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Patterns of Phenological Characteristics of Important Tree species of Kumaun Himalaya

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Abstract

Phenology is one of the simplest and most effective study to understanding the role of climate change in recent scenario. A number of biotic and abiotic drivers controlled the timing and duration of various phenophases in same or different species. Temperature, rainfall and photoperiod are key drivers which adversely affect the phenology of woody plant. The study sites were conducted at 413 and 2345 m elevation in Nainital forest division of Kumaun Himalaya. The phenological study were carried out on *Shores robusta, Mallotus philippinensis, Pinus roxburghii, Myrica esculenta, Quercus leucotrichophora and Rhododendron arboreum.* The phenological observations were made at 15 days interval for low activity period and weekly in the periods of high activity. Phenological records were made for four phenophases, viz., leafing, leaf drop, flowering and seed fall. The leaf fall in *S. robusta* started from March 2nd week and was complete by the end of April. In *M. philippinensis* the fruiting commenced from the beginning of December and seed fall was complete by the 3rd week of April. In *M. esculenta* male flowers appear from August end and flowering was complete by October end. In *R. arboreum* seed dispersal started from February end and all the capsules had opened by mid-March. It is apparent from the present study that the phenological events of species controlled/shifted due to climatic irregularities and temperaturerise and these phenomena showed worldwide. Microclimatic condition also responsible for controlling/shifting the phenological patterns of same or different species.

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Introduction

The entire Himalaya region is highly vulnerable to the impacts of global warming and forest ecosystem can be seriously impacted in these changes. Phenological events of the plants are good indicators of climate differences.[1,2] Phenology involves precise documentation of timing and duration of different phenological events at species level, their interrelations and possible causal links between environmental variables and phenology.[3] The various phenological events such as leaf-expansion, abscission, flowering, bud-burst, fruiting, seed dispersal and germination of Himalayan species all take place in due season.[3,4] Phenological studies are as important to understand the species interactions and community function because each phenological events of each species occurs in its own calendar slot.[5] Fruiting must wait upon flowering; seed dispersal cannot precede fruiting even an individual flower undergoes a sequence of events.[4,6]

A number of studies in different parts of the world indicate that global warming of last three decades has advanced by a few days several spring time activities such as leaf production flowering and fruiting in plants.[7,8] The observed change may be a positive sign because species are apparently adapting to changing climatic conditions, or they may be negative sign because they show that climate change is indeed impacting living systems.[9] A number of studies have convincingly demonstrated that plants are already responding to climate change with earlier leafing, flowering and leaf drop.[10-12] It is an important component for predicting how species will respond to global warming and increasing drought stress in recent scenario of changing climatic patterns.[13] The most significant ways by which trees can react and cope with rapid environmental change could be adjustments of phenological pattern, allowing trees to persist in their environment.[14, 15] Phenological phases are closely linked with temperature, rainfall and photoperiod and adversely affect the pattern of phenology in same or different species on a small region. A number of evidences have been reported by various researches that phenophases of several species changed by changing climatic patterns. The present work focuses on the documentation of the phenological events and compared with earlier studies to find the shift the phenophases in last three decades and effect of climate change on phenological events ofsal, chir-pine and banj oak dominated forests in Nainital forest division of Kumaun Himalaya.

Material and Methods

The study sites were selected across an altitudinal transect located between 413 and 2345 m elevation (between 29^0 18/ and 29^0 24/ N and 79^0 19/ and $79^0$30/ E) in sal, chir-pine and banj oak dominated forests in Nainital forest division of Kumaun Himalaya. In the sal dominated forest *Shorea Robusta Rox* (Sal) and *Mallotus philippinensis* (Lam.) *Muell. Arg* (Rohini) in chir-pine dominated forest *Pinus roxburghiisarg* (Chirpine) and *Myrica esculenta Thumb* (Kaphal) and in Oak dominated forest *Quercus leucotrichophora A.camus* (Banj Oak) and *Rhododendron arboreum Wall* (Buransh) were selected for detailed phenological observation (Table 1).

Table 1: Physiographic features of selected forests studied sites

Site	Study species	Elevation(m)	Aspect	Latitude N	Longitude E
I	*S. robusta and M. philippinensis*	413-983	Level ground	29018/35.1// 29019/9.5//	079022/40.6// 079022/43.9//
II	*P. roxburghii and M. esculenta*	1760-1810	South-East	29023/15.1// 29023/18.5//	079029/32.5// 079030/38.3//
III	*Q. leucotrichophora and R.arboreum*	1761-2345	North-East	29023/16.0// 29023/42.1//	079030/31.0// 079026/59.1//

In sal forest the average annual precipitation was 1201 mm and mean annual temperature was 23.4^{0}C with mean minimum temperature was 7.5^{0}C in the months of December and mean maximum temperature was 35.5^{0}C in the months of June. In oak and pine forest average annual precipitation was 2258 mm of which two third occurred during rainy season (mid-June to mid-September. Mean annual temperature was 15.2^{0}C with mean minimum temperature was 4.6^{0}C in the months of January and mean maximum temperature was 25.9^{0}C in the months of June.

Irrespective of site 30 individual trees of each selected species (one dominant and one under canopy species) were marked for *S.robusta, M. philippinensis, P. roxburghii, M. esculenta, Q. leucotrichophora* and *R. arboreum* over a 2.0 ha area. The phenological observations were made at 15 days interval during low activity period and weekly in the periods of high phenological activity.[4,16] Phenological records were made for four phenophases, viz., leafing, leaf drop, flowering and seed fall for all studied species for a two-year period and compared with earlier studies to find the shift in phenological events in last three decades.

Results and Discussion

Shorea Robusta

Across all the sites the leaf fall in *S. robusta* started from March 2nd week and was complete by the end of April. Flower bud break started from March 2nd week and flowering was in <10% trees after 2-3 days of flower bud break. Flowering had peaked in the 4th week of March (75% trees had flowered). New leafing started after one week of floral bud opening and by the April end trees had maximum new leafing (95%). However, in seedlings and saplings it continued till July end. Seed fall started from June first week and almost all fruits had fallen after the torrential rain in the third week of June (Fig. 1 and 2).

Mallotus Philippinensis

In this species the leaf fall started in the 2nd week of June and was complete in August 2nd week. New leaves started appearing from May 3rd week and leafing was completed in August 1st week. However, in saplings and seedlings new leaves appeared after July during August and September. Flowering started from September end and was completed in the mid of November. Fruiting commenced from the beginning of December and seed fall was complete by the 3rd week of April (Fig.1 and 2).

Pinus Roxburghii

Needle bud enlargement started from February end and was complete by the 2nd week of March. Needles had attained their maximum length ranging between 14.3cm to 17.1cm by May end. Leaf fall started from March last week and was over by May 2nd week. Seed dispersal commenced from April 2nd week and was completed by June 2nd week (Fig. 1 and 2).

Myrica Esculenta

Leafing started from April 2nd week and was completed by May end when >95% trees and saplings had leafed. Leaf fall started from June 2nd week and continued till 2nd week of July. Seed fall was observed from April end and was completed by 3rd week of May only occasional trees had fruits. Only a few trees (10%) of *M. esculenta* had seeds, and it may be concluded that year as a lean seed year. Male flowers appear from August end and flowering was complete by October end. Maximum flowering was observed between August end and September 2nd week when 80% trees had flowers (Fig.1 and 2).

Quercus Leucotrichophora

Seed fall commenced from 2nd week of November and seed fall was complete (85%) by January end. Bud bursting started from February end and was completed by March end across all the sites. Leafing started in the 1st week of March and was completed in the 1st week of April in trees. Leaf fall started simultaneously with bud bursting and continued till April end. Acorn appeared from March 1st week and continued to appear till 2nd week of April. Seedlings and saplings showed late bud opening, leafing and leaf fall compared to matured trees. Bud bursting was earlier at the disturbed sites (Fig.1 and 2).

Rhododendron Arboreum

Flower bud bursting and flowering started from 1st week of February (<5% trees had flowers). However, occasional trees started flowering from February 1st week. Flowering peaked in 1st week of April (>75% tree had flowered) and was completed by the end of May. New leaves appear after the completion of flowering from May 3rd week and was completed by the end of rainy season. Leaf fall took place round the year but was maximum during the summer months (May-June). Seed dispersal started from February end and all the capsules had opened by mid-March. Leaf longevity of this species is more than 16 months (Fig.1 and 2).

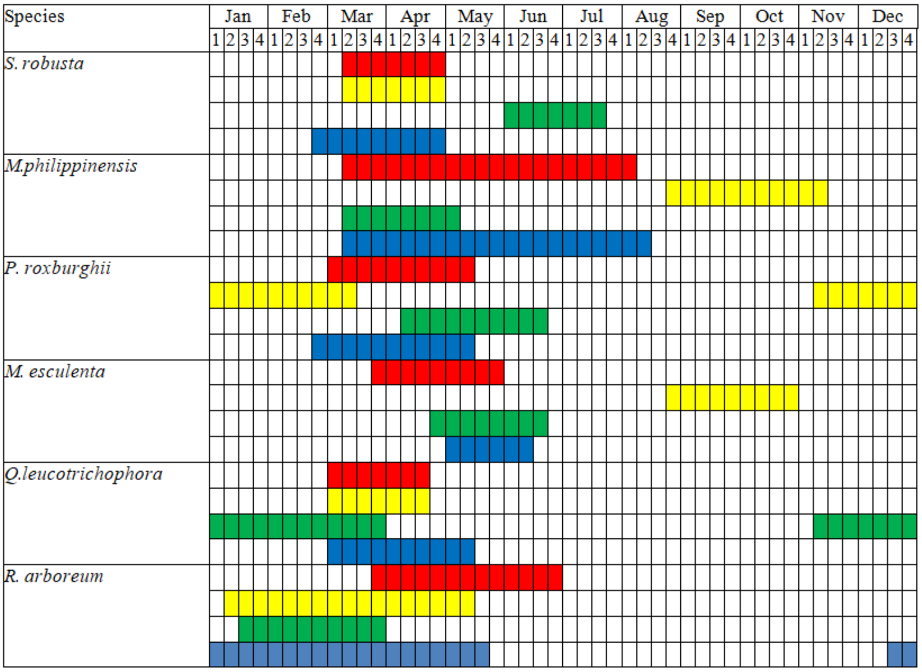

Fig .1: Timing of phenological events during year 1 in all the studied species in different weeks of each month. 1=week 1, 2=week 2, 3=week 3, 4=week 4. Red colour line indicates leafing; yellow: Flowering; Green: Seed fall; Blue: Leaf fall

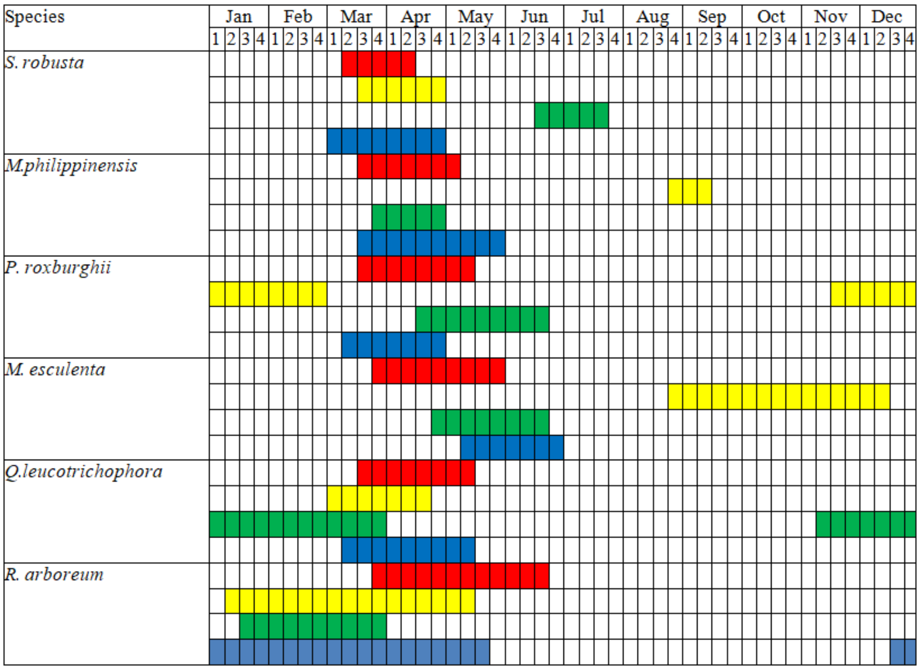

Fig. 2: Timing of phenological events during year 2 in all the studied species in different weeks of each month. 1=week 1, 2=week 2, 3=week 3, 4=week 4. Red colour line indicates leafing; yellow: Flowering; Green: Seed fall; Blue: Leaf fall

Table2: Comparison of changes in timing of leaf drop, leafing and flowering in studied species with earlier studies

Species	Leaf drop	Leaf flush	Flowering	Source
S. robusta	Mar-June	Mar-July	Apr-May	Ralhan, 1985
	Feb-Apr	Mar-June	Feb-Apr	Negi, 1989
	Feb IV-Apr IV week	Mar II-Apr IV week	Mar II-Apr IV week	Yr 1 present study
	Mar I-Apr IV week	Mar III-May I week	Aug IV-Sept II week	Yr 2 present study
M.philippinensis	Mar II-Aug II	Apr-May	Sep-Oct	Ralhan, 1985
	Mar II-Aug II week	Mar II-Aug I week	Aug IV-Nov II week	Yr 1 present study
	Mar III-May IVweek	Mar III-May Iweek	Aug IV-Sept IIweek	Yr 2 present study
P.roxburghii	May-June	Feb-Apr	Feb-Mar	Ralhan, 1985
	Apr-June	Mar-Apr	Jan-Feb	Negi, 1989
	Feb IV-May II week	Mar I-May II week	Nov II-Mar II week	Yr 1 present study
	Mar II-Apr IV week	Mar III-May II week	Nov III-Feb IV week	Yr 2 present study
M.esculenta	Mar-May	Apr-May	Feb-Mar	Negi, 1989
	Apr II-May II week	Mar IV-May IV week	Feb IV-Mar IV week	Yr 1 present study
	Apr II-May II week	Mar IV-May IV week	Feb IV-Mar IV week	Yr 2 present study
Q.leucotrichophora	Apr-May	Mar-Aug	Mar-Apr	Ralhan, 1985
	Feb-Apr	Mar-Apr	Mar-Apr	Negi, 1989
	Mar I-May II week	Mar I-Apr III week	Mar I-Apr III week	Yr 1 present study
	Mar II-May II week	Mar III-May II week	Mar I-Apr III week	Yr 2 present study
R.arboreum	Jan-Dec	Mar-Apr	Jan-Apr	Ralhan, 1985
	Feb-Apr	Apr-May	Feb-Mar	Negi, 1989
	Dec III-May III week	Mar IV-June IV week	Jan II-May II week	Yr 1 present study
	Dec III-May III week	March IV-June III week	Jan II-May II week	Yr 2 present study

We compared the timing of phenological events of present study with the earlier studies of.[17,18] In *S. robusta* when we compared the timing of flowering initiation and completion with earlier studies, we do not find any significant shifts in timing of these phenological events.[17,18] There was no perceptible change in the initiation of leaf drop and leaf fall completion in comparison.[18] However, the period of leaf flushing has become small by approximately a month in comparison to earlier studies (Table 2). In *M. phillippinensis* the period of leafing has been reduced by approximately 4-6 week. The period of leaf drop and leaf flushing were similar to.[17] In *P. roxburghii* the time of flowering initiation has become earlier by 4-6 weeks. Similarly, commencement of needle drop was also earlier by 4-5 weeks in comparison to earlier studies (Table 2). In *M. esculenta* the timing of flowering initiation and completion showed no change in comparison to earlier studies. Leaf flushing initiation was earlier by 4 weeks in both the years whereas leaf drop initiation was delayed by 2 week and completion was same incomparison to earlier studies (Table 2). In *Q. leucotrichophora* there appear to be no major changes in the timing of flowering and new leaf flushing; however, the period of leaf drop has become extended by 2-3 weeks in comparison to earlier studies (Table 2). In *R. arboreum* it has reported flowering initiation in January extending up to April.[17] Earlier researcher has given more restricted period of flowering February-March for the species.[18] In our study flowering commenced from January II week and continued up to May II week in both the years showing more extended flowering period. The period of leaf drop also shows an extended period coupled with leaf flushing (Table 2).

Conclusion

It is apparent from the present study that due to climatic irregularities and temperaturerise the role of temperature would become paramount in controlling/ shifting of the phenological events. Many species shifted their flowering time across the worldwide. Global warming could be a primary cause for these changes some other factors also responsible for these changes such as precipitation pattern, soil and water stress, moisture condition and photo period that would be useful to better understand spatial patterns in the sensitivity of phenological responses to temperature. Microclimatic condition also responsible for controlling/shifting the phenological patterns of same or different species. Hence, more detailed investigations at the local level are required to examine the influence of these events in future studies.

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Conflict of Interest
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