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Full Length Research Paper

An assessment and impact of three invasive species in the Shivalik hills of Himachal Pradesh, India

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The Shivalik hills in Northwestern Himalayan range of India have a rich floral diversity. Unfortunately during the last two decades there has been drastic reduction in the diversity of the natural vegetation. The available niches have been occupied by invasive exotic species that were either introduced or have entered accidently. It has resulted from a numbers of factors including increased inter and intra-continental links, import-export and climate change. These exotic species possess certain traits that provide them competitive advantage over the natives and thus aid in their fast spread in the alien environment. Even some of the plants introduced for beneficial purposes have acquired weedy habit. It has greatly altered the structure of the natural ecosystems and caused a dramatic shift in the diversity and dynamics of native flora. The situation has further aggravated due to lack of awareness, insufficient information on the species and its dimensions of the spread besides wide ecological amplitude. It was observed that the diversity, evenness and richness of the native species were drastically reduced in the forest invaded by the exotics.

Key words: Northwestern Himalayan, Shivalik hills, invasive, diversity.

INTRODUCTION

Invasive plant species alter native community composition, deplete species diversity, affect ecosystem process and thus cause huge economic and ecological imbalance. These plants possess a set of remarkable traits that allow them to colonize huge areas upon invasion. Studies of invasive species introductions in the past revealed that the impacts of their invasion are complex and can permanently alter the structure and function of communities, cause local extinctions and changes in ecosystem processes. The increased incidence of invasion around the world poses a major threat to indigenous biological diversity (Preisser et al., 2008).

Plants being the determinants of the casual/opportunistic/dependent consumers at the primary, secondary or tertiary levels (Hobbs and Huenneke, 1992) thus hold a great promise in population are an organized unit with a typical floristic composition and morphological structure which have resulted from the interaction of species populations through time. The distribution of species depends upon several factors directly related to phenotypic plasticity, genotypic adaptability and competitive, reproductive and tolerance capacity of the species (Sharma, 1986). Ecological distribution and floristic studies of vegetation have become very important due to the growing threat of invasions to different ecosystems (Kikvidze et al., 2005; Lesica et al., 2006).

Maheshwari, 1960 and Nayar, 1977 estimate that aliens constitute nearly 40 and 18% of the Indian flora of which 55% is American, 10% Asian, 20% Asian and Malaysian and 15% European and Central Asian species. Apart from these workers, few more studies have compiled the exotic flora of different regions of India (Sharma and Pandey, 1984; Pandey and Parmer, 1994; Nagar et al., 2004). However, recent studies conducted by Dogra (2007) estimated more than 40% species of Himachal Pradesh are exotics. Out of these, majority of the exotic species are native to American continent followed by Eurasia, Europe, Asia, Africa and Australia. Although large number of exotics have become naturalized in India and have affected the distribution of native flora to some extent, only a few have conspicuously altered the

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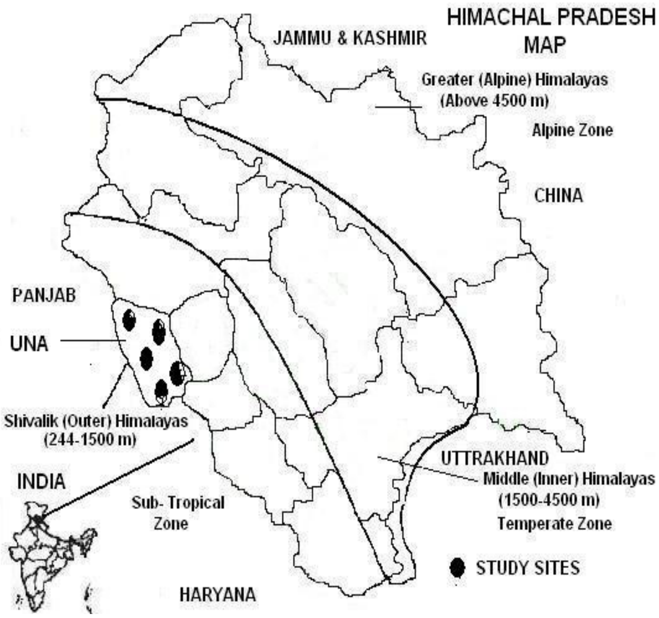

Figure 1. Map of Himachal Pradesh showing study sites in Una district in lower Shivalik hills.

vegetation patterns of the country.

Cytisus scoparius, Eupatorium odorataum, Eupatorium adenophorum, Lantana camara, Mikania micrantha, Tagetes minuta, Ageratum conyzoides, Mimosa invisa, Parthenium hysterophorus and Prosopis juliflora among terrestrial exotics and *Eichhornia crassipes* and *Pistia stratiotes* among aquatics have posed serious threat to the native flora (Sharma et al., 2005; Kohli et al., 2004).

Ageratum conyzoides, Lantana camara, Parthenium hysterophorus, Ricines communis, Eupatorium odoratum, Artemisia scoparia, Datura stramonium, Chenopodium ambrosioides, Cassia occidentalis and *Bidens pilosa* were highly established invasive plant species in the Shivalik hills. Among these in, *Ageratum conyzoides, Lantana camara, Parthenium hysterophorus* created a threat to the establishment of other plant species (Kohli et al., 2004). So, present work was carried out to find the intensity of invasion (dominance, density, abundance, frequency and importance value index) of these three invasive species in lower Shivalik hills and to understand the impact of invasive plants on the structure and composition of other species.

WORK METHODOLGY

Study site (Shivalik hills of Himachal Pradesh)

Himachal Pradesh is situated in the **northwestern** Himalayas of India between latitudes 30°22'44″N - 33°12'40″N and longitude 75° 45'55″E - 79°04'20″E with an area of 55, 673 km^2. The altitude of the state varies from 244 - 6791 m from the mean sea level (msl). Himachal Pradesh is divided into 3 regions, that is, lower or outer Himalayas, middle or inner Himalayas and upper or greater Himalayas. This range of outer (lower) Himalayas is well known as 'Shivalik hills' (also known as *Manak Parbat* in ancient times). Shivalik literally means 'tresses of the Shiva'. It covers the lower hills of district Kangra, Hamirpur, Una, Bilaspur and lower parts of Mandi, Solan and Sirmaur districts. The altitude of this zone varies from 244 to 1500 m above mean sea level (Balokhra, 1999).

Climate

The climate in the area is subtropical to mild warm temperate. The year in Shivalik hills is divided into three seasons, that is, winter from October to February, summer from March to June and rainy from July to September (Balokhra, 1999). The average rainfall in this area is about 1500 - 1800 mm. The minimum temperature in the Shivalik hills is 5°C in January (winter) and maximum in June up to 40°C (summer).

Vegetation analysis

Vegetation analysis was done by random-systematic design and gradsect methods (Barbour et al., 1999; Singh and Singh, 1992). Five sites invaded with each weed were selected at random in the lower Shivalik hills of Una district (Figure 1) within a radius of approximately 25 km. A parallel control (non-invaded with invasive plants) was also selected to compare the species richness, diversity and composition of vegetation in the invaded and non-invaded areas. In each invasive plant invaded and non-invaded site (control) an area of 200 m^2 was selected and 50 quadrats of 1 m^2 were laid randomly. All the plant species appeared in the invaded and non-invaded areas sampled, identified and their various ecological indices (abundance, frequency, density, dominance and importance value index) were 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, P. hysterophorus* and *L. camara*. The vegetation from invaded and non-invaded areas of any 5 quadrats (per square meter) each was uprooted and their fresh and dry biomass (after oven drying 80°C for 36 h) measured.

The plants were identified with the help of herbaria of the Department of Botany, Panjab 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 Panjab University, Department of Botany; FRI, Dehradun; BSI, Dehradun and other floras like Polunin and Stainton, (1984); Chowdhary and Wadhwa, (1984) and Chauhan (1999. The plants were categorized according to their habits like tree, shrub, herb, sedges, climber and vine.

Methods used for calculation of ecological indices

$$\text{Density (per square meters)} = \frac{H/I}{A}$$

Where: H = Total no. of individuals of a species in all the quadrats.
I = Total quadrats studied.
A = Area of the quadrat.

Abundance = H/J

Where: H = Total no. of individuals of a species in all the quadrats.
J = No. of quadrats in which the species occurred.

Frequency = J/I x 100

Where: J = No. of quadrats in which the species occurred.
I = Total quadrats studied.

Basal area (B) = πr^2

Where: π = 3.14.
r = Radius.

Dominance = B $\times$ Density

Where: B = Basal area.

Importance vale index (IVI) = Rden + Rfr + Rdom

(Mishra, 1968)
where: Rden = Relative density.
Rfr = Relative frequency.
Rdom = Relative dominance.

Various diversity indices of species richness, evenness and dominance were calculated as per the method given by Ludwig and Reynolds (1988)

Margalef's index of richness (R) = R_1: S–1/ in (n)

(Margalef, 1958)
where S = The total number of species in a community.
n= Total number of individuals a species.

Simpson's Index (λ) = $\Sigma_{i=1}^{s} Pi^2$ = (n_i/N)

(Simpson, 1949)

where Pi is the proportional abundance of the *i*th species.
N*i* = Number of individual of the *i*th species.
N = Total number of individuals of all species in the population.

Shannon's Index or α diversity (H′) = H′ = $-\Sigma_{i=1}^{s} (p_i \log_2 p_i)$

or H′ = $-\Sigma_{i=1}^{s} (n_i/n) \log_2 (n_i/n)$

(Shannon and Weaver, 1963)
where: H′ = Shannon's diversity index.
p_i = Proportion of total sample belonging to *i*th species.
p_i's are population parameters, $\log_2 = 3.322 \log_{10}$.
n*i* = Number of individuals of species *i* in the sample, n = Total number of all species

Diversity number N_1 : $e^{H'}$

where: H′ is Shannon's Index (Hill, 1973).

Diversity number N_2 :1/λ

where λ is Simpson's Index.

Index of evenness $E = \frac{1/(1/\lambda)}{e^{H'}-1}$ or $E = \frac{N_2-1}{N_1-1}$

(Hill, 1973)
where N_1 and N_2 are Hill's diversity numbers.

Index of similarity $S = \frac{2C}{A+B} \times 100$

Index of similarity $S = \frac{2C}{A+B} \times 100$

(Sorensen, 1948)
Where: A is the number of species in one stand.
B is the number of species in other stand.
C is the number of species common to both stands of vegetation.

Index of dissimilarity Ds = 100- S

(Sorensen, 1948)
Where: S is Similarity index of species.

Statistical 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. In case of experiments in field experiments involving more than two treatments or parameters, analysis was done with one way analysis of variance (ANOVA) followed by separation of means using Tukey's Test. The significance of data was checked at only 5 % level.

RESULTS

A total of 190 alien plants form 51 families of flowering plants were documented from the lower Shivalik hills of Himachal Pradesh during the survey conducted in the year 2002 - 2004. These alien plants included various life forms such as herbs, shrubs, grasses, trees, vines, sedges and climbers. Most of the herbaceous plants were aliens as compared to other life forms. *Asteraceae* found to be most dominant family among the alien species followed by *Fabaceae*, *Poaceae* and *Lamiacea*. There were majority of alien species from American continent followed by Eurasia, Europe, Asia, Africa and Austarlia. Out of these species, *A. conyzoides* L., *P. hysterophorus* and *L. camara* L. from subtropical America were found to be highly dominant in the Shivalik hills. These species directly or indirectly affecting the ecosystem and function in the invaded habitats in lower Shivaliks (Kohli et al., 2004).

Status and average distribution of three invasive plants in lower Shivalik hills

The average distribution of three invasive plants was calculated through the mean values of all the ecological indices in lower Shivaliks at various sites (Table 1). It was found that *A. conyzoides* and *P. hysterophorus* were equally and significantly more abundant as compared to *L. camara* which was least abundant. Average frequency of *A. conyzoides* was comparatively more than that of *P. hysterophorus* and *L. camara*.

The average density of *A. conyzoides* (23.03 ± 3.74) was 42.51% more than that of *P. hysterophorus* (13.24 ± 4.84) and 95.73% from *L. camara* (1.03 ± 0.43). The density of *P. hysterophorus* was also higher by 92.22% as compared to *L. camara*. The dominance or basal cover of of *L. camara* was quit high as compared to *A. conyzoides*

Table 1. Average distribution of three invasive plants in lower Shivalik hills (values in %).

Ecological Indices	*Ageratum*	*Parthenium*	*Lantana*
Abundance	8.74 ± 2.66^a	7.47 ± 2.67^a	0.53 ± 0.23^b
Frequency	5.08 ± 1.25^a	3.15 ± 0.76^b	3.71 ± 0.78^b
Density	23.03 ± 3.74^a	13.24 ± 4.84^b	1.03 ± 0.43^c
Dominance	3.37 ± 1.95^b	3.38 ± 2.84^b	17.80 ± 6.87^a
IVI	10.49 ± 1.92^a	6.59 ± 2.59^b	7.52 ± 2.29^b

Different alphabets represent significance difference among values at 5% level of significance after applying Tuke's test.

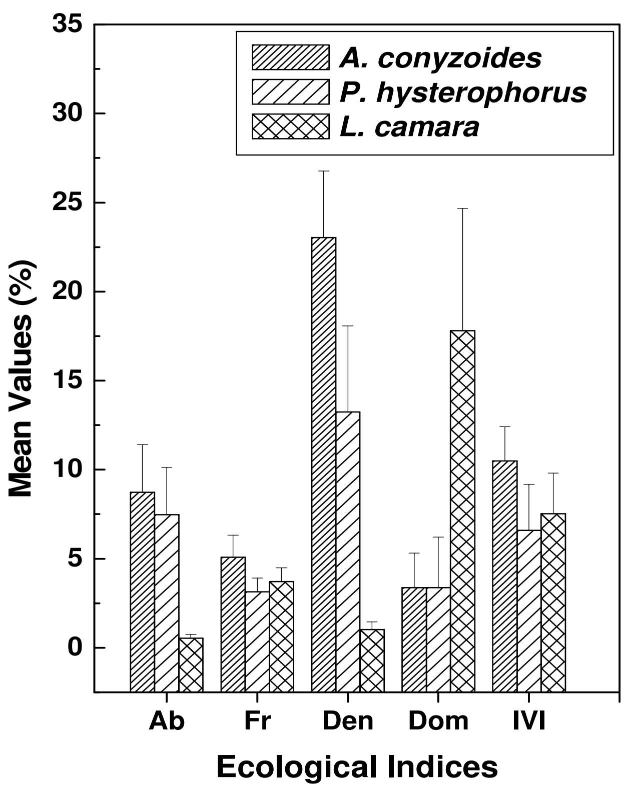

Figure 2. Average comparative distribution of *A. conyzoides P. hysterophorus* and *L. camara* in lower Shivalik hills (values in %).

and *P. hysterophorus*. It was 81.07 and 81.01% higher as compared to *L. camara*. But in case of their importance value index, it was comparatively higher for *A. conyzoides* as compared to other two invasive species (higher by 30.89 and 37.18% respectively) in Shivalik hills (Figure 2).

Distribution of three major invasive plants in relation to other species

The abundance and frequency of the three invasive species was 16.08 and 10.96% and other species had 83.92 and 89.04% in Shivalik hills (Table 2). These three invasive species had quit higher impact on the density of other species in these areas. Alone, they were 31.57% dense as compared to other species (68.33%) found in these invaded habitats. The dominance and IVI of three invasive species was almost similar, that is, 22.20 and 22.60% respectively. These results showed that more than 20% vegetational area in lower Shivalik hills is covered by these three invasive species.

Impact of three invasive plants on the plant diversity and biomass

The number of plant species highly reduced in the areas invaded by *A. conyzoides, P. hysterophorus* and *L. camara* and the decrease was 30.19, 36.07, 47.56% respectively (Table, 3, 4 and 5). Similarly, Margalef index of species richness was also decreased by 36.22, 35.53 and 37.57% respectively. The index of dominance increased by 52.63, 60.71 and 56.25% in the *Ageratum, Partrhenium and Lantana* invaded areas. Its higher value among the invaded plant communities predicts the homogenous nature of the vegetation. The α-diversity of vegetation was drastically reduced due to the invasion of these three plant species in Shivalik hills. It was decreased by 39.62, 41.26, 41.03% respectively in the *Ageratum, Parthenium* and *Lanatna* invaded areas. Likewise, number of abundant species (N_1) and very abundant species (N_2) and index of evenness were also significantly decreased in the areas invaded by these three invasive plant species. The comparison of the fresh and dry biomass of vegetation between the invaded and un-invaded areas also shows the decrease in productivity of communities in the invasive invaded areas. The similarity index of species was also decreased drastically among the un-invaded and areas invaded by these three invasive species.

Overall, the invasion oft these three species highly reduced the species diversity and composition in the Shivaliks. The decrease in diversity indices and biomass in the invaded sites showed that plant communities become less productive due to the invasion of these alien plant species in the lower Shivaliks of Himachal Pradesh.

DISCUSSION AND CONCLUSIONS

Plants are the primary producers and all the living beings are dependent upon them for their food requirements. The plant diversity around the world is facing various threats and is reducing very rapidly. The invasion of alien plant species in the new regimes became a second highest threat to plant diversity after the habitat loss (Hobbs and Humphries, 1995). The spread of species beyond their natural hills has always played a key role in the dynamics of biodiversity. But the present rate of species exchange is unprecedented and has become one of the most intensively studied fields in ecology.

Table 2. Distribution of three invasive plants and other species in lower Shivalik hills (Values in %).

Ecological indices	*Ageratum*	*Parthenium*	*Lantana*	Three invasive species	Other species
Abundance	8.74	7.47	0.53	16.08	83.92
Frequency	5.08	3.15	3.71	10.96	89.04
Density	23.02	13.24	1.03	31.57	68.33
Dominance	3.37	3.38	17.80	22.20	77.80
IVI	10.49	6.59	7.52	22.60	77.40

Table 3. Number of species, biomass and various ecological indices of vegetation in an un-invaded area (control) and one invaded by *A. conyzoides* in lower Shivalik hills.

Parameters	Control	Invaded	% decrease over control
Total Species	53	37	(–) 30.19
Average Fresh Biomass (g/m^2)	518.17 ± 28.75	324.58 ± 14.99	(–) 37.36
Average Dry Biomass (g/m^2)	327.88 ± 15.50	183.13 ±12.51	(–) 44.15
Margalef Index of Richness (R_1)	4.97 ± 0.42	3.17 ± 0.44	(–) 36.22
Simpson's Index of Dominance (λ)	0.09 ± 0.03	0.19 ± 0.04	(+) 52.63
Shannon's Index of Diversity (H')	3.13 ± 0.40	1.89 ± 0.25	(–) 39.62
Diversity Number (N_1)	15.99 ± 2.73	8.14 ± 0.95	(–) 49.09
Diversity Number (N_2)	11.37 ± 2.99	5.33 ± 1.15	(–) 53.12
Index of Evenness (Es)	0.82 ± 0.04	0.70 ± 0.07	(–) 14.63
Similarity Index	60.25 ± 7.29		
Dissimilarity Index	39.74 ± 7.29		

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

Table 4. Number of species, biomass and various ecological indices of vegetation in an un-invaded area (control) and one invaded by *P. hysterophorus* in lower Shivalik hills.

Parameters	Control	Invaded	% decrease over control
Total Species	61	39	(–) 36.07
Average fresh Biomass (g/m^2)	317.20 ± 22.85	196.68 ± 10.19	(–) 37.99
Average dry Biomass (g/m^2)	197.30 ± 9.25	104.55 ± 6.62	(–) 47.01
Margalef Index of Richness, R_1	5.46 ± 0.39	3.52 ± 0.37	(–) 35.53
Simpson's Index of Dominance, λ	0.11 ± 0.02	0.28 ± 0.04	(+) 60.71
Shannon's Index of Diversity, H'	2.86 ± 0.23	1.68 ± 0.04	(–) 41.26
Diversity Number, N_1	14.36 ± 2.09	6.53 ± 0.26	(–) 54.53
Diversity Number, N_2	9.06 ± 1.60	3.64 ± 0.50	(–) 59.82
Index of Evenness (Es)	0.76 ± 0.03	0.62 ± 0.02	(–) 18.42
Similarity Index	65.55 ± 7.19		
Dissimilarity Index	34.45 ± 7.19		

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

Table 5. Number of species, biomass and various ecological indices of vegetation in an area un-invaded (control) and invaded by *L. camara* in lower Shivalik hills.

Parameters	Control	Invaded	% decrease over control
Total Species	82	43	(–) 47.56
Average Fresh Biomass (g/m^2)	551.53±12.67	364.56 ± 14.35	(–) 33.91
Average Dry Biomass (g/m^2)	401.09±15.45	229.93 ± 15.06	(–) 42.67
Margalef Index of Richness (R_1)	7.16 ± 0.31	4.47 ± 0.25	(–) 37.57
Simpson's Index of Dominance (λ)	0.07 ± 0.002	0.16 ± 0.03	(+) 56.25
Shannon's Index of Diversity (H')	3.51 ± 0.03	2.07 ± 0.14	(–) 41.03
Diversity Number (N_1)	21.93 ± 1.31	10.27 ± 0.35	(–) 53.17
Diversity Number (N_2)	14.20 ± 0.40	6.41 ± 0.13	(–) 54.85
Index of Evenness (Es)	0.81 ± 0.01	0.70 ± 0.01	(–) 13.58
Similarity Index	51.81 ± 5.01		
Dissimilarity Index	48.19 ± 5.01		

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

Invasions of new territories follow accidental or deliberate introductions by man or are caused by climatic changes (Hurka et al., 2003). *A. conyzoides*, *P. hysterophorus* and *L. camara* are fast colonizing invasive aliens from tropical America which has spread in various areas of Himachal Pradesh especially in the Shivalik hills (Kohli et al., 2004).

The strong invaders reduced the species diversity and density in the invaded areas (Ortega and Pearson, 2005). The factors affecting species richness and diversity vary with the geographical positions (Wills and Whittaker, 20 02). The multiple analyses of different ecological parameters at different locations can derive general explanations of impact on the species richness, diversity and distribution patterns (Zhao and Fang, 2006).

In the present study it was seen that *A. conyzoides* have quit higher density compared to other two alien plant species. Contrastingly the cover or basal area of *L. camara* was higher and it was due to its shrubby nature as other two invasive plants are herbaceous in nature (Jones et al., 1994). The higher cover or basal area of *L. camara* supported the growth of lesser number of species in its vicinity as compared to other species.

Overall the IVI which show a clear picture about the distribution of a particular species in an area was higher for *A. conyzoides* followed by for *L. camara* and *P. hysterophorus* as it depends not only on single factor but on relative frequency, relative density and relative dominance. This clearly shows that *A. conyzoides* highly established alien plant species followed by *L. camara* and *P. hysterophorus* in the lower Shivalik hills of Himachal Pradesh.

In Shivalik hills more than 47% species were lost in the *Lantana* invaded areas as compared to more than 30 and 36% respectively in the *Ageratum* and *Parthenium* invaded areas. The alleleopathic nature of these three species maximally contributed towards the loss of number of plant species in the habitats invaded by them (Batish et al., 2006; Singh and Achhireddy, 1987; Kohli et al., 20 06). The higher value of species richness index in the un-invaded area shows that plant communities in the uninvaded areas are heterogeneous in nature and vice versa in the invaded areas. The higher value of index of dominance in the invaded areas predicts the dominance of single species over others and homogenous plant communities in the invaded areas by these three invasive in lower Shivalik hills (Kohli et al., 2004). This decrease in number of species also directly affected the α-diversity of species in the invasive plant invaded areas. More than 39% of α-diversity loss was recorded in the invaded areas as compared to un-invaded (Dogra, 2007). Likewise, all other diversity indices were also decreesed in the invaded areas in Shivalik hills. The maximum decrease in similarity index in case of *L. camara* also shows its dominance over other species in Shivalik hills as compared to other aliens. The fresh and dry biomass of other species per square meter in the invaded areas also reduced drastically when compared with the un-invaded areas. This loss was quite high in biological terms which indicated that the invaded habitats become less productive (Kohli et al., 2004).

In conclusion the invasion of these three invasive plant species highly reduced the available habitats or niches for the growth of other useful plant species. They directly or indirectly become responsible for the loss of productivity and diversity of species in the invaded areas. So these species drastically alters the structure, function and dynamics of invaded habitats. Thus, there is an urgent need for the management of these indigenous or medicinally valuable plants in the invaded areas under their natural habitats.

REFERENCES

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 and Schwartz MW (1999). Terrestrial Plant Ecology. 3rd Edition. Addison Wesely Longman Inc., Menlo Park, California.

Batish DR, Singh HP, Kohli RK, Johar V, Yadav S (2006). Phytotoxicity of *Ageratum conyzoides* towards growth and nodulation of *Cicer arietinum*. Agri. Ecosyst. Envir. 113: 399-401.

Chauhan NS (1999). Indigenous Medicinal Plants. Today and Tomorrow's Printers and Publishers New Delhi, India pp. 199-205.

Chowdhery HJ, Wadhwa BM (1984). *Flora of Himachal Pradesh, Analysis*. Vols. 1-3. BSI, Calcutta.

Dogra KS (2007). Impact of Some Invasive Species on the Structure and Composition of Natural Vegetation of Himachal Pradesh. Ph.D. thesis, Panjab University, Chandigarh, India.

Hill MO (1973). Diversity and evenness: A unifying notation and its consequences. Ecol. 54: 427-249.

Hobbs RJ, Huenneke L (1992). Disturbance, diversity, and invasion: Implications for conservation. Conser. Biol. 6: 324-337.

Hobbs RJ, Humphries SE (1995). An integrated approach to the ecology and management of plant invasions. Conser. Biol. 9: 761-770.

Hurka H, Bleeker W, Neuffer B (2003). Evolutionary processes associated with biological invasions in the Brassicaceae. Biol. Invasions 5: 281-292.

Jones RH, Shartiz RR, Dixon PM, Segal DS, Schneider RL (1994). Woody plant regeneration in four floodplain forests. Ecol. Mono. 64: 345-367.

Kikvidze Z, Pugnaire FI, Brooker RW, Chpler P, Lortoe CJ, Michalet R, Callaway RM (2005). Linking patterns and processes in alpine plant communities: A global study. Ecol. 86 (6): 1395-1400.

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.

Kohli RK, Dogra KS, Batish DR, Singh HP (2004). Impact of invasive plants on the structure and composition of natural vegetation of North Western Indian Himalayas. Weed Tech. 18: 1296-1300.

Lesica P, Yurkewycz R, Crone EE (2006). Rare plants are common where you find them. Amer. J. Bot. 93: 454-459.

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

Maheshwari JK (1960). Studies on the naturalised flora of India. In: Proceedings of the Summer School of Botany (Eds. Maheshwari P, Johri BM and Vasil IK) pp. 156-170.

Margalef R (1958). Temporal succession and spatial heterogeneity in phytoplankton. In: Perspective in Marine Biology (Ed. Buzgati-Traverso AA). University of California Press, Berkeley, USA pp. 323-347.

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

Nagar PS, Pathak SJ, Pandya SM (2004) The alien flora of the Barda hills and its surroundings in Gujarat, India. Ind J Forest 27: 25–38.

Nayar MP (1977). Changing patterns of the Indian flora. Bull. Bot. Survey India 19: 145-154.

Ortega YK and Pearson DE (2005). Weak vs. strong invaders of natural plant communities: Assessing invasibility and impact. Ecol. Appl. 15: 651-661.

Pandey RP, Parmer PJ (1994). The Exotic Flora of Rajasthan. J. Econ. Taxon. Bot. 18:105–135.

Polunin O, Stainton A (1984). Flowers of the Himalaya. Oxford University Press, New Delhi, India.

Preisser EL, Lodge AL, Orwig DA, Elkinton JS (2008). Range expansion and population dynamics of co-occurring invasive herbivores. Biol. Invasions 10:201–213.

Shannon CE, Weaver W (1963). The Mathematical Theory of Communication. Urbana, IL, University of Illinois Press, USA Pp. 31-35.

Sharma BD, Pandey DS (1984). Exotic Flora of Allahabad District. Botanical Survey of India, Kolkata, India.

Sharma BM (1986). Phytosociological observations on the vegetation of burnt and unburnt areas near Ibadan, Nig. J. Range Manage. 39: 76-81.

Sharma GP, Singh JS, Raghubanshi AS (2005). Plant invasions: Emerging trends and future implications. Curr. Sci. 88: 726-734.

Simpson EH (1949). Measurement of diversity. Nature 163: 688.

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

Singh M, Achhireddy NR (1987). Influence of lantana on growth of various citrus rootstocs. Hort. Sc. 22: 385-386.

Sorensen T (1948). A method of establishing groups of equal amplitude in plants sociology based on similarity of species content. Det Kongelige Danske Videnskabernes Selskabs Biologiske Skrifter (Copenhagen) 5(4): 1-34.

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.