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A study on the flowering and fruiting Phenology of Plants at Jorbeer Conservation Reserve, Bikaner (Rajasthan)

Priyanka Devra, Smita Jain

Department of Botany, Govt. Dungar College, Bikaner, Rajasthan, India

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Abstract— *Phenology is the study of the timing of various life history events such as bud burst, leaf expansion, abscission, flowering, fertilization, fruiting, seed set, seed dispersal, and seed germination in plants. Phenological events such as flowering and fruiting are key ecological indicators that reflects plant responses to climatic factors, and they play a crucial role in shaping ecosystem dynamics. This paper deals with the study of phenological activities such as flowering and fruiting time of plants at Jorbeer Conservation Reserve, Bikaner (Rajasthan) for two years from 2021-2024. The study area visited regularly two times in a month and systematic phenological monitoring were conducted to record duration of fruiting and flowering time period for each plant species. The flowering and fruiting phenology of 35 plant species reveal distinct seasonal pattern, with the majority of plant species exhibiting flowering phase during the monsoon season (July-September) and fruiting phase extending into the post-monsoon season (October-December).*

Keywords— ***Phenology, Flowering, Fruiting, Jorbeer Conservation Reserve, Phenology, Rajasthan***

I. INTRODUCTION

Phenology refers to the study of how plants respond to climatic variations. The term originates from the Greek word 'phainomai', meaning "to appear" or "come into view". In ecological context, phenology generally describes the timing of seasonal events, including when certain phenomena first or last occur. Even slight changes in climate can significantly affect vegetation. Patterns of phenological events are often used to characterize different vegetation types (Shimwell, 1972; Opler et al., 1980). Studying phenology helps us understand how plant grow and develop over time, and reveals how environmental conditions and selective pressures influence flowering and fruiting behaviors (Zhang et al., 2006).

The timing of flowering is an extensively studied aspect of plant phenology, researched at various scales ranging from the level of community (Murali & Sukumar, 1994) to that of individual flower analysis (Herrera, 1995). Variation in flowering period, relative to vegetative growth, can be triggered by factors such as substantial rainfall in winter or summer, changes in day length, or drought-induces leaf shedding, resulting in diverse flowering patterns among tropical trees (Borchert et al., 2002). Phenological study also plays a vital role in understanding how species interact with each other and with their surrounding environment. Differences in phenophases, whether among individuals of the same species or between different species, have been associated with environmental disturbance (Suresh & Sukumar, 2011).

A considerable amount of phenological data is available on different plant species from different part of India including subtropical humid seasonal forest in northeastern India (Shukla & Ramakrishnan, 1982), tropical moist forests (Bhat, 1992), tropical deciduous forest in India (Singh & Kushwaha, 2006). In tropical dry deciduous forest of Bhadra Wildlife Sanctuary, southern India (Nanda *et al.,* 2014), Katerniaghat Wildlife Sanctuary of Uttar Pradesh (Chaudhary *et al.,* 2014), Girnar Reserve Forest, Gujrat, (Nakar & Jadeja ,2015), Amrabad Tiger Reserve of Telangana, India (Shankar *et al.*, 2022), sub-tropical moist forest trees of northeastern India (Devi *et al.,* (2023), tropical evergreen forests of Andaman and Nicobar Islands, India (Dey *et al.* 2023).

Several studies conducted on phenology of various plant species across different parts of Rajasthan including herbaceous vegetation around Pilani, Rajasthan (Kumar A. *et al.,* 1980), Ambagarh reserve forest, Jaipur (Mathur & Bhatnagar, 1992), tropical dry deciduous forest of Rajasthan (Yadav & Yadav 2008), Sariska tiger reserve of north-eastern Rajasthan, (Yadav & Gupta, 2009). IGNP at Shri Ganganagar district, Rajasthan (Chand *et al*., 2014), Indian tropical trees (Singh and Kushwaha, 2006), Northwestern Punjab Kaur et al. (2013) and reproductive biology of *Salvadora oleoides* in various parts of Rajasthan (Barman *et al.,* 2018).

II. MATERIALS AND METHODS

2.1 Study Area

The Jorbeer Conservation Reserve of Bikaner District (Rajasthan) is situated in the western part of the Thar Desert. Jorbeer is situated southeast of Bikaner at a distance of 10 km, which is both the district and sub-district headquarters of Jorbeer village. The geographical location of the area is 28 º 3' north latitude and 73º5' east longitude at a height of 234.84 MSL. The total geographical area of Jorbeer is 7583 hectares. It experiences an arid climate characterised by intense heat and minimal precipitation. The climate of Jorbeer is dry with an average rainfall of 100 mm and temperature ranges from a minimum of -1 to -2 degrees in winter to a maximum of 49.5 degrees in summer. The winter month from November to February provides the most favourable climate for visiting Jorbeer Conservation Reserve with mild temperatures and optimal conditions for wildlife sighting and exploration. The Flora of Jorbeed Conservation Reserve is well adapted to desert conditions like water deficiency and extreme temperatures. The Flora of the study area primarily comprised grasses and xerophytic plants with sparse trees. The reserve's vegetation creates a conductive habitat for a variety of fauna, especially for herbivores and grassland avian species

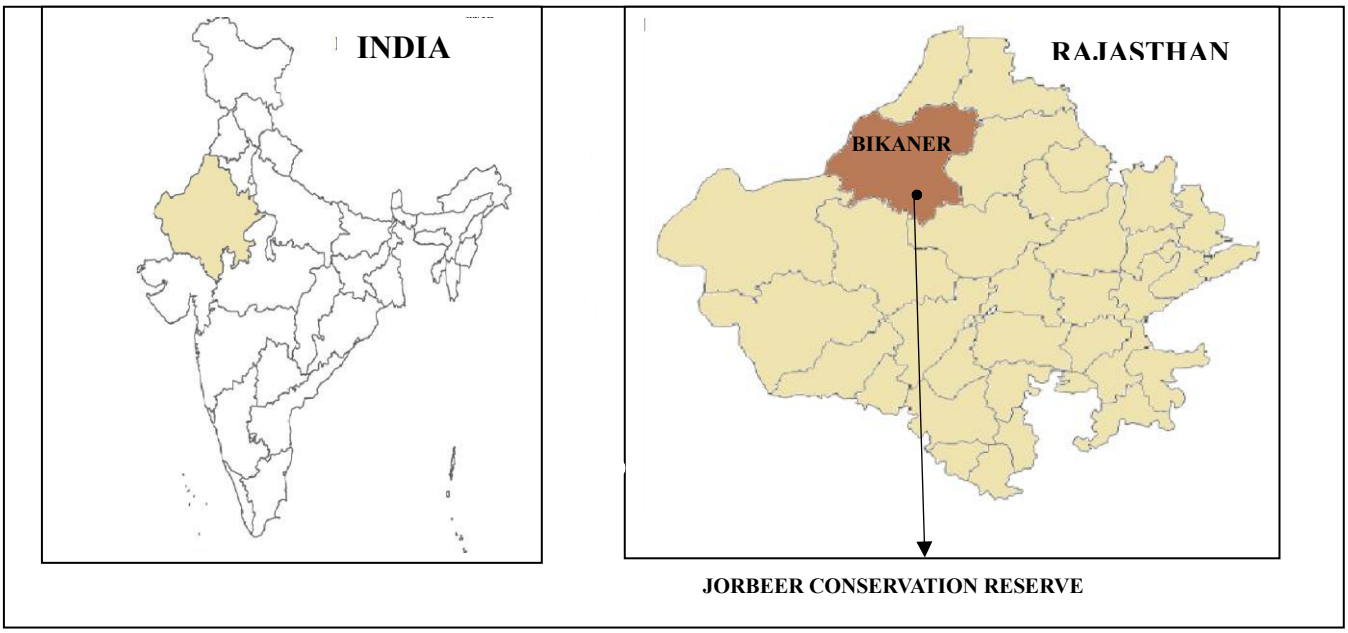

Fig 1: Key Map of Study Area

2.2 Methodology

Phenological observation was carried out from 2021-2024, for the period of two year to evaluate the phenology of 35 plant species in Jorbeer Conservation Reserve of Bikaner District. Phenological studies involve observing, recording and interpretation of the timing of life history events of plants. The present study considers the phenology of flowering and fruiting time in a range of species. First, we selected the 10 individual of each plant species and marked them for easy identification. The study area visited regularly two times in a month and record observation on phenophase such as fruiting and flowering time period for each marked specimen. Details observed were noted in a field notebook and geotag photographs were taken. The year is divisible into four seasons: winter season (January to March), summer season (April to June), monsoon season (July to September) and post-monsoon season (October-December).

III. RESULTS

In the present study, the monsoon season (July-September) stands out as the most significant flowering period (Fig. 2). Among 35 plant species, 25 species (67.56%) initiate or peak in their flowering during July-September, indicating flowering correlates strongly with the increased moisture availability from the monsoon rain, which plays a crucial role in enhancing reproductive development. Most of the species are herbaceous vegetation, including grasses. During the post-monsoon season (October-December), flowering was observed in 4 species (10.81%), including *Abutilon indicum* L., *Pulicaria crispa* (Cass.), *Cassia angustifolia* M. Vahl. and *Leptadenia pyrotechnica* (Forssk.) Decne. The winter season (January-March) exhibited flowering in 5 species (13.51%) such as *Chenopodium album* Linn., *Echinops echinatus* Roxb., *Solanum surattense* Burm, *Prosopis cineraria* (L.) Druce. f. and *Prosopis juliflora* (Swartz). DC. The summer season (April-June) marks the flowering period for three species (8.10%), prominently including *Capparis decidua* (Forssk.) Edgew., *Calotropis procera* (Alt.) R. Br. and *Salvadora oleoides* Decne. These species are adapted to thrive in extremely arid conditions and initiate flowering in the warmer months of the year.

The post-monsoon season (October-December) was observed as the primary fruiting season (Fig. 3). Among 35 species, 24 species (62.66%) produced fruits during these months. The post-monsoon season provides favourable conditions for seed maturation and dispersal that follow the monsoon-induced flowering phase. During the winter months (January-March), 6 species (16.66%) produced fruits, including *Abutilon indicum* L., *Acacia tortilis* (Forssk.) Hayne., *Chenopodium album* Linn., *Echinops echinatus* Roxb., and *Leptadenia pyrotechnica* (Forssk.) Decne. And *Solanum surattense* Burm. f. These species likely fruit in response to the late flowering observed from the previous season. The summer months (April-June) account for fruiting in 4 species (11.11%), particularly *Capparis decidua* (Forssk.) Edgew., *Salvadora oleoides* Decne. and *Prosopis cineraria* (L.) Druce and *Prosopis juliflora* (Swartz). DC. Fruiting was observed in only 2 species (5.55%) during the monsoon season, such as *Citrullus colocynthis* (Linn.) Schard. and *Cucumis callosus* (Rottl.) Cong. *Prosopis juliflora* (Swartz.) DC. blooms and bears fruit continuously throughout the year, highlighting their invasive and xerophytic nature. This continuous reproductive ability not only reflects their perennial nature but also their strong capacity to adapt to diverse ecological conditions.

IV. DISCUSSION

The reproductive phenology of 35 plant species at Jorbeer Conservation Reserve showed that the flowering phase in the highest percentage of species occurred in the monsoon season (July-September) and while fruiting occurred in the post-monsoon season (October-December). Indian monsoon plays a vital role in shaping plant phenology, including the timing of flowering, fruiting, and other developmental stages. In Rajasthan, flowering phenology is strongly influenced by the timing and intensity of monsoon rainfall, particularly in its arid and semi-arid regions. Many plant species began or peaked in flowering during the monsoon, attributed to the favourable conditions characterised by warm, humid weather and adequate soil moisture. Kumar et al. (1980) conducted significant research on herbaceous vegetation in the Pilani Region of Rajasthan, demonstrating that climatic factors significantly influenced the phenology of herbaceous species, including grasses. The majority of these species were annuals that thrived during rainy seasons. Similar to the present study, Nakar and Jadeja (2015) studied the phenology of flowering and fruiting of shrubs, under-shrubs, and herbs at Girnar Reserve Forest, Gujarat. According to them, flowering and fruiting were primarily studied in August and September, with a second peak observed during March and April, although the percentage of flowering during this time was lower compared to the August and September periods. After examining 39 species of shrubs and trees in Sariska Tiger Reserve, Northeast Rajasthan, Yadav (2009) concluded that flowering and fruiting occurred year-round, showing two peaks, one during the summer (March-April) and the other during the Monsoon (July-August). About 33 % of species flowered in summer, 26 % during the rainy season, while only 3 species bloomed during cold months. Similarly, Yadav and Yadav (2008) reported two flowering peaks in 26 woody species of the tropical dry deciduous forest in Rajasthan, one in July-August and the other in March-April, while fruit maturation peaked in September-October, fruit dehiscence generally completed in June, before the monsoon. Meanwhile, Mathur and Bhatnagar (1992) conducted a phenological study in Ambagarh Reserve Forest, Jaipur, on ten key species including *Prosopis cineraria, Ziziphus nummularia, Acacia tortilis, Dichrostachys cinerea, Adhatoda vesica, Prosopis juliflora, Acacia nilotica, Anogeissus pendula* and *Holoptelea integrifolia.* Furthermore, Singh and Kushwaha (2006) reported that out of 119 tropical tree species in India, summer-flowering species are the most dominant. The prevalence of summer flowering along with leaf flushing in summer appears to be a distinctive adaptation in trees, enabling them to survive in strong seasonal condition of tropical climates. Kaur et al. (2013) found that in some

phanerogams (trees and shrubs) of Northwestern Punjab, flowering showed a peak during the beginning of the summer season and others during the post-monsoon season, while fruiting was observed in March, April, and May. The variation between their results and the current study can be attributed to differences in species selection and climatic conditions.

V. CONCLUSION

The present study concludes that the reproductive phenology of herbs, shrubs, and trees is mainly characterised by flowering peaks in July–September and subsequent fruiting in post-monsoon (October-December). This timing of flowering and fruiting allows the plant to take advantage of the monsoon season for reproductive success and the post-monsoon season for effective seed dispersal, ensuring its survival and ecological success in arid and semi-arid environments. A small number of species show adaptability to extreme conditions by flowering or fruiting during summer or winter, or persisting year-round. This seasonal flowering distribution revealed that monsoon rainfall acts as a key ecological cue for reproductive activity in the arid zone of Jorbeer Conservation Reserve. The alignment of flowering with the start of the monsoon highlights an adaptive survival strategy among many native species, enabling them to utilise optimal moisture conditions for effective pollination and formation of seed. The presence of seasonal peaks in flowering and fruiting suggests an adaptive mechanism, and further research is necessary to better understand the reproductive phenological sequences of specific region.

Table 1: Flowering and Fruiting Phenological study of Jorbeed Conservation Reserve

S. No.	Botanical Name	Family	Flowering phenology	Fruiting phenology
1.	*Abutilon indicum* L.	Malvaceae	October-December	January-March
2.	*Acacia Senegal* (Linn.) Willd.	Fabaceae	July-October	September-December
3.	*Acacia tortilis* (Forssk.) Hayne.	Fabaceae	July-November	December-March
4.	*Aerva persica* (Burm. f.) Merril.	Amaranthaceae	August-October	August-October
5.	*Boerhavia diffusa* Linn.	Nyctaginaceae	July-September	September-October
6.	*Boerhavia erecta* L.	Nyctaginaceae	July-September	September-October
7.	*Brachiaria ramosa* (Linn.) Stapf.	Poaceae	July-August	September-October
8.	*Calotropis procera* (Ait.) R. Br.	Asclepiadaceae	April-September	September-December
9.	*Capparis decidua* (Forssk.) Edgew.	Capparaceae	March-April & July-August	May-June & September-October
10.	*Cassia angustifolia* M. Vahl.	Fabaceae	August-October	October-December
11.	*Cassia italica* (Mill.) Spreng.	Fabaceae	July-September	September-December
12.	*Cenchrus biflorus* Roxb.	Poaceae	July-September	September-December
13.	*Cenchrus ciliaris* Linn.	Poaceae	July-September	September-December
14.	*Chenopodium album* Linn.	Chenopodiaceae	February-March	February-March
15.	*Citrullus colocynthis* (Linn.) Schard.	Cucurbitaceae	June-September	July-September
16.	*Cleome viscosa* L.	Cleomaceae	July-September	July-September
17.	*Cucumis callosus* (Rottl.) Cong.	Cucurbitaceae	June-September	July-October
18.	*Cyperus rotundus* Linn.	Cyperaceae	July-September	October-December
19.	*Dactyloctenium aegyptium*	Poaceae	July-September	September-November
20.	*Echinops echinatus* Roxb.	Asteraceae	January-February	February-March
21.	*Eragrostis ciliaris* (Linn.) R. Br.	Poaceae	July-September	September-November
22.	*Euphorbia serpens.*	Euphorbiaceae	July-September	October-November
23.	*Fagonia indica* Burm. f.	Zygophyllaceae	July-September	October-December
24.	*Heliotropium curassavicum.*	Boraginaceae	July-September	October-December

25.	*Leptadenia pyrotechnica* (Forssk.) Decne.	Asclepiadaceae	August-December	November-February
26.	*Lycium barbarum* Linn.	Solanaceae	July-September	October-December
27.	*Mollugo cerviana* (Linn.) Ser.	Molluginaceae	August-October	October-November
28.	*Prosopis cineraria* (L.) Druce.	Fabaceae	January-April	March-June
29.	*Prosopis juliflora* (Swartz.) DC. Prod.	Fabaceae	January-March & July-September	April-June & October-December
30.	*Pulicaria crispa* (Cass.) Benth. & Hook. F.	Asteraceae	September-November	October-December
31.	*Salvadora oleoides* Decne.	Salvadoraceae	March-May	May-July
32.	*Solanum surattense* Burm. f.	Solanaceae	December-February	January-March
33.	*Tribulus terrestris* L.	Zygophyllaceae	July-September	September-December
34.	*Verbesina encelioides* (Cav.) Benth. & Hook. f. A. Gray.	Asteraceae	August-October	October-December
35.	*Ziziphus nummularia* (Burm. f.) Wt. & Arn.	Rhamnaceae	July-September	October-December

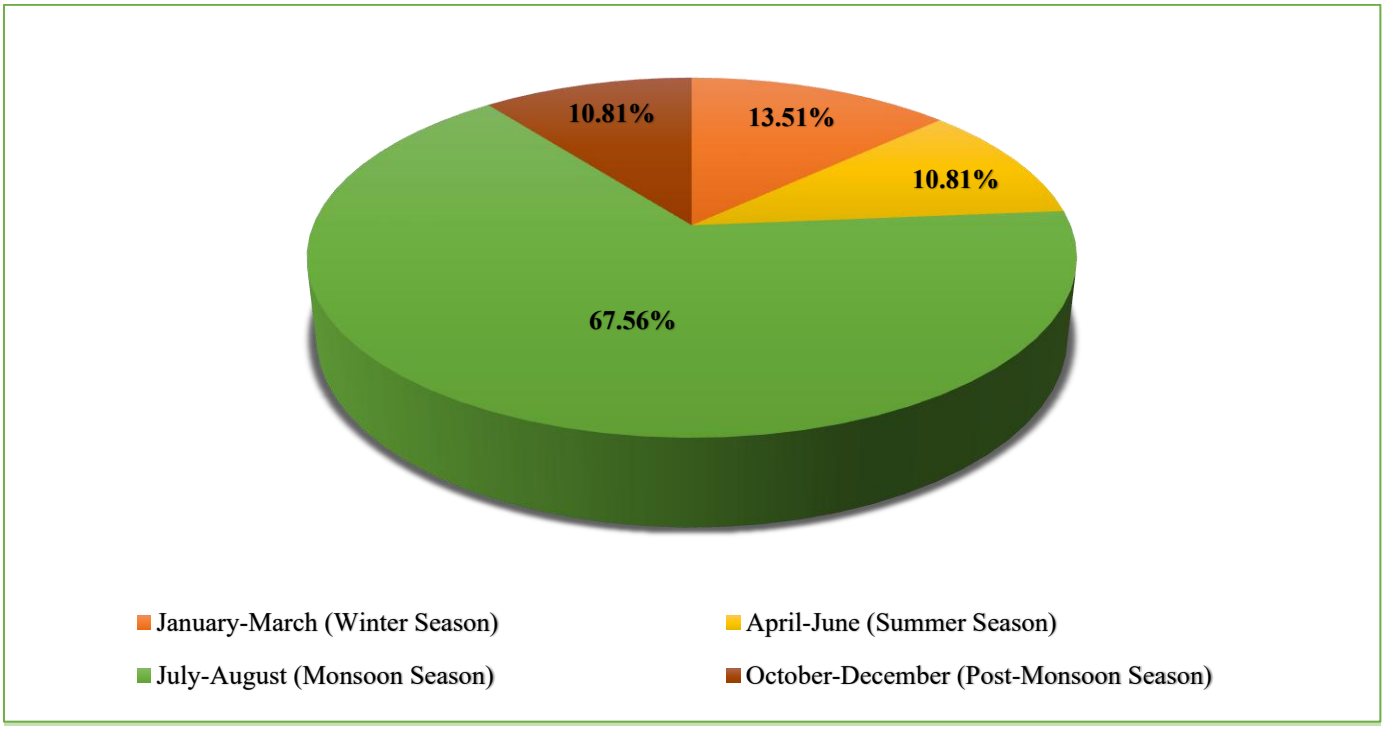

Fig 2: Flowering Phenology of Plants

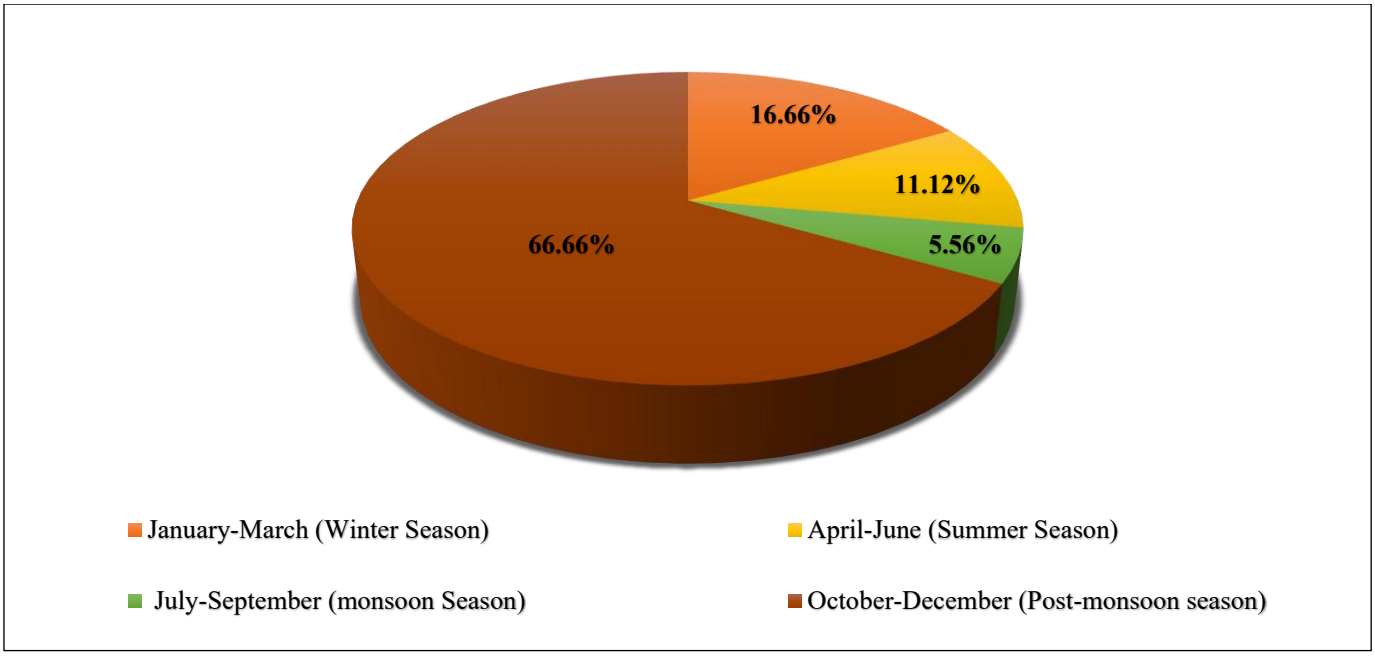

Fig 3: Fruiting Phenology of Plants.

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