Effect of fertilizer on plant biomass distribution and net accumulation rate in an alpine meadow in central Himalaya, India

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Abstract

The objective of this study was to observe the effect of nitrogen application on the plant biomass and rate of net aboveground accumulation in an alpine grassland of Central Himalaya, dominated by the grass *Danthonia cachemyriana*, Jaub. and Spach. Nitrogen was applied in the form of urea at the rate of 250 kg ha^{-1} in late May 1984 and late April 1985. Aboveground and belowground biomass from both fertilized and control plots were measured from a day before fertilization and at 30-day intervals throughout the growing season in 1984 and 1985. The aboveground net accumulation (ANC) in 1984 was 409 g m^{-2} for the control and 450 g m^{-2} for treated plots, and in 1985 it was 382 g m^{-2} in the control and 458 g m^{-2} in the treated plots. The differences in ANC between control and fertilized plots were significant at $P<0.05$ for 1984 and $P<0.01$ in 1985. The belowground net accumulation (BNA) in 1984 was slightly greater in the treated plots (314 g m^{-2}) compared to the control (207 g m^{-2}), but in 1985 the BNA was significantly ($P<0.05$) higher (328 g m^{-2}) for the control plots compared to treated plot (222 g m^{-2}). Results indicate that this alpine meadow is less nitrogen limited than the grasslands studied elsewhere. Nitrogen fertilization had more effects on the pattern of biomass allocation than on total production.

Key Words: fertilizer, plant biomas, net primary productivity

Nutrient availability limits growth of most tundra plants, as shown by fertilization experiments in many locations throughout the arctic (Babb and Whitfield 1977; Mckendrick et al., 1978, 1980; Shaver and Chapin 1980, 1986; Shaver et al. 1986). The availability of nitrogen, more than any other element, is the critical determinant of both the structure and productivity of grassland communities (Date 1973). Henry et al., (1986) found, for the tundra plant communities, the response to nitrogen to be weaker in the more mesic and wet-mesic locations compared to desert communities.

The present study deals with the effect of nitrogen application on plant biomass and net dry matter accumulation rates in a Central Himalayan alpine grassland, dominated by the grass *Danthonia cachemyriana* Jaub and Spach. In this grassland, plant growth during the favorable growth period (May–September) seems not to be limited by moisture. Sufficient soil moisture is provided by the snow-melt from May to mid-June and rainfall is quite high from mid-June to mid—September due to the monsoon (Ram et al. 1988). We hypothesized that because of the favorable moisture, nutrient release from litter of the previous year should be adequate for the growing season so that plant productivity would not be limited by a shortage of nitrogen.

Methods and Materials

The study site Rudranath, lies between 30° 28′ N lat. and 79° 20′ E long., at an average elevation of 3,600 m. The mean daily temperature in 1984 ranged from 5.0 and 21.2° C and the mean daily minimum between 2.0 and 10.5° C from April to November. The low values occurred in November and the high in June. During May–October the site received 1,586 mm rainfall. The soil is a residue from crystalline silty loam in texture with a mean depth of 30 cm. The pH ranged between 4.5–5.3, Kjeldahl nitrogen ranged between 0.4–0.9%, and available phosphorus between 0.001–0.007% (Ram et al. 1989).

The effect of nitrogen application was studied during the snow-free period (from May to September) of 1984 and 1985. Six physiognomically similar plots each of 10 × 10 m area were selected for the study. Three of these plots were maintained as control (Co), while the remaining 3 were fertilized once in 1984 (F_1) and again in 1985 (F_2) in a randomized block design. Each plot was divided into 1 × 1-m subplots. Nitrogen in the F_1 and F_2 plots was applied in the form of urea at the rate of 250 kg/ha^{-1} in late May 1984 and late April 1985.

The aboveground and belowground plant biomass from both fertilized and control plots were measured. Starting from a day before the fertilization, sampling was done at 30-day intervals through 30 October each year. For aboveground biomass, three 1 × 1-m subplots were harvested at random from each treatment plot on each sampling date. No subplot was harvested more than once. The harvested material from each subplot was separated into live shoots and dead shoots. Litter was collected from each subplot subsequent to its harvest.

The belowground plant material was collected using one monolith (25 × 25 × 30 cm) from each harvest subplot after the aboveground components had been sampled. Roots were washed free of soil particles using a thin jet of water. All plant samples were dried at 80° C and weighed.

The aboveground net accumulation (ANC) was the peak live shoot biomass of the community. The belowground accumulation, was the difference between maximum and minimum biomass values during the study period.

The rate of biomass increment was calculated on the basis of live shoot dry weight as follows:

$$\text{Increment rate} = W_2\ W_1/t_2\text{–}t_1$$

where, W_1 and W_2 are the shoot dry weights (g m^{-2}) at the beginning (t_1) and at the end (t_2) of the sampling period. The interval t_2–t_1 is in days.

Results

Aboveground Biomass

The time-series biomass of live shoots, dead shoots, litter, and belowground parts for both treatments are shown in Figure 1 for the 2 study years. The data were subjected to Analysis of Variance using the SPSS (New Version) programme (SPSS Inc. Chicago, Illinois).

In 1984 the live shoot biomass increased from 100 g m^{-2} in May to 409 g m^{-2} in August in the control plots (CO_{84}) and from 94^{-2} in May to 450 g m^{-2} in August in the fertilized plots (F_1). Thereafter the live shoot biomass declined and reached a minimum (33 and 34 g m^{-2}) in October.

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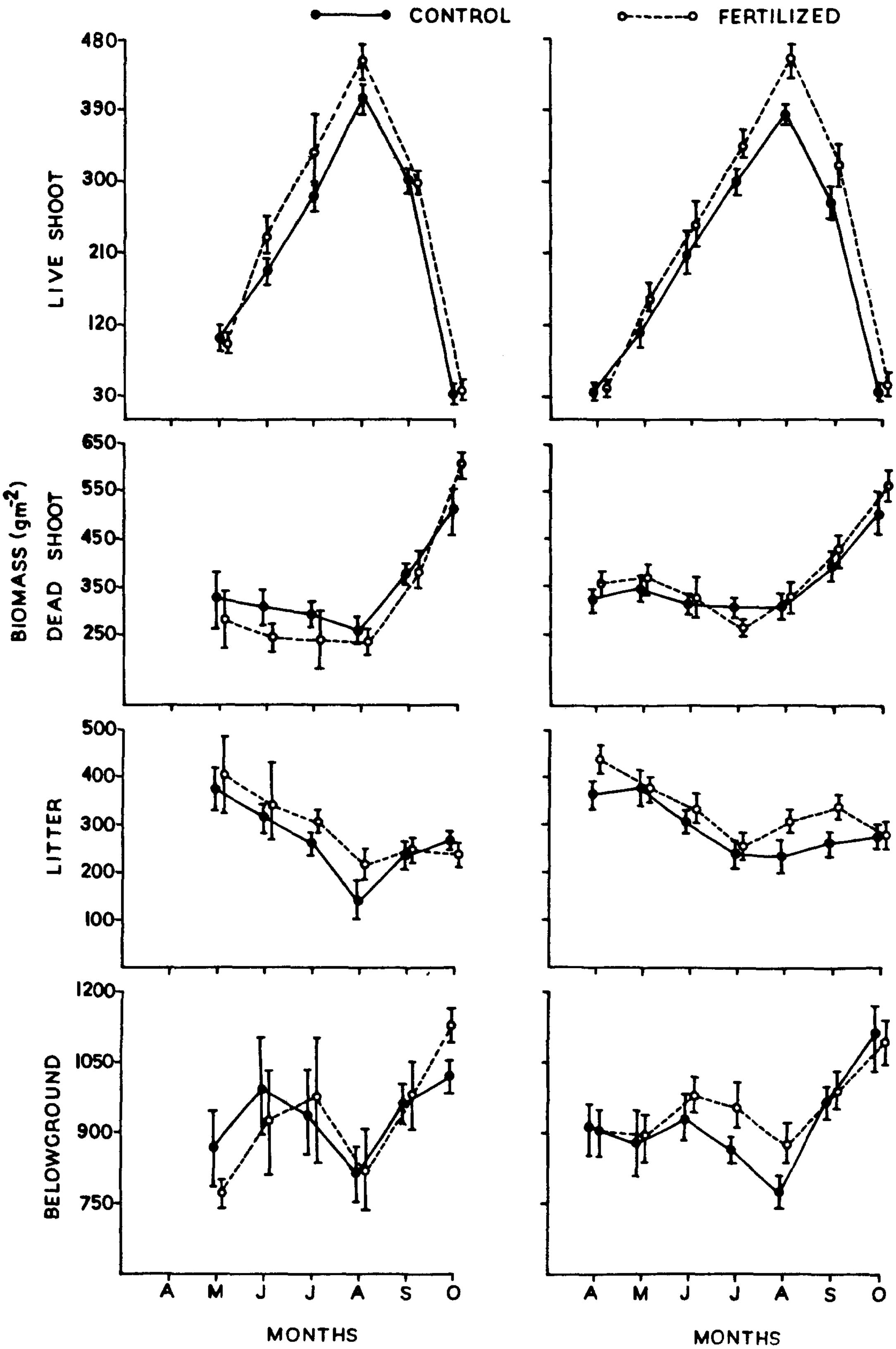

Fig. 1. Variation in the biomass of various primary producer compartments in an alpine meadow of Central Himalaya. The solid line is for control and broken line is for fertilizer treatment. Vertical bars represent ± 1 SE.

In 1985, the biomass increased from 43 g m^{-2} in April to 458 g m^{-2} in August in the fertilized plots (F_2), compared to 33 g m^{-2} in April and 382 g m^{-2} in August in the control plots (Co_{85}). The differences due to month were significant ($p<0.01$) but not due to year. The peak biomass was significantly higher in fertilized plots than in control plots in both years, ($p<0.05$ in 1984 and $p<0.01$ in 1985).

The dead shoot biomass declined from May to August each year in both the control and fertilized plots. Values were 323 g m^{-2} in May and 286 g m^{-2} in August in Co_{84} and 275 g m^{-2} in May and 235 g m^{-2} in August in the fertilized plot. After August the dead shoot biomass increased and attained a peak (509 g m^{-2} and 500 g m^{-2} in control plots and 610 g m^{-2} and 559 g m^{-2} in fertilized plots in 1984 and 1985, respectively) in October. The differences due to year were not significant but those due to months ($p<0.01$) and due to fertilization ($p<0.01$) were significant.

The litter mass declined from May to August in both the control and fertilized plots in both the years. The seasonal patterns of dead biomass and litter in fertilized plots were simlar to that in the control plots both years. However, peak values were significantly ($p<0.01$) different (375 g m^{-2} vs 404 g m^{-2} in 1984 and 376 vs 443 g m^{-2} in 1985). The differences due to months were also significant for both years ($p<0.01$).

Belowground Biomass and Root:Shoot Ratio

The seasonal patterns of the belowground biomass were similar for control and fertilized plots and the differences due to months were significant ($p<0.05$). Fertilization did not show a significant effect on the peak biomass of belowground components.

The root:shoot ratio decreased from April and May to August, increasing in September–October. It ranged from 1.1 : 1 (August) to 2.6 : 1 (May) in control and from 1.1 : 1 (August) to 2.3 : 1 (May) in the fertilized plots during the 2 years of study.

Effect of Fertilizer on Net Aboveground Biomass Accumulation

The aboveground net accumulation (ANC) was 409 g m^{-2} for Co_{84} and 450 g m^{-2} for F_2 treatment and 382 g m^{-2} for Co_{85} and 458 g m^{-2} for F_1 treatments (Fig. 2). The ANC was significantly different between the control and the treated plots ($p<0.05$ in 1984 and $p<0.01$ in 1985).

The belowground net accumulation (BNA) was slightly but not significantly higher in F_1 (314 g m^{-2}) than in Co_{84} (207 g m^{-2}). However, in 1985 the BNA was 328 g m^{-2} in Co_{85} and 222 g m^{-2} in F_2 plots ($p<0.05$). Obviously, double fertilization brought about a change in allocation of biomass to plant parts, causing a dramatic increase in accumulation of biomass in shoots partly at the expense of roots.

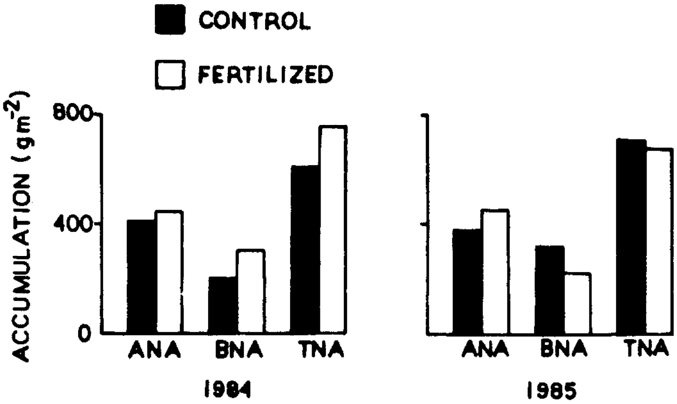

Fig. 2. Effect of fertilizer on aboveground net accumulation (ANA), Belowground net accumulation (BNA) and total net accumulation (TNA) in 2 years of study.

Discussion

Lorentz and Rogler (1973a) have reported that spring growth can be stimulated by application of fertilizer nitrogen. Earlier initiation of spring growth and accelerated growth rate early in the season following application of nitrogen have also been observed by others (Rogler and Lorentz 1965, Johnston et al. 1967) as well. In a study of mixed prairie, Lorentz and Rogler (1973b) have reported that subsequent to fertilization the cool-season species found in the mixed prairie begin growth early in the spring, a time when low soil temperature restricts natural nitrification processes. Therefore, response to application of nitrogen early in the growing season is sizeable, even on soils relatively high in total nitrogen.

The increase in the live shoot biomass after application of fertilizer was significantly different from the control during both years of study. The litter mass was significantly greater in the second year of the study, evidently as a consequence of induced production. These results indicate net accumulation in the Central Himalayan alpine meadow is somewhat nutrient limited, but far less than that of the tussock tundra, Alaska (Table 1). For, the latter Shaver and Chapin (1986) reported that fertilization caused an increase in total

Table 1. Effect of fertilizer on aboveground biomass and production, and comparison with other Alpine studies.

	Biomass (g m^{-2})				Production (g m^{-2})		Vegetation type	Source
	Once fertilized		Twice fertilized		Control	Fertilized		
	Control	fertilized	Control	fertilized				
Mt. Washington Alpine (44° N)	146.0	151.4	—	—	146.0	151.4	*Carex* meadow	Bliss (1966)
Toalik Lake, Alaska (68°)	155.6	278.7	—	—	70.1	131.1	*Eriophorum vaginatum*	Chapin and Shaver (1985)
Eagle Creek Alaska (65°)	212.1	330.6	—	—	—	—	*E. vaginatum*	Shaver and Chapin (1986)
Kuparuk Ridge (68°)	151.7	169.4	—	—	—	—	*E. vaginatum*	Shaver and Chapin (1986)
Kuparuk Ridge (68°)	139.6	152.3	139.6	206.3	—	—	*E. vaginatum*	Shaver and Chapin (1986)
Sagwon (69°)	—	—	161.7	288.1	—	—	*E. vaginatum*	Shaver and Chapin (1986)
Rudranath Himalaya (30° N)	409.0	450.0	382.0	458.0	382.0–409.0	450-458	*Danthonia cachemyriana*	Present study

community aboveground production up to 300% and aboveground biomass 110%. In this study total net biomass accumulations in F_1 and F_2 plots were 15 to 20% greater than the control plots (Table 1).

The effect of nitrogen fertilization during the first year on the net accumulation of belowground biomass was conspicuous in the later part of the season (September–October), the value being 140 g m^{-2} compared to 67 g m^{-2} in the control plot. It seems that this large accumulation of biomass in the belowground component in fertilized plots supports a particularly faster growth of shoots in the first month of the second year of the study than occurred in control plots. A part of this increase in shoot growth was at the expense of the belowground parts. We suggest that the retranslocation of nutrients from the belowground component to growing shoots made plants relatively independent of the soil nutrient pool. The effect of fertilization when soil temperatures are lower is likely to be insignificant on shoot growth for low temperatures would limit the nitrogen uptake by physiologically inactive plants.

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