The Replacement of Grasses and Other Herbs in the Himalayan Grassland by Allelopathic Impacts of Exotic Weed *Eupatorium glandulosum*

Indu Tiwari[1] and Govind S. Rajwar[2]

[1]Department of Botany, Government Post Graduate College, New Tehri, Uttarakhand, India.
[2]Department of Botany, Government Post Graduate College, Rishikesh 249201, Uttarakhand, India.
rajwargs@hotmail.com

Abstract: The present study was conducted with the objective to evaluate the effects of *Eupatorium glandulosum* on primary productivity, germination and growth of some native plant species in grasslands of the outer Garhwal Himalaya. *E. glandulosum* has caused reduction in species diversity, biomass and primary productivity on the sites dominated by this exotic weed and its leaf leachate showed inhibitory effects on growth and germination of some economic species. The replacement of economically important species by *Eupatorium glandulosum* is a serious environmental problem as it is decreasing species status and reduction in fodder and medicinal species, thereby affecting the biodiversity and the economy based on these grasslands. [New York Science Journal 2010;3(3):50-54]. (ISSN: 1554-0200).

Keywords: *Eupatorium glandulosum*, allelopathic effects, grassland, biodiversity, Garhwal Himalaya

1. Introduction

Allelopathy involves positive or negative influences on growth, behaviour, reproduction and survival of other species and significant effects on plant succession and composition of plant communities (Muller, 1969). Allelopathic interactions are widely known in algae, lichens, and annual and perennial weeds (Putnam, 1958). Allelopathy involves a complex chain of chemical communication between plant species and these interactions may play a key role in influencing the distribution of vegetation in nature, the yield of various crop species and weed interference (Kiminsky, 1981; Harborne, 1987). Evidence indicates that all allelopathic compounds get out of plants by volatilization, exudation from roots, leaching from plants, residues by rain or decomposition of residues(Wilson and Rice, 1968). The reason behind allelopathy is the release of various non-nutritional chemical groups known as allelochemicals such as phenols, terpenoids, alkaloids and organic acids (Reese, 1979; Rice, 1984). The increasing knowledge and awareness towards allelopathy is aiding greatly in our understanding of many ecological phenomena under which certain plants or exotic weeds cause allelopathic effects on the subsequent plants. The active concentration of allelochemicals is determined primarily by rate of input to the environment (i.e., leaf leachate, root exudates or decomposition and leaching of plant debris), absorption and adsorption by seeds and roots, fixation by soil component and leaching and microbial degradation and furthermore, the concentration of allelochemicals in the natural field depends on density and growth of allelopathic plant, habitat, pattern of cultivation and agricultural practices (Dalton et al., 1983; Inderjit and Dakshini, 1994). Generally, in allelopathic studies, leachates, extracts, residues or plant parts are added to the soil for assessing the allelopathic potential of the plant (Mersie and Singh, 1987). Several weed species like *Parthenium hysterophorous, Lantana camara, Chenopodium album* etc., are replacing many other herbaceous plants of the Himalayan grasslands.

2. Materials and Methods

2.1 Study Area

The study area Agrakhal-Hindolakhal lies in the district Tehri Garhwal of Uttaranchal State in the Indian Himalayan region. The area of investigation is located at 30^0 5' N latitude and 78^0 23' E longitude ranging in elevation from 1300 to 1800 m in montane zone and is covered with dense forest. The study area is divided into six different sites as SW_1 (South-West 1), SW_2 (South-West 2), NW_1 (North-West 1), NW_2 (North-West 2), NE_1 (North- East 1), NE_2 (North-East 2) on the basis of the aspect and density of *Eupatorium glandulosum*. The sites

SW_1, SW_2, NW_1 and NE_1 were dominated by *Eupatorium glandulosum*.

The climate of the study area is monsoonic with extreme cold conditions. Maximum mean temperature varied from 10.5 (January) to 29.8◦C (May), whereas the minimum mean temperature ranged from 3.1 (January) to 28.4◦C. Highest rainfall was recorded in the month of August (799.6 mm). The study area was divided into spring (March-April), summer (May- June), rainy (July-September) and winter (October-February) seasons.

2.2 Methods

Soil study has been carried out to analyse the soil nutrients on different sites by taking samples from three different depths. Total nitrogen was determined by micro-Kjeldahl's method as described by Jackson (1957). Estimation of phosphorous was done by calibration curve method and potassium by flame photometric method as described by Jackson (1957). Detection of organic carbon has been determined by the method of Walkey and Black as outlined by Piper (1944).

In the present investigation, aboveground and belowground productivity has been estimated by summing up the positive increments in the aboveground and the belowground biomass (Singh and Yadava, 1974). Total net production was measured as the sum of the aboveground and belowground productivity.

To find out the allelopathic impacts of *Eupatorium glandulosum* HBK. on germination, some dominant herbaceous native species of the study area were selected. The species selected for these experiments were *Tagetes minuta*, *Chrysopogon echinulatus* and *Ageratum conyzoides*, which are used as fodder as well as raw material for medicines. These experiments were conducted in the laboratory conditions with some control germination sets based on the method described by Al-Naib and Rice with some modifications (Al-Naib and Rice, 1971). Detection of allelochemicals has been done through high performance liquid chromatography (HPLC) (Harborne, 1973).

3. Results

Soil colour of the study area was differentiated from dark brown in uppermost layer (0-5 cm) to reddish-brown in the lowest layer (20-25 cm). The amount of total nitrogen content ranged from 0.10 to 0.54 % for all sites and seasons, the highest being at 0-5 cm depth, whereas the amount of phosphorous showed a range from 0.004 to 0.026 % indicating a decreasing trend with increasing depth for all the sites and seasons. The exchangeable quantity of potassium showed values ranging from 0.10 to 0.26%, which also decreased with increasing depth in most of the sites. The values of organic carbon were recorded from 1.20 to 4.50% on different sites and for all seasons.

Table 1. Total net primary productivity (TNP) on all study sites.

Site	TNP values (g m^{-2} yr^{-1})
South-West 1 (SW_1)	2163.40
South-West 2 (SW_2)	1953.40
North-West 1 (NW_1)	1675.60
North-West 2 (NW_2)	1528.50
North-East 1 (NW_1)	1710.90
North-East 2 (NW_2)	1496.90

The annual aboveground net primary production (ANP) ranged from 528.30 to 1022.60 g m^{-2} yr^{-1} on different sites (Table 1). The annual aboveground net primary production on the sites dominated by *Eupatorium glandulosum* amounted 1022.60, 759.20, 764.50 and 731.10 g m^{-2} yr^{-1}on SW_1, SW_2, NW_1 and NE_1 respectively. The annual belowground net primary production (BNP) ranged from 911.10 to 1194.20 g m^{-2} yr^{-1} on different sites amounting to 1140.80, 1194.20, 911.10 and 979.80 g m^{-2} yr^{-1} on SW_1, SW_2, NW_1 and NE_1 sites respectively. Annual data of total net primary production (TNP) showed highest value on SW_1 site (2163.40 g m^{-2} yr^{-1}), which was followed in the order of importance by SW_2 (1953.40 g m^{-2} yr^{-1}), NE_1 (1710.90 g m^{-2} yr^{-1}) and NW_1 (1675.60 g m^{-2} yr^{-1}) sites.

Leaf leachates of *Eupatorium glandulosum* suppressed the germination of all the three tested herbaceous species as compared to their control sets. The tested herbaceous species were the dominant native species in these grasslands. Germination percentage of all the three tested species showed maximum inhibitory effect when treated with 100% leaf leachate concentration of *Eupatorium glandulosum*. *Tagetes minuta* showed 72% and 58% germination at 25% and 50% concentrations of leaf leachate solution, whereas at 75% and 100% leachate concentrations, the germination percentage values were 52.66% and 41.33% respectively, and 88% for the control set (Table

2). The germination percentage for 100% leachate was reduced to about half of the value obtained for the control set. Germination percentage values of *Chrysopogon echinulatus* were 72% and 62.66% at 25% and 50% concentrations of leaf leachate solution, and at 75% and 100% concentrations, the germination was 58.66% and 57.33% respectively, whereas it was 84% for the control set. For 100% leachate concentration, the germination percentage was reduced to about two-third of the value obtained for the control set. The germination percentage values of *Ageratum conyzoides* at 25% and 50% concentrations of leaf leachate solution were 54% and 46%, and at 75% and 100% concentrations, the germination percentage was 44% and 40%, whereas it was 76.66% for the control set. The germination percentage was much lower than the value observed for the control set. For 100% leaf leachate concentration the germination was reduced to about half of the value obtained for the control set.

Table 2. Effect of leaf leachates of *Eupatorium glandulosum* on germination of other species.

Concentration of *Eupatorium glandulosum* leaf leachate	Germination percentage after 7 days of germination (± SD)		
	Tagetes Minuta	*Chrysopogon echinulatus*	*Ageratum conyzoides*
25%	72.00 ± 1.0	72.00 ± 1.7	54.00 ± 1.0
50%	58.00 ± 1.0	62.66 ± 1.5	46.00 ± 1.0
75%	52.66 ± 1.5	58.66 ± 1.5	44.00 ± 1.0
100%	41.33 ± 0.6	57.33 ± 1.5	40.00 ± 1.0
Control	88.00 ± 3.6	84.00 ± 1.0	76.66 ± 1.5

Significant (t-test) at $P<0.05$

The oven-dry weight of the plants under control set and those treated with leachates of *Eupatorium glandulosum* were measured and compared with the control set (Figure 1). These values were found to be significant at $t>0.05$. The growth of all the herbaceous species was significantly reduced by treatment with different concentrations of *Eupatorium glandulosum* leaf leachates. Oven-dry weight of *Tagetes minuta* at 25% and 50% concentrations of leachate solution was 171.0 mg and 140.46 mg, and it was 100.23 mg and 60.20 mg at 75% and 100% concentrations respectively, whereas 178.86 mg dry weight was recorded for the control set. The oven-dry weights obtained for *Chrysopogon echinulatus* at 25% and 50% concentrations were 105.76 mg and 90.45 mg, and at 75% and 100% these were 70.20 mg and 59.70 mg respectively. The dry weight for the control set was 110.03 mg. The oven-dry weight was reduced to about half for the 100% concentration solution with respect to the values obtained for the control set. The oven-dry weight values of *Ageratum conyzoides* were 65.60 mg and 56.40 mg at 25% and 50% concentrations respectively, and at 75% and 100% leachate concentrations, the oven-dry weight values were 31.36 mg and 24.40 mg respectively, whereas the control set indicated 69.93 mg dry weight. For 100% leachate concentration, the oven-dry weight was much lower as compared to the values obtained for the control set.

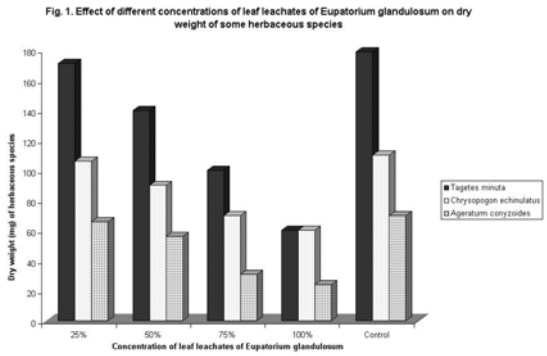

Figure 1. Effect of different concentrations of leaf leachates of *Eupatorium glandulosum* on dry weight of some herbaceous species

Table 3. Allelochemicals detected in the leaf extract of *Eupatorium glandulosum*

Organic acids	Alkaloids	Terpenoids	Phenols
Malic Acid	Theobromine	Coumarines	Sesquiterpenes
Fumaric acid	Caffeine		

The presence of organic acids (malic and fumaric acid), alkaloids (theobromine, caffeine), terpenoids (sesquiterpenes) and phenols (coumarines) has been detected in the HPLC analysis of the leaf extract of *Eupatorium glandulosum* (Table 3). The presence of these allelochemicals might be responsible for the inhibitory effect on the germination percentage and growth of the tested herbaceous species.

4. Discussion

In the present study, the soil analysis revealed that percent values of nitrogen, organic carbon, available amount of phosphorous and potassium were reduced with increasing depths of the soil. These observations indicated that the upper surface of the soil had high content of organic matter. It has been reported that decrease in the ionic concentration of nutrients in the soil with depth is related to high root biomass, turnover rate, weathering of soil material near the soil surface and activity of microorganisms (Monk and Day, 1985). The status of nitrogen in different grassland ecosystems and availability of potassium in Indian soils have been studied by various workers (Tiwari, 1982; Raychaudhary, 1963).

In the present study, values of aboveground and belowground, and total net primary productivity ranged from 528.30-1022.60 g m^{-2} yr^{-1}, 931-1231 g m^{-2} $yr^{-1}$and 1496.90-2163.40 g m^{-2} yr^{-1}, which are in conformity with the values recorded for various temperate grasslands (Pant, 1987; Rajwar and Ramola, 1990).

Phytotoxicity of *Cassia fistula* on *Triticum aestivum* seedlings has been reported (Joshi et al., 1998). Importance of alkaloids, coumarins and abscisic acid in allelopathy as seed germination inhibitors has been established (Neill and Rice, 1971; Chou and Waller, 1980). Concentration of several organic acids like malic acid, citric acid, fumaric acid and tartaric acid has been reported to inhibit seed germination (Evenari, 1949). Inhibitory allelopathic effects of *Eupatorium glandulosum* on germination of *Cajanus cajan* and *Glycine max* have also been reported (Bughani and Rajwar, 2003). Allelopathic potential of *Eupatorium glandulosum* as a dominant ruderal weed of Meghalaya has been studied and inhibitory allelopathic effects of cadinenes from *Eupatorium glandulosum* has been reported (Tripathi et al., 1981; Baruah et al., 1994).

5. Conclusion

Present study has evidenced the replacement of native herbaceous species by *Eupatorium glandulosum* in the grassland of the Himalaya. The allelochemicals present in *Eupatorium glandulosum* has caused decrease in the germination and dry weight of native species as shown by the results of the experiments described. The replacement of grasses and economically important medicinal plant species by *Eupatorium glandulosum* is a serious environmental problem as it is decreasing species status and reduction in fodder and medicinal species, thereby affecting the biodiversity and the economy based on these grasslands.

Corresponding Author:
Dr. Govind S. Rajwar FLS
Department of Botany
Government Post Graduate College
Rishikesh 249201, Uttarakhand, India
Telephone: +91 135 2430495 (work), +91 135 2454131 (home)
Email: rajwargs@hotmail.com

References

1. Al-Naib FAG, Rice EL. Allelopathic effects of Platanus occidentalis. Bulletin of Torrey Botanical Club. 1971;98:75-82.
2. Baruah NC, Sarma JC, Sarma S, Sharma RP. Seed germination and growth inhibitory cadinenes from Eupatorium adenophorum. Journal of Chemical Ecology 1994;20:1885-92.
3. Bughani I, Rajwar GS. Allelopathic effects of *Eupatorium glandulosum* on germination of *Cajanus cajan* and *Glycine max*. In: Kumar A, ed. Proceeding of National Symposium on Science & Ethics of Environmental Care & Sustainability. Allahabad. 2003;2:281-6.
4. Chou CH, Waller GR. Possible allelopathic constituents of *Coffea arabica*. Journal of Chemical Ecology 1980;6:643-54.
5. Dalton BR, Blum U, Weed SB. Allelopathic substances in ecosystems: Effectiveness of sterile soil component in altering recovery of ferulic acid. Journal of Chemical Ecology 1983;9:1185-201.
6. Evenari M. Germination inhibitors. Botanical Review 1949;15:153-94.
7. Harborne JB. Chemical signals in the ecosystems. Annals of Botany 1987;60:39-57.

8. Harborne JB. Phytochemical Methods. Champion & Hall, London. 1973.
9. Inderjit, Dakshini KMM. Effect of cultivation on allelopathic interference success of the weed *Pluchea lanceolata*. Journal of Chemical Ecology 1994; 20:1179-88.
10. Jackson ML. Soil Chemical Analysis. Prentice Hall, New Jersey. 1957.
11. Joshi RK, Prasad D, Nautiyal R, Pant G, Rawat MSM. Phytotoxicity of *Cassia fistula* on *Triticum aestivum* seedlings. Journal of Hill Research 1998;11:43-8.
12. Kaminsky R. The microbial origin of the allelopathic potential of *Adenostoma fasiculatum*. Ecological Monographs 1981;51:365-85.
13. Mersie W, Singh M. Allelopathic effects of lantana on some agronomic crops and weeds. Plant & Soil 1987;98:25-30.
14. Monk CD, Day FP. Vegetational analysis, primary production and selected nutrient budget for a southern Appalachian oak forest: A synthesis of IBP studies at Coweata. Forest Ecology & Management 1985;10:87-113.
15. Muller CH. Allelopathy as a factor in ecological processes. Vegetatio 1969;18:348-57.
16. Neill RL, Rice EL. Possible role of *Ambrosia psilostachya* on patterning and succession in old-fields. American Midland Naturalist 1971;86:344-57.
17. Pant SC. Vegetation, Litterfall and Litter Decomposition and Ground Vegetation Production on the North-West and South-West Facing Slopes in Forest at Gopeshwar, Garhwal Himalaya. Ph.D. Thesis, Garhwal University, Srinagar, Garhwal, India. 1987.
18. Piper CS. Soil and Plant Analysis. Inter Science Publishers, New York. 1944.
19. Putnam AR. Weed allelopathy. In: Duke SO, ed. Weed Physiology. CRC Press, Boca Raton, Florida. 1958;132-55.
20. Rajwar GS, Ramola VC. Variation in net primary productivity of east and west facing slopes of montane grasslands of Uttarkashi, Garhwal Himalaya. Indian Forester 1990;16:717-22.
21. Raychaudhary SP. Land Resource of India. Indian Soil: Their Classification, Occurrence and Properties, Communities on Natural Resources, Planning Commission, Govt. of India, New Delhi. 1963;1:74-88.
22. Reese JC. Interaction of allelochemicals with nutrients in herbivore foods. In: Rosenthal GP, Janzen DH, eds. Herbivores: Their Interaction with Secondary Plant Metabolites. Academic Press, New York. 1979;308-30
23. Rice EL. Allelopathy. Academic Press, Orlando, Florida. 1984.
24. Singh JS, Yadava PS. Seasonal variation in composition, plant biomass and primary productivity of a tropical grassland at Kurukshetra, India. Ecological Monographs 1974;44:351-76.
25. Tiwari SC. Estimation of nitrogen content in the elevated grassland of Garhwal Himalayas: Standing state in soil vegetation ingredients. Indian Journal of Ecology 1982;9:210-17.
26. Tripathi RS, Singh RS, Rai JPN. Allelopathic potential of *Eupatorium adenophorum*: A dominant ruderal weed of Meghalaya. Proceedings of Indian National Science Academy 1981;47:458-65.
27. Wilson RE, Rice EL. Allelopathy as expressed by *Helianthus annus* and its role in old field succession. Bulletin of Torrey Botanical Club 1968;95:432-48.

11/04/2009