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Flowering Phenology of *Rhododendron arboreum* Sm. at Two Elevations in Phawngpui National Park, Mizoram: Climate Change Implications

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ABSTRACT

We studied flowering phenological events of *Rhododendron arboreum* Sm. at two altitudes (1945 m and 2157 m asl) in Phawngpui National Park for 4-years period. Our results revealed that all the flowering phenophases (onset, peak and end) were significantly influenced by altitude mediated atmospheric temperature and soil surface temperature. The low altitude which experienced higher surface and atmospheric temperature induced early onset of flowering of this species by 9-16.days, peak flowering by 7-9 days and showed better flowering synchrony and higher flowering amplitude compared to those plants at high altitude. However, flowering duration was not affected by the variations in temperature induced by altitude. These findings provide clues for climate change influence on the altering phenological pattern of this species.

Key Words: Rhododendron, Flowering phenology, phenological synchrony, climate change, Phawngpui National Park, Mizoram.

INTRODUCTION

Phenology is considered as one of the most initial and perceptible characters by which the plants response to change of climate (Wolkovich et al. 2014). Notwithstanding, plants have internal mechanism to sense the change in temperature, humidity and other external factors, and response to life cycle events. Therefore, plant phenology which is strongly influenced by climate could be the most reliable bio-indicators of ongoing climate change (Fitter and Fitter 2002; Parmasen and Yohe 2003; Mulder et al. 2016). The shifts in phenological events are considered among the most sensitive biological response to climate change (Parmesan and Yohe 2003; Lu et al. 2006). Many studies have suggested that factors like precipitation, temperature and photoperiods trigger the phenology of species (Ranjitkar et al. 2013). Several studies supported by experimental evidences have shown that plants have shifted their flowering time earlier by several days to weeks in step with rising temperatures attributed to global warming (Parmesan and Yohe 2003; Miller-Rushing and Primack 2008; Wolkovich et al. 2014). This may also cause a phenological mismatch between the flowering plants and their pollinators (Miller-Rushing et al. 2010) and may affect ecosystem functioning, productivity and ecological interactions across trophic levels (Zhang et al. 2018). Despite growing linkages of plant phenology with rising temperatures, phenology responses to other environmental cues, including day long, rainfall, nutrient availability are well reported (Wielgolaski 2001; Cleland et al. 2007; Forrest and Miller-Rushing 2010). Plant phenology is also reportedly influenced by the status of soil nitrogen and organic matter (Ma et al. 1997; Nord and Lynch 2009) and altered precipitation regimes (Hoover et al. 2012). Shift in plant species composition and diversity may too alter timing and distribution of flowering events (Wolf et al. 2016). There is a growing body of literature in temperate, sub-alpine and alpine regions on plant phenology, and most of these studies have experienced advancement of spring phenology with climate warming (Pearson 2019), however the effect of climate change on phenological behavior of trees in sub-tropical warm and humid regions are very few and far between, and especially Indian sub-continent. Systematic observation on various phenophases of plant species therefore can contribute to better understanding of the species, and its response to different microclimate in Indian context. The phenological research can significantly contribute too to the tracking the rhythms of the season in the face of global change (Morisette et al. 2009).

Rhododendron arboretum Sm. is a key dominant but primitive flowering plant with considerable ecological and economic importance (Basnett and Devy 2013), found in South Asian countries like India, Nepal, Bhuatn, Mynamar, Sri Lanka, Thailand, Vietnam and China. The species is distributed at high altitudes (range of 1500-3000 m) in several hilly Indian states such as Arunachal Pradesh, Meghalaya, Mizoram, Nagaland, Manipur, Sikkim, West Bengal, Uttarakhand and Himachal Pradesh (Pradhan and Lachungpa 1990; Paul et al. 2005, 2010; Malsawmkima 2016; Mao et al. 2017). In the state of Mizoram, it is well distributed at elevation range from 1302 m asl (Champhai Bethel) to 2157 m asl in (Phawngpui National Park) in Mizoram (Malsamkima 2016). Many tourists visit Phawngpui National Park for ecotourism, not only to experience the scenic beauty of the park but also to enjoy the beautiful flower of this species during the peak flowering seasons. The species is valued beyond its flowers, and for various ecological services (Basnett and Devy 2013). Several studies have revealed the present day climate change has brought several biological changes in this species in the Indian Himalayan region (Boojh and Ramakrishnan 1981; Pangtey et al. 1990; Sundriyal 1990; Gaira et al. 2014; Paul et al. 2018). Many tree species across various taxonomic groups are reported to have shifted their phenological events (Shah et al. 2014; Singh and Sahoo 2019; Thapliyal et al. 2020). There could be several factors such as change in atmospheric temperature, water-limiting conditions, prolonged photoperiod etc. which might modify the genes that are responsible in inducing flowering in trees (Thapilyal et al. 2020), however, it may be difficult to interpret, and explain the individual variations within and between populations of a given species. In view of the fact that *R. arboretum* can sustain well in the fragile ecosystem (Tiwari and Chauhan, 2006), it will be of paramount importance to document the phenological events of this species, and to relate these to environmental variables. We therefore carried out a study on the flowering phenology of this species at two elevations at Phawngpui National Park, the highest mountain peak of the state of Mizoram for a 4-years period to understand the basic pattern of flowering phenology across time, and to observe climate change implication on its flowering behaviour.

MATERIALS AND METHODS

Study site

The study was carried out at Phawngpui (Blue mountain) National Park (22^0 36' 37"- 22^0 41'33" N and 93^0 00'41"-93^0 04'57" E) situated in Lawngtlai district of Mizoram (Fig. 1). The park was notified as a National Park (area 50 Km^2) following the provision under Wildlife Protection Act (1972) and is presently managed by Range Officer with headquarter at Sangau village and Beet Officers under the control of District Forest Officer (DFO) Lawngtlai. The park mountain is a high point on one of the many rugged ridges that run roughly south to north in the state and lies under the sub-tropical Hill forest and includes the highest peak (2157 m asl) in the state. The climate is humid sub-tropical and characterized by long winter. In summer, the temperature ranges from 18°C to 24 °C and in winter 4 °C to 15 °C. Winter starts in November and ends in February. The area is under direct influence of monsoon and receives maximum rainfall between May and September, and the annual rainfall is about 2300 mm a small extent of

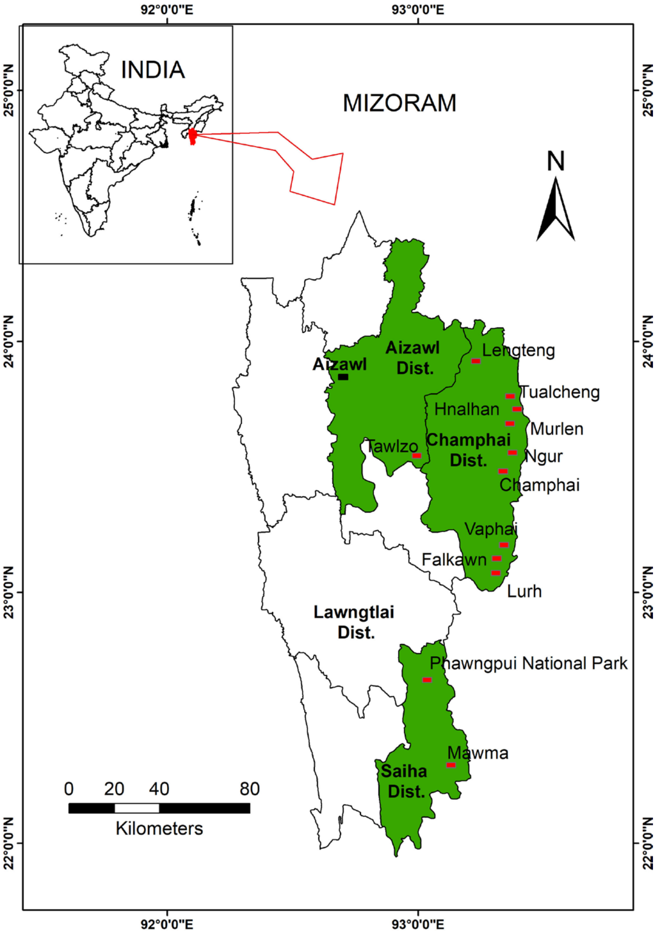

Figure 1. Distribution of *Rhododendron arboreum* in Mizoram and location of the study site

grassland plateau known as “Far Pak” is situated towards top of the hill and the sylvan of temperate oak trees and *Rhododendron* abound with orchids from first week of January to last week of August. The variations in mean monthly rainfall, temperature and relative humidity during 2011-2014 are shown in Fig. 2.

Flowering phenology

Two sites differing in altitudes (1945 m and 2157 m) were selected for the detailed phenological studies whose physiographic and edaphic characteristics are shown in Table 1. The low altitude was relatively less sloppy and had south-west aspect, while the high altitude site was having north-east aspect topography. The study was carried out from first week of January 2011 to last week of August 2014 spanning a period of 56 months of continuous monitoring. In order to study the flowering phenology, 10 healthy individual trees, free from any malfunction and disease were randomly marked and tagged with aluminum tag for visual monitoring of the selected individuals following the methods suggested by McIntosh (2002). Phenological observations were made on each date on four variables: a) first flowering date/ floral initiation, b) flowering peak date, c) flowering duration d) flowering amplitude and flowering synchrony from first week of January to last week of August. Phenological events were observed in 10 days interval during low activity period and at weekly interval at peak activity period for each phenological event. Every phenophase was considered to be at peak when more than 70% of the marked tree showed the phenological event. Highest abundance (the raw number of flower per plant) through visual flower count yielded the peak flowering date. When there were more than one date having equal flower abundance, peak flowering date was taken as the mid-point between these dates. The phenophase were taken to have initiated when less than 15% of the marked trees showed the events. For the estimation of the floral initiation (onset) ten selected individual trees in a site were monitored, and the mean values of first flower were marked from the sample trees which were used as the floral initiation for plant, and for the whole population (25 trees) the first flower among population was used.

Duration of flowering was estimated as the duration of mean values of the first and last flower of selected individual for a plant but for the population it was estimated as the duration between the first flower and the last flower among population. Peak flowering was estimated as mean flowering date i.e., the average of the census dates during which that individual was flowering,

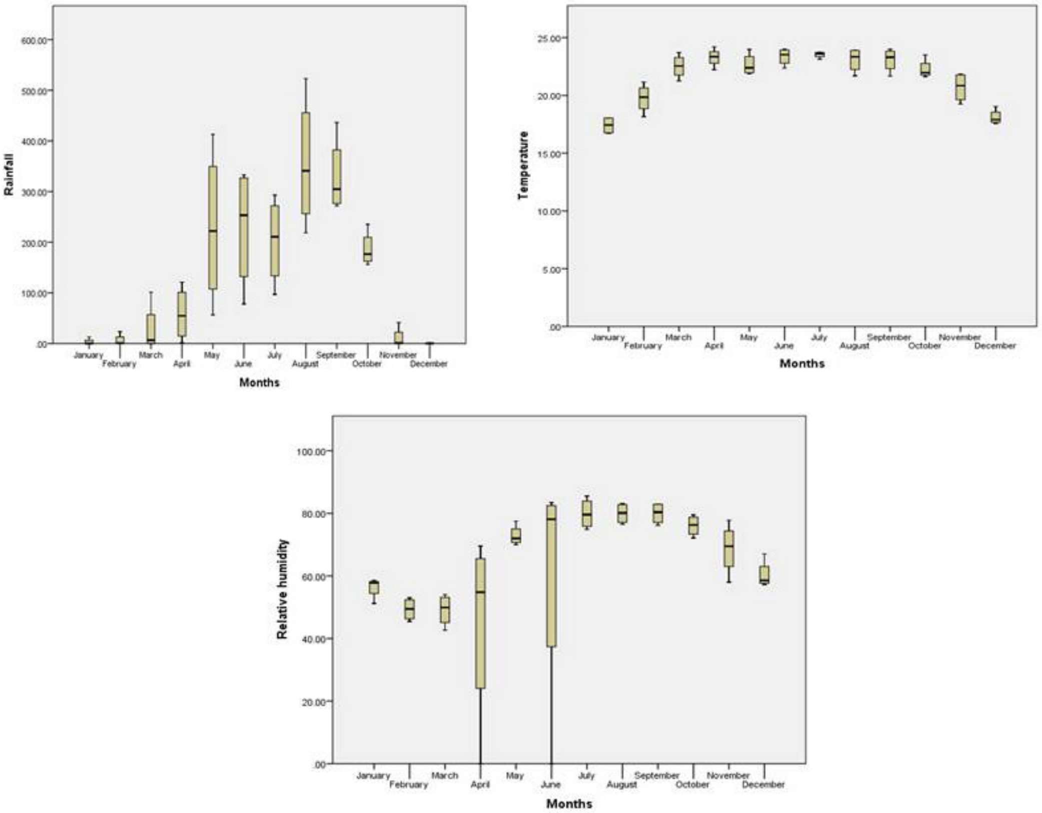

Figure 2. Variations in mean monthly rainfall, temperature and relative humidity during 2011-2014 at Phawngpui National Park.

Table 1. Physiographic features and soil (0-30 cm depth) characteristic features of two *Rhododendron* growing sites at Phawngpui National Park, Mizoram

Parameters	Low elevation	High elevation
Altitude (m, asl)	1945	2157
Slope (%)	15-20	25-30
Aspect	South-West	North-East
Relative humidity (%)	52.01 ± 0.50	50.07 ± 0.51
Mean air temperature (°C)	16.84 ± 0.48	16.84 ± 0.48
Soil textural class	Sandy loam	Sandy loam
Sand (%)	62.38 ± 0.06	56.12 ± 0.16
Silt (%)	16.36 ± 0.02	15.30 ± 0.06
Clay (%)	21.36 ± 0.03	28.58 ± 0.12
Soil pH	4.92 ± 0.01	4.75 ± 0.03
Bulk density (g cm^{-3})	1.35 ± 0.01	1.12 ± 0.02
Soil moisture content (%)	32.31 ± 0.50	31.1 ± 0.43
Water holding capacity (%)	51.26 ± 0.54	45.78 ± 0.22
Soil organic carbon (%)	4.26 ± 0.04	4.15 ± 0.02
Total kjeldahl Nitrogen (%)	0.53 ± 0.03	0.42 ± 0.01
Available Phosphorus (P_2O_5) μg.g-1	6.75 ± 0.26	5.08 ± 0.32
Exchangeable Potassium (K_2O) μg.g-1	370.58 ± 6.23	358.36 ± 4.92

with each census date valued by the number of flowers in that period. Flowering amplitude was estimated during flowering period of total of ten days for the selected ten individuals in which number of flowers were counted and expressed as number of flowers/number of plants/ number of days

Flowering synchrony within an individual plant was the degree to which blooming period of the plant overlapped the blooming period of all the other plants within the population. Synchrony was calculated using the method of Augspurger (1980) modified by Primack (1980). For each individual, the number of days when the flowering overlapped that of other individuals was estimated. The index of synchrony (*X*) for an individual plant (i) was estimated as: Synchrony of a given individual with its conspecifics: X, the index of synchrony for individual i , is defined as

$$Xi = \left(\frac{1}{n-1}\right)\left(\frac{1}{f_i}\right)\sum_{j=i}^{n} e_{j\neq i}$$

where,

e = number of days both individuals i and j are flowering synchronously, $j \neq i$
f = number of days individual i is flowering;
n = number of individuals in population.

When X = 1.0, perfect synchrony occurs, i .e., all flowering days of individual i overlap with all flowering days of each other individual, $j \neq i$, in the population.

When X = 0.0, no synchrony occurs, i.e., no overlap occurs among any of the flowering days of individual i and any other individual, in the population. The amount of overlap of all individuals with each other in the population defines population synchrony (Z), which equals the mean of the values of individual's synchrony. The index includes the entire flowering time, and also considers the temporal overlap between each set of two individuals in the population from the perspective of both individuals which advances Primack's (1980) method that summarizes overlap from the perspective of only one of the two individuals.

At each sampling date soil surface temperature and soil moisture were measured randomly close to the ground at different sites. The air temperature and relative humidity were measured using a thermo-hygrometer. Soil temperature was measured using a soil thermometer. Soil samples were periodically collected to estimate total Kjeldahl nitrogen using automatic KEL PLUS nitrogen estimation system.

Statistical analysis

The variations between the peak flowering timing with respect to year and altitude was using analysis of variance (ANOVA, 2-ways) through SPSS version 16.0 (SPSS Inc). The existence of significant correlations between the flowering timing with various environmental parameters was performed using Spearman correlation coefficients.

RESULTS

Flowering phenology and duration

The flowering phenological events (onset, peak and end) in the species showed wide fluctuations between the sites, and years, and between the plant and population levels (Table 2). At high altitude the onset of flowering started between 31st January (2014) to 4th February (2012) at the plant level, while it started between 15th January (2012) to 20th January (2011/2013) at population level. At low altitude, the onset of flowering was earlier by 9-15 days at plant level and by 11-16 days at population level (Table 2). At high altitude the flowering peak occurred between 21 February (2014) to 2nd March (2011) at plant level, and between 25th February (2013) to 2nd March (2011) at population level. At lower altitude, the peak flowering was earlier by 8-17 days at plant level, and 10-19 days at population level. At high altitude flowering continued till 19th March at plant level, while it continued till 2nd April at population level, while at low altitude the respective dates for end flowering were 6th March and 31st March at plant and population levels, respectively (Table 2).

Duration of flowering at high altitude ranged between 42 days to 44 days for the mean values of the first and last flower of selected individual for a plant for four successive years, but for the population it ranged between 82 to 91 days. At low elevation the mean plant value of flowering duration ranged from 40 to 43 days, and for the population it ranged between 80 to 87 days. In overall the flowering duration was about one and half month while for the population it was two and half month duration (Table 3), however altitude-induced variations in temperature did not influence the duration of flowering.

Peak flowering timings

Peak flowering timing reached between 21-29 days at plant level and 36-45 days at population level, while the corresponding values were 21-30 days, and 40-42 days for plant and population levels, respectively at low altitude. The results revealed that peak flowering time at plant level reached 7-9 days earlier at low altitude than the high altitude during 2011 and 2012 while the in the subsequent two years, the altitude did not have any discernable influence on the peak flowering time. Similarly, at population level the low attitude showed peak flowering earlier by 1-4 days than the high altitude (Fig. 3)

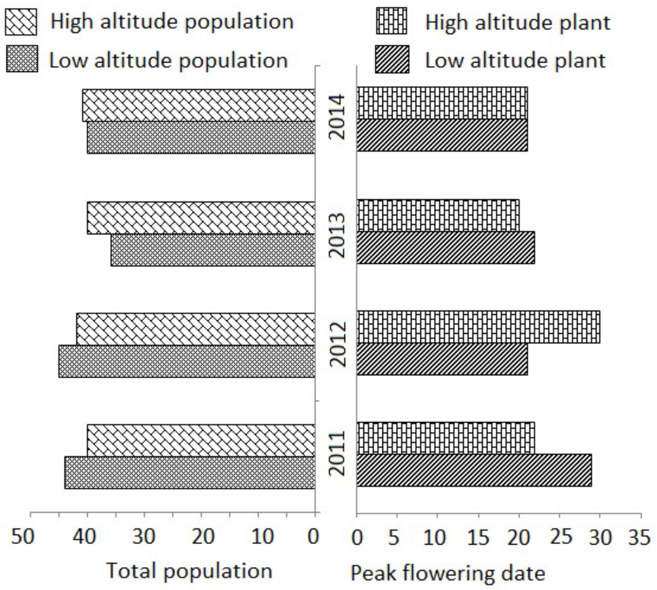

Figure 3. Peak flowering timings reached at both plant and population levels in two altitudes in different years.

Flowering amplitude and flowering synchrony

Flowering amplitude ranged from 2.67 to 3.05 at high altitude and from 3.42 to 3.95 at low altitude. There was no clear trend on the increase / decrease in flowering amplitude across the years in this species though during the fourth years of study higher flowering amplitude was noticed. The species registered higher synchrony between the sites and it was higher in low altitude than high altitude in all the study years except in 2011 (Table 4).

Table 2. Flowering phenological observation on *Rhododendron arboreum* at two altitudes in Phawngpui National Park, Mizoram

Observed Variables		2011		2012		2013		2014	
Plant		Population	Plant	Population	Plant	Population	Plant	Population	
High altitude	Onset	3-Feb	20-Jan	4-Feb	15-Jan	2-Feb	20-Jan	31-Jan	19-Jan
	Peak	2-Mar	4-Mar	25-Feb	29-Feb	24-Feb	25-Feb	21-Feb	28-Feb
	End	19-Mar	16-Apr	18-Mar	14-Apr	18-Mar	2-Apr	15-Mar	10-Apr
Low altitude	Onset	23-Jan	5-Jan	26-Jan	7-Jan	21-Jan	5-Jan	23-Jan	8-Jan
	Peak	14-Feb	14-Feb	15-Feb	18-Feb	10-Feb	14-Feb	13-Feb	18-Feb
	End	5-Mar	27-Mar	5-Mar	31-Mar	2-Mar	26-Mar	6-Mar	31-Mar

Table 3. Flowering duration in Rhododendron arboreum at two altitudes during 2011-2014 (values are mean of all plant/population values ± standard deviation)

	Observed variables		2011	2012	2013	2014
Duration	High altitude	Plant	43d ±4	44d ± 4	42d± 4	44d ± 4
		Population	87 d	91d	84d	82d
	Low altitude	Plant	42d± 4	40d ± 5	41d ± 4	43d ± 4
		Population	81d	87d	80d	83d

Table 4. Intra-specific variation of flowering amplitude and flowering synchrony (the values are the mean of all plant values ± standard deviation).

Year	Flowering synchrony		Flowering amplitude	
	High altitude	Low altitude	High altitude	Low altitude
2011	0.486 ± 0.047a	0.467 ± 0.040a	2.92 ± 0.30a	3.42 ± 0.54c
2012	0.525 ± 0.048a	0.545 ± 0.062c	2.81 ± 0.33a	3.57 ± 0.23c
2013	0.499 ± 0.045a	0.500 ± 0.048a	2.67 ± 0.07b	3.78 ± 0.14d
2014	0.466 ± 0.037b	0.480 ± 0.046a	3.05 ± 0.08a	3.95 ± 0.16d

The values within and between rows showing the same letter for a given flowering attribute is not significant at $P<0.05$

Correlation between peak flowering timings with climatic variables

Among the climatic variables, maximum atmospheric temperature and soil surface temperature showed positive and pronounced effect ($P<0.05$) with the peak flowering timing in both the altitudes. The correlation values (spearmen r) values were relatively higher at the lower altitude than the high altitude. The rainfall, minimum atmospheric temperature, soil moisture and soil nitrogen did not have any influence on the peak flowering time. Soil moisture and rainfall had negative relation with peak flowering time; however relationships were not conspicuous (Table 5).

Table 5. Spearman rank correlation coefficient (*rs*) between peak flowering time with climatic features at two altitudes

Year	Climatic features	Low altitude	High altitude
2011	Rainfall	0.313ns	0.353ns
	Maximum air temperature	0.837**	-0.617*
	Minimum air temperature	0.348ns	0.234ns
	Soil surface temperature	0.568*	0.523*
	Soil moisture	-0.318ns	-0.218ns
	Soil nitrogen	0.126ns	0.256ns
2012	Rainfall	-0.228ns	-0.256ns
	Maximum air temperature	0.536*	0.478*
	Minimum air temperature	0.326ns	0.312ns
	Soil surface temperature	0.738**	0.513*
	Soil moisture	-0.374ns	-0.215ns
	Soil nitrogen	0.214ns	0.326ns
2013	Rainfall	-0.277ns	-0.422ns
	Maximum air temperature	0.552*	0.342ns
	Minimum air temperature	0.352ns	-0.314ns
	Soil surface temperature	0.526*	0.382ns
	Soil moisture	-0.374ns	-0.267ns
	Soil nitrogen	0.265ns	0.334ns
2014	Rainfall	-0.326ns	-0.256ns
	Maximum air temperature	0.878**	0.637**
	Minimum air temperature	0.295ns	0.378ns
	Soil surface temperature	0.538*	0.512*
	Soil moisture	-0.178ns	-0.232ns
	Soil nitrogen	0.174ns	0.234ns

*,** significant at $P<0.5$, 0.01 level respectively, ns-not significant

DISCUSSION

The timing of flowering initiation is an important adaptive trait because it synchronizes reproduction with most favourable season of the year for seed development (Caffara and Donnelly 2011; Gerst et al. 2017) and essential for a species survival, and is shown in many studies to be highly correlated with plant fecundity (Stinson 2004). It can strongly influence the reproductive success of a plant in several ways (Rathcke and Lacey 1985). The linkages between phenology, pollination and reproduction are important for successful plant life (Bawa et al. 1985; Kudo 1993; Kudo et al. 2008). In the present study flowering in *Rhododendron arboreum* Sm. at low elevation started almost two weeks earlier in all the years than high elevation site while there was no conspicuous variation between the years in flowering of this species. The species is reported to have active phenophase throughout the year (Paul et al. 2018) and its flowering phenology extending from February to April in Arunachal Himalaya. However, in the present study, flowering of the species culminated in March. With rise in elevation, delay in flower onset timing and contraction in flowering duration has been documented elsewhere as well (Singh 2014; Gaira et al. 2014). In the present study variation in the timing of flowering (onset, peak & end) in *Rhododendron arboreum* was high between the sites comparison to another *Rhododendron* species (*Rhododendron veitchianum* Hook.) in the site (Malsawmkima 2016). This shows that at higher altitude sites the onset, peak flowering and end of flowering were late, while at lower altitude sites onset, peak and end of flowering were short and early. This may be because every character of the tree needs a particular set of temperatures for its growth and development. This optimum set of temperatures is met early at low elevation and later as elevation increases. In high mountainous regions, flowering phenology changes along elevation gradients, with plants at lower elevation typically flowering earlier than those of the same species growing at higher elevations. (Bertiller et al. 1990; Ziello et al. 2009; Singh et al. 2015). Generally, air temperature in mountainous regions decreases strongly with increasing elevation at a lapse rate of about 0.6 °C every 100 m (IPCC 2014). This temperature gradient is a crucial factor in the timing of biological events. Atmospheric circulation pattern, precipitation and sunshine duration vary strongly in mountainous regions due to variation in aspect and inclination. This creates strongly variable microclimates within mountain regions, which lead to differences between phenology at high altitudes compared to lower sites (Inouye and Wielgolaski 2003). The effect of changing pattern of flowering appears to further mediate by abiotic factors such as increasing soil temperature and soil moisture (Wolkovich et al. 2014), soil nutrient status (Hoover et al. 2012) which interactively affect plant-pollinator mutualism. The positive correlation between increasing soil surface temperature and air temperature with peak flowering time suggest their role in advancing phenological shifts in the *R. arboretum*. The most important proximal environmental cues determining flowering time are considered to be temperature and day length (Reeves and Coupland 2000). The differential response of light and temperature on bud burst suggests temperature is the strongest driver of phenology (Ranjitkar et al. 2013). Occasional deviation from this pattern along elevation gradients may have been caused by variation in micro- environmental factors (Gimenez-Benavides et al. 2007). In many cases, flowering phenology is largely determined by seasonal changes in resources availability; however, in some other, climatic factors such as heat sum are the best predictors of flowering (Dieringer 1991). Anomalies in flowering pattern in *Rhododendron arboreum* has also been reported in central Himalaya (Gaira et al. 2014), in Arunachal Himalaya (Paul et al. 2018). Shift (advanced/delayed) in various phenophases due to climate change has also been recorded for various tree species (Singh and Sahoo 2019); in seed maturity of *Mesua esculenta* and *Pyracantha crenulata* (Shah et al. 2013) and flowering in *Populus deltoides* (Thapliyal et al. 2020). The off-season flowering in *M. esculenta* was noticed in July while the normal flowering for the species is October (Chaukiyal 2011) and similarly for *P. deltoides* flowering was noticed in October while the usual flowering occurs in March-April (Thapliyal et al. 2020). Advances in first bloom dates and increased occurrences of yearly second bloom (Ge et al. 2011) are recorded in eastern China. Nevertheless, the immediate cause of flowering is the development of flower initials in the appropriate meristematic tissues, resulted on account of heat sum, however, in others, flowering may be a physiological response to a very specific environmental cue (Dieringer 1991). In high mountainous regions, flowering phenology changes along elevation gradients, with plants at lower elevation typically flowering earlier than those of the same species growing at higher elevations (Bertiller et al. 1990; Ziello et al. 2009; Luedelling et al. 2011). Our study is in conformity with the longevity of individual flowers increases with altitude (Blionis et al. 2001). The species has a long duration of flowering of population in both sites which sometimes goes to 80 to 91 days and hence reproductive fecundity is also high, i.e. 71.19% to 81.7% fruit set for the natural pollination. Our observation was also in the line with Augspurger (1980) showing higher synchrony occurred where flowering amplitude was high. The longevity of various phenophases were longer at high elevation may be due to changes in the temperature and soil moisture and other climatic conditions. The lower elevations experienced warmer air and soil temperature compared to higher elevation, resulting in early initiation of flowering.

There was good synchrony in blooming noticed within the population. Synchrony among individuals increases cross pollination via attraction of pollinators (Aguspurger 1980) and enhances pollinator visitation frequency and thereby results in better reproduction. Therefore, synchrony is of prime importance for successful seed setting, maximum outcrossing and species fitness and ecological stability. Decreasing synchrony in flowering date can lead to assortative mating since early bloomers are more likely to be pollinated by other early plants, while late bloomers by late plants (Wang et al. 2016). Besides, the synchrony among plants could augment bee visitation rates by attracting more pollinators or decrease the rate by competing for pollinators.

Climate change implications

Our findings suggest that the species is sensitive to climate change, and especially the increasing surface and air temperature are likely to bring change in flowering time which may in turn disrupt flowering synchrony within its population, and may too affect the pollinators. The species appear to be more adjusting to the temperature at high altitude than the low altitude in the site. The Phawngpui National Park being a tourist attraction centre during peak flowering time of *Rhododendron*, the change in flowering timing too may affect tourist flow and related revenues, and livelihood issues of the surrounding villages.

CONCLUSION

The present field observation during 2011-2014 reveals that a considerably higher number of trees of this species bloom during January to February and early part of March, with an early flowering period of nearly a week at the low elevation compared to the high elevation, contrary to most published literature on the species which reveal that flowering phase of *R. arboreum* is from March to May. This suggests that the shift in phenological character may be associated with the climate change; however, long term studies are necessary to confirm this claim.

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Author Contributions: BM designed the study and conducted the field survey and data collection. BM and UKS analyzed the data; BM wrote the first draft; UKS supervised the work and contributed in final write up. Both authors have read and approved the manuscript.

Conflict of interest: We declare that we have no conflict of interest

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