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Pitaya (*Stenocereus stellatus*) fruit growth is associated to wet season in Mexican dry tropic

(With 2 Figures & 1 Table)

El crecimiento del fruto de pitaya (Stenocereus stellatus) está asociado a la estación húmeda en el trópico seco mexicano

(Con 2 Figuras y 1 Tabla)

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Abstract. In this work we contribute to the knowledge of the reproductive phenology of *Stenocereus stellatus* (Pfeiffer,Riccobono), a columnar cactus that produces fruits of high commercial perspectives known as "pitayas". This kind of pitayas are produced for local commercialization in back orchards in some regions of the Mexican dry tropics. These fruits are produced only in the apical part of the cactus "arms". Our results show that fruit development of pitayas is highly associated to the rainy season of the year. This behavior is different from the reproductive strategy of other columnar cactus species that produce other kinds of pitaya in the same ecological region.

Key words: Columnar cacti, pitaya fruit, phenology, water stress.

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Resumen. En este trabajo contribuimos al conocimiento de la fenología reproductiva de *Stenocereus stellatus* (Pfeiffer,Riccobono) el cual es un cacto tipo columnar que produce frutos con una gran perspectiva comercial conocidos como "pitayas". Este tipo de pitayas son producidos en huertos de traspatio en algunas regiones del trópico seco Mexicano y son comercializados localmente. Estos frutos solo son producidos en la parte apical de los "brazos" de la planta. Nuestros resultados muestran que el desarrollo de los frutos de pitaya está fuertemente asociado al período lluvioso del año. Este comportamiento es diferente de la estrategia reproductiva de otras especies de cactos columnares que producen otro tipo de pitayas y que crecen en la misma región ecológica.

Palabras clave: Cactos columnares, fruto de pitaya, fenología, estrés hídrico.

INTRODUCTION

The understanding of the environmental factors that affect fruit production is very important for the optimal utilization of resources. One of the most important phenomenon in horticulture is the phenology of species and, in cacti, phenology is particularly poorly known. Rainfall amount and distribution can significantly affect the reproductive behavior of many plant species. Sexual reproduction of the majority of the species in the deciduous tropical forest (including some cacti) takes place during the middle or at the end of the dry season (Rzendowsky, 1978). Janzen (1978) establishes a strong correlation between the time of sexual reproduction of tropical plants and the existence and activities of their pollinators and dispersal agents (insects and animals).

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).

There is increasing commercial interest in fruits of some columnar cacti which have an economic value in national and international markets. This has motivated the establishment of commercial orchards; such is the case for fruits known regionally as "pitayas". Pitaya is a generic name for fruits produced by different Mexican cacti species, such as, *Stenocereus griseus* (Haw) and *Stenocereus stellatus* (Pfeiffer) Riccobono in Oaxaca and Puebla (Piña-Lujan, 1977); *Stenocereus queretaroensis* in Querétaro, Jalisco and Michoacán (Pimienta-Barrios & Nobel, 1995; Mizrahi et al., 1997), and *Stenocereus fricci* in Michoacán (Rebollar-Alviter et al., 1997). *Stenocereus stellatus* (Pfeiffer) Riccobono is a columnar cactus endemic to central México. Its location is centered on the Tehuacán Valley and La Mixteca Baja, in the states of Puebla, Oacxaca and Guerrero (Casas et al., 1999). The fruits produced by these plants under natural conditions are important economic income sources to different marginal communities, and are a food source for human and animals. The cultivation of this crop is feasible using relatively low inputs (Pimienta-Barrios & Nobel, 1998).

In this paper we report the phenological observations of "pitaya" plants (*Stenocereus stellatus*) in a rural orchard. We show that the pattern of fruit growth of this cactus is related to the rainy season, which contrasts with other pitaya species (*Stenocereus queretaroensis, Stenocereus griseus*) where part of the reproductive period occurs during the dry season. These pitaya species are also components of the Mexican Tropical Deciduous Forest.

MATERIALS AND METHODS

Study site. The study was conducted at a rural orchard in Chiautla, Puebla, México. The orchard was formed using different wild plant parts ("arms") established by vegetative propagation (López-Gómez et al., 2000).

Phenological observations. Eighty adult individuals plants were marked and phenological observations were taken monthly for one year, starting in February 2000. Fruit length and diameter were taken using a vernier every 15 days for the different fruits produced in the selected plants. Fruit volume was calculated according to the formula $V = \pi r^2 h$ where 'V' is fruit volume, 'r' is the fruit radius (r = diameter/2), and 'h' is fruit length. We tagged and determined the date when a group of fruits (group 1; n = 250 fruit) first appeared in the reproductive period in different arms of each plant. We also tagged a second fruit group (group 2; n = 100 fruits) which formed 15 days after the first group.

Statistical analysis. Regression and correlation analyses were made using the software SYSTAT version 9.01 to establish the relationship between rainfall during the wet season and the rate of fruit growth. The rate of fruit growth was determined as the change of the fruit volume. Rainfall data were obtained from a weather station maintained by the Comisión Nacional del Agua in Chiautla, Puebla, México.

RESULTS AND DISCUSSION

Phenology data were used to build a phenological diagram (Fig. 1a). Flowers and fruits in this cactus only appeared in the apical part of the arms. The flowering period of this species began in May and June and ended in August, while the fructification period went from June through November. The highest number of green (immature) fruits were observed in August, while the ripe fruits were found in August and September. Fruits ripened 60-90 days after anthesis. This reproductive period coincided with the rainy period of the year. Figure 1b shows the average rainfall for a 10-year period in the Chiautla region. The reproductive behavior of this cactus is different from that of other cacti species that produce pitayas like *Stenocereus queretaroensis* and *S. griseus*, which bear fruits during the dry period of the year (Benito-Bautista et al., 1992; Pimienta-Barrios & Nobel 1998; Areta-González et al., 1999).

We determined the relationship of fruit growth versus precipitation in the pitaya of *S. stellatus* using a biphasic model for the group 1 of fruits, and a simple lineal regression for the fruits of group 2. The parameters of the correlation are shown in Table 1 and plotted in Fig. 2.

Table 1. Correlation parameters for the relationship of pitaya fruit growth with rainfall.

Tabla 1. *Parámetros de correlación para la relación del crecimiento del fruto de pitaya con la lluvia.*

Fruit Group	Adjusted Model	R^2	Parameters	Value
1	$Y = \left(X \leq \frac{a2 - a1}{b1 - b2}\right) \times (a1 + b1 * X) + \left(X > \frac{a2 - a1}{b1 - b2}\right) \times (a1 + b1 * X)$	0.84	a2	15.82
			a1	105.06
			b1	1.01
			b2	4.03
2	$Y = a + b \times X$	0.73	a	1.41
			b	1.18

Y represents fruit volume (cm^3) , X expresses the number of days. The parameters a (a,a1,a2) and b (b,b1,b2) represent the ordinate and straight slopes. R is the correlation coefficient.

Y representa el volumen del fruto (cm^3), X expresa el número de días. Los parámetros a (a, a1, a2) y b (b, b1, b2) representan la ordenada y las pendientes lineales. R es el coeficiente de correlación.

Fig. 1(a). Phenology of *Stenocereus stellatus.* Solid lines represent immature flowers and green fruits. Dotted lines represent mature flowers and fruits. More than 60% of the cacti plants produce flowers and 90% of the produced fruits reach a complete development and ripen. **(b)** Rainfall diagram at Chiautla Puebla (Mixteca region), ten-year-mean. The wet period coincides with the reproductive behavior of the pitaya plants.

Fig. 1. (a). *Fenología de* Stenocereus stellatus. *La línea sólida representa flores inmaduras y frutos verdes. La línea punteada representa flores maduras y frutos maduros. Más de 60% de las plantas de cactus producen flores y 90% de los frutos producidos alcanzan un desarrollo completo y maduran.* ***(b)*** *Diagrama de lluvias en Chiautla Puebla (región Mixteca); se presenta el promedio de 10 años. El período húmedo coincide con el comportamiento reproductivo de las plantas de pitaya.*

Fig. 1(a).

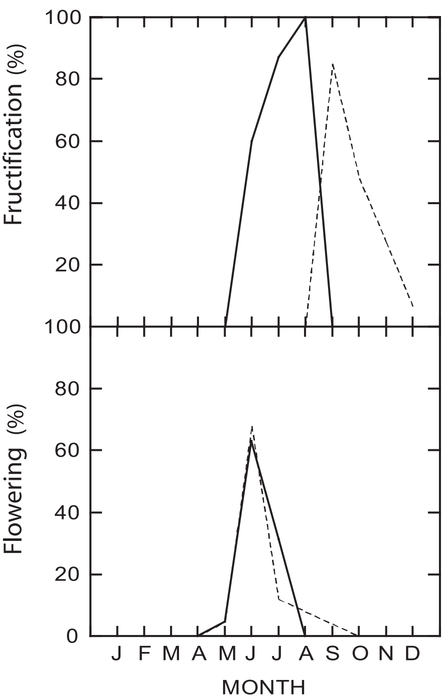


Fig. 1(b).

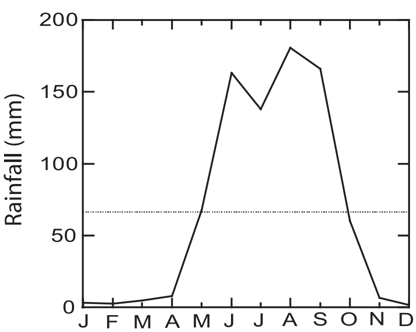
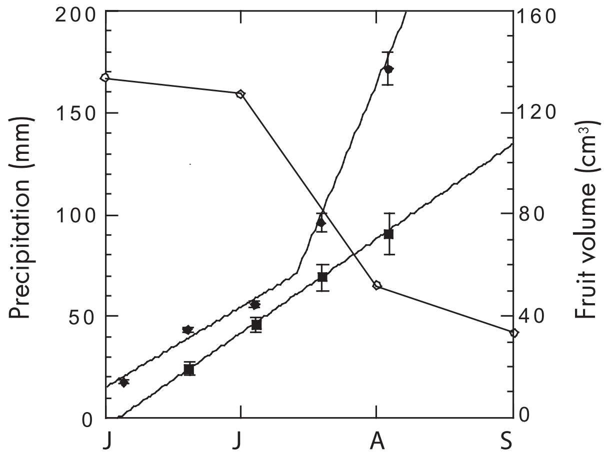


Fig. 2. Patterns of pitaya fruit growth and rainfall during the summer [wet season (June-September)]. Clear circles represent the monthly cumulative rainfall. Black circles represent the fruit growth rates of group 1, while black squares represent the fruit growth rate of group 2. Fruits of group 1 reached a bigger size and better quality than those of group 2.

Fig. 2. *Modelos del crecimiento del fruto de pitaya y de la lluvia durante el verano (estación húmeda de Junio a Setiembre). Los círculos vacíos representan la lluvia mensual acumulativa. Los círculos negros representan la tasa de crecimiento del fruto del grupo 1, mientras que los cuadrados negros representan la tasa de crecimiento del fruto del grupo 2. Los frutos del grupo 1 alcanzaron un mayor tamaño y mejor calidad que aquellos del grupo 2.*



For the first group of fruits (group 1) there were two stages in fruit development based on the pattern of growth rate over time. In the first stage, fruit growth rate was 1.01 cm^3/d and the timing of this stage coincided with the beginning of the rain period and the first maximum in rainfall. The second stage of fruit growth is probably a consequence of a rise in the rainfall amount (June). In the second stage, fruit growth rate was about four times (4.03 cm^3/d) as high as in the first stage (Fig. 2). This fruit growth pattern is different from of a double sigmoid pattern reported for opuntia fruits (De la Barrera & Nobel, 2004). Fruits of group 2 showed a growth rate that was almost constant during fruit development (Table 1, Fig. 2). In addition, fruits from group 2 reached a smaller size, ripened faster and had a lower eating quality than those from group 1. Possibly this growth behavior is a consequence of a low fruit osmotic potential as a result of the accumulation of osmolytes that would create a driving force for increasing fruit water uptake immediately after a rainfall event. Several horticultural species (e.g., tomato, melon, cherries) show an increased water uptake by the fruit after irrigation or a rainfall event preceded by a period of water stress (Huang et al., 2000; Kozlowski et al., 2002; Moing et al., 2004).

The reproductive behavior of plants after a precipitation event has been explained in the ecological context of the pulse reserve model, which addresses the response of some desert plants to precipitation. This model predicts that there are biologically important rainfall events that stimulate plant growth and reproduction. These pulses of precipitation may play a key role in long term plant function and survival in desert plants (Ogle & Reynolds, 2004).

The different patterns of response to rainfall events by pitaya-producing cacti may have horticultural applications. Mixed orchards could be established combining species such as *S. griseus* or *S. queretaroensis* which produce fruits during the dry season, with species such as *S. stellatus* or *S. fricii* which produce fruits during the wet season.

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