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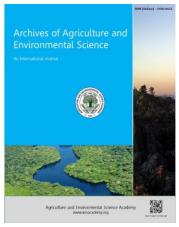

ORIGINAL RESEARCH ARTICLE

Occurrence and floral details of four new invasive alien species in Uttarakhand, India

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ABSTRACT

The present paper deals with the communication of four new species which are addition to the old reported species out of these 91 species which were studied. Four new invasive alien species (IAS) are *Acmella radicans* (Jacq. R.K. Jansen), *Eclipta prostrata* (L.) L., *Euphorbia cyathophora* Murray and *Senna alata* (L.) Roxb. was recorded as new elements in IAS flora of Uttarakhand. The study is conducted during 2011- 2015 to compile a comprehensive list of Invasive alien species. A total of 91 Invasive Alien Species were collected from the different areas of Pantnagar. These 91 IAS belonged to 70 genera under 30 families. Dicotyledons were representing by 82 species belonging to 63 genera under 25 families, whereas monocotyledons were represented by 9 species belonging to 7 genera under 5 families. The taxonomic analysis of IAS revealed dominance of Asteraceae with 16 species in 14 genera followed by Amaranthaceae with 10 species in 7 genera, Fabaceae with 8 species in 6 genera, Malvaceae with 7 species in 6 genera, Convovlvulaceae with 7 species in 3 genera, Solanaceae with 6 species in 4 genera, Poaceae with 4 species in 3 genera and Euphorbiaceae with 4 species in 2 genera. Results of this study clearly indicate presence of 52.60% of IAS flora of India and 55.82% of IAS flora Uttarakhand in such a small area of Pantnagar. Eradication of these species is impractical and costly; however, their population needs regular monitoring and any new introduction need eradication as early as possible.

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INTRODUCTION

Environment is an intricate system of various elements which are related to each other on this earth. Plants are the major group of organisms present on the earth. Every species has its own role to play in the environment (Sala *et al.,* 2000; McNeely, 2001; Balakrishan *et al.,* 2012). Humans and most other animals are totally depending on the plants directly or indirectly. Introduction of a plant in an area may be natural or in a planned manner. Some species become established in a new environment outside their natural range, spread rapidly and cause harm to other species, communities or entire ecosystem and to human well beings. Plant invasion is recognised as an important driver of global biodiversity change around the world. An invasive alien species (IAS) is considered as a species that is non-native to the ecosystem and cause negative impact on the biodiversity. Invasion by the alien species dramatically affect the distribution, abundance and reproduction of many native species. Invasive alien species compete with native flora for resources such as nutrients, light, physical space, water and food. Such species are considered as invasive alien species (IAS). They are known by several other names such as non native, introduced, non indigenous, exotic and foreign species. Invasive alien species occur in all groups of plants and animals (McNeely *et al.,* 2001; Sharma *et al*., 2005). IAS is widely distributed in all type of ecosystem throughout the world and includes all categories of living organism. The invasive alien plants are the subgroup of naturalized plants that produce reproductive off springs, often in a very large numbers, at significant distances from the parent plants, and consequently have the capability to spread in the large areas (McNeely, 2001). Invasive alien species are one of the most significant drivers of environmental change worldwide (Mooney and Hobbs, 2000; Sala *et al.,* 2000). The invasive species generally have dramatic and negative effect on the other

species and even entire ecosystem to the extent that it includes the extinction of species or sometimes even the hydrology and nutrition cycles of entire ecosystems have changed. Invasive alien species may be found in all taxonomic groups from prokaryotes to the higher plants and animals. These species have a quality that they exploit bare soil and empty niches (Singh *et al.,* 2010; Balakrishan *et al.,* 2012). The first step to manage these species is to recognise them. Plant invasion is a continuous process so its take several year to remove invasive species in that particular area. If invasive species is well established it is very difficult to remove it from the area. Invasion of species in any region takes place in different phases. Firstly, the invasive species arrival in that area by numbers of way, intentionally or unintentionally. Then the establishment of that species takes place and finally the species spread in that place successfully. So mostly the invasive species are the successfully invaders (Sharma *et al*., 2005; Karthikeyan *et al.,* 2009; Singh *et al.,* 2010; Balakrishan *et al.,* 2012).

A new challenge is to identifying these alien species and removal or control of these species in that area. Most of the countries facing the problem of invasion and the impact of invasion are mostly irreversible. The biological invasion of the plants species is a natural phenomenon. The biological invasion of invasive plants presents one of the most serious threats to the sustainability of the health of the ecosystem and their biodiversity (Westman, 1990; Tyser and Key, 1988; Graft, 1992). Moreover, it may pose a major threat to the endemic or indigenous diversity of the livings. Thus, the biological invasion and invasive species are becoming a growing issue to many scientists during the last few decades (Kubinova and Krahulee, 1999, Pysek *et al*., 1995) and therefore, there is an urgent need with an unparallel opportunity for ecological studies on the biological invasions (Vitousek, 1990; Pysek *et al.,* 1995). Plant invasion is a global problem and need global coordination for its effective monitoring and management (McNeely, 2001; Sharma *et al*., 2005; Karthikeyan *et al.,* 2009; Singh *et al.,* 2010; Balakrishan *et al.,* 2012). Therefore, in the present study was conducted for the exploration of new species of invasive alien flora in Uttarakhand, India.

MATERIALS AND METHODS

The present work is an outcome of exploration of invasive alien flora in the entire area of Pantnagar during August 2011 to December 2015. Previous floristic literature and reports about flowering plants of Pantnagar, herbarium specimens available in G.B. Pant University Herbarium Pantnagar (GBPUH) and study of flora Pantnagar (Rawat and Rao, 2015) was also undertaken to compile the information during this period.

Study area: The study area is the campus of G.B. Pant University of Agriculture and Technology having a perimeter of 28.52 km and 10,000 acres of land area. It is the first Agriculture University of India established on 17 November 1960 by the first Prime Minister of India Pt. Jawaharlal Nehru. The University area is spread in an area of 12,661 acres (51.24 Km^2) which makes it the second largest university in the world, in terms of continuous area. In Pantnagar area natural stands of Tarai forest vegetation are completely removed for cultivation or activities related with urbanization. As such this area presents a good example of removal of native flora partially or completely and invasion of vegetation by alien elements.

Floristic account: A tentative list of IAS species based on Reddy (2008) and Sekar *et al.* (2012) was compiled and attempts were made to search these species in the study area. Plants of the invasive alien species were collected from the different localities in Pantnagar. These localities were visited in different seasons to find out the exact flowering and fruiting time of these plants. Collected specimens were accompanied with information on locality, date, and other important information as suggested by Jain and Rao (1976), Simpson (2010). Later on, plant specimens were identified with the help of different floras relevant to this area like Duthie (1903-29), Babu (1977), Gaur (1999), Maheshwari (1963), Osmaston (1927), Raizada (1976), Flora of India vol. 1-5,12,13,23 (Sharma *et al.,*1993; Sharma *et al.,* 1993; Sharma and Sanjappa, 1993; Hajra *et al.,* 1997; Singh *et al.,* 2000; Hajra *et al.,* 1995; Balakrishnan *et al.,* 2012) and other important taxonomic documents. The origin and invasive nature of the plants were mainly determined according to Babu (1977); Bailey (1949); Duthie (1903-1929); Gaur (1999); Graf (1992); Khuroo *et al.* (2007); Negi and Hajra (2007); Rao (1994); Reddy (2008); Sharma and Pandey (1984); Sekar *et al.* (2012).

Collection of plants: Plants of the Invasive alien species were collected from different localities in Pantnagar including different research centres, gardens, residential areas, wastelands, areas along roads of University, Nagla bypass, NH 109 in different seasons of the year. Field trips were regularly made in different parts of study area and observations were made on habit, habitat, colour of flower and other morphological character of the plant species with special attentions on abundance, flowering and fruiting and other important information as suggested by Jain and Rao (1976), Simpson (2010). With the help of the field press fresh plant specimens were dried to prepare herbarium specimens. A field notebook was used to record information like date of collection, habitat, locality, flower colour, place of collection, vernacular names etc.

Identification and nomenclature of plant specimens: Plants specimens were primarily identified with the help of available regional floras like Flora of Upper Gangetic plain (Duthie, 1903-29), Flora of Delhi (Maheshwari, 1963), Supplement to Duthie's Flora of Upper Gangetic Plain (Raizada, 1976), Herbaceous Flora of Dehradun (Babu, 1977), Flora of Chamoli, (Naithani, 1984-1985) and Flora of District Garhwal Northwest Himalayas (Gaur, 1999). More recently, few important international floras like Flora of China, Flora of Pakistan, Flora of North America are now freely available online at www.efloras.org. These are also used, wherever needed, for confirmation of identity. In addition to conventional floras a new web source 'eflora of India' (https://sites.google.com.site/efloraofindia/home) having multiple images of large number of species of India

which are also used for identification of species. The fresh plant specimens were also compared with the plant images available in eflorapantnagar (Rawat and Rao, 2015) having identified images of more than 425 flowering plant species of Pantnagar area. In addition to literature method, plant specimens were also compared with authentically identified specimens housed at the Herbaria of Botanical Survey of India (BSD), Dehradun and National Botanical Research Institute, Lucknow, India.

Preparation of herbarium

Pressing and drying of plant specimens: Collected plant specimens were pressed under field press in between the sheets of news papers following the method suggested by Lawrence (1951) and Smith (1971).

Poisoning and preservation of plant specimens: Herbarium specimens are damaged by insect attack and to avoid this, the specimens were preserved by the use of repellents or insecticides. Pressed plant materials are poisoned with $HgCl_2$ solutions, as suggested by Lawrence (1951), to prevent the attack the pest, fungi during storage. Naphthalene balls are used as insect repellent in storage of specimen.

Mounting: The specimens were mounted on the standard Herbarium sheets (11.5 × 16.5 inch) and labeled by a label of 6.5 × 10.5cm as suggested by Jones and Luchsinger (1987).

Nativity of species: The origin and invasive nature of the plants were determined according to regional flora (Babu, 1977; Duthie, 1903-29; Gaur, 1999), important research publications (Khuroo *et al.,* 2007; Negi and Hajra, 2007; Reddy, 2008; Sekar *et al*., 2012), publication on ornamental and cultivated plants (Bailey, 1949; Graf, 1992; Karthikeyan, 2000), other publication (Rao, 1994; Sharma and Pandey, 1984) and web resources like Global compendium of weeds (GCW, 2017).

RESULTS AND DISCUSSION

Acmella radicans (Jacq.) R.K. Jansen Syst. Bot. Monogr. 8: 69. 1985. 69 1985; *Spilanthes radicans* Jacq. Hajra *et al*., Fl. India 12: 409. 1995; Karthikeyan *et al*., 2009 Flowering Pl. India- Dicot 1: 278. 2009 (Figure 1).

Vernacular name: White spot flower (English)

Annual, erect herbs. Stem terete, minutely pubescent. Leaves ovate, obtuse at the base, acute at apex, petiole hairy. Inflorescence terminal or in leaf axils. Head white, solitary, discoid, 0.8cm long, peduncles, 0.3 cm long, receptacles glabrous, palea, solitary concave boat shaped, glabrous, homogenous. Involucral bracts oblong or subulate, obtuse 0.5 cm long, 3 nerve from the base, minutely hairy from the outside. Disc florets 50-60, corolla white, 0.5 cm long, lobes papillose, triangular-ovate, corolla tube 0.3 cm long. Achene dimorphic brownish- black, marginal trigonous, others ellipsoid, laterally compressed. Pappus of 2 subequal bristles, 0.2 cm long.

Senna alata (L.) Roxb. Sp. Pl. 378. 1753; *Cassia alata* L., Baker in Hook. f., Fl. Brit. India 2: 264. 1878; Sanjappa, Legumes India. 14. 1992 (Figure 2).

Vernacular name: Candle bush (English), Dadmurdan (Hindi)

Annual, erect, shrubs. Stem branched, greenish brown, solid. Leaves 30-60 cm long, alternate, stipulate, auriculate, unipinnate compound. Leaflets 4-15 pairs, sessile or shortly petiolulate, 5-15 × 3.5-7.0 cm, obovate-oblong, emarginated, mucronate at apex. Inflorescence axillary or terminal raceme. Flowers yellow in color, bracteates, bisexual. Calyx 5 or 4, 1.4-1.5 × 0.6-0.7 cm long, unequal. Petals 5, yellow, 1.8-2.3 × 1.2-1.4 cm long, one posterior odd petal larger than other 4 petals. Stamens 10, free, unequal, 7 fertile, 3 sterile. Ovary stipitate, linear, lanceolate, style long, slender, stigma simple. Pod tetragonal, black, many seeded. Seeds dark brown, compressed, deltoid.

Eclipta prostrata (L.) *Mant. Pl. 2 286 1771.* Hook. f., Fl. Brit. India 3: 309. 1881; Duthie, FUGP 1: 427. 1903-29; Maheshwari, Fl. Delhi 197. 1963; Babu, Herb. Fl. D.Dun 242.1977; Naithani, Fl. Chamoli 1: 324. 1985; Rao *et al*., Fl. ind. enum. Asterac. 34. 1988; Hajra *et al*., Fl. India 12: 381.1995; Gaur, Fl. District Garwhal 560. 1999; Flowering Pl. Uttarakhand 155. 2007; Karthikeyan *et al*. (2009) Flowering Pl. India- Dicot 1: 227. 2009 (Figure 3).

Vernacular name: False Daisy (English), Bhringraj (Sanskrit), Kesharaj (Hindi)

Annual, prostrate or erect herbs. Stems hairy, creeping and branching at the base. Leaves subsessile, elliptic, oblong or oblong lanceolate, papery, hairy, base narrow, margin serrulate, and apex acuminate. Heads 0.6-1.0 cm across, axillary or terminal, peduncle slender, 2-4.5 cm. Involucral bracts ovate- lanceolate, acute 0.5 - 0.3 × 0.4 - 0.2 cm. Ray florets 0.4 cm long, in 2-3 series with bi dentate corolla, white. Disc florets 0.2 cm, many, corolla 0.4 cm long, 4 lobed. Stamens sagittate. Achene 0.2-0.25 cm long, margin ribbed, oblong-turbinate, dark brown.

Euphorbia cyathophora Murray *Comment. Soc. Regiae Sci. Gott. 7: 81 1786.* Balakrishnan *et al.,* Fl. India 23: 329. 2012 (Figure 4).

Vernacular name: Fire on the mountain, Painted leaf (English)

Annual or sub-perennial, erect, herbs. Stem branched, glabrous, hollow, woody at base. Leaves alternate, stipulate, brownish glands, caducous, lower leaves ovate, middle leaves panduriform, upper leaves elliptic-lanceolate, margins shallowly and irregularly toothed, apex obtuse, leaves entirely red, 3-8 × *2-4 cm long*. Cyathia 0.2-0.3 cm long, terminal involucre barrel shaped, glabrous, margin deeply and bluntly toothed, basal bracts similar to leaves with bright orange red blotch, upper bracts smaller, lanceolate, red. Male floret in 3 or 4 fasicles of 5 or 6 flowers each. Bracteoles ligulate, feathery. Stamens 1.2 cm long. Female floret 0.4 cm long, ovary 2.5 cm long, pedicellate, glabrous; style 0.1 cm long, connate at base, stigma capitate. Fruits 0.3 × 0.5 cm long, glabrous, pedicels 2.5 × 0.3 cm long, deeply 3 lobed. Pedical 2.5 × 0.3 cm. Seeds ovoid-conical, 0.2 × 0.2 cm long, greyish black.

In the present study four species *viz., Acmella radicans* (Jacq.) R.K. Jansen. (Asteraceae), *Senna alata* L. (Fabaceae), *Eclipta prostrata* (L.) L. (Asteraceae), *Euphorbia cyathophora* Murray (Euphorbiaceae) was collected. These species were not recorded in the invasive alien flora of Uttarakhand Himalaya (Sekar *et al*., 2012) and thus are new records to IAS flora of the Uttarakhand state. *Acmella*

radicans (Jacq.) R.K. Jansen (*Spilanthes radicans*) was recorded in and around the construction sites and this indicates its introduction in Pantnagar through building material, particularly sand from adjacent areas. This species seems to be one of the greater threat as in Flora of India (Chowdhery, 1995) reported distribution of this species only in Kerala state of India. Later, Karthikeyan *et al*. (2009) reported its occurrence in North and South India. These two references suggest a rapid spread of this species throughout India within a short span of one and a half decade. Sekar *et al.* (2012) did not mention this species in Uttarakhand. It appears that it is a recent introduction in the state and need to be monitored in future as in worst scenario it may invade the native vegetation like other noxious weeds of Asteraceae like *Parthenium hysterophorus* L. and *Eupetorium adenophorum, Acmella radicans* (Jacq.) R.K. Jansen and *Senna alata* (L.) Roxb. are also new additions to the flora of the Uttarakhand state.

Flowering and fruiting: October- January
Seeds production: 400- 500 seeds/plant
Seed germination: 14.50%
Multiplication method: Seeds
Method of seed dispersal: Animals, wind, humans.
Nativity: This species is a native of South America (Chandra Sekar *et al*., 2012; Chandra Sekar, 2012; Singh *et al.,* 2010; Reddy, 2008).
Distribution: Recorded along the roadsides and in waste lands.

Figure 1. *Floral description of Acmella radicans (Jacq.).*

Flowering and fruiting: October- December
Seed production: 150-200 seeds/plant
Multiplication method: Seeds
Method of seed dispersal: Wind, humans
Nativity: This species is native of Tropical America (Reddy 2008).
Distribution: Rare, recorded along roads in Haldi.

Figure 2. *Floral description of Senna alata (L.) Roxb.*

Flowering and fruiting: July- December
Seeds production: 600- 700 seeds/plant
Seed germination: 51.00%
Multiplication method: Seeds
Method of seed dispersal: Human, wind and animals
Nativity: This species is a native of Tropical America (Chandra Sekar *et al*., 2012; Chandra Sekar, 2012, Singh *et al.,* 2010; Reddy, 2008).
Distribution: Commonly present along the roadsides, waste land, crop fields and garden in moist area etc.

Figure 3. *Floral description of Eclipta prostrata (L.).*

Flowering and fruiting: April- November
Seeds production: 50-60 seeds/plant
Seed germination: 96.00%
Multiplication method: Seeds
Method of seed dispersal: Human, wind
Nativity: This species is a native of Tropical America (Reddy 2008).
Distribution: Common weed along the roadside, waste and, cultivated fields.

Figure 4. *Floral description of Euphorbia cyathophora Murray Comment.*

Conclusions

It is concluded from the present study that the invasive alien species *viz., A. radicans*, *S. alata*, *E. prostrate and E. cyathophora* was not listed previously. Biological species which acre introduced to a new geographic area other than its natural home range are called as alien, exotic or non- native species. Some of the alien species invade the natural vegetation and called invasive alien species. These species are introduced in any area both accidentally or intentionally. The presence of these species in that area modifies the structure and the function of the ecosystems. Biological diversity faces many threats throughout the world. One of the major threats to native biological diversity is caused by Invasive Alien Species (IAS). IAS is causing enormous damage to the biodiversity and the valuable natural agricultural system upon which we depend. The impacts of IAS are increasing serious damage to nature and these effects are irreversible. IAS represses or replaces native species either directly or indirectly by outcompeting them for resources and also alters the species composition in an ecosystem. Invasive alien plants are capable to reproduce large number of reproductive offspring's and are able to disperse rapidly over extensive area. These invasive alien species are the successful invaders because these species are very adaptable, reproduce quickly, develop rapidly and evolve viable population at low resources. There are some factors determining the success rate of invasive species in an area. The G. B. Pant University of Agriculture and Technology Pantnagar is a small land area devoid of natural stands of vegetation and suffer from continuous agricultural operations and human activities, which seems to be the reasons behind the presence of large number of IAS flora here.

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