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Characterization of the damage and its effect on the production of pitayas *Stenocereus pruinosus* and *S. stellatus* under different forms of management in Central Mexico

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Abstract. The use of several columnar cacti stretches back several thousand years and is still going at the present. In many of them, their populations within their range of distribution, are subject to three forms of management, including wild*, in situ*, and cultivated, each of one exposed to different types of damage, biological or physical. This study attempted to characterize the types of damage affecting pitayas (*Stenocereus pruinosus* and *S. stellatus*) in central and southern Mexico, and to analyze the relationship between some types of damage under different forms of management, and its effect on reproductive success. The two species were sampled in three populations with different forms of management. The branches (167-180) were selected and measured the amount of damage, characterized the types of damage, and a percentage of the total damage together with the number of fruits that were produced throughout their annual fruiting season were estimated. A x^2 test was used to determine the variations in the characterized damage, and the effects of the damage on fruit production in populations with different forms of management was assessed using linear regressions. The eight different types of damage were listed, its frequency, and the effect of damage on fruit production varies in populations. Depending on human management, populations managed demonstrate acceptance of some types of damage by pitaya farmers: bird nests and external black scar, which do not affect the production of fruits; and reduction of others, branch rot and ant herbivory, the latter of which does affect the production of fruits. The fisheye disease, anthropogenic, gray scab and sooty mold and branch rot damage should be addressed in plant health activities in all populations, and the exchange of knowledge with pitaya farmers should be developed to propose measures to attend to these damages. This will support the sustainable use of the species.

Keywords: *columnar cacti, damage, ethnobotany, fruit production, human selection*

Introduction

The columnar cacti have been used since the beginning of Mesoamerican agriculture, some 8,000 years ago (Callen, 1967; Smith, 1967), and several are currently being domesticated (Casas *et al*., 1999; Luna-Morales, 2004; Casas and Parra, 2007). The fruits and seeds have been consumed fresh or processed in water, ice creams, jams, and fermented drinks; the flowers have been consumed in elaborate dishes, the stems for medicine, living fences, fodder, and soil retention and the wood is used for fuel, craft constructions like fences and roofs, and handicrafts (Casas, 2002; Luna-Morales, 2004).

Between 70 to 80 of the 170 species of columnar cacti found in North America are thought to exist in Mexico (Bravo, 1978), of which 45 are used by people and are managed in three different forms, which reflect a gradient of domestication process, 1) Wild. Forty-five species are gathered in their natural area of distribution. These species are considered under an incipient domestication process; 2) Tolerance or *in situ* management. This suggests an agroforestry management strategy, that includes tolerating desired phenotypes primarily through vegetative propagation in the various agroecosystems and eliminating those who have undesirable characteristics, along with specific agricultural practices, like weeding and pruning, among others. It is estimated that 17 species can be managed under this strategy. 3) Cultivation. The selected phenotypes are established in household orchards or commercial orchards mostly by vegetative propagation, which are subject to more intensive cultural practices like clearing the soil, fertilizing, weeding, and trimming, among others. Twelve species are listed in this form of management and are subject to an intensive domestication process (Casas *et al*., 2002) (Figure 1). Even human selection varies inside each management, there are interbreeding processes between them because individuals of different forms of management can grow in sympatry, which allows for pollen exchange due to insects and bat pollinators, as well as seeds dispersal between populations by birds and bats (Valiente-Banuet, 2002).

Figure 1. The forms of management in populations of the two pitaya´s species (*S. pruinosus* and *S. stellatus*), in south-central Mexico. A. Wild populations in the tropical deciduous forest. B. Populations managed *in situ* in a semi-abandoned farmland. C. Cultivated in a commercial orchard population.

Changes in damage, defense mechanisms, and reproductive success due to domestication in cacti

The damage is a common consequence of interaction between plants and herbivores, and cacti are not free from it. According to a recent review on damage in the Cactaceae family conducted by our working group (Bravo-Avilez *et al*., 2019b), different species showed biological damage, made by different organisms, including insects, mammals, fungi, bacteria, and non-biological damage produced by solar radiation, frost, and humans (who have damaged branches with fire, firearms, and bowie knives).

The herbivore damage can have a detrimental effect on fitness in perennial woody plants and columnar cacti (Silva and Martínez del Río, 1996; Medel, 2001; Mueller *et al*., 2005; Campos *et al*., 2006; Goheen, *et al*., 2007; Peco *et al*., 2011). The types of damage and their impact on fitness in populations with various levels of management in species that are in the process of domestication, however, have not been assessed.

The humans during domestication process, select phenotypes from populations, either consciously or unconsciously, thus promoting evolutionary changes in their morpho-physiology, genetics, and life history; these modifications are known as domestication syndromes (Heiser, 1988; Rendón and Nuñez-Farfan, 1998). The unconscious changes include loss of seed dispersal and dormancy ability, compact growth that reduces competitive capacity, increased self-pollination and/or vegetative reproduction that is associated with sterility, as well as a decrease in the concentration of toxic compounds and the reduction or loss of physical structures. The conscious changes include morphology such as increased size, shapes, colors, and flavors of the parts that are targeted for selection (Schwanitz, 1966; Harlan, 1975; Rindos, 1984; Heiser, 1988; Gepts and Papa, 2002).

The recent surveys have demonstrated the impact of domestication on damage levels, defense mechanisms and reproductive success in different cacti, demonstrating how resistance, fruit and seed production, and germination rate have changed in species of columnar cacti. As compared to wild populations, managed populations of *S. stellatus* exhibited higher damage level and reduced resistance in populations with a higher management intensity, while produced more fruits and seeds (Patiño-López *et al*., 2022; Bravo-Avilez *et al*., 2022). The wild populations of *S. pruinosus* exhibited higher damage level but also a higher seed production and germination rates (Bravo-Avilez *et al*., 2022). These results indicate that damage in these species has promoted different responses in defense mechanisms.

The objective of this study was to evaluate the different types of damage that populations exhibit along a gradient of human management (wild, *in situ*, and cultivation), and to analyze the relationship between these types of damage with reproductive success in the “pitaya” populations of *S. pruinosus* and *S. stellatus*.

Material and Methods

Species

The two columnar cactus species studied were *S. pruinosus* and *S. stellatus*, both subjected to three human forms of management, are included in the study. They are commonly known as "pitayas".

Stenocereus pruinosus. These columnar species, branched cactus with a common name of "pitaya de mayo" that grows in parts of Mexico (Chiapas, Guerrero, Oaxaca, Puebla, Tamaulipas, Veracruz, and Yucatán), and Guatemala, at elevations ranging from 800 to 1,900 m.a.m.s.l. The wild populations flourish in tropical deciduous forests; they bloom in March to May and produces fruit in May to June. The fruits are consumed fresh or in different processed forms. Its production in backyards has implied an intensive management to generate a high production of good quality fruits.

Stenocereus stellatus. These columnar cacti, also called "pitaya xoconochtli " is 2 to 4 meters long. The natural populations of this cactus grow in deciduous tropical forest and xerophilous scrub, at elevations between 500 and 1,900 m.a.m.s.l. This species is endemic in the central Mexico, distributed in Guerrero, Morelos, Oaxaca, and Puebla states which represent most of its territory. The flowering is from June to September and bears fruits from September to October. The people who live in the plant's distribution area appreciate its tasty fruits.

Study area

The Tehuacan Valley and the Mixteca Baja, areas of distribution and historical and present-day use of both species, were chosen as the sites for the study. The twelve populations -one for each form of management (3), each region (2), and each species (2)- were used for this study (Figure 2).

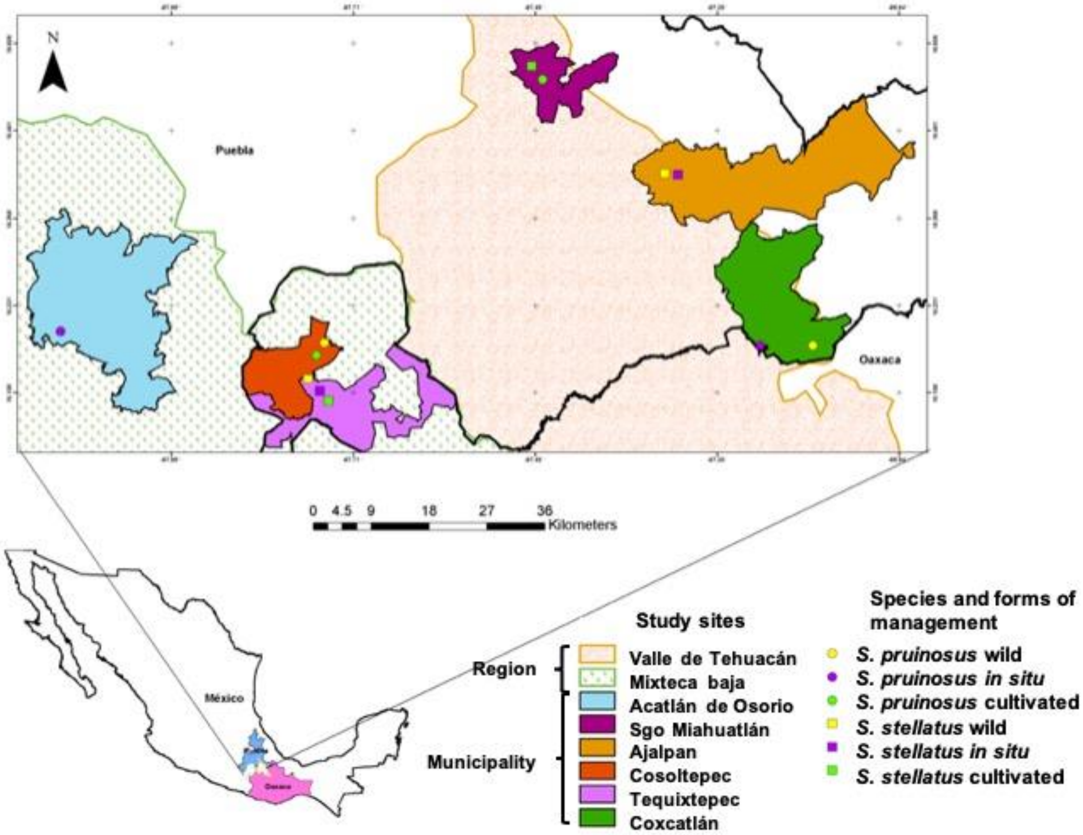

Figure 2. Location of the study sites of the populations of *S. pruinosus* and *S. stellatus*, under three different forms of management, wild, *in situ*, and cultivated, in two regions, Tehuacan Valley and Mixteca Baja, in south-central Mexico.

The Tehuacan Valley has a surface area of about 10,000 km^2, is located at 600 to 1,500 m.a.m.s.l., has a semi-arid to desert climate, and receives 300 to 500 mm of annual precipitation (Smith, 1965; García, 1988). The thorny scrub, deciduous tropical forest, thorny forest, pine-oak forest, grassland, and izotal are the main types of vegetation (Rzedowski, 1978). The Chinantecos, Cuicatecos, Ixcatecos, Mazatecos, Mixtecos, Nahuas, and Popolocas have all lived there in the past. There is evidence of agriculture practices from 7,000 years ago. The municipalities Ajalpan, Coxcatlán, and Santiago Miahuatlán of this region were selected for this study. The Mixteca Baja covers an area of about 10,000 km^2, in the Oaxaca, Puebla, and Guerrero states (Luna-Morales, 2002). The altitude ranges from 1,000 to 1,900 m.a.m.s.l., with semi-warm, sub-humid to semi-arid climates, and annual rainfall from 500 to 800 mm (Anonymous, 1970; García, 1988). According to Rzedowski (1978), palm groves, thorny scrub, thorny forests, and deciduous tropical forest are the main types of vegetation. The use of plants by the Ñuu Yata and Ñuiñe Mixtec tribe dates back roughly two millennia (Winter, 1996). The municipalities selected for the study were Acatlán de Osorio in Puebla state, and Cosoltepec and San Pedro and San Pablo Tequixtepec in Oaxaca state.

Classification of the damage types

In May 2012, 167 *S. pruinosus* and 180 *S. stellatus* plants with heights ranging from 121 to 760 cm were selected; then, everyone was randomly sampled 50% of its branches to evaluate the damage and fruit production. The sample was done in 1,036 branches for *S. pruinosus* and 1,003 branches for *S. stellatus*. The damages were noted from each branch in accordance with a classification that was developed at the start of the sample and supported by literature. It is important to note that a single branch may exhibit multiple types of damage, thus each one was recorded; in this instance, associations of various types of damage are considered for analysis.

Variations in damage types depending on the form of management

The database to record the different types of damage reported by each of the 2039 branches was done including presence - absence. A contingency table with 12 populations (three forms of management, two regions, two species), and eight types of damage was designed to count the number of branches with each type of damage in each of the populations. The null hypothesis was that there is independence in the types of damage in populations with different management, regions, and between species. A X^2 test was used to determine the differences in frequency of the damage types between populations with different management, regions, and species. Thus, a significant X^2 means that some populations experience different types of damage more frequently depending on the species and/or form of management, and there are possible relations between some types of damage. The population that displayed variation in the frequency of the various types of damage was then identified using an adjusted residual test (Everitt, 1992).

Correlation between damages and reproductive success under different form of management

The number of fruits produced in the year of the study, from May to June 2012 for *S. pruinosus* and from August to September for *S. stellatus* was registered. The branches with the same damage or group of damages were classified and the average number of fruits and damage was obtained to analyze the linear regressions between reproductive success and damage level, the total percentage of damage was considered, regardless of the types of damage present in each branch (Bravo-Avilez *et al*., 2022).

Results and discussion

Classification of the damage types

The different types (eight in total) of damage were recorded in both *Stenocereus* species.

A) Branch holes. Smaller than two centimeter-sized holes in the branches, probably formed by insects that only damage the branches' outer layer and by bullets from guns used for hunting animals. The photosynthetic and reproductive processes can continue despite the damage (Figure 3A).
B) Bird nests. More than four-centimeter-long, and at least one-meter-deep holes produced by woodpeckers (*Melanerpes hypopolius* Wagler) primarily to utilize them as nests, were formed in branches (Figure 3B). The photosynthetic and reproductive processes can continue despite the damage. This damage was recorded only in 5 branches of the three forms of management of *S. stellatus.*
C) Anthropogenic. This damage is caused by cuts with a bowie knife that are not caused by pruning, as well as by fire, which occurs when cane is burned in neighboring plantations. Bowie knife blows can cause slight infections in damaged branches, yet some repair the cut and have no aftereffects; fire burns are conditions that limit their photosynthetic activities for a short period of time; in the long run, they can recover, but in others, there is no recovery (Figure 3C).
D) Ant herbivory. The ants of the genus *Atta* and *Crematogaster* mostly browse the apical section of the branches, sometimes excessively so, reducing reproductive activity (Figure 3D).
E) External black scar. An unidentified insect larva carries it. These larvae forage on the branch's exterior, causing a big black scar. Apparently, the branch does not develop more damage, such as infections, thus branches still survive (Figure 3E).

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F) Fisheye disease. The damage to the cuticle of the branches made by a pathogenic fungal complex, *Colletotrichum gloeosporioides* - *Fusarium oxysporum*, characterized by a circular crusty development of orange-beige color. This injury has been documented for *Myrtillocactus geometrizans* (Mart. ex Pfeiff.) Console, a columnar cactus called “garambullo”. The authors state that the spots spread until they cover entire branches, resulting in dry rot (Monreal-Vargas *et al*., 2014) (Figure 3F).

G) Gray scab and sooty mold disease. The damage to the cuticle of the branches, which appears silvery gray to dark in the case of grey scab, and black in the case of sooty molds. This disease spreads on the branch and may spread to neighboring branches. The damage is aggressive, weakening the branches and making them vulnerable due to cuticle softness. Monreal-Vargas *et al*. (2014) characterized these diseases in *M. geometrizans* and discovered that the grey coast was caused by the fungus *Phoma* sp. and that the disease sooty mold was presumably caused by *Phoma epicoccin* (Figure 3G).

H) Branch rot. The insects including *Cactophagus spinolae* larvae (Bravo-Avilez *et al*., 2014), beetles of the Hydrophilidae family, and *Aleochara* sp. larvae (Bravo-Avilez *et al*., 2019a), can inflict this type of damage. The rot spreads throughout the plant as the larvae move, can infect multiple branches of the same individual, and can even kill the affected individuals (Figure 3H); when only a few branches are afflicted while the rest continue to perform photosynthetic and reproductive functions, it is conceivable that the larvae have relationships with bacteria and/or fungi that are interacting and contributing to the rot damage.

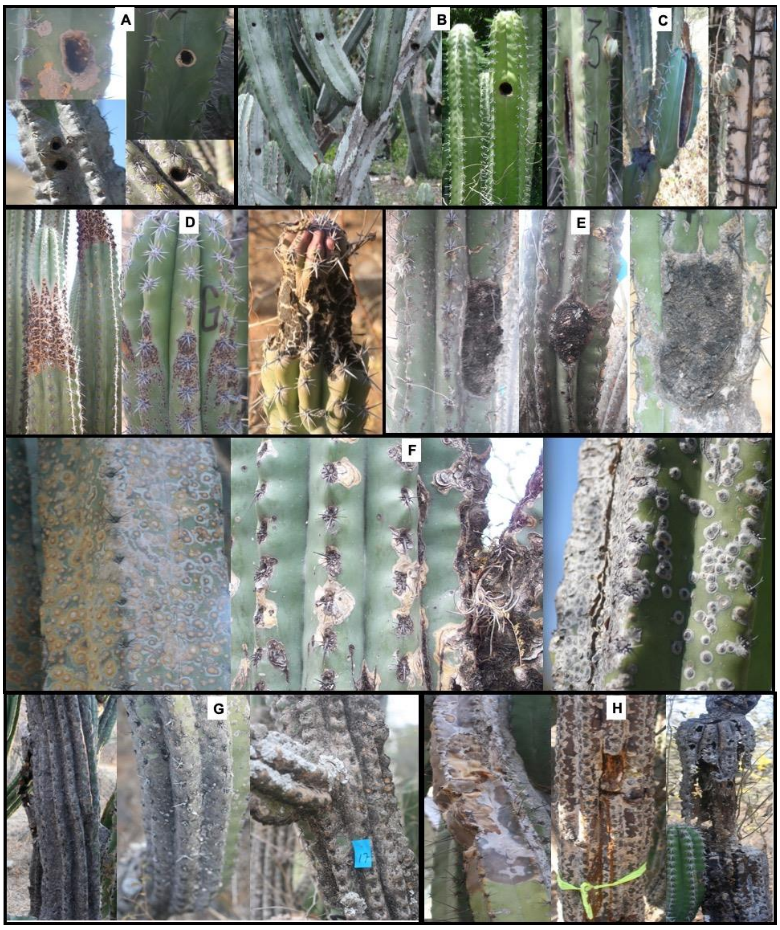

Figure 3. The several types of damage seen in two pitaya´s species, *S. pruinosus* and *S. stellatus* in south-central Mexico. A. Branch holes, B. Bird nests, C. Anthropogenic, D. Ant herbivory, E. External black scar, F. Fisheye disease, G. Gray scab and sooty mold disease, H. Branch rot damage.

Variation in types of damage between species and forms of management

The X^2 test revealed significant differences in the type of damage between populations of both species (X^2=261.34; p=0.05; df=77). The populations with significant differences are beyond the confidence limit range (-1.96 to 1.96) and differ by the existence of damage in the different populations (Figure 4, Table 1).

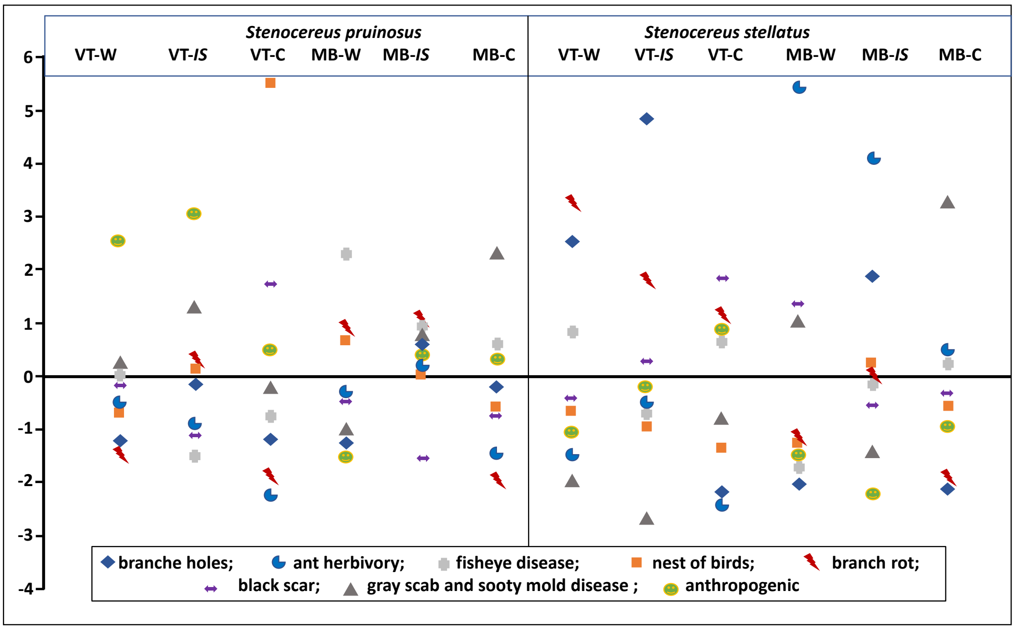

Figure 4. X^2 test for the frequency of the eight types of damage in two pitaya´s species in south-central Mexico, *S. pruinosus* and *S. stellatus* under three different forms of management W: wild, IS: *in situ*, C: cultivated; in the regions VT: Tehuacan Valley and MB: Mixteca baja. The points outside the confidence interval (-1.96 to 1.96) have considerably different damage frequencies than points within it.

Table 1. The types of damage recorded in the three forms of management of both species of *Stenocereus*, according with X^2 analysis.

Species	Region	Form of management	Greater abundance	Least abundance
S. pruinosus	Mixteca Baja	Wild	Fisheye disease	-
		In situ	-	-
		Cultivated	Gray scab and sooty mold disease	Branch rot
	Tehucan Valley	Wild	Anthropogenic	-
		In situ	Anthropogenic	-
		Cultivated	Nest of birds	Ant herbivory Branch rot
S. stellatus	Mixteca Baja	Wild	Ant herbivory	Branch holes Fisheye disease
		In situ	Ant herbivory	Anthropogenic
		Cultivated	Gray scab and sooty mold disease	Branch holes Branch rot
	Tehuacan Valley	Wild	Branch holes Branch rot	Gray scab and sooty mold disease
		In situ	Branch holes	Gray scab and sooty mold disease
		Cultivated	-	Branch holes Ant herbivory

The cultivated populations of both species have a higher presence of gray scab and sooty molds, but a lower presence of branch rot damage. The cultivated populations of *S. pruinosus*, had more bird nests damage, whereas wild and *in situ* managed populations had a high frequency of anthropogenic and fisheye damage. The wild and *in situ* managed populations of *S. stellatus*, showed a higher frequency of damage by branch holes and ant herbivory, but a lower frequency of damage caused by gray scab and sooty mold, anthropogenic and fisheye disease.

Eight different types of damage in the two-pitaya species were found; some of these have been mentioned for the edible cacti *M. geometrizans* ("garambullo"), such as fisheye disease and gray scab and sooty molds (Monreal-Vargas *et al*., 2014). Other studies has been reported branch rot damage in pitaya species (Bravo-Avilez *et al*., 2014; Bravo-Avilez *et al*., 2019a, b), as well as other columnar and climbing cactus (Maya *et al*., 2011; Ramírez-Delgadillo *et al*., 2011; López-Martínez *et al*., 2016a, b). The vectors are many species of insects, the most notable of which are the "weevils" curculionids, which seems to be extending their hosts, because the first records were in *Opuntia* (Badii and Flores, 2001; Ángeles-Núñez *et al*., 2014) and *Agave* (Romo and Morrone, 2012). The ant (*Atta*) damage has been observed in *Stenocereus queretaroensis* (F.A.C.Weber ex Mathsson) Buxb. (Pimienta *et al*., 1999), as well as bird damage in *Carnegiea gigantea* (Engelm.) Britton & Rose and *Stenocereus griseus* (Haw.) Buxb. (Danzer and Drezner, 2014; Villalobos *et al*., 2007). Even though most of the species reported with these damages are of cultural and economic importance. The effect of the damage on fruit production has not been studied in different forms of management that some of the species present, so our study provides information on this subject.

Intrapopulation variation and the effect of damage on reproductive success

The different patterns were detected in the association between the type and number of damages registered per branch and fruits production. In relation to the form of management, regardless of the damage that the plants showed, a greater fruit production was recorded as the intensity in the management increases, which was detected in the cultivated plants of *S. pruinosus* and the *in situ* managed populations of *S. stellatus* (Figure 5).

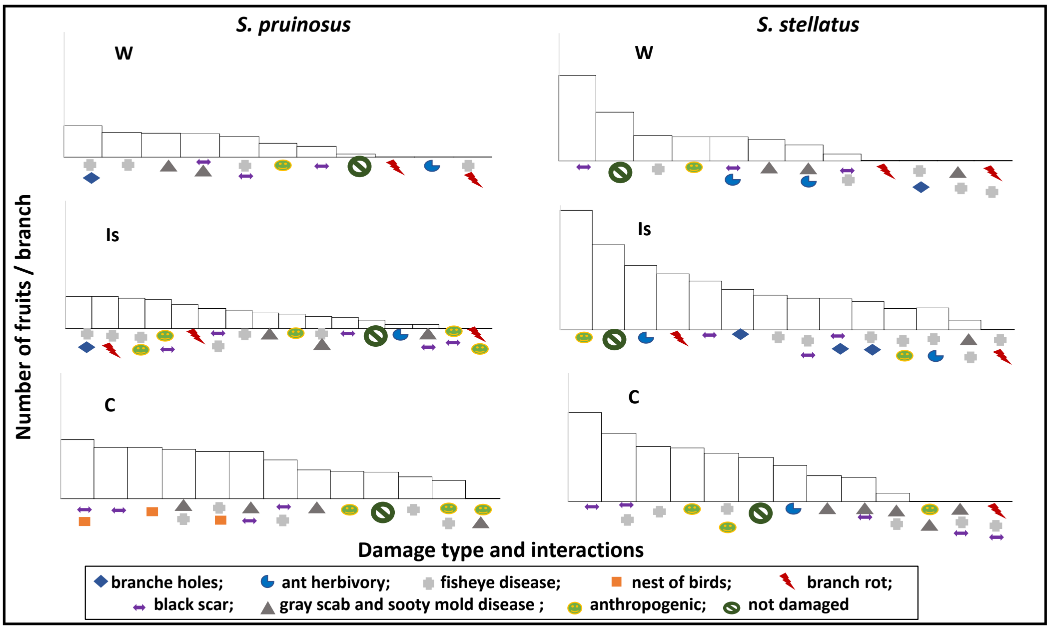

Figure 5. The average number of fruits produced per branch in two pitaya´s species, *S. pruinosus* and *S. stellatus* under three different forms of management, W: wild, IS: *in situ*, C: cultivated in south-central Mexico.

In all populations, branch rot, fisheye disease and gray scab and sooty molds were related with no reproductive success, whereas the branch holes and bird nests exhibited the highest reproductive success. The interactions between damages are also related to lower fruit production, such as fisheye, gray scab and sooty molds in interaction with other damages. The undamaged branches of *S. stellatus* exhibited a medium to high reproductive success, whereas *S. pruinosus* has low one, regardless the form of management.

The fisheye damage interacting with branch holes, external black scar and gray scab and sooty mold results in enhanced fruit production on branches in wild populations. The fisheye disease, branch rot, and especially ant herbivory for *S. pruinosus* and gray scab and sooty molds for *S. stellatus* did not produce fruits.

In the case of *in situ* management, branches with fisheye damage interacting with branch holes and anthropogenic were the ones with the maximum fruit production in *S. pruinosus*, and branches with ant herbivory damage had good fruit production in *S. stellatus*. The anthropogenic damage and gray scab and sooty molds in *S. pruinosus* and fisheye in *S. stellatus*, as well as branch rot damage in both species, did not produce fruits.

In the cultivated populations, branches with external black scar, bird nests, and fisheye disease produced the most fruits, while anthropogenic damage, gray scab and sooty mold in both species, and damage by branch rot, fisheye disease, and external black scar on *S. stellatus* did not produce fruits.

The linear regressions revealed that the presence of specific types of damage had a substantial negative effect on reproductive success in wild and *in situ* managed populations of *S. pruinosus*, as well as *in situ* managed and cultivated of *S. stellatus*. The fruit production in *S. pruinosus* is negatively correlated to fisheye damage and interactions in the wild population, as well as anthropogenic damage and interactions in *in situ* managed populations. In the case of *S. stellatus*, fisheye disease and interactions, as well as ant herbivory, have a negative relationship with fruit production in the *in situ* managed population, whereas in cultivated populations, the damage is fisheye, gray scab and sooty mold, anthropogenic, and interactions (Table 2).

Table 2. Significant linear regressions between damage types and fruit production in *S. pruinosus* and *S. stellatus*, under three forms of management in south-central Mexico.

Species	Form of Management	Damage type vs fruit production	r^2
Stenocereus pruinosus	Wild	Fisheye disease and interactions	0.023769 *
	In situ	Anthropogenic	0.26473 **
	In situ	Anthropogenic and interactions	0.059669 **
Stenocereus stellatus	*In situ*	Fisheye disease	0.092596 ***
	In situ	Fisheye disease and interactions	0.051099 **
	In situ	Fisheye disease, fisheye disease, and interactions	0.078072 ***
	In situ	Ant herbivory	0.26924 **
	Cultivated	Fisheye disease	0.05149 *
	Cultivated	Gray scab and sooty mold disease, and interactions	0.123378 *
	Cultivated	Anthropogenic and interactions	0.386161 *

Statistical significance: * Significant at the 0.05 probability level; ** Significant at the 0.01 probability level; *** significant at the 0.001 probability level.

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The higher reproductive success in cultivated populations relative to wild populations that was found has been described as one of the domestication syndromes in columnar cacti (Casas *et al.,* 1997; Casas *et al.,* 2002; Blancas *et al*., 2009). Silva and Martínez del Río (1996) studied the negative effect of damage on fruit production and discovered that the parasitic plant *Tristerix aphyllus* (Miers ex DC.) Tiegh. ex-Barlow & Wiens reduced the production of buds, flowers, and fruits in the columnar cactus *Echinopsis chilensis* (= *Leucostele chiloensis* (Colla) Schlumpb.In this study, no damages from parasitic plants were found, but an epiphytes of the genus *Tillandsia* on cultivated populations of *S. stellatus* in the Mixteca was found; given the large number of these, it would be interesting to see if they have any negative effects (Castellanos-Vargas *et al*., 2009). Pimienta *et al.* (1999) describes a decrease in fruit yield due to the ant (*Atta*) damage in the columnar cactus *S. queretaroensis*; these findings are consistent with the current study. Peco *et al*. (2011) reported a decrease in flower and fruit production due to the effect of introduced cattle browsing on the columnar cactus *Echinopsis terscheckii* (= *Leucostele terscheckii* (J.Parm. ex Pfeiff.) Schlumpb.), but the evidence of browsing damage observed in this study was not abundant, so it was not considered in this study.

The bird damage was found in all populations of both species; however, the damage was more frequent in the cultivated plants of *S. pruinosus*, due to its low frequency in the other populations, it was not incorporated in the regression analysis. The fruit production on branches with this damage was high in these populations (Figure 5). This bird-cacti association should be investigated, because pitaya farmers claim that "tambo or chiquiton" woodpeckers (*Melanerpes* spp.) are the main causes of this damage and feed on insect larvae that can cause branch rot damage (e.g., *Cactophagus spinolae*), and may be a natural predator of these insects, as has been reported in other study (Jiménez *et al*., 2016). Thus, it appears that pitaya farmers permit bird damage in their orchards, which does not influence reproductive success but regulates the abundance of insect larvae, which can cause branch rot damage.

The branches with exclusive fisheye disease and anthropogenic damage, as well as an interaction between these and other types of damage, allow a high reproductive success, indicating that the interaction between the different damages is important and could be regulate the relationships with reproductive success. These interactions and their effect on fitness and defense mechanism must be experimentally studied.

The result of this study shows that the types of damage found in both species are similar, but human management may be altering their frequency. Thus, in the *in situ* and cultivated management populations of *S. pruinosus*, some types of damage were associated with higher fruit production, due to an evolutionary tolerance response (Bravo-Avilez *et al*., 2022), which pitaya farmers unconsciously use to guarantee and satisfy fruit production. Thus, management may entail pitaya farmers accepting certain types of damage in cultivated and *in situ* management, such as bird nests, gray scab and sooty molds, and a reduction in branch rot and ant herbivory damage. Despite this, the prevalence of damage such as fisheye, ant herbivory, gray scab, and sooty mold in all populations did result in a cost in reproductive success and should be investigated further.

The anthropic activities in wild populations and *in situ* management can accelerate the presence of damage related to low fruit production, which represent external factors not directly related with domestication processes, burning practices in crops close to populations under *in situ* management, bowie knife damage to branches; additionally, branch rot damage, although it is not related to a decrease in fruit production, due to its high abundance, at least in *S. stellatus*, must be addressed in plant sanitation programs, in order to ensure the environmental benefits that these

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wild resources give, as well as the complement of the harvest of fruits that pitaya farmers in these locations employ.

Conclusions

Eight types of damage were identified that affect both species, *S. pruinosus* and *S. stellatus* from central Mexico and populations with different forms of management. Because of the differences found, the frequency of these damages and their effect on fruit production is related, in principle, to the effects of domestication, so the most managed populations, in cultivation, show a possible acceptance by pitaya farmers of certain types of damage, bird nests, external black scar, that did not affect fruit production. Through some cultural practices they reduce the presence of others, like branch rot damage and ant herbivory. However, some types of damage do affect seriously reproductive success like fisheye disease, anthropogenic and gray scab and sooty.

The branch rot and fisheye diseases must be addressed in plant health activities and/or programs in wild populations; even though the former is not associated with a decrease in fruit production, it does affects individuals in these populations. It is also necessary to raise public awareness of the negative impact of anthropogenic damage on fruit production. Because traditional knowledge involves traditional practices that allow an acceptable fruit production, field work with farmers should be sought in an exchange of knowledge that improve some practices to control those damages that negatively affect fruit production, and to ensure the sustainable use and production of these species.

Ethics statement

Not applicable.

Consent for publication

Not applicable.

Availability of supporting data

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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