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Exploring the Phenological Patterns of Selected Tree Species in District Yamuna Nagar, Haryana

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ABSTRACT: This study explores the phenological events of selected tree species in Yamuna Nagar district of Haryana, during the calendar year 2024. Systematic observations of the plants were conducted from January to December. The research focused on key phenophases including leaf flush, flowering, fruiting, and senescence of leaves across commonly occurring tree species such as *Albizia lebbeck* (L.) Benth., *Azadirachta indica* A.Juss., *Cordia myxa* L., *Dalbergia sissoo* Roxb. ex DC., *Delonix regia* (Bojer ex Hook.) Raf., *Ficus religiosa* L., *Jacaranda mimosifolia* D.Don., *Melia azedarach* L., *Pterospermum acerifolium* (L.) Willd., *Terminalia bellirica* (Gaertn.) Roxb, *Toona ciliata* M. Roem., and *Syzygium cumini* (L.) Skeels. The plants exhibited distinct phenological behaviors influenced by local environmental conditions. The major phenological events, like leaf flush, flowering, and fruiting took place in the months of March to May. The senescence of leaves started in autumn and continued in winters. The study revealed species-specific variations in the timing and duration of phenophases, with notable sensitivity to seasonal fluctuations. Also the study shall provide valuable baseline information for long-term ecological monitoring, biodiversity conservation, and adaptive forest management practices with expected climate change in the near future.

Keywords: Phenophases, Climate change, Forest management, Yamuna Nagar.

INTRODUCTION

Phenology is the study of regular occurrences in the life cycle of living organisms influenced by seasonal and yearly climate variations. Phenological stages arise from a combination of biological rhythms and environmental influences. These factors over the course of evolution have led species to adapt to various climatic conditions (Orlandi *et al*., 2007). A number of studies on phenophases of plants have been carried out by different workers in different regions of the world (Kaur *et al.*, 2013; Liu *et al.*, 2023; Kanwar and Sharma 2023). According to Chhetri *et al.* (2020), an understanding of the diversity of phenological patterns, which show variations in the timing of phenophases in the different plant species, is essential for determining the status and development of trees throughout the year. Plants depend on one or more of the factors for their phenological processes with the changing environmental conditions. Keerthana *et al.* (2022) in their study on *Glycine max* (L.) Merrill observed that increasing the seed-space during sowing improves phenology and seed quality. In a study on *Lupinus perennis* L., Pushpa *et al.* (2022) found that application of Gibberellic acid improves the phenology of flowering and yield of the plant. In another study on tropical forests, Numata *et al.* (2022) concluded that the phenological processes across different species in various ecosystems showed variable responses.

Phenological patterns in tropical plants are typically linked to the distinct seasonal rainfall patterns, characterized by sharply contrasting wet and dry seasons (Marques *et al*., 2004). Nanda *et al.* (2017) in a study on tropical evergreen forests observed that rainfall had a notably negative impact on both vegetative and reproductive phenological events. All phenophases of these phenologies, except for leaf senescence, displayed significant seasonal patterns. Identifying a specific relationship with air temperature makes it possible to regulate the species composition and quantity when establishing this type of plantation. Kopp *et al.* (2020) examined a large number of plants and their phenology in certain regions of North America. They found that there was a sensitive relationship between temperature and the flowering of plants. They also suggested that further studies are required to establish the effect of global warming on plant phenology. The progression of phenophases and the timing and length of plants' phenological cycles are consistently influenced by seasonal climate variations, such as the regular alternation of seasons with differing day lengths, temperatures, and precipitation levels (Adamenko *et al.*, 2023).

Due to climate change, seasonal perennial plants face several physiological challenges. Identifying and understanding the timing of physiological stress tolerance can offer managers a valuable tool for adapting to and reducing the effects of expected change in climate (Grossman, 2023). Ibáñez *et al*. (2010), from their study, concluded that it is utmost important to study multiple plant species in different geographical conditions so as to express change in phenological

behaviour of plants. Climate change is shifting the timing of biological events in species, yet the ecological and conservation impacts of these changes remain underestimated (Mendes *et al.*, 2023).

The effects of climate change on plant phenology are being increasingly studied, but most of the research tends to overlook woody species (Verbényiné Neumann *et al.*, 2023). According to Pancharoen *et al.* (2021), urban forests are vital for reducing urban heat and influencing the microclimate, which can affect tree phenology. Mrekaj *et al*. (2024) in their study on forest trees of Slovakia concluded that temperature was the main factor influencing different phenophases of the plants. Bartosova *et al*. (2025) compared the phenology of crops and wild plant species in Central Europe. They concluded that studies on natural vegetation can give better information regarding phenological changes due to shifting climate patterns. Using remote sensing technology, Kleinsmann *et al.* (2023), studied the phenological behaviour of different plants and concluded that tracking of the phenomena is crucial for gaining insights into ecosystem dynamics and evaluating how they respond to climate change. A detailed study of these interactions can form the basis for urban planners to choose the most suitable trees for the plantation activity.

MATERIALS AND METHODS

Study site. The present study has been conducted on some important tree species in district Yamика Nagar of Haryana (Figure 1). The district lies between 29° 55' to 30° 28' North latitudes and 77°09' to 77°36' East longitudes at 274 meters AMSL (DCOH, 2011). The climate of the study area is subtropical, with the majority of rainfall taking place in the monsoonal season. The hot summers start from April and go up to June. This is followed by the arrival of the South-West monsoon that lasts up to the month of September. A Period from October to November is called post-monsoon (Autumn) and the winters start from December to February. A transition period is there in the month of March called the spring season. The annual rainfall during the study period has been recorded as 855 mm (Fig. 2) for the calendar year, with the highest peak of 270 mm in September 2024. The average minimum and maximum monthly temperature were recorded in January (6°C) and May (46°C), respectively. The meteorological data has been collected from the office of the district administration and the weather stations of Saraswati Sugar Mill at Yamuna Nagar, Haryana.

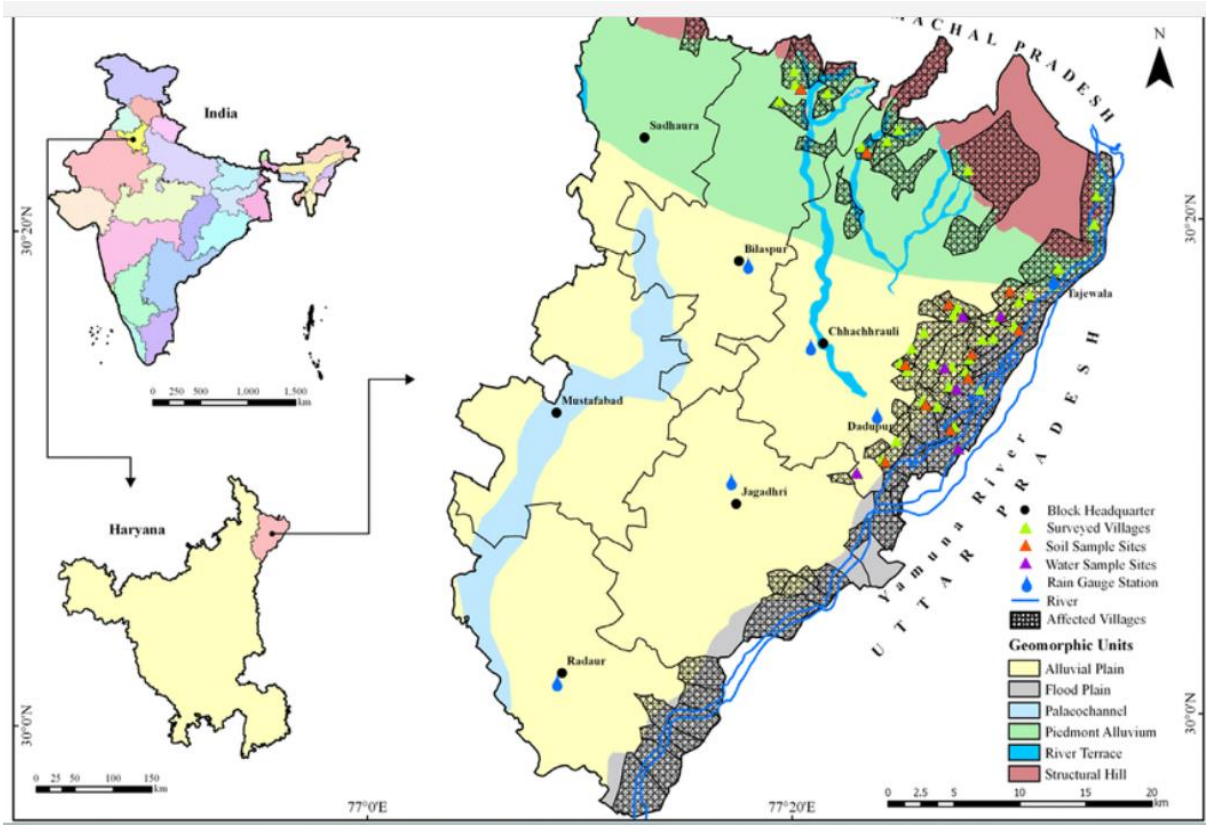

Fig. 1. Map of the Study Area.

Phenology. The phonological events of 12 tree species have been recorded from villages Parwalo (P), Buria (B), Manakpur (M) and Jaroda (J). These selected plants belong to 12 genera and 8 families (Tabel 1). The sites of study area were chosen as there was a wide diversity of tree species. Different phenological activities were recorded for the calendar year 2024. The phenophases included -Leaf budding (Lb), Leaf flush (Lf), Senescence of leaves (Sl), Complete leaf fall (Cl), Flower budding (Fb), Flowering (Fl), Fruiting (Fr), Fruit maturation (Fm), fruit fall (Ff) and last years fruit fall (Ffl) as shown in Table 2. Visits were paid to the site fortnightly but weekly during the period of higher activity from Feb to May to record the phenological events.

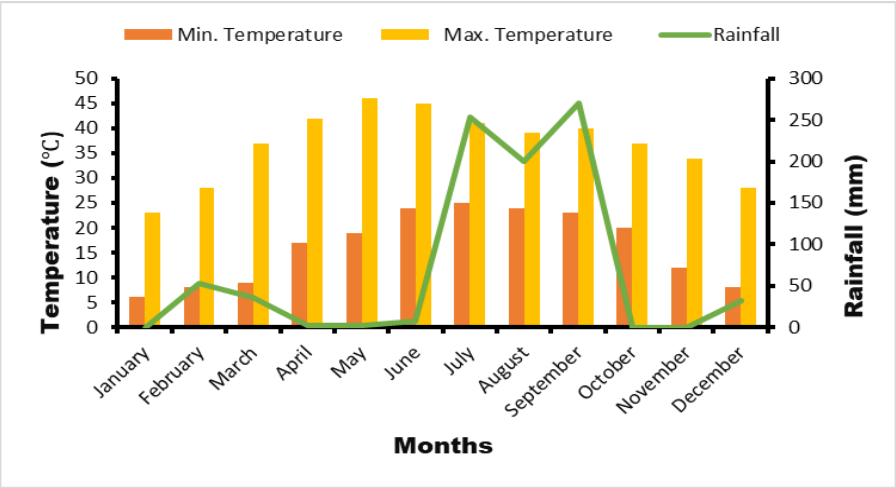

Fig. 2. Record of monthly temperature and rainfall of the study area during 2024.

RESULTS AND DISCUSSIONS

The phenological observation for 12 trees in the year 2024 has been recorded in Table 2. Most of the trees under study were found to be in the stage of leaf senescence or completely leafless in the month of January 2024. Towards the second half of February, Leaf buds were reported in 83% of the trees, and leaf flush also started in the last week of the month in 41.7 plant species (Fig. 3). The months of March and April were having the highest numbers of activities like leaf flush, flower budding and flowering. In April 91.6% of the species were in the flowering phase, and 6 species had started the process of fruiting. In May 2024, all the tree species were in the fruiting phase and that continued in June with almost half of the species. Fruits started maturing in the month of June, and the phenomenon lasted till August. The fruit fall took place in July and August in *Azadirachta indica* A.Juss., *Cordia myxa* L., *Melia azedarach* L., *Toona ciliata* M.Roem., *Ficus religiosa* L., *Syzygium cumini* (L.) Skeels *and Dalbergia sissoo* Roxb. ex DC.

For the members of the family Meliaceae the process of leaf flush, flowering and fruiting was first noticed in *Melia azedarach* L. followed by *Toona ciliata* M.Roem. and *Azadirachta indica* A.Juss., while in the family Fabaceae the order was *Dalbergia sissoo* Roxb. ex DC., *Albizia lebbeck* (L.) Benth and *Delonix regia* (Bojer ex Hook.) Raf. Senescence started in most of the plants towards the end of the rainy season in the second half of September and continued till the end of the year as the winters arrived. In *Jacaranda mimosifolia* D.Don, *Terminalia bellerica* (Gaertn.) Roxb and the members of the family Fabaceae the fruits were still attached to the plants in the cold winter seasons when the senescence of leaves was taking place. In case of *Pterospermum acerifolium* (L.) Willd. the last year's fruits started dehiscing while the next year flowering, and fruiting was taking place in the month April and May.

From this study it was observed that the peak season for most of the physiological activities, including leafing, flowering, and fruiting, was from March to May. This observation is similar to some other phenological studies (Chhetri *et al.*, 2020; Kaur *et al.*, 2013). Fruit maturation took place in most of the plants during the rainy season. As the winters approach, there is a decline in temperature and day length and the process of leaf senescence starts in most of the plants. A few studies on senescence as reported by some workers (Wang *et al.*, 2023; Wang *et al.*, 2025), have shown temperature to be the factor responsible for this process.

Table 1: List of tree species selected for the study of phenological events.

Sr. No.	Scientific Name	Family	Common Name
1.	*Albizia lebbeck* (L.) Benth.	Fabaceae	Siris
2.	*Azadirachta indica* A.Juss.	Meliaceae	Neem
3.	*Cordia myxa* L.	Boraginaceae	Lisoda
4.	*Dalbergia sissoo* Roxb. ex DC	Fabaceae	Sheesham
5.	*Delonix regia* (Bojer ex Hook.) Raf	Fabaceae	Gulmohar
6.	*Ficus religiosa* L.	Moraceae	Peepal
7.	*Jacaranda mimosifolia* D.Don	Bignoniaceae	Jacaranda
8.	*Melia azedarach* L.	Meliaceae	Deck
9.	*Pterospermum acerifolium* (L.) Willd.	Malvaceae	Muchkund
10.	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	Baheda
11.	*Toona ciliata* M.Roem.	Meliaceae	Toon
12.	Syzygium cumini (L.) Skeels	Myrtaceae	Jamun

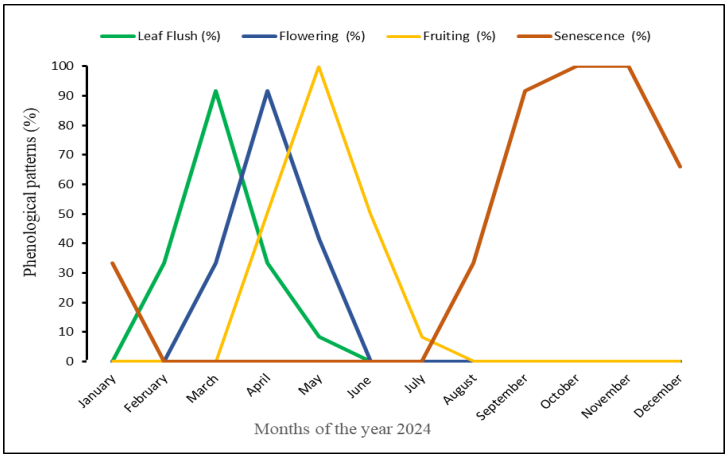

Fig. 3. Important Phenological patterns (%) of the selected plants during January to December 2024.

Table 2: Phenophases of selected plant species during the study period from January to December 2024.

Sr. No.	Botanical Name /Months	January	February	March	April	May	June	July	August	September	October	November	December
1.	*Albizia lebbeck* (L.) Benth.	Cl, Ffl	Lb, Ffl,Lf	Lf,Fb	Fb,Fl	Fl,Fr	Fr	Fm	Fm	Sl	Sl, Ff	Sl	Cl
2.	*Azadirachta indica* A.Juss.	Cl	Lb	Lf	Fb,Fl	Fl,Fr	Fr	Fm, Ff	Ff,Sl	Sl	Sl	Sl	Sl
3.	*Cordia myxa* L.	Sl	Cl	Lb,Lf, Fb	Lf,Fl	Fl,Fr	Fm,Ff	Ff	Sl	Sl	Sl	Sl	Sl
4.	*Dalbergia sissoo* Roxb. ex DC	Cl, Ffl	Cl,Lb, Ffl	Lf, Fb	Lf, Fl, Fr	Lf, Fr	Fm	Fm	Ff	Ff, Sl	Ff,Sl	Ff, Sl	Sl
5.	*Delonix regia* (Bojer ex Hook.) Raf	Cl, Ffl	Lb,Ffl	Lf,Fb	Fb,Fl	Fl,Fr	Fr	Fr, Fm	Fm	Sl	Sl	Sl	Sl
6.	*Ficus religiosa* L.	Sl	Cl	Lb,Fb,fL	Lf, Fr	Fr	Fm	Fm	Ff	Ff	Sl	Sl	Sl
7.	*Jacaranda mimosifolia* D.Don	Cl, Ffl	Ffl, Lb, Fb	Lf, Fb, Fl	Fl, Fr	Fr	Fr, Fm	Fm	Fm	Sl	Sl	Sl	Cl
8.	*Melia azedarach* L	Cl	Lb, Lf	Lf, Fb,Fl	Fl, Fr	Fr	Fm	Ff	Ff	Sl	Sl	Sl	Cl
9.	*Pterospermum acerifolium* (L.) Willd.	Sl	Lb, Lf	Lf, Fb	Fb, Fl, Ffl	Fl, Fr, Ffl	Fr	Fm	Fm	Fm, Sl	Sl	Sl	Sl
10.	*Terminalia bellirica* (Gaertn.) Roxb.	Cl, Ffl	Lb, Lf	Lf,Fb	Fb,Fl, Fr	Fr	Fr	Fm	Fm	Sl	Sl	Sl	Sl
11.	*Toona ciliata* M.Roem.	Cl	Lb, Lf	Lf, Fb,Fl	Lf, FlFr	Fr	Fm	Ff	Sl	Sl	Sl	Sl	Cl
12.	*Syzygium cumini* (L.) Skeels	Sl	Lb	Lf	Fb, Fl	Fr	Fm	Fm, Ff	Sl	Sl	Sl	Sl	Sl

ABBREVIATIONS: Lb- Leaf budding
Lf- Leaf flush
Sl - Senescence of leaf
Fb-Flower budding
Fl-Flowering
Fr- Fruiting
Fm- Fruit maturity
Ff- Fruit fall
Ffl- Fruit fall of last year
Cl-Complete leaf fall

CONCLUSIONS

The impacts of global warming are now being felt and some studies have observed a change in the phenology of plants and higher temperature is the major contributor (Mrekaj *et al.*, 2024). In a warmer world, the seasons of spring, summer and autumn may change and alter the phenological processes in plants. Therefore, such studies are important to understand the phenological shift due to climate change.

FUTURE SCOPE

This study can provide a baseline to monitor the effects of climate change on tree species in Yamuna Nagar. It may help in biodiversity conservation by identifying sensitive species and improving forest and agroforestry practices. Understanding phenology can also support urban planning by selecting suitable trees for green spaces. Future work could expand to remote sensing, climate modelling, and citizen science initiatives. Overall, the findings can guide local policies on environmental management and climate adaptation.

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Conflict of Interests. None.

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