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Mixed Cacti Orchards – A Horticultural Alternative for Mexican Semiarid Tropics

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1. Introduction

One of the most determinant phenomenon in horticulture is the phenology of cultivated species, a factor that is poorly known for cacti. Sexual reproduction in the majority of species belonging to the deciduous tropical forest communities (including some cacti) takes place during the middle or the end of the dry season (Rzedowski, 1978). There is an increasing interest in the fruits of some columnar cacti with economic value in the national and international markets. Such is the case in the state of Oaxaca, México of fruits of *Stenocereus griseus* (Haw) Buxbaum, locally known as "pitaya de mayo," *S. stellatus* (Pfeiffer) Riccobono, "tunillo" or "pitaya de aguas" and *Escontria chiotilla* (Weber) Rose, "jiotilla," species which produce fruits of economic relevance for several marginal communities in the state. The fruits of these columnar cacti are consumed fresh or used for making ice cream. The diversity in pulp color is an additional attractive of the fruits of the "pitayas" (*Stenocereus* spp.), which can be red, yellow, orange, purple or colorless, while those of "jiotilla" are invariably of red color. Several works have been made about the nutritional characteristics and diversity of the fruits of these cacti, mainly in their size and color (Ayala & Beltrán, 2007; Benito et al., 1992; Piña, 1977; Beltran et al., 2005; Casas, 2005; Tenango, 2005). The objective of the present work was to observe the phenological behavior of these species in their natural ecosystem, in order to obtain information about differences in their reproductive phenology that could be used for the establishment of mixed cacti orchards in the semiarid tropical lands of Mexico.

2. Materials and methods

A sampling area for phenological data was delimited for each one of the three studied species (Figure 1): 32 plants of "pitaya de mayo" were marked in a rural orchard at Joluxtla,

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in the municipality of Cosoltepec, district of Huajuapan de León, Oaxaca, at 1640 m.a.s.l. (Figure 1A); 30 plants of "tunillo" were marked in a rural orchard at Agua del Espino, municipality of La Compañía, district of Ejutla, Oaxaca, at 1420 m.a.s.l. (Figure 1B); and for "jiotilla," an area of approximately 0.1 ha was delimited located 7 Km S of San Pedro Totolápam, municipality of San Pedro Totolápam, district of Tlacolula, Oaxaca, at 950 m.a.s.l. (Figure 1C) 45 plants were marked.

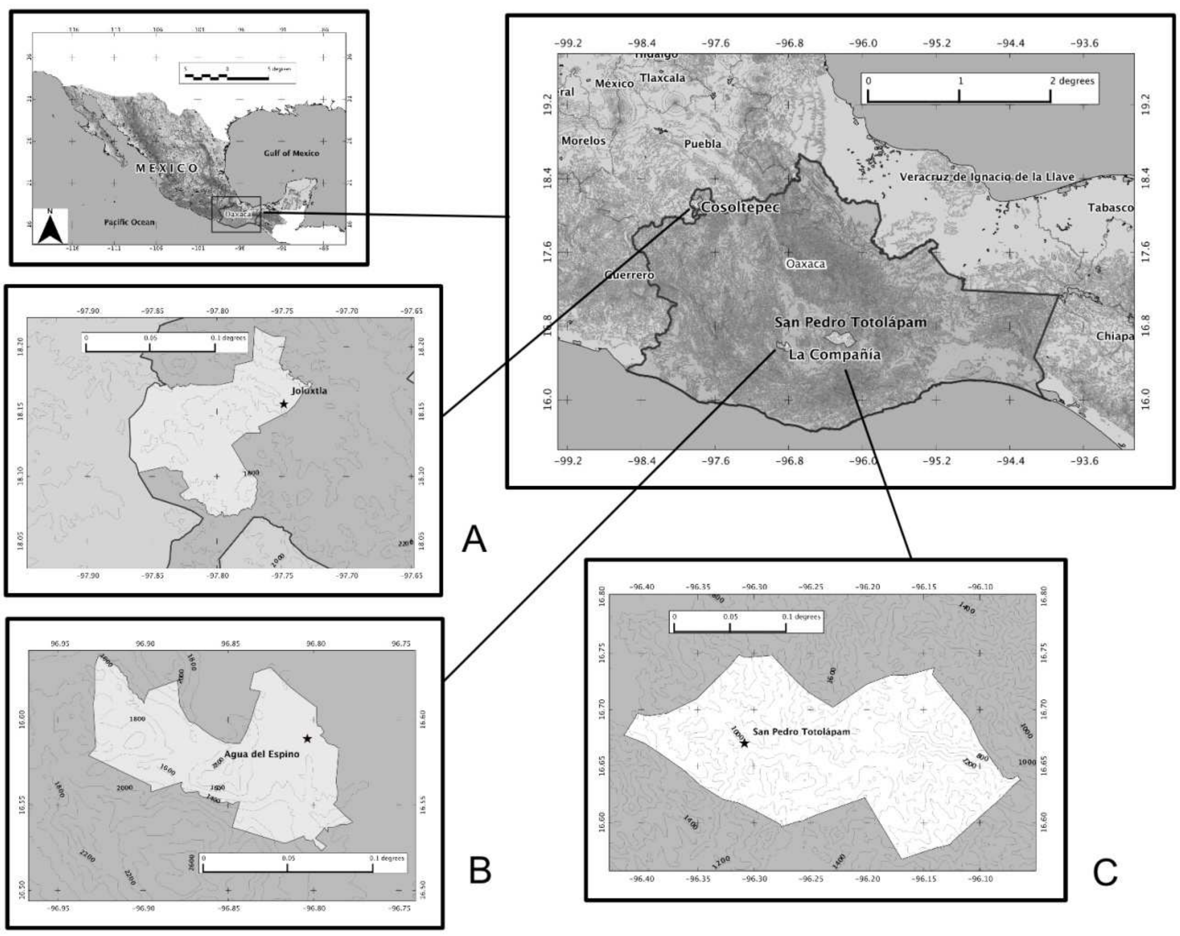

Fig. 1. Localization of study area and sampling sites for phenological data. A. Joluxtla: *Stenocereus griseus,* "pitaya de mayo;" B. Agua del Espino: *Stenocereus stellatus,* "tunillo;" C. San Pedro Totolápam: *Escontria chiotilla*, "jiotilla."

The sampling areas were visited every 30 days throughout the 2005 year and phenological data were recorded. The phenological stages were defined as following:

Fl_1.- Buds before anthesis
Fl_2.- Flowers after anthesis
Fr_1.- Immature fruits
Fr_2.- Mature fruits
Veg.- Vegetative

For the three phenological data sampling areas, ombrothermic diagrams were constructed using the climatic data for the last ten years from the nearest meteorological stations.

3. Results and discussion

The climatic conditions for the three study areas are represent in the ombrothermic diagrams shown in Figures 2A, 2B and 2C. These areas present similar climatic conditions with average temperature between 25-30 ºC , a midsummer drought and an average annual precipitation of 600-800 mm.

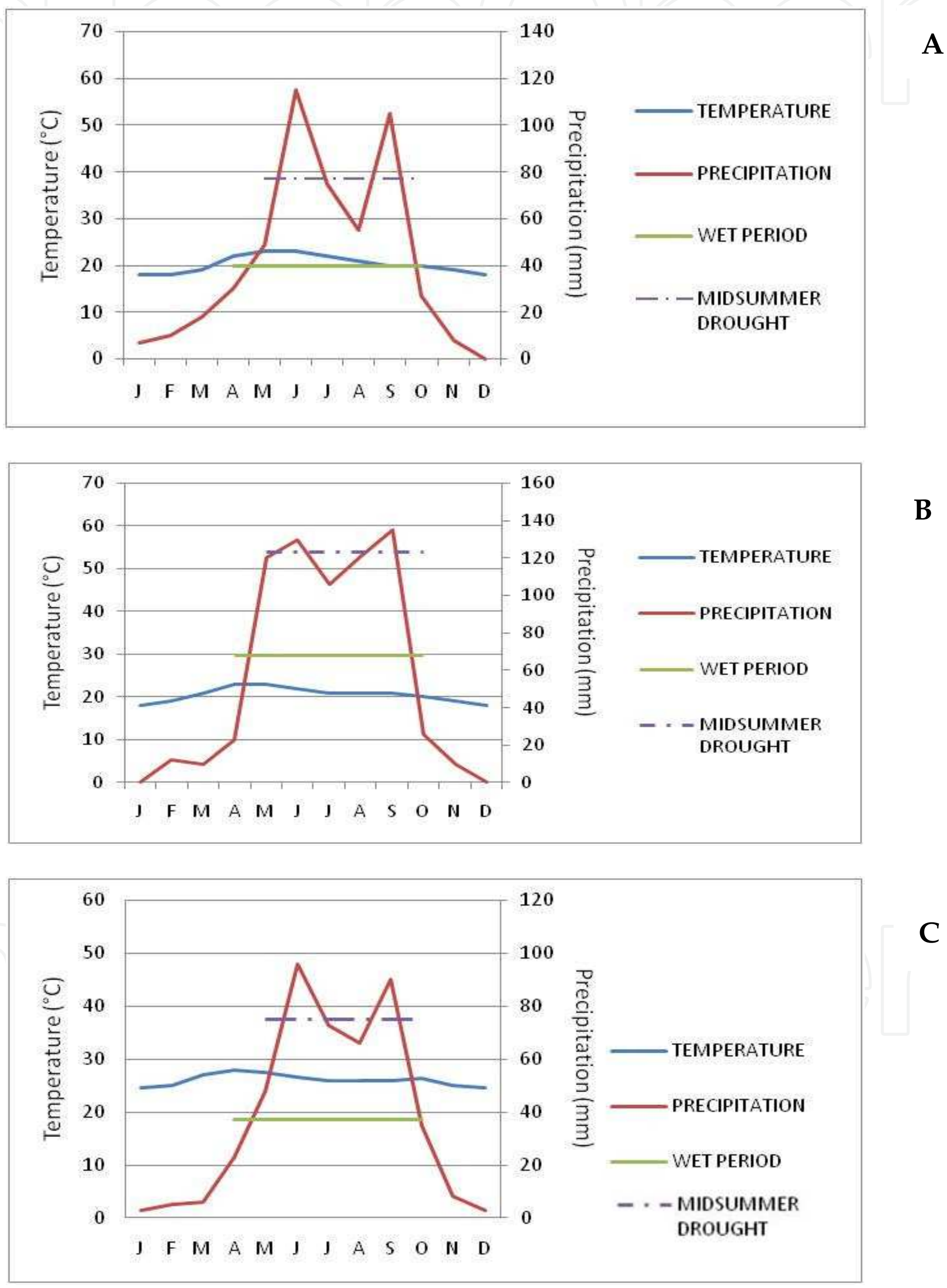

Fig. 2. Ombrothermic diagrams of sampling sites of phenological data of fruit producing columnar cacti; A) Chazumba for "pitaya" B) Ejutla for "tunillo" and C) Totolapan for "jiotilla."

In the "pitaya" area, 76.6% of the plants were observed to have reproductive structures during the months from January to June (Figure 3) with a maximal of fruit production during May (hence the local name of "pitaya de mayo," alluding to the month of May). 90% of the plants in reproductive phase produced mature fruits. *Stenocereus griseus* has also been reported to be of economic importance in Colombia, with two fruit production periods associated to rain seasons (Villalobos et al., 2007).

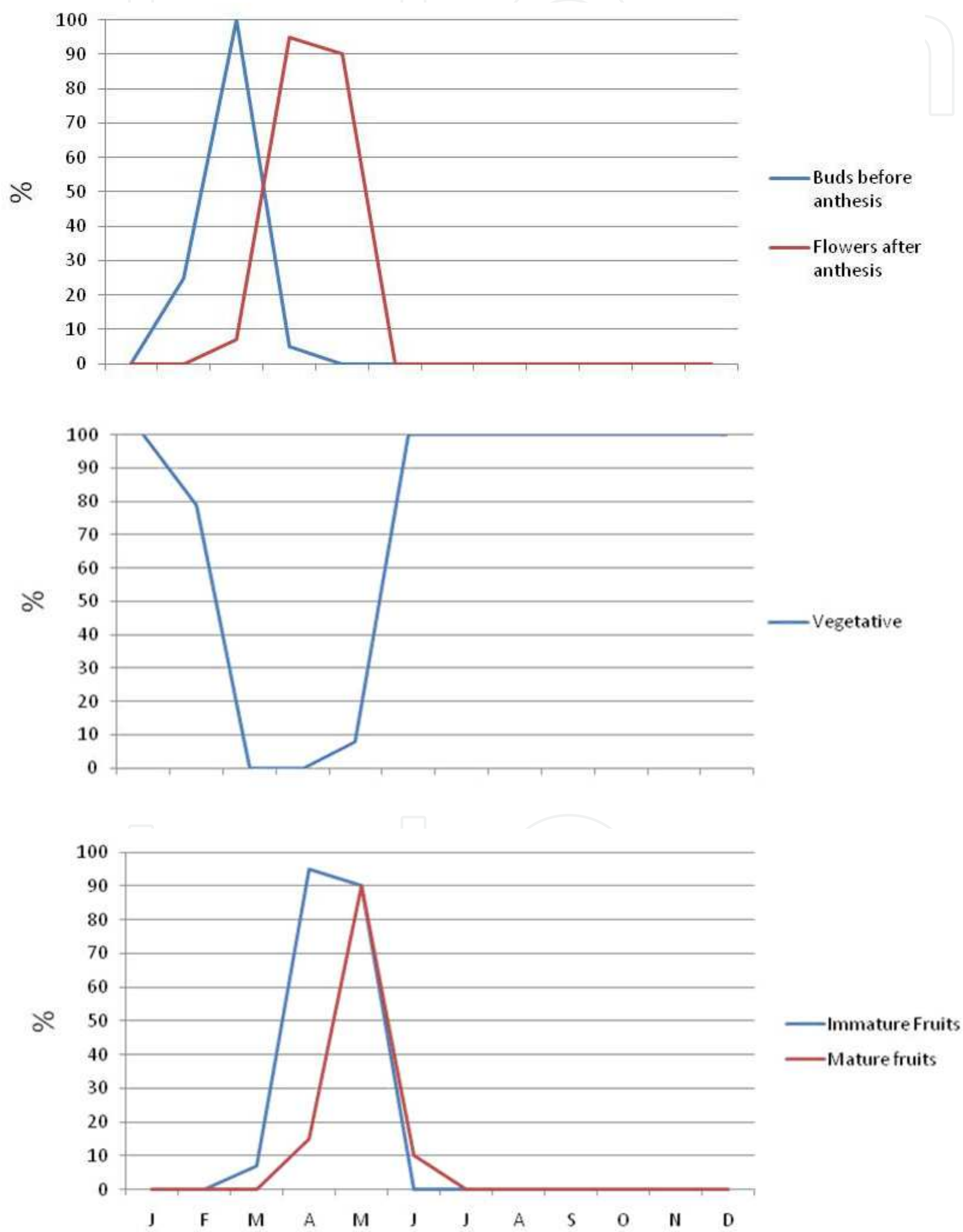

Fig. 3. Phenological diagram for "pitaya" (*Stenocereus griseus*).

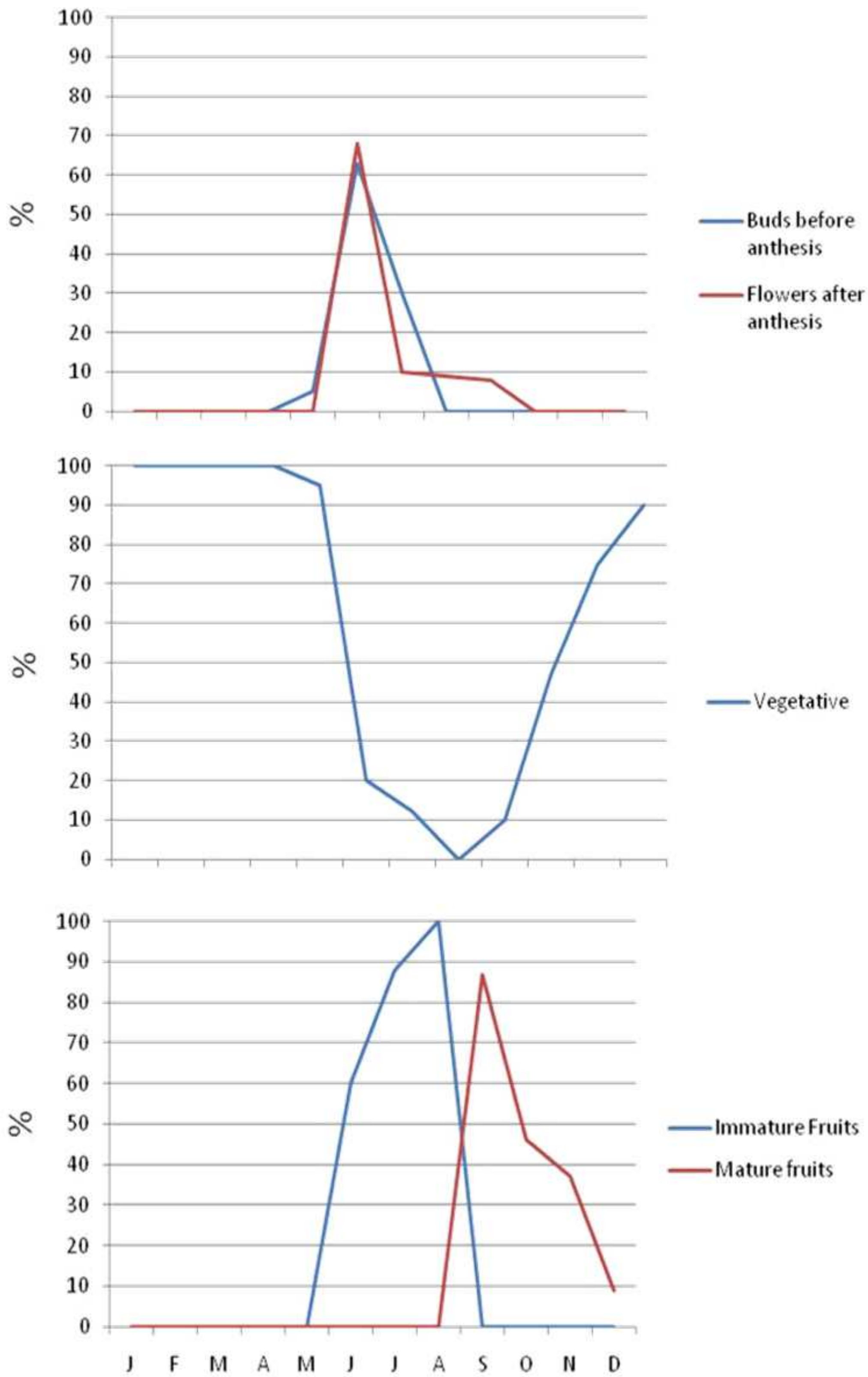

Fig. 4. Phenological diagram for "tunillo" (*Stenocereus stellatus*)

The phenological behavior of "tunillo" (*Stenocereus stellatus*) is represented in Figure 4. The reproductive period of this species is from May to October and mature fruits are present during the time period from June to September, i.e., during the rainy season. A relationship between precipitation and fruit growth has been reported for this species (García-Suárez et al., 2007). The phenology of *Escontria chiotilla* differs from that of *Stenocereus queretaroensis*, which is phenologically more similar to *S. griseus* ("pitaya de mayo") (Pimienta et al., 1994). The majority (80%) of the monitored plants of tunillo presented fruits. The fruits are only produced in the apical part of the stems. Some observations in *Stenocereus stellaus* shown that cultivated populations have more branches and fruit production that wild populations (Casas et al., 1999)

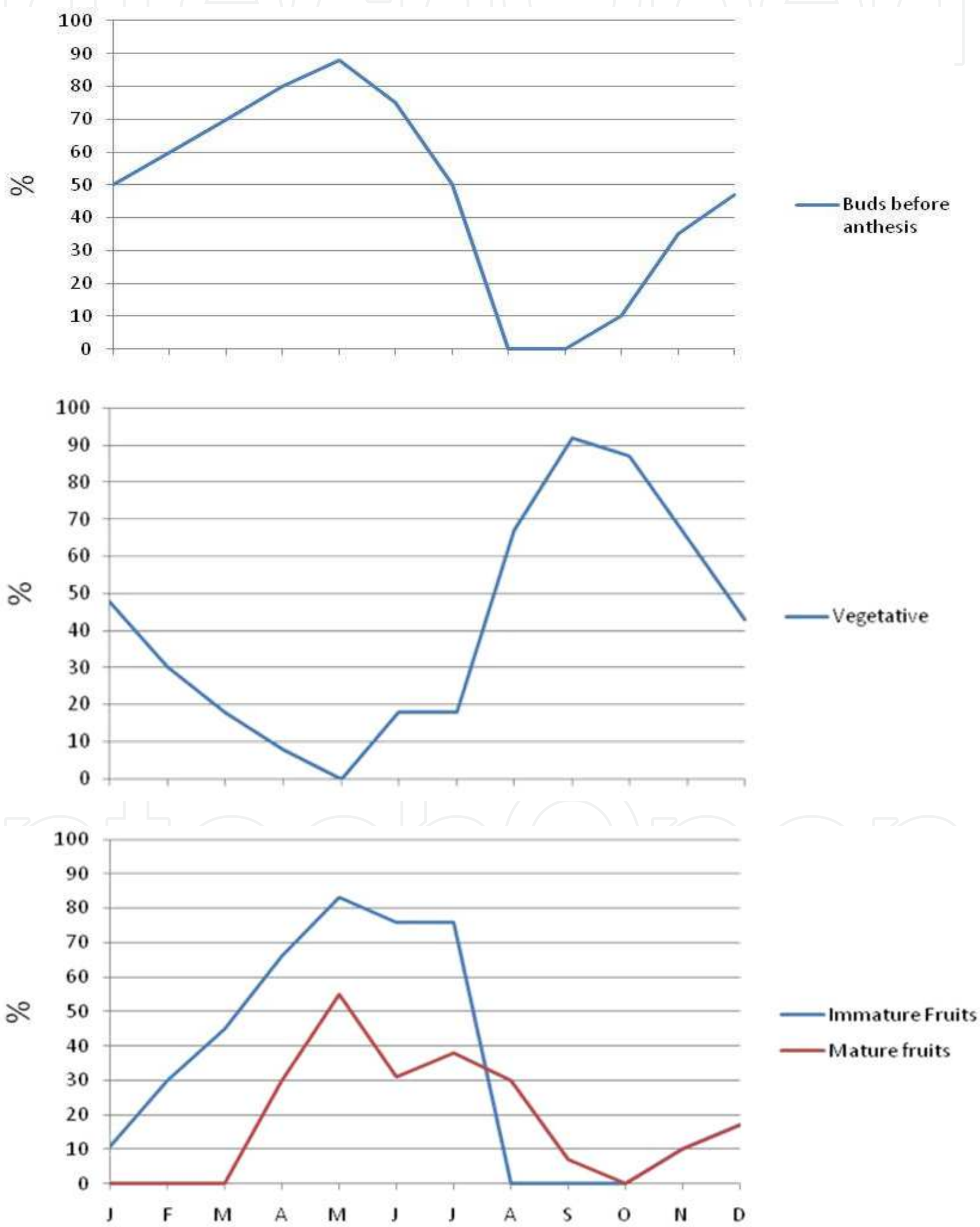

Fig. 5. Phenological diagram for "jiotilla" (*Escontria chiotilla*).

The fruits of "jiotilla" (*Escontria chiotilla*) were produced between January and September and during the time of monitoring only 25.8% of the plants presented reproductive structures, of which 80% produced mature fruits (Figure 5). However, we observed that the majority of marked plants (74.2%) did not bear reproductive structures. This could be the consequence of the presence of many immature plants in the monitored wild population.

Our results suggest that "pitaya" and "jiotilla" have a reproductive period that is similar to the majority of the plants of the tropical deciduous forest, i.e. in the middle or at the end of the dry season, which corresponds to the short day (SD) period. The difference in the reproductive period of the tunillo could be the consequence of a response to either the rainy season or to long days (LD) occurring during the rainy season. Due to the morphological characteristics of cacti flowers, their pollination is carried out by insects or by bats (Osborn, 1988). In the case of *Stenocereus stellatus*, the pollination is principally accomplished by bats and flower anthesis is nocturnal (Casas et al., 1999). These characteristics led us to believe that reproduction of these species could be related to the existence or high activity period of their pollinators. "Jiotilla's" flowers also undergo anthesis during the night.

Our observations show that the studied species respond to climatic conditions in different ways, given that despite growing in similar climatic conditions as seen in the similarity of the ombrothermic diagrams (Fig. 2), their phenological responses are different. Bullock & Solis (1990) state that most elements of the tropical deciduous forest reproduce during the wet season, and that there is a relation between phenology and water availability as is suggested by the flowering of some species during atypical rainfall events in December or January.

Assuming that humidity may be determinant for fruit development in cacti, the pitaya and the jiotilla appear to store water in their stems (Gibson & Novel, 1986) during the rainy season to be used for filling of fruits after the end of the dry season. A bimodal reproductive behavior has been reported for *Stenocereus griseus* (pitaya) in Colombia (Villalobos et al., 2007; Bustamante & Búrquez 2005), suggesting the effect of latitude in the phenology of that specie.

In the case of tunillo (*Stenocereus stellatus*), we observed that water availability determines the change to a reproductive phenological state. García-Suárez et al., (2007) demonstrated a correlation exists between fruit development and the wet season. In arid ecosystems most plants respond to precipitation. The pulse-reserve model addresses the response of individual plants to precipitation and predicts that there are "biologically important" rain events that stimulate plant growth and reproduction (Ogle & Reynolds, 2004).

These two phenological behaviors suggest differences in the flowering-fructification genetic programs of these cacti in response to light (Valverde et al., 2004)

Adequate fruit development depends on a successful pollination. Although the flowers of cacti are hermaphrodite, most species display genetic self-incompatibility so fruit setting is largely dependent on pollinating insects or bats (Bustamante & Búrquez, 2005). In the case of the studied species, with flowers having nocturnal anthesis, bats have been reported to be the main pollinators (Casas et al., 1999; Nassar et al., 1997). The presence of common pollinators for the three studied species strengthens our proposal.

Although the environmental factors determining the phenology of the studied species may not be established based on the data herein presented, and that the phenology of cacti may respond to light too, day length in particular, or to a combination of environmental factors (De la Barrera et al., 2009), it is possible to use phenological behavior for the establishment of orchards with elements of the native plant communities that allow for the sustainable development of marginal rural communities inhabiting the semiarid tropical regions of our country. From a commercial point of view and based on the results of the present work, we propose the establishment of "mixed orchards" using the three studied cacti species taking advantage of their phenological behavior and climatic conditions. Actually, some regions have been proposed for the use of only one of these species in rural orchards (Piña, 1997; Pimienta et al., 1994; Sánchez-Cortéz, 2011). Figure 6 represents the F_2 phenophase for the three studied species; and as can be seen in the graph, marketable fruits were found to be present throughout an 8 month period. If we add that the physicochemical behavior of the fruits of the studied species is known to be similar (Benito et al., 1992), evidence is found supporting that, by establishing mixed orchards of these columnar cacti, local producers in the study area could harvest a sufficient amount of fruit to sustain a diversified agroindustry for the production of processed commodities such as jams, juices, ice cream and colorants, in addition to the marketing of fresh fruit.

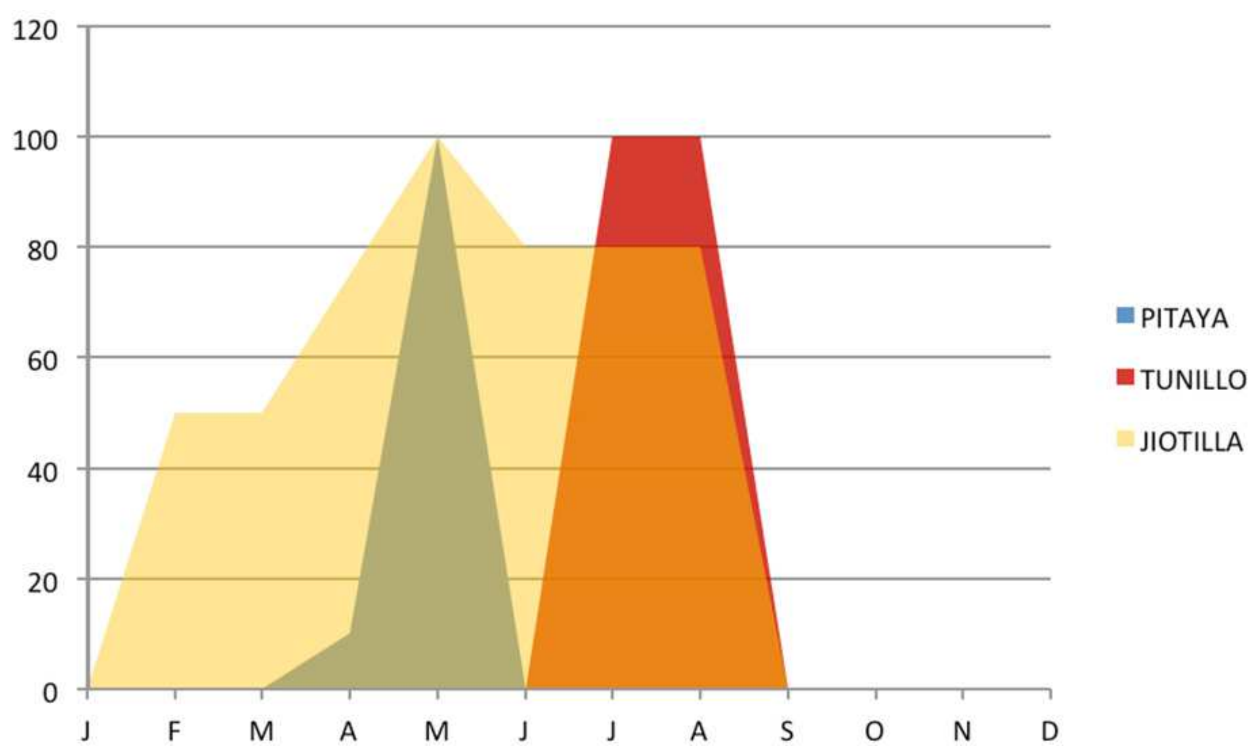

Fig. 6. Annual fruit production periods of "pitaya," "tunillo," and "jiotilla."

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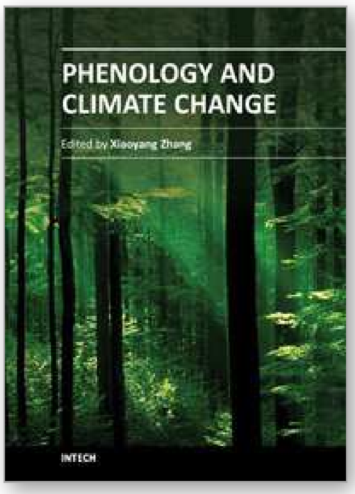

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Phenology, a study of animal and plant life cycle, is one of the most obvious and direct phenomena on our planet. The timing of phenological events provides vital information for climate change investigation, natural resource management, carbon sequence analysis, and crop and forest growth monitoring. This book summarizes recent progresses in the understanding of seasonal variation in animals and plants and its correlations to climate variables. With the contributions of phenological scientists worldwide, this book is subdivided into sixteen chapters and sorted in four parts: animal life cycle, plant seasonality, phenology in fruit plants, and remote sensing phenology. The chapters of this book offer a broad overview of phenology observations and climate impacts. Hopefully this book will stimulate further developments in relation to phenology monitoring, modeling and predicting.