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Primary Productivity and the Impacts of the Exotic Weed *Eupatorium Glandulosum* in a Montane Grassland of Garhwal Himalaya

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Summary. The biomass and productivity of a montane grassland of Garhwal Himalaya were estimated with the objectives to compare these values of the dominant exotic species, *Eupatorium glandulosum* HBK. (Asteraceae) with other species, and to compare the sites more dominated by this species with other study sites. The effect of dominance of this species on other species was undertaken because of its continuous spread in the grasslands of the Garhwal Himalaya causing replacement of some native grasses and economically important herbaceous plants. Out of six study sites, SW_1, SW_2, and NE_1 were more dominated by *Eupatorium glandulosum.* Total net primary productivity (TNP) ranged from 1528.5 to 2163.4 g m^{-2} yr^{-1}. *Eupatorium glandulosum* showed individual highest biomass on all the study sites, and the sites more dominated by this species showed higher values of primary productivity, thereby reducing the biomass and production of other species on these sites.

Keywords: montane forest, Garhwal Himalaya, grassland, primary production, *Eupatorium glandulosum*

Introduction

Estimation of biomass and productivity is a prerequisite to understanding of ecosystem properties and functions (Singh and Singh, 1992). The net productivity varies from month to month in both aboveground and belowground parts and is generally influenced by abiotic factors like precipitation, temperature, growing season, evaporation and vegetation composition (Gupta, 1985). Grasslands consist of plant communities with a mixture of grasses and other herbaceous plants and are economically important in producing abundant fodder for livestock because of their richness in proteins, minerals and vitamins. In addition to grazing, these lands are also important as recreational areas because of their aesthetic value. Grasslands in the Garhwal Himalaya cover large areas intermixed with forest vegetation.

The montane grasslands of the Kumaun Himalaya were studied mainly by Saxena and Singh (1980) and Sah *et al.* (1994) while those of the Garhwal Himalaya have been evaluated by Tiwari (1980), Rajwar and Ramola (1990), Sah and Saxena (1990) and Dhaulakhandi *et al.* (2000). Because no work has been done on the effects of invasion on biomass, productivity and species replacement by exotic species in the Himalayan region, our present work was undertaken to evaluate these effects caused by the exotic species *Eupatorium glandulosum*, which is spreading as an invasive species in all the grasslands of the Himalaya.

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Material and methods

Study area

The study area, Agrakhal-Hindolakhal lies in the montane zone of the district Tehri of Garhwal Himalaya in Uttaranchal state of India between 30° 5′ N latitude and 78° 23′ E longitude ranging in elevation from 1140–1800 m. The forests near these grasslands are covered with dense oak forest dominated by *Quercus leucotrichophora* A. Camus (Fagaceae), *Terminalia tomentosa* (Roxb.) Wt. & Arn. (Combretaceae), *Bauhinia variegata* L. (Caesalpiniaceae), *Mallotus philippensis* (Lam) Muell.-Arg. (Euphorbiaceae), *Rhododendron arboreum* Smith (Ericaceae), *Lyonia*

ovalifolia (Wall.) Drude (Ericaceae) and *Myrica esculenta* Buch.-Ham. ex D. Don (Myricaceae). Common shrub species found on and near these sites were *Lantana indica* Roxb. (Verbenaceae), *Inula cappa* (Buch.-Ham. Ex D.Don) DC. (Asteraceae), *Rubus ellipticus* Smith (Rosaceae) and *Indigofera heterantha* Wall. ex Brandis (Fabaceae). Commonly found cypers (Cyperaceae) were *Carex caricina* (D. Don) Ghildyal & Bhattacharya, *C. setosa* Boott, *Cyperus alulatus* Kern and *C. difformis* L. and common grasses (Poaceae) were *Chrysopogon serrulatus* Trinius, *Apluda mutica* L., *Cynodon dactylon* (L.) Pers., *Arundinella nepalnesis* Trinius, *A. setosa* Trinius, *Setaria glauca* (L.) P. Beauv. and *S. tomentosa* (Roxb.) Kunth. In addition to *Eupatorium glandulosum* HBK (Asteraceae) other dominant herbaceous were *Boenninghausenia albiflora* (Hook.) Reichb. ex Meisn. (Rutaceae), *Dicliptera roxburghiana* Nees (Acanthaceae) and *Ageratum conyzoides* L. (Asteraceae).

The study area was divided into six 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$_1$) and NE_2 (North-East$_2$). Among these sites, SW_1, SW_2 and NE_1 were more 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.

Eupatorium (Family Asteraceae) has 1200 species distributed throughout world except Australia, 10 in India. It as a common weed found in moist as well as exposed localities. *Eupatorium glandulosum* HBK., a perennial herb introduced in India recently is found in north-east and south India. This weed is spreading rapidly in the grasslands of the Himalaya and its foothill zone and invasion by this species is causing threat to many economically important native species.

Biomass structure

Aboveground biomass

Sampling in the study area was done at monthly intervals from June 2000 to June 2001. Ten quadrats of 50 × 50 cm were selected randomly from each site for the harvesting as described by Singh and Yadava (1974). The plant material from the harvested plot was categorised as green parts (live), standing dead parts (dead) and litter. All the aboveground plant parts were

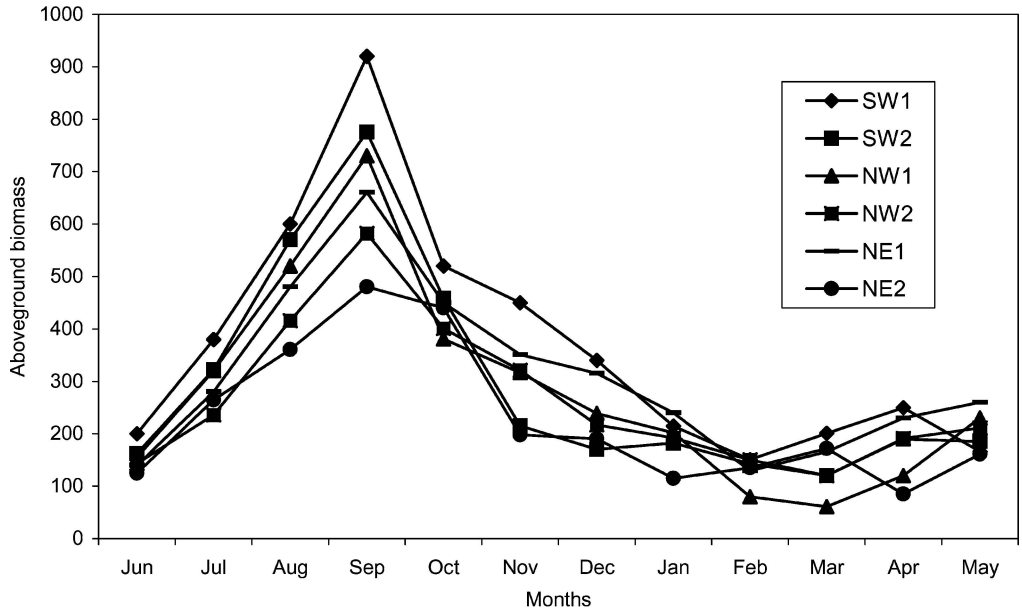

Figure 1. Aboveground biomass (g m^{-}2) on the study sites.

put in hot air oven at 80°C for 24 hrs. to dry and were then weighed.

Belowground biomass

For measuring the belowground biomass, monoliths (soil blocks) of 25 × 25 × 30 cm size each from harvested plots were dug out from the field at monthly intervals. These blocks were washed carefully and dried completely at 80°C until constant weight.

Net primary productivity

Aboveground net primary production (ANP) was calculated by summing up the positive monthly increments in the aboveground biomass (Singh and Yadava, 1974). Belowground primary production (BNP) was estimated by summation of the significant positive changes in the monthly belowground biomass (Dahlman and Kucera, 1965). Total net productivity (TNP) in the present investigation is the sum of the aboveground net production and belowground net production.

Statistical analysis was done to determine the relationship between rainfall and total live shoot biomass, and between rainfall and total ANP of all the study sites, and for live shoot biomass and ANP of *Eupatorium glandulosum* on all sites with rainfall. Correlation coefficient (r) was calculated to correlate these data. The values of r were tested for significance of these relationships by calculating t-test at different probability levels.

Results

Biomass

Eupatorium glandulosum was the maximum biomass contributor among all the herbaceous species recorded during the study period on all the sites showing highest live shoot biomass ranging between 230.1 (site NW_1) and 275.9 g m^{-2} (site NE_1) in the month of September. However, on site SW_1 it was observed in the month of October (246.1 gm^{-2}). The values of highest live shoot biomass of this species observed on the sites SW_2, NW_2 and NE_2 were 250.9, 275.5 and 220.1 gm^{-2} respectively. The highest live shoot biomass contributed by this species accounted for 31.5% (NW_1) to 47.3% (SW_1 and NW_2). The values of maximum dead shoot biomass of *Eupatorium glandulosum* on the sites SW_1, SW_2, NW_1, NW_2, NE_1 and NE_2 were 52.9 (May), 88.1

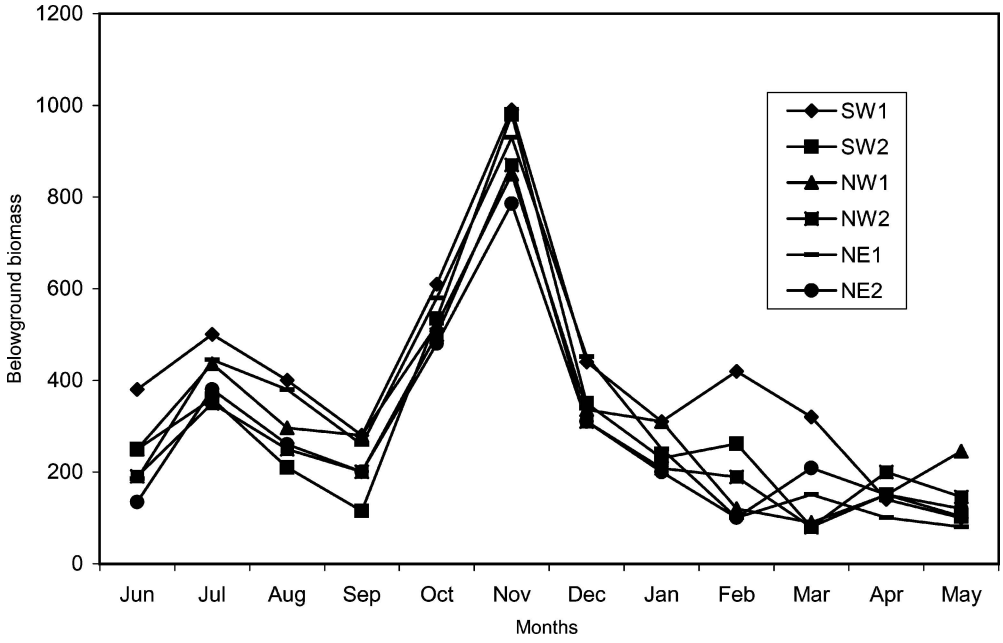

Figure 2. Belowground biomass (g m^{-2}) on the study sites.

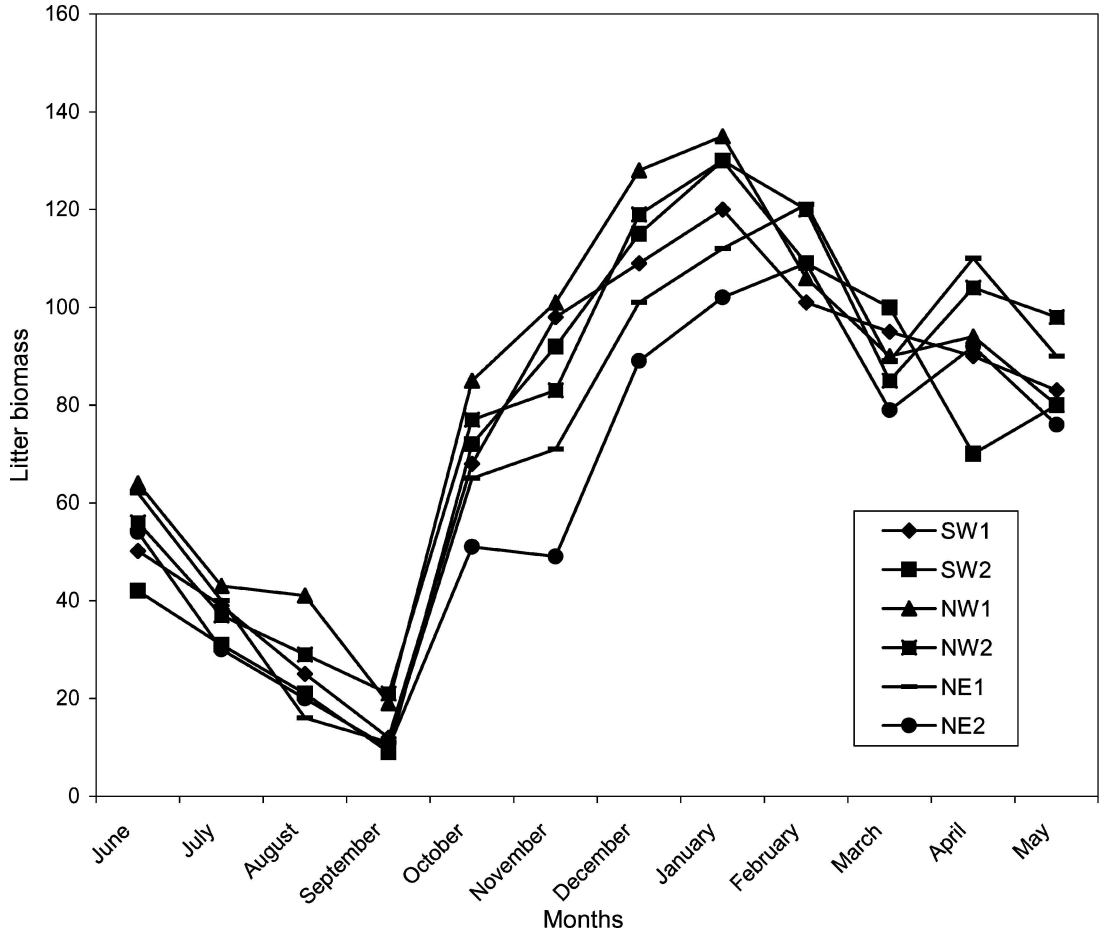

Figure 3. Litter biomass (g m^{-2}) on the study sites.

(June), 82.6 (November), 105.6 (December), 106.4 (November) and 62.8 g m^{-2} (December) respectively.

The maximum aboveground biomass was recorded in the month of September and maximum belowground biomass in November on all sites (Figs. 1–2). Sharp decline in the litter biomass was observed specially in the month of September and highest values after December on all the sites. Maximum amount of litter was recorded on sites SW_1, SW_2, NW_1 and NW_2 in the month of January, while on sites NE_1 and NE_2 it was observed in the month of February (Fig. 3).

Productivity

Maximum aboveground net production was observed during the rainy season. Forbs and grasses contributed maximum dry matter production. *Eupatorium glandulosum, Boenninghausenia albiflora* and *Dicliptera roxburghiana* were the main contributors among forbs and *Cynodon dactylon, Setaria tomentosa* and *Carex caricina* among grasses. On sites SW_1 and NW_1 the maximum dry matter production was recorded in the month of September, whereas on sites SW_2, NW_2 and NE_1, the maximum value was recorded in August and on NE_2 in the month of July. The annual aboveground net primary production amounted 1022.6, 759.2 and 731.1 g m^{-2} yr^{-1} on the sites SW_1, SW_2 and NE_1 which were dominated more by *Eupatorium glandulosum,* and 764.5, 579.5 and 528.3 g m^{-2} yr^{-1} on sites NW_1, NW_2 and NE_2 respectively (Fig. 4). Annual aboveground net primary productivity of *Eupatorium glandulosum* alone ranged from 311.1 (NW_1) to 407.2 g m^{-2} yr^{-1} (Fig. 5).

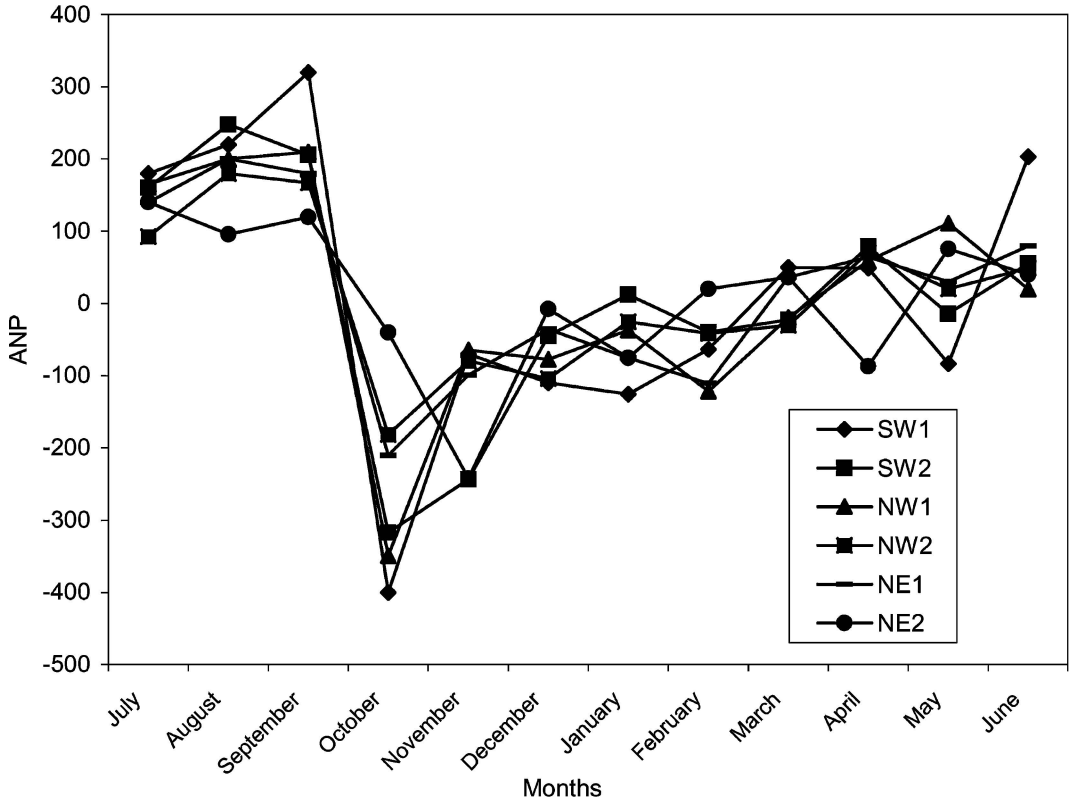

Figure 4. Aboveground net production (ANP) on the study sites (g m^{-2}).

Maximum dry matter production of belowground biomass was recorded in the month of November on all the sites. The annual belowground net primary productivity (BNP) ranged from 911.1 to 1194.2 gm^{-2} yr^{-1} on different sites (Fig. 6) and was observed maximum during winter season. On the sites more dominated by *Eupatorium glandulosum* (SW_1, SW_2 and NE_1) belowground net production amounted 1140.8, 1194.2 and 979.8 g m^{-2} yr^{-1} respectively. Annual litter biomass production was observed maximum on sites SW_1 and SW_2 (Fig. 7). Annual total net primary productivity ranged from 1496.90 to 2163.40 g m^{-2} yr^{-1} showing highest value on site SW_1 followed by sites SW_2 NE_1, NW_1, NW_2 and NE_2 (Fig. 8).

Discussion and conclusion

In the present investigation, *Eupatorium glandulosum* was the dominant herbaceous species on all the study sites followed by *Boenninghausenia albiflora*, *Ageratum conyzoides*, and *Dicliptera roxburghiana*. The composition of biomass in an ecosystem is mainly controlled by climatic conditions and edaphic characteristics (Singh and Singh, 1980). The values of total live shoot biomass in the present study were found positively correlated with rainfall on all the sites (Table 1). Values of live shoot biomass of *Eu-*

Table 1. Relationship of rainfall with total live shoot biomass and aboveground net primary productivity (ANP) on the study sites (values of correlation coefficient, r^2)

Site	Rainfall and total live shoot biomass	Rainfall and total ANP
SW_1	0.519**	0.708*
SW_2	0.608*	0.741*
NW_1	0.570*	0.634*
NW_2	0.492**	0.761*
NE_1	0.544**	0.759*
NE_2	0.562*	0.648*

*Significant (t-test) at $P < 0.05$.
**Significant (t-test) at $P < 0.10$.

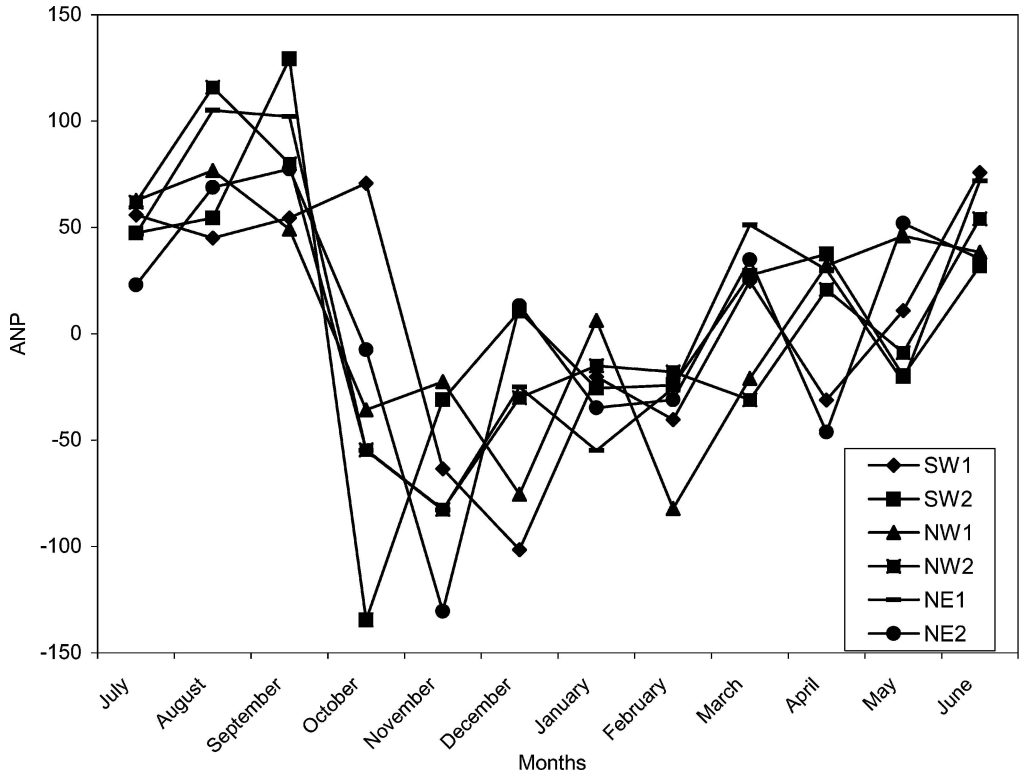

Figure 5. Aboveground net production (ANP) of Eupatorium glandulosum on the sudy sites (g m^{-2}).

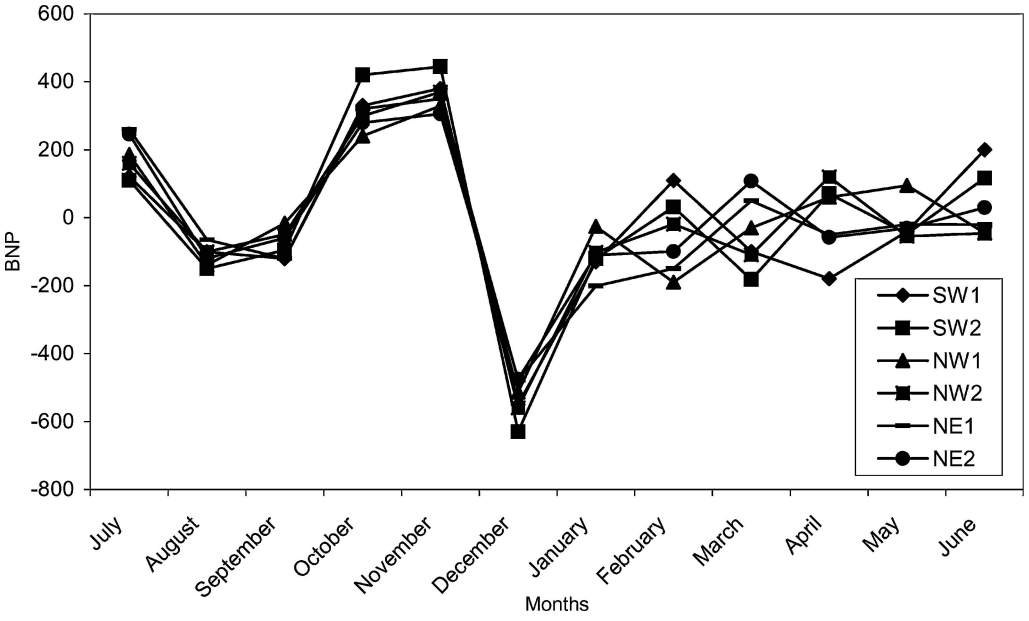

Figure 6. Belowground net production (BNP) on study sites (g m^{-2}).

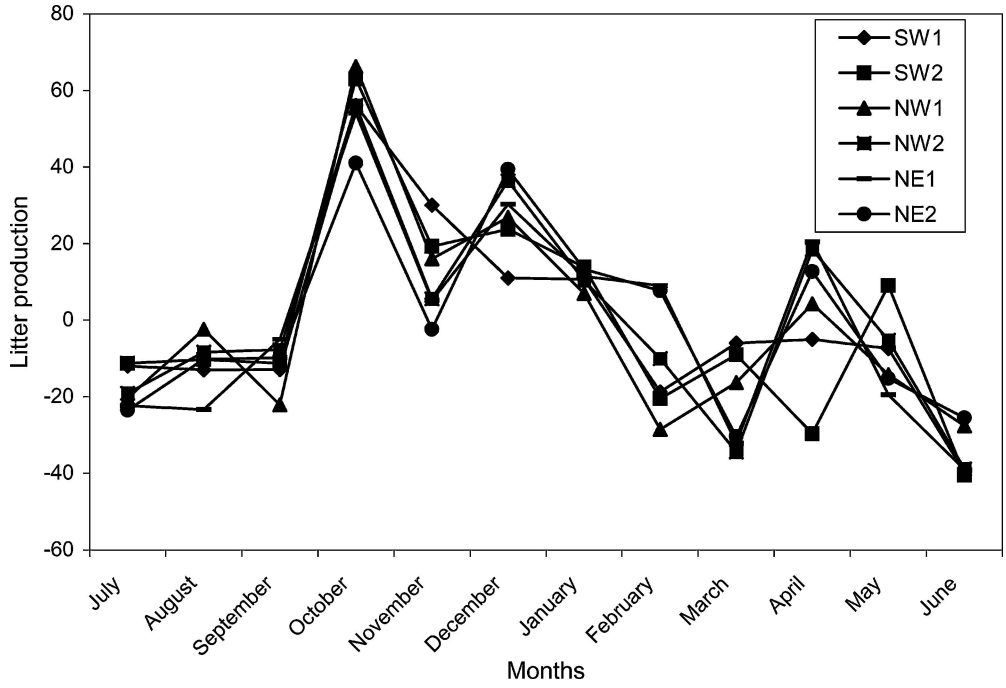

Figure 7. Litter production on the study sites (g m^{-2}).

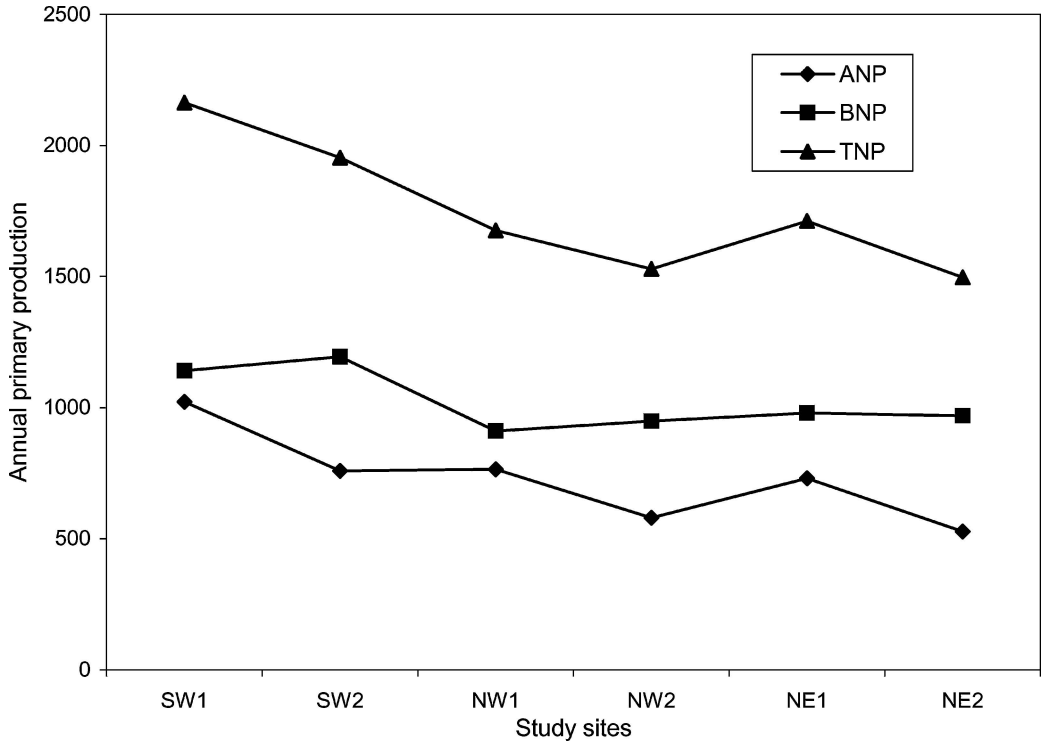

Figure 8. Aboveground (ANP), belowground (BNP) and total net primary production (TNP) on the study sites (g m^{-2} yr^{-1}).

Table 2. Relationship of rainfall with live shoot biomass and aboveground net primary productivity (ANP) of *Eupatorium glandulosum* on the study sites (values of correlation coefficient, r^2)

Site	Rainfall and live shoot biomass	Rainfall and ANP
SW_1	0.187***	0.546**
SW_2	0.412****	0.571*
NW_1	0.466****	0.704*
NW_2	0.459****	0.855*
NE_1	0.433****	0.702*
NE_2	0.440****	0.505**

*Significant (t-test) at $P < 0.05$.
**Significant (t-test) at $P < 0.10$.
***Significant (t-test) at $P < 0.60$.
****Significant (t-test) at $P < 0.20$.

patorium glandulosum were also found positively related with rainfall on all the sites. These relationships showed significance (t-test) at different probability levels (Table 2). These analyses indicate that the increase in rainfall favoured more production of live shoot biomass. The values of aboveground biomass of *Eupatorium glandulosum* were more than 32% of the total biomass of all species, which clearly demonstrate its dominance in the study area.

In the present study maximum amount of litter biomass among all the sites was within the range of highest values for temperate grasslands (Saxena and Singh, 1980; Tiwari, 1980). The total belowground biomass fluctuated greatly thoroughout the study period. This may also be a result of the dominance of *Eupatorium glandulosum*, which had much higher aboveground biomass than the belowground biomass.

The rainy season favoured higher aboveground (ANP) and belowground (BNP) net primary production. The values of ANP, BNP and total net primary productivity (TNP) were higher than the values recorded for other montane grasslands of the Himalaya (Singh and Singh, 1980; Tiwari, 1986; Rajwar and Ramola, 1990), which might have been caused by the dominance by *Eupatorium glandulosum*. The individual highest contribution of biomass and TNP by the exotic weed *Eupatorium glandulosum* has caused reduction in the biomass and production of other species.

The dominance of *Eupatorium glandulosum* is more pronounced on the sites more dominated by it. It is evident from the study that due to the dominance and invasive effect of this exotic species, fodder grasses and other economic herbs are being replaced. The invasive nature of this species has also become stronger due to its more tolerant and expanding nature and due to the its little or no palatability as fodder or any other economic use. Therefore, this exotic weed is causing a serious threat to the grassland composition and the loss of grasses and other economic species in the Himalayan region.

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