowledgements

The authors are thankful to Prof.Vijai Malik, Prof. Mammen Daniel, Dr. Nidhan Singh and Dr. Sushant Sharma for their assistance in the field identification of flora.

References

Agrawal, S. and Narayan, R. 2017. Spatio-temporal organization and biomass dynamics of plant communities in a dry tropical peri-urban region: deterministic role of alien flora in anthropo-ecosystems. *Current Science*. 53-62.

Babu, C.R. 1977. *Herbaceous flora of Dehradun*, PID CSIR, New Delhi.

Chaudhary, N., Narayan, R. and Sharma, D. K. 2015. Differential biomass allocation to plant organs and their allelopathic impact on the growth of crop plants: A case study on the invasibility of *Ageratum conyzoides* in Indian dry tropics, *Indian Journal of Agricultural Sciences.* 85(11): 1405-1411.

Delnatte, C. and Meyer, J.Y. 2012. Plant introduction, naturalization, and invasion in French Guiana, (South America). *Biological Invasions.* 14: 915-927, https://doi.org/10.1007/s10530-011-0129-1.

Duthie, J.F. 1960. *Flora of Upper Gangetic Plains*, Botanical Survey of India Publisher 1 & 2.

Gaur, R.D. 1999. *Flora of the District Garhwal North West Himalaya*, Trans Media Srinagar Garhwal, UP, India.

Gioria, M., Pysek, P. and Moravcova, L. 2012. SSBs in plant invasions: promoting species invasiveness and long-term impact on plant community dynamics, *Preslia* 84: 327-350.

Gupta, S. and Narayan R. 2006. Species diversity in four contrasting sites in a peri-urban area in Indian dry tropics. *Tropical Ecology.* 47 (2): 229-242.

Gupta, S. and Narayan, R. 2010. Brick kiln industry in long-term impacts biomass and diversity structure of plant communities. *Current Science*. 10: 72-9.

Gupta, S. and Narayan R. 2011. Plant diversity and dry-matter dynamics of peri-urban plant communities in an Indian dry tropical region. *Ecological Research.* 26 (1): 67-78.

Gupta, S. and Narayan R. 2012. Phenotypic plasticity of *Chenopodium murale* across contrasting habitat conditions in peri-urban areas in Indian dry tropics: Is it indicative of its invasiveness? *Plant Ecology.* 213 (3): 493-503.

Gurarni, D., Arya, N., Yadava, A. and Ram, J. 2010. Studies on plant biodiversity of pure *Pinus roxburghii* Sarg, Forest and mixed pine-oak forest in Uttarakhand Himalaya. *New York Science Journal.* 3 (8): 1-5.

Hongyuan, M.A., Jingpeng, L.I., Fan, Y.A.N.G., Xiaotao, L.U., Yuepeng, P.A.N. and Zhengwei, L.I.A.N.G. 2018. Regenerative role of soil seed banks of different successional stages in a saline-alkaline grassland in Northeast China. *Chinese Geographical Science.* 28: 694-706, https://doi.org/10.1007/s11769-018-0966-2.

Joshi, K. and Rawat, D.S. 2011. A Preliminary Investigation on Alien and Native Elements in the Flora of Pantnagar, Uttarakhand, India. *The Journal of Indian Botanical Society.* 90(1&2): 66-74.

Khanna, K.K. 2009. Invasive alien angiosperms of Uttar Pradesh. *Biological Forum.* 1 (2): 34-39.

Khuroo, A.A., Rashid, I., Reshi, Z., Dar, G.H. and Wafai, B.A. 2007. The alien flora of Kashmir Himalaya, *Biological Invasions.* 9 (3): 269-292, doi:10.1007/s10530-006-9032-6.

Kolodziejek, J. and Patykowski, J. 2015. Effect of Environmental Factors on Germination and Emergence of Invasive *Rumex confertus* in Central Europe. *The Scientific World Journal.* 1-11.

Kumar, N.S. and Bihari, S.K. 2015. Diversity, Uses and Origin of Invasive Alien Plants in Dhenkanal district of Odisha, India. *International Research Journal of Biological Science.* 4 (2): 21-27.

Maheshwari, J.K. 1963. *The Flora of Delhi,* CSIR, Delhi.

Nagar, P.S., Pathak, S.J. and Pandya, S.M. 2004. The alien flora of the Barda hills and its surroundings in Gujarat, India. *Indian Journal of Forestry* (India).

Narayan, R. 1992. *Analysis of structure of Sal-bearing dry tropical forests,* Ph.D. Thesis, Banaras Hindu University, Banaras, India.

Nayar, M.P. 1977. Changing pattern of the Indian Flora. *The Bulletin of the Botanical Survey of India.* 19: 145-155.

Negi P.S. and Hajra, P.K. 2007. Alien Flora of Doon Valley, North West Himalaya. *Current Science.* 92 (7): 968-978.

Pandey, R.P. and Parmer, P.J. 1994. The Exotic Flora of Rajasthan. *Journal of Economic Taxonomic Botony* 18: 105-135.

Pauchard, A. and Shea, K. 2006. Integrating the study of non-native plant invasions across spatial scale. *Biological Invasion.* 8: 399-413.

Pekas, K.M. and Schupp, E.W. 2013. Influence of aboveground vegetation on seed bank composition and distribution in a Great Basin Desert sagebrush community. *Journal of Arid Environments.* 88: 113-120.

Pimentel, D., McNair, S., Janecka, J., Wightman, J., Simmonds, J., Connell, C. O'., Wong, E., Russel, L., Zern, J., Aquino, T. and Tsomondo, T. 2001. Economic and environmental threats of alien plant, animal and microbe invasions. *Agriculture, Ecosystem & Environment.* 84: 1-20.

Pollnac, F., Seipel, T., Repath, C. and Rew, L.J. 2012. Plant invasion at landscape and local scales along roadways in the mountainous region of the Greater Yellowstone Ecosystem. *Biological Invasions.* 14: 1753-1763, https://doi.org/10.1007/s10530-012-0188-y.

Pyšek, P. 1998. Alien and native species in Central European urban floras: a quantitative comparison. *Journal of Biogeography.* 25(1): 155-163.

Reddy, C.S. 2008. Catalogue of Invasive Alien Flora of India. *Life Science Journal.* 5 (2): 84-89.

Sanou, L., Savadogo, P., Zida, D. and Thiombiano, A. 2018. Contrasting land use systems influence soil seed bank composition and density in a rural landscape mosaic in West Africa. *Flora,* https://doi.org/10.1016/j.flora.2018.11.013.

Santos, D.M.D., Silva, K.A.D., Santos, J.M.F.F.D. and Araujo, E.D.L. 2018. Soil seed bank and its importance in the natural regeneration of degraded areas. *Ethnobiology and Conservation.* 7 (5).

Sekar, K.C. 2012. Invasive Alien Plants of Indian Himalayan Region- Diversity and Implication. *American Journal of Plant Sciences.* 3 (2): 177-184, https://doi.org/10.4236/ajps.2012.32021.

Sharma, B.D. and Pandey, D.S. 1984. *Exotic flora of Allahabad District*, BSI, Howrah.

Sharma, L.K. 1980. *Floristic studies of district Bulandshahr and morphological studies of DasmodiumDesv. and AlysicarpurNeek, With special reference to fruit structure*, Ph. D. thesis, Meerut University, Meerut, India.

Shiferaw, W., Demissew, S. and Bekele, T. 2018. Ecology of soil seed banks: Implications for conservation and restoration of natural vegetation: A review. *International Journal of Biodiversity and Conservation.* 10(10): 380-393.

Singh, K.P., Shukla, A.N. and Singh, J.S. 2010. State-level inventory of invasive alien plants, their source regions and use potential. *Current Science.* 99: 107–114.

Singhal, S. 2014. *Phenotypic and allocational plasticities of six common weeds and impact of their leaf-residues on the growth of crop plants,* Ph.D. Thesis, Chaudhary Charan Singh University, Meerut, India.

Song, G., Li, X. and Hui, R. 2017. Effect of biological soil crusts on seed germination and growth of an exotic and two native plant species in an arid ecosystem. *Plos One.* 12 (10).

Southwood, T.R.E. 1978. *Ecological Methods with Particular Reference to the Insect Population*, ELBS edition, Cambridge.

Ssali, F., Moe, S.R. and Sheil, D. 2018. Tree seed rain and seed removal, but not the seed bank, impede forest recovery in bracken (*Pteridium aquilinum* (L.) Kuhn)-dominated clearings in the African highlands. *Ecology and Evolution.* 8: 4224-4236.

Sternberg, M., Gutman, M., Perevolotsky, A. and Kigel, J. 2003. Effects of grazing on soil seed bank dynamics: An approach with functional groups. *Journal of Vegetation Science*. 14: 375-386.

Taiwo, D.M., Oyelowo, O.J., Ogedengbe, T.C. and Woghiren, A.I. 2018. The Role of SB in Forest Regeneration. *Asian Journal of Research in Agriculture and Forestry*. 1 (4): 1-10.

Teketay, D. 2005. Seed and regeneration ecology in dry Afromontane Forests of Ethiopia: I. Seed production - population structures. *Tropical Ecology.* 46 (1).

Thiele, J., Schuckert, U. and Otte, A. 2008. Cultural landscapes of Germany are patch-corridor matrix mosaics for an invasive megaforb. *Landscape Ecology.* 23: 453-465,https://doi.org/10.1007/s10980-008-9202-2.

Thompson, K. and Grime, J.P. 1979. Seasonal variation in the SB of herbaceous species in ten contrasting habitats. *Journal of Ecology.* 67: 893-921.

Uniyal, B.P., Sharma, J.R., Chaudhary, U. and Singh, D.K. 2007. *Flowering Plants of Uttarakhand* (A Check List), BSMPS, Dehradun.

Weerasinghe, M., Ashton, M.S., Hooper, E.R. and Singhakumara, B.M.P. 2019. Floristics of soil seed banks on agricultural and disturbed land cleared of tropical forests. *Restoration Ecology*. 27: 138-147, https://doi.org/10.1111/rec.12711.

Wu, S.H., Hsieh, C.F. and Rejmánek, M. 2004a. Catalogue of the naturalized flora of Taiwan. *Taiwania.* 49: 16-31.

Wu, S.H., Hsieh, C.F. and Rejmánek, M. 2004b. Plant invasions in Taiwan: Insights from the flora of casual and naturalized alien species. *Diversity and Distributions.* 10: 349-362.

Zerbe, S., Choi, I.K. and Kowarik, I. 2004. Characteristics and habits of non-native plant species in the city of Chonju. southern Korea. *Ecological Research.* 19 : 91-98.