Floral Calendar of Tree Species associated with Insect Pollinators in Coastal Odisha of India

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Abstract— *Understanding of temporal patterns of tree flowering is essential for assessing the availability of floral resources to sustain the pollinator population throughout the year. The present study examined the flowering phenology of fifteen tree species used as forage of insect pollinators in coastal Odisha during 2024, documenting variations in early, middle, and late flowering phases. Two species such as Moringa oleifera and Santalum album exhibited biannual flowering, with Moringa oleifera flowering for the longest duration (22 weeks), followed by Santalum album (19 weeks). The overall order of flowering duration revealed that a few species substantially dominated the floral calendar, ensuring prolonged resource availability. Month-wise analysis indicated that February, March, and April supported the highest number of insect species (five species each) in their middle flowering phase, reflecting a spring peak in floral abundance. While most species showed middle-phase flowering for two consecutive months, Peltophorum ferrugineum extended to three months. Moringa oleifera and Santalum album again stood out for flowering twice annually and for more than three months in the middle phase, offering extended forage for pollinators. The floral calendar demonstrated distinct species-specific phenological patterns, with eight tree species flowering mainly in spring during February to March and fewer tree species (three each month) flowering during July to December. January, May, and June recorded moderate flowering activity with five, six, and five tree species respectively. The extended flowering periods of Moringa oleifera, Santalum album, Peltophorum ferrugineum, and Tectona grandis contributed significantly to year-round floral resource availability. These overlapping flowering periods, spanning two to four months for many species, play a crucial role in sustaining diverse insect pollinators.*

Keywords— Floral Calendar, Insect Pollinators, Coastal Odisha, Tree Species, Biannual Flowering.

I. INTRODUCTION

Floral calendar plays a crucial role in ecosystem conservation by tracking the phenology of native plant species. Floral calendar, which tracks the phenology of flowering in plants, is essential tool for understanding the dynamics between plant species and insect pollinators. The timing and sequence of flowering events play a critical role in sustaining healthy pollinator populations, as they determine the availability of nectar and pollen, two key resources for insects like bees, butterflies, and other pollinators. These calendars are particularly important for identifying periods of abundance and scarcity of floral resources, which can directly impact pollinator health and, consequently, ecosystem stability. Since flowering times often fluctuate annually with weather conditions, floral calendars help identify main blooming and dearth periods, allowing beekeepers to introduce supplemental plants to bridge forage gaps (Onyango *et al.* 2019). This information can inform strategies for adaptation and mitigation in response to changing environmental conditions. It contributes to biodiversity monitoring by highlighting the

presence of different plant species over time. Understanding the timing and sequence of flowering events through floral calendars is crucial for sustainable apiculture, apisilviculture, pollinator management, and ecosystem conservation The timing and sequence of plant flowering events are fundamental to the health and sustainability of pollinator populations and the broader ecosystems they support. Trees serve as a continuous source of forage by offering nectar, pollen, and suitable habitats throughout the year. The type, quantity, and quality of pollen and nectar vary among tree species and influence pollinator preferences (Ahmed *et al.* 2023). Their extended flowering periods ensure a steady food supply, reducing forage shortages and stabilizing insect populations. In recent years, there has been increasing recognition of the role of trees in sustainable agriculture and pollinator management, particularly in agroforestry systems.

Tracking flowering times helps to understand which species are thriving and which are at risk, providing insights into the overall health of an ecosystem. In recent years, there has been increasing recognition of the pivotal role of trees in supporting biodiversity and ensuring food security, especially within agroforestry systems and natural forests (Garibaldi *et al.*, 2014). Trees that flower at different times can provide year-round resources, such as seeds, fruit, or resin, and also help maintain biodiversity. In agroforestry systems, integrating trees with staggered flowering times can improve productivity by supporting multiple income streams and optimizing the use of land throughout the year. It are therefore essential tools for efficient apiary management, helping to determine periods of abundance and scarcity of forage, and enabling proper colony management of bees. (Singh *et al.* 2023). They also provide valuable data for future studies on climate change impacts and promote the use of beekeeping as a tool for conserving native flora (Onyango et al. 2019). A floral calendar outlines the approximate timing and duration of flowering for major nectar and pollen-producing plants in a given area (Onyango *et al.* 2019). The flowering period of plant species varies across different locations and times. Each landscape possesses its own unique composition of honeybee flora and experiences specific periods of floral abundance and scarcity. (Bhattarai *et al.*, 2023).

Such records are valuable for studying plant–pollinator relationships, biodiversity conservation, and the influence of climate change. The systematic monitoring of plant phenology provides critical data for numerous scientific and applied fields, including predicting forest productivity, modeling global carbon cycles, managing agricultural systems and most critically understanding the cascading consequences of climate warming on species interactions (Wolkovich *et al.*,2017).

Coastal Odisha, located along India's eastern coastline, experiences a tropical monsoon climate, characterized by distinct wet and dry seasons, as well as fluctuating temperatures and humidity levels. These climatic conditions significantly influence the phenology of plants, determining the timing of flowering. Despite the acknowledged importance of phenology and the environmental sensitivity of the region, systematic and quantitative data on the floral dynamics of forest tree species in coastal Odisha remain critically limited in published literature

This study aims to document the floral calendars of selected tree species in coastal Odisha that are associated with insect pollinators, contributing to the growing body of research on floral phenology in tropical coastal regions. By examining the seasonal flowering patterns of key tree species, this research seeks to identify periods of nectar scarcity, assess their implications for pollinator populations, and propose strategies for enhancing pollinator conservation in both natural and agricultural landscapes. Ultimately, the findings will provide valuable insights into the role of trees in sustaining pollinators, promoting biodiversity, and supporting the livelihoods of local communities dependent on these ecosystems

II. MATERIALS AND METHODS

2.1 Study area:

The present study was carried out in and around Bhubaneswar which is aerially 35km away from east coast of India along Bay of Bengal. The experimental site is located between 20025' - 20035' N latitude and 85080' - 85085' E longitude with elevation 30-60m above mean sea level. The google map of the experimental area is given in Fig 1.

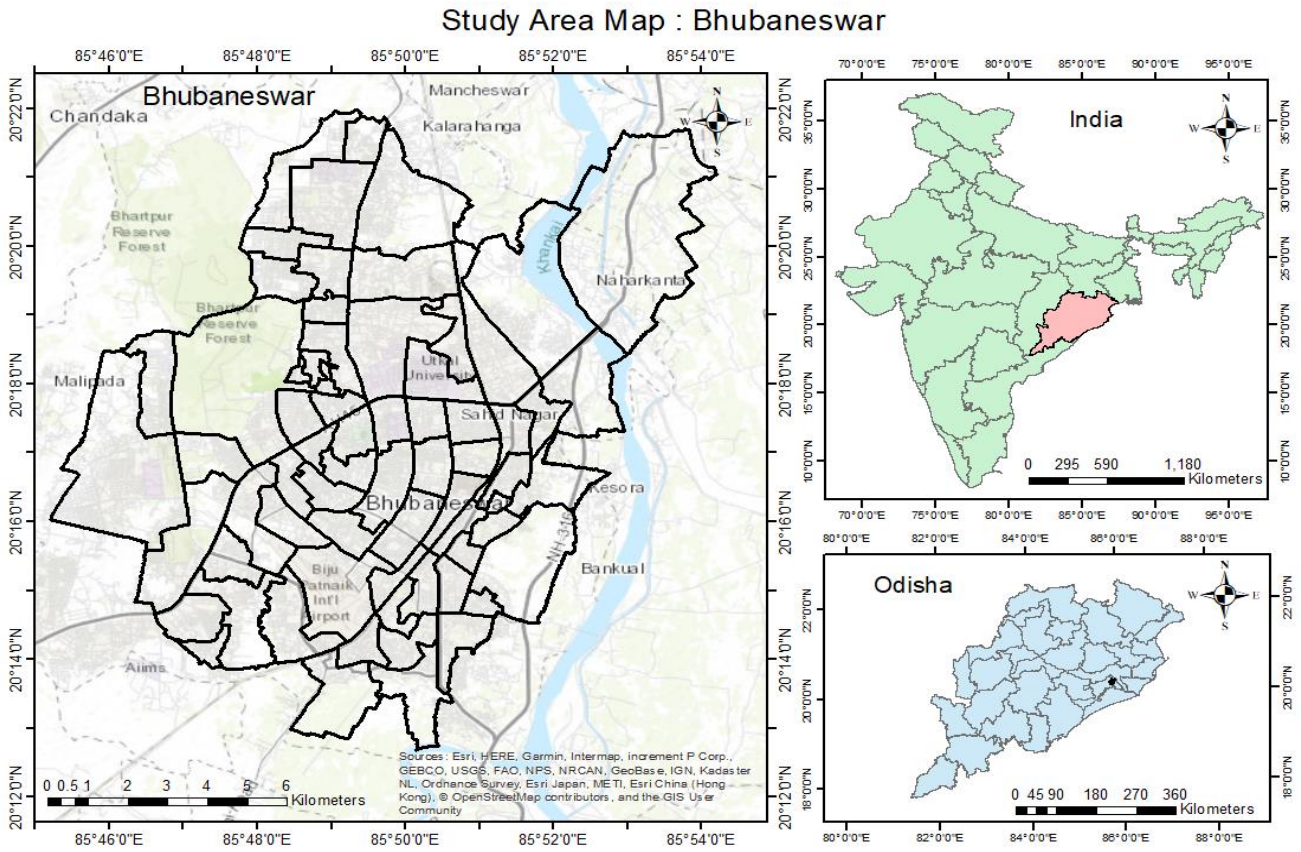

FIGURE 1: The google map of the experimental area

2.2 Climate and Weather

The study area comes under tropical climate. It has a warm and moist climate characterized by humid summer and mild winter. In general, the climate of Bhubaneswar comes under the group of moist and hot climate. The area receives an average annual rainfall of 1495 mm major portion during June to October from south-west monsoon.

2.3 Treatments

For preparation of floral calendar, fifteen number of tree species which have strong association with insects in coastal Odisha condition were considered such as: (a) *Mangifera indica,* (b) *Gliricidia sepium,* (c) *Moringa oleifera,* (d) *Litchi chinensis,* (e) *Cinnamomum zeylanicum,* (f) *Pongamia pinnata,* (g) *Peltophorum ferrugineum,* (h) *Lagerstroemia speciose* (i) *Caesalpinia coriaria,* (j) *Tectona grandis,* (k) *Santalum album,* (l) *Ziziphus mauritiana,* (m) *Alstonia scholaris,* (n) *Sapindus mukorossi* and (o) *Anacardium occidentale.*

2.4 Floral calendar for selected tree species

To develop floral calendars for selected tree species, systematic field observations were carried out over a period of 12 months. Regular survey was carried out in Bhubaneswar and adjoining areas during the early flowring, middle flowering and late flowering. Each selected tree species was studied in three different locations of at least 1 km away from one another as per availability. For each selected tree species two trees will be considered from each location. The floral calendar included the names of tree species in Latin along with their local names and flowering period. According to the range of blooming period, the particular trees got entry to the defined months.

2.5 Observations recorded

Time of flowering: For determining the flowering period of different tree species, systematic observations were carried out at on weekly basis through the blooming period.

Early, middle and late of flowering phases: The early phase of flowering was considered when the flowers cover one third of the canopy. Like-wise middle phase was considered when the flowering covered half of the canopy and late phase was considered as the last two third part of the canopy.

III. RESULTS

3.1 Flowering time of different tree species associated with insect pollinators:

The flowering time of different tree species associated with insect pollinators in coastal Odisha is presented in Table 1. In the year 2024, it was found that there were 15 number of major tree species associated with insect pollinators such as *Mangifera indica, Gliricidia sepium, Moringa oleifera* (Flowering 1 & 2), *Litchi chinensis, Cinnamomum zeylanicum, Pongamia pinnata, Santalum album* (Flowering 1 & 2), *Peltophorum ferrugineum, Lagerstroemia speciosa, Caesalpinia coriaria, Tectona grandis, Ziziphus mauritiana, Alstonia scholaris, Sapindus mukorossi* and *Anacardium occidentale*. Different tree species witnessed flowering at different time of the year. Further, there was a difference of time within the flowering period as early, middle and late phase of flowering of the tree. *Moringa oleifera* and *Santalum album* flowered twice in a year. *Moringa oleifera* flowered for maximum period of 22 weeks followed by *Santalum album* (19 weeks). The order of flowering period in terms of week in a year was observed to be: *Moringa oleifera >Santalum album > Peltophorum ferrugineum =Tectona grandis> Mangifera indica = Pongamia pinnata = Lagerstroemia speciose> Gliricidia sepium= Litchi chinensis = Caesalpinia coriaria = Ziziphus mauritiana> Cinnamomum zeylanicum =Alstonia scholaris= Sapindus mukorossi > Anacardium occidentale.*

Mangifera indica started flowering in the 1st week of January to the 3rd week, reached its middle phase during the 4th week of January and continued till 4th week of February and late flowering occurred in march 1st week to 3rd week. *Gliricidia sepium* initiated flowering in the 4th week of January to 1st week of February and closed flowering in March 3rd week to 1st week of April with a middle flowering during February 2nd week to March 2nd week. *Moringa oleifera* began first flowering in the 4th week of January to the 2nd week of February and reached middle phase during February 3rd week till March 4th week. It closed flowering during the 3rd week of April. Further, it flowered in May 4th week reached, its mid- flowering in June 3rd week to July 3rd week and late flowering occurred in the 4th week of July to August 1st week.

Litchi chinensis started flowering in the 1st week of February and continued until the 2nd week of February, middle phase occurred between 3rd week of February and 3rd week of March. The last phase lasts from the 4th week of March to the 2nd week of April. The early flowering of *Cinnamomum zeylanicum* extended from the 4th week of February to 2nd week of March and its middle flowering took place from the 3rd week of March until the 2nd week of April. The late Flowering phase continued from 3rd week to 4th week of April.

Santalum album displayed two cycles of flowering, the first began in the 4th week of February to the 2nd week of March, middle phase of took place from the 3rd week of March to April 2nd and had a late flowering phase from the 4th week of April to 1st week of May. The second cycle started from the 1st week of August to 2nd week of August and concluded its late phase from the 4th week of September to 1st of October with middle flowering from the 3rd week of August to September 3rd week.

In *Pongamia pinnata,* flowering began during the 2nd week of March and continues until the 4th week of March. The middle flowering period is from the 1st week of April to 2nd week of May, after which it closes flowering in the 3rd to 4th week of May. *Peltophorum ferrugineum* commenced flowering from the 4th week of March to the 1st week of April, middle phase was observed from the 3rd week of April up to June 1st week, and ended its late phase from the 2nd week to 4th week of June. *Lagerstroemia speciosa* floral initiation took place from the 1st week of April to the 3rd week April, had its middle flowering from the 4th week of April to the 4th week May and ended flowering in the 1st week to 3rd week of June.

Caesalpinia coriaria set into flowering from the 3rd week to 4th week of May, peaked from the 1st week of June to the 2nd week of July and the late phase was from the 3rd week to 4th week of July. *Tectona grandis* initiated flowering in the 3rd week of June to the 1st week of July, and ceased flowering from the 1st to the 3rd week of September. It had mid flowering in July 2nd week which continued up to August 4th week. *Ziziphus mauritiana* started flowering phase from the 1st week of September to the 3rd week and closed flowering from the 1st week to 2nd week of November with a middle phase of flowering from the 4th week of September to 4th week of October.

TABLE 1

FLOWERING TIME OF DIFFERENT TREE SPECIES ASSOCIATED WITH INSECT POLLINATORS

Sl.No	Name of tree species (Scientific name)	Common Name of tree	Family	Flowering time			Total number of weeks of flowering	
				Initial phase	Middle flowering phase	Late phase		
1	*Mangifera indica*	Mango	Anacardiaceae	January 1st week- January 3rd week	January 4th week- February 4th week	March 1st week - 3rd week	11	
2	*Gliricidia sepium*	Gliricidia	Fabaceae	January 4th week- February 1st week	Feb 2nd week- March 2nd week	March 3rd week- April 1st week	10	
3	*Moringa oleifera*	Drumstick	Moringaceae	January 4th week- February 2nd week	February 3rd week – March 4th week	April 1st week- 3rd week	12	22
				May 4th week- June 2nd week	June 3rd week - July 3rd week	July 4th week - Aug 1st	10	
4	*Litchi chinensis*	Litchi	Sapindaceae	February 1st- February 2nd week	Feb 3rd week- March 3rd week	March 4th week-April 2nd week	10	
5	*Cinnamomum zeylanicum*	Dalchini	Lauraceae	February 4th week – March 2nd week	March 3rd week- April 2nd week	April 3rd week – 4th week	9	
6	*Santalum album*	Sandal	Santalaceae	February 4th week – March 2nd week	March 3rd week – April 3rd week	April 4th week- May 1st week	10	19
				August 1st week – 2nd week	August 3rd week – September 3rd week	September 4th week- October 1st week	9	
7	*Pongamia pinnata*	Karanj	Fabaceae	March 2nd week- 4th week	April 1st week – May 2nd week	May 3rd week – 4th week	11	
8	*Peltophorum ferrugineum*	Radhachuda	Fabaceae	March 4th week- April 2nd week	April 3rd week- June 1st week	June 2nd week- 4th week	13	
9	*Lagerstroemia speciosa*	Pride Of India tree	Lythraceae	April 1st week- 3rd week	April 4th week- May 4th week	June 1st week – June 3rd week	11	
10	*Caesalpinia coriaria*	Divi divi	Fabaceae	May 3rd week - 4th week	June 1st week - July 2nd week	July 3rd week- 4th week	10	
11	*Tectona grandis*	Teak	Lamiaceae	June 3rd week- July 1st week	July 2nd week- August 4th week	September 1st week- 3rd week	13	
12	*Ziziphus mauritiana*	Ber	Rhamnaceae	September 1st week- 3rd week	September 4th week - October 4th week	November 1st week – 2nd week	10	
13	*Alstonia scholaris*	Devil's tree	Apocynaceae	October 1st week- 2nd week	October 3rd week- November 3rd week	November 4th week- December 1st week	9	
14	*Sapindus mukorossi*	Reetha	Sapindaceae	November 2nd week -3rd week	November 4th week- December 4th week	Jan 1st week-2nd week	9	
15	*Anacardium occidentale*	Cashewnut	Anacardiaceae	December 4th week- January 1st week	January 2nd week – February 1st week	February 2nd week- 4th week	8	

Alstonia scholaris commenced flowering from the 1st week to the 2nd of October, mid flowering was evident from October 3rd week to November 3rd week. It had a late phase from 4th week of November to the 1st week of December. *Sapindus mukorossi* set into flowering from the 2nd to 3rd week of November and reached at mid flowering during November 4th week to December 4th week and finished flowering in the 1st and 2nd week of January. *Anacardium occidentale* initiated flowering from the 4th week of December to the 1st week January and middle phase was noted in the 2nd week of January to 1st week of February and late flowering took place from the 2nd to 4th week of February.

3.2 Month-wise middle flowering of different tree species:

A perusal of data in Table 2 indicates that different months of the year 2024 recorded middle flowering of different tree species having an association with insect pollinators. January 2024 registered the middle flowering of species like *Anacardium occidentale* and *Mangifera indica* which were associated with insect pollinators. The month of February 2024 witnessed middle flowering of *Anacardium occidentale, Mangifera indica, Gliricidia sepium, Moringa oleifera* (Flowering 1) and *Litchi chinensis.* In the month of March 2024, middle phase of flowering of *Gliricidia sepium, Moringa olifera* (Flowering 1), *Litchi chinensis, Cinnamomum zeylanicum* and *Santalum album* (Flowering 1) was noticed. In April 2024 various tree species which were linked with pollinators that witnessed their middle flowering were *Cinnamomum zeylanicum, Santalum album* (Flowering 1), *Pongamia pinnata, Peltophorum ferrugineum* and *Lagerstroemia speciosa*. The month May 2024 also registered flowering of *Pongamia pinnata, Lagerstroemia speciosa* and *Peltophorum ferrugineum* which flowered in the previous month. June 2024 experienced middle flowering of *Moringa oleifera* (Flowering 2) and *Caesalpinia coriaria* in addition to *Peltophorum ferrugineum* which continued middle flowering from the previous flowering. In the month of July of the same year recorded the continued flowering of *Moringa oleifera* (Flowering 2), *Caesalpinia coriaria* in addition to *Tectona grandis.* August 2024 which falls in the peak rainy season got flowering of only *Tectona grandis* and *Santalum album* (Flowering 2) having insect pollinator association. September 2024 also recoded continued flowering of *Santalum album* (Flowering 2) and middle flowering of *Ziziphus mauritiana.* October month of the same year received flowering *Alstonia scholaris* tree along with *Ziziphus mauritiana* which had flowering in the previous month also. November 2024 exhibited middle flowering of *Alstonia scholaris* and *Sapindus mukorossi.* December 2024 which is the winter month of the year recorded the continued flowering of *Sapindus mukorossi* which was associated with insect pollinators.

The Table 2 revealed that flowering of all the tree species mentioned above is more than one month. Most of the species showed flowering for 2 months. Species like *Peltophorum ferrugineum* flowered for 3 months. Some tree species like *Moringa olifera* and *Santalum album* showed middle flowering twice in the same year and covered more than 3 months which can provide forage for sustaining the insect pollinators for longer period of time. The overlapping of flowering time of different tree species observed for two to four months helps in the sustenance of the life of the various insect pollinators.

TABLE 2
MONTH-WISE FLOWERING OF SELECTED TREE SPECIES ASSOCIATED WITH INSECT POLLINATORS

Sl No.	Month	Name of the tree species
1	Jan-24	*Anacardium occidentale, Mangifera indica*
2	Feb-24	*Anacardium occidentale, Mangifera indica, Gliricidia sepium, Moringa oleifera* (Flowering 1), *Litchi chinensis*
3	Mar-24	*Gliricidia sepium, Moringa olifera* (Flowering 1), *Litchi chinensis, Cinnamomum zeylanicum, Santalum album* (Flowering 1)
4	Apr-24	*Cinnamomum zeylanicum, Santalum album* (Flowering 1), *Pongamia pinnata, Peltophorum ferrugineum, Lagerstroemia speciosa*
5	May-24	*Pongamia pinnata, Lagerstroemia speciosa, Peltophorum ferrugineum,*
6	Jun-24	*Peltophorum ferrugineum, Moringa oleifera* (Flowering 2), *Caesalpinia coriaria*
7	Jul-24	*Moringa oleifera, Caesalpinia coriaria, Tectona grandis*
8	Aug-24	*Tectona grandis, Santalum album* (Flowering 2)
9	Sep-24	*Santalum album* (Flowering 2), *Ziziphus mauritiana,*
10	Oct-24	*Ziziphus mauritiana, Alstonia scholaris*
11	Nov-24	*Alstonia scholaris, Sapindus mukorossi*
12	Dec-24	*Sapindus mukorossi*

3.3 Floral calendar of different tree species:

The floral calendar of the different tree species associated with different insect in coastal Odisha for the year 2024 has been prepared and depicted in tabular form in Table 3. In this calendar three phases of flowering such as early, middle and late phase have been included. January witnessed flowering of 5 tree species interacting with insect pollinators such as *Sapindus mukorossi, Anacardium occidentale, Mangifera indica, Gliricidia sepium* and *Moringa olifera* (Flowering 1). The calendar accommodates 7 tree species in the month of February which are *Anacardium occidentale, Mangifera indica, Gliricidia sepium, Moringa oleifera, Litchi chinensis, Cinnamomum zeylanicum* and *Santalum album* (Flowering 1). This month recorded two more species compared to previous month. In the month of March, flowering of 8 tree species such as *Mangifera indica, Gliricidia sepium, Moringa olifera* (Flowering 1), *Litchi chinensis, Cinnamomum zeylanicum, Santalum album* (Flowering 1), *Pongamia pinnata* and *Peltophorum ferrugineum* in the study area having association with insect pollinator were recorded and the number of tree species were higher than January and February. As for to the month of April 2024, the number of tree species (8) remained the same as of the previous month. This month witnessed flowering *Gliricidia sepium, Moringa olifera* (Flowering 1), *Litchi chinensis, Cinnamomum zeylanicum, Santalum album* (Flowering 1), *Pongamia pinnata, Peltophorum ferrugineum* and *Lagerstroemia speciosa* that have association with insect pollinator. May in the floral calendar of the 2024 registered 6 tree species such as *Santalum album* (Flowering 1) *Pongamia pinnata, Lagerstroemia speciosa, Peltophorum ferrugineum, Moringa oleifera* (Flowering 2) and *Caesalpinia coriaria w*hich was comparatively less than the previous month. June exhibited 5 number of tree species which were relatively lesser from the previous month that included the species such as *Peltophorum ferrugineum, Lagerstroemia speciosa, Caesalpinia coriaria, Moringa oleifera* (Flowering 2) and *Tectona grandis.* The next month July accommodated 3 number of tree species associated to inset pollinators which were *Caesalpinia coriaria Moringa oleifera* and *Tectona grandis.* Similar trend was observed in month of August, September, October, November and December in which 3 tree species been registered in each month. However, August exhibited a different set of the species such as *Moringa oleifera* (Flowering 2), *Tectona grandis* and *Santalum album,* while in September tree species were *Tectona grandis, Santalum album* (Flowering 2) and *Ziziphus mauritiana.* October, 2024 recorded flowering of *Santalum album* (Flowering 2), *Ziziphus mauritiana* and *Alstonia scholaris.* November included flowering of *Ziziphus mauritiana, Alstonia scholaris* and *Sapindus mukorossi.* December had also 3 number of species that were *Alstonia scholaris, Sapindus mukorossi* and *Anacardium occidentale.*

TABLE 3

FLORAL CALENDAR OF DIFFERENT TREE SPECIES ASSOCIATED WITH INSECT POLLINATORS IN COASTAL ODISHA OF INDIA

Tree Species	Month																																			
	Jan				Feb				Mar				April				May				June				July				Aug				Sept				Oct				Nov				Dec			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Mangifera indica (T_1)																																															
Gliricidia sepium (T_2)																																															
Moringa oleifera (Flowering 1) (T_3)																																															
Litchi chinensis(T_4)																																															
Cinnamomum zeylanicum(T_5)																																															
Santalum album (Flowering 1) (T_6)																																															
Pongamia pinnata(T_7)																																															
Peltophorum ferrugineum(T_8)																																															
Lagerstroemia speciosa(T_9)																																															
Caesalpinia coriaria(T_{10})																																															
Moringa oleifera (Flowering 2) (T_{11})																																															
Tectona grandis(T_{12})																																															
Santalum album (Flowering 2) (T_{13})																																															
Ziziphus mauritiana(T_{14})																																															
Alstonia scholaris(T_{15})																																															
Sapindus mukorossi(T_{16})																																															
Anacardium occidentale(T_{17})																																															

IV. DISCUSSION

4.1 Flowering time of different tree species associated with insect pollinators:

The flowering time of different tree species associated with insect pollinators in coastal Odisha varied remarkably from one another (Table 1 & Fig 2). In this research effort it has been observed that among the 15 selected tree species in coastal Odisha, the onset of flowering ranged from the month of January to December, with varying middle flowering periods. Species like *Moringa oleifera* and *Santalum album* flowered twice in the year 2024. Flowering time is controlled by an interplay of environmental cues (light/ photoperiod, temperature/chill/heat, water availability, nutrients) and endogenous signals (hormones, carbohydrate status, gene regulatory networks). Singh and Kushwaha (2006) have reported diversity of flowering and fruiting phenology in Indian dry-tropical trees having five flowering types relative to leaf flush; time lag between vegetative and reproductive phases correlated with leafless period. Suresh and Krishnamurthy (2014) have also observed variation of flowering and phenology patterns in dry deciduous forest at Bhadra Wildlife Sanctuary, Southern India and found flowering peaks in summer; leafing, fruit-bud etc. correlated with monsoon, temperature, rainfall etc. Bhol and Parida (2022, 2024) have also reported the variation of flowering time of different tree species. They have mentioned similar flowering time of *Tectona grandis* and *Santalum album*. Wang *et al.* (2020) showed that the flowering phenology among the trees relates to the tree height, flowering and fruit type and growth rate to optimise their reproductive success. Wang and Ding (2023) revealed that molecular mechanism have impact on the flowering of the tree species. Alves-de-Lima *et al.* (2023) documented the difference in flowering of same species to reduce overlapping of the pollinator usage. Onyango *et. al.* (2019) also reported that the months of April and May had highest forage availability and lowest was in December.

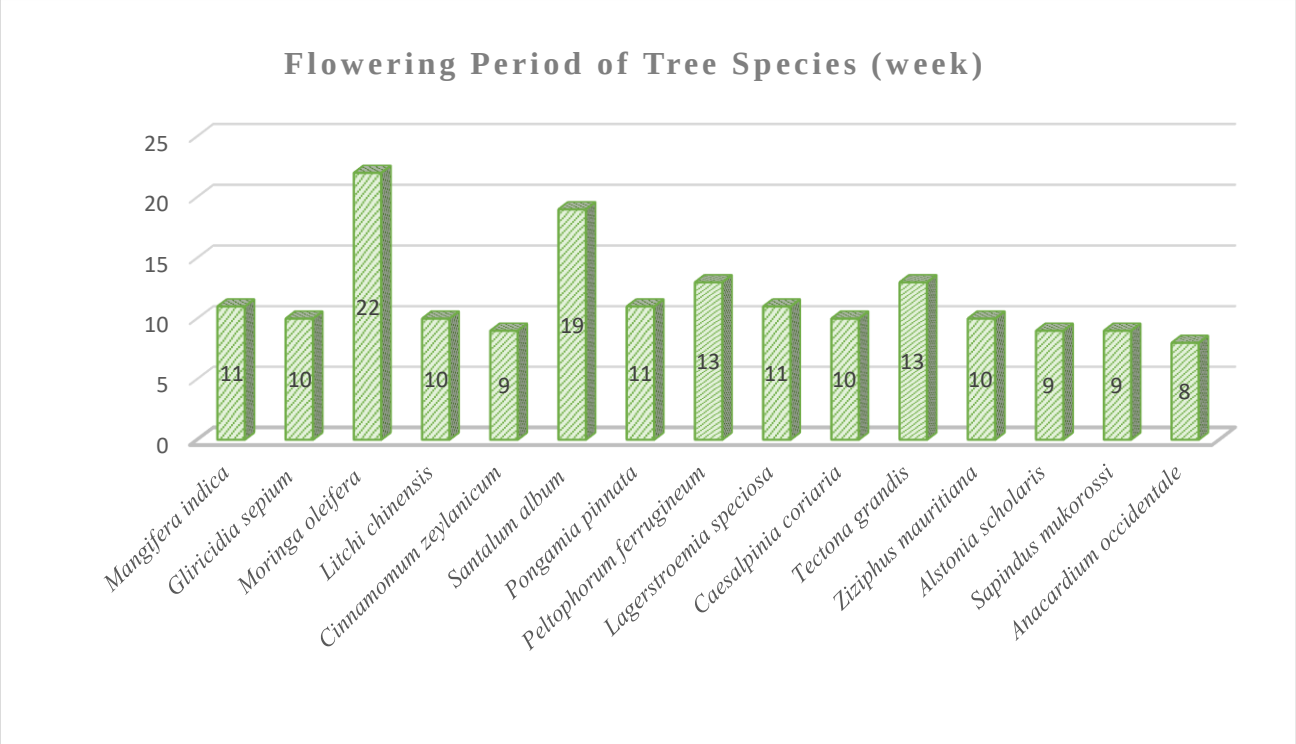

FIGURE 2: Flowering period of different tree species

4.2 Month-wise middle flowering of different tree species

The data on month-wise middle flowering of different tree species (Table 2) revealed that the middle flowering of different tree species occurred in the month of February, March and April suggesting that this period as the principal reproductive season

for many tree species. Similar observations were made by Pande and Ramakrushna (2018), who found that March had the greatest percentage of bee flora abundance and highest bee flora availability. Essien (2020) also demonstrated that the highest level of flowering activity was recorded during the month February and March. Neupane *et al.* (2024) also reported that the maximum number of flowerings of the plant species were during the month of April and sufficient number of flowerings was observed in the month of February and March. Panigrahi *et al.* (2020) observed that the main flowering and honey flow period extended from November to April, supporting bee colony development and honey production, while the remaining months showed limited floral activity. Certain species such as *Moringa oleifera* and *Santalum album* had two flowering peaks and the bimodal pattern of flowering reflects the adaptive plasticity for the purpose of reproductive active which may be due climatic or genetic factor. These results align with findings of Thakur *et al.* (2024) who reported similar biannual pattern on *Santalum album* and Jyothi *et al.* (1990) who observed the similar sequence biannual flowering in *Moringa oleifera.*

4.3 Floral calendar of different tree species associated with insect pollinators

The floral calendar of different tree species associated with insect pollinator in coastal Odisha which comes under tropical climate, for the year 2024 has been depicted as Table 3 and Fig 3. It was observed that the calendar continuous throughout the year starting from January to December 2024. Among the 15 tree species studied in every month more than one species contributed forage to different insect pollinators. However, the number of tree species was different in different months of the year. The period of February, March and April was prominent with respect to flowering of maximum number of trees (8 numbers) which supported as good as 11 numbers of insect pollinators. The flowering abundance was maximum during this period because in coastal Odisha condition climate is tropical and maximum tree species exhibit flowering during this period. Prior to this time usually winter occurs and with approach spring season (Feb to April) major species flower in this region. Nanda *et al.* (2014) showed that flowering activities occur in the summer or pre-monsoon and flower bud initiates in January with a peak in April and May. Pao *et al.* (2016) stated that middle flowering occurred in the month of March and April. Rijial *et al.* (2018) found that most bee forage was available from February to September, whereas flowering declined between November and January.Hosamani *et al*. (2018) observed that peak honey flow occurred during June to October and January to March, while a dearth period extended from mid-April to mid-June, indicating two distinct foraging seasons linked to climatic patterns. In contrast to the findings, Waykar and Baviskar (2015) reported distinct seasonal flowering patterns, noting that 15 wild species flowered in summer, 18 in winter, and 21 during the monsoon, their study identified mid-October to mid-December as the major honey flow period, while mid-May to mid-August represented a critical dearth period.

The flowering phenology of 8 tree species such as *Mangifera indica, Gliricidia sepium, Moringa oleifera, Litchi chinensis, Cinnamomum zeylanicum, Pongamia pinnata, Peltophorum ferrugineum* and *Lagerstroemia speciosa* coincides in the month of February to April in coastal Odisha ecosystem. The meteorological data that have been given in the Table 3.1 can suggest that the weather condition may be helpful for the blooming of the tree species. This floral calendar gradually became narrow from the month of May to December. This may be attributed to start of vegetative phase of majority tree species in coastal Odisha agroclimatic condition as monsoon shower started in May and continued strongly upto October, even to some extent in November and December 2024. The rainfall data has been given in table 3.1. Number of tree species with flowering phase varied from 3 months to 5 months as shown in Table 4.3. In January the floral calendar was further wider because tropical tree like *Sapindus mukorossi, Anacardium occidentale, Mangifera indica, Gliricidia sepium* and *Moringa oleifera* flowered in this time. Jaswal *et al.* (2022) observed that late summer and the rainy season were marked as critical dearth periods for honey bees due to less availability of bee flora. Singh and Kushwaha (2006) stated that predominance of summer flowering with summer leaf flushing is a unique adaptation in trees to survive under a strongly seasonal tropical climate.

FIGURE 3: Floral colander of different tree species associated with insect pollinators in coastal Odisha of India

V. CONCLUSION

The flowering phenology of the fifteen tree species examined in coastal Odisha during 2024 revealed clear temporal variation across early, middle, and late flowering phases, contributing to a diverse and extended floral resource base. Species such as *Moringa oleifera* and *Santalum album* demonstrated biannual and prolonged flowering durations, making them particularly important for sustaining pollinator activity over extended periods. The concentration of middle-phase flowering during February to April, along with multi-month flowering in several species, highlights a strong spring peak supported by the region's tropical climate. At the same time, the presence of at least a few flowering species in all months of the year indicates a continuous, though variable, supply of nectar and pollen vital for insect pollinators. The floral calendar constructed from these observations underscores the ecological significance of flowering overlap among species, which enhances pollinator survival and stabilizes ecosystem functioning throughout the year. Future studies should explore how climate variability and long-term climate change may further influence flowering patterns and pollinator dynamics, enabling better conservation planning and adaptive management.

ETHICAL STANDARDS

All authors declare that the submission is original, unpublished, and not under consideration elsewhere.

Explanation of any issue relating to journal policies

There is no issue relating to journal policies.

Declaration of any competing interest

There is no competing interest.

Confirmation that all authors have approved the manuscript for submission

All authors declare that they have approved the manuscript for submission.

Data availability

Data will be made available on request.

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AUTHOR CONTRIBUTIONS

Sushree Rojalina Mahapatra made data collection, analysis, review of literature and writing of manuscript. Nirakar Bhol designed the research work, guided manuscript writing and made critical review of the manuscript. Pravasini Behera identified insect pollinators and guided insect related studies. Prajnashree Mallick assisted in data collection, analysis of data and collected reviews of works done. Subhasmita Parida guided in data collection, contributed to manuscript writing and made critical review of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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