LA GRANJA:
REVISTA DE
CIENCIAS DE LA VIDA
pISSN:1390-3799; eISSN:1390-8596
http://doi.org/10.17163/lgr.n32.2020.07

Scientific paper/ Artículo científico

PLANT PATOLOGIES

THRIPS (*Thysanoptera*) ASSOCIATED WITH PITAHAYA *Selenicereus undatus* (HAW.) D.R. HUNT. SPECIES, POPULATION LEVELS AND SOME NATURAL ENEMIES

Thysanoptera) ASOCIADOS CON LA PITAHAYA *Selenicereus undatus* (HAW.) D.R. HUNT. ESPECIES, NIVELES POBLACIONALES, DAÑOS Y ALGUNOS ENEMIGOS NATURALES

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Article received on October 17th, 2019. Accepted, after review, on May 7th, 2020. Published on September 1st, 2020.

Abstract

The pitahaya, *Selenicereus undatus* (Haw.) D.R. Hunt (Cactaceae) is a species whose fruit is appetizing for its appearance and flavor, which has increased its demand in the international market. Ecuador has increased its planting reaching 1108 ha. This crop could be affected by pests, such as thrips, whose effects on pitahaya are unknown. During the period February - June 2019, a field study was carried out in the province of Manabí, Ecuador, with the aim of identifying the species of thrips, estimating population levels on the plant, organs (flower bud, flowers, fruits), as well as, determine the percentage of damage and the associated predators. Thrips species and populations were analyzed using the Kruskal-Wallis H test ($P<0.05$). Thrips populations ($P <0.05$) were correlated with rainfall and a regression analysis was performed between the latter and the percentage of damage to fruits. The most abundant species was *Frankliniella occidentalis* (Pergande). Populations ranged from 0.3 to 6.0 individuals per plant, which were not correlated with rainfall. The thrips showed a marked preference for flowers. The regression model [$Y = 1.87 + 1.04 (X)$, $R^2 = 0.83$, $P <0.05$] showed an increase in fruit damage as a function of thrips populations. Four taxa of predatory arthropods were observed. As far as knowledge goes, this represents the first study on species, population levels, damage from thrips and predators associated with pitahaya.

Keywords: *Cactaceae*, dragon fruit, damage, population level, pest.

Resumen

La pitahaya roja, *Selenicereus undatus* (Haw.) D.R. Hunt (Cactaceae) es una especie cuya fruta es apetecible por su apariencia y sabor lo que ha aumentado su demanda en el mercado internacional. Ecuador ha incrementado su siembra alcanzando 1108 ha. Este cultivo podría ser afectado por plagas, como los trips, cuyos efectos sobre pitahaya se desconocen. Durante el período febrero-junio 2019, se realizó un estudio de campo en la provincia de Manabí, Ecuador, con el objetivo de identificar las especies de trips, estimar niveles poblacionales sobre la planta, órganos (botón floral, flores, frutos), así como, determinar el porcentaje de daño y los depredadores asociados. Las especies de trips y las poblaciones fueron analizadas mediante la prueba H de Kruskal-Wallis (P<0,05). Se correlacionaron las poblaciones de trips (P<0,05) con las precipitaciones y se realizó un análisis de regresión entre éstas últimas y el porcentaje de daños en frutos. La especie más abundante fue *Frankliniella occidentalis* (Pergande). Las poblaciones se presentaron entre 0,3 a 6,0 individuos por planta, las cuales no estuvieron correlacionadas con las precipitaciones. Los trips mostraron una marcada preferencia hacia las flores. El modelo de regresión [Y = 1,87 + 1,04(X), R^2 = 0,83, P<0,05] mostró un incremento de los daños en los frutos en función de las poblaciones de trips. Cuatro taxones de artrópodos depredadores fueron observados. Hasta donde llega el conocimiento este representa el primer estudio sobre especies, niveles poblacionales, daños de trips y depredadores asociados con la pitahaya.

Palabras clave: *Cactaceae*, fruta de dragón, daños, niveles poblacionales, plaga.

Suggested citation: Meza, K., Cusme, M., Velasquez, J. and Chirinos, D. (2020). Thrips (*Thysanoptera*) associated with pitahaya *Selenicereus undatus* (Haw.) D.R. Hunt. Species, population levels and some natural enemies. La Granja: Revista de Ciencias de la Vida. Vol. 32(2):91-103. http://doi.org/10.17163/lgr.n32.2020.07.

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1 Introduction

Pitahaya, Selenicereus undatus (Haw.) D.R. Hunt (Cactaceae) is a perennial species, native from America. It is consumed as a fresh fruit, and it is valued for its unique appearance, flavor and nutritional properties, which has influenced the increase in its demand in the international market (Le Bellec et al., 2006; Montesinos Cruz et al., 2015). In Ecuador this crop has increased rapidly in recent years, reaching an estimated of 1108 ha in 2017, of which approximately 200 ha have been planted in provinces of the Ecuadorian coast, among these Manabí, with a national yield of 7.6 Tm.ha^{-1} (MAG, 2017).

As with other agroecosystems, the production of pitahaya species could be affected by phytosanitary problems caused by pest arthropods, as observed in yellow pitahaya *Selenicereus megalanthus* (K. Schum. ex Vaupel) Moran (Medina and Kondo, 2012; Salazar Restrepo, 2012; Kondo et al., 2013), other *Selenicereus species* (Ramírez-Delgadillo et al., 2011), and red pitahaya or dragon fruit (Choi et al., 2013). Thrips species (*Thysanoptera*) have been referred to as important pests in several fruit trees, such as grape, *Vitis vinifera L.* (Vitaceae) (Mujica et al., 2007), avocado, *Persea americana Mill.* (Lauraceae) (Cambero et al., 2010), mango *Mangifera indica L.* (Anacardiaceae) (Aguirre et al., 2013) and guava, *Psidium guajava L.* (Myrtaceae) (Pérez Artiles et al., 2009), which indicate that they could also affect the cultivation of red pithaya, *S. undatus*.

Although thrips can infest flowers and floral buds, the most significant damage is in the fruits is because when feeding on fruits, causing deformations in the epicarp (Aguirre et al., 2013; Denmark and Wolfenbarge, 2013). The increase in the fruit size also increases the size of the lesions, causing brown scars that range from very small to large, depending on the severity of the damage. These deformations decrease the quality of the fruit, which induces farmers to perform frequent sprays of chemical insecticides, which are economically, ecologically and socially unsustainable. Despite this, there is little research that support the incidence of thrips species on pitahaya crop, *S. undatus*. In this matter, the literature reported is the research by Kumar et al. (2012) who conducted a survey in South Florida to determine the fruit crops with more thrips, *Scirtothrips dorsalis* (Hood) (Thysanoptera: Thripidae), and found pitahaya *S. undatus* among the main hosts of this thrips species, without mentioning the population levels achieved by the insect in the crop.

The increment of the crop production in a country must be accompanied by adequate scientific-technological support for sustainability purposes. One of the relevant aspects to be considered is the study of arthropods that may affect the crop production, hence to implement measures for the sustainable management. Due to the limited knowledge of the incidence of thrips species in this crop, this research aimed to study the species present in red pitahaya *S. undatus*, and to estimate the population levels achieved by the plant, reproductive organs (floral buds, flowers and fruits), the damage and occurrence of associated arthropod predators related to thrips.

2 Materials and methods

2.1 Field

This research was carried out during February- June 2019, in a 2000 m^2 parcel of 3.5-year-old red pitahaya, within a planting of 20 ha located in La Estancilla, Tosagua, Rocafuerte (coordinates X: 568479 and Y: 990287), Province of Manabí, whose life area corresponds to a very Dry Tropical Forest according to Holdridge. The study had a descriptive, field and laboratory methodology, where thrips species, population levels per plant and organ, lesions, as well as the presence of some natural enemies were observed. The area was managed without the use of pesticides that could have affected the development of thrips populations in the plant.

For the sampling, 20 plants were marked by collecting at random two floral buds, two flowers and two fruits for each. The floral buds were placed in waterproof plastic bags (25 $\times$ 25 cm, width $\times$ height). An A4 white cardboard was placed under each flower, and the flower was delicately squeezed so that the trips would fall on the cardboard. Subsequently, the specimens were obtained with the help of a fine brush and placed in an eppendorf tube containing 75% of ethyl alcohol. For the fruits, those about approximately one week old, which were placed individually, were taken to the plastic bags described above. The floral buds and fruits were refrigerated in iceboxes at 10°C at the Plant Health Laboratory of the Agency of Phyto and Zoosanitary Regulation and Control (Agrocalidad), in Manta, Zone 4, province of Manabí for their counting and identification. Thrips populations per plant are the result of the sum of the observed populations between floral buds, flowers and fruits. Samples were taken once a week, for a total of 15 samples.

2.2 Laboratory

In the laboratory, floral buds and fruits were observed under a stereoscope with 10 to 100X, counting the number of individuals per organ, and for their counting these were placed in a Petri capsule containing 75 % ethyl alcohol by using a fine brush. The flower specimens collected in the field were placed in Petri dishes for their counting. Then, the specimens were separated into genus or species. Previously, individuals were placed in KOH for two hours to discolor them to better observe the body structures of the insect. Subsequently, three washes with distilled water were performed and finally glycerin was placed and they were proceeded to be mounted on slides using Hoyer solution as a culture medium (Anderson, 1954). The dishes were dried on the stove at 50°C for 24 hours and the borders of the slides were sealed with clear enamel. The taxonomic key of Mound et al. (2009) was used for the identification of the thrips species. After the counting, the percentage of abundance was calculated using Equation 1

$$\% = \frac{\#\text{ individuals per specie or gender}}{\text{Total of individuals}} \times 100 \qquad (1)$$

The severity of the damage was estimated weekly on ten physiologically mature fruits by assigning a visual randomized scale, assigning degrees based on deformations or scars in the pericarp relative to the fruit area: Degree 0: without damage, Degree 1: 1 to 5 % damage, Degree 2: 6 to 25 %, Degree 3: 26 to 50 %, Degree 4: 51 to 75 %, Degree 5: 76 to 100 %. The number of fruits was counted on each scale, which calculated the damage percentage, using the Equation 2 referred by Rivas et al. (2017). Where g is damage scale, f is number of fruits on the scale, N is the number of evaluated fruits and G is maximum scale set.

$$\%\text{ damage} = \frac{g \times f}{N \times G} \times 100 \qquad (2)$$

In the case of predators, those anthropods that fed on the trips were observed in the same plant, then were obtained each week with an insect vacuum cleaner for their further evaluation. For conducting the identification, the reference collection of the Agroquality Laboratory was used, which was complemented by the diagnostic characteristics referred by Najera-Rincón and Souza (2010). The specimens of thrips and natural enemies were included in the Entomological Collection of Agroquality, Manta, Ecuador.

2.3 Data analysis

The variables: percentage of abundance of thrips species and number of thrips per organ were compared with the Kruskal-Wallis H test (P<005). A correlation analysis was conducted between the number of thrips and the monthly rainfall obtained from INAMHI (2019) (P<0.05). A regression analysis was also performed between the percentage of fruit damage and the populations obtained per plant (P<0.05). Statistical analyses were carried out with the Infostat program (2018).

3 Results

3.1 Identification and abundance of species

The characteristics that correspond to each species or genus observed in this research are presented in Figures 1-3. A total of 866 specimens were collected during this study, identified as the western thrips of flowers, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) (Figure 1) the most abundant species, followed by the thrips, *Strepterothrips sp.* (Thysanoptera: Phlaeothripidae) (Figure 2) and bean thrips, *Caliothrips fasciatus* (Pergande) (Thysanoptera: Thripidae) (Figure 3) as the least abundant species (Table 1), with no significant differences between the last two.

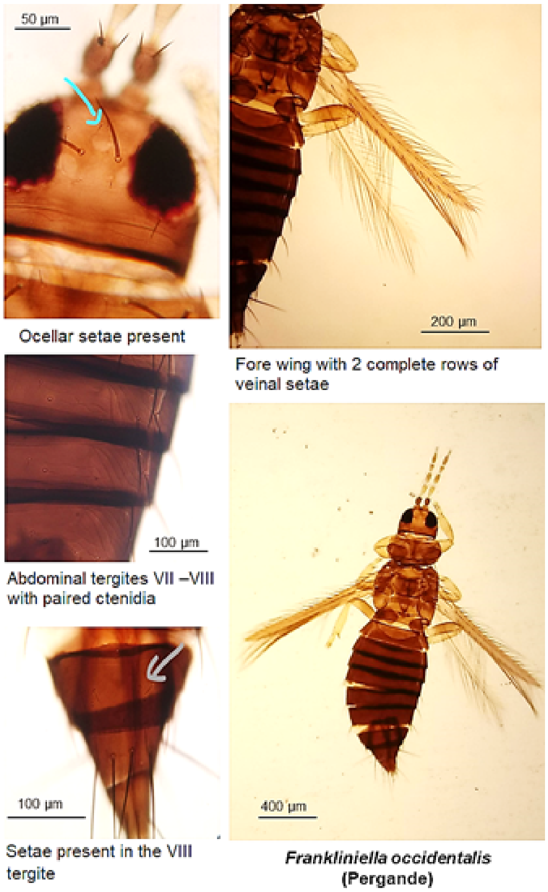

Figure 1. *Franklinilella occidentalis* (Pergande) (Thysanoptera: Thripidae)

Table 1. Abundance of thrip species by pitahaya plant, *Selenicereus undatus* (Haw.) D.R. Hunt in field conditions, Rocafuerte, Manabí. Period February- June 2019.

Species	Percentage of abundance (%)
Franklinella occidentalis	91.2 a
Strepterothrips sp.	8.2 b
Caliothrips fasciatus	0.3 bc

Means ± standard mean error. Means with equal letters do not differ significantly. Mean comparisons were made with Kruskal-Wallis test. H=23.49, P<0.05.

3.2 Population levels and damage

Thrips populations detected at the beginning of the study were low, ranging from 0.5 to 2.0 individuals per plant in the first five samplings (February-March, Figure 4), increasing during the first three weeks of April, in which the largest populations were detected, reaching their peak at the sixth sampling (six individuals per plant). After this period, populations decreased to levels inferior to a specimen per plant. These low populations at the beginning of the study agreed with high rainfall (96-114 mm) (Figure 4) and subsequently high populations (April) were associated with lower precipitation. However, towards the end of the study (late April- June) there was less rainfall and the populations were low. A non-significant correlation was found (r: 0.14; P>0.05), between thrips populations and precipitations registered during the research.

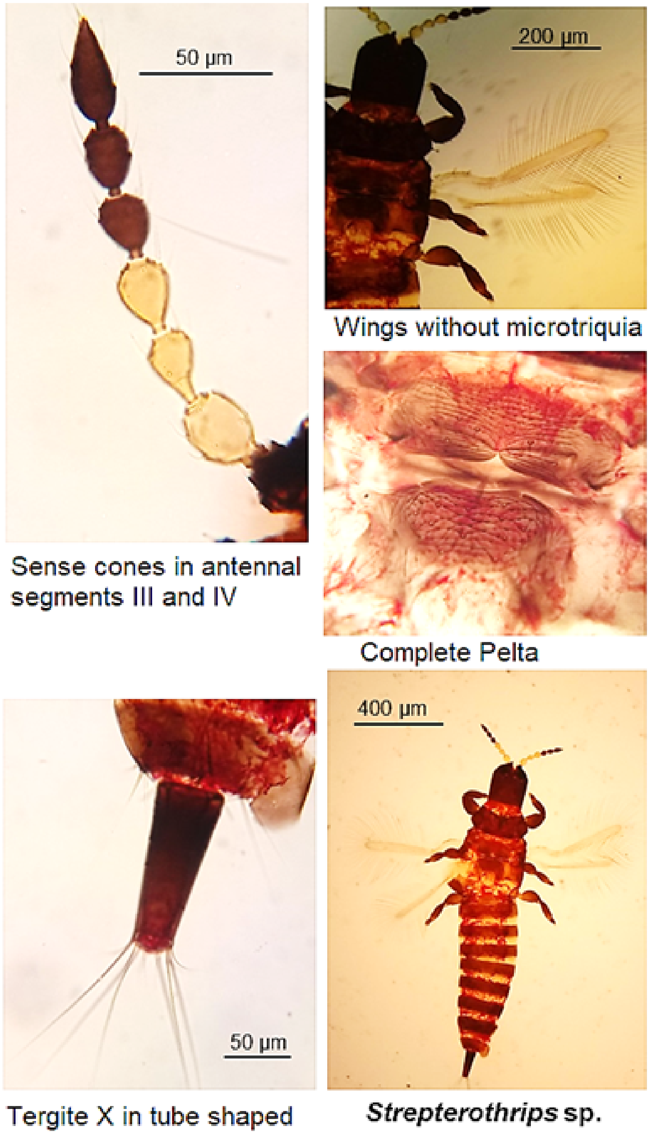

Figure 2. *Streterothrips sp.* (Pergande) (Thysanoptera: Phlaeothripidae).

When analyzing populations in the reproductive organs of pitahaya during the research, the highest number of thrips was found on the flowers (Figure 5B), which resulted into different populations on flower buds and fruits (Table 2). Flowers were present in the plant in greater abundance in April and the highest populations were detected on this organ, and at the end of the trial there were no flowers and the populations declined abruptly (Figure 5B). On floral buds, there were two population peaks in April (7 and 9 individuals) and these ranged from 0 to 1 (Figure 5A) in the rest of the samples.

In fruits, the populations were lower than the floral buds, reaching maximum values of 3 to 4 individuals in the last two weeks of March and the first week of April (Figure 5C). Despite these numerical differences between floral buds and fruits, populations of thrips on these organs did not differ significantly (Table 2, P <0.05).

The calculated simple regression model shows that the increase in the damage percentage of fruits (Y) is based on the increase in thrips populations (X), with a significant (P <0.05) and high determination coefficient (R^2 : 0,83) (Figure 6). Figure 6 also shows that the least fruit damage was about 2 % and the estimated maximum value was around 8 %. Using the equation, it was estimated that a population of 18 thrips would get 20 % of damage and with 47 trips, there would be 50 % damage on fruits.

Table 2. Average number of thrips per pitahaya plant, *Selenicereus undatus* (Haw.) D.R. Hunt, in field conditions, Rocafuerte, Manabí. Period February- June 2019.

Organ	Number of individuals
Floral bud	1.8 ± 0.2 b
Flowers	2.5 ± 0.3 a
Fruits	1.1 ± 0.1 b

Means with equal letters do not differ significantly. Mean comparisons were done using Kruskal-Wallis test. H= 8.06; P <0.05.

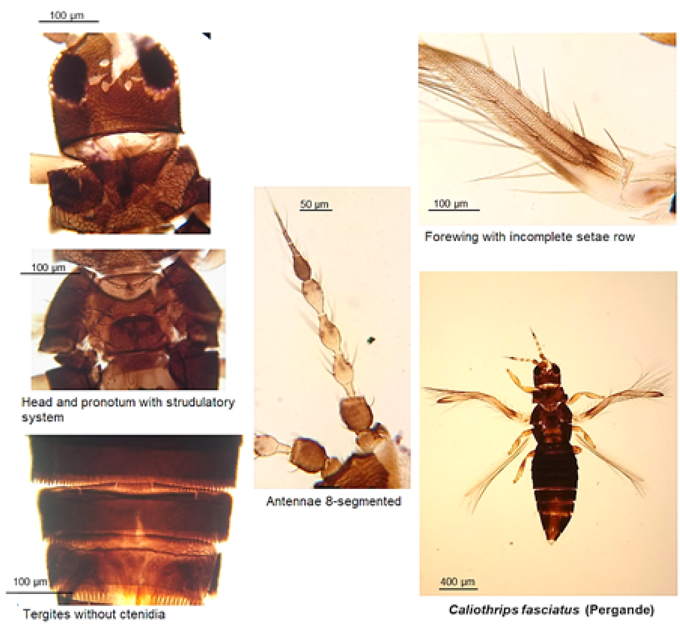

Figure 3. *Caliothrips fasciatus* (Pergande) (Thysano ptera: Thripidae).

3.3 Predators

Four taxa of natural enemies were detected: a species of undetermined chrysopid (Neuroptera: Chrysopidae), *Zelus sp.* (Hemiptera: Reduviidae), *Orius insidiosus* (Say) (Hemiptera: Anthocoridae) and an unidentified species of spider (Aranae: Salticidae) (Table 3). The abundance of these natural enemies differed significantly (P<0.05). Thus, *Chrysopidae* and *Zelus sp.* were significantly superior, being O. insidiosus the least abundant species (Table 3).

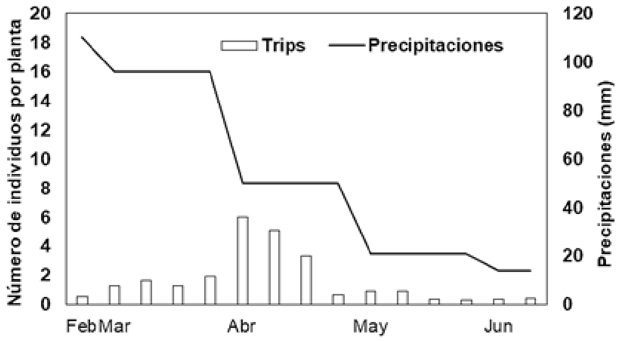

Figure 4. Population levels of Thrips on pitahaya, *Selenicereus undatus* (Haw.) D.R. Hunt, and precipitation. Rocafuerte municipality, Manabí. Period from February to June, 2019.

Table 3. Abundance of natural thrips enemies per pitahaya plant, *Selenicereus undatus* (Haw.) D.R. Hunt, under field conditions, Rocafuerte, Manabí. Period February- June 2019.

Natural enemy	Abundance (%)
Neuroptera: Chrysopidae	27.0 a
Zelus sp.	27.0 a
Aranea: Salticidae	24.3 ab
Orius insidiosus	21.7 b

Means $\pm$ standard mean error. Means with equal letters do not differ significantly.
Mean comparisons were done using Kruskal-Wallis test. H= 22.01; P>0.01.

4 Discussion

4.1 Identification of species

The results obtained show that *F. occidentalis* was the most abundant species. It is a polyphagia insect which is able to feed on more than 250 species of plants distributed in 60 botanical families (Reitz, 2009). This species of thrips has a high capacity to develop resistance to insecticide applications, consequently, ecological aspects and population levels must be well known to manage the damage of this insect (Reitz, 2009). Herein lies the importance to know the species present in a crop, i.e., if determined that the species is resistant to insecticides it is necessary to look for other control alternatives in case they represent damage to it.

The second species detected belongs to the genus *Strepterothrips*. The described species of this genus mainly feeds on fungi (Mound and Tree, 2015). In Ecuador, *Strepterothrips floridanus* (Hood) and *Strepterothrips sp.*, were reported in Galapagos Island as part of a survey made in the area and whose specimens are in the Collection of Terrestrial Invertebrates at the Charles Darwin Research Station (Hoddle and Mound, 2011). *Caliothrips fasciatus*, the least abundant species, is from North America and is particularly associated with plants belonging to the Fabaceae family, whose adults sometimes hide within the navels of some fruit trees such as orange, where they can cause damage (Rugman-Jones et al., 2012). It is possible that the preference of thrips for other hosts species explains the low abundance detected in red pitahaya during this research.

4.2 Population levels and damage

Several studies that evaluated aspects related to thrips in other crops show different results between the populations obtained, levels of damage and their relation to climatic conditions. Thus, low populations obtained in this research with *S. undatus* agree with those found by Thongjua et al. (2015), in mango in Thungsong, Thailand, observing no correlation between climatic conditions and thrips populations, *Scirtothrips dorsalis* Hood. Likewise Aguirre et al. (2013) carried out a research in two production cycles (2009 and 2010) in Castamay, Campeche, Mexico, due to the ignorance of the species associated with mango, as well as their population fluctuation and levels of damage, observing very low populations (amplitude: 0.00 - 0.35 individuals per leaf) that were not associated with climatic conditions and did not significantly affect the fruit production.

In contrast, in a study conducted in Nayarit, Mexico to determine the population fluctuation of thrips in squash, *Cucurbita moschata L.* (Cucurbitaceae), high population peaks of various species were found (upper level: 50 individuals in a week) associated with low rainfall, concluding that the absence of rainfall favors the increase of population densities of the thrips on the crop (Valenzuela-García et al., 2010). A marked preference for thrips to be placed in the flowers was observed, which could be directly related to the fact that more than 90% of the observed individuals belonged to the species *F. occidentalis*, which is known by its preference for this reproductive organ (Reitz, 2009) especially towards light-colored flowers (Arce-Flores et al., 2014), as the case of the red pitahaya, whose flower is white.

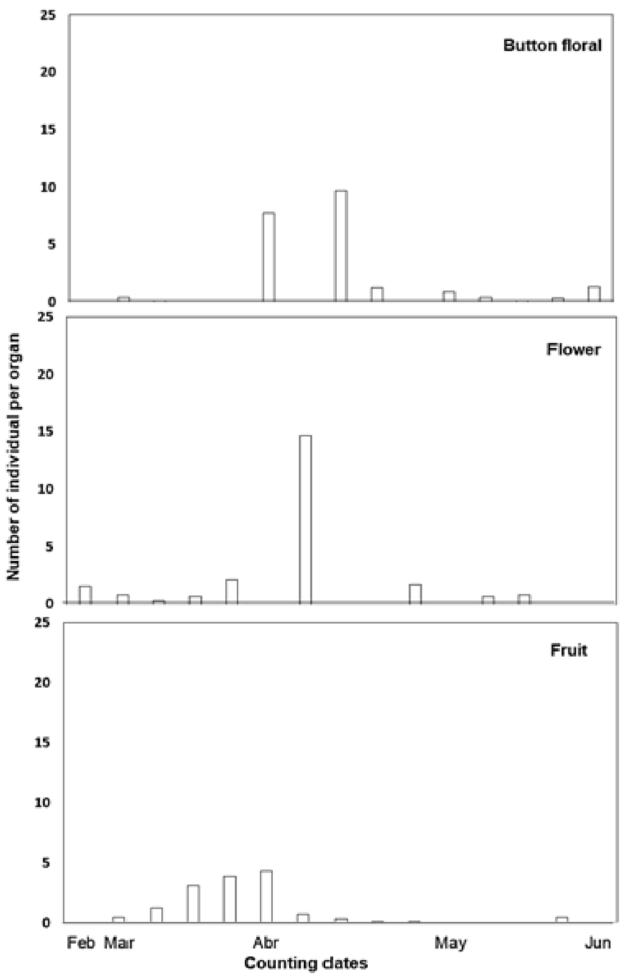

Figure 5. Population levels of thrips on pitahaya plants, *Selenicereus undatus* (Haw.) D.R. Hunt, and precipitation. Rocafuerte, Manabí. Period February-June 2019.

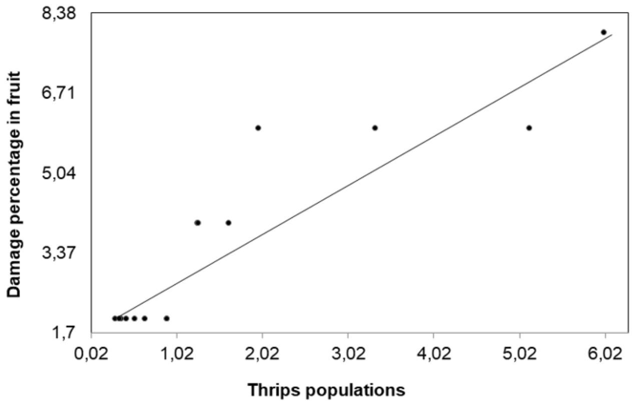

Figure 6. Regression equation between trip populations (X) and observed damage in fruits (Y) in pitahaya plants, *Selenicereus undatus* (Haw.) D.R. Hunt, under field conditions, Rocafuerte, Manabí. Period February- June 2019.

The increase in population densities of several thrips species has been referred to, associated with the presence of flowers for other crops, which agrees with these results (Urías-López et al., 2007; Palomo et al., 2015; García-Escamilla et al., 2016). Duran Trujillo et al. (2017) in a research carried out on a mango plantation in Guerrero, Mexico, found that the high populations of several *Frankliniella* species were mainly favored by the phenological state of flowering. Mujica et al. (2007), in a study conducted in Uruguay in white grape vineyards, detected high populations of F. occidentalis at the time of flowering.

Regarding the fruit damage, a population density of 47 thrips per plant is required to achieve 50% of damage. This is similar to what Sengonca et al. (2006) estimated for populations of *F. occidentalis* on nectarine, *Prunus persica L.* (Rosaceae) where populations of 50 individuals in flowers were associated with 37.5% of non-marketable fruits. In contrast, in an avocado study with greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché) was estimated only two thrips per plant, with 40% of damage on leaves or fruits (Larral et al., 2018).

4.3 Predators

The predators detected represent biological control factors for various pests in other crops. Rocha et al. (2015) states that the survey of natural enemies is the basis for determining their role in regulating pest populations. Given the increased resistance to insecticides shown by some thrips species, among these, *F. occidentalis*, the use of biological controllers is being evaluated as a management alternative.

Chrysopidae species have been relevant in some studies. Laboratory and greenhouse research conducted with several species of Chrysopidae suggests its effectiveness in the control of *F. occidentalis* in cucumber, *Cucumis sativus L.* (Sarkar et al., 2019). The mortality of thrips individuals ranged from 40 to 90% when they were preyed upon by third-urging larvae from *Chrysoperla pallens* (Rambur) under laboratory conditions (Shrestha et al., 2013). Predatory bugs of the genus *Zelus*, which were abundant, have been referred to as an important biological controller of thrips associated with lemon, *Citrus aurantifolia* Swingle (Miranda-Salcedo and Loera-Alvarado, 2019) and with bean *Phaseolus vulgaris L.* (Blanco and Leyva, 2013). Spiders (Aranea) also represent biological control agents of several phytophagia species and their role as thrips mortality factors has been mentioned in some research (Rocha et al., 2015; Medina and Kondo, 2012).

Although *O. insidiosus* was not abundant, in other studies it has constituted a primary biological control agent. **?** pointed this species as a relevant biological controller of thrips, which feed on all stages (nymphs and adults). Anthocoridae species (Hemiptera: Anthocoridae), including those of the genus *Orius*, which are the main predators of thrips in Chiapas, Mexico and Florida, United States (Rocha et al., 2015).

5 Conclusions

Frankliniella occidentalis (Pergande) *Strepterothrips sp.* and *Caliothrips fasciatus* (Pergande), were detected in red pitahaya *Selenicereus undatus* (Haw.) D.R. Hunt, being F. occidentalis the most abundant with more than 90% of the total individuals. Flowers seem to be more attractive for the identified thrip species, which use them as elements of sheltering and feeding.

At least 47 thrips individuals are required to achieve 50% of damage in red pitahaya fruits *S. undatus*. Natural enemies represent an essential component as natural biological control agents of these phytophages. As far as this study is known, this research represents the first identification report of thrip species, population levels, damage and their relation to some natural enemies in the of red pitahaya.

Financial support and sponsor

This research was supported by "Identificación de las principales plagas, enemigos naturales y virosis en algunos cultivos de importancia en Ecuador y Venezuela" project from Universidad Técnica de Manabí, Portoviejo- Ecuador.

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