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IMPACT OF INTER-ANNUAL CLIMATE CHANGE ON SOME PHENOLOGICAL ASPECTS OF *HOLOPTELEA INTEGRIFOLIA* PLANCH AND *GMELINA ARBOREA* ROXB

ARBEEN AHMAD BHAT AND ASHOK K JAIN **

S K Jain Institute of Ethnobiology
Jiwaji University, Gwalior – 474011 (M.P.)
Email: sagararbeen007@gmail.com, asokjain2003@yahoo.co.in
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ABSTRACT

Present study deals with impact of climate change on the phenology of two tree species of Chambal eco-region of Madhya Pradesh, India between the years 2009 to 2011..Meteorological data for twenty years (1990-2011) indicate about an increase in average maximum and minimum temperature by 0.27ºC and 0.53ºC respectively. The yearly precipitation also has reduced during these two decades. It was also observed that the average spring temperature (T24) has increased from 2000 to 2011. The vegetative and reproductive phenology of selected species were differentially influenced due to changes in some climatic parameters. Leaf bud burst, flowering and fruiting of both the species were advanced by significant number of days but the leaf fall in both the species was delayed.

Keywords : Angiospermic species, phenology, climate Change, Leaf Fall variation,

Introduction

There is a worldwide consensus that global warming is a real, rapidly advancing, and widespread threat faced by humans. Scientists have presented evidence and tested models to substantiate this truly alarming fact (Parmesan, 1996; Pounds *et al.,* 1999; IPCC, 2007; Woodward, 2002;Klanderud and Birks, 2003; Hall and Fagre, 2003 and Chaudhari and Arya, 2009). The timing of life-cycle events became an excellent bioindicator due to its sensitivity and dependence facing to several climate variables, such as ambient temperature (Ahas*et al.,* 2000; Both *et al.,* 2004) or water availability (Penuelas*et al.,* 2004).

Phenology is the study of seasonal occurrence of developmental or life cycle events, such as bud break, flowering or autumn leaf drop (Rathcke and Lace,1985). The timing of these events is known to be sensitive to short- and long-term variability in climate and is thus a robust indicator of the effects of climate change, especially observed rising temperatures (Badeck*et al*., 2004; Chuine*et al*., 2004; Fitter and Fitter, 2002; Schwartz *et al*., 2002; White *et al*., 1997 and White and Nemani, 2003). In Britain, mean flowering dates of 385 plant species advanced by 4.5days during the 1990s compared with the 1954-1990 mean flowering dates and the change has been attributed to recent warming trends (Fitter and Fitter, 2002). In the northeastern United States, changes in lilac, apple and grape phenology suggest that spring has advanced by 2-8 days over the last three or four decades, consistent with patterns across North America as a whole (Schwartz and Reiter, 2000; Wolfe *et al*., 2005). Furthermore, there is also strong indirect evidence that the onset of spring has

***Corresponding author:* Ph. No. +91 751-2442771 (O)

been occurring progressively earlier in recent decades (Badeck *et al*., 2004; Fitzjarrald *et al*., 2001 and Keeling *et al*., 1996). Climate change, ascribed to human-induced emission of greenhouse gases into the atmosphere, is widely recognized as having potentially serious impacts on the global environment. Since the industrial revolution, atmospheric CO_2 concentrations have increased from approximately 280 µmol mol^{-1} in 1750 to 365µmol mol^{-1} at present, and will exceed 700µmol mol^{-1} by the end of the present century if emissions continue to rise as predicted (IPCC,2001).

Phenological analysis of trees provides a potential tool to address critical questions related to modeling and monitoring of climate change(Schwartz, 1999). Climate change will affect many aspects of the biology of tropical treesand its effect on plant phenology would be of immense significance (Corlett and Lafrankie, 1998). In recent years, therefore, the focus of phenological studies has shifted to questions of how phenology will be affected by global climate change and what consequences any climatic change may have for species distribution and ecosystem function. The control of phenology in tropical trees is not well understood (Borchert *et al*., 2002). Much of the available phenological information on tropical trees is inadequate, partly because of lack of standardized terminology and because most studies have been for a short term and have focused at community level patterns only (Newstrom *et al*., 1994).

A study carried out by Indian Institute of Science (Ravindranath *et al*., 2006) assessed the impact of projected climate change on forest ecosystems in India. The main conclusion is that in 2085, between 68% and 77% of the forested grids in India are likely to experience shift in forest types depending upon projected climate change scenarios. Climate of India is largely controlled by annual monsoon, and appears to be experiencing increasingly severe and erratic precipitation.

Chambal eco-region of Madhya Pradesh comprises eight districts where over 800 species of angiosperms occur in wild condition. Several workers while studying the district or specific geographical floras have recorded the phenology of a large number of species in this region but no observations have been made on impact of climate change on the phenology of these tree species. Therefore, present study was carried outto assess the changes in phenology of two tree species, if any, due the rapid changing climate.

Material and Methods

Study site and species

Present observations were made in Chambal eco-region of Madhya Pradesh mainly comprising Gwalior district located at 26.22° North Latitude and 78.18° East Longitude, on the northern most part of Madhya Pradesh (Fig. 1). The average elevation is about 197 meters above the sea level and spread over an area of 5214.00 sqkm in the Chambal river valley. Climate of Gwalior is an integral part of the geography of Gwalior. Marked by scorching summers, the temperature during the summer months goes on ascending and reaches up to a high of 48° C. The mean annual maximum temperature of the region is 33° C. The winter months on the other hand are chilling and the temperature varies from 1°C to 3°C and the mean annual minimum temperature in the winter months is 18.5° C. The mean annual precipitation received by the study area is over 700 mm. The region experiences rainfall only in the monsoon months. The type of soil present in the region is black soil having low organic matter, calcareous, neutral to moderately alkaline (PH 7.0 to 8.5) and has high clay content.The vegetation of the region is characterized by deciduous forests with scrub forest patches at most places. Two important forest species viz., *Holoptelea integrifolia* (Roxb.) Planch and *Gmelina arborea* Roxb. of the region were selected for observing the impact of inter-annual climate change.

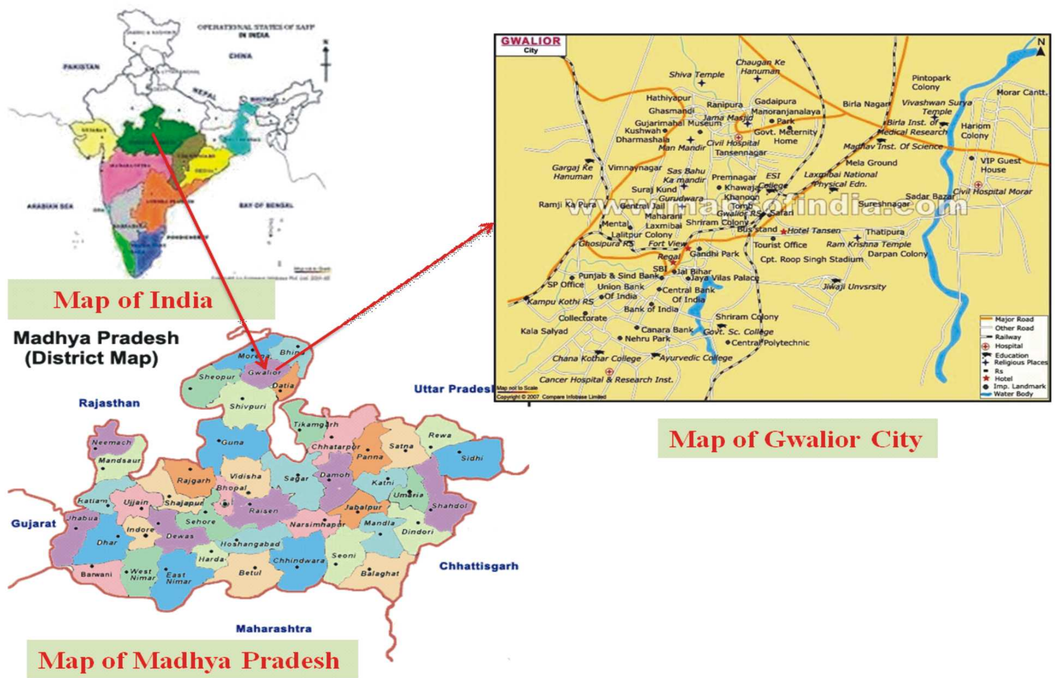

Fig. 1– Map of the study area

Collection of phenological and meteorological data

Visual observations were made by repeated visits of ten days interval to the study area to record the phenological parameters. Special binoculars were used to closely observe the phenophasefor tall trees. To observe the synchrony,eight to ten marked individuals per species were selected for phenological observation. For phenological data, all dates were expressed in **Julian days (Day of the Year)** for convenience in data analysis. Phenological periods investigated during the study period were leaf bud formation, leaf flushing, flowering (initiation, full and cessation), fruiting (initiation, full and shedding), leaf senescence and leaf fall. The former four events are termed as spring phenology and the latter two as autumn phenology. The phenological parameters we used include growing season length (difference between the starting date of leaf bud formation and ending date of leaf falling period), starting date (the time when nearly 50% ofthe species have attained a certain phenological event), ending date (the time when most of the species have finished this event) and duration of a certain phenological event (Yang and E YH 2000).

Meteorological data was obtained from Indian Meteorological Department (IMD), Gwalior 3 km from the study area. Both temperature and precipitation have been found to have a pronounced impact on phenology of tree species (Chmielewski and Rotzer,2001). Temperature of the study years (2009, 2010 and 2011) exhibited a slight change during these three years.The maximum monthly temperature averaged 32.2° C in 2009, 33.4° C in 2010 and 33.9° C in 2011showing an increasing trend. The minimum monthly temperature averaged 19.5°C in 2009, 20.4°C in 2010 and 20.8°C in 2011.Total rainfall during 2009 was 981.3 mm, 941.3 mmin 2010 and 642 mm in 2011.

Results

Changes in air temperature

Analysis of meteorological data indicates that during last two decades (1990–2011) there has been an increase in average maximum and minimum temperature by 0.27°C and 0.53°C ($P < 0.05$) respectively (Fig. 2). The average yearly precipitation i.e. 941mm, has also been reduced by 250mm between 1990 to 2011 (Fig. 3). The rise in temperature (T_{24}) by 0.65°C ($P<0.01$) during spring season i.e. February and April is again a good climatic indicator.

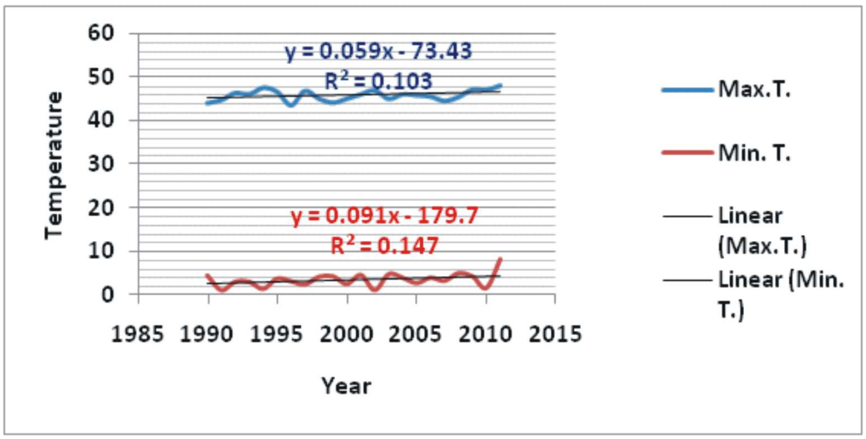

Fig. 2 –Yearly average maximum and minimum temperature (ºC) during last two decades

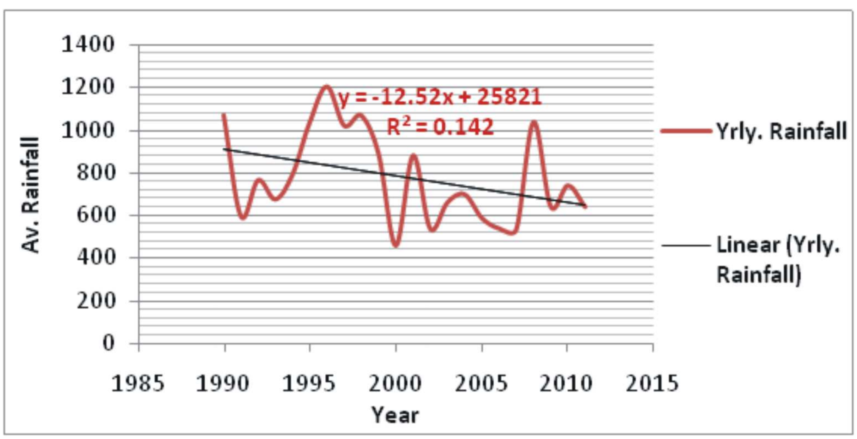

Fig. 3 – Average yearly rainfall during last two decades

Impact on leaf fall and leaf flush

Owing to deciduous nature of selected species, maximum leaf fall occurs between February to March. Each species exhibits a single episode of leaf lessness each year. The duration between the beginning and end of leaf fall varied between 1 to 2 months but selected species remain leaf less for about 20 to 30 days. Timing of leaf fall initiation alsodiffered during the study period. *H. integrifolia* started shedding leaves in second week of February (2009), infirst week of February (2010) and in third week of February (2011) showed a clear delaying trend (Fig.-4, Table-1), but lost all its leaves in first week of March (mean, 41 ± 5.29). These phenophases were correlated and the trend was found to be statistically significant ('r'=0.65, P<0.03).

Table 1– Correlation coefficient of the phenophases of selected species.

Phenophase	'r'		P
	H. integrifolia	*G.arborea*	
Leaf Fall	0.65	0.98	**0.03**
Leaf Bud Burst	-0.90	-0.80	**0.001**
Flowering initiation	-0.78	-0.99	**0.029**
Fruiting initiation	-0.43	-0.50	0.12

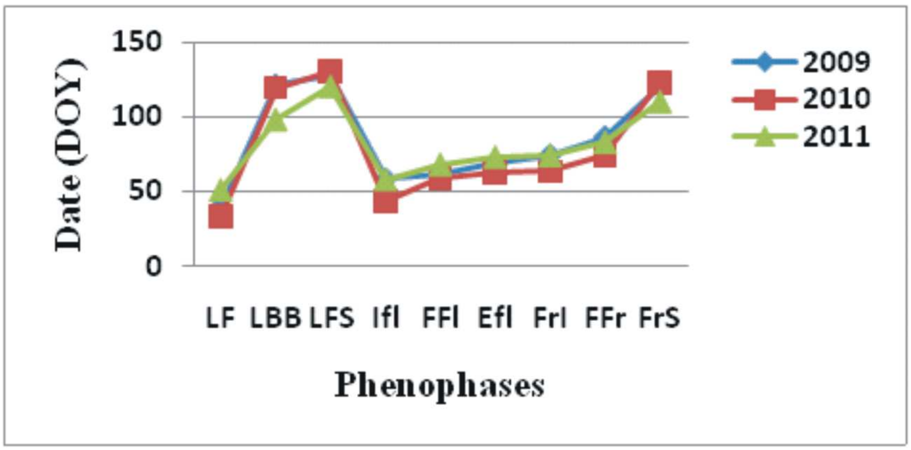

Fig. 4 – Dates (DOY= Day of the year) of phenological parameters of*H.integrifolia*

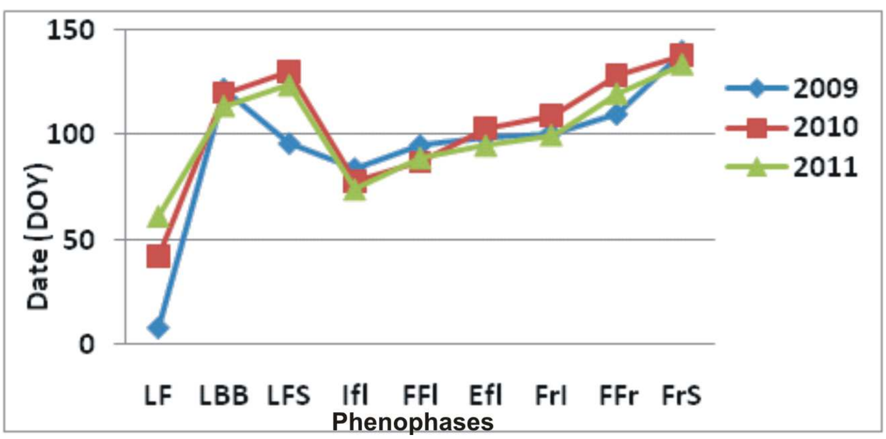

Fig. 5 – Dates (DOY=Day of the year) of phenological parameters of *G. arborea* species

Similar trend in leaf fall was observed in *G.arborea* where leaf shedding was started in thefirst week of January(2009), second week of February (2010) and first week of March (2011)with mean value 37 ± 15.5, thus shows a delayed trend (Fig. 5, Table-1) ('r'=0.98, P< 0.03).

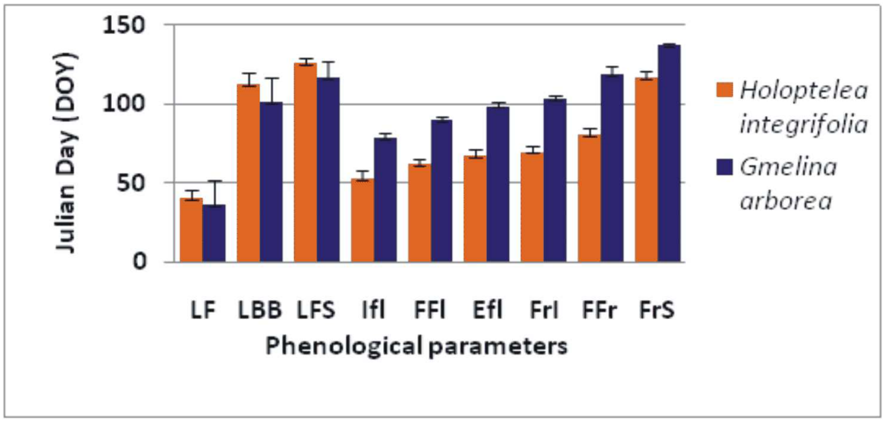

Fig. 6 – Dates of all the phenological parameters (mean ±standard error)

Leaf flushing in both the species was observed in April and May with *H. integrifolia* on 121th day (2009), 119th day (2010) and 98th day (2011) indicatesa clear advancing and statistically significant trend (mean 113 ± 7.35, 'r' = - 0.90, P < 0.01). The leaf cover washigher on 126th day (mean). In *G.arborea* the leaf bud burst started on 122th day (2009), 120th day (2010) and 114th day (2011) also indicates an advancing and statistically significant trend P<0.01 (mean, 119 ±2.38, 'r'= -0.96).This significant advancement in leaf emergence phase is bound to have substantial influence on growth pattern.

Flower production

In *H. integrifolia* the flowering started in last week of February (2009), third week of February (2010) and in second week of February (2011) exhibited a clear advancing trend which was well correlated with the increasing average temperatures of the study years ('r'= -0.71, P<0.01). The mean flowering day (2009-2011) was 47th day of the year (S.E.± 5.8).

G.arborea also produced flowers soon after its leaf fall and continued until flushing of the new leaves. These flowers lasted for three weeks. In 2009, it produced flowers in end of the third week of March, in the beginning of third week of March (2010) and second week of March (2011). The correlation of flowering phenophase with average temperature of these study years was found to be statistically significant ('r'= -0.99, P <0.01). The mean flowering day in case of *G.arborea*was found to be 79th day of the year (S.E.± 2.90). Both the tree species seem to respond climate change by adjusting their phenophases.

Fruiting

The initiation and span of fruiting in both the species varied during the study years. *H. integrifolia* exhibited a longer episode of fruit production i.e. for seven to eight weeks and *G. arborea,* a shorter duration for three weeks.In both the species, the fruiting showed quite asynchrony with respect to the study years. In case of *H.*

integrifolia the mean date of initiation of fruiting was found to be on 69th day of the year ('r' = -0.35, P<0.05) whereas it was 103.33th day in case of *G.arborea* ('r'=-0.10, P<0.5).The dates of full fruiting in both the species varied quitesignificantly with respect to all the three study years. The mean full fruiting day was 81 and 119.33 in *H. integrifolia* and *G. arborea* respectively. Both species shed their fruits after seven to eight weeks i.e. 117.33 (S.D±3.71, 'r'= -0.77 P<0.05) and 134th (S.D.±1.76, 'r'= -0.98 P<0.01) day of the year both showing an advancing trend.

Discussion

In present study, a clear delaying trend in leaf fall was observed in both the species which exhibits variation in leaf fall phenophase. This trend further signifies the observations made by Singh and Kushwaha (2005). The vegetative bud break may be triggered by different control mechanisms e.g. leaf fall, first significant rainfall (Rivera *et al.,* 2002). In both species, leaf flushing occurred during spring season (April-May) before rainfall signifying the main role of temperature and photoperiod in triggering the phenophase (temperature ~40°C). It is in conformity of the observations made onseveral tree species of dry tropical forests in Argentina, Costa Rica, Java and Thailand and savanna in Brazil (Rivera *et al.,* 2002, Elliot *et al.,* 2006). Reports by Singh and Kushwaha (2005) and Prasad and Hedge (1986) also justify the present observations.

Flower production in both the species was markedly dependent on the photoperiod and temperature. Both species flowered in March and April during all three study years when the temperature is high. Flowering in both species occurred during leafless stage. The total or partial loss of leaf cover may result in rehydration of the stem and trigger flowering (Singh and Kushwaha, 2006). The flowering may rely on the use of internal water reserves in both species (Borchert,1994b). In Costa Rica forests, some trees have been found to reduce transpiration before all leaves fall, allowing an increase in stem water content, which allows flower production during the dry season (Reich and Borchert, 1984).

In *H. integrifolia* number of flower and fruit production was much more in 2009. It might have resulted from a combined effect of rainfall difference and lepidopteranherbivory (pollination behaviour). In March (2009), a little rainfall was witnessed which was associated in triggering more flower production and later high fruit production. It might be because flowers transpire and may require a large water requirement (Daubenmire, 1972; Bullock and Sollis-Magallanes, 1990).

Duration of fruit production in both species further coincides with the observations made by Singh and Kushwaha (2006). In *H. integrifolia* with flower production during the dry season (Fig. 4), fruit production is ca 2 months and in *G. arborea,* which also produced flowers during the dry season, the fruit production lasts about 2 months (Fig. 5). The type of fruit also plays a role in deciding the duration of the fruit attachment with its branchand flower phenophases, because species with larger fruits require more time to develop, therefore, such trees exhibit early flowering (Singh and Kushwaha, 2006).

Conclusion

Present study clearly indicates that vegetative and reproductive phenology of both species aredifferentially influenced by the changing climatic parameters (temperature and rainfall). Generally small changes occur at a very low rate in a long period, however, present observations indicate that the changes are very fast in a short period.Shifting in flowering, fruiting or any phenological parameter would certainly have an impact on various activities of man. In India and various other parts of the world quite a good number of festivals, rituals and ceremonies are associated with plants and celebrated on a particular day or period. It also depends upon the availability of particular plant part. If such changes occur continuously, it would be difficult for people to celebrate them on scheduled time due to unavailability of required plant parts on time. The change in availability may also affect the trade and economy of the people. Further, it is necessary to develop phenological models in India for all important species in order to estimate the impact of climate change on plant growth and development.

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