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Research Article

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EFFECT OF ELEVATION AND LATITUDE ON SPRING PHENOLOGY OF RHODODENDRON AT KANCHENJUNGA CONSERVATION AREA, EAST NEPAL

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Abstract

Mountainous terrain in the East corner of Nepal is a good location for phenological studies. Spring phenology in *Rhododendron arboreum* Sm. was monitored around the Ghunsa river valley in Kanchenjunga Conservation Area of Nepal. Observations were carried out following the crown density method; flowering events of the selected species were recorded in 15-days interval. Flowering activity including duration of flowering and synchrony were determined. In addition, expected difference in flower onset time in two consecutive monitoring plots was determined. Elevation, latitude and longitude were regressed against the flower onset to determine the effect of each variable on flower onset. Delay in flower onset along with rise in elevation, North latitude and West longitude was found in the results of the regression. Full bloom phase was found highly synchronized throughout the elevation gradient with contraction of flowering duration. High synchrony also indicates that the reproductive timing might plastic enough to cope with short-term change in environment.

Keywords: Ghunsa, *Rhododendron arboreum*, flower onset, flowering intensity, synchrony

Introduction

In the recent decades, there has been a growing interest in change in phenology as indicators of global change (Menzel et al. 2006). Phenology is a useful indicator because it integrates climate signals over a sustained period of time and is easily measured. It is the first reported biological footprint (Chuine 2010) and shift in plant phenology is one of the earliest responses to global warming. Detecting long term change in phenology is not possible in the mountainous terrain of Nepal because of lack of data. Alternatively, notable change in the altitude provides good location to monitor and study change in phenology in such terrains. In high mountains flowering phenology changes along elevation gradients, with plants at lower elevations typically flowering earlier than plants of the same species that grow at higher elevations (Ziello et al. 2009). Temperature has been documented as the most critical factor during the early stages of the growing season (Miller-Rushing and Primack 2008).

In the mountains, it is elevation gradients that govern the change in temperature. Generally, air temperature in mountainous regions decreases with increasing elevation at a lapse rate of about 0.6°C every 100m (Du et al. 2007). Some interesting variations have been documented for lapse rate such as temperature inversion (Du et al. 2007), which make lower elevation areas colder than high elevation areas. Effect of elevation along with latitude and longitude on the phenology of in plants and animals is described by Hopkins (Hopkins 1920). He formulated the relationship of elevation, latitude and longitude to seasonal events such as the arrival of springtime. The relationship was coined the "Law of Bioclimatics", which states that spring advances or phenological events vary at the rate of four days for each degree of geographical latitude northward, five degrees of longitude westward, and 400feet (121.92m) higher in elevation. This law is extremely generalized, has geographical limitations and is difficult to apply to individual plant species, but still it could be useful to predict the tentative date of flower onset for trees that flowers during spring.

Early flowering of *Rhododendron arboreum* Sm. is very commonly reported in recent news. With the beginning of spring this species begin to onset flower and it grows on steep slopes of temperate mountains. All this makes this species good candidate for the phenological research along the elevation gradient. The purpose of this study is *in-situ* monitoring of phenology events in *R. arboreum* to track the changes in the flowering phenology across an elevation gradient and relation of flower onset with geographical factors like elevation, latitude and longitude.

Materials and methods

Study area and monitoring plots

Study site is in Ghunsa river valley of Kanchenjunga Conservation Area (KCA) in Taplejung district of Eastern Nepal. It is intemperate to sub-alpine ecological zone, where major vegetation types are broad-leaved mixed forest with forest components like *Quercus semicarpifolia*, *Lyonia ovalifolia* at lower altitude, *Rhododendron campanulatum*, *R. barbatum*, *Larix griffithiana*, *Juniperus recurva* at mid-elevation and *Betula utilis*, *J. indica* at the higher elevations. *R. arboreum* is found in all of these forest types as well as a pure stand.

About 8km long transect was set along the Ghunsa river valley (Fig. 1), where12 monitoring plots (20×20m) were established along the elevation gradient of 621m (2976 to 3597masl). Phenology monitoring was carried out in 96 trees (eight in each plot), which were tagged properly during establishment of the monitoring plots.

Phenological observation

Flowering phenology events in the tagged trees were recorded at 15-day intervals from the time of flower onset to the time of flower drop. Phenology events were recorded using the concept of the crown density observation method (Koelmeyer 1959), where tree canopy are scored in linear scale from 0 to 6. Absence of particular phenophase is represented by 0 whereas the values of 6 to 1 represent the maximum intensity, to one-sixth proportion respectively. Different phenophase recorded during monitoring were – (a) bud (B), (b) flower onset (BB), (c) full bloom (FB),(d) flower drop / young fruit emerge (FD), (e) fruiting (Fr) and (f) new bud (NB). For the analysis, the following flowering stages were used – (a) flower opening in inflorescence (< 25%; regarded as flower onset, which is number of days from 1 January to open flower), (b) full bloom (at least 25 – 50% flowers in inflorescence bloom; regarded as peak flowering or inflorescence bloom), and (c) bloom duration (number of days the plant remained in bloom). Each phenophase stage was scored based on their coverage to corresponding branches and then totaled. Branch without bud were not considered during measurement and scoring.

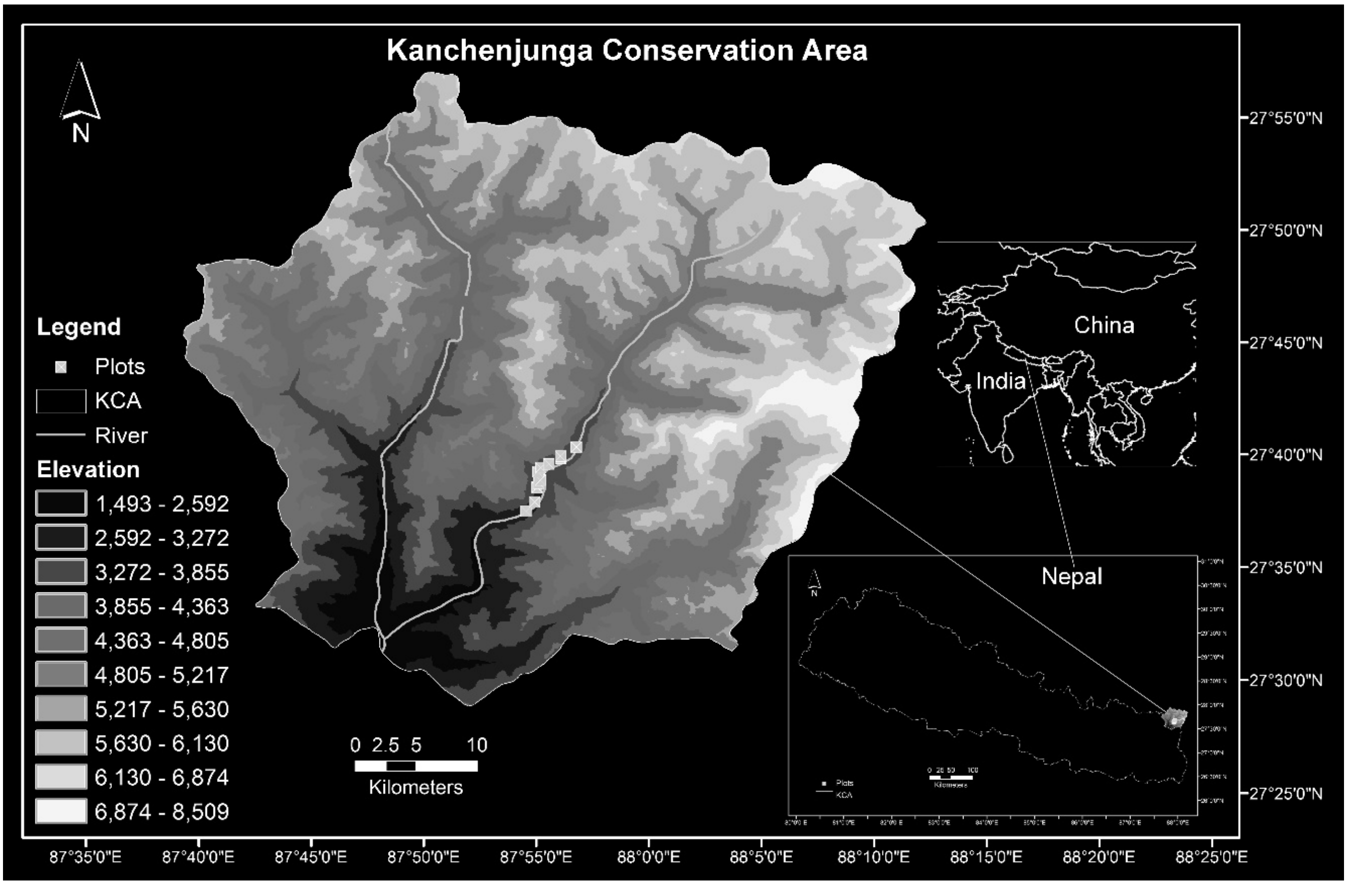

Fig. 1: Study area showing elevation gradient and monitoring plots

Phenophase change analysis

(a) Fournier's index: Phenophase scores were calculated in percentage and averages percentage for each site were used for analyzing phenophase activity, which is known as Fournier's percentage or index (Morellato et al. 2010). Recorded monitoring data were expressed as percentage values for each phenophase, using the Eqn.1.

$$\% \text{ FI } = \left[\sum_{i=1}^{n} x_i / (n \times 6)\right] \times 100 \quad \text{- Eqn.1}$$

Where, % FI is Fournier index, n is the number of individuals monitored in each plot and x_i is the value of the semi quantitative scale attributed to the individual i.

(b) The percentage index was used to represent phenophase pattern of Fournier index in the study area. The average values for each site were further averaged to obtain result for lower elevation (3000-3300 m) and higher elevation (3300-3600 m) to compare time of maximum full bloom.

(c) Flowering synchrony (S): Number of days when the flowering of one individual overlaps with the flowering of every other plant in the population. For synchrony Eqn.2 modified from Augspurger (1981) in (Giménez-Benavides et al. 2007) was used.

$$S = \frac{1}{(n-1)} \times \sum \frac{aij}{bij} \quad \text{- Eqn.2}$$

where n is the number of plants, 'aij' is the number of days individuals i and j are simultaneously in bloom, and 'bij' is the number of days at least one of them is in bloom. 'S' ranges between 1, when flowering completely overlaps, and 0, when there is no synchrony.

(d) Relation described in the bioclimatic law (Hopkins 1920) was used to calculate difference in number of days in the arrival of spring in two consecutive monitoring plots. Each time two monitoring plots were taken for calculating the number of days that is expected to differ in a particular phenophase between the two plots, and Eqn.3 was used:

$$\triangle D = \frac{\triangle Ele}{30.48 \times 1.25} + \triangle Lat \times 4 + \triangle Lon \times 1.25 \text{- Eqn.3}$$

Where, $\triangle D$ is the number of days differ in flowering time, '$\triangle Ele$', '$\triangle Lat$' and '$\triangle Lon$' are respectively the elevation (m), latitude (°) and longitude (°) difference between two monitoring plots.

The calculated days ($\triangle D$) were correlated with the difference in observed days of flower onset in monitoring plots. A linear regression was carried out to examine the relationship between flowering days and geographical variables (elevation, latitude and longitude). For all analysis R-statistical package and MS-excel was used.

Results and Discussion

Flowering intensity and duration

The first flower opened in the third week of March and highest bloom was recorded between the fourth week of April to the second week of May. Percentage for individual phenophase calculated based on Fournier's index from all monitoring plots show full bloom period was between 118 to 135 days, i.e., April 28 to May 15 (Fig. 2a). There was no significant difference in full bloom days or duration of flowering period within the monitoring plots. We found about 13 days difference in the mean full bloom period between the two altitude classes (Fig. 2b). From the field observation, evidently flowering took place in lower elevation plots earlier than in higher plots. With rise in elevation, delay in flower onset timing and contraction in flowering duration has been documented elsewhere as well (Crimmins et al. 2009) and also anomalous behavior from normal trend is reported (Giménez-Benavides et al. 2007).

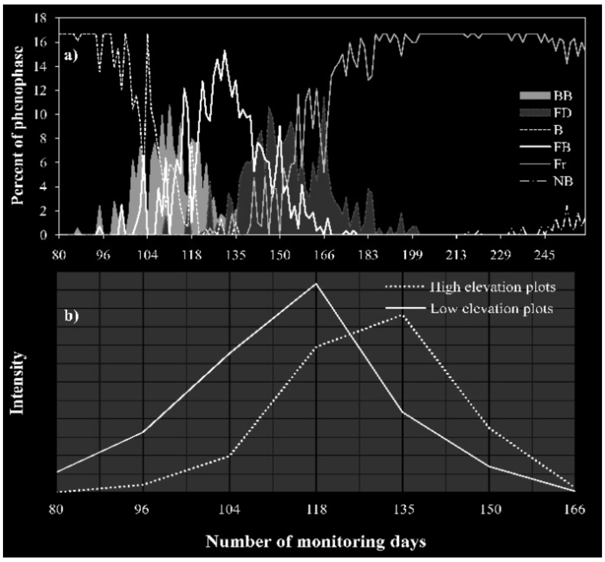

Fig. 2: Phenophase recorded during the monitoring (a) percent of phenophase in all plots (b) intensity of flowering phase averaged for higher and lower elevation monitoring plots. The number of monitoring days is based on counting from January 01 as day 1, (For figure legend see method and material section).

Flowering along elevation gradient and synchrony

The flower onsetwas delayed with a rise in elevation in general. Also a notable reduction in the days of flowering activity was observed in higher elevation than in lower elevation. Difference in flower onset in two consecutive monitoring plots were highly correlated with the difference in the arrival of spring (0.89, $p<0.001$). Generally flower onset followed the law of bioclimatics but some plots show earlier flower onset than expected arrival of spring, e.g., in plots between 4 and 5, 6 and 7, and 8 and 9 (Fig. 3). Temperature inversion is very common in the high mountain valleys (Du et al. 2007) similar to the study site. In the study area such inversion in temperature is reported (Ranjitkar et al. 2013). Probably such inversion in temperature trigger plants like *R. arboreum* to onset flower earlier than normal flower onset time as false alarm of arrival of spring.

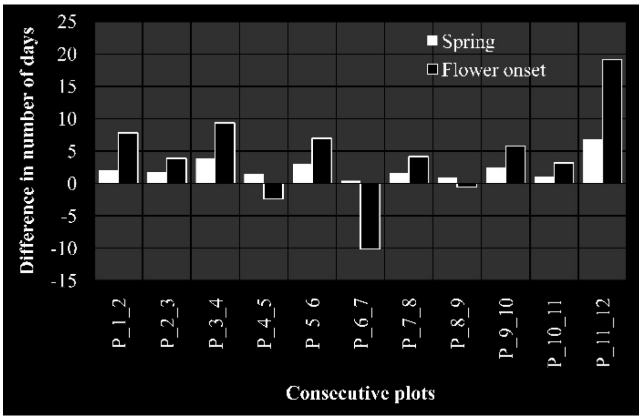

Fig. 3: Difference in expected spring arrival and flower onset (between two consecutive plots indicated by P_1_2 for plot 1 and 2, and so on)

There was a high degree of flowering synchrony throughout monitoring plots (Fig. 4). Synchrony in individual trees at each monitoring plots was low, while the mean overlapping period between each pair of monitoring plots was higher. Mean synchrony was 0.78 in all the monitoring plots. Elevation gradient as well as latitude and longitude were found to influence the timing of flower onset, however, throughout the elevation range flowering duration and flower bloom was heavily overlapping (Fig. 4). Ranjitkar et al. (2013) suggested such overlapping of flower bloom could be an adaption trait to ensure the visit of pollinator, which do not appear synchronously with the flowering of the host plant. During field observation pollinators like honey bees, sun birds, bumble bees were found frequent visitors and they can forage some hundred meters to several kilometers (Pahl et al. 2011). High overlapping in the flower bloom ensures the higher chance of cross-pollination, which is a key to reproductive success in the plants. High synchrony also indicates that the reproductive timing in *R. arboreum* might plastic enough to cope with short-term change in environment.

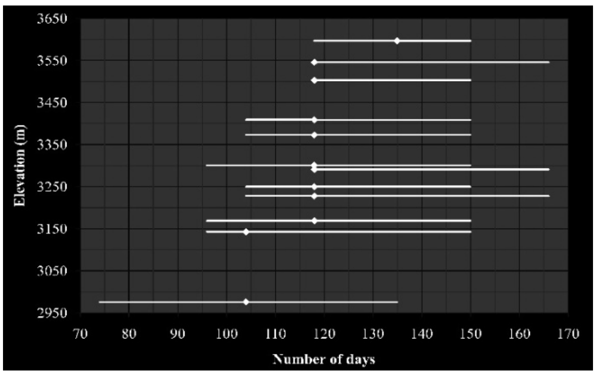

Fig. 4: Duration of spring phenology indicating onset, full bloom (black dot) and flower drop.

Linear regression

There was significant correlation between altitude, latitude and longitude with flower onset date averaged within each monitoring plot. Adjusted R2 was 0.768 ($p<0.001$) for a linear model using elevation as explanatory variable and flower onset date as response (Fig. 5a). Similarly adjusted R^2 was 0.775 and 0.745 for linear models with latitude and longitude respectively as an explanatory variable (Fig. 5b and c). All the correlation were negative and significant ($p<0.001$), indicating a general delay in the flower onset with rise in elevation, latitude toward north and longitude toward east.

From figure 5 it is evident that elevation and latitude could affect the flower onset. Although high R^2, longitude does not seem highly affect flower onset because of the clustering of most point and the trend line obtained was based on few points. With the change in elevation and latitude, air temperature, solar radiation and chilling differ. Air temperature, winter chilling and solar radiation are well established environmental factors that affect phenology of trees (Körner and Basler 2010). All these factors could be important while discussing phenology along an elevation gradient. Normally in Himalayas, temperature significantly changes with rise in altitude. Rhododendron does not need chilling requirements (Sharp et al. 2009). Photoperiod is not so important within a small change of latitude and climate change does not affect the seasonal variation in day length (Vänninen et al. 2012). Consequently, only temperature change along an elevation or latitude gradient could be more meaningful in seasonal change in the tree species like Rhododendron. While the anomaly in phenology pattern could be because of temperature inversion.

Conclusion

This study does not cover a large area but shows phenology could be influenced by some geographical factors and this result could be generalized. There are some influences of geographical factors like elevation and latitude on the phenology of tree, which could alter the date of flower onset and help of range shift of species. Widely spread species such as *R. arboreum* may profit from a warmer climate at high elevation areas, which is expected to get warmer with climate change. Benefit from a warmer climate may thus gain a competitive advantage for species like *R. arboreum* over photoperiod-sensitive and winter chill requiring taxa.

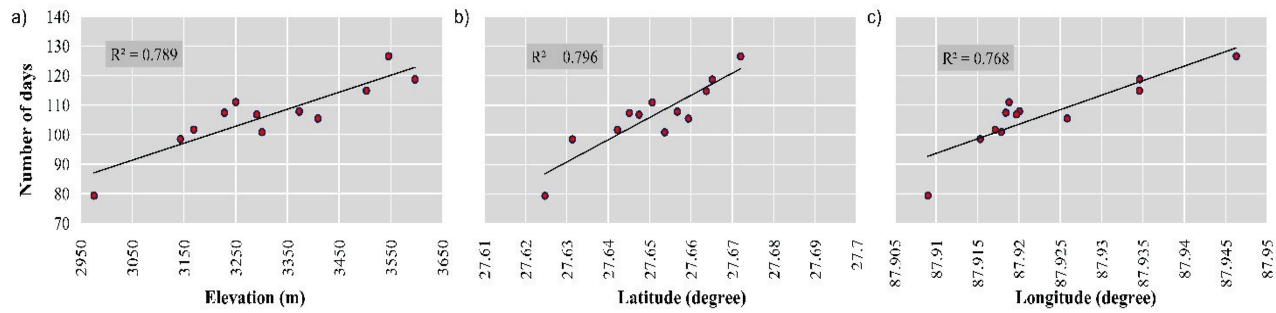

Fig. 5: Linear relation of flower onset with (a) elevation, (b) latitude and (c) longitude

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