Phenology of plants in relation to ambient environment in a subalpine forest of Uttarakhand, western Himalaya

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Abstract Observations on phenology of some representative trees, shrubs, under-shrubs and herbs in a subalpine forest of Uttarakhand, western Himalaya were recorded. With the commencement of favorable growth season in April, occurrence of leaf fall was indicative growth phenomenon in *Quercus semecarpifolia*, *Q. floribunda* and *Abies spectabilis*. However, active vegetative growth in herbaceous species starts onward April and fruit maturation and seed dehiscence are completed from mid of September to October. In general, vegetative growth and reproductive stages in majority of the studied species seems to be dependent on adequate moisture content and also flowering and fruiting in subalpine plants correlate ambient temperature.

Keywords Adaptive features · Growth season · Herbaceous species · Phenology · Subalpine forest

Introduction

Ambient variables, such as temperature, photoperiod and rainfall are important for triggering phenological events in plant growth (Hamann 2004). However, available soil moisture content is considered as a key variable for triggering

phenological events in plants (Singh and Singh 1992). Phenological patterns of different plant species occurring in the diverse habitats is also determined by their genetic character (Pollard and Briggs 1982). Subalpine habitats are characterized by short growth season, heavy snowfall, low and fluctuating diurnal temperature, occasional hailstorms and physiologically unavailable soil moisture content. The phenomenon of freezing and thawing in these habitats also acts as physiological stress for native plants. In order to cope up with harsh growth conditions, subalpine and alpine plants adopt periodicity and seasonality in growth pattern (Ram et al. 1988; Nautiyal et al. 2001; Viswanath et al. 2002; Bisht et al. 2013). Periodicity and seasonality in plants growth pattern is triggered by variety of biotic and abiotic factors (Tesfaye et al. 2011) and understanding of phenological pattern is important for analyzing structure and function of plant communities (Sharma and Khanduri 2007; Yadav and Yadav 2008). Phenology of some representative trees, shrubs-under shrubs and herbaceous species in a subalpine forest of Uttarakhand, western Himalaya in relation to ambient growth conditions is reported in this communication.

Materials and methods

Study area

Panar, a subalpine forest area (from 3265 to 3383 m asl; with northern aspect) in district Chamoli, Uttarakhand was selected for present study. Overall climate of this region is monsoon dependent. December to March are intense cold months with heavy snowfall, while, during May and June, pre-monsoon showers and occasional hailstorms are common and from July to early September heavy and regular rainfall in this area is a characteristic feature. Generally, April to October are favorable months for vegetative and reproductive growth of the

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plants. Based on ambient conditions, this area may be categorized as “moist temperate sub-alpine” and general description of this area is presented in Table 1.

Representative species selected for studies on phenology

A total 35 native species; i.e. 10 trees, shrubs or under shrubs (*Abies spectabilis* (D. Don) Mirbel, *Acer caesium* Wall. ex Brand., *Betula utilis* D. Don, *Litsea elongata* (Nees) Hook. f., *Quercus floribunda* Lind. ex Rehder, *Quercus semecarpifolia* Smith, *Rhododendron arboreum* Sm., *Rhododendron campanulatum* D. Don, *Sorbus microphylla* Wenzig and *Taxus baccata* L.) and 25 herbaceous species (*Achyranthes aspera* L., *Arundinaria falcata* Nees, *Dactylorhiza hatagirea* D. Don, *Echinops cornigerus* DC., *Fragaria nubicola* Lind. ex Lacaita, *Inula grandiflora* Willd., *Jurinea dolomiaea* Boiss., *Malaxis muscifera* (Lind.) Kuntz., *Morina longifolia* Wall. ex DC., *Picrorhiza kurrooa* Royle ex Benth., *Polygonatum cirrhifolium* (Wall.) Royle, *Polygonum affine*

D. Don, *Polygonum amplexicaule* D. Don, *Polygonum macrophyllum* D. Don, *Potentilla atrosanguinea* Ledd., *Potentilla fulgens* Wall. ex Hook., *Primula denticulata* Sm., *Prunella vulgaris* L., *Saxifraga diversifolia* Wall. ex Seringe, *Skimmia laureola* (DC.) Sieb., *Tanacetum dolichophyllum* (Kitam.) Kitam., *Taraxacum officinale* Weber, *Thalictrum foliolosum* DC., *Viola biflora* L. and *Viola serpens* Wall. ex Gingins) were selected for undertaking observations on phenology.

Observations on phenology

Observations on phenology of selected representative species were recorded during April to November 2009 in 10 study plots marked for both categories of plants species (i.e. 10×10 m for trees and other woody species, and 1×1 m for under canopy herbaceous species). All individuals of representative tree species having >30 cm diameter at breast height (DBH) within marked areas and all herbaceous species within marked

Table 1 General description of the study area

Parameters of Study area		
Location		30°28'–30°28' to 79°20'–79°21'
Upper limit of tree line (m asl.)		3265–3383
Aspects		North, south-east to south
Forest type		Moist temperate semi-evergreen
Dominant tree/woody species		<i>Acer caesium</i> , <i>Rhododendron campanulatum</i> , <i>Quercus semecarpifolia</i> , <i>Q. floribunda</i> , <i>Abies spectabilis</i> and <i>Sorbus microphylla</i>
Dominant under-storey herbaceous species		<i>Arundinaria falcata</i> , <i>Fragaria nubicola</i> , <i>Polygonatum cirrhifolium</i> , <i>Polygonum amplexicaule</i> , <i>P. macrophyllum</i> , <i>Viola biflora</i> , <i>V. serpens</i> , <i>Potentilla fulgens</i>
Species richness	Woody species	10
	Under-storey herbaceous species	25
Density (individual's ha ⁻¹)	Woody species	750–1260
	Under-storey herbaceous species	56,000–110,000
Temperature (April to November)	Maximum (°C)	15.1
	Minimum (°C)	1.0
Humidity (April to November)	Maximum (%)	98
	Minimum (%)	43
Soil	pH	6.45±0.43–6.70±0.15
	Colour	Reddish brown to dark brown
	Texture	Loam-sandy loam
	Moisture (%)	48.78±7.38 - 51.87±6.64
	Water holding capacity (%)	61.24±8.41–81.52±3.60
	N (%)	0.53±0.15 - 0.59±0.23
	P (Kg ha ⁻¹)	10.12±3.74–13.47±3.29
	K (Kg ha ⁻¹)	233.00±28.59–251.46±20.73
	OC (%)	1.99±0.30–2.30±0.32

±— SD, n=8

areas were observed for phenological events (such as budding, shoot and leaf flushing, flowering, fruiting, leaf fall and seed dehiscence) at an interval of ~10 days. Occurrence of particular growth phase in more than 5 % individuals was considered as initiation of particular phenophase and remaining particular phenophase in less than 5 % individuals was assumed as completion of particular phenophase as per Nautiyal et al. (2001).

Data analysis

Analysis of variance (ANOVA) was determined for number of species in flowering and fruiting stage in relation to different months and least significant difference (LSD) was also estimated. Spearman's Correlation Coefficients (r_s) was calculated for determining relationships between flowering-fruiting (for woody and herbaceous species respectively) and native climatic factors viz. mean monthly temperatures and mean monthly relative humidity.

Results and discussion

Initiation of growth, including budding, shoot elongation and leaf flushing in herbaceous species and some broad leaved woody species was started with the commencement of favorable growth season during April. Shoot/leaf or floral bud formation was observed in five trees/woody species (*Acer caesium*, *Betula utilis*, *Litsea elongata*, *Rhododendron campanulatum*, and *Sorbus microphylla*) during April, while during this month, three tree species (*A. spectabilis*, *Q. semecarpifolia* and *Q. floribunda*) were observed in flowering stage (Fig. 1). In these species leaf fall was key event during April. Also, seed dehiscence was observed as key phase in *A. spectabilis* during April. Excluding *A. spectabilis*, majority of species selected for observations on phenology exhibit shoot elongation during May, while shoot elongation and flowering in *A. spectabilis* occurred during June (Fig. 1). Flowering in some of woody species like *Quercus floribunda*, *Q. semecarpifolia* and *Rhododendron arboreum* begin in April and continued up to May. On the other and flowering in *Acer caesium*, *Litsea*

Figure 1 Phenological stage of selected species in a subalpine forest during study period

Species	Name of the Species	Months							
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Woody	<i>Abies spectabilis</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Acer caesium</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Betula utilis</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Litsea elongata</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Quercus floribunda</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Quercus semecarpifolia</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Rhododendron arboreum</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Rhododendron campanulatum</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Sorbus microphylla</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Taxus baccata</i>	☐	☐	☐	☐	☐	☐	☐	☐
Herbaceous	<i>Achyranthes aspera</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Arundinaria falcata</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Dactylorhiza hatagirea</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Fragaria nubicola</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Echinops cornigerus</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Inula grandiflora</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Jurinea dolomiaea</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Malaxis muscifera</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Morina longifolia</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Picrorhiza kurrooa</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Polygonatum cirrhifolium</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Polygonum affine</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Polygonum amplexicaule</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Polygonum macrophyllum</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Potentilla atrosanguinea</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Potentilla fulgens</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Primula denticulata</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Prunella vulgaris</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Saxifraga diversifolia</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Skimmia laureola</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Tanacetum dolichophyllum</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Taraxacum officinale</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Thalictrum foliolosum</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Viola biflora</i>	☐	☐	☐	☐	☐	☐	☐	☐
	<i>Viola serpens</i>	☐	☐	☐	☐	☐	☐	☐	☐

☐ - Germination/Resprouting phase; ☐ - Shoot elongation/vegetative growth phase; ☐ - Flowering phase; ☐ - Fruiting phase; ☐ - Seed dehiscence phase; ☐ - Leaf fall phase

elongata and *Rhododendron campanulatum* was observed during May and June. *Betula utilis*, *Sorbus macrophylla* and *Taxus baccata* flowered during June and flowering in *Abies spectabilis* was observed during July (Fig. 1). During June (*Acer caesium*, *Quercus floribunda*, *Rhododendron arboreum*, *R. campanulatum*), July (*Acer caesium*, *Litsea elongata*, *Quercus floribunda*, *Rhododendron arboreum*, *R. campanulatum* and *Taxus baccata*) and August (excluding *Q. floribunda*) majority of trees or woody species were observed in the fruiting stage in selected subalpine forest (Fig. 1). Excluding *Abies spectabilis*, *Quercus floribunda* and *Q. semecarpifolia*, seed dehiscence in selected woody species was common during October or up to early November. During this period, leaf fall also occurs in the majority of native subalpine woody species. It was interesting to note that, during April to November, no particular period was observed for leaf fall in *Taxus baccata*.

Emergence of new leaves, shoots and floral parts from preceding buds in April was common in selected under canopy herbaceous species (Fig. 1). In selected subalpine forest area, shoot elongation and vegetative growth of herbaceous flora was key feature during May and June (Fig. 1). Majority of herbaceous plants in selected subalpine forest were observed to be in flowering stage during July and August, however in some plants flowering may start in April (*Primula denticulata*), May (*Achyranthes aspera*, *Arundinaria falcata*, *Frageria nubicola*, *Polygonatum cirrhifolium*, *Potentilla astrosanguinea*, *Viola biflora* and *V. serpens*) or June (*Echinops cornigerus*, *Morina longifolia*, *Picrorhiza kurroo*, *Polygonum affine* and *Skimmia laureola* etc.), (Fig. 1). Simultaneously fruiting in herbaceous species occurs during July, August and September and in general, onward September to November fruit dehiscence was observed as common phenophase in subalpine herbaceous plants (Fig. 1). Majority of herbaceous species reach to the leaf fall during October and November (Fig. 1). In woody species, flowering was found to have significant relation with favourable seasons ($P < 0.05$), and showed strong positive relationship with temperature ($r_s = 0.83$) and humidity ($r_s = 0.59$). Flowering in herbaceous plants and favorable seasons in subalpine area was significant ($P < 0.05$). Also, flowering showed positive relation with the temperature ($r_s = 0.95$) and humidity ($r_s = 0.93$). Fruiting in trees at subalpine forest showed strong positive relationship with temperature ($r_s = 0.76$), and positive but non-significant relationship with humidity ($r_s = 0.26$). Fruiting in herbaceous plants also showed a non significant but somewhat positive relationship with temperature ($r_s = 0.45$) and humidity ($r_s = 0.07$).

Almost 96 % (24) species of herbaceous plants were observed to be in sprouting phase at beginning of favorable growth season (April). Possibly, gradually increasing temperatures and enough moisture content after snow melt may have triggering effects on initiation of vegetative growth of preceding innovation buds. These life forms require sufficient soil

moisture content for vegetative growth (Hartvigsen and Montgomery 2006). On the other hand, 80 % of the selected woody species were observed in fruiting stage during rainy months (July and August). Fruiting in majority of the herbaceous species is completed during rainy season or in September. This may be an adaptational strategy of plants growing in the harsh environmental conditions of subalpine forest area. Completion of leaf maturation and initiation of flowering prior to rainy season is an adaptive feature of subalpine species (Sorenson 1941; Singh and Kushwaha 2005).

Conclusions

Vegetative growth in herbaceous plants and fruiting in both either woody species or herbaceous plants in selected subalpine forest area depicted, utilization of stored or available resources for growth and development is well adapted phenomenon in subalpine plants. Seed dehiscence in herbaceous species before to winter seems be a mechanism for acquiring chilling treatments prior to next growth season and in some broad leaved species like *Quercus*, seed dehiscence before or during rainy season may be a strategy for enhanced seed germination due to sufficient moisture content. Based on the finding on phenology of representative plants in subalpine forest, it may be stated that, the enough moisture content and temperature during favorable growth season are key determinants for growth and development of plants in the subalpine areas. Despite minor variations in phenophases and corresponding vegetative and reproductive phase, genetically and phenotypically subalpine plants are well adapted to their native environment.

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