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Primary productivity and system transfer functions in an alpine grassland of Western Garhwal Himalaya

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Alpine and sub-alpine grasslands have developed relatively on steep slopes at an elevation where the climate is too cold and severe for tree growth (Yadava & Singh 1977). Tropical alpine grasslands have not been explored extensively for their diversity, productivity and system transfer functions. Unplanned grazing in these grasslands has caused erosion and threat to the survival of species and their habitats. In Indian Himalaya, a few workers have attempted to analyse various phytosociological characteristics and productivity of the alpine grasslands (Joshi *et al*. 1988; Ram *et al*. 1989). Present study was undertaken with an objective to analyse upper and lower altitude sites of an alpine grassland of the Garhwal Himalaya to provide information on species composition, biomass, productivity and system transfer functions.

The study area lies between 30^0 23'-25' N latitude and 78^0 25'-30' E longitude. The range of altitude for lower study site was 3550 - 3580 m, and for upper site 3600 - 3780 m). The study area is an alpine tract between Bhojbasa and Gaumukh on right side of the river Bhagirathi in Uttarkashi district of the Garhwal Himalaya. The total rainfall during the study period (1995) from May to October at Gangotri was 1606 mm with minimum (26 mm) in October and maximum (525 mm) in August. The temperature ranged from 6.5 ^{0}C (May) to 22.4 ^{0}C (June) during the growing season. Snowfall was frequent from December to April.

Quadrat sampling (50 x 50 cm) was done for phytosociological analysis. The importance value index was calculated following Curtis & McIntosh (1950). Diversity calculation was based on Shannon & Wiener (1963).

Biomass production was recorded for six months (growing period) from May to October 1995 at monthly intervals by harvest method. Sampling size for estimation of aboveground biomass was 50 x 50 cm (quadrat), and 25 x 25 x 30 cm (monolith) for belowground biomass estimation. Aboveground net primary production (ANP) and belowground net primary production (BNP) were determined by the method described by Singh & Yadava (1974). The net accumulation and disappearance rates were calculated on the basis of the methods given by Singh & Yadava (1974) and Sims & Singh (1978a,b).

Both the alpine sites had more than 60 % sedges followed by grasses and forbs. On the basis of IVI the community on the upper site may be called *Bothriochloa-Stellaria-Nepeta* community, and *Arundinella-Potentilla* community on the lower site (Table 1). The index of diversity was higher for the upper site (2.39) than that for the lower site (1.91), which falls within the range of diversity values reported for other alpine sites (Ram *et al*. 1989; Rikhari & Negi 1994).

On both the sites, aboveground biomass increased from May to August and decreased thereafter (Table 2). The live shoot biomass was

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positively related to the monthly rainfall values in upper and lower sites (r = 0.844 and t-test value = 3.149; and r = 0.781 and t-test value = 2.503, respectively). Belowground biomass ranged from 1503 to 2005 g m^{-2}, and 1805 to 2237 g m^{-2} on upper and lower sites respectively. Monthly aboveground net production ranged between 39.7 and 164 g m^{-2} on the study sites. Maximum monthly belowground net production was recorded for the month of September and June on upper and lower sites respectively. In alpine pastures the vegetation revives just after snow melting in April-end and the beginning of May. The life cycle of alpine plants is completed within six months, and most of them perennate by bulbs, root-stocks, rhizomes and suckers. The live shoot biomass production recorded during April-August showed the favourable climatic conditions for plant growth. The higher productivity in alpine sites as compared to Indian plains, may be attributed to snow-melt which makes the water available to plants. During September-October when temperature falls till next growing season, accumulation in the belowground parts occurred.

The peak accumulation rate of live shoot biomass indicates optimum growing conditions, which was observed in August (around 5 g m^{-2} day^{-1}) which falls within the range of peak net accumulation rates (1.7 to 7.9 g m^{-2} day^{-1}) for other alpine communities of the Himalaya (Joshi *et al.* 1988; Ram *et al.* 1989; Rikhari & Negi 1994). Limited differences in peak biomass and ANP

Table 1. Importance values (IVI) of plant species on upper and lower alpine sites.

Species	IVI of plant species	
	Upper alpine site	Lower alpine site
Bothriochloa kuntzeana	75.1	9.2
Stellaria webbiana	45.1	17.4
Nepeta discolor	44.8	32.1
Geranium ocellatum	35.1	--
Rasularia alpestris	20.8	5.9
Polygonum rumicifolium	19.7	19.5
Arundinella setosa	16.3	91.2
Potentilla sibbaldis	13.5	17.3
Potentilla fulgens	--	74.4
Anaphalis cuneifolia	11.9	24.6
Morina longifolia	11.3	--
Thymus serpyllum	--	7.7
Cynoglossum wallichii	5.8	--

Table 2. Monthly variations in the amounts of aboveground and belowground biomass, standing dead, aboveground net primary productivity (ANP), belowground net primary productivity (BNP) and total net primary productivity (TNP) of upper and lower alpine sites.

Months	Site	Aboveground live biomass (g m^{-2})	Standing dead (g m^{-2})	Litter (g m^{-2})	Belowground biomass (g m^{-2})
May	Upper	24.8 ± 8.3	10.8 ± 3.4	16.2 ± 4.9	1503 ± 80
	Lower	12.3 ± 6.1	11.2 ± 4.1	12.8 ± 3.6	1805 ± 118
June	Upper	78.2 ± 14.1	18.2 ± 7.1	18.5 ± 6.1	1584 ± 109
	Lower	128.7 ± 28.7	16.2 ± 2.7	27.7 ± 14.1	2108 ± 213
July	Upper	121.4 ± 26.7	36.2 ± 11.2	32.8 ± 11.5	1618 ± 118
	Lower	168.4 ± 26.6	30.7 ± 7.3	38.4 ± 12.9	2237 ± 368
Aug.	Upper	285.8 ± 44.3	48.6 ± 10.3	38.2 ± 8.2	1566 ± 261
	Lower	318.6 ± 38.3	38.8 ± 11.7	42.5 ± 22.4	1903 ± 221
Sept.	Upper	177.1 ± 24.2	42.8 ± 6.9	52.5 ± 12.6	2005 ± 311
	Lower	284.3 ± 35.1	8.2 ± 19.3	39.2 ± 16.7	2217 ± 196
Oct.	Upper	57.8 ± 13.5	63.2 ± 12.5	61.5 ± 11.4	1608 ± 128
	Lower	108.7 ± 31.9	54.6 ± 18.8	57.1 ± 23.2	1808 ± 133
Total	Upper	261 (ANP)		554 (BNP)	815 (TNP)
	Lower	306 (ANP)		646 (BNP)	952 (TNP)

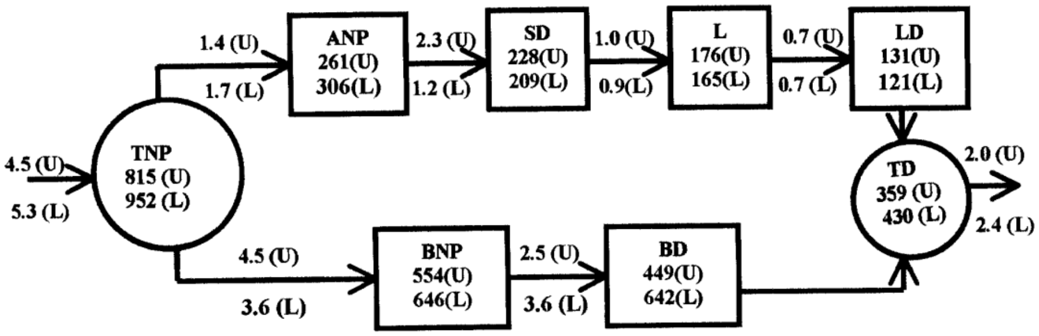

Fig. 1. Accumulation and disappearance rates ($gm^{-2}day^{-1}$) on upper and lower sites during the study period (180 days) (Values for upper site are shown by '(U)' and for lower site by '(L)'; ANP = Aboveground net primary production; BNP = Belowground net primary production; TNP = Total net primary production; SD = Standing dead; L = Litter; LD = Litter disapperance; BD = Belowground disapperance; TD = Total disappearance).

indicate that majority of the species assimilated peak biomass simultaneously. The values of BNP in the present sites are higher than the values reported for an alpine grassland of the Himalaya by Ram *et al.* (1989). The values of ANP and TNP for the present sites (Table 2) are also comparable with the values for other alpine grasslands of the Himalaya.

The net accumulation and disappearance of dry matter in both the sites have been given in Fig. 1. The total input into the system was around 5 g m^{-2} day^{-1} in these sites, and the total values of output after disappearance on upper and lower sites were 2.0 and 1.8 g m^{-2} day^{-1}, respectively. Other transfer functions range from 32 % to 99 %.

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