Phenology of the jobo (*Spondias mombin* L.)

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ABSTRACT

Objective: To identify the flowering and fruiting periods of the species by examining the correlation between climate conditions and phenophases.

Design/Methodology/Approach: *Spondias mombin* L. is an underutilized species with minimal or no management. An edaphoclimatic characterization of the study area was conducted, along with an assessment of its vulnerability to climate change. Botanical identification of the species and its main propagation methods were also performed. Additionally, temperature and precipitation data for the year 2021 were analyzed, enabling a phenological evaluation.

Results: Full flowering occurred between April and May, while fruit ripening progressed gradually throughout July and August. Defoliation was linked to a decline in temperatures during November and December, marking the onset of the dormant phase. The phenology of *S. mombin* exhibited variability in its phenophases depending on the specific environmental conditions of its habitat, particularly during the fruit ripening stage. The individuals studied showed asynchronous phenological patterns, with flowering and fruiting occurring at different times.

Limitations/Implications: This study faces certain limitations, including its local scope, climatic variability, and a limited number of samples. *Findings/Conclusions*: Although this study provides valuable insights into the phenology of *Spondias mombin*, further research is essential to deepen the understanding of how climate change influences this species and to assess its potential for agroforestry applications.

Keywords: climate change, temperature, precipitation, phenological behavior.

Citation: García-Alonso, F., Casanova-Pérez, L., Martínez-Martínez, R., San Juan-Martínez, A., Grifaldo-Alcántara, P. F., & Vargas-Madriz, H. (2025). Phenology of the jobo (*Spondias mombin* L.). *Agro Productividad*. https://doi.org/10.32854/fh4yfn40

Academic Editor: Jorge Cadena Iñiguez
Associate Editor: Dra. Lucero del Mar Ruiz Posadas
Guest Editor: Daniel Alejandro Cadena Zamudio

Received: October 4, 2025.
Accepted: December 3, 2025.
Published on-line: February 18, 2026.

Agro Productividad, 18(12). December. 2025. pp: 29-36.

INTRODUCTION

Spondias mombin L. (commonly known as jobo) is an undervalued species, as it receives minimal or no management and its care largely depends on the interest of individual families. Its survival has therefore relied mainly on natural cycles. Under conditions of temperature and precipitation variability factors exacerbated by climate change active participation by producers and the incorporation of research are necessary for the development of technological interventions that can be adopted by farmers (Ruenes-Morales, 2018). Additionally, the species is recognized for its adaptive, nutritional, and ethnobotanical advantages, which are strongly associated with agroforestry practices

(Arce-Romero *et al*., 2017; Álvarez-Vargas *et al*., 2017). *S. mombin* grows wild throughout tropical America, primarily in hard-to-access areas, though some individuals form part of the species composition in home gardens. Arce *et al*. (2017) emphasize its cultural significance, noting that in recent years, consumption particularly of the fruit pulp has increased in urban areas adjacent to the study site. The species is also commonly used as a natural marker for land boundaries. Furthermore, it is considered a tolerated species, meaning it persists or is accepted within the local agricultural or environmental system, and has gained renewed interest in recent times. According to Avitia *et al*. (2000) and Álvarez *et al*. (2017), approximately 3,000 species have been identified with potential for use in tropical regions worldwide, yet very few are cultivated, as most remain semi-domesticated or in a wild state. Such strategies cannot be effectively designed without valuable, locally contextualized information as is the case here. A key component of this information is knowledge of the species' phenology, including the identification of critical phases and management practices for its conservation and sustainable use. However, there is very limited information on this topic, particularly within the context of climate change (Lambers *et al*., 2021). The genus *Spondias* comprises 17 species within the Anacardiaceae family seven of which are Neotropical, and ten are found in the Asian tropics. Among them, *Spondias mombin* L. is native to Mexico, though it is also found in other tropical regions of the Americas (notably Ecuador, Brazil, and Peru), as well as parts of Asia and Africa (Fortuny *et al*., 2017).

In Mexico, *S. mombin* grows from near sea level up to elevations of 1,200 meters above sea level, with its optimal altitudinal range between 100 and 800 meters. It is distributed along the Pacific coast in the states of Sinaloa, Nayarit, Jalisco, Colima, Michoacán, Guerrero, and Oaxaca, and along the Atlantic coast in Tamaulipas, San Luis Potosí, Hidalgo, Puebla, Tabasco, Campeche, Yucatán, and Quintana Roo. In Hidalgo, the species is commonly known as jobo, and its fruit is increasingly accepted in local municipal markets (Arce-Romero *et al*., 2017). Therefore, the aim of this study was to identify the flowering and fruiting periods of *S. mombin* and examine the correlation between climate and its phenophases.

MATERIALS AND METHODS

Study area

The research was conducted in the town of Teacal, Huejutla de Reyes, Hidalgo. Its geographic location corresponds to 21° 08' N and 98° 25' W at an altitude of 140 meters above sea level (INEGI 2001).

Edaphoclimatic characteristics and climate change vulnerability

The climate of the study area is classified as humid semi-warm (A)C(m)(w), with an average annual temperature of 31.1 °C and annual rainfall of 1,500 mm, concentrated between June and September (García, 1988; INEGI, 1992). The soil units present in the area include Rendzina, Lithosol, Phaeozem, Vertisol, and Regosol (INEGI, 2001). To evaluate the vulnerability of the area to climate change, projections reported by the National Institute of Ecology and Climate Change (INECC, 2022) were considered. These

Figure 1. Location of the study area.

projections indicate an expected anomaly over the coming decades, with an increase of 4.5 °C in average temperature and a 9% decrease in annual precipitation.

Botanical characteristics

Spondias mombin is a common forest tree, deciduous, reaching heights between 15 and 30 meters, and trunk diameters ranging from 50 cm to 2 meters at breast height. It grows in both natural and semi-cultivated forests (Mantietto & Mata, 2011). The flowers are small, yellowish-white, and appear in panicles emerging from the axils of new leaves (Liogier, 1978). It is a monoecious and/or polygamo-dioecious species, presenting both female and hermaphroditic flowers. The panicles are large, terminal, and can measure up to 60 cm in length and between 15 and 25 cm in width. The fruit is a small ovoid drupe, 3 to 5 cm long, with a thin yellow skin and a bittersweet flavor (Alia-Tejacal *et al.*, 2012). The edible mesocarp contains 70% water and provides an average of 104 calories per gram. Fruit and seed production typically begins around five years of age. The pulp is used in the preparation of juices, popsicles, ice creams, yogurts, jams, and a fermented drink known as jobito (Soares *et al.*, 2006). The species holds cultural significance, particularly as a seasonal fruit in the Huastec region (Centurión-Hidalgo *et al.*, 2019). The wood of *S. mombin* is white and of limited commercial value; however, Little and Wadsworth (1967) note that it can be used as firewood or for charcoal production. In several countries, the plant is traditionally used to treat various ailments, including infectious diseases (Asuquo *et al.*, 2012). Decoctions made from the bark or root are used as antiseptics, while the leaves are applied for treating colds, fevers, gonorrhea, and for cleaning wounds. Finally, extracts from the leaves, bark, seeds, fruits, and roots of *S. mombin* contain nitrogen, sulfur, and oxygen atoms that act as corrosion inhibitors for metals under aggressive environmental conditions (Umoren & Ebenson, 2008). In agroforestry systems, the species is commonly used as a live fence (Vargas-Simón *et al.*, 2011).

Species propagation

S. mombinis commonly propagated naturally via sexual reproduction (seeds). However, farmers often relocate spontaneously emerging seedlings or propagate the species asexually

(FAO, 1986). Cuttings measuring 50 to 100 cm in length and 5 to 10 cm in diameter from branches are vertically inserted into moist soil to half their length. Young trees sprout easily, and mature trees may also regenerate after being cut (Pennington & Sarukhán, 2005). These propagation practices have facilitated the species' introduction into various regions across Africa, Asia, North America, and several Pacific islands (Ruenes-Morales, 2018).

Climate data analysis

Temperature and precipitation data for the year 2021 in the study area were obtained from the Meteorological Station of the Instituto Tecnológico de Huejutla. Additionally, information from the Climate Change Vulnerability Atlas (AVCC, 2022) was used to understand short-, medium-, and long-term climate impacts in the region. Data from the Mexico Drought Monitor (MSM) and the North American Drought Monitor (MS-CNA, 2022) both publicly accessible government platforms were also consulted.

Phenological evaluation

The phenological evaluation of *S. mombin* consisted of monitoring the observable phenological stages of the species. Observations were carried out weekly from January to December 2021. A total of 10 mature trees (15 years old) located in cultivated fields and home gardens (solar) were assessed. Recorded variables included the duration of phenophases such as inflorescence emergence, flowering, anthesis, green and ripe fruit presence, leaf fall, and leaf flushing. The methodology of Fournier (1974) was applied to conduct the quantitative evaluation of phenological characteristics.

Data analysis

The data were systematized in an Excel spreadsheet for analysis. A descriptive statistical analysis was applied, including the calculation of frequencies, means, and durations of the observed phenophases such as flowering, fruiting, ripening, harvest, leaf development, and defoliation. This analysis made it possible to identify and quantify the occurrence and duration of specific phenological events, facilitating the interpretation of phenological patterns throughout the study period (Bencke & Morellato, 2002). Additionally, descriptive analysis was essential for correlating these events with environmental and climatic variables, providing a foundation for ecological and agronomic studies.

RESULTS AND DISCUSSION

Temperature and precipitation patterns

In 2021, the total annual accumulated precipitation was 1,001 mm (Figure 2). Variations were observed in the temporal patterns of temperature and precipitation throughout the year, characterized by an increase in maximum temperatures from April to June and a reduction in both the amount and distribution of rainfall, which was concentrated between June and September.

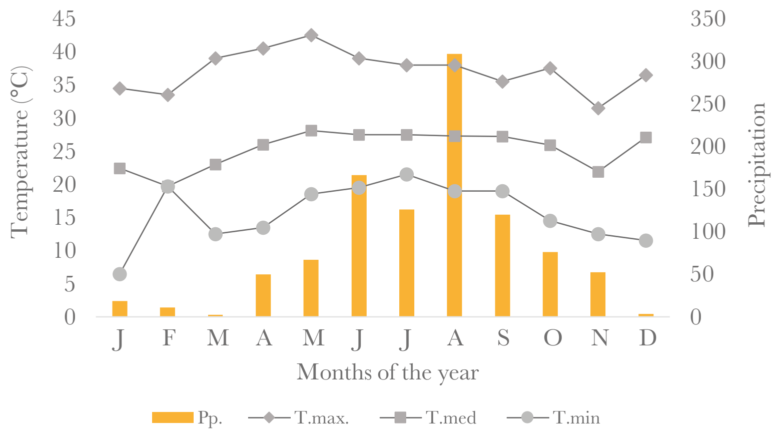

Figure 2. Temperature and precipitation patterns throughout the year. Source: Prepared by the authors using SNM data.

This increase in temperature, combined with the decrease in precipitation, is closely associated with the higher frequency and intensity of droughts in the region. According to data from the Drought Monitor (MS) for the period 2003–2021, both the occurrence and severity of droughts have progressively increased (Figure 3). These climatic changes significantly affect the phenophases of Spondias mombin, threatening the continuity and survival of its natural populations, as the species' persistence depends primarily on the proper timing of its phenological cycles.

Phenological behavior of the species

In the study area, Spondias mombin exhibited flowering that was nearly simultaneous with leaf flushing, with flower emergence occurring mainly between March and June. A high flowering rate was also observed, resulting in excellent fruit production. This phenological behavior is detailed in Table 1.

Fruit ripening in *S. mombin* occurred gradually during July and August, progressing slowly during the first month, following the flowering peak. As shown in Table 1,

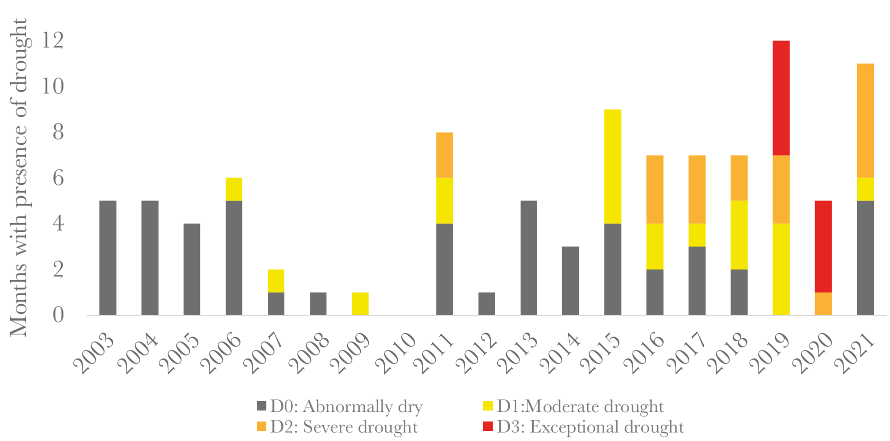

Figure 3. Presence and intensity of droughts from 2003 to 2021.

Table 1. Phenological development stages of the *Spondias mombin* L. plant.

Phases/months	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Flowering				■	■							■
Fruiting					■	■						
Ripening							■	■				
Harvest								■				
Leaves			■	■	■	■	■	■	■	■	■	
Defoliation											■	■
Dryness	■	■										■

defoliation begins as temperatures drop in November and December, marking the onset of the dormant phase. This phase, which follows the completion of defoliation, extends from November to February and coincides with low temperatures and the absence of rainfall during the autumn-winter season. This behavior is characteristic of native species adapted to temperate climates.

The phenology of *S. mombin* showed variations depending on the environmental conditions of the planting sites, reflecting the species' strong interaction with its surroundings. These differences highlight the species' variable behavior. For example, if rainfall is frequent, a second flowering may occur in December. In 2021, this phase was observed, albeit with low intensity. Based on the analyzed data, it is evident that in the municipality of Huejutla, the main agroclimatic variables temperature and precipitation are experiencing increased variability. Projections suggest a rise in temperature and a reduction in precipitation in the coming decades, as demonstrated by past trends (INEGI, 1992) when compared to historical averages (CONAGUA, 2014). This correlation has been documented in other studies, such as in Panama, where reduced flowering in several species, including *S. mombin*, was linked to disruptions in rainfall patterns caused by an El Niño event (Foster, 1992). This context highlights the urgent need to understand how the species is adapting to climate variability and how this is expressed in its local phenological behavior. Foster (1992), in his study in Barro Colorado, Panama, reported peak flowering in April and May, which aligns with the flowering pattern observed in this study. In Bolivia, due to higher elevation, the flowering phenophase of *S. mombin* occurs between February and April, with slight variations among different populations (Justiniano & Fredericksen, 2000a). Lovera and Núñez (2000) noted that fruit yield is limited due to a short harvest period. Fruit production intensity varies and depends on factors such as flower abundance, pollinator availability, and especially rainfall occurring after flower fertilization (Justiniano *et al.*, 2001). These agroclimatic conditions positively influence vegetative development stages such as leaf flushing, flowering, fruiting, defoliation, and dormancy, which together form an annual productive cycle for species like *S. mombin* (Del Villar, 1978). This pattern is consistent with findings reported by Lorenzi (1992), Vázquez & Coimbra (1996), INIA-OIMT (1996), and Justiniano & Fredericksen (2000).

CONCLUSIONS

In the studied area, the phenological phases of *Spondias mombin* show a clear dependence on fluctuations in key agroclimatic variables, particularly temperature and precipitation, with a notable impact during fruit maturation. Although the species has historically followed stable natural reproductive cycles, recent alterations in rainfall and temperature regimes have introduced greater uncertainty to its natural reproduction. This context underscores the urgent need for further research to generate detailed knowledge about the species, aiming to develop and implement effective strategies for its conservation and sustainable use.

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