BioOne COMPLETE

Phenology and Growth Form Distribution in an Alpine Pasture at Tungnath, Garhwal, Himalaya

Authors: Nautiyal, M. C., Nautiyal, B. P., and Prakash, Vinay

Source: Mountain Research and Development, 21(2) : 168-174

Published By: International Mountain Society

URL: https://doi.org/10.1659/0276-4741(2001)021[0168:PAGFDI]2.0.CO;2

BioOne Complete (complete.BioOne.org) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Downloaded From: https://bioone.org/journals/Mountain-Research-and-Development on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Mountain Research and Development Vol 21 No 2 May 2001: 168–174

M. C. Nautiyal, B. P. Nautiyal, and Vinay Prakash

Phenology and Growth Form Distribution in an Alpine Pasture at Tungnath, Garhwal, Himalaya

Studies on phenology and growth form distribution in an alpine pasture of Garhwal Himalaya were undertaken from 1988 to 1998. One hundred seventy-one species were recorded and classified as 5 different growth forms. These species were also classified as early- and late-growing type, on the basis of initiation of their aerial sprouts. Cushion-forming forbs generally emerge as the season commences, that is, immediately after snowmelt. However, the vegetative growth of grasses and other forbs peaked randomly after arrival of the monsoon. Phenophases of different species at higher elevations respond to the availability of the soil moisture and nutrient regimes as well as to temperature and different photoperiodic induction. The spectrum of life forms in the region indicated a hemicryptophytic and geophytic plant climate.

Keywords: *Phenophases; growth forms; perennials; alpine pastureland; Garhwal Himalaya, India.*

Peer reviewed: *March 2000.* ***Accepted:*** *September 2000.*

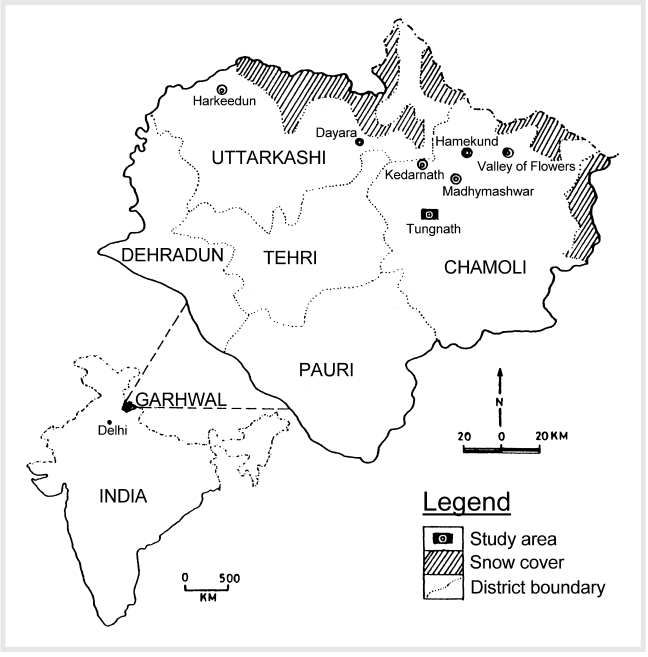
Introduction

It is generally known that the distribution pattern of alpine vegetation is governed by adverse edaphic and climatic factors. Scanty rainfall, high wind velocity, low temperature, high ultraviolet (UV) radiation, snowstorms, and blizzards are common at high altitudes. Vegetation in the alpine zone exhibits a characteristic adaptation to the environment. The plants are generally dwarfed, stunted, wooly or spiny, and develop a mosaic patch of different plant forms. They possess an early growth initiation with a short vegetative span ranging from several days to a few months. The community as a whole usually exhibits seasonal fluctuations, and its structure and composition are strongly influenced by the extent to which periodic phenomena in the individuals are adjusted to each other. Therefore, in pursuance of structural and functional attributes of ground vegetation in alpine meadows, knowledge of different phenophases for individual species is imperative to understand the complexity of the system. In addition, the life forms of species represent the adjustment of perennating organs and plant life history to environmental conditions, an important characteristic in describing vegetation that offers a preliminary picture of the ecological character of the vegetation (Kershaw 1973). A great deal of work has been done on the alpine communities of Garhwal (Semwal et al 1981; Sundriyal et al 1987; Ram and Arya 1991; Nautiyal et al 1997). But there is little information on the phenology and growth form distribution of alpine vegetation at the community level. The present article examines the phenological response of 171 species of flowering plants in a variety of microhabitats in Tungnath in relation to growth cycle, growth initiation period, timing of flowering and fruiting, and life form distribution.

The study area

The study was conducted in the surrounding areas of our Field Research Station at Tungnath in Garhwal Himalaya, situated at 30°14′N latitude and 79°13′E longitude, at an altitude between 3400 and 4400 m (Figure 1). The timberline in this area reaches an elevation of 3500 m (Figure 2). The meadows here are gentle at the base, becoming gradually steeper until they form summits. The main rock components are crystalline and metamorphic, with sedimentary deposits dating back to the Paleozoic Age. Meadows with deep soil cover are seen in northern aspects, while the southern faces generally have large rock spurs and crevices and are either barren or have a few lithophytes. The soil is loam or sandy loam, light gray to brown in color at low-

FIGURE 1 Location map of the study area. (Map by B. P. Nautiyal)



Downloaded From: https://bioone.org/journals/Mountain-Research-and-Development on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

FIGURE 2 Dispersed timberline (reaching up to 3500 m) near Tungnath, Garhwal Himalaya. The trees have been lopped for fuelwood and the terrain shows the impact of overgrazing and soil erosion due to frost. (Photo by B. P. Nautiyal)



er altitudes and sandy with large debris above 4000 m. Surface soil pH ranges between 4.9 and 5.6.

Climate

Like other alpine and arctic zones of the globe, the climate of this alpine zone is cold, with intense irradiance and low partial gas pressure. Heavy frost, blizzards, and hailstorms prevail throughout the year except for a few months. Meteorological data recorded at the experimental station are shown in Figure 3. Minimum and maximum temperatures were recorded as 2 and 26°C, respectively. The soil temperature was least affected by abrupt fluctuations of air temperature and always increased gradually from 8 AM to 4 PM.

Precipitation was observed in the form of snow, hail, heavy rains, and showers during the year. The snowfall occurs from November to April. Snowmelt occurs during April and May, providing an abundance of soil water prior to the monsoon period. Maximum rainfall was recorded in July–August, and hardly a day was observed without rain or showers. The mean highest light intensity was 79,200 Lux at 12 noon in May and the least was 2500 Lux at 12 noon in September.

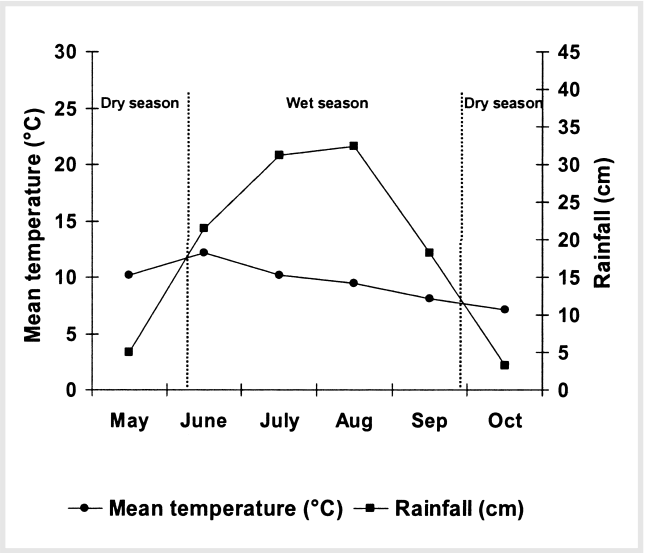


FIGURE 3 Pluviothermic diagram showing wet and dry months at Tungnath. Based on mean rainfall and temperature from 1990–1997.

Downloaded From: https://bioone.org/journals/Mountain-Research-and-Development on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE 1 Distribution of species of various growth forms according to categories of growth cycle and growth initiation.

Growth forms	Total no. of species (% in brackets)	Types of growth cycle			Types of growth initiation	
		Short growth cycle (<2 months)	Intermediate growth cycle (2–4 months)	Long growth cycle (>4 months)	Early growing (before 31 May)	Late growing (after 31 May)
Shrubs and undershrubs	22 (13)		16 (23)	6 (27)	14 (64)	8 (36)
Tall forbs	30 (18)	1 (3)	12 (40)	17 (57)	17 (57)	13 (43)
Medium forbs	38 (22)	2 (5)	24 (63)	12 (32)	13 (34)	25 (66)
Short forbs	65 (38)	16 (25)	35 (54)	14 (21)	27 (42)	38 (58)
Grasses, sedges, and other monocots	16 (09)		9 (56)	7 (44)	10 (63)	6 (37)
Total no. of species	171 (100)	19 (11)	96 (56)	56 (33)	81 (47)	90 (53)

Methods

General phenological observations of the plants were recorded for 10 years (1988–1998) during the growth season (May–October). The growth period lasts only 5–7 months because the area is completely covered by snow from January to April. Senescence occurred in all alpine plants during November and December due to heavy frosting and occasional snowfall. Observations of 171 species were made at regular intervals of 4–5 days on different sites marked on different slopes and habitats. For each species, the sites where its population was most extensive were selected for detailed phenological observation. The phenophases of each species were determined on the basis of sprouting of propagules and germination of seeds, vegetative phase, flowering, fruiting, seed formation, and senescence. The onset of senescence was recognizable due to a rather abrupt change in the color of leaves, which proceeded to the death of the shoots. If a given phenophase was observed in at least 5% of individuals of a species, the phenophase was considered to have started. When less than 5% of individuals of a species remained in a given phenophase, the phase was regarded as completed for that species.

The species were classified into the following growth forms: (1) shrubs and undershrubs, (2) tall forbs (>40 cm tall), (3) medium forbs (20–40 cm tall) and short forbs (<20 cm tall), and (4) grasses, sedges, and other monocots. On the basis of length of the growth cycle, we also recognized the following 3 species categories: short growth cycle (species completing growth cycle within 2 months), intermediate growth cycle (2–4 months), and long growth cycle (species completing growth cycle in more than 4 months). Likewise, if a species commenced growth before 31 May, it was considered an early growth species. If growth commenced after 31 May, the species was considered a late growth species.

The collected plants were also assigned to various life form classes according to Raunkier (1934).

Results

Growth forms and growth cycle period

Of the 171 species recorded, 9% were grasses, sedges, other monocots, and undershrubs, and 78% were forbs, of which 18% were tall forbs, 22% medium forbs, and 38% short forbs (Table 1). Annuals were represented by only 4% of the species. Eleven percent of the species had a short growth cycle, 58% an intermediate growth cycle, and 33% a long growth cycle. Forty-seven percent of the species were classified as early growing and 53% as late growing.

General phenophases at community level

During most of the early growth cycles, species growth initiation coincided with the beginning of the rise in temperature that initiates the snowmelt during the last week of April or in May. In some species, such as *Aconitum balfourii,* growth took place even under the snow cover, while in species such as *Geum elatum,* growth was initiated after a few days of snowmelt, thus demonstrating a high temperature threshold for growth. In late-growing species, however, growth only began in June or early July.

About 16 species were observed in the flowering phase in May immediately after snowmelt. In these species, flowering buds remain dormant throughout the months of snow cover, with flowering commencing immediately after snowmelt. While *Gentiana argentea* and *Oxygraphis polypetala* emerged early and were the most dominant species, *Podophyllum hexandrum* was scarce and showed vegetative growth as well as flowering. Together, these species illustrate adaptation for survival under harsh climatic conditions. Most of the species were at the flowering stage during June to late July or early August. In early-growing species, fruiting began as early as the beginning of June, and in other species, peak fruiting occurred during August. Afterward, it declined sharply, and by the beginning of October, only a few species bore fruit. Seed formation in

Downloaded From: https://bioone.org/journals/Mountain-Research-and-Development on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

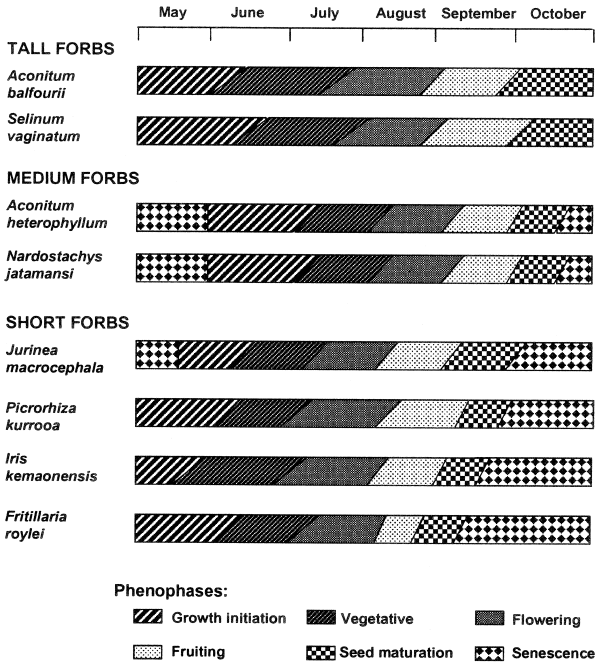


FIGURE 5 Diagram of phenophases for 8 species representing 3 different classes of forbs.

species with short growth cycles began in the latter half of June, and in annuals and other species, maximum seed formation was recorded until the first half of September (Figure 4). Senescence at the community level was gradual from July to early September, after which it was sudden and massive, depending on the growth cycle of the species. Due to heavy frosting and snowfall from the beginning of October, darkening of tissues and sudden death manifested senescence.

Intergrowth form variation in general phenophases

Commencement of growth was observed earlier in the cushion-forming forbs and grasses (in the first half of May) than in other forms (Figure 5). Short forbs showed earlier growth emergence than tall forbs. This temporal variation in growth graduation seems to enable the smaller forms to escape the competitive influences of the larger forms for resource utilization such as light. The peak growth initiation in graminoids, which are by far the most massive forms of alpine vegetation, coincided with that for short forbs. However, they did not affect the short forbs because of microlevel spatial separation in distribution.

The cushion-forming forbs (the shortest growth form) also displayed relatively earlier peaks for vegetative and flowering phases than the short and tall forbs before the commencement of the monsoon. The effect of the monsoon is not substantially weakened at these higher elevations, as reported earlier by Champion and Seth (1968). Nor is the amount of rainfall much different from that in lower ranges. However, seed formation and senescence peaked simultaneously in all growth forms (Figure 5). This synchronization in seed formation among growth forms was obviously in response to the rapid decline in temperature during the later part of the growth period.

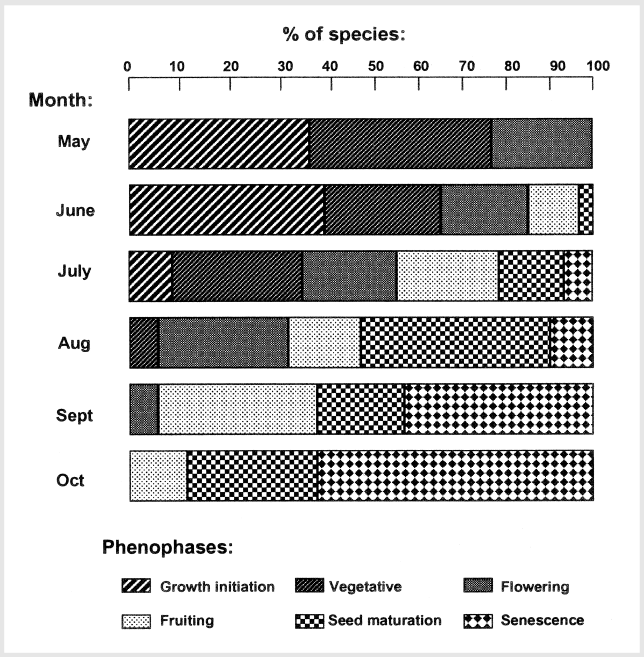


FIGURE 4 Percentage of total number of species under different phenophases in the course of the months of May–October.

Life form distribution

All species encountered at the study site were categorized in terms of life forms and biological spectrum (Table 2). Life form analysis revealed that phanerophytes (Ph), chamaephytes (Ch), hemicryptophytes (He), geophytes (Ge), and therophytes (Th) were represented by 11, 18, 82, 50, and 10 species, respectively.

Discussion

An understanding of phenological progression in plants is needed to understand the functioning of alpine grassland and its importance in sound resource management. Phenology is associated with plant growth rate (Taylor 1974), nutrient transfer (Sosebee and Wiebe 1973), thermal requirements (Nuttonson 1955), plant–water relationship, and even evolutionary change (Kikuzawa 1995). The community as a whole usually exhibits seasonal fluctuations, and its structure and composition are strongly influenced by the extent to which periodic phenomena in individuals adjust to each other. Depending on the heterogeneity of environmental gradients, the pattern of phenological stages between communities and within a community can vary

Downloaded From: https://bioone.org/journals/Mountain-Research-and-Development on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

TABLE 2 Life form spectrum in Tungnath in comparison with other alpine pastures and Raunkier's biological spectrum. The differences between Nautiyal (1996) and Ram and Arya (1991) are due to differences between the types of pastures and microclimatic conditions in the study areas. The area studied by Sundriyal et al (1987) was limited in comparison to the study area for the present study. Abbreviations: phanerophytes, Ph; chamaephytes, Ch; hemicryptophytes, He; geophytes, Ge; and therophytes, Th.

Site	Altitude (m)	Life forms in %					Author citation
		Ph	Ch	He	Ge	Th	
Panwali Kantha	3000–3700	8.25	6.79	44.66	34.95	5.33	Nautiyal (1996)
Rudranath	3400–4200	2.8	31.0	24.6	28.9	12.70	Ram and Arya (1991)
Snow line vegetation of Central Himalaya	3600–5600		46.70	30.0	18.30	5.00	Pangtey et al (1990)
Tungnath	3200–3700		27.0	43.0	18.0	12.0	Sundriyal et al (1987)
Tungnath	3400–4400	6.43 (11)	10.53 (18)	47.95 (82)	29.23 (50)	12.00 (10)	Present study
Yusmarg	3400	10.40	46.40	25.40	10.20	6.20	Gupta and Kachroo (1981)
Raunkier's spectrum		46.6	9.0	26.0	6.00	13.00	Raunkier (1934)

from species to species. Dickinson and Dodd (1976) and Sundriyal et al (1987) have stated that, although annual variation occurs in phenological progression within a species in response to variations in regional weather, there appears to be little variation of the species sequence between growing seasons.

In Tungnath, the vernal season typically begins with a rise in atmospheric and soil temperature, with availability of soil water after snowmelt from the first week of April, and continues up to June. Mooney and Billings (1960) observed that, at an alpine site, the growth of a species during the early and late growing seasons can be attributed to the ability of a plant to absorb water at low temperature. The premonsoon period in May and June in the study area is characterized by abundant soil water due to snowmelt, which usually begins in March–April. Because of the early availability of moisture, a majority of the species at alpine sites initiate growth and do not wait for the onset of the monsoon. The factor that decides growth initiation is snowmelt, which not only supplies soil water but also indicates a rise in temperature (Ram et al 1988). May and Webber (1982) also found that, in a typical year, the onset of plant growth in the tundra is controlled by the disappearance of snow cover. However, as the season progressed into the late snow-free period, all species tended to complete their growth cycles in the short time still available. Consequently, in all growth forms, flowering and seed-setting peaks occurred over a relatively short period of time (Negi et al 1992). The early-growing species (cushion form) can have an unusual water-absorbing ability at low soil temperatures, which is perhaps related to high levels of soluble carbohydrates in root stocks. In the study area, more abundant roots occurred in the upper soil layers, where temperatures were relatively higher or where the water requirement for early growth was low. The shallow root systems of some species (*Oxygraphis polypetala, Taraxacum officinale, Primula* spp, etc) also favor early growth because they restrict water use in the upper soil layer; moreover, they need little water because of their small size (Oberbauer and Billings 1981). Several late-growing species with shallow roots depend more on rainfall due to their varied tolerance and low leaf-water potential than early-growing species. In contrast, the large-rooted species tap deep soil moisture that infiltrates from snowmelt (Sundriyal et al 1987). This also helps in avoiding competition for resources, that is, light and nutrients.

Flowering time varies from species to species because photoperiodic and thermoperiodic responses are different. At higher elevations, temperature is the most important factor in different phenological stages (Holway and Ward 1965). Ram et al (1988) have correlated phenological development directly with the moisture regimes. Short and long vegetative periods before flowering were associated with early and late flowering. Usually there is low seed production and seedling survival at high altitudes, which is compensated by vegetative propagation to ensure the survival of species even after continuous exposure to unfavorable flowering conditions.

The observations made to assess the life form spectrum in Tungnath found a hemicryptophyte habitat at the study site (47.95% He). This was followed by geophytes (29.93% Ge). Heavy grazing pressure and adverse climatic conditions lead the plants to reproduce and regenerate mostly through underground parts (Figure 6). These abiotic and biotic interferences also inhibit flowering and fruiting as the plants are removed, trampled, or senescenced due to heavy frost and snow fall before attaining maturity. Braun Blanquet (1932) found that a high percentage of hemicryptophytes characterized the flora of Central Europe, where a snow cover for 4–5 months is followed by fairly warm but highly moist springs. Similar conditions prevail for hemicryptophytes and geophytes. Deschenes

Downloaded From: https://bioone.org/journals/Mountain-Research-and-Development on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

FIGURE 6 Intensive grazing in an alpine region in Garhwal Himalaya. The alpine vegetation in this area is mainly perennial and propagates through underground perennating parts (ie, hemicryptophytic and geophytic life forms). (Photo by B. P. Nautiyal)



(1969) also found the hemicryptophytic habitat to be the predominant type in grazed pastures in northern New Jersey. Singh and Ambasht (1975) have stated that therophytes develop especially in an area where the native vegetation has been disturbed by overgrazing on tropical lands. Sapru et al (1975) interpreted the presence of chamaephytes in a similar way. Singh and Yadava (1974) suggested that therophytes are indicators of the degree of biotic influence on the habitat. It is generally believed that the life forms of the flora of each of the associations is maintained by the intensity of grazing. The percentage of therophytes and chamaephytes is lower at the present site than in other regions and in Raunkier's biological spectrum (Table 2). This is because the region was represented mostly by forbs that have adapted to reproducing mainly by means of underground perennating organs.

The alpine region of West Himalaya is rich in plant diversity and is considered a hot spot for plant endemism, with approximately 1750 endemic species. Many plant species in the region are considered medicinal, including those in the present study. These species are extensively used in the Indian System of Medicine, in local health care, and in the modern pharmaceutical industry. However, their availability is restricted because they are found for very short time periods in nature. Because there is a definite period for a particular stage of the life cycle of each species, the presence of the species in that particular stage will indicate the time (month, season) required for medicinal uses. The underground parts (tubers, rhizomes, etc) of these species are generally harvested for medicinal purposes. On the basis of phenological information, harvesting time can be determined after the maturation of seeds during October or November, when seeds are shed and the underground parts accumulate more biomass and secondary metabolites, resulting in greater production. Harvesting after seed shedding provides opportunities to grow new plants of the same species and to maintain the species' population; many of these species are

Downloaded From: https://bioone.org/journals/Mountain-Research-and-Development on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

threatened because of overexploitation and illegal exploitation. Different phenophase times will provide information about morphological and functional attributes that is useful in understanding adaptation features. Although phenophases of the same species may vary from one region to another and even in different microhabitats because of environmental factors, the required germplasm can be collected from inaccessible areas in the Himalaya in accordance with the developmental stages of these species.

AUTHORS

M. C. Nautiyal, B. P. Nautiyal, and Vinay Prakash
High Altitude Plant Physiology Research Centre (HAPPRC), HNB Garhwal University, Srinagar Garhwal 246 174, India.

ACKNOWLEDGMENTS

The authors are grateful to Prof A. N. Purohit, Director, HAPPRC, HNB Garhwal University, Srinagar (Garhwal) for his support and encouragement in the course of this study.

REFERENCES

Braun Blanquet J. 1932. *Plant Sociology* (translated by G. D. Fuller and H. S. Conard). New York: McGraw Hill.
Champion HG, Seth SK. 1968. *A Revised Survey of the Forest Types of India*. Delhi: Government of India Press.
Deschenes JM. 1969. Life form spectra of contrasting slopes of the grazed pastures of Northern New Jersey. *Naturaliste Canadien* 96:965–978.
Dickinson CE, Dodd JL. 1976. Phenological pattern in the short-grass prairie. *American Midland Naturalist* 96:367–378.
Gupta VC, Kachroo G. 1981. Relation between photosynthetic structure and standing biomass of meadow land communities of Yusmarg in Kashmir Himalayas. *Journal of the Indian Botanical Society* 60:236–240.
Holway JG, Ward RT. 1965. *Phenology of Alpine Plants*. 3rd ed. Oxford: Oxford and IBH Publications.
Kershaw RA. 1973. *Quantitative and Dynamic Plant Ecology*. London: Edward Arnold.
Kikuzawa K. 1995. Leaf phenology as an optimal strategy for carbon gain in plants. *Canadian Journal of Botany* 73:158–163.
May DE, Webber PJ. 1982. Spatial and temporal variation of the vegetation and its productivity, Niwot Ridge, Colorado. *In:* Halfpenny JC, editor: *Ecological Studies in the Colorado Alpine*. Institute of Arctic and Alpine Research (INSTAAR) Occasional Paper 37. Boulder, CO: University of Colorado, pp 35–62.
Mooney HA, Billings WD. 1960. The annual carbohydrates cycle of alpine plants as related to growth. *American Journal of Botany* 47:594–598.
Nautiyal BP. 1996. *Studies on Structure and Function in an Alpine Meadow of Garhwal, Central Himalaya* [PhD thesis]. Srinagar, Garhwal: HNB Garhwal University.
Nautiyal BP, Nirmala Pandey, Bhatt AB. 1997. Phytosociological studies of an alpine zone in Northwest Himalaya: a case study of Garhwal Himalaya with reference to diversity and distribution pattern. *International Journal of Ecology and Environmental Science* 23:49–65.
Negi GCS, Rikhari HC, Singh SP. 1992. Phenological features in relation to growth forms and biomass accumulation in an alpine meadow of the Central Himalaya. *Vegetatio* 101:161–170.
Nuttonson MY. 1955. *Wheat–Climate Relationship and the Use of Phenology in Ascertaining the Thermal and Photothermal Requirements of Wheat*. Washington, DC: American Institute of Crop Ecology.
Oberbauer SF, Billings WD. 1981. Drought tolerance and water use by plants along an alpine topographic gradient. *Oecologia* 50:325–331.
Pangtey YPS, Rawat RS, Bankoti NS, Samant SS. 1990. Phenology of high altitude plants of Kumaun in Central Himalaya, India. *International Journal of Biometeorology* 34:122–127.
Ram J, Arya P. 1991. Plant forms and vegetation analysis of an alpine meadow of Central Himalaya, India. *Proceedings of the Indian National Science Academy* 57:311–318.
Ram J, Singh SP, Singh JS. 1988. Community level phenology of grassland above treeline in Central Himalaya. *Arctic and Alpine Research* 20:325–332.
Raunkier R. 1934. *The Life Form of Plants and Statistical Geography*. Oxford, UK: The Clarendon Press.
Sapru BL, Dhar U, Kachroo P. 1975. Vegetational studies in Jhelum Valley. *The Botanique* 6:153–164.
Semwal JK, Gaur RD, Purohit AN. 1981. Floristic pattern of an alpine zone, Tungnath, in Garhwal Himalaya. *Acta Botanica Indica* 9:110–114.
Singh UM, Ambasht RS. 1975. Biotic stress and variability in structure of organic production of grassland communities of Varanasi, India. *Tropical Ecology* 16:86–95.
Singh JS, Yadava PS. 1974. Seasonal variation in composition, plant biomass and net primary productivity of a tropical grassland at Kurukshetra, India. *Ecological Monograph* 44:351–376.
Sosebee RE, Wiebe W. 1973. Effect of phenological development on radio phosphorus translocations from leaves in crested wheat grass. *Oecologia* 13:103–112.
Sundriyal RC, Joshi AP, Dhasmana R. 1987. Phenology of high altitude plants at Tungnath in Central Himalaya. *Tropical Ecology* 28:289–299.
Taylor FG Jr. 1974. Phenodynamics of production in a mesic deciduous forest. *In:* Lieth H, editor: *Phenology and Seasonality Modeling*. Ecological Studies 8. New York: Springer-Verlag, pp 237–254.

Downloaded From: https://bioone.org/journals/Mountain-Research-and-Development on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use