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Studying the patterns of alien and native floras of some habitats in Srinagar city, Kashmir, India

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Abstract

Introduction: Urban flora is an important component of human-dominated ecosystems that links urban dwellers with nature. This study aims at compiling and analysing the alien and native vascular plant species of some selected habitats in the Srinagar city, Kashmir, India.

Methods: Bi-seasonal sampling was employed and each habitat type (*viz*., graveyards, grasslands, orchards and wastelands) was sampled at seven different sites.

Results: The number of species recorded from graveyards was 96; from grasslands 112; 141 from orchards and 110 from wastelands. The level of invasion among habitats varied from 67.27% to 68.75%, with a mean value of 67.86%; out of clubbed species list, 64.84% were alien. Asteraceae, Poaceae, Brassicaceae and Fabaceae were the biggest families in all four habitat types.

Conclusions: Our research shows that across habitats, alien plant species are the predominant part of their floras.

Keywords: Alien; Flora; Herbs; Srinagar city; Level of invasion

Introduction

Important environmental services in cities like removal of dust, mitigation of microclimatic extremes and modulation of humidity are being provided by biodiversity (Bolund and Hunhammar 1999; Haase et al. 2014). The latter also delivers amenity values, such as aesthetic enjoyment and recreation (Miller 2005 and Miller 2006; Qureshi et al. 2013) and psychological benefits resulting from human biophilia (Wilson 1984). Most people live and work in cities (Miller and Hobbs 2002), and access to urban nature and natural habitats improves their quality of life (Turner et al. 2004; Qureshi 2010, Qureshi et al. 2013). Even for these people, the biotas that survive in cities are their only contact with nature (Thompson and McCarthy 2008).

But urban areas are characterised by relatively intense stress levels associated with pollution by sewage, nutrients, toxic chemicals, heat and biological pathogens (including invasive species) (Pickett et al. 2001). With ever increasing urbanisation, natural areas are becoming increasingly fragmented (Qureshi et al. 2014; Saunders et al. 1991; Hobbs and Yates 2003), creating ever more urban/wildland interfaces. These urban/wildland interfaces facilitate access and opportunities for humans to disturb natural habitats (Bolger et al. 1997), and disturbance is recognised as an important determinant of invasibility (Hobbs and Huenneke 1992; Davis 2003). Increased isolation and proliferation of edges are some features which subject the remnant natural habitats lying inter-digitated within urban landscapes (Kupfer et al. 2006) to invasibility, and the theory of island biogeography predicts fewer plant species habitation on these relatively small and isolated habitat patches (Bastin and Thomas 1999; Guirado et al. 2006).

The advantageous ability of alien plant species to grow and survive in urban areas gives them an edge over native plants which are unable to survive there (Kühn and Klotz 2006). Many alien species thrive in urban environments probably due to the 'urban heat island effect' (Ricotta et al. 2009; Wang et al. 2011). Because of the considerable potential exhibited by alien plants to disperse propagules to long distances (Pyšek and Hulme 2005), there is an understandable concern that urban areas may act as source centres from which alien plant species will spread into the wider surrounding environments (Catling and Porebski 1994; Sullivan et al.

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2005; Houlahan et al. 2006) and hence could become detrimental to regional biodiversity. A recent cross-continental comparison revealed that invasive plants significantly reduce native plant diversity in non-native habitats but not at home (Shah et al. 2014). The invasive species can do so through many mechanisms (Levine et al., 2003), and the role of urbanisation-driven changes in ecological settings to influence such mechanisms is yet poorly understood.

Given the fact that urbanisation facilitates alien plant invasion, we carried out floristic sampling in selected habitats in Srinagar city, India and its suburbs to compile alien and native floras of these habitat types to unravel which group of plants (alien or native) are selected by regional landscape and which habit/life form is selected by the habitats?

Methods

Study area, study sites and habitat types

Srinagar city is located at an average elevation of 1,600 m above mean sea level and it is spread over in the heart of the oval-shaped valley of Kashmir. It is situated between 74°56′ and 75°79′ east longitude and 33°18′ and 34°45′ north latitude. Srinagar is the largest urban centre in the lap of Himalayas and its landscape is adorned by the Dal, the world-famous freshwater lake. In the east, the city is bounded by Zabarwan Mountains, hillocks of 'Takth-i-Suliman' in the east and 'Kohi-Maraan' (Hariparbat) in the centre which adds to its beauty. The famous Dachigam National Park, the last abode of the Kashmir stag 'Hanglu,' lies on the eastern part of city.

All the study sites were located in Srinagar city and its suburbs. Any two study sites were at least 0.75 km apart. These habitats were surrounded by a typical urban matrix of residential, commercial, industrial and recreational land use. Four major terrestrial habitats selected were grasslands, graveyards, orchards and wastelands. Each habitat type (*viz*., graveyards, grasslands, orchards and wastelands) was sampled at seven different sites. Floristic sampling was conducted twice during the year 2010 to 2011.

Data collection

The first sampling was carried out in April and May and the second one in August 2010 and September 2011. During the present investigation, all spontaneously established vascular plant species, including garden escapes and seedlings of spontaneously regenerating planted trees and shrubs, were recorded using the stratified quadrat sampling technique (Figure 1). A quadrat size of 0.25 m × 0.25 m was used for herbaceous plant species, 5 m × 5 m for shrubs and 10 m × 10 m for trees. A total of 210 (0.25 m × 0.25 m) quadrats were randomly laid for herbs, 140 (5 m × 5 m) for shrubs and 140 (10 m × 10 m) for trees in each habitat type.

Floristic element profiling: definitions and terminology

All the recorded species were classified as either native or alien according to their status in the region i.e. Kashmir valley. The native geographical range of the plant species was obtained from every possible source, such as (Khuroo et al. 2007), Germplasm Resources Information Network (GRIN) of the US Department of Agriculture. The alien plant species were characterised at different stages of

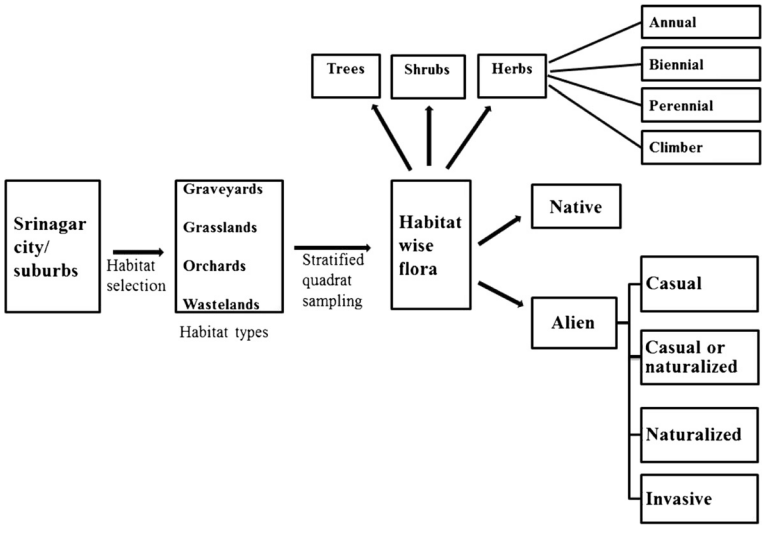

Figure 1 Schematic representation of the sequence of steps followed in the present study. Different habitat types were identified and surveyed in the Srinagar city and its suburbs. Habitat wise floras were generated using the stratified quadrant sampling approach that were further segregated into native and alien elements followed by growth form characterisation. Alien species were further categorised on the basis of stages of invasion.

the invasion process along the introduction-naturalisation-invasion continuum (see Richardson et al. 2000) (Figure 1). In this study, we defined 'casual' alien species as those alien species that do not form self-replacing populations (Pyšek et al. 2004). Those alien species that reproduce consistently and sustain self-replacing populations over many life cycles without direct intervention by people (or in spite of human intervention) have been categorised as 'naturalised' alien species (*sensu* Richardson et al. 2000; Pyšek et al. 2004). 'Casual or naturalised' alien plant species were those alien plant species about which adequate field information was not available (Wu et al. 2004). We used the term 'invasive' for those alien species that cause apparent damage or pose potential threats to species, ecosystems or to the economy (IUCN (International Union for the Conservation of Nature) (1999); Wang et al. 2011). In this sense, invasives should be considered as a subset of naturalised species capable of spreading considerably and with harmful effects, a definition which could also be likened with the terms 'transformers' and 'weeds' as defined by Richardson et al. (2000) and Pyšek et al. (2004).

With regard to habit, the species were classified into trees, shrubs, sub-shrubs, lianas, climbers and herbs. The species were characterised on the basis of lifespan into various categories like annuals, biennials and perennials. The level of invasion was measured as the total numbers of alien plant species or their proportion of the total species richness (Jauni and Hyvönen 2010). Finally, the specimens bearing collection no. 200-351 *SM Andrabi* dated 2010 have been deposited in KASH (herbarium of the Department of Botany at the Centre for Biodiversity and Taxonomy, University of Kashmir, Srinagar).

Results

Floristic diversity of specific habitat types

Flora of graveyards

The graveyard flora in urban areas comprised 96 plant species belonging to 77 genera and 32 families (Table 1). Six families namely Asteraceae (23 species), Poaceae (10 species), Brassicaceae (7 species), Fabaceae (6 species), Lamiaceae (5 species) and Apiaceae (4 species) accounted for 57.29% of plant species (Table 2). Sixteen families had one representative each in the urban graveyard flora, five families were represented by two species each and five families were represented by three species each. Out of 77 genera, only *Poa* and *Iris* were represented by three species each, 15 genera were represented by two species each and 60 genera were represented by just one species each.

Growth form and life span profile of graveyard flora Of the 96 species recorded in urban graveyards, 91 (94.79%) were herbs (43 annual, 8 biennial, 39 perennial and 1 aquatic), and only 1 and 4 were sub-shrub and trees, respectively (Figure 2).

Out of 91 herbs recorded, 61 (67.03%) were alien and 30 (32.97%) were native. The only one sub-shrub species and all four tree species that were recorded were alien in the study area, and no native species from these two groups were recorded.

Proportion of alien and native species In terms of species status in the region 66 (68.75%), the species were alien (Figure 3) and 30 species (31.25%) were native. Of the 66 aliens, casuals were represented by four species, casuals or naturalised aliens were represented by just one (1.52%) species, 24 (36.36%) and 37 (56.06%) plant species were grouped under naturalised and invasive categories, respectively (Table 3).

Flora of grasslands

The present study revealed the presence of 112 species belonging to 92 genera and 33 families (Table 1). Seven families namely Poaceae (22 species), Asteraceae (19 species), Fabaceae (10 species), Brassicaceae (6 species), Rosaceae (6 species), Scrophulariaceae (6 species), and Apiaceae (4 species) accounted for 65.18% of species (Table 2). Seventeen (51.51%) families were each represented by one species, five families each by two species and remaining four families each were represented by three species. Out of 92 genera, only *Poa* and *Veronica* were represented by four species each and *Medicago* by three species. Twelve genera were each represented by two species and remaining 77 (83.69%) genera were represented each by just one species.

Growth form and life span profile of grassland flora The analysis of the urban grassland flora revealed that 105 species belonged to herbaceous habit and accounted for about 93.75% of species. They belonged to various life forms like annuals represented by 56 species, biennials by 6 species, perennials by 40 species, aquatics by 2 species and 1 parasitic species. Two species were sub-shrubs, three were shrubs and two tree species were also recorded (Figure 2).

Out of the 105 herbs, 71 (67.62%) were alien and 34 (32.38%) were native to the Kashmir. Of the two sub-shrubs, one was alien and the other one was native to the region. Of the three shrubs recorded, all were alien to the Kashmir. Similarly, two tree species belonged to alien category and no native tree species was recorded from the study area.

Proportion of alien and native species Out of 112 species recorded in urban grasslands, 77 (68.75%) were alien (Figure 3) and 35 (31.25%) were native to the Kashmir. Out of 77 alien species, casuals included 2 species, casuals or naturalised category included 2 species, naturalised category included 33 species and 40 (51.95%) species belonged to invasive category (Table 3).

Table 1 Conspectus of plant species in various habitats of Srinagar city

Name of plant species	Family	Group	Species status in the region	Growth form	Invasion status	Graveyard	Grassland	Orchards	Wastelands
Achillea millefolium L.	Asteraceae	Dicot	Alien	P	In	+	+	+	−
Aegilops tauschii Cosson	Poaceae	Monocot	Alien	A	In	−	+	+	+
Ageratum conyzoides L.	Asteraceae	Dicot	Alien	A	In	+	−	−	−
Ailanthus altissima Sw.	Simaroubaceae	Dicot	Alien	T	In	+	−	+	+
Althaea rosea Cav.	Malvaceae	Dicot	Alien	B	Cs	+	−	−	−
Amaranthus caudatus L.	Amaranthaceae	Dicot	Alien	A	In	+	−	+	+
Amaranthus spinosus L.	Amaranthaceae	Dicot	Alien	A	In	+	+	−	+
Anagalis arvensis L.	Primulaceae	Dicot	Alien	A	In	−	−	+	−
Anchusa ovata Lehm.	Boraginaceae	Dicot	Alien	A	Nt	−	−	+	−
Anthemis cotula L	Asteraceae	Dicot	Alien	B	In	+	+	+	+
Arctium lappa L.	Asteraceae	Dicot	Alien	P	In	+	+	+	+
Arenaria serpyllifolia L.	Caryophyllaceae	Dicot	Alien	A	In	−	+	−	−
Artemisia absinthium L.	Asteraceae	Dicot	Alien	Ss	In	+	+	+	+
Artemisia dubia Wall. ex Besser	Asteraceae	Dicot	Native	P		−	−	+	−
Artemisia tournefortiana Reichb.	Asteraceae	Dicot	Alien	A	Nt	+	−	+	−
Asparagus filicinus Ham.	Liliaceae	Monocot	Native	P		−	+	+	−
Avena sativa L.	Poaceae	Monocot	Alien	A	Cs	−	+	+	−
Bellis perennis L.	Asteraceae	Dicot	Alien	P	Nt	+	+	−	−
Bidens cernua L.	Asteraceae	Dicot	Alien	P	Nt	−	−	+	−
Bothriochloa ischaemum Keng	Poaceae	Monocot	Alien	P	In	−	+	+	+
Brachiaria eruciformis Griseb.	Poaceae	Monocot	Native	A		−	+	−	+
Breea arvensis Less.	Asteraceae	Dicot	Native	P		+	+	+	+
Bromus japonicus Thunb.	Poaceae	Monocot	Alien	A	Nt	+	+	+	+
Cannabis sativa L.	Cannabiaceae	Dicot	Alien	A	In	+	+	+	+
Capsella bursa-pastoris Medic.	Brassicaceae	Dicot	Alien	A	In	+	+	+	+
Cardamine hirsuta L.	Brassicaceae	Dicot	Alien	A	Nt	−	+	+	−
Carex fedia Nees	Cyperaceae	Monocot	Native	P		−	−	+	−
Carex notha Kunth.	Cyperaceae	Monocot	Alien	B	In	−	−	+	−
Carpesium abrotanoides L.	Asteraceae	Dicot	Alien	A	Nt	+	+	+	+
Carpesium cernuum L.	Asteraceae	Dicot	Native	P		+	−	+	−
Celtis australis L.	Ulmaceae	Dicot	Alien	T	Nt	+	−	−	+
Cerastium vulgatum L.	Caryophyllaceae	Dicot	Native	P		+	+	+	−
Ceratocephalus falcatus Pers.	Ranunculaceae	Dicot	Alien	A	Nt	−	+	−	−
Chenopodium album L.	Chenopodiaceae	Dicot	Alien	A	In	+	−	+	+
Chenopodium botrys L.	Chenopodiaceae	Dicot	Alien	A	Nt	+	+	−	+
Chenopodium hybridum L.	Chenopodiaceae	Dicot	Alien	A	In	−	−	−	−
Cichorium intybus L.	Asteraceae	Dicot	Alien	P	In	−	+	+	−
Cirsium falconeri Petrak	Asteraceae	Dicot	Native	P		+	+	+	+
Clinopodium umbrosum C. Koch	Lamiaceae	Dicot	Alien	P	Nt	−	+	+	−
Clinopodium vulgare L.	Lamiaceae	Dicot	Alien	P	Nt	+	−	+	−

Table 1 Conspectus of plant species in various habitats of Srinagar city *(Continued)*

Convolvulus arvensis L.	Convolvulaceae	Dicot	Alien	P	In	+	+	+	+
Conyza bonariensis Cronquist	Asteraceae	Dicot	Alien	A	Cs	+	−	+	+
Conyza canadensis Cronquist	Asteraceae	Dicot	Alien	B	In	+	+	+	+
Coronopus didymus Sm.	Brassicaceae	Dicot	Alien	A	Nt	+	+	+	+
Cotula anthemoides L.	Asteraceae	Dicot	Native	A		+	+	−	+
Crataegus songarica K. Koch	Rosaceae	Dicot	Alien	T	Cs	−	+	+	−
Crepis sancta Babc.	Asteraceae	Dicot	Alien	A	In	−	+	+	−
Cuscuta europaea L.	Cuscutaceae	Dicot	Native	Ph		−	+	−	+
Cynodon dactylon L.	Poaceae	Monocot	Native	P		+	+	+	+
Cynoglossum glochidiatum Wall. ex Benth.	Boraginaceae	Dicot	Native	A		+	+	+	+
Cyperus iria L.	Cyperaceae	Monocot	Alien	Aq	Nt	−	+	−	−
Cyperus rotundus L.	Cyperaceae	Monocot	Alien	P	In	+	+	+	+
Dactylis glomerata L.	Poaceae	Monocot	Alien	P	In	−	−	+	−
Datura stramonium L.	Solanaceae	Dicot	Alien	A	In	+	−	−	+
Daucus carota L.	Apiaceae	Dicot	Alien	B	In	+	+	+	−
Delphinium roylei Munz.	Ranunculaceae	Dicot	Native	A		−	−	−	+
Descurainia sophia Webb.	Brassicaceae	Dicot	Alien	A	Nt	+	+	+	+
Digitaria cruciata A. Camus	Poaceae	Monocot	Native	A		−	+	−	−
Echinochloa crus-galli P. Beauv.	Poaceae	Monocot	Alien	Aq	Nt	−	+	−	+
Echinops cornigerus DC.	Asteraceae	Dicot	Native	P		−	+	−	−
Equisetum debile Roxb. ex Vaucher	Equisetaceae	Pteridophyte	Native	P		−	−	+	−
Equisetum ramosissimum Desf.	Equisetaceae	Pteridophyte	Native	P		−	−	+	−
Erodium cicutarium L'Herit. ex Ait.	Geraniaceae	Dicot	Alien	A	Nt	+	+	+	+
Eryngium billardieri Del.	Asteraceae	Dicot	Native	P		+	+	+	+
Eryngium coeruleum M-Bieb.	Asteraceae	Dicot	Native	P		+	+	+	+
Euclidium syriacum R. Br.	Brassicaceae	Dicot	Native	A		−	−	+	−
Euphorbia helioscopia L.	Euphorbiaceae	Dicot	Alien	A	In	+	+	+	+
Euphorbia wallichii Hook. f.	Euphorbiaceae	Dicot	Native	P		−	−	+	−
Foeniculum vulgare Mill.	Apiaceae	Dicot	Alien	P	Cs	+	−	−	+
Fumaria indica H. N.	Fumariaceae	Dicot	Native	A		−	+	+	+
Galinsoga parviflora Cav.	Asteraceae	Dicot	Alien	A	In	+	−	+	+
Galium aparine L.	Rubiaceae	Dicot	Alien	A	Cn	+	+	+	+
Garhadiolus minutissimus Kitamura	Asteraceae	Dicot	Alien	A	Nt	−	+	−	−
Geranium nepalense Sweet	Geraniaceae	Dicot	Native	A		−	+	+	−
Geranium pusillum Burm. f.	Geraniaceae	Dicot	Native	A		+	+	+	+
Geum roylei Bolle	Rosaceae	Dicot	Native	P		−	−	+	−
Herniaria hirsuta L.	Caryophyllaceae	Dicot	Native	P		+	−	−	−
Hesperis matronalis L.	Brassicaceae	Dicot	Alien	B	Cn	−	−	+	−
Hordeum murinum L.	Poaceae	Monocot	Native	A		+	+	+	+
Hypericum perforatum L.	Hypericaceae	Dicot	Alien	P	Nt	+	+	+	−

Table 1 Conspectus of plant species in various habitats of Srinagar city *(Continued)*

Imperata cylindrica P. Beauv.	Poaceae	Monocot	Alien	P	Nt	−	+	−	−
Indigofera heterantha wall. ex Brand.	Fabaceae	Dicot	Native	S		−	−	+	−
Ipomoea purpurea Roth.	Convolvulaceae	Dicot	Alien	C	Nt	−	−	−	+
Iris ensata Thunb.	Iridaceae	Monocot	Alien	P	In	+	+	+	−
Iris germanica L.	Iridaceae	Monocot	Alien	P	Nt	+	−	−	−
Iris kashmiriana Baker	Iridaceae	Monocot	Native	P		+	−	−	−
Kikxia spuria Dum**.**	Scrophulariaceae	Dicot	Native	A		−	+	−	−
Lactuca serriola L.	Asteraceae	Dicot	Native	B		+	−	+	+
Lamium amplexicaule L.	Lamiaceae	Dicot	Native	A		−	−	+	−
Lathyrus aphaca L.	Fabaceae	Dicot	Alien	A	Nt	−	−	+	−
Lepidium latifolium L.	Brassicaceae	Dicot	Native	P		+	−	−	−
Lespedeza cuneata G. Don.	Fabaceae	Dicot	Native	Ss		−	+	+	−
Leucanthemum vulgare Lam.	Asteraceae	Dicot	Alien	P	In	−	−	+	−
Linaria dalmatica Miller	Scrophulariaceae	Dicot	Alien	P	Cn	−	−	−	+
Lithospermum arvense L.	Boraginaceae	Dicot	Alien	A	In	−	−	+	+
Lolium perenne L.	Poaceae	Monocot	Alien	P	Nt	−	+	+	+
Lolium persicum Boiss. and Hoh. ex Boiss.	Poaceae	Monocot	Native	A		−	−	−	+
Lotus corniculatus L.	Fabaceae	Dicot	Alien	P	Nt	−	+	+	+
Malcolmia africana R. Br.	Brassicaceae	Dicot	Alien	A	Nt	−	−	−	+
Malva mauritiana L.	Malvaceae	Dicot	Alien	A	Cs	−	−	+	−
Malva neglecta Wall.	Malvaceae	Dicot	Alien	B	Nt	+	+	+	−
Malva parviflora L.	Malvaceae	Dicot	Native	A		+	−	+	+
Marrubium vulgare L.	Lamiaceae	Dicot	Alien	P	In	+	+	+	+
Mazus pumilus Van Steenis	Scrophulariaceae	Dicot	Native	A		−	−	−	+
Medicago lupulina L.	Fabaceae	Dicot	Alien	P	Nt	−	+	+	−
Medicago minima Grufb.	Fabaceae	Dicot	Native	A		+	+	+	−
Medicago polymorpha L.	Fabaceae	Dicot	Alien	A	In	+	+	+	+
Medicago sativa L.	Fabaceae	Dicot	Alien	B	Nt	−	−	+	+
Melia azedarach L.	Meliaceae	Dicot	Alien	T	Cs	+	−	−	−
Melilotus albus Desr.	Fabaceae	Dicot	Native	A		−	−	−	+
Melilotus officinalis Pall.	Fabaceae	Dicot	Native	B		−	−	−	−
Mentha longifolia L.	Lamiaceae	Dicot	Alien	P	In	−	−	+	+
Morus alba L.	Moraceae	Dicot	Alien	T	Nt	−	−	+	+
Muehlenbergia duthieana Hack.	Poaceae	Monocot	Native	A		−	−	−	+
Myosotis micrantha Pall. ex Lehm.	Boraginaceae	Dicot	Native	A		−	−	+	−
Myosotis sylvatica Hoffm.	Boraginaceae	Dicot	Native	P		−	+	−	+
Narcissus tazetta L.	Amaryllidaceae	Monocot	Alien	P	In	+	−	−	−
Nepeta cataria L.	Lamiaceae	Dicot	Alien	P	Nt	+	−	+	+
Oenothera biennis L.	Onagraceae	Dicot	Alien	B	Nt	−	+	+	−
Oenothera rosea Ait.	Onagraceae	Dicot	Alien	A	In	−	+	+	+
Onopordum acanthium L.	Asteraceae	Dicot	Alien	P	Nt	+	−	+	+
Ornithogalum umbellatum L.	Hyacinthaceae	Monocot	Alien	P	Cs	−	−	+	−

Table 1 Conspectus of plant species in various habitats of Srinagar city *(Continued)*

Oxalis corniculata L.	Oxalidaceae	Dicot	Alien	P	Nt	+	+	+	+
Papaver macrostomum Boiss. & Heut ex Boiss.	Papaveraceae	Dicot	Alien	A	Cn	–	–	+	–
Paspalum paspaloides Scribner	Poaceae	Monocot	Alien	A	Nt	–	+	–	–
Peganum harmala L.	Zygophyllaceae	Dicot	Native	P		+	–	–	+
Phleum alpinum L.	Poaceae	Monocot	Native	P		–	+	+	+
Phleum paniculatum Huds.	Poaceae	Monocot	Native	A		+	+	–	–
Phragmites australis Trin.	Poaceae	Monocot	Alien	P	In	–	+	–	–
Plantago lanceolata L.	Plantaginaceae	Dicot	Alien	P	In	+	+	+	+
Plantago major L.	Plantaginaceae	Dicot	Alien	P	In	+	+	+	+
Poa angustifolia L.	Poaceae	Monocot	Alien	P	Nt	+	+	+	+
Poa annua L.	Poaceae	Monocot	Alien	A	In	+	+	+	+
Poa bulbosa L.	Poaceae	Monocot	Native	A		+	+	+	+
Poa pratensis L.	Poaceae	Monocot	Alien	P	Nt	–	+	–	–
Polygonum heterophyllum Lindman	Polygonaceae	Dicot	Native	A		+	+	+	+
Polygonum hydropiper L.	Polygonaceae	Dicot	Alien	A	In	–	–	+	+
Polygonum plebejum R. Br.	Polygonaceae	Dicot	Native	A		–	+	–	–
Polypogon fugax Nees ex Steud.	Poaceae	Monocot	Alien	A	Nt	+	–	–	+
Populus alba L.	Salicaceae	Dicot	Alien	T	Nt	–	–	–	+
Portulaca oleracea L.	Portulacaceae	Dicot	Alien	A	Nt	–	+	–	+
Potentilla nepalensis Hk.	Rosaceae	Dicot	Native	P		–	+	–	+
Potentilla reptans L.	Rosaceae	Dicot	Alien	P	Nt	+	+	+	+
Potentilla supina L.	Rosaceae	Dicot	Alien	A	Nt	–	–	–	+
Prunus armeniaca L.	Rosaceae	Dicot	Alien	T	Cs	–	–	–	+
Prunus domestica L.	Rosaceae	Dicot	Alien	T	Cs	–	–	+	+
Ranunculus arvensis L.	Ranunculaceae	Dicot	Alien	A	In	–	–	+	+
Ranunculus laetus Wall. ex Hk. f. and T.	Ranunculaceae	Dicot	Alien	P	In	–	–	+	–
Ranunculus muricatus L.	Ranunculaceae	Dicot	Alien	A	In	–	+	–	+
Robinia pseudoacacia L.	Fabaceae	Dicot	Alien	T	In	+	+	+	–
Rorippa islandica Borbas	Brassicaceae	Dicot	Alien	Aq	Nt	+	–	+	+
Rorippa sylvestris Besser.	Brassicaceae	Dicot	Native	P		+	+	+	+
Rosa brunonii Lindl.	Rosaceae	Dicot	Alien	S	Nt	–	+	+	–
Rubia cordifolia L.	Rubiaceae	Dicot	Alien	C	Nt	–	–	+	–
Rubus niveus Thunb. non Wall.	Rosaceae	Dicot	Alien	S	Nt	–	+	+	–
Rubus ulmifolius Schott.	Rosaceae	Dicot	Alien	S	In	–	+	+	+
Rumex dentatus L.	Polygonaceae	Dicot	Alien	A	Nt	+	+	+	+
Rumex nepalensis Spreng.	Polygonaceae	Dicot	Alien	P	Nt	+	–	+	+
Salvia moorcroftiana Wall. ex Bth.	Lamiaceae	Dicot	Native	P		+	–	+	+
Sanguisorba minor Scop.	Rosaceae	Dicot	Alien	P	Nt	–	–	+	–
Scandix pecten-veneris L.	Apiaceae	Dicot	Alien	A	Nt	–	+	+	–
Scirpus setaceus L.	Cyperaceae	Monocot	Native	P		–	+	–	–

Table 1 Conspectus of plant species in various habitats of Srinagar city *(Continued)*

Sclerochloa dura P. Beauv.	Poaceae	Monocot	Native	P		+	−	−	−
Scorozonera virgata DC.	Asteraceae	Dicot	Native	P		−	−	+	−
Scrophularia lucida Hk. f.	Scrophulariaceae	Dicot	Native	P		−	−	+	−
Setaria viridis P. Beauv.	Poaceae	Monocot	Alien	A	In	−	+	−	−
Siegesbeckia orientalis L.	Asteraceae	Dicot	Alien	A	In	−	−	+	−
Sisymbrium loesellii L.	Brassicaceae	Dicot	Alien	A	In	+	+	+	+
Sisymbrium officinale Scop.	Brassicaceae	Dicot	Native	A		−	−	+	+
Solanum nigrum L.	Solanaceae	Dicot	Native	A		+	−	+	+
Sonchus asper Hill	Asteraceae	Dicot	Native	A		−	−	+	−
Sonchus oleraceus L.	Asteraceae	Dicot	Native	A		−	+	+	+
Sorghum halepense Pers.	Poaceae	Monocot	Alien	P	In	−	+	+	−
Stachys floccosa Benth.	Lamiaceae	Dicot	Native	P		+	−	+	−
Stellaria media Cyr.	Caryophyllaceae	Dicot	Alien	A	In	+	+	+	+
Taraxacum officinale Weber	Asteraceae	Dicot	Alien	P	In	+	+	+	+
Torilis japonica DC.	Apiaceae	Dicot	Alien	A	Nt	+	+	+	+
Torilis leptophylla Reichb. f.	Apiaceae	Dicot	Alien	A	Nt	+	+	−	+
Tragopogon kashmirianus Gurcharan singh	Asteraceae	Dicot	Native	B		+	−	+	+
Trifolium pratense L.	Fabaceae	Dicot	Alien	P	In	+	+	+	+
Trifolium repens L.	Fabaceae	Dicot	Alien	P	In	+	+	+	+
Trigonella foenum-graecum L.	Fabaceae	Dicot	Alien	A	Cs	−	−	−	+
Tulipa clusiana DC.	Liliaceae	Monocot	Native	P		−	−	+	−
Tulipa lanata E. Regel	Liliaceae	Monocot	Alien	P	Nt	−	−	+	−
Tussilago farfara L.	Asteraceae	Dicot	Native	P		−	−	−	+
Urtica dioica L.	Urticaceae	Dicot	Alien	P	In	+	+	+	+
Valerianella eriocarpa Desv.	Valerianaceae	Dicot	Native	A		−	+	+	+
Verbascum thapsus L.	Scrophulariaceae	Dicot	Alien	B	In	+	+	+	−
Verbena officinalis L.	Verbenaceae	Dicot	Native	A		+	+	+	+
Veronica agrestis L.	Scrophulariaceae	Dicot	Native	A		+	+	+	+
Veronica anagallis-aquatica L.	Scrophulariaceae	Dicot	Alien	A	Nt	−	+	−	−
Veronica persica Poir.	Scrophulariaceae	Dicot	Alien	A	In	+	+	+	+
Veronica stewartii Penn.	Scrophulariaceae	Dicot	Native	A		−	+	+	−
Vicia angustifolia L.	Fabaceae	Dicot	Native	A		+	+	+	+
Vicia sativa L.	Fabaceae	Dicot	Alien	A	Cn	−	+	−	−
Viola indica Bkr.	Violaceae	Dicot	Native	P		−	−	+	−
Vulpia myuros Gmel.	Poaceae	Monocot	Alien	A	In	+	+	+	+
Xanthium spinosum L.	Asteraceae	Dicot	Alien	A	In	+	+	+	+
Xanthium strumarium L.	Asteraceae	Dicot	Alien	A	In	+	−	+	+

Growth form: A, annual herb; B, biennial herb; P, perennial herb; Ss, sub-shrub; S, shrub; T, tree; Aq, aquatics; C, climber; L, liana; Ps, parasitic herb. Invasion status: Cs, casual aliens; Cn, casual or naturalised aliens; Nt, naturalised aliens; In, invasive aliens; (+) presence of a species; (−) absence of a species.

Flora of orchards

The present study revealed the presence of 141 species belonging to 110 genera and 39 families (Table 1). Six families namely Asteraceae (29 species), Poaceae (14 species), Fabaceae (12 species), Brassicaceae (10 species), Lamiaceae and Rosaceae (8 species each) accounted for 57.45% of the species (Table 2). Eighteen (46.15%) families were represented by one species each, seven families were represented by two species each, five families by three species each, two families (Polygonaceae and Boraginaceae) were represented by four species and the other one family (Scrophulariaceae) by five species. Out of the 110 genera

Table 2 Taxonomic structure of the floras of different habitat types in Srinagar city

Family	Number of species				
	Clubbed	Graveyards	Grasslands	Orchards	Wastelands
Asteraceae	35	23	19	29	20
Poaceae	27	10	22	14	16
Fabaceae	16	6	10	12	8
Brassicaceae	12	7	6	10	8
Rosaceae	11	–	6	8	6
Scrophulariaceae	9	3	6	5	4
Lamiaceae	8	5	2	8	4
Apiaceae	5	4	4	3	3
Boraginaceae	5	–	2	4	3
Cyperaceae	5	–	3	3	–
Polygonaceae	5	3	3	4	4
Ranunculaceae	5	–	2	2	3
Caryophyllaceae	4	3	3	2	–
Malvaceae	4	3	–	3	–
Chenopodiaceae	3	2	–	_	2
Geraniaceae	3	2	3	3	2
Iridaceae	3	3	–	–	–
Liliaceae	3	–	–	3	–
Amaranthaceae	2	2	–	–	2
Convolvulaceae	2	–	–	–	2
Equisetaceae	2	–	–	2	–
Euphorbiaceae	2	–	–	2	–
Onagraceae	2	–	2	2	–
Plantaginaceae	2	2	2	2	2
Rubiaceae	2	–	–	2	–
Solanaceae	2	2	–	–	2

Only the families with two or more representatives are shown. (–) absence of a species.

only one genus, *Medicago* was represented by four species. *Artemisia*, *Malva*, *Poa* and *Veronica* were represented by three species each, 20 genera by two species each and 85 (77.27%) genera were represented by just one species each.

Growth form and life span profile of orchard flora Out of 141 species, 130 (92.19%) were herbaceous (60 annual, 11 biennial, 57 perennial, 1 aquatic and 1 climber), 2 were sub-shrubs and 4 were shrubs. Five tree species were also recorded in the study area (Figure 2).

Eighty-five (65.38%) of the total 130 herbaceous species were alien and 45 (34.62%) were native to the region. Out of two sub-shrubs, one was alien and other was native to the region. Out of four shrubs, three were alien and one was native. All the five tree species were alien to Kashmir.

Proportion of alien and native species Out of 141 species, 94 (66.67%) were alien (Figure 3) and 47 (33.33%) were native to Kashmir. Out of 94 alien species, 6 were casuals, 3 were casuals or naturalised; naturalised category included 35 species, and 50 (53.19%) species represented invasive category (Table 3).

Flora of wastelands

Urban wasteland flora comprised 110 species, belonging to 89 genera and 36 families (Table 1). Five families, namely Asteraceae (20 species), Poaceae (16 species), Brassicaceae (8 species), Fabaceae (8 species) and Rosaceae (6 species) accounted for 52.73% of species (Table 2). Nineteen families were represented by single species each, six families by two species each, three families by four species each and three families were represented by three species each. The maximum number of species i.e. three species was of *Poa* and *Potentilla.* Seventeen

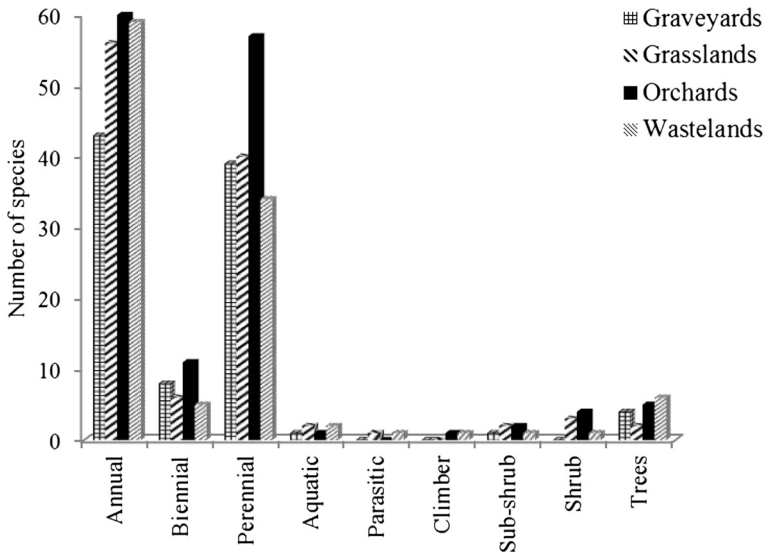

Figure 2 Habit and life form of the floras of various habitat types in Srinagar city.

genera were represented by two species each, and the remaining 70 (78.65%) genera were represented by single species each.

Growth form and life span profile of wasteland flora Out of 110 species, 102 (92.59%) were herbaceous (59 annual, 5 biennial, 34 perennial, 2 aquatic, 1 climber and 1 parasitic), besides 1 sub-shrub, 1 shrub and 6 tree species (Figure 2).

Proportion of alien and native species Out of 110 species, 74 (67.27%) were alien (Figure 3) and 36 (32.73%) were native to Kashmir. Casuals included 5 species; casuals or naturalised category included 2 species; 28 species were grouped under naturalised category and 39 species were grouped under invasive category (Table 3).

Discussion

This study revealed a preponderance of alien plant species across all habitat types. The proportion of alien species among habitats varied from 67.27% to 68.75%, with a mean value of 67.86% and 64.84% in the clubbed species list. Several studies across the globe have reported a higher proportion of alien species in city floras. Pyšek (1998) in a study, involving 54 central European cities, reported a high proportion of alien plant species which ranged between 20% and 60%. The proportion of alien species found in Ensenada, a fast-growing city located in the north-western peninsula of Baja California (Mexico) was also as high as 61% (Garcillán et al. 2009). Kowarik (1990) also reported that Polish cities have an average of 50% to 70% alien plant species.

Across all habitats, four families such as Asteraceae, Poaceae, Fabaceae and Brassicaceae were having dominant contribution to the respective floras and they contributed

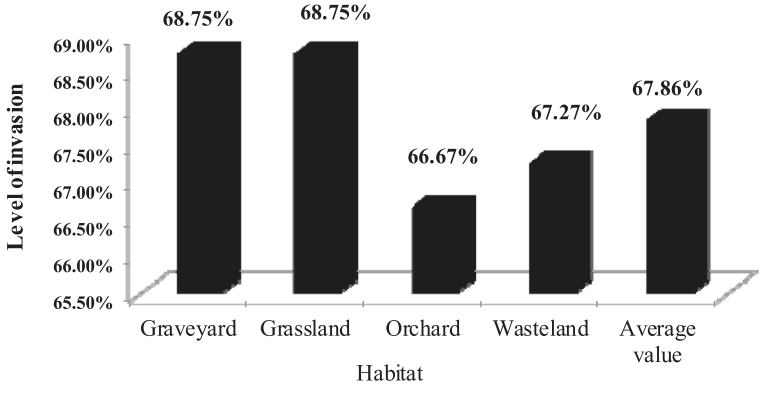

Figure 3 Comparison of level of alien plant invasion in various habitats of Srinagar city.

Table 3 Comparison of alien plant species at different stages of invasion in various habitats of Srinagar city

Habitat	Aliens						Total species
	Casual	Casualised or naturalised	Naturalised	Invasive	Total alien species	Percentage of respective habitat flora	
Graveyards	4	1	24	37	66	68.75	96
Grasslands	2	2	33	40	77	68.75	112
Orchards	6	3	35	50	94	66.67	141
Wastelands	5	2	28	39	74	67.27	110

46.09% to 50.89% species to respective habitat floras. The clubbed species list was dominated by large global plant families which have a weedy tendency. The family that included the largest number of species was Asteraceae, followed by Poaceae, Fabaceae, Brassicaceae and Rosaceae. These five families accounted for 50.75% of alien plant species in the clubbed species list in the present study and have been reported to be dominant in other alien floras in Europe (e.g. Weber 1997; Pyšek et al. 2002; Celesti-Grapow et al. 2009) and in Asian countries (China Weber et al. 2008 and India Khuroo et al. 2012). By and large, all genera are represented equally and no genus or few of them dominated the species pool in urban landscapes.

This study revealed that plant species with herbaceous habitat dominated the clubbed species list as well as respective habitat floras and accounted for 92.46% of all species. The annual and perennial herbs were represented by 45.23% and 37.69% of plant species, respectively. This seems to commensurate with the reports that Kashmir Himalayan region has witnessed 25% introductions for landscaping and ornamenting purposes only (Khuroo et al. 2007). The dominance of herbaceous plant species, with annual and perennial lifespan, is in agreement with findings of Khuroo et al. (2007) who also reported preponderance of annual (32% of all alien species) and perennial herbs (27% of all alien species) in alien flora of Kashmir Himalaya. Wang et al. (2011) also reported the preponderance of herbaceous habit in naturalised plant species recorded in Beijing Municipality, China. The dominance of alien plant species with herbaceous habit found in urban landscapes of Kashmir valley is presumably due to high anthropogenic disturbance. In areas frequently disturbed, those species have an advantage that can colonise rapidly and make use of the additional resources created by the disturbance such as herbs or grasses with a low canopy height (Hobbs 1989; Lake and Leishman 2004).

Conclusions

Srinagar city is one of the fastest-growing urban centres where frequent disturbances due to rapid infrastructure development create bare niches and pave way for alien introductions. This is testified by the predominance of alien plant species in the flora of Srinagar city across habitats as found in the present study. The growing preference over time for using alien rather than native species in urban landscaping and ornamenting, despite the Kashmir Himalaya region being quite rich in native ornamentals, has exacerbated the urbanisation-mediated invasions. The role of disturbance, a hallmark of urbanisation, in facilitating plant invasions is also indicated by the dominance of fast-colonising herbaceous plant species as compared to other growth forms in almost all the investigated habitats. The rapid pace of urbanisation and consequent burgeoning invasion in the Srinagar city's studied habitats call for careful policy planning to devise effective strategies for the management of urban landscapes. In fact, using native plant species in developing the urban landscapes and new green zones should be the rule, not the exception.

Abbreviation

GRIN: Germplasm Resources Information Network.

Competing interests

The authors declare that they have no competing interest.

Authors' contributions

SMA and ZAR conceived and designed the study. SMA carried out the floristic sampling, and MAS and SQ helped with the coordination and contributed to discussions and data analysis. All authors read and approved the final manuscript.

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