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IMPACT OF CLIMATE CHANGE ON PHENOLOGY OF SOME PLANTS OF LUG VALLEY OF KULLU DISTRICT, HIMACHAL PRADESH

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The composition of tree species, their stratification, life span and phonological periodicity are some important analytical characteristics of a plant community. Plant phenological study has great significance because it not only provides knowledge about plant growth pattern but it also provides information on the effects of environment and selective pressure on flowering and fruiting behavior of plant species. Thus, studies were carried out to analyze the phenological characters of some dominant tree species and shrub species of Lug valley which is located in the North-West of Kullu District. This is occupied with rich biodiversity of floras. It is 8 km away from headquarter of Kullu, Himachal Pradesh. The results suggest that there is a strong seasonality in phenological pattern of tree and shrub species commonly found in the area, exhibited considerable diversity in leaf initiation, flowering and fruiting behaviour. It was found that the flowering of most plants begins in the month of February and with a peak in March. The data compared with the earlier observation and people perception showed that there is change in the phenological events. It was also observed that the maturation of fruits begins and peak stage occurred during April-June and continued more or less throughout the year. These variations in the flowering and fruiting was due to the change in the climate and fluctuation in the temperature and precipitation may promote the growth of some plants while making some sensitive species vulnerable to the change. It can hence be interpreted how the plants may *respond to the changing trends of climate by observing their past and present distribution and phenological trends which are highly influenced by the temperature and precipitation pattern. Phenological changes will probably be the most obvious short-term result of rapid climate change and upon observation provide evidence for advancement in the start of the growing season. Therefore, a monitoring of phenology over long period is done, the impact of climatic change can be better understood, which will help in devising better copping strategies.*

Keywords: Phenology, Climate change, Lag valley, Kullu, Himachal Pradesh

Introduction

Global climate change is a reality, a continuous process that needs to be taken seriously, even though there are large uncertainties in its spatial and temporal distribution. Over the past 100 years, the global average temperature has increased by approximately 0.6°C and is projected to rise at a rapid rate. The third assessment report from the Intergovernmental Panel on Climate Change (IPCC 2001) projects that the earth's average surface temperature will increase by 1.4 to 5.8°C between 1990 and 2100, if no major efforts are undertaken to reduce the emissions of greenhouse gases. This is significantly higher than what the panel predicted in 1995 (1.8–3.5°C). The effect of climate change on seasonal activity in terrestrial ecosystem is significant and well documented (Penults and Felecia 2001; Walther *et. al*. 2002; Root *et. al*.2003). The rates of chemical reactions are temperature dependent and generally increase with increasing temperature. Environmental factors other than temperature also modify plant phenology. The second most important trigger of spring phenological phases is photoperiod length. This has been shown in experimental studies (Saxe *et. al.* 2001). Evidence for effects on spring phenology of precipitation, nutrients and soil physical properties are scarce, and where effects have been found the effect is small relative to the temperature effect (Sparks *et. al.*, 1997). In addition to changes in the physical climate, an increasing CO_2 -mixing ratio is a dominant trait of climate change.

Phenology refers to the study of the response of living organisms to seasonal and climatic changes of the environment in which they live. Plants are adapted to the annual seasonal cycle and all the life-cycle stages are regulated by seasonal atmospheric changes. Seasonal changes include variations in the duration of sunlight, precipitation, temperature and other life-controlling factors. Phenology offers evidence of climate change happening now and helps in assessment of the significant effect on plants in future. Erratic weather patterns will have long-term effects on life-cycle stages and phenological patterns of almost all plant species. Change in plant phenology may be one of the earliest observed responses to rapid global climate change and could potentially have serious consequences both for plants and animals that depend on periodically available resources. . It is evident that climate change will occur during the long lifespan of tree species and changes in phenology may be the major visible short-term response (Badeck *et al*., 2004). In fact, tree phenological observations have proved to be most effective impact indicators of climate change (Kushwaha and Singh, 2008) as many species are highly sensitive even to the smallest change in the long prevailing climate of any ecosystem (Anonymous, 2009 (NBRI)). Thus, phenological models can be used as predictors of ecological changes related to agricultural production, drought monitoring, wildfire risk assessment, and in the management of pests (Betancourt *et. al.* 2007). Moreover, variations in phenological stages are a valuable source of information for investigating the possible impact of climate change on plant species (Chmielewsky and Rötzer 2002). Recent studies indicating changes in phenological stages in plant and animal species provide evidence that ecosystems are responding to climate change (Menzel 2000; Wolfe *et. al*. 2005, Menzel *et. al*. 2006). Many research projects were conducted to assess local and regional changes in phenology of plant and animal species throughout Europe (Ahas and Aasa 2006; Chmielewsky and Rötzer 2002; Menzel *et. al*. 2006), North America (Wolfe *et. al.* 2005, Bradley *et. al.* 1999), and Asia (Ho *et. al.* 2006; Zheng *et. al*. 2002). . Shifts in phenology are relevant for nature conservation planning and the seasonal suitability of landscapes for recreational activities. It has been shown that phenology plays a crucial role in the carbon balance of terrestrial ecosystems (Keeling *et. al*., 1996); in determining shifts in agricultural zoning (Fischer *et. al*., 2002); in vegetation feedback onto the atmospheric boundary layer (Schwartz & Crawford, 2001); in plant competition (Rathcke & Lacey, 1985); in pest and disease control (Penfound *et. al* ., 1945); and in pollen flight forecasts (Traidl-Hoffmann *et. al.*, 2003). In addition to affecting our food supply, phenological events can also affect human health. Pollen allergies can be exacerbated by some changes in growing conditions.

Changes in the timing of phenological events have important implications for scientific research. Scientists use phenological data in computer models that project future climate scenarios and projected impacts of such changes on the environment. Scientists are also interested in how phenology can inform the monitoring of draught conditions and the assessment of risk related to wildfires. Therefore, the present study has been undertaken with the following objectives:-To record different phenophases of some selected plants and to find out the impacts of climate change on phenology of these plants.

The present study was conducted in Lug valley of Kullu District. Lugvalley is located to the North-West of Kullu District. This is occupied with rich biodiversity of floras. It is 8 km away from headquarter of Kullu. Kullu district is situated in the central part of Himachal Pradesh, India. It is spatially extended between 31^{o}20’-32^{o}26’North and 76^{o}59’-77^{o}50 ’East and is a centrally located district of the state with its headquarters at Kullu. Climate of the district is cool and dry, The average rainfall is 80cm and maximum temperature is 38^{o}C and minimum temperature is 5.2^{o}C., In Kullu district the vegetation is a mixture of tropical and temperate species.

Map of Himachal Pradesh

The study area endowed with rich biodiversity, people were asked about the impact of climate change on plant phenology (change in flowering time, flushing of leaves, early or late fruit ripening, change in pollination time, about leaf dropping).The old age people having age groups of 55-75 were also questioned to gain knowledge about the change in environmental condition such as temperature, rainfall and snowfall etc over the period of time and their impact on the life cycles of plants. A detailed survey was undertaken to record different trees of the area .However, keeping in view the phenological characters 13 different species of plants inhabiting different regions of study area were selected for phenological observation. These 13 species included 9 species of trees and 4 species of shrubs. In this study the change in the leaf initiation, flower bud formation, flowering and fruiting events of trees and shrubs were observed. These events were compared with the older observations made by local people about phenology of the trees and shrubs found in the area. Observations were made on the leaf initiation, flowering and fruiting of plant.

Result & Discussion

Leaf initiation

After data analysis it was found that majority of the tree and few shrub species start leaf initiation in February continued up to March. *Rhododendron arboreum* started leaf flushing in June –July.

Flowering activity

It was found that flowering occurred in *rhododendron arboreum* from March-April, in *Robinia pseudoaccacia* May-June, in *Celtis australis* late march-April, in *Juglans regia* from March-April, in *Prunus armenica* February-March, in *Prunus domestica* February-march, in *Prunus persica* March-April, in *Pyrus pashia* March-April, in *Rosa brunonni* during May, in *Rubus elipticus* February-April, in *Princepia utilis* February-March, in *Zanthoxylum armatum* March-April.

Fruiting activity

It was found that fruiting period occurred in *Rhododendron arboreum* from April-November, in *Robinia pseudoaccacia* from June-August, in *Celtis australis* from April-June, in *Juglans regia* from late April to september, in *Prunus armenica* from April- June , in *Prunus domestica* from March-June , in *Prunus persica* from April- August, in *Pyrus pashia* from May-December, in *Rosa brunonni* from June-November, in *Rubus elipticus* from late April-June, in *Princepia utilis* from April-may, in *Zanthoxylum armatum* from April-August .

Lug valley is experiencing a lot of changes due to effect of climate change. Phenological changes occur due to irregular rainfall and snow fall, increasing temperature, decreasing moisture contents as a result all plants have changed their new leaf formation time, flowering and fruiting time. A total of 13 species of tree and shrub selected for this study out of which 1 evergreen (*Rhododendron arboretum*) and 12 deciduous species including 4 shrub species (*Zanthoxylum armatum, Rubus ellipticus, Prinsepia utilis and Rosa brunonii*) and 8 tree species (*Robinia pseudoaccacia, Juglans regia, Prunus armenica, Prunus cerasoides, Prunus domestica, Prunus persica, Pyrus pashia, celtis australis*). Leaf flush occurred in the early part of pre-monsoon dry period during which the rainfall was minimum. The reasons for emergence and maturation of leaves in the pre-monsoon period could be that this dry period is short, temperature is at its maximum and day length increases. On the other hand, leaf fall coincided with short day length and decrease in temperature; however, leaf abscission occurred over a wider span of time than did leaf emergence.

The larger flowering peaks occurred in March/April. Deciduous species tended to flower in pre-monsoon dry period but *Prunus cerasoides* flower in November to December. Advantage of dry-season flowering is that it makes flowers more visible to pollinators since the trees lack leaves. In the evergreen species flowering is mostly after leaf flushing but deciduous species exhibited four basic pattern of flowering in relation to leaf flushing: (i) Flowering before leaf flushing e.g. *Prunus persica*, *Prunus domestica.* (ii) Flowering and leaf flushing simultaneously in the species e.g. , *Juglans regia.* (iii) flowering soon after the flushing showed in species e.g. *Celtis australis* , etc. (iv) flowering later after the leaf flushing is shown in *Pyrus pashia, Rubus ellipticus* and *Rosa brunonii, Robinia psedoaccacia* . All these exhibited flower initiation in response to increasing length to photoperiod. The fruit development period was different for different species. The peak period of ripening of fruit was May–June for some tree and shrub species. However in *Rhododendron arboerum* fruiting period occurred from March to November, *In Juglans regia late April- September, in Pyrus pashiafrom* May to December, in *Rosa brunonii* from June to November, In *Prunus cerasoides* due to flowering in the month of November and December, maturation of fruit took place earlier than the other plant species in the month of February.

The change in the phenological pattern of some of the tree species can be taken as an indicator of the climate change as some plants are highly sensitive to even a slight change in their normal climate pattern especially with respect to the temperature and precipitation pattern. It is evident that climate change will occur during the long lifespan of tree species and changes in phenology may be the major visible short-term response. In fact, tree phenological observations have proved to be most effective impact indicators of climate change (Chmielewski and Rotzer, 2001; Kushwaha and Singh, 2008). In response to short fluctuations in -environmental conditions, plants may vary the start time, intensity, and duration of the phenophase. The intensity of a given phenophase is expected to vary more than the duration or the start time of the phenophase, because the timing of one phenophase will affect that of the other phenophases. For example, if the initiation of flowering is delayed, the timing of fruiting will be offset as well, and may not coincide with optimal fruiting conditions (Anderson *et. al.,* 2005). There can also be differences in response to climate change between species at particular sites or with time of season (Walther *et. al.,* 2002).

Flower initiation is an important phenophase, which is the result of cumulative reflection of all the vital physiological processes in any individual tree (Thakur *et. al.*, 2008). Reproductive events generally occur during the period of low photosynthetic activity or after the period of high rates of reserve accumulation (Singh and Kushwaha, 2006). Flowering and fruiting pattern are also found to be influenced by rainfall pattern (Van Schaik *et. al.*, 1993; Ragusa-Netto and Silva, 2007). Singh and Kushwaha (2006) recorded a wide range of time lag (1-8 months) between the start of vegetative (first-leaf flush) and reproductive (first-visible flower) phases in deciduous species which was correlated with the extent of the leafless period. Several studies have shown significant variation (advanced or delayed) in onset dates of flowering (Fitter and Fitter, 2002) and fruiting responses (Chapman *et. al*., 2005) in tree species as a result of climatic change. Probably the climate change impact can be better assessed at the level of functional types based on the duration of deciduousness and timing of onset of the reproductive phase (first-visible-flower). Temperature is a main driver of many plant developmental processes, and in many cases higher temperatures have been shown to speed up plant development and lead to earlier switching to the next ontogenetic stage (Badeck *et. al*., 2004). Flowering is likely to be delayed by low temperatures (Yadav & Yadav, 2008). For the spring development of plants mainly the temperature changes in winter and early spring are important, which steer the period of dormancy and ontogenetic development (Burroughs, 2002; Chmielewski *et. al.*, 2004).

An increase in the temperature by 1°C has shown to advance flowering by 7 days (Sparks and Menzel, 2002). Chmielewski *et. al*., (2004) observed in Germany during 1961-2000 that an increase in average air temperature between February and April of 1°C lead to an advance in the beginning of growing season and blossoming of fruit trees by about 5 days. Thakur *et. al.*, (2008) during their study in the region of Western Himalayas found that climate change in terms of rising temperature (which increased by 3.7°C within eight years) and reduced rainfall significantly advanced the flower initiation phase and the leaf emergence phase of 10 out of 11 multipurpose tree species (*Grewia optiva, Morus alba, Bauhinia variegata, Robinia pseudoacacia, Melia azedarach, Dalbergia sissoo, Toona ciliata, Celtis australis, Gmelina arborea, Sapindus mukurosii and Albizia stipulata)* ranging between 31 and 46 days within eight years (1999–2006). The flower initiation phase advanced by 40 days in *M.alba*, followed by *M. azedarach*, *D. sissoo* and *T. ciliata* where, the flower initiation phase advanced by 35 days and in *G. optiva, B. variegata, R. pseudoacacia, C. australis and A. stipulata*, the flower initiation phase advanced by 10–27 days. The tree species seem to respond to climate change by adjusting their phenophases. These adjustments have been experienced in just eight years. Yadav & Yadav, (2008) during his study in Bala-fort tropical dry deciduous thorn forest located in north-eastern Rajasthan, observed delayed flowering in *Ehretia laevis* during drought which indicated the role of soil moisture in its flowering activity. Borchert (1994) also suggested that the stored water buffers the impact of seasonal drought and enables flowering and flushing during the dry season. Yadav & Yadav, (2008) also found that the synchronization of flowering and leaf flushing to be related to moisture, temperature and day length.

Flowering date of wild cherry *Prunus avium* at Geisenheim, Germany has displayed a very strong relationship with early spring temperatures (Menzel, 2002). This clearly demonstrates that most of the variability experienced in flowering date can be accounted for by temperature (Sparks and Menzel, 2002). Kailash S.Gaira, Ranbeer S.Rawal, Balwant Rawat and Indira D. Bhatt generated evidences of changes in flowering phenology of an important trees species, *Rhododendron arboreum* in Indian central Himalaya. Real-time field observations (2009– 2011) showed peak flowering during early February to mid-March. Analysis on long-term temperature data revealed significant ($P < 0.01$) increase in seasonal (winter and post-monsoon) and annual mean maximum temperature. Generalized additive model (GAM) using real-time field observations (2009–2011) and herbarium records (1893–2003) predicted 88–97 days early flowering over the last 100 years Furthermore, GAM using long-term temperature data, real-time field observations and herbarium records depicted annual mean maximum temperature responsible for shifts in flowering dates of the target species. The study provides an important insight of species response to climate change in the Indian central Himalaya.

The results of this study suggest that there is a strong seasonality in phenological pattern of tree and shrub species commonly found in the area. The tree and shrub species exhibited considerable diversity in leaf initiation, flowering and fruiting behavior. It was found that the flowering of most plants begins in the month of February and with a peak in March. The data compared with the earlier observation and people perception showed that there is change in the phenological events. It was also observed that the maturation of fruits begins and peak stage occurred during April-June and continued more or less throughout the year. Seasonal variations in environmental factors have a vital role to regulate the phenological pattern of tree and shrub species. These variation in the flowering and fruiting time was due to the change in the climate
The fluctuation in the temperature and precipitation may promote the growth of some plants while making some sensitive species vulnerable to the change. It can hence be interpreted how the plants may respond to the changing trends of climate by observing their past and present distribution and phenological trends which are highly influenced by the temperature and precipitation pattern. Phenological changes will probably be the most obvious short-term result of rapid climate change and upon observation provide evidence for advancement in the start of the growing season. Thus phenology has emerged as an important measure to assess the impact of climate change on ecosystems. Long-term phenological records provide a useful measure of changes in the species-level biological responses to variations in climate at specific sites.

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Table: 1 Showing Phenological events in plants based on primary and secondary data

S.N.	Botanical name	Local name	Family	Leaf initiation	Flowering period	Fruiting period	Flowering period	Fruiting period
1	Rhododendron arboreum	Burans	Ericaceae	Throught year	Mid March - April	April - November		
2	Robinia pseudoaccacia	Kikar	Fabaceae	Late February-March	May -June	June-August		
3	Celtis australis	Khdak	Ulmaceae	February - March	Late March-April	Apirl-June	April-May**	May**
4	Juglans regia	Akhrot	Juglandac-eae	February - march	March-April	Late April-August	February-March*	July-August*
5	Prunus armenica	khubani	Rosaceae	February-March	February-March	April-June		
6	Prunus Cerasoides	Pajja	Rosaceae	October-November	October-November	February-June	October-November*	February-March*
7	Prunus Domestica	Plum	Rosaceae	February-March	February - March	March-June	February-April**	May-June**
8	Prunus Persica	Aru	Rosaceae	February-March	March-April	April-August	February-March**	May – October**
9	Pyrus pashia	Shaigal	Rosaceae	February-March	March-April	May-August	January-February*	October-November *

10	Rosa brunonni	Kuja	Rosaceae	February-March	May	June-August	May-April*	September-October*
11	Rubus ellipticus	Anche	Rosaceae	February-March	February-April	Late April-June	January-February*	March-April*
12	Zanthoxylum armatum	Tirmira	Rosaceae	February-March	March-April	April-August	April-May****	June****
13	Prinsepia utilis	Bhekhal	Rosaceae	February	February-March	April-May	January-February*	April-May*

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