



Biomass Variation in The Alpine Pastures of Mandi District, Himachal Pradesh

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Received: August 31, 2023 Accepted: January 3, 2024

OPEN ACCESS

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Citation

Kumar, A. and Prashar, K.K. 2024.
Biomass variation in the alpine pastures
of Mandi district, Himachal Pradesh.
Annals of Arid Zone 63(1): 47-52
doi: 10.59512/aaz.2024.63.1.5
[https://epubs.icar.org.in/index.php/AAZ/
article/view/141778](https://epubs.icar.org.in/index.php/AAZ/article/view/141778)

Abstract: The present study deals with seasonal variation in the biomass dynamics of different plant compartments at six sites, varying in elevation from 2550 to 3350 m of Mandi district, Himachal Pradesh. In the present study, the aboveground biomass and belowground biomass at all the six study sites were recorded maximum in rainy season and minimum in the winter season while the standing dead vegetation and litter biomass at all the six study sites were recorded maximum in winter season and minimum was recorded in the rainy season during the year. The aboveground biomass varied from 42 ± 6 gm⁻² to 290 ± 25 gm⁻² while belowground biomass varied from 66 ± 5 gm⁻² to 374 ± 37 gm⁻² while standing dead vegetation varied from 8.6 ± 2 gm⁻² to 36 ± 7 gm⁻² and litter biomass varied from 11.2 ± 2 gm⁻² to 31.4 ± 7 gm⁻² at six different alpine pasture sites. The differences in the biomass dynamics of different plant compartments were mostly due to variations in climate, elevation and the intensity of biotic interferences.

Key words: Alpine, Aboveground biomass, Belowground biomass, Standing dead vegetation, Litter biomass.

The term "alpine" is derived from the Latin word "albus" which means white (or snow- covered) originally referring to the peaks of Alps (Love, 1970). Alpine refers to those lands lying above climatic limit of upright trees. It is a region of open vegetation, above the timberline where general environment and the vegetation are extensively different from that of lowland. These alpine regions are characterized by low atmospheric pressure, low temperature, and intense insulation, rapid and high ultraviolet radiation along with other correlated effects as chain reactions. These alpine regions frequently fall in the great Himalayan ranges. The great alpine Himalayas lie in the north temperate zone. In the western Himalayas, roughly 60% of the total geographical area of Himachal Pradesh falls in the lesser and greater Himalayan zone. The important alpine regions in Himachal Pradesh are the Dhauladhar and Pir Panjal ranges (Santvan, 1993). The key component of alpine ecosystems is the vegetation cover which controls the functional integrity of high altitudes in terms of stabilizing the mountain slopes, prevention of soil erosion and source of primary production for all the trophic levels.

The pastures in the alpine zone occupy about 1.52% of the total land area in the country and are chiefly concentrated in the Himalayan states of Arunachal Pradesh, Sikkim, Uttarakhand, Himachal Pradesh and Union Territory of Jammu & Kashmir. The Himalayan land in India is enclosed by alpine pastures usually found at an altitude above 2400 m and where climate is not suitable for growth of any trees. In Himachal Pradesh alpine pastures cover around 10,052 km² area which otherwise represent 18.1% of the total geographical area of the state (Verma and Kapoor, 2014). These alpine pastures are locally known as Dhar in Himachal Pradesh.

The study of biomass provides useful information about the quantity of organic matter produced in a given time under the existing environmental conditions. Biomass estimates provide one way of assessing land for browse, forage, and potential wildlife productivity. Biomass assessments are particularly useful in management of biomass dynamics of different plants compartments. A study was conducted to analyze the seasonal variation in the biomass dynamics of different plant compartments of Mandi district, Himachal Pradesh.

Materials and Methods

The study was conducted in six alpine pasture of Mandi district, Himachal Pradesh (Table 1). The present study deals with seasonal biomass dynamics of different plant compartments such as aboveground biomass, belowground biomass, litter and standing dead vegetation during the year 2018. Biomass can either be expressed in fresh weight or in dry weight but it is more appropriate to express it in dry weight to eliminate the error due to moisture content. The study was carried out in summer season in May, rainy season in August and winter season in November. The climatic data for these alpine pastures are not

available. The data for rainfall and temperature was considered from Mandi district station. The climatic data was obtained from Climate Forecast System Reanalysis. During the year seasonal precipitation ranged from 30.5 mm in May to 434.0 mm in August while the monthly average maximum temperatures typically range from 22.5°C November to 33.3°C in May and the average minimum temperature ranged from 8.8°C November to 16.9°C in May. The study mainly concerned with the total herbage production not species-wise. The biomass of different plant compartments was evaluated by harvest method. Ten quadrates (1 x 1 m) were laid randomly at each site for estimating herb biomass. The plant material was clipped at ground level, packed in polythene bags and brought to the laboratory. The phytomass thus collected, was washed in laboratory and packed separately in paper bags. Standing dead vegetation was clipped at surface level and was packed separately. Litter was handpicked after the removal of green biomass and washed in laboratory to remove any adhering soil fractions and was packed in paper bags. Belowground biomass was also sampled every time by digging 10 monoliths up to 30 cm, where maximum root biomass remains concentrated. They were broken in the field and roots were packed in polythene bags. The plant material of aboveground shoots, standing dead vegetation, litter and belowground root were oven dried at 80°C till constant weight was obtained for biomass determination.

Results and Discussion

The aboveground biomass at all the six study sites was recorded maximum in rainy season while minimum was recorded in the winter season during the year. The aboveground biomass at Prashar alpine pasture varied from 45 ± 4 gm⁻² (Winter season) to 236 ± 31 gm⁻² (Rainy season), for Tikkagahar alpine pasture

Table 1. Six different alpine pastures study sites in District Mandi, Himachal Pradesh

S.No.	Study sites	Altitude (m)	Latitude	Longitude
I	Prashar	2550-2750	31°44'54.61"N to 31°44'57.72"N	77°06'32.53"E to 77°06'55.14"E
II	Tikkagahar	2800-2900	32°03'29.63"N to 32°03'33.64"N	76°47'13.82"E to 76°47'19.69"E
III	Kamrunag	2850-2950	31°28'07.50"N to 31°28'19.85"N	77°03'30.39"E to 77°03'33.97"E
IV	Pandar	2850-3050	31°27'50.39"N to 31°27'56.26"N	77°03'55.78"E to 77°04'26.63"E
V	Thachi	2950-3100	31°38'14.94"N to 31°38'17.16"N	77°15'07.48"E to 77°15'23.52"E
VI	Shikari Devi	3100-3350	31°28'45.50"N to 31°28'49.36"N	77°09'32.54"E to 77°10'02.18"E

Note: N = North, E = East, m = meter

Table 2. Seasonal variations in aboveground biomass at six alpine pastures

Season	Above ground biomass (gm ²)					
	Prashar	Tikkagahar	Kamrunag	Pandar	Thachi	Shikari Devi
Summer	114 ± 25	106 ± 23	148 ± 28	170 ± 27	167 ± 29	175 ± 26
Rainy	236 ± 31	227 ± 36	265 ± 34	279 ± 32	276 ± 30	290 ± 25
Winter	45 ± 4	42 ± 6	51 ± 7	64 ± 9	62 ± 7	69 ± 8

Table 3. Seasonal variations in belowground biomass at six alpine pastures

Season	Below ground biomass (gm ²)					
	Prashar	Tikkagahar	Kamrunag	Pandar	Thachi	Shikari Devi
Summer	172 ± 22	156 ± 24	195 ± 23	223 ± 21	220 ± 25	228 ± 24
Rainy	300 ± 31	295 ± 29	332 ± 33	362 ± 34	358 ± 36	374 ± 37
Winter	70 ± 7	66 ± 5	79 ± 8	88 ± 7	87 ± 6	91 ± 8

aboveground biomass varied from 42 ± 6 gm² (Winter season) to 227 ± 36 gm² (Rainy season), for Kamrunag alpine pasture aboveground biomass varied from 51 ± 7 gm² (Winter season) to 265 ± 34 gm² (Rainy season), for Pandar alpine pasture aboveground biomass varied from 64 ± 9 gm² (Winter season) to 279 ± 32 gm² (Rainy season), for Thachi alpine pasture aboveground biomass varied from 62 ± 7 gm² (Winter season) to 276 ± 30 gm² (Rainy season) and for Shikari Devi alpine pasture aboveground biomass varied from 69 ± 8 gm² (Winter season) to 290 ± 25 gm² (Rainy season) respectively (Table 2). The increase in aboveground biomass of alpine pastures from summer season onward and peaked during rainy season reflected the active growth period for various plant species while decline in winter season was caused by the senescence of annual species, as well as senescence of some perennial species due to their short life cycle and senescence of herbaceous vegetation due to heavy frosting condition. Similar results reported by Santvan (1993); Dhaulakhandi *et al.* (2000); Gavali (2003); Singh and Sundriyal (2005); Dhaulakhandi and Rajwar (2007); Dhaulakhandi *et al.* (2010b); Joshi and Rawat (2011); Joshi and Pant (2012); Joshi *et al.* (2012); Namgail *et al.* (2012); Prakash and Paliwal (2012) and Mitra (2018). The aboveground biomass was recorded maximum at Shikari Devi alpine pasture while minimum was recorded at Tikkagahar alpine pasture during the year.

Belowground plant material is the main contributor of biomass production in the alpine community. During the year, the belowground biomass at Prashar alpine pasture varied from 70 ± 7 gm² (Winter season) to 300 ± 31 gm²

(Rainy season), for Tikkagahar alpine pasture belowground biomass varied from 66 ± 5 gm² (Winter season) to 295 ± 29 gm² (Rainy season), for Kamrunag alpine pasture belowground biomass varied from 79 ± 8 gm² (Winter season) to 332 ± 33 gm² (Rainy season), for Pandar alpine pasture belowground biomass varied from 88 ± 7 gm² (Winter season) to 362 ± 34 gm² (Rainy season), for Thachi alpine pasture belowground biomass varied from 87 ± 6 gm² (Winter season) to 358 ± 36 gm² (Rainy season) and for Shikari Devi alpine pasture belowground biomass varied from 91 ± 8 gm² (Winter season) to 374 ± 37 gm² (Rainy season) respectively (Table 3). In the present study, the belowground biomass of all the six study sites was recorded maximum in rainy season while minimum was recorded in the winter season during the year. Belowground biomass in the present study was increased from summer season and peaked in rainy season and then declined in winter season. The increase biomass in rainy season could be due to higher translocation of organic matter and the accumulation of dead shoots while lower values in winter season could be due to continuous removal of aboveground parts by heavy grazing which does not allow much of the photosynthates to deposit in their underground parts and also due to completion of life cycle of most of the plants hence death of many plants occurred. Similar results reported by Bawa (1986); Pandey and Singh (1992); Rikhari and Negi (1994); Bhandari *et al.* (1999); Kar (2012) and Prakash and Paliwal (2012). The belowground biomass was recorded maximum at Shikari Devi alpine pasture while minimum was recorded at Tikkagahar alpine pasture during the year.

Table 4. Seasonal variations in standing dead vegetation at six alpine pastures

Season	Standing dead vegetation (gm ⁻²)					
	Prashar	Tikkagahar	Kamrunag	Pandar	Thachi	Shikari Devi
Summer	16.6 ± 4	17.4 ± 5	18.2 ± 6	18 ± 5	19.2 ± 7	19.8 ± 8
Rainy	8.8 ± 3	8.6 ± 2	9 ± 4	9.4 ± 5	10.4 ± 5	10.8 ± 6
Winter	32.4 ± 6	33.6 ± 7	34.4 ± 6	35.2 ± 5	35 ± 6	36 ± 7

Table 5. Seasonal variations in litter biomass at six alpine pastures

Season	Litter (gm ⁻²)					
	Prashar	Tikkagahar	Kamrunag	Pandar	Thachi	Shikari Devi
Summer	20.8 ± 3	21.4 ± 4	22 ± 4	22.8 ± 5	23.6 ± 4	24.2 ± 5
Rainy	11.2 ± 2	11.6 ± 2	12 ± 3	12.2 ± 3	12.6 ± 4	14 ± 5
Winter	28.8 ± 5	29.4 ± 6	30.2 ± 6	30.6 ± 8	31.2 ± 7	31.4 ± 7

In the present study during the year, the standing dead vegetation value of Prashar alpine pasture varied from $8.8 \pm 3 \text{ gm}^{-2}$ (Rainy season) to $32.4 \pm 6 \text{ gm}^{-2}$ (Winter season), for Tikkagahar alpine pasture standing dead vegetation value varied from $8.6 \pm 2 \text{ gm}^{-2}$ (Rainy season) to $33.6 \pm 7 \text{ gm}^{-2}$ (Winter season), for Kamrunag alpine pasture standing dead vegetation value varied from $9 \pm 4 \text{ gm}^{-2}$ (Rainy season) to $34.4 \pm 6 \text{ gm}^{-2}$ (Winter season), for Pandar alpine pasture standing dead vegetation value varied from $9.4 \pm 5 \text{ gm}^{-2}$ (Rainy season) to $35.2 \pm 5 \text{ gm}^{-2}$ (Winter season), for Thachi alpine pasture standing dead vegetation value varied from $10.4 \pm 5 \text{ gm}^{-2}$ (Rainy season) to $35 \pm 6 \text{ gm}^{-2}$ (Winter season) and for Shikari Devi alpine pasture standing dead vegetation value varied from $10.8 \pm 6 \text{ gm}^{-2}$ (Rainy season) to $36 \pm 7 \text{ gm}^{-2}$ (Winter season) respectively (Table 4). In the present study, the standing dead vegetation of all the six study sites were recorded maximum in winter season while minimum was recorded in the rainy season during the year. The high values of standing dead material in winter season followed by summer season can be attributed to ageing of the plants, since most of the plant species completed their active growth till September/October, thereafter senescence of the plants started. Low values of standing dead biomass in rainy season revealed that during this period active growth of plant occurred. Similar result reported by Singh and Joshi (1985) and Ram *et al.* (1989). The standing dead vegetation was recorded maximum at Thachi alpine pasture during the year while minimum was recorded at Prashar alpine pasture. The low values of standing dead vegetation in different seasons can be ascribed due to the grazing. The

herbivores consumed aboveground biomass before it could turn into standing dead material thus showing low values of standing dead vegetation.

During the year, the litter biomass of Prashar alpine pasture varied from $11.2 \pm 2 \text{ gm}^{-2}$ (Rainy season) to $28.8 \pm 5 \text{ gm}^{-2}$ (Winter season), for Tikkagahar alpine pasture litter biomass varied from $11.6 \pm 2 \text{ gm}^{-2}$ (Rainy season) to $29.4 \pm 6 \text{ gm}^{-2}$ (Winter season), for Kamrunag alpine pasture litter biomass varied from $12 \pm 3 \text{ gm}^{-2}$ (Rainy season) to $30.2 \pm 6 \text{ gm}^{-2}$ (Winter season), for Pandar alpine pasture litter biomass varied from $12.2 \pm 3 \text{ gm}^{-2}$ (Rainy season) to $30.6 \pm 8 \text{ gm}^{-2}$ (Winter season), for Thachi alpine pasture litter biomass varied from $12.6 \pm 4 \text{ gm}^{-2}$ (Rainy season) to $31.2 \pm 7 \text{ gm}^{-2}$ (Winter season) and for Shikari Devi alpine pasture litter biomass varied from $14 \pm 5 \text{ gm}^{-2}$ (Rainy season) to $31.4 \pm 7 \text{ gm}^{-2}$ (Winter season) respectively (Table 5). Litter biomass of all the six study sites were recorded maximum in winter season while minimum was recorded in rainy season during the year. High litter biomass was recorded in winter season which was followed by summer season and rainy seasons. This can be attributed to ageing factor of plants and completion of their life cycles hence reaching maturity. Besides this, high temperature during summer season also played an important role in it. Similar result reported by Kapoor (1987); Ram *et al.* (1989); Santvan (1993) and Gavali (2003). The litter biomass was recorded maximum at Shikari Devi alpine pasture and minimum was recorded at Kamrunag alpine pasture during the year. Litter biomass production can be attributed by grazing due to herbage removal by the herbivores which reduced litter formation. The fluctuation in the

litter biomass from season to season can be attributed to source of production and its rate of disappearance.

It was observed that the belowground biomass was higher than the aboveground biomass at all alpine pastures in different seasons during the year, can also be attributed to the removal of aboveground biomass by herbivores. Similar findings were reported by Singh and Sundriyal (2005); Anthwal (2007) and Dhaulakhandi *et al.* (2010a). The differences in the biomass dynamics of different plant compartments from site to site were mostly due to variations in climate, elevation and the intensity of biotic interferences.

The some important plants species of these alpine pastures were *Achillea millefolium*, *Ainsliaea latifolia*, *Ajuga bracteosa*, *Allium humile*, *Anaphalis contorta*, *Anaphalis triplinervis*, *Anemone obtusiloba*, *Anemone rivularis*, *Anemone vitifolia*, *Arisaema jacquemontii*, *Arisaema propinquum*, *Bergenia ciliata*, *Bergenia stracheyi*, *Chenopodium album*, *Cirsium falconeri*, *Cirsium wallichii*, *Clinopodium umbrosum*, *Corydalis govaniana*, *Delphinium vestitum*, *Diplazium esculentum*, *Euphrasia himalayica*, *Fragaria vesca*, *Fritillaria roylei*, *Galium aparine*, *Geranium wallichianum*, *Mazus surculosus*, *Mentha longifolia*, *Mentha spicata*, *Nepeta elliptica*, *Nepeta govaniana*, *Nepeta leucophylla*, *Origanum vulgare*, *Parnassia nubicola*, *Phlomis bracteosa*, *Plantago depressa*, *Polygonatum verticillatum*, *Prunella vulgaris*, *Roscoeia alpina*, *Selinum vaginatum*, *Tanacetum dolichophyllum*, *Taraxacum officinale*, *Thalictrum foliolosum*, *Thymus linearis*, *Verbascum thapsus*, *Veronica persica*, *Viola biflora*.

Biomass estimates provide one way of assessing potential of pasture. Biomass assessments are particularly useful in management of biomass dynamics of different plants compartments. The increase in biomass over a certain period is a determination of vitality of plants in different environmental conditions during that time. The biomass continuously changes from one season to the other by the process of production, mortality and disappearance. The rate of change varies from season to season and influenced by abiotic and biotic factors. The different species of a community vary in their time of germination, growth, maturity and senescence. These differences cause them to reach their maximum

and minimum biomass in different seasons of the year. Thus, it was clear that in these alpine pastures, the biomass production was regulated either directly or indirectly by both abiotic and biotic variable. Grazing directly influences biomass production by herbage removal and changes the microhabitat of these pastures. In order to improve these alpine pastures, the scientific managements of these pastures needs to be consider and controlled & rotational grazing should be initiated on the basis of the potential of pastures.

Credit authorship contribution statement:

Akshay Kumar: Investigation, data collection, analysis, interpretation of results, Writing – original draft, review & editing. Kamlesh Kumar Prashar: review & editing. This paper is part of research work during Ph.D.

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