International Journal of Biodiversity and Conservation Vol. 1(4) pp. 135-145 September, 2009
Available online http://www.academicjournals.org/ijbc

Full Length Research Paper

Impact of *Ageratum conyzoides* L. on the diversity and composition of vegetation in the Shivalik hills of Himachal Pradesh (Northwestern Himalaya), India

Kuldip S. Dogra[1], Ravinder K. Kohli[2], Sarvesh K. Sood[1] and Praveen K. Dobhal[2]

[1]Department of Biosciences, Himachal Pradesh University Summer Hill Shimla (India) – 171005.
[2]Department of Botany, Panjab University Chandigarh (India) – 160014.

Accepted 12 May, 2009

The flora of the Shivalik hills of Himachal Pradesh, India is under threat due to the rapid invasion of invasive species. Invasive species means an alien species, which becomes established in natural or semi-natural ecosystems and threatens native biological diversity. In their new regimes they show diverse life forms, habit, morphology, reproductive biology, grow fast, have the ability to grow under different habitats, produce enormous number of very small, light weight seeds that and can - survive in soil for years helping long distance dispersal and spread. They can out-compete native species, reduce wildlife habitat potential, alter natural ecosystem processes and limit overall biodiversity. *Ageratum conyzoides* is one such widely adaptive weed from sub-tropical America that has entered in the Shivalik hills of Hamrpur district of Himachal Pradesh. It has grown as monocultures, in grasslands, forests, agricultural, plantations and horticultural fields in Himachal Pradesh. Hence, it was decided to evaluate the impact *of A. conyzoides* on the diversity and floristic compositions of native species. It was found that as compared to control, in the Ageratum invaded area; the average number of plant species has reduced by 32.10%; the α diversity has reduced by 41.21% and the dry biomass of plants has also reduced significantly. It was concluded that invasion of *A. conyzoides* is drastically affecting the productivity and diversity of the invaded areas in Shivalik hills of Hamirpur district.

Key words: Invasive species, biological diversity, shivalik hills.

INTRODUCTION

The biota of the world is being homogenized as a result of the decline of native species and their replacement by a relatively small number of alien species that either deliberately or accidentally moves beyond their natural ranges (McKinney and Lockwood, 1999). These invasive alien species have encroached into many ecosystems and communities throughout the world, disrupting eco-system structure, function and reducing native biodiversity (Borgmann and Rodewald, 2005). These out-compete native species or occupy the available niches in alien environment (Cowie, 1998a; 1998b) and cause major economic loss in countries around the world, by decreasing growth and productivity of useful species (Pimentel et al., 2000).

Increase in the rate of invasion and deliberate intro-duction of aliens into an area by man is the by-product of the globalization of regional economics. Large parts of the world are currently dominated by human modified ecosystems that often comprise a greater biomass of introduced than native organisms (Vitousek et al., 1997). Besides human actions, several other factors contribute

*Corresponding author. Email: dograks6@yahoo.co.in; Mobile: + 91 09816740648

Figure 1. Photo of *Ageratum conyzoides* at flowering stage.

Figure 2. Monoculture of *Ageratum conyzoides* in Shivalik hills of Himachal Pradesh.

to successful invasion by alien plants. The climatic and edaphic similarities between the original and new habitats are very important factors for the establishment of alien species (Holdgate, 1986). Biological invasion are clearly a potent force of change, operating on a global scale and affecting many dimensions of society (Wilcove et al., 1998; Ohlemuller et al., 2006).

Ageratum conyzoides (Figure 1 & 2) is a native of tropical America. It has spreads world wide in the tropical and subtropical areas (Wagner et al., 1999). In India, it was introduced in 1860 as an ornamental plant (National Focal Point for APFISN, India, 2005). Later it escaped as a weed in various habitats throughout India. In Himachal Pradesh, the weed is established dominantly up to 1800

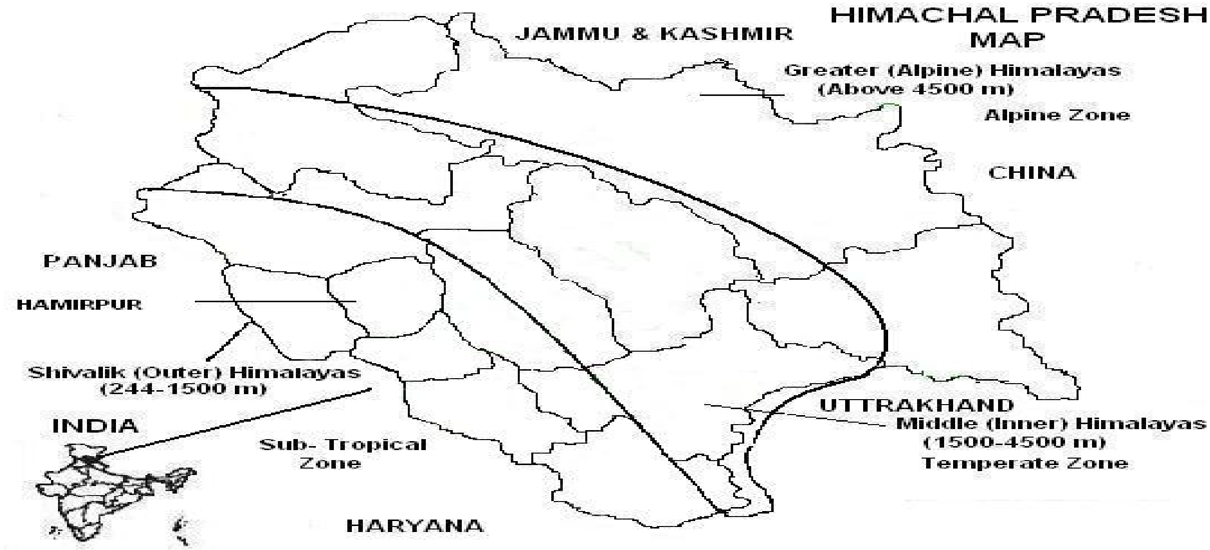

Figure 3. Map of Himachal Pradesh showing Hamirpur district.

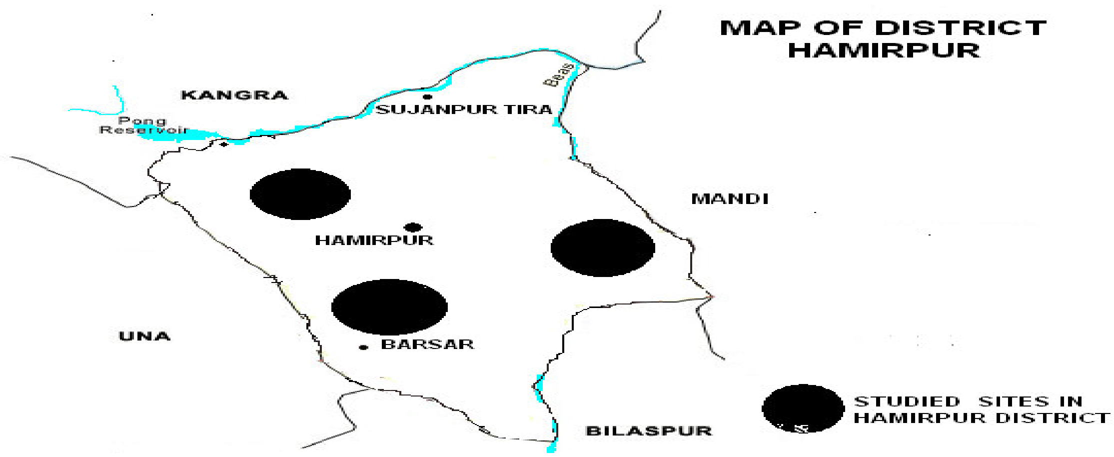

Figure 4. Map showing studied sites in Hamirpur district of Himachal Pradesh.

m. It is an annual aromatic herbaceous plant and gaining height up to 2 m in the Shivalik hills (Dogra, 2008; Dogra et al. 2009). It has a pubescent stem and ovate to ovate-rhomboid leaves. The plant has a purplish blue coloured inflorescence which produces an enormous number of seeds (*Cypsela*; more then 40,000 from a single plant). These seeds easily dispersed into wide areas in the hilly tracts of Shivalik hills by wind and water, which will help in their establishment in a wide range of climatic conditions (Kohli et al., 2006).

In Shivalik hills *A. conyzoides* L. has invaded predominantly in the grasslands, agricultural fields, forests, wastelands and in pastures. The invasion of bill goat weed created a pressure on the existence of useful medicinal plant species and as a result drastically affects the diversity and composition of vegetation in the Shivalik hills.

METHODOLOGY

Study Area

The lower Himalaya of Northwestern Indian state of Himachal Pradesh is also known as Shivalik hills (Figure 3). The Hamirpur district (area 1118 Km^2) is situated between 31°52' and 31°30' North latitude and 76°18' and 76°44' East longitude in the Shivalik hills of Himachal Pradesh (Figure 4). The altitude in Hamirpur district varies from 400 to 1100 m above mean sea level. The climate in the area is subtropical to mild warm temperate. The average rainfall in this area is about 1500 to 1800 mm. The minimum temperature in the Shivalik hills is 5°C in January (winter) and maximum in June up-to 40℃ (summer). The potential vegetation of the area is commonly includes tropical thorn forests, northern tropical dry forests, subtropical broad leaved forests and tropical pine forests (Balokhra, 1999).

Vegetational Analysis

Vegetation analysis was done by random-systematic design and gradsect methods (Barbour et al., 1999; Singh and Singh, 1992). Three sites invaded with *A. conyzoides* were selected at random in the Shivalik hills of Hamirpur district. A parallel control (non-invaded with *Ageratum*) was also selected to compare the species richness, diversity and composition of vegetation in the invaded and non-invaded areas. In each invaded and non-invaded site an area of 200 m^2 was selected and 20 quadrats of 2 m^2 were laid randomly in both areas. All the plant species appeared in the invaded and non-invaded areas sampled, identified and their importance value index was calculated (Mishra, 1968). Further, species richness, diversity, index of dominance, similarity, dissimilarity index and evenness of invaded and non invaded areas was calculated and compared to find out the loss due to invasion of *A. conyzoides*. A variety of indices are available but to avoid conceptual and technical problems and to get precision, only a few such as Margalef's richness, Hill's evenness, Shannon's diversity, Simpson's index of dominance are applicable (Ludwig and Reynolds (1988). The vegetation other than invasive species under study per square meter of the area from any 3 quadrats from each site was uprooted and their fresh and dry biomass (after oven drying) measured.

To study the impact of *A. conyzoides* on other plant species a vegetational analysis was done during October 2006 to March 2007.

The plants were identified with the help of herbaria of the Department of Botany, Punjab University Chandigarh and YSP University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. Confirmation of names was done by comparing with herbaria specimens maintained in Punjab University, Department of Botany; Forest Research Institute, Dehradun; Botanical Survey of India, Dehradun. The plants were categorized according to their habits like tree, shrub, herb, sedges, climber and vine.

Soil Analysis

The changes in phenolics, soil pH, electric conductivity, amount of organic carbon, organic matter, available nutrients e.g. nitrogen (N), phosphorus (P), potassium (K), sodium (Na), calcium (Ca), magnesium (Mg) and chloride (Cl) were compared between the *A. conyzoides* invaded habitats with their respective controls (weed free areas). The soils were collected from the *A. conyzoides* invaded habitats and from their respective controls. They were collected after removing litter from the top surface layer (4 - 6 cm) in each habitat. The sample of the soils were sieved, shade dried and stored for further use.

The pH and electric conductivity of the soil was measured after preparing a soil extract in the ratio of 1:2, soil: water (w/v) by using EcoScan digital pH meter and EcoScan Con 5 digital conductivity meter respectively. The phenolic content of the soils was estimated by the method of Swain and Hillis (1959) using Folin- ciocalteu reagent. Organic carbon and organic matter were estimated by the rapid titration method of Walkey and Black (1934). Available N was estimated using alkaline potassium permanganate as per the method of AOAC (1960). Available P was determined by the method of Olsen et al. (1954). Available Na and K were estimated using ammonium acetate as per Bower and Gschwend (1952). The available Ca, Mg and Cl were determined by the methods given by Black (1973).

Statistics Analysis

For each experiment, statistical analysis was done using software programmes like SPSS ver. 10.0, Origin 6 and Micorstat. For determining the significance of a single treatment with control (paired treatment), student's 2 sample *t*-test was applied. Significance of difference between soil characteristics of control and weed invaded sites was determined using 2 sample *t*-test at $P < 0.05$ or $P < 0.01$.

RESULTS

Impact of *A. conyzoides* on the plant diversity

Invasion of *Ageratum conyzoides* drastically affected the diversity and composition of vegetation in the Shivalik hills of Himachal Pradesh. As per the survey conducted during present study there were 81 species found in the control or un-invaded area as compared to 55 in *Ageratum* invaded area (Table 1). The number of species decreased by 32.10% in the *Ageratum* invaded area as compared to control. Further, Margalef's index of species richness, alpha species diversity and evenness index were reduced by 37.01, 41.21 and 15.48%, respectively in the *Ageratum* invaded areas. Likewise, the number of abundant species (N_1) and very abundant species (N_2) were also in the *Ageratum* invaded areas. The higher value of index of dominance in the invaded areas predicts that communities were homogenous in nature and dominated by a single species. On the other hand communities were showing more heterogeneity in the un-invaded areas. The similarity index of the communities in the invaded and un-invaded areas was only 52.12%, which shows clear indication of loss of species due to invasion of *Ageratum*. The comparison between fresh and dry biomass of invaded and un-invaded areas also show significant change as these decreased by 52.12 and 47.88%, respectively in the invaded areas.

Impact of *Ageratum* invasion on the floristic composition

The floristic composition describes the pattern of distribution of species in any particular habitat. *Ageratum* invasion heavily disturbs the composition and structure of species in the invaded habitats. In the present study floristic composition between *Ageratum* invaded and un-invaded areas was compared. A total of 94 plant species belonging to 37 families of flowering plants were collected during the present study. The number of plant families was 35 in the control area in contrast to only 25 in the *Ageratum* invaded areas. Among 94 plant species, 42 species were found common in control and invaded areas (Table, 2,). Thirty nine species [*A. scandens*, *A. viridis*, *A. arvensis*, *A. scoparia*, *A. vulgaris*, *B. paniculata*, *C. asiatica*, *C. ambrosioides*, *C. indica*, *C. arvense*, *D.*

Table 1. Impact of *Ageratum conyzoides* invasion on the plant diversity and biomass.

S.N.	Parameters	Control	Invaded	% decrease over control
1	Total Species	81	55	(–) 32.10
2	Average Fresh Biomass (g/m^2)	612.83 ± 36.01	372.68 ± 40.41	(–) 39.19
3	Average Dry Biomass (g/m^2)	449.26 ± 19.97	231.54 ± 17.08	(–) 48.46
4	Margalef Index of Richness (R_1)	6.29 ± 0.46	3.96 ± 0.50	(–) 37.04
5	Simpson's Index of Dominance (λ)	0.06 ± 0.03	0.15 ± 0.004	(+) 60.00
6	Shannon's Index of Diversity (H')	3.81 ± 0.31	2.24 ± 0.24	(–) 41.21
7	Diversity Number (N_1)	20.97 ± 0.97	10.30 ± 0.85	(–) 50.88
8	Diversity Number (N_2)	14.29 ± 1.30	6.09 ± 0.15	(–) 57.38
9	Index of Evenness (Es)	0.84 ± 0.01	0.71 ± 0.002	(–) 15.48
10	Similarity Index	52.12 ± 7.64		
11	Dissimilarity Index	47.88 ± 7.64		

All values significant at 5% significance level after applying two population *t* test; (–) show less value and (+) show high value in invaded site.

sissoo, *D. indica*, *D. viscosa*, *E. alba*, *E. microphylla*, *F. indica*, *G. indicum*, *G. optiva*, *I. carnea*, *I. pentaphylla*, *I. quamoclit*, *L. esculentum*, *M. lupulina*, *N. linearis*, *P. minima*, *P. annua*, *P. arillata*, *P. plebium*, *R. arvensis*, *R. capitata*, *R. hastatus*, *S. officinalis*, *S. candicans*, *S. orientale*, *S. media*, *T. bartramia*, *U. labota*, *V. hirsute* and *V. tetrasperma*] were found absent in the *Ageratum* invaded areas. Thirteen plant species (*B. wightiana*, *B. diffusa*, *C. bursa-pastoris*, *C. arvense*, *D. repens*, *I. nil*, *L. stivus*, *L. cephalotus*, *M. alba*, *R. dentatus*, *S. nigrum, T. emodi*) were growing only in the *Ageratum* invaded areas.

A. conyzoides was found to be a major plant species in the invaded area besides *C. dactylon*, *D. annulatum*, *T. repens*, *B. pilosa*, *S. glauca* and *C. carandas*; while *M. koenigii* was well established plant species in the control areas along with *C. dactylon*, *D. annulatum, B. pilosa, C. carandas, A. vasica*, *A. aspera,* and *T. repens*.

The number of herbal species was quite high as compared to other life forms in both types of areas. But the number of herbs decreased sharply as compared to other life forms in the invaded areas. It significantly shows that herbal vegetation was affected maximally as compared to other type of vegetative (Table 2). The species sequence of commonly found species in both type of areas plotted in the decreasing order of their IVI values shows that the species become less stable in the *Ageratum* invaded areas (Figure 5).

Major medicinal plants in the control areas were *M. koenigii, D. annulatum, C. dactylon, T. repens, A. aspera, A. vasica* and *C. carandas* (Figure 6). These were the most affected medicinal plants due to the invasion of *A. conyzoides*. The IVI values of these species were found very less in the invaded areas as compared to un-invaded areas. The IVI of *M. koenigii* and *A. vasica* in the control area was 9.89 and 4.47%, respectively; and both the species were not recorded in the top 10 plants in the invaded areas. The IVI of *C. dactylon* was reduced by 42.34% in the invaded area. *Dichanthium annulatum* and *C. carandas* had 59.67 and 63.88% less IVI in the invaded area. The IVI of *A. aspera* was reduced by 53.08%. Further, species sequence of commonly found species in both type of areas plotted in the decreasing order of their IVI values shows that the species become less stable in the *Ageratum* invaded areas (Figure 7).

Impact on soil nutrients

The amount of phenolic in the soil of *A. conyzoides* invaded area was 40.90% more as compared to the control area (Table 3). The pH in the control and invaded soil was near neutral; in the control area it was slightly less whereas in *A. conyzoides* invaded area it was slightly more than 7. The conductivity of the ions was 31.20% more in the *A. conyzoides* invaded area as compared to control. Percent organic carbon and organic matter also increased in the invaded area by nearly 49%. The increase in the available nitrogen content was highest among all other nutrients. It increased by 56.85% in the invaded area. The amount of available phosphorus, potassium and sodium were more by 47.51, 37.91 and 25.29% respectively in the *A. conyzoides* invaded soil as compared to the control soil. Similarly, the amount of available calcium, magnesium and chloride also increased in the *A. conyzoides* invaded soils. The increase was 37.48, 31.54 and 32.67% respectively in the invaded soil as compared to the control soil.

DISCUSSION AND CONCLUSION

Being primary producers, the plants are the major components of the ecosystem. So, it is very important to

Table 2. Floristic composition of the vegetation in the control and *A. conyzoides* invaded areas (alphabetical order).
Total species = 94; Total species in control site = 81.
Total species in invaded site = 55; Common species = 42.

Name Of Plants	Control	Invaded
Achyranthes aspera L.	+	+
Adhatoda vasica Nees	+	+
Aerva scandens L.	+	-
Ageratum conyziodes L.	-	+
Ajuga bracteosa Wall. ex Benth.	+	+
Amaranthus viridis L.	+	-
Anagallis arvensis L.	+	-
Anisomeles indica (L.) Kunt.	+	+
Argemone mexicana L.	+	+
Artemisia scoparia Waldst and Kit.	+	-
Artemisia vulgaris L.	+	-
Asparagus facemasks Willd.	+	+
Bidens pilosa L.	+	+
Blumea membranacea DC.	+	+
Blumea wightiana DC.	-	+
Boerhavia diffusa L.	-	+
Buddleia paniculata L.	+	-
Cannabis sativa L.	+	+
Capsella bursa-pastoris (L.) Medic.	-	+
Carissa carandas L.	+	+
Cassia angustifolia L.	+	+
Cassia occidentalis L.	+	+
Cassia tora L.	+	+
Centella asiatica L. Urb.	+	-
Chenopodium ambrosioides L.	+	-
Cirsium arvensis (L.) Scop.	-	+
Cocculus indica L.	+	-
Convolvulus arvensis L.	+	-
Cynodon dactylon (L.) Pers.	+	+
Dalbergia sissoo Roxb.	+	-
Datura stramonium L.	+	+
Dichanthium annulatum (Forssk.) Stapf.	+	+
Dillenia indica L.	+	-
Dodonaea viscosa (L.) Jacq.	+	-
Duchesnea indica (Andr.) Focke	+	+
Duranta repens L.	-	+
Eclipta alba L.	+	-
Euphorbia granulates L.	+	+
Euphorbia hirta L.	+	+
Euphorbia microphylla B. Heyne ex Roth	+	-
Flacourtia ramontchi L. Herit	+	+
Fumaria indica (Hausskn.) Pugsley	+	-
Gnaphalium indicum L.	+	-
Grewia optiva Drumm. ex Burret	+	-
Indigofera trifoliata L.	+	+
Ipomoea carnea Jacq.	+	-
Ipomoea nil (L.) Roth.	-	+

Table 2 contd.

Ipomoea pentaphylla Cav.	+	-
Ipomoea quamoclit L.	+	-
Lantana camara L.	+	+
Lathyrus sativus L.	-	+
Launaea fallax (Jaub. and Spach) Kunt.	+	+
Leucas cephalotes Spreng.	-	+
Lycopersicon esculentum Mill.	+	-
Mallotus philippensis (Lam.) Muell.-Arg.	+	+
Malvastrum coromandelianum (L.) Garcke	+	+
Medicago lupulina L.	+	-
Mimosa pudica L.	+	+
Morus alba L.	-	+
Murraya koenigii (L.) Spreng.	+	+
Nepeta linearis Royle ex Benth.	+	-
Oxalis corniculata L.	+	+
Parthenium hysterophorus L.	+	+
Phyllanthus amarus Schumach and Thonn	+	+
Physalis minima L.	+	-
Poa annua L.	+	-
Polygala arillata Buch.-Ham ex D. Don	+	-
Polygonum plebium R. Br.	+	-
Ranunculus arvensis L.	+	-
Rhynchosia capitata (Roth.) DC.	+	-
Rubus ellipticus Sm.	+	+
Rumex dentatus L.	-	+
Rumex hastatus D. Don	+	-
Salvia officinalis L.	+	-
Salvia plebeia R. Br.	+	+
Saussurea candicans C.B. Cl.	+	-
Sesamum orientale L.	+	-
Setaria glauca (L.) Beauv.	+	+
Sida cordifolia L.	+	+
Solanum indicum L.	+	+
Solanum nigrum L.	-	+
Sonchus oleraceus L.	+	+
Stellaria media (L.) Cirillo	+	-
Trichodesma indicum L. Sm.	+	+
Tridax procumbens L.	+	+
Trifolium repens L.	+	+
Trigonella emodi Benth.	-	+
Triumfetta bartramia L.	+	-
Urena labota L.	+	-
Vernonia cinerea L. Less	+	+
Vicia hirsuta (L.) S.f. Gray.	+	-
Vicia tetrasperma L. Schreb.	+	-
Xanthium strumarium (Mill.) Torrey and A. Gray	+	+
Ziziphus jujuba Mill.	+	+

save the plant kingdom from various threats to sustain all other living beings. The higher loss in case of the plants growing in invaded areas shows that they become less productive in comparison with the plants in the control

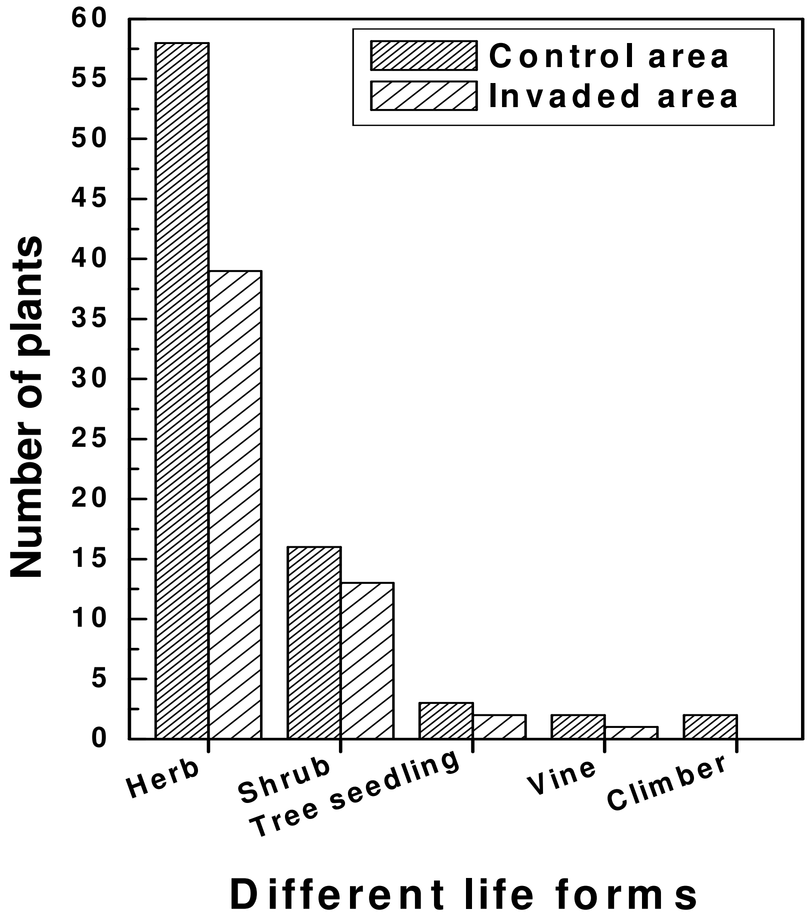

Figure 5. Comparison of different forms of plants in control and *Ageratum* invaded areas.

area. Biomass is directly related to the productivity of the plant species as they lose their normal physiological functions because of the interference by the invading species. The pressure created by the invasive species in the invaded habitats disturbs the functions of biological communities and reduce the diversity of species and dependent fauna (Kinzig et al., 2001). To respond effectively to the invasive species problems, quantitative measurements of the impact of invasion on diversity are required (Schooler et al. (2006).

Ageratum conyzoides has become a very strong invader in the Shivalik hills in Himachal Pradesh and it has increased its density and abundance in the invaded habitats as a result posing a threat to the extinction of native species. An increasing abundance of the invaders can decrease the diversity of species (Kercher and Zedler, 2004). Much effort has been put into identifying determinants constraining broad-scale variability in species richness (Francis and Currie, 2003; Rahbek, 2005). It is apparent that the factors influencing patterns of species richness vary with the geographical extent and sample resolution (Willis and Whittaker, 2002). Therefore, only by multiple analyses scales for different locations and at various spatial scales general explanations of broadscale species richness, diversity and distribution patterns can be derived (Zhao and Fang, 2006).

It's concluded from the studies that *A. conyzoides* is a strong invader in these areas and its increased abundance, cover and density poses a threat to the native species which also include medicinally important species. The decrease rate of biomass and various ecological indices (∝-diversity, abundant species, Margalef's index etc.) in the *Ageratum* invaded habitats clearly signifies that these become less productive and stable as compared to non-invaded habitats. There were some species which totally lost in the invaded areas while some other species preferred to grow there. The absence of seedlings of tree species like *Dalbergia sissoo* and *Acacia catechu* in the invaded areas showed that it inhibited their seedling growth. Thus, *Ageratum cony-*

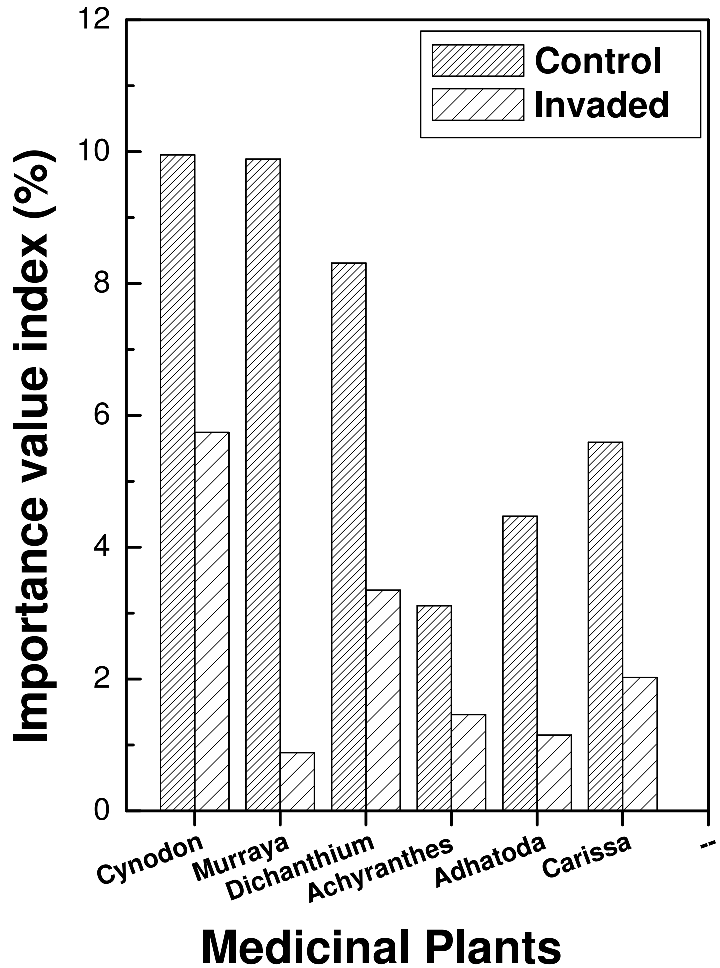

Figure 6. Impact of *A. conyzoides* on the IVI (%) of some medicinal plant species. All values are significant at 5% significance level after applying two population *t*-tests.

zoides directly alters the growth of other plant species by forming its own monocultures.

The invasion of *Ageratum conyzoides* also alters the physico-chemical properties of soils in the invaded areas. The soils in the invaded areas become nutrient rich which generally help in the growth of invasive species. It was clear from the results that the values of all soil nutrients found to be higher in the *Ageratum* invaded areas as compared to control. Minimum change was observed in case of pH compared to other parameters. Likewise, the phenolics- a well known group of allelochemical- were found to be more in weed-invaded soil as compared to the control soil. These phenolics are released from the plant part through various mechanisms such as leachation from above ground parts, root exudation, volatilization or microbial degradation. These allelochemicals besides imparting the plant allelopathic property also regulate the biotic communities of soil and alter the physical and chemical properties of soil (Nardi et al., 2000). Many studies suggest that allelopathy may contribute to the ability of particular alien species to become dominant in the native plant communities (Abdul-Wahab and Rice, 1967; Vaughn and Berhow, 1999; Ridenour and Callaway, 2001). Several aggressive weeds exhibit the phenomenon of allelopathy as a mechanism of interference which provides them competitive advantage over other plants.

El-Ghareeb (1991) studied the allelopathic effect of the invasive plant *Tribulus terrestris* on surrounding vegetation in an abandoned field of Kuwait. His study demonstrated that besides the growth inhibitory effect of plant on other plants, the soil moisture and concentration of N, P and K were significantly higher in *T. terrestris* site. In the present study too the amounts of available nutrients were significantly more in weed-invaded soils as compared to the weed free soils. Abundant evidences support the idea that higher resource availability increases the susceptibility to invasion of plant commu-

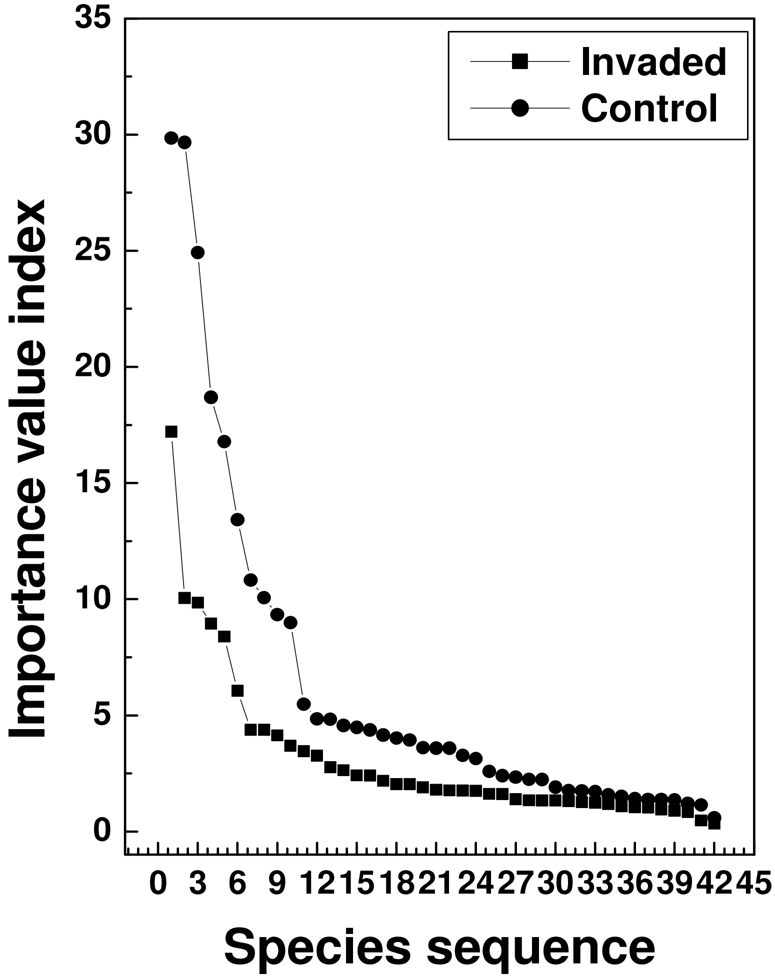

Figure 7. Distribution of common species in control and *Ageratum* invaded sites (decreasing order of Importance Value Index).

Table 3. Comparison of selected physico-chemical properties of soil collected from areas invaded by *A. conyzoides* or free from it (control).

S.N.	Parameters	Control	Invaded
1	Phenolics (ìg/100 g soil)	12.33 ± 1.05	20.88 ± 1.53**
2	pH	6.78 ± 0.01	7.09 ± 0.01**
3	EC (ìS)	129.66 ± 1.72	188.47 ± 3.35**
4	Organic Carbon (%)	0.49 ± 0.02	0.96 ± 0.06**
5	Organic Matter (%)	0.84 ± 0.03	1.66 ± 0.11**
6	N (kg/ha)	92.09 ± 3.40	213.40 ± 7.26**
7	P (ppm)	64.53 ± 3.18	122.95 ± 2.05**
8	K (ppm)	88.39 ± 4.08	142.35 ± 3.09**
9	Na (ppm)	39.29 ± 3.55	52.59 ± 4.06**
10	Ca (g/100g)	4.17± 0.28	6.67 ± 0.28**
11	Mg (g/100g)	2.17 ± 0.29	3.17 ± 0.28**
12	Cl (g/100g)	3.40 ± 0.20	5.05 ± 0.20**

** means significant from control at $P < 0.01$ after applying student *t*- test.

nities (Burke and Grim, 1996; Maron and Connor, 1996).

Further, the absorption of phenolics - the allelopathic compounds- by soil particles and their microbial breakdown and may account for the outcome of present observations (Dalton, 1999; Huang et al., 1999; Wardle et al., 1998) which are further affected by various soil factors such as soil texture, organic carbon and organic matter etc. (Kobayashi, 2004).

The reason why some invasive plants are so successful in new environments may be that they bring novel mechanisms of interactions with the recipient community. However, Dietz et al. (1996) concluded that factors other than allelopathy might be operating in nature that favours rapid establishment and persistence of dense stands of alien species.

REFERENCES

Abdul-Wahab AS , Rice EL (1967). Plant inhibition by Johnson grass and its possible significance in old-field succession. Bull Torr. Bot. Club, 94: 486-497.

AOAC (1960). Association of Official Agricultural Chemist. Methods and Analysis. AOAC, Washington, DC

Balokhra JM (1999). The Wonderland of Himachal Pradesh. Rev. and Enl. 4th Ed. H.G. Publications, New Delhi.

Barbour MG, Burk JH, Pitts WD, Gilliam FS, Schwartz MW (1999). Terrestrial Plant Ecology. 3rd Edition. Addison Wesely Longman Inc., Menlo Park, California.

Black CA (1973). Soil Plant Relationships. 2nd Ed. Scientific Publishers, Jodhpur.

Borgmann KL, Rodewald AD (2005). Forest restoration in urbanizing landscapes: Interactions between land uses and exotic shrubs. Restor. Ecol., 13(2): 334-340.

Bower CA , Gschwend FB (1952). Exchangeable cation analysis of saline and alkali soils. Soil Sci., 73: 251-261.

Burke MJW , Grime JP (1996). An experimental study of plant community invasibility. Ecol., 77: 776-790.

Cowie RH (1998*a*). Patterns of introduction of non-indigenous non marine snails and slugs in the Hawaiian Islands. Biodivers. Conserv., 7: 349-368.

Cowie RH (1998*b*). Homogenisation of Pacific Island snails. World Conservation; Quarterly Bulletin IUCN-The World Conservatin Union, 4/97-1/98: 18.

Dalton BR (1999). The occurrence and behavior of plant phenolic acids in soil environment and their potential involvement in allelochemical interference interactions: Methodological limitations in establishing conclusive proof of allelopathy. In: Principles and Practices in Plant Ecology: Allelochemical Interactions (Eds. Inderjit S, Dakshini, KMM , Foy CL) CRC Press, Boca Raton, FL, pp: 57-74.

Dietz H, Steinlein T, Winterhalter P , Ullmann I (1996). Role of allelopathy as a possible factor associated with the rising of dominance of *Bunias orientalis* L. (Brassicaceae) in some native plant assemblages. J. Chem. Ecol., 22: 1797-1811.

Dogra KS (2008). Impact of Some Invasive Species on the Structure and Composition of Natural Vegetation of Himachal Pradesh. Ph.D. thesis, Panjab University, Chandigarh, India.

Dogra KS, Kohli RK, Sood SK (2009). An assessment and impact of three invasive species in the Shivalik hills of Himachal Pradesh, India. Inter. J. Biodivers. Conserv. 1(1): 004 - 0010.

El-Ghareeb RM (1991). Suppression of annuals by *Tribulus terrestris* in an abandoned field in the sandy desert of Kuwait. J. Veg. Sci., 2: 147-154.

Holdgate MW (1986). Summary and Conclusions: Characteristics and Consequences of Biological Invasions. Philosophical Transactions of the Royle Society, London.

Huang PM, Wang MC, Wang MK (1999). Catalytic transformation of phenolic compounds in the soil. In: Principles and Practices in Plant Ecology*:* Allelochemical Interactions (Eds. Inderjit S, Dakshini KMM , Foy CL). CRC Press, Boca Raton, FL, pp: 287-306.

Kercher SM, Zedler JB (2004). Multiple disturbances accelerate invasion of reed canary grass (*Phalaris arundinacea* L.) in a mesocosm study. Oecologia, 138: 455-464.

Kinzig AP, Pacala SW, Tilman D (2001). The Functional Consequences of Biodiversity. Princeton University Press, Princeton, NJ.

Kobayashi K (2004). Factors affecting phytotoxic activity of allelochemicals in soil. Weed Biol. Manage., 4: 1-7.

Kohli RK, Batish DR, Singh HP, Dogra KS (2006). Status, invasiveness and environmental threats of three tropical American invasive weeds (*Parthenium hysterophorus* L., *Ageratum conyzoides* L., *Lantana camara* L.) in India. Biol. Invasions, 8: 1501-1510.

Ludwig JA, Reynolds JF (1988). Statistical Ecology- A Primer on Methods and Computing. John Wiley and Sons, New York, pp: 337.

Maron JL, Connor PG (1996). A native nitrogen-fixing shrub facilitates weed invasion. Oecologia, 105: 302-312.

McKinney ML, Lockwood JL (1999). Biotic homogenization: A few winners replacing many losers in the next mass extinction. Trends Ecol. Evol., 14: 450-453.

Mishra R (1968). Ecology Work Book. Oxford and IBH Company, New Delhi, India, pp. 244.

Nardi S, Concheri G, Pizzeghello D, Sturaro A, Rella R , Parvoli G (2000). Soil organic matter mobilization by root exudates. Chemosphere, 5: 653-658.

National Focal Point for APFISN, India (2005). Stocktaking of National Forest Invasive Species Activitis, India (India Country Report 101005). New Delhi, India: Ministry of Environment and Forests.

Ohlemuller R, Walker S, Wilson JB (2006). Local vs regional factors as determinants of the invisibility of indigenous forest fragments by alien plant species. Oikos, 112: 493-501.

Olson SR, Cole CV, Watanabe FS, Dean LA (1954). Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circular 939: 1-19.

Pimentel D, Lach L, Zuniga R , Morrison D (2000). Environmental and economic costs of non indigenous species in the United States. Biosciences 50: 53-65.

Ridenour WM, Callaway RM (2001). The relative importance of allelopathy in interference: The effects of an invasive weed on a native bunchgrass. Oecologia, 126: 444-450.

Schooler SS, McEvoy PB, Coombs EM (2006). Negative per capita effects of purple loosestrife and reed canary grass on plant diversity of wetland communities. Diversity Distrib., 12: 351-363.

Singh JS, Singh SP (1992). Forests of Himalaya, Structure, Functioning and Impact of Man. Gyanodaya Prakashan, Nainital, India.

Swain T, Hills WE (1959) The phenolic constituents of *Prunus domestica* I. The qualitative analysis of constituents. J. Sci. Food Agric., 10: 63-68.

Vaughn SF, Berhow MA (1999). Allelochemicals isolated from tissues of the invasive weed garlic mustard (*Alliaria petiolata*). J. Chem. Ecol., 25: 2495-2504.

Vitousek PM, Mooney HA, Lubchenco J, Melillo JM (1997). Human domination of earth's ecosystems. Science, 277: 494-499.

Walkley A, Black IA (1934). An examination of the Ditjareff method for determining soil organic matter and a proposed modification of chromic acid titration method. Soil Sci., 37: 28-38.

Wardle DA, Barker GM, Bonner KI, Nicholson KS (1998). Can comparative approaches based on plant ecophysiological traits predict the nature of biotic interactions and individual plant species effects. J. Ecol. 86: 405-420.

Wilcove DS, Rothstein D, Dobow J, Phillips A, Losos E (1998). Quantifying threats to imperiled species in the US. Biosciences, 48: 607-615.

Willis KJ, Whittaker RJ (2002). Species diversity-scale matters. Science, 295: 1245-1248.

Zhao S, Fang J (2006). Patterns of species richness for vascular plants in China's nature reserves. Diversity Distrib., 12: 364-372.