



ISSN: 0976-3376

Available Online at <http://www.journalajst.com>

ASIAN JOURNAL OF
SCIENCE AND TECHNOLOGY

Asian Journal of Science and Technology
Vol. 09, Issue, 04, pp.8007-8015, April, 2018

RESEARCH ARTICLE

INVASIVE ALIEN SPECIES IN THE FLORA OF JAMMU, JAMMU AND KASHMIR, INDIA

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ARTICLE INFO

Article History:

Received 27th January, 2018
Received in revised form
13th February, 2018
Accepted 17th March, 2018
Published online 30th April, 2018

Key words:

Globalization,
Native
Species,
Extinction

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ABSTRACT

Biodiversity ensures natural sustainability for all the life on this planet. Major drivers of global change such as climate warming, deforestation, habitat fragmentation and rapid economic development have been accelerating the invasion process since globalization. The influence of invasive alien species (IAS) has become a threat to several ecosystems. Such species are one of the biggest threats to biodiversity. Many invasive alien species reported to have successfully colonized in the area and have contributed significantly to drag some native species towards rarity and vulnerability with serious threat of extinction from this face of earth. The co-ordinated and sustained efforts are required immediately to control and eradicate them so that the biodiversity of the region is timely conserved and restored.

INTRODUCTION

The wide variety of all the species existing on earth is essential for the healthy and balanced state of all the ecosystems. Biodiversity ensures natural sustainability for all the life on this planet. Disturbance of any type in an ecosystem tends to reduce its biodiversity. Those alien species that become established in a new environment, then proliferate and spread in ways that are harmful to the global environment besides human beings are considered as invasive alien species (IAS). These are non-native species that are introduced intentionally or unintentionally in areas outside of their native range, where they grow, survive, reproduce and produce invasive populations. Major drivers of global change such as climate warming, deforestation, habitat fragmentation, changes in land use and land cover, rapid economic development, and population explosion accelerate the invasion process. The global extent and rapid increase in invasive alien species is homogenizing the world's flora and fauna (Mooney and Hobbs, 2000) and is recognized as a primary cause of global biodiversity loss. The influence of invasive alien species (IAS) has become a global threat to several ecosystems. The damage caused by the invasive alien species in terms of the biodiversity loss and disruption of natural ecosystems outweighs their benefits. Invasive alien species stand as the second largest threat to biodiversity. The global community has been showing an intense concern to this growing menace. United Nations General Assembly at its 65th session declared

the period 2011-2020 to be “ the United Nations Decade on Biodiversity” with a view to contribute to the implementation of the Strategic Plan for Biodiversity. United Nations Convention on Biodiversity, adopted in 1992 binds all the 191 nations who were parties to the convention to prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitat or species. Throughout the ‘United Nations Decade on Biodiversity’ governments are encouraged to document status survey of biodiversity for its overall conservation at regional, national and international level. Worldwide there is a growing catalogue of the potential impacts of invasive species on native species, disturbance regimes, and ecosystem services (Pys̆ek *et al.* 2011; Simberloff *et al.* 2013). However, in parts of Asia the issue of invasive alien species has low profile attention and priority due to a number of other priority concerns of socio-economic and political nature. The present study in part will support the implementation of the Strategic Plan for Conservation of Biodiversity. The aim of the study is to document the invasive alien species present in the region, to determine their dispersal mechanisms, impact on biodiversity, control and eradication.

MATERIALS AND METHODS

The study followed a random sampling method so that no bias is introduced in the collection of data. The survey areas were selected in all the districts of Jammu division. To the ease of data collection survey areas were spread to different villages, urban and sub-urban localities. The author has conducted many random field trips in different localities of the research area. Each study unit was sub-divided into different land use types such as riparian areas, forest areas, orchards, grasslands,

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disturbed areas, wet lands and waste lands. The various localities visited for the purpose of sampling include Samba, Reasi, Ramban, Doda, Padder, Gool, Nowshera, Surankote, Sundarbani, Bishnah, Khour, Akhnoor, Katra, Jindra, Galak, Lowang, Badnota and Thein. The sampling areas of study were visited many a times of the year in order to record each and every stage of the species like flowering, fruiting, seed dispersal etc. The samples and specimens were collected, systematically pressed, dried and preserved for identification. The plant specimens were identified by applying taxonomic keys and reference to the local floras. The identification was also facilitated by way of consultations with experts in the field of taxonomy and final confirmation was done by visiting to the local herbaria. Online identification system and ISSG database were also used to identify and determine the alien origin of species. The common names of the plants were ascertained by way of investigations from the local inhabitants. The information gathered by way of questioning to the native men was cross verified. The equipments, tools and other related material employed in the study include microscopes, dissection microscope, camera lucida, magnifying lens, plant press, cutters, Photographic camera and field note-book. The plant specimens were also photographed in the wild form in the ecosystems of their occurrence. The plant specimens and photographs of species explored during the course of study were handed over and kept for record in nearest concerned institution. The survey and data collection on the invasive alien weeds of Jammu was carried out from 2014 to 2017.

Study Area

The area of study is the southern part of the state of Jammu and Kashmir. It is situated between 32° 17' to 34° 12' north latitudes and 73° 58' to 76° 47' east longitudes covering an area of 26,293 Sq. Kms. The territorial area of Jammu division has been sub-divided into 10 districts. The region presents an intricate mosaic of mountain ranges and hills with river terraces and valleys. Physiographically it consists of foothill plains, Siwalik Hills and Pir-Panjal region. The foothill plain is a narrow tract along the Siwalik stretching from the east of Ravi to the west of Akhnoor with an average height of 366 m above sea level. It is an extension of the northern plains of India with a width of 6 to 42 Kms. The three districts of Kathua, Jammu and Samba lie in this foothill plain though some of their areas lie in the Siwaliks. District Kathua shares its border with Punjab and Himachal Pradesh whereas district Samba is sandwiched Kathua and Jammu. The Siwalik Hills, which is an outer part of the Himalayas, border the foothill plains on the northern periphery. These hills extend in the form of a long chain of narrow and low hills in south-east to north-west trend almost parallel to the Pir-Panjal range with a varying width of 23 to 58 Kms. Siwalik Hills rise with a gentle slope, attain an altitude of about 600 m and end abruptly inwards in steep escarpments. At places, the Siwalik hills are separated from the lesser Himalayas by flat-bottomed valleys termed as 'duns'. Jammu city, the winter capital of the state is situated on the banks of river Tawi at an altitude of 366 m on the southern slope of Siwalik. It extends into the outer plains which lie towards the south-west. In the Siwalik Hills are the famous lakes of Mansar and Surinsar to the east of Jammu city. The Pir-Panjal region constitutes the northern part of the division. Raising abruptly from the Siwalik the region extends up to snowclad peaks of Pir-Panjal and the great Himalayan ranges in the north and northeast respectively.

The Middle-Himalayas in Jammu region sprawl between Ravi in the east and Poonch in the west though they continue towards north-west beyond Muzzafrabad. They vary in their altitude between 1820 m to 2240 m with a width of about 60 Kms in the east and 10 Kms in west. The Pir-Panjal representing the Middle-Himalayan ranges consists of lofty mountains with an altitude of 3500 m to 5000 m. The range is traversed by many passes like Pir-Panjal 3491 m, Budhal Pir 4261 m and Banihal pass 3224 m. The region is rich in drainage with upper courses of the river Chenab and its tributaries. The other parts of the region are drained by Tawi, Ravi, Minawar Tawi, Ujh, Basantar, Ans and Poonch rivers besides many tributaries. The famous Trikuta hills near Katra are a part of Middle-Himalayas. The region is dotted by small valleys like Bhaderwah, Kishtwar, Padder, Reasi, Ramnagar, Rajouri and Poonch. The upper course of the Chenab lies in Himachal Pradesh, where it is formed of two main feeders Chandra and Bhaga. These two feeders have their origin on the opposite sides of Bara Lacha pass in the Trans-Himalayan region. They unite at Tandi in Himachal Pradesh and then enter the Jammu division through a narrow gorge at Padder. Between Kishtwar and Reasi it receives the waters of Karnal Gad, Kar Gad, Kantha, Niru, Paggi and Painthal streams. After leaving the Himalayas it enters the plain area of Akhnoor where it divides into many channels.

One of the bifurcated channels continues to flow close to the border till it receives the waters of Tawi. After leaving the division it flows in south-westerly direction forming a doab between it and Jehlum. On the other side, Tawi takes its rise in the Seojdhar range north-east of Ramnagar. In its upper course it drains Dudu valley that penetrates deep into the east for about 64 Kms from Chaneni. Many rivulets meet it enroute towards Chaneni. After flowing towards west in a zigzag course it reaches Jammu and finally merges with one of the bifurcating channels of Chenab about 29 Kms west of Jammu. In Jammu division, there is much diversification in climatic conditions due to variation in elevation and aspect. In general, it has humid sub-tropical (monsoon type) to temperate type of climates, with variations in temperature, depending on the amount of rainfall and altitude of the place. The South-west monsoons significantly influence the climate of the region from the first week of July to mid September causing rainfall almost in the entire region. The months of April to June are very hot with mean maximum and mean minimum temperatures in June for the year 2016 recorded at 38.20°C and 26.29°C respectively. Since most of the area is mountainous the temperature in mountainous and valleys generally remains mild in summer. The winter season is generally characterized by low temperatures over most of the region. During winter season the western disturbance from the Mediterranean Sea generally brings moderate to intense rainfall in the low lying areas and snowfall in the highlands. The mean maximum and mean minimum temperatures in January, the coldest month, for the year 2016 recorded at 12.76°C and 3.39°C respectively at Batote.

RESULTS AND DISCUSSION

The study revealed the presence of 19 invasive alien species (IAS) in the Jammu division of Jammu and Kashmir State. All the 19 species belonging to 14 families of angiosperms have been studied and documented. They were found growing under different habitat such as forest land, grass land, fallow land,

waste land, marsh land, wet land and agricultural areas. The habit, morphology, dispersal mechanisms and the impacts of invasive alien species on the native biodiversity besides agriculture and the people were observed, analyzed and recorded. Out of 19 invasive alien species recorded in the study area thirteen have their origin in South and Central America, three in North America, two in Africa and one species has its native range in Europe. All the 19 invasive alien species are discussed as under:

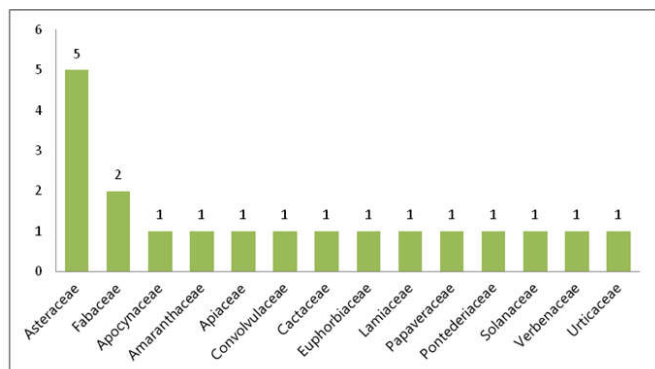


Fig. 1 Dominant families of Invasive Alien Species (IAS) present in Jammu region

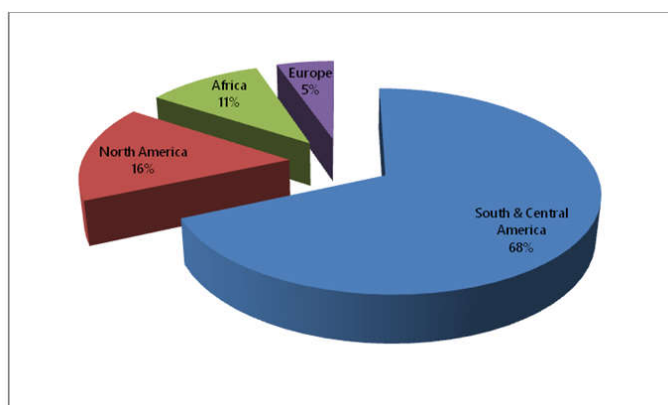


Fig. 2 Native Range of Invasive Alien Species (IAS) present in Jammu region

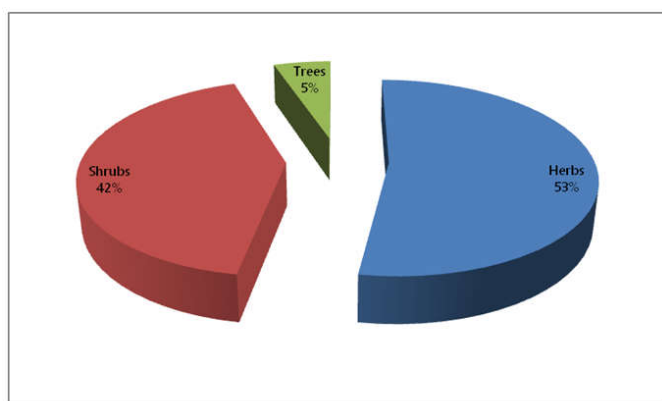


Fig. 3 Predominant life-forms of Invasive Alien Species (IAS) present in the area

Prosopis juliflora (Sw.) DC.

Family: Fabaceae.

Common Name: Southwest thorn, Mesquite.

Native Range: South America and Mexico.

Description: A deciduous tree or shrub, 3-12 m tall, bark brownish, fissured in long vertical stripes, main branches crooked, young zigzag, more or less flat topped canopy, spines axillary, paired, rarely absent, straight, divergent, 1-4 cm long. Leaves bipinnate, pinnae 1-3 pairs, 4-18 cm long, leaflets elliptic-oblong, emarginate or obtuse, up to 29 pairs. Flowers in axillary racemes, cylindrical, 7-15 cm long, solitary or 2-4, florets pale to greenish yellow, sessile, densely clustered, mildly fragrant and visited by bees. Fruit a compressed legume, 10-25 cm long, curved, straw yellow, endocarp segments up to 25. Seeds oval and brown.

Dispersal: Propagation occurs through seeds which are dispersed by different agencies like animals, humans and water.

Impact: An aggressive colonizer adapted to a wide range of soils and seen growing in grassland, fallow land, forest land and disturbed land where by virtue of forming dense thorny thickets and competition it exerts negative impact on local biodiversity.

Prevention and Control: (i) It is difficult to control the weed through mechanical and chemical methods due to reintroduction and re-establishment of seeds. The widespread use of herbicides has adverse effects on the environment. (ii) Cultural control practices like hand clearance and burning of young seedlings prevent dense thicket formation. (iii) Integrated control by using mechanical clearance coupled with herbicide treatment seems more effective to curb the menace.

Argemone mexicana L.

Family: Papaveraceae.

Common Name: Mexican Poppy.

Native Range: Mexico, West Indies.

Description: A prickly, annual herb, 60-100 cm tall. Stem branched, glaucous, glabrous with yellow sap. Leaves alternate, semi-amplexical, simple, lobed, sinuate-pinnatifid, variegated, lamina 10-20 cm long, veins white, spinous. Flowers solitary-terminal, 2.5-5 cm in diam., sessile or subsessile, calyx 3, prickly, corolla yellow, petals 4-6, free, caducous, stamens 13 or more, free.

Ovary unilocular, stigma sessile. Capsule ellipsoid, 2-4 cm long, prickly, 4-6 valves. Seeds 300-400, globose, netted, brownish-black.

Dispersal: Propagation takes place through seeds formed in large numbers and dispersed through water, animals and man.

Impact: It is widely distributed in arable land, cereal crops, grassland, wasteland and fallow land. Dense crowding and allelopathy reduces native species diversity. Seeds are highly toxic which through adulteration of vegetable oil cause epidemic dropsy.

Prevention and Control: (i) The uprooting of seedlings reduces infestation.

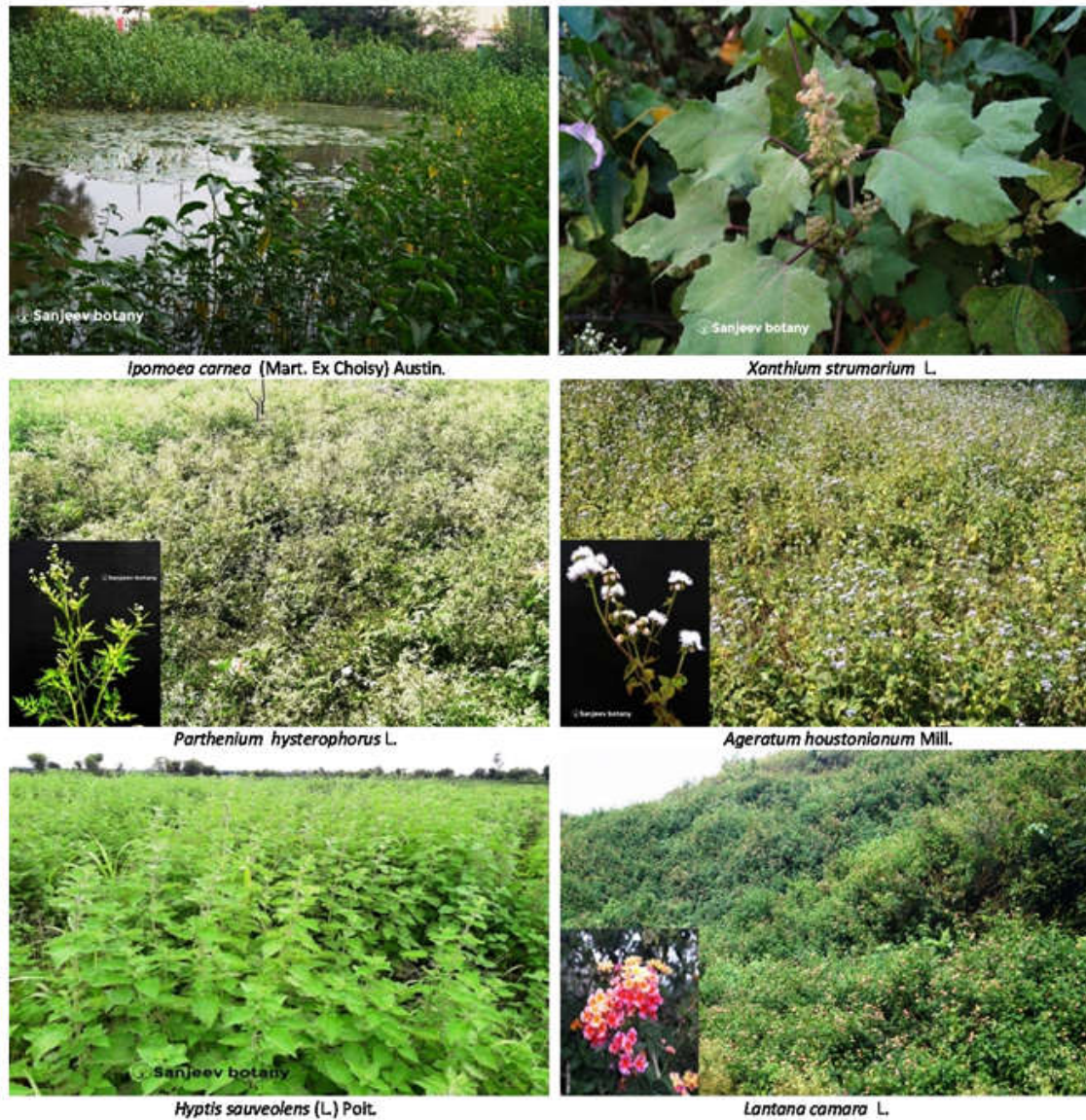


Fig. 4 Invasive Alien Species (IAS) present in different ecosystems of the study area

A light tillage of the affected land at the seedling stage controls the aggressive colonization of weed. (ii) It is susceptible to a wide range of standard herbicides like picloram, butachlor, 2, 4-D, dicamba, diuron and terbutryne.

Ageratum conyzoides Linn.

Family: Asteraceae.

Common Name: Billy goat weed, White Weed.

Native Region: South and Central America.

Description: An erect, softly hairy, annual herb with rank smell, stems 10-50 cm tall. Leaves ovate, crenate, cordate or cuneate, lamina 4-5 cm long. Heads pale-blue or pinkish purple or white, 6-10 mm in diam., in dense, terminal corymbs. Involucral bracts narrowly linear, ribbed, scarious margined, glabrous. Achenes black, hairy along the angles, pappus hairs concave below.

Dispersal: Propagation occurs through seeds which are easily blown by wind to long distances.

Impact: An aggressive weed commonly seen in thick patches in agricultural land, grassland, forestland, orchards, fallow land and by virtue of competition, habitat destruction and allelopathy it reduces the native plant diversity. The toxicity of weed results in liver lesions and tumors.

Prevention and Control: (i) Due to its shallow rooted habit it is relatively easy to uproot and control the weed by using mechanical means rather than hand-picking. (ii) It is susceptible to a wide range of broad leaved standard herbicides like butachlor, 2, 4-D, bentazone, oxidiazon, ametryne, terbutryne and acetochlor.

Parthenium hysterophorus Linn.

Family: Asteraceae.

Common Name: Congress grass.

Native Range: North America.

Description: An annual herb, stem 50-150 cm tall, rigid, branched, whitish hairy, longitudinally grooved.

Leaves simple, pinnately and irregularly much dissected, alternate, forming rosette in younger plants, dissected, tips acute, entire. Heads axillary and terminal, whitish with minute or hairy involucre bracts, 4-5 mm across, heterogametic, ray florets usually 5, fertile, disc florets 50 or more. Achenes ellipsoid-obovate and dark brittle.

Dispersal: Propagation occurs through seeds formed in large numbers with high longevity and dispersed by wind, water, birds, and vehicles.

Impact: An invasive noxious and allelopathic weed of crops, forest land, grass land and fallow land disrupting natural ecosystems by replacing native species and also drastically reduces crop yields. It is toxic to cattle and humans causing dermatitis, respiratory disorders and occasional death.

Prevention and Control: (i) Hand picking of weed is not advisable due to allergic effects. (ii) Eucalyptus oil is used as a natural herbicide. (iii) It is susceptible to the selective application of standard broad leaved herbicides like 2, 4-D, dicamba, glyphosate, atrazine and S-metolachlor. (iii) Biological control through leaf feeding beetle *Zygogramma bicolorata* remained partially successful.

Lantana camara L.

Family: Verbenaceae.

Common Name: Lantana, Tick berry.

Native Range: Central and South America.

Description: An aromatic straggling, gregarious shrub, branches prickly, 4-angled, densely interlaced into large impenetrable thickets. Leaves rugose, scabrid with rough hairs, ovate or ovate-oblong, 3-10 by 3-6 cm, base cordate, cuneate or rounded. Flowers variable, yellow or orange-red. Fruit black and shining.

Dispersal: Propagation occurs both vegetatively through axillary shoots and seeds dispersed by birds to long distances.

Impact: It is an aggressive colonizer of grassland, field margins, forest edges, disturbed land, banks of canals and often forming permanent thickets with serious negative impacts on the local plant diversity. It is also toxic to cattle.

Prevention and Control: (i) It is susceptible to the selective application of broad-leaved standard herbicides. Often cleared areas are rapidly colonized through root sprouting or seed. (ii) A combination of mechanical and chemical treatment is more effective to control this weed in smaller areas. (iii) Biocontrol by using natural pests and pathogens need to be encouraged.

Datura innoxia Mill.

Family: Solanaceae.

Common Name: Indian Apple, Downy thorn Apple.

Native Range: Tropical and Sub-tropical America.

Description: A stout erect or somewhat spreading, strongly foetid, shrubby annual, up to 1 m tall, softly tomentose. Leaves

deep-bluish green, broad ovate to ovate-lanceolate 10 by 8-15 cm, entire or repand-toothed. Flowers white, 11-14 by 5-8 cm, with spreading 10-toothed corolla-limb. Capsule globose, 4-5 cm diam., nodding, covered with long spines.

Dispersal: Propagation occurs through seeds which are formed in large numbers and dispersed by water, humans and animals.

Impact: An invasive weed which commonly colonizes in overgrazed grasslands, disturbed land, forest land, fallow land and by virtue of competition and allelopathy it reduces local biodiversity besides being highly toxic to humans and animals causing hallucination.

Prevention and Control: (i) The management of weed at the seedling stage like hand pulling of the isolated plants before seed set is very effective. (ii) It is susceptible to the selective application of broad-leaved systemic herbicides like 2, 4-D, glyphosate, dicamba and atrazine.

Conyza canadensis (L.) Cronq.

Family: Asteraceae.

Common Name: Canadian fleabane.

Native Range: North America.

Description: A coarse hairy erect annual herb, about 1.5 m tall, stem rigid, branched. Leaves sessile, narrowly lanceolate or oblanceolate, elliptic, alternate, lamina up to 10 cm long, about 1 cm wide with some shallow teeth, margin ciliate, acute, sparsely hairy. Heads arranged in terminal and axillary panicles, 2-3 mm across, bracts leafy. Ray florets 25-45, pistillate, corolla white, linear. Disc florets 12-25, perfect, corolla tubular, pale-yellow. Achenes 1-1.5 mm long, light yellowish-grey, narrowly cylindrical-ellipsoid, pappus hairs white.

Dispersal: Propagation occurs through seeds which are formed in large numbers and dispersed by wind.

Impact: It is an invasive and competitive colonizer of riparian land, fallow land, grassland and forest fringes with negative impacts on native species diversity besides causing significant losses to crop yield.

Prevention and Control: (i) The infestation of weed is controlled by tillage in the initial phase. Hand weeding and crop rotation are also useful practices. (ii) It is susceptible to the selective application of broad-leaved herbicides like glyphosate, 2, 4-D, dicamba, paraquate and triazines.

Eichhornia crassipes (Mart.) Solms.

Family: Pontederiaceae.

Common Name: Water hyacinth.

Native Range: South America.

Description: A perennial, free-floating, large herb, up to 1 m in height, rhizome and roots submerged. Leaves 6-10, glabrous, in basal rosettes, petiole swollen, lamina up to 15 cm across, roughly circular. In dense stands, petioles are elongated up to 1 m in length with circular leaves, but are short, about 30 cm and bulbous, with kidney shaped leaves where the plants

are not in dense mats. Spike up to 50 cm high, flowers 8-15, sessile, perianth tube with 6 mauve or purple lobes, standard perianth lobe with yellow diamond patch surrounded by deep purple, carpels 5, stamens 6. Fruit a capsule. Seeds up to 450, 1-3 mm long.

Dispersal: Propagation occurs through seeds as well as by stolons. Seeds are dispersed to long distances by birds. Dispersal may also take place through water, humans and mammals.

Impact: An invasive weed usually seen in thick stands over shallow streams, ponds, pools, ditches and marsh lands where it dramatically alters the ecosystem causing reduction in species.

Prevention and Control: (i) An integrated control involving both physical removal, restricted herbicide treatment and biological control by exploiting fungal pathogens like *Alternaria eichhorniae*, *Cercospora rodmanii* and insect pests like *Neochetina bruchi*, *Bellura densa*, *Xubida infusellus* are better management strategies.

Ageratum houstonianum Mill.

Family: Asteraceae.

Common Name: Blue Weed, Mexican Paint Brush.

Native Range: Central America.

Description: An annual, hairy herb, 15-60 cm long, erect or decumbent, stem reddish to green, pubescent. Leaves ovate to deltoid, lower opposite, upper alternate, hairy, lamina 3-6 by 2-4 cm, crenate-serrate. Heads homogametic, in terminal corymbs, 5-8 mm across, several disc florets only, ray florets absent, corolla 5, tubular, lavender blue, pink, lilac or white. Involucral bracts stipitate glandular on outer surface. Achenes hairy, pappus scales 5, white.

Dispersal: Propagation occurs through seeds dispersed by agencies like wind, water, animals and vehicles.

Impact: An invasive and allelopathic weed which usually grows in dense patches in grass land, agricultural land, forestland and fallow land with negative impact on the native plant species diversity besides causing reduced crop yield.

Prevention and Control: (i) Hand picking of weed is not advisable due to allergic effects. (ii) A 20% solution of common salt can be safely used in non-cropping areas. It is susceptible to the selective application of standard broad leaved herbicides like 2,4-D, picloram, dicamba and metsulfuron-methyl.

Xanthium strumarium Linn.

Family: Asteraceae.

Common Name: Cocklebur

Native Range: South America.

Description: A stout, unpleasant smelling, coarse annual up to 1.3 m tall with purple spotted stem. Leaves undulate, scabrid,

5-14 cm long, as broad, obscurely lobed, toothed. Heads green, males 6 mm diam., distal, female involucre with 2 enclosed apetalous flowers. Fruiting involucre ovoid, hard, 1.5-2 cm long, clothed with hooked prickles. Achenes black, 1.5 mm long, ribbed on the faces, topped with remains of styles.

Dispersal: Propagation occurs through seeds which remain viable up to 5 years. The spiny burs get attached to animal fur, human clothing and also dispersed by water.

Impact: An invasive weed of agricultural land, grass land, fallow land, disturbed land and open land, often forming thick monospecific stands with serious negative impacts on biodiversity besides drastically reducing soil fertility and crop yield. The glandular hairs on leaves and stem cause dermatitis.

Prevention and Control: (i) The cultivation of land reduces the infestation of weed. (ii) It is susceptible to the selective application of the broad-leaved herbicides like glyphosate, 2,4-D, dicamba, paraquate and triazines. (iii) Biocontrol of weed by using natural insect pests and fungal pathogens like *Puccinia xanthii* and *Alternaria helianthi* is useful to check the growing populations.

Heracleum lanatum Michx.

Family: Apiaceae.

Common Name: Cow parsnip, white leaf hogweed.

Native Range: North America.

Description: An erect, pubescent, perennial shrub, up to 2 m in height, stem robust, branched, grooved, hollow, rootstock perennial, odorous. Leaves pinnately lobed, 20-60 cm, pinnae 2-3 pairs, elliptic to ovate, 7-10 cm by 3-5 cm, densely white tomentose, serrate, apex mucronate or obtuse, upper sheathed, sheath large and boat shaped. Inflorescence in compound umbels, 10-20 cm across, peduncles 15-28 cm long, pubescent, umbellules 20-25 flowered, flowers small, white, bracts usually absent, bracteoles 5-8, calyx teeth minute, petals 5, free, notched at tip, outer petals large, bi-lobed. Fruit flattened, obconic, 7-12 mm long, 4-6 mm wide, with broad lateral wings, minutely hairy, glabrous when mature, primary rays many, hairy.

Dispersal: Propagation occurs mainly through seeds dispersed by agencies like wind, animals and humans.

Impact: An invasive weed which generally grows in thickets in woodland, open slopes, meadows and moist places. The invasive growth in thick stands by virtue of competition and habitat disruption results in a significant reduction in the native species diversity. Due to the presence of furano-coumarins in the sap it causes skin rashes and dermatitis to humans.

Prevention and Control: The management of the infestation of cow parsnip is difficult due to the presence of underground rhizomes and seeds formed in large quantities. The severity of infestation around the fields can be contained by repeated cutting over the years and land cultivation.

Ipomoea carnea (Mart. Ex Choisy) Austin.

Family: Convolvulaceae.

Common Name: Morning glory.

Native Range: Tropical America.

Description: A robust, perennial shrub, up to 3 m tall, erect or sub-erect, gregarious, diffuse, milky latex present in all parts, stem slender, woody, hollow, glabrous, light-brown in older parts. Leaves simple, alternate, petiolate, ovate, cordate, entire, acute, pubescent, 12-26 by 5-15 cm. Flowers purplish-pink, in terminal cymes, 7-8 cm by 6-7 cm., sepals 5, free, petals 5, gamopetalous, funnel-shaped, stamens 5. Capsule ovoid, 1.5 by 1.2 cm. Seeds black, densely silky with long and brownish hairs.

Dispersal: Propagation occurs through stem fragments and seeds which are dispersed through wind and water.

Impact: An invasive and allelopathic weed which generally forms thick stands in swamps, pools, ponds, ditches as well as on land with negative impacts on disruption of ecosystem and biodiversity.

Prevention and Control: (i) Both manual and mechanical removal is not effective in the aquatic environment. (ii) Although the weed is susceptible to the commonly used herbicides but their use is restricted in aquatic habitats due to the harmful effects on other organisms.

Urtica dioica L.

Family: Urticaceae.

Common Name: Stinging Nettle, European Nettle.

Native Range: Europe.

Description: A stinging herbaceous perennial, 80-175 cm. Stem robust, upright, grooved, pubescent, fibrous arising from basal rhizomes. Leaves simple, opposite, 5-10 cm, lower ovate, upper lanceolate, base cordate, acuminate, coarsely serrate, petiolate, stipules free, four at each node, lamina with conspicuous stinging hairs at least on the upper surface, non-stinging hairs relatively coarse and sparse. Inflorescences axillary, spike-like, four per node, many-flowered, flowers small, greenish, unisexual, male and female flowers on separate plants, flowers tiny, greenish, the males more upright or patent and the females tending to be pendent, male with four perianth segments and four stamens, female with two smaller and two larger perianth segments, ovary one-celled, stigma sessile, tufted. Fruits achenes, flattened, encircled by persistent perianth.

Dispersal: Propagation takes place through underground rhizomes and seeds formed in large numbers. Seeds are dispersed through wind, water and animals.

Impact: An invasive weed generally seen in large patches in places like wastelands, fallow lands, grasslands, orchards, roadsides and often forming monospecific stands which besides its horizontal spread through rhizomes destroys habitat and restricts or prevents the growth of native species. The stinging trichomes cause irritation, pain and burning sensation related health problems in humans and animals.

Prevention and Control: The control and eradication of stinging nettle is difficult due to stinging leaves and a large root mass.

(i) It can be controlled to some extent by repeated tillage and cultivation of the infested area. Repeated cutting also prevents monospecific stand formation. (ii) Repeated and selective herbicide treatment by using picloram, 2,4-D, clopyralid, triclopyr and dicamba. (iii) Biocontrol by using natural pests and pathogens like *Eupateryx urticae*, *Liocoris tripustulatus*, *Dasinura urticae* and *Trioza urticae* needs to be employed.

Calotropis procera (Willd.) R.Br.

Family: Apocynaceae.

Common Name: Apple of Sodom.

Native Range: Tropical Africa.

Description: Erect or sub erect, perennial, hoary shrub, 1-1.5 m in height, branched, densely white tomentose. All parts containing milky latex. Leaves opposite-decussate, thick, ovate-oblong to elliptic, 6-18 cm by 4-12 cm, cordate or amplexicaul, shortly acuminate, entire, white tomentose when young, later glabrescent, glaucous. Inflorescence a dense, multi-flowered, axillary and terminal, umbellate cymes, flowers white, blotched with purple or purplish-pink, 2-2.5 cm diam., peduncles stout, calyx 5, free, corolla 5, fused, twisted, corona staminal, stamens 5, fused with stigma forming gynostegium, bicarpellary, syncarpous, ovary superior, enclosed in staminal tube. Follicles turgid, 8-10 cm by 4-6 cm, obliquely ovoid, recurved. Seeds many, flat, pappus silky white.

Dispersal: Propagation occurs through seeds which are formed in large numbers and dispersed chiefly by wind.

Impact: An invasive weed which is generally seen in dense thickets in poor and over-grazed areas like grasslands, fallow lands, open lands, waste lands and roadsides causing reduction in native species diversity. It is also toxic to humans and animals.

Prevention and Control: It is difficult to control due to the deep feeder root system and succulent habit of the weed. The weed control involves (i) uprooting the weed through mechanical methods. (ii) selective application of herbicide foliar spray to the seedlings. Chemical control is only successful if the top of the roots is also removed.

Senna tora (L.) Roxb.

Family: Fabaceae.

Common Name: Sickle Senna.

Native Range: Tropical America.

Description: Erect, 30-75 cm tall, gregarious annual, strong unpleasant odour, stem cylindrical, branched. Leaves pinnately compound, alternate, leaflets usually in 3 pairs, obovate-oblong, 2-6 cm by 1-3.5 cm, apex obtuse, margins ciliate. A rod like gland is situated between each of the lowest two pairs of leaflets. Flowers about 1.2 cm long, axillary, 1 or 2, sepals 5, free, corolla of 5 petals, free, unequal, yellow, fertile stamens 7, carpel 1, ovary superior. Fruit a legume, slender,

falcate, 12-20 cm long, imperfectly septate between the seeds, brown. Seeds many, cylindrical, obliquely truncate, brownish, shining.

Dispersal: Propagation occurs through seeds dispersed by water, animals, as contaminant of agricultural produce and human activities.

Impact: An invasive and gregarious weed of fallow land, waste land, grassland, forest land and agricultural crops where it out-competes and eliminates native plant species of the ecosystem. It also reduces crop yield.

Prevention and Control: (i) The uprooting of seedlings reduces infestation. A light tillage of the affected land at the seedling stage controls the aggressive colonization of weed. (ii) It is susceptible to the selective application of a wide range of standard herbicides like picloram, butachlor, 2, 4-D, dicamba, diuron and terbutryne. (iii) Biological control by way of the introduction of seed bruchid *Sennius instabilis* seems promising. The fungal pathogens- *Pseudocercospora nigricans* and *Pseudoperonospora cassiae* with herbicidal effects also need to be employed.

Opuntia stricta (Haw.) Haw. var. *stricta*

Family: Cactaceae.

Common Name: Common prickly pear.

Native Range: South America.

Description: Erect or sprawling, succulent, perennial, shrub, 2-3 m, stem branched from base. Cladodes green to bluish-green, flattened, obovate, 10-25 cm by 7-10 cm., glabrous, areoles scattered bearing tiny glochids and spines. Spines yellowish, stout, curved, 2-4 cm long, arise from areoles. Leaves dark brown, about 5 mm long, slightly recurved, caducous. Flowers yellow, arise from the margins of cladodes, 5-6 cm in diam., epigynous, perianth 12, free, yellow, outside red or pinkish, stamens many, free. Fruit a berry, obovoid, succulent, 4-8 cm long, covered with glochids, deeply depressed at apex, reddish when ripe, purplish or reddish pulp containing several seeds.

Dispersal: The pulpy fruits are eaten and dispersed by birds and mammals. Clonal propagation occurs through dislodged cladodes.

Impact: It often forms dense stands in open lands, grasslands, fallow lands, wastelands in arid and semi-arid areas. Infestation increases pressure on pastures and grasslands besides negative effects on agriculture, forestry, animal husbandry, humans, biodiversity, aesthetics and recreation.

Prevention and Control: (i) It is difficult to control the weed through physical and even mechanical methods. Isolated plants are cleared physically. (ii) Many herbicides are effective against the weed but the treatment proves very costly. (ii) Biocontrol by involving insect pests like cactus moth *Cactoblastis cactorum* and the cochineal *Dactylopius opuntiae* need to be employed.

Alternanthera philoxeroides (Mart.) Griseb.

Family: Amaranthaceae.

Common Name: Alligator weed.

Native Range: Tropical America.

Description: A decumbent or ascending perennial herb, aquatic or terrestrial, stem cylindrical, branched, hollow, root from the nodes or float in water. Leaves simple, opposite, sessile, elliptical, 2-7 cm by 1-2 cm, glabrous, entire, acute or mucronate, base cuneate. Inflorescence terminal and axillary, almost round clusters, flowers imperfect, bracts and bracteoles subequal, sepals 5, subequal, oblong, white, petals lacking, stamens infertile. Fruit if present, an indehiscent utricle.

Dispersal: Propagates asexually through stem fragments in the absence of seed formation due to infertile stamens.

Impact: An invasive weed which grows in the moist agricultural fields, rice fields, marshes, irrigation channels, ditches and shallow slow moving water bodies, often forming dense mats and destroying habitat, and also reduces native species diversity, clogs water channels and reduction in crop yields.

Prevention and Control: It is difficult to control the weed from land due to extensive underground biomass. (i) Physical removal is both time consuming and expensive. (ii) An integrated management of weed involves both the physical and chemical control. It is susceptible to the standard broad leaved herbicides like 2, 4-D, picloram, glyphosate sprayed to control the terrestrial infestation.

Ricinus communis Linn.

Family: Euphorbiaceae.

Common Name: Castor bean.

Native Range: North-eastern Africa.

Description: Evergreen shrub, up to 5 m tall, glaucous, stem branched, hollow, non woody. Leaves simple, 15-50 cm long, alternate, long petiolate, stipulate, stipules 1-3 cm long, fused into a sheathing bud, caducous, lamina orbicular, membranous, palmately lobed, lobes 5-12, coarsely toothed, reddish-purple to bronze when young, with a reddish tinge when mature. Inflorescence a terminal panicle, cyathia unisexual, in lateral cymes, shortly pedicellate, calyx 3-5, fused, lobed, corolla lacking, male cyathia towards base with many branched stamens, female cyathia distal in position, tricarpeal syncarpous gynoeceum represents female cyathium, styles 3, reddish, ovary superior, softly spiny. Fruit an ellipsoid to sub-globose, dehiscent, brown, spiny, 1.5-2 cm long, seeds compressed, mottled, shining, with caruncle at the base.

Dispersal: Propagation takes place through seeds formed in large numbers and dispersed by birds, rats, water and humans.

Impact: An invasive weed which is generally seen in thick stands in grasslands, riparian land, disturbed land, field margins, fallow land and waste lands with negative impact on native species diversity. Seeds are highly poisonous due to the presence of ricin which is the most toxic naturally occurring substance.

Prevention and Control: (i) Physical removal of seedlings and young plants reduces infestation. (ii) Large plants require stump-treatment with herbicides such as glyphosate, picloram and 2, 4-D which are effective if applied before the fruit formation.

Hyptis suaveolens (L.) Poit.

Family: Lamiaceae.

Common Name: Bush Mint.

Native Range: Tropical America.

Description: An annual hairy herb, up to 1 m tall, strongly aromatic, stem furrowed. Leaves opposite, ovate, 2-10 cm. by 4-6 cm, pubescent, serrate. Flowers 2-5, in axillary racemes, corolla bilipped, middle lobe of lower lip tripartite, purplish-blue.

Impact: An invasive weed of open land, riparian land, grass land, forest land and roadsides where its populations often displace and reduce the native species diversity.

Prevention and Control: (i) The uprooting of seedlings reduces infestation. A light tillage of affected land at the seedling stage controls the aggressive colonization of weed. (ii) It is susceptible to the standard herbicides like picloram, butachlor, 2, 4-D, dicamba, diuron and terbutryne.

Conclusion

The severity of the invasion problem has grown tremendously as the global economy has reached into virtually all the corners of world. Due to the negative impacts on all nations the problem of invasive alien species requires a significant global response. The seriousness of the problem varies from region to region and states with major problem have realized too late, that a small investment of time and money on prevention, early detection and control would have saved a huge amount spend on failed attempts to eradicate and repair the badly disrupted ecological systems. The invasive alien species have naturally intruded into the area from adjoining parts of the union of India over the period of time. Majority of the invasive alien species have their origin in the countries of Tropical America besides Europe and Africa. Such alien species exploit highly evolved inherent capacities like more physiological adaptability, higher rates of reproduction, more efficient seed dispersal mechanisms, drought resistance, allelopathy and other chemical defense mechanisms in order to colonize and proliferate in the new ecosystems. All the reported invasive alien species have successfully colonized in almost all the districts of the study area with varying toxicity levels and ecological impacts on the organisms and environment leaving much more scope for further investigations. The invasive alien weeds seriously affect the native biodiversity and have contributed significantly to drag some of the native species of the area to a vulnerable state with serious threat of extinction from this face of the earth. Apart from the threat to biodiversity the negative impacts of such species on agriculture, horticulture, forestry and aquaculture threaten the food security of the people. Such species are also seriously affecting the human health and even endangering the life of the people. There has been a lack of co-ordinated and sustained efforts to control and eradicate them.

The co-ordinated efforts are required immediately to control and eradicate the invasive alien weeds so that the fragile biodiversity of the region is conserved and restored. The management of the invasive alien weeds requires serious collaborative efforts of several people. Some elements recommended in response to the growing challenge of invasive alien species are: (i) Build management capacity (ii) Promote sharing of information (iii) Build public awareness and engagement.

Conflict of interest: The author declares that there is no conflict of interest regarding the publication of this paper. All the contents of this article including observations, results and discussion, conclusion and figures are based on the original research work of the author.

Acknowledgements: The author is thankful to the Head, Department of Botany, University of Jammu for providing access to departmental herbarium and library, and also Director, Environment, Forest and Remote Sensing, Government of Jammu and Kashmir for providing required information and facilities during the course of research work.

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