DOI: https://doi.org/10.52756/ijerr.2023.v36.024 *Int. J. Exp. Res. Rev.*, Vol. 36: 244-252 (2023)

Original Article | Peer Reviewed | Open Access

International Journal of Experimental Research and Review (IJERR)

ISSN: 2455-4855 (Online)
www.iaph.in

A Comparative Phenological Studies of High-Value Medicinal Herbs: *Cassia tora* and *Argemone maxicana* in Achanakmar Regions of Chhattisgarh, India

Jagesh Kumar Shriwas* and Lata Sharma

Department of Botany, Dr. C.V. Raman University, Kota, Bilaspur, India

E-mail/Orcid Id:

JKS, jageshshrivas77@gmail.com, https://orcid.org/0009-0002-4313-1855;
LS, lata.sh.bsp@gmail.com, https://orcid.org/0009-0003-1742-9217

Article History:

Received: 6th Sept., 2023
Accepted: 14th Dec., 2023
Published: 30th Dec., 2023

Keywords:

Argemone maxicana, *Cassia tora*, Medicinal Plant, Phenophase

How to cite this Article:
Jagesh Kumar Shriwas and Lata Sharma (2023). A Comparative Phenological Studies of High-Value Medicinal Herbs: *Cassia tora* and *Argemone maxicana* in Achanakmar Regions of Chhattisgarh, India. *International Journal of Experimental Research and Review*, *36*, 244-252.
DOI: https://doi.org/10.52756/ijerr.2023.v36.024

Abstract: The phenological behaviour of two herb species, Cassia tora and Argemone maxicana, were studied in Shivtarai Achanakmar regions of Chhattisgarh state, India, from January 2020 to December 2022. Both these species showed marked variations in their phenological behavior studied, such as new foliage, Leaf fall, Flowering and Fruiting, by showing significant variation (P value < 0.05). In the present study, it was revealed that, in *Cassia tora*, the mean ± SD values of new foliage, leaf fall, flowering and fruiting days were 40±5, 27±5, 127±5, and 102±18 respectively, whereas, in *Argemone maxicana*, these are 42±6, 36±5, 103±17, 87±2 respectively. In the present study, it was observed that in *Cassia tora*, the leaf bud busting initiation occurred in July-August, and in *Argemone maxicana*, it was observed at the end of August. In *Cassia tora*, the appearance of minimum total mature leaves was observed to occur in September, whereas, in *Argemone maxicana*, it was in December-January. Moreover, in *Cassia tora*, the appearance of a maximum number of mature leaves was found in the month of November, whereas in *Argemone mexicana*, it was in March-May. The length of the reproductive stage was observed to occur in *Cassia tora* for 3 to 4 months, whereas in *Argemone maxicana* it was 7-8 months. The Appearance of mature flowers was observed to occur in the month of October for *Cassia tora* and April-May for *Argemone maxicana*. The fruit formation was found in Dec-Jan in *Cassia tora* and in *Argemone maxicana* in May. The last fruit/fruit fall was initiated in February in Cassia tora and in Argemone mexicana in May to June. The phenological behavior plays a significant role in the study of vegetation patterns in the studied regions, in the field of biochemistry and the field of pharmacology. The plant has evolved in varied phenological phages to attain maximum beneficial phytoconstituents for medicinal purposes in different phenophases and must be studied for future prospects.

Introduction

Phenology is often defined as observing and quantifying temporal occurrences (Gray and Ewers, 2021). Phenology is the study or science of phenomena because the word is made up of the parts "pheno" which refers to phenomena, and "logy," which is frequently used to imply science or study. Practically speaking, phenology studies the seasonal succession and timing of living things, mostly plants and animals, including insects (Park and Post, 2022). Climate and local environmental factors, such as the amount of sunlight, precipitation, temperature, and other life-sustaining elements, directly regulate and control this (Park and Post, 2022). Because some unforeseen climatic changes could result in many different problems, the recent climate changes make it worthwhile to have a thorough understanding of phenology.

The study of cyclical, predictable changes in plant and animal life cycles is known as phenology. These cyclical changes occur all the time in nature. Typically, mature terrestrial angiosperm plants go through indicative reproductive phenological phases, including flowering and fruiting, as well as vegetative phenological phases like leaf flush, leaf change, or deciduousness. Animals depend on primary producers, and their structure, composition, and seasonality are all greatly impacted by

*Corresponding Author: jageshshrivas77@gmail.com

the phenological cycles of plants. In light of this, it is critical to comprehend the reasons behind and effects of phenological shifts in our world that is undergoing rapid change.

According to evolutionary theory, plants should be subject to selection in order to align their phenology with the proper environment. For instance, dry-season deciduousness is a common phenological plant feature in tropical forests that undergo seasonal water stress, and leaf fall coincides with the peak dry season (Gray and Ewers, 2021). Similar to how mutualists like pollinators and seed dispersers may have their availability and phenology timed, plants' reproductive phenology may also be coordinated. Plants may have evolved to synchronize reproductive phenophases (like flowering) at the population or community level in order to maximise pollination success or seed set (Ramaswami et al., 2019; Bolmgren and Eriksson, 2015). Additionally, fruiting peaks may be related to frugivore abundance, local and long-distance seasonal migration, and resident frugivore abundance (Ramaswami et al., 2019). Numerous biotic and abiotic factors that can affect the beginning and duration of phenophases might affect plant phenology.

Biotic stresses like diseases and herbivores may impact plants' reproductive and vegetative phenology. Insect pests' herbivory causes plants' vegetative development and flowering to develop more slowly (Lemoine et al., 2017). It has also been documented that plant phenology influences the phenology and quantity of herbivores (Posledovich et al., 2015; Velasque and Del-Claro, 2016).

Furthermore, the effects of biotic elements are frequently mixed up by prevailing abiotic factors, as demonstrated by Rodríguez-Pérez and Traveset (2016) and Tunes et al. (2017).

The vegetative and reproductive phenology of plants has been demonstrated to be influenced by abiotic factors such as growth-season temperature, duration and intensity of precipitation, water stress, and duration of solar irradiance across a range of latitudes and habitats. Seasonal rainfall has been demonstrated to link positively with leaf growth and productivity (Ramaswami et al., 2019; de Camargo et al., 2018). Tropical trees' phenology (the timing of blossom and fruit production) is affected by various environmental conditions, including temperature, light, rainfall, relative humidity, solar radiation, and edaphic factors (Ramaswami et al., 2019). Photoperiod, temperature and moisture have been found to be the three main abiotic variables that signal blooming (Ramaswami et al., 2019).

Impact of Climate Change on Phenology in Tropical Regions

The absence of pronounced seasonal temperature changes is a significant characteristic of tropical climates. In contrast, variations in rainfall and the transition between the dry and wet seasons establish more distinct phases within tropical annual cycles. Along with sunlight, humidity, and slight temperature fluctuations, rainfall frequency, intensity, and absence, all play a significant role in how tropical plants alter phenologically. The great species diversity in tropical environments results in various complicated phenological reactions within species and populations to those causes. Most of the tropics experience seasonal variations in precipitation, which may be more pronounced than temperature variability (Sharma et al., 2023).

In contrast to temperate places, it is difficult to predict how plant phenology may alter due to climate change in the tropics (Richardson et al., 2013). Phenological reactions to seasonal variations in temperature and precipitation are remarkably different in the tropics, where variability in phenological responses to abiotic factors is poorly understood (Sharma et al., 2023).

Concerns regarding the potential cascade impact of phenological alterations brought on by climate change in primary producers on higher trophic levels are emerging. Understanding the true scope of disruptions caused by climate change and setting priorities for mitigation actions may need a perspective that spans trophic levels. For many herbivores, the timing of vegetative phenophases is crucial. For instance, the phenology of pedunculate oaks and winter moths can coexist. Decoupling the phenophases of plants can harm both sets of interactants because the reproductive phases of plants are equally crucial for mutualists that pollinate them and those who disperse their fruit. Bee phenologies and those of the species they pollinate have been the subject of several studies. Although this system is more resilient to climate change than others, it shows signs of de-synchronization (Bartomeus et al., 2011). This is because plants and bees have been seen to advance their phenologies to adjust to climate change.

Similar studies have demonstrated phenological correlations between ants and the reproductive phenology of the plants whose seeds they disseminate, with plants responding to climate change by advancing their blooming and fruiting periods while ant phenology is advancing to a lesser extent (Ramaswami et al., 2019).

DOI: https://doi.org/10.52756/ijerr.2023.v36.024

About *Cassia tora*

Cassia tora, commonly known as Sickle Senna or Tora, also Charota (in Chattisgarh, so named), is a plant species belonging to the family Fabaceae (legume/ pea family). It is native to tropical regions of Asia but has spread to various parts of the world due to its medicinal and other uses.

Systematic position of *Cassia tora*

- Kingdom: Plantae (Plants)
- Clade: Tracheophytes (Vascular plants)
- Clade: Angiosperms (Flowering plants)
- Clade: Eudicots
- Clade: Rosids
- Order: Fabales
- Family: Fabaceae (Leguminosae)
- Subfamily: Caesalpinioideae
- Tribe: Cassieae
- Genus: Senna (sensu lato)
- Species: *Cassia tora*

Botanical Features

Leaves

- The leaves of Cassia tora are alternate and pinnately compound, meaning they consist of multiple leaflets arranged along a central stalk.
- Each leaf typically has 3 to 8 pairs of leaflets, plus one terminal leaflet.

Leaflets

- The leaflets are lanceolate (shaped like a lance or spear), with a smooth margin.
- They are usually 2 to 5 centimetres long and 1 to 2 centimetres wide.

Flowers

- The flowers of *Cassia tora* are bright yellow and occur in clusters at the tips of the branches.
- Each flower has five petals, with the two upper petals smaller than the three lower ones.
- The flowers are hermaphroditic, containing both male and female reproductive organs.

Inflorescence

- The flowers are arranged in racemes, elongated clusters where short stalks attach the individual flowers along a central axis.

Fruit and Seed Pods

- After flowering, *Cassia tora* produces cylindrical, slender, and slightly curved seed pods. These pods are characteristic of the genus *Cassia*.
- The pods are green when young and turn brown as they mature.
- Each pod contains several small, flat, and kidney-shaped seeds.

Stem

- The stem of *Cassia tora* is usually erect and cylindrical and can grow up to 1 to 1.5 meters in height.
- The stem may have a reddish tinge and may be slightly hairy or glabrous (without hairs).

Root System

- The plant has a taproot system that anchors it in the soil and helps it access water and nutrients.

Growth Habit

- *Cassia tora* is an annual plant that completes its life cycle within a year.

Flowering Period

- The plant typically flowers during the warmer months, from late spring to early fall.

Leaf Shape

- The leaflets are generally elongated and narrow, with a pointed tip.

Habitat

- *Cassia tora* is often found in open fields, disturbed areas, roadsides, and waste places.

About Argemone maxicana

Argemone mexicana, commonly known as Mexican prickly poppy or yellow thistle, belongs to the family Papaveraceae.

The systematic position of *Argemone mexicana*

- Kingdom: Plantae (Plants)
- Clade: Tracheophytes (Vascular plants)
- Clade: Angiosperms (Flowering plants)
- Clade: Eudicots
- Order: Ranunculales
- Family: Papaveraceae
- Subfamily: Papaveroideae
- Tribe: Chelidonieae
- Genus: Argemone
- Species: *Argemone Mexicana*

Botanical features

Leaves

- The leaves of *Argemone mexicana* are alternate, spiny, and deeply lobed.
- They have a bluish-green color and a waxy or glaucous surface.
- The leaves can vary in size but are generally around 5 to 15 centimetres long.

Flowers

- The flowers are large and showy, with bright yellow petals typically 4 to 6 centimetres in diameter.
- They have a papery texture and a distinctive appearance.
- The flowers have numerous stamens with yellow anthers and a central stigma.

DOI: https://doi.org/10.52756/ijerr.2023.v36.024

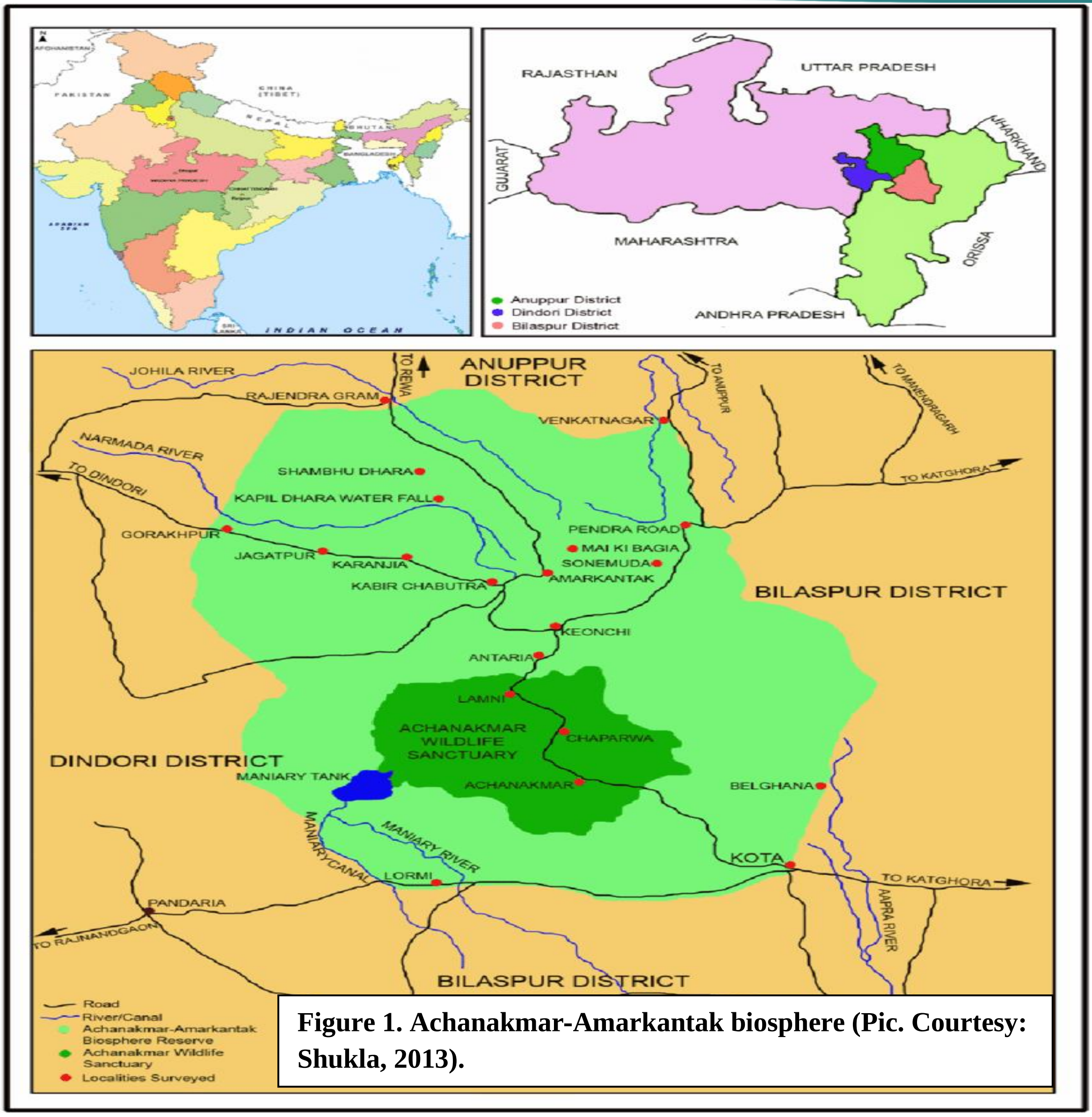


Figure 1. Achanakmar-Amarkantak biosphere (Pic. Courtesy: Shukla, 2013).

Inflorescence

- The flowers are solitary or may appear in small clusters at the ends of branches.
- They have a cup-shaped structure with four to six petals.

Fruit and Seed Capsules

- After flowering, *Argemone mexicana* produces spherical seed capsules.
- These capsules are covered in spiny prickles, giving them a thorny appearance.

Stem

- The plant's stem is erect and branched and can grow up to 1 to 1.5 meters in height.
- It is often covered with spines or prickles, particularly on younger growth.

Root System

- The plant has a fibrous root system that helps it adapt to various soil conditions.

Growth Habit

- *Argemone mexicana* is an annual or biennial plant that completes its life cycle within one or two years.

Leaf Shape

- The leaves are deeply lobed with irregular margins, giving them a distinctive appearance.

Seed Dispersal

- The prickly seed capsules split open when mature, releasing the tiny black seeds. The prickles on the capsules aid in dispersal by attaching to passing animals or clothing.

Flowering Period

- The plant typically flowers during the warmer months, from late spring to early fall.

Phenological diversity refers to the variability and range of timing and occurrence of different biological events, such as flowering, fruiting, leaf emergence, and other life cycle stages, within a population, species, or ecosystem. It encompasses the variation in the timing of these events in response to environmental cues, such as temperature, photoperiod (day length), and precipitation (Sharma et al., 2023).

Table 1. Meteorological data of study area in 3 consecutive years: Data source: POWER | Data Access Viewer (nasa.gov)

NASA/POWER CERES/MERRA2 Native Resolution Monthly and Annual

Dates: 01/01/2020 through 12/31/2022, Location: Latitude 22.5035 Longitude 81.7849, Achanakmar Tiger Reserve - NH-45, Pendra road

Elevation from MERRA-2: Average for 0.5 × 0.625 degree lat/lon region = 482.18 meters

Parameter (s):

RH2M MERRA-2 Relative Humidity at 2 Meters (%)

T2M_MAX MERRA-2 Temperature at 2 Meters Maximum (^{0}C)

T2M_MIN MERRA-2 Temperature at 2 Meters Minimum (^{0}C)

WS50M_RANGE MERRA-2 Wind Speed at 50 Meters Range (m/s)

PARAMETERS	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
RH2M	2020	67.62	56.19	60.06	38.44	39.56	73.12	86.44	**88.88**	86.25	81.44	72.38	56.31	67.31
RH2M	2021	48.69	35.56	21.88	16.56	46.75	73.62	85.81	88.25	88.56	80.56	70.69	60.38	59.94
RH2M	2022	63.94	46.88	30.38	**15.25**	32.56	53.5	85.94	88.62	88.81	84.06	73.5	60.94	60.5
WS50M	2020	3.72	3.98	3.26	4.02	4.23	4.59	3.92	**5.23**	3.09	3.52	3.48	**2.93**	3.83
WS50M	2021	3.26	2.96	3.64	3.9	4.86	4.71	5.2	4.56	4.15	3.58	3.33	3.59	3.98
WS50M	2022	3.46	3.81	3.74	3.84	4.91	4.23	4.23	4.52	4.37	3.69	3.2	3.58	3.97
T2M_MAX	2020	26.94	30.49	35.96	41.15	43.44	38.7	32.3	31.63	31.63	30.17	28.05	28.69	43.44
T2M_MAX	2021	30.1	35.26	41.39	42.48	41.06	39.55	31.72	31.44	30.61	30.55	28.69	27.86	42.48
T2M_MAX	2022	27.8	32.64	41.98	**45.21**	44.47	45.08	31.91	30.67	30.19	29.51	27.29	28.19	45.21
T2M_MIN	2020	**2.95**	5.95	12.7	18.62	21.12	22.12	22.05	22.3	20	14.75	8.86	6.43	2.95
T2M_MIN	2021	6.69	7.24	14.18	18.48	21.92	22.43	22.77	22.27	21.88	11.74	10.03	4.44	4.44
T2M_MIN	2022	4.5	6.23	13.04	22.02	24.15	23.59	22.37	21.63	20.65	12.73	8.7	8.16	4.5

In a broader context, phenological diversity reflects how different organisms respond to changing environmental conditions and how their life cycle events are timed to seasonal or climatic patterns. This diversity can be observed within a single species and across multiple species within an ecosystem.

Phenological diversity has ecological implications, as it can impact interactions among species, including pollinators, herbivores, and predators. It can also influence ecosystem processes such as nutrient cycling and energy flow. Studying phenological diversity provides insights into how species adapt to environmental changes and how ecosystems respond to shifts in climate and other factors.

In the present study, both of these above-mentioned plants have been studied comparatively for their phonological behaviour in different microclimatic behaviours in three successive years, i.e., from January 2020 to December 2022.

Material and Methods

Study area

The Achanakmar region in Chhattisgarh, India, primarily refers to the Achanakmar Wildlife Sanctuary, a protected area known for its biodiversity and natural beauty. Here is more detail about the area of study within the Achanakmar region:

Achanakmar Wildlife Sanctuary

- **Area:** The sanctuary covers an area of about 557.55 square kilometres.
- **Location:** It is located in the northern part of Chhattisgarh, bordering Madhya Pradesh.
- **District:** Achanakmar Wildlife Sanctuary is part of the Bilaspur district of Chhattisgarh.
- **Topography:** The sanctuary features diverse topography, including hills, plateaus, valleys, and riverine areas.
- **Ecosystems:** The sanctuary encompasses various ecosystems, including mixed deciduous forests, tropical moist deciduous forests, and bamboo forests.

DOI: https://doi.org/10.52756/ijerr.2023.v36.024

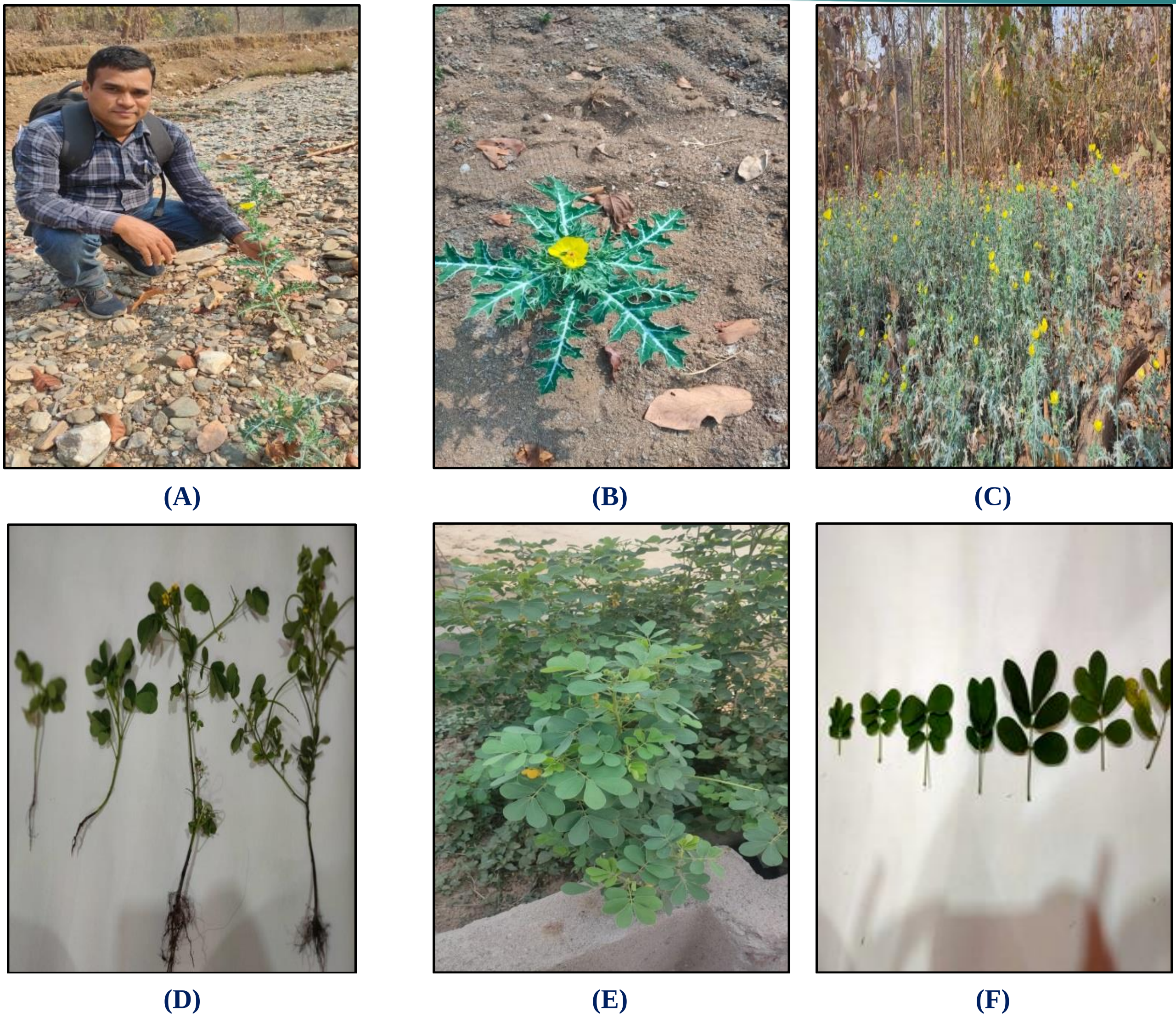


Figure 2. ***(A) A. maxicana*** **in the field (B)** ***A. maxicana*** **in flowering (C)** ***A. maxicana*** **in late flowering (D)** ***C. tora*** **in branch phenology (E)** ***C. tora*** **in flowering (F)** ***C. tora*** **in leaf phenology.**

- **Biodiversity:** Achanakmar is home to a range of flora and fauna, including various species of mammals, birds, reptiles, and plants.

Plant phenological study

- Phenological characteristics like new foliage, leaf fall, flowering and fruiting were studied using the method of Opler et al. (1980) for three years, from January 2020 to December 2022.

Morpho-phenological characters

- Morpho-phenological features like branches per species, leaf per branch, Inflorescences per branch, flowers per branch, and fruit observations were made at regular intervals of one month. For this, 5 marked plant branches were selected, and Individual characteristics were then recorded bi-monthly.

Statistical analysis

- Using MS-Excel 2010, simple metrics like average, minimum, and maximum were determined. One-way ANOVA was used to analyze variance using the SPSS software.

Results and Discussion

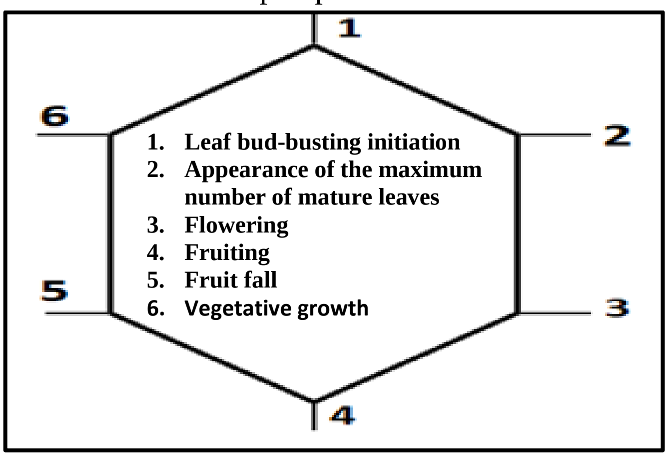
- A three-year (Jan 2020- Dec. 2020, Jan 2021- Dec. 2021, Jan 2022- Dec. 2022) analysis found that the maximum temperature was 45.21°C in April 2022, and the minimum temperature was 2.95°C in January 2020. The highest value of Relative Humidity at 2 Meters (%) was observed to occur in August 2020 and was 88.88 %, while the lowest value was 15.25% and was observed to occur in April 2020. The Wind Speed at 50 Meters Range (m/s) was 5.23 m/s in the highest value and 2.93 m/s in the lowest value in the same year, 2020, August and December, respectively.
- In the present investigation, both these plants have been studied comparatively for their Vegetative growth, Leaf bud busting initiation, Leaf maturation time required, Average age of leaf, Appearance of minimum total mature leaves, Appearance of maximum number of mature leaves, Length of reproductive stage, Flower bud initiation, Appearance of mature flower, Fruit formation, Last fruit/Fruit fall,

DOI: https://doi.org/10.52756/ijerr.2023.v36.024

Vegetative growth has been represented in Figure 3 and Table-2 respectively.

- In the present study, it was observed that in *Cassia tora*, the leaf bud busting initiation was observed to occur in July-August and in *Argemone maxicana*, it was observed at the end of August. The period required for leaf maturation for *Cassia tora* and *Argemone maxicana* was 1 to 2 months and 1 month, respectively. The average leaf age for *Cassia tora* was 7-8 months, and for *Argemone maxicana,* it was 9-10 months. In both plants, the appearance of minimum total mature leaves was observed to occur in September. However, in *Cassia tora,* the appearance of a maximum number of mature leaves was found in the month of November, whereas in *Argemone mexicana*, it was in April. The length of the reproductive stage was observed to occur in *Cassia tora* for 3 to 4 months, whereas in *Argemone mexicana*, it was 7-8 months.

Flower bud initiation in *Cassia tora* was observed to occur in July-September, and in *Argemone maxicana*, it was in March-April. The appearance of mature flowers was observed to occur in both the plants in the month of October in *Cassia tora* and in *Argemone Mexicana* in the month of April. Fruit formation was found in Dec-Jan in *Cassia tora,* and in *Argemone maxicana* it was in April-May. The last fruit/fruit fall was initiated in February in *Cassia tora* and in *Argemone mexicana* in May -June. The vegetative growth of both these studied plants was observed to occur throughout the year. The phenological behavior plays a significant role in the study of vegetation patterns in the studied regions, in the field of biochemistry and the field of pharmacology. The plant has evolved in varied phenological phages that attain maximum beneficial phytoconstituents in different phenophases that must be studied for future prospects.



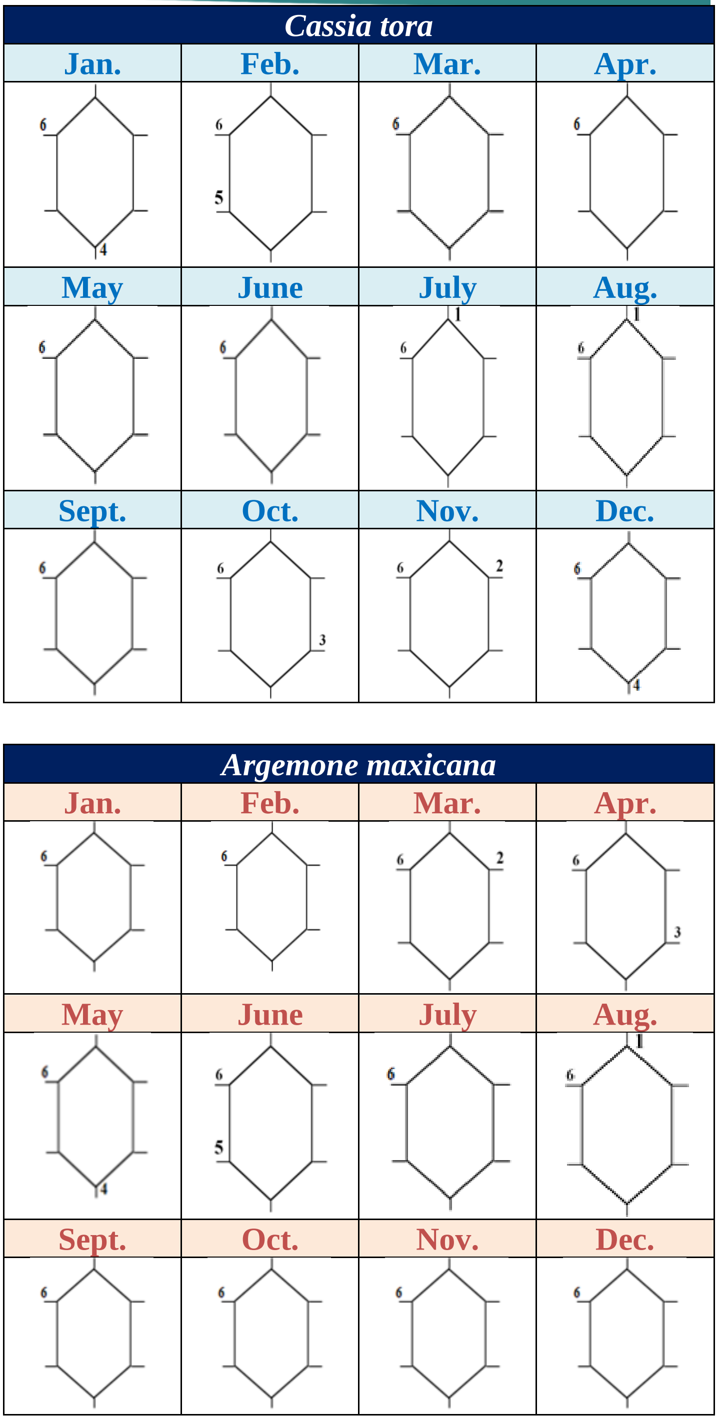


Figure 3. Different phenophase in *Cassia tora* and *Argemone maxicana.*

Conclusion

The most significant phenological phenomena for plants are flowering and fruiting. The periodicity of flowering provides pertinent information about the fruiting period because flowering constantly precedes fruit production, which will aid in predicting the frequency of seed germination and the ideal time for its harvest. In the current study, *Cassia tora* showed the flower bud production during July with a peak in August, whereas, in *Argemone maxicana* it was in September. In the present study,

Table 2. Different phenophase in *Cassia tora* and *Argemone maxicana*.

Sl. No.	Phenophases	*Cassia tora*	*Argemone maxicana*
1	Leaf bud-busting initiation	Jul-Aug	End of August
2	Leaf maturation time required	1 to 2 months	1 month
3	The average age of the leaf	7-8 months	4-5 months
4	Appearance of minimum total mature leaves	September	Dec-Jan
5	Appearance of maximum number of mature leaves	November	March-May
6	Length of reproductive stage	3 to 4 months	7-8 months
7	Flower bud initiation	Jul-Aug	March-April
8	Appearance of mature flower	October	April-May
9	Fruit formation	Dec-Jan	May
10	Last fruit/Fruit fall	February	May -June
11	Vegetative growth	Throughout the year	Throughout the year

Table 3. Phenological diversity in the mean number of days from Achanakmar Reserve Forest.

Year	New foliage		Leaf fall		Flowering		Fruiting	
	Cassia tora	*Argemone maxicana*	*Cassia tora*	*Argemone maxicana*	*Cassia tora*	*Argemone maxicana*	*Cassia tora*	*Argemone maxicana*
2020-21	42	45	33	36	122	95	85	87
2021-22	34	35	27	42	127	123	101	90
2022-23	45	46	22	32	132	92	122	85
Mean ±SD	40±5	42±6	27±5	36±5	127±5	103±17	102±18	87±2

it was revealed that, in *Cassia tora*, the mean ± SD values of new foliage, leaf fall, flowering and fruiting days were 40±5, 27±5, 127±5, and 102±18 respectively, whereas, in *Argemone maxicana*, these are 42±6, 36±5, 103±17, 87±2 respectively. The current study provides information on the duration of the several life phases of *Cassia tora* and *Argemone maxicana*. The current data is helpful in the restoration of disturbed regions since it enables the planning and gathering of seeds of studied plants for restoration efforts. The existing data can be utilised as a baseline for further examination of phenological fluctuations in response to climate change.

Future scope

The future of plant phenological study holds immense potential for addressing pressing environmental and agricultural challenges. It involves a combination of advanced technology, interdisciplinary collaboration, and a greater understanding of the intricate relationships between plants, climate, and ecosystems. The observations of the present study on two medicinally important plants viz., *Cassia tora* and *Argemone maxicana* will contribute to our ability to adapt to and mitigate the effects of a changing world.

Conflict of interest

There is no conflict of interest to disclose.

Authors contributions

The first author contributed research design, data collection from the field with various tools, analyzed the data. The second author assisted in writing the paper and also finalized the manuscript.

Acknowledgement

The authors of this article are thankful to the indigenous People of the Achanacmar region for their valuable cooperation in the data collection. The authors are also grateful to Prof. Ravi Prakash Dubey, Honourable Vice-Chancellor, Dr. C.V. Raman University, for allowing the research work.

References

Bartomeus, I., Ascher, J. S., Wagner, D., Danforth, B. N., Colla, S., Kornbluth, S., & Winfree, R. (2011). Climate associated phenological advances in bee pollinators and bee-pollinated plants. *Proceedings of the National Academy of Sciences*, *108*(51), 20645–20649.

Bolmgren, K., & Eriksson, O. (2015). Are mismatches the norm? Timing of flowering, fruiting, dispersal and germination and their fitness effects in Frangula alnus (Rhamnaceae). *Oikos*, *124*(5), 639–648.

de Camargo, M. G. G., de Carvalho, G.H., de C. B., Alberton, P., & Morellato, L. P. C. (2018). Leafing patterns and leaf exchange strategies of a cerrado woody community. *Biotropica*, *50*(3), 442–454

Gray, R.E.J. & Ewers, R.M. (2021). Monitoring Forest Phenology in a Changing World. *Forests*,*1*(12), 297. https://doi.org/10.3390/f12030297

Lemoine, N. P., Doublet, D., Salminen, J. P., Burkepile, D.E., & Parker, J. D. (2017). Responses of plant phenology, growth, defense, and reproduction to interactive effects of warming and insect herbivory. *Ecology*, *98*(7), 1817–1828.

Opler, P. A., Frankie, G. W., & Baker, H. G. (1980). Comparative phenological studies of treelet and shrubs species in tropical wet and dry forests in the lowlands of Costa Rica. *Journal of Ecology*, *68*, 167- 188.

Park, J.S., & Post, E. (2022). Seasonal timing on a cyclical Earth: Towards a theoretical framework for the evolution of phenology. *PLOS Biology*, *20*(12), e3001952. https://doi.org/10.1371/journal.pbio.3001952

Posledovich, D., Toftegaard, T., Wiklund, C., Ehrlén, J., & Gotthard, K. (2015). The developmental race between maturing host plants and their butterfly herbivore - the influence of phenological matching and temperature. *Journal of Animal Ecology*, *84*(6), 1690–1699.

Ramaswami, G., Datta, A., Reddy, A., & Quader, S. (2019). Tracking phenology in the tropics and in India: the impacts of climate change. Varanasi, India - a case study. *Journal of Agrometeorology*, *16*(1), 44–51.

Richardson, A. D., Keenan, T. F., Migliavacca, M., Ryu, Y., Sonnentag, O., & Toomey, M. (2013). Climate change, phenology, and phenological control of vegetation feedbacks to the climate system. *Agricultural and Forest Meteorology*, *169*, 156–173.

Rodríguez-Pérez, J., & Traveset, A. (2016). Effects of flowering phenology and synchrony on the reproductive success of a long-flowering shrub. *Annals of Botany Plants*, *8*, plw007.

Sharma, A., Patel, S. K., & Singh, G. S. (2023). Variation in Species Composition, Structural Diversity, and Regeneration Along Disturbances in Tropical Dry Forest of Northern India. *Journal of Asia-Pacific Biodiversity*, *16*(1), 83-95. https://doi.org/10.1016/j.japb.2022.11.004.

Shukla, A., & Singh, K. (2013). Glimpses of the Lichen Flora of Achanakmar-Amarkantak Biosphere Reserve in Central India. *American Journal of Plant Sciences*, *03*, 697-708. https://doi.org/10.4236/ajps.2012.36084.

Tunes, P., Alves, V.N., Valentin-Silva, A., Batalha, M.A., & Guimarães, E. (2017). Does fire affect the temporal pattern of trophic resource supply to pollinators and seed-dispersing frugivores in a Brazilian savanna community? *Plant Ecology*, *218*(3), 345–357. https://doi.org/10.1007/s11258-016-0695-5

Velasque, M., & Del-Claro, K. (2016). Host plant phenology may determine the abundance of an ecosystem engineering herbivore in a tropical savanna. *Ecological Entomology*, *41*(4), 421–430. https://doi.org/10.1111/een.12317.

How to cite this Article:

Jagesh Kumar Shriwas and Lata Sharma (2023). A Comparative Phenological Studies of High-Value Medicinal Herbs: *Cassia tora* and *Argemone maxicana* in Achanakmar Regions of Chhattisgarh, India. *International Journal of Experimental Research and Review*, *36*, 244-252.

DOI : https://doi.org/10.52756/ijerr.2023.v36.024