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Testing *Opuntia ficus-indica* genotypes for resistance against *Dactylopius coccus* (Hemiptera: Dactylopiidae)

Prueba de genotipos de *Opuntia ficus-indica* para resistencia a *Dactylopius coccus* (Hemiptera: Dactylopiidae)

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Abstract: Besides being a beneficial insect when it is cultivated for the production of carminic acid, the cochineal insect (*Dactylopius coccus*) is also a threat to the prickly pear cactus (*Opuntia ficus-indica*), a plant that is extremely important as a source of food, cattle feed, income, and soil and water conservation. A crucial component of an integrated pest management approach is the use of resistant varieties. In a greenhouse, a test for resistance of four cactus pear genotypes to cochineal insects was conducted at the University of Guadalajara, Center of Sciences for Biology and Agriculture. Three of these genotypes ('Punto 1', 'Punto 2', and 'Sandate 2') were shown to be non-hosts for *D. coccus*. These genotypes can be used for further research and development purposes of prickly pear cactus.

Keywords: Cochineal insect, cactus pear, pest management, resistant, scale insect.

Resumen: Aparte de ser un insecto benéfico cuando se cultiva para la producción del ácido carmínico, la grana cochinilla (*Dactylopius coccus*) también se considera como una amenaza para el nopal (*Opuntia ficus-indica*), una planta que es extremadamente importante como fuente de alimento, forraje para el ganado, ingresos y conservación del suelo y el agua. Un componente crucial para un enfoque de manejo integrado de plagas es el uso de variedades resistentes. Se realizó una prueba de resistencia a la grana cochinilla con cuatro genotipos de nopal en un invernadero del Centro Universitario de Ciencias Biológicas y Agropecuarias de la Universidad de Guadalajara. Se demostró que tres de los genotipos ('Punto 1', 'Punto 2' y 'Sandate 2') no son huéspedes de *D. coccus*. Estos genotipos se pueden utilizar para fines de investigación y desarrollo posteriores.

Palabras clave: Grana cochinilla, insecto escama, manejo de plagas, nopal, resistencia.

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Introduction

Opuntia ficus-indica (L.) Mill. (Cactaceae), known as prickly pear cactus, is a multipurpose plant of great significance due to its ability to tolerate high temperatures, dry conditions, and marginal areas (Barbera et al., 1992). Stintzing and Carle (2005) characterized the prickly pear cactus as a "miracle plant, dromedary of the plant world and bank of life"; a plant of great agricultural importance in the semi-arid area of Tigray, Ethiopia (Gebremeskel et al., 2013). Almost all rural communities in eastern and southern Tigray and some parts of central Tigray use cacti as a staple food for about four months and as a cash crop, covering 360,000 ha of land, of which half is planted around home yards (Brutsch, 1997).

The cochineal insect, *Dactylopis coccus* Costa (Hemiptera: Coccomorpha: Dactylopiidae) is a prickly pear cactus insect that reproduces sexually; the female has 2 nymphal instars before reaching the adult stage, whereas the males go through 2 feeding nymphal instars, and non-feeding prepupal and pupal stages before reaching the adult stage which has a pair of wings (Pacheco da Silva et al., 2022). *Dactylopius* spp. is often considered beneficial for producing a red dye and also used for controlling weedy cacti (especially in South Africa and Australia). However, they are considered pests when they attack cultivated cacti (Kondo, 2022). *Dactylopius coccus* has been reared commercially as a source of cochineal dye for centuries and is widely used as a coloring agent in foods, including beverages, cosmetics, and pharmaceutical products, and to dye textiles; the dried body of adult females (known as 'grana') is produced commercially in Bolivia, Chile, Mexico, Peru and Spain (Pacheco da Silva et al., 2022). Damage caused by *D. coccus* and other species of the genus *Dactylopius* includes chlorosis (yellowing of the cladodes), dehydration and weakening of the host, and dieback of the plants in 6-10 months (Pacheco da Silva et al., 2022). On several continents, *Dactylopius* species pose a threat to prickly pear cactus. *D. coccus* was reported to damage large areas planted with prickly pear cactus in Tigray in Ethiopia (Belay, 2015; Berhe et al., 2020), and *D. opuntiae* is a significant pest that has been rapidly spreading over several nations, especially in the Mediterranean basin (Bouharroud et al., 2016; Kondo, 2022; Mazzeo et al., 2019). Prickly pear cactus production suffers severe losses because of the *D. opuntiae* epidemic in Brazil's semiarid region (Pacheco da Silva et al., 2022; Torres & Giorgi, 2018). The pest consequences of *D. coccus* in Tigray, Ethiopia, are socioeconomic losses such as income reduction and youth migrations (Berhe & Siyum, 2022). It is also registered as a pest in Chile (IPPC, 2010).

Developing and utilizing resistant varieties is a vital constituent of an integrated pest management strategy to control *D. coccus* (Berhe et al., 2020; Primo, 2020; Sabbahi & Hock, 2022). Tovar et al. (2005) reported that *D. coccus* performance was poor in certain varieties. Since *D. coccus* had not established itself, Méndez-Gallegos et al. (2010) suspected some form of resistance. Hence, selecting cochineal-resistant prickly pear cactus genotypes is important for mitigating the pest problem (Berhe et al., 2020).

Materials and methods

The experiment was conducted in a greenhouse, at the Center of Biology and Agriculture Sciences (CUCBA) of Guadalajara University in Mexico from December 2021 to April 2022 in a greenhouse. Four genotypes were tested: 'Sandate 2, 'Punto 1', and 'Punto 2'; and one susceptible host ('Chicomostoc'). These genotypes and their species were selected based on field observations and information obtained from growers. The experiment was arranged in a completely randomized design (CRD) with three replications (cladodes as an experimental unit). The plants were grown in pots and cladodes for each plant were selected to be inoculated, while they were attached to their mother plant. 'Punto 1', and 'Punto 2' were grown from seeds while the others were vegetatively propagated. Adult females of *D. coccus* were reared in separate cladodes and were prepared for inoculation. The adult females were removed from their original host cladodes with a fine brush and kept in small paper bags. The insects were inoculated by fixing the paper bags with spines holding 20 mature females each. The paper bags remained attached to the cladodes for seven days allowing the ovipositing and infestation of the cactus pear cladodes (Figure 1 a-d) (Gusqui Mata, 2013; Vigueras et al., 2005).

The number of first-instar nymphs after one week of infestation, and the number of adult females at maturity (100 days after infestation), were counted. The number of first-instar nymphs was counted seven days after infestation, while the number of adult females was counted when they started oviposition. The data were subjected to descriptive statistical analysis and average values were calculated.

Figure 1. Cochineal insect infestation status of *Opuntia ficus-indica* genotypes tested after 7 days of inoculation, white spots are observed that show the presence of cochineal insects (a, Chicomostoc; b, Punto 1; c, Punto 2; and d Sandate 2), and after the completion of the insect life cycle period (e, Chicomostoc, a susceptible host with cochineal insects that completed the life cycle; f, Punto 1 (resistant) the insects could not develop beyond the first-instar stage; g, Punto 2 (resistant) without cochineal insects; and h, Sandate 2 (resistant) without cochineal insects.

Results

All genotypes had first-instar nymphs (crawlers) on the 7th day of infestation with a number ranging from 180 to 350 (Table 1 and Figure 1a-d). The nymphs reached maturity at the host genotype ('Chicomostoc') and 224 individuals were counted (Table 1 and Figure 1f-h), remained at the first-instar stage at 'Punto 1', the whole life cycle period, but died at 'Punto 2' and 'Sandate 2' genotypes (Figures 1b and 1c). Similar screening works for *Dactylopius* spp. resistance has been reported before. Kuti (1990) identified five resistant *Opuntia* genotypes, while Batista et al. (2022) screened four *D. opuntia* genotypes as resistant out of 121 tested genotypes. Berhe et al. (2022) also found one resistant *O. ficus-indica* cultivar against *D. coccus*. The genotypes may be resistant through several mechanisms/strategies, both chemical and physical (Akroud et al., 2021). Being in the first-instar stage at accession 'Punto 1' is an indication of *Opuntia*'s variable resistance mechanisms (Musengi et al., 2021).

Table 1. Average ± Standard error (SE) number of nymphs and adult female insects in the genotypes tested.

Accession	Average number of nymphs	Average number of female adults	Remark
Chicomostoc	350±10.48	224±8.33	Susceptible/control
Punto 1	200±16.83	0	Resistant
Punto 2	250±10.41	0	Resistant
Sandate 2	180±13.84	0	Resistant

Conclusion and recommendations

The evaluated genotypes of *O. ficus-indica* cultivars, namely 'Chicomostoc', 'Punto 1', 'Punto 2', and 'Sandate 2' showed different responses to *D. coccus*. All genotypes except 'Chicomostoc' were found resistant to *D. coccus* because the insects could not develop and complete their life cycle, and died at the first-instar stage, except on 'Punto 1' at which the insects remained at the first-instar stage. These resistant genotypes can be used as part of *D. coccus* integrated management in areas where this insect is considered a pest. They can also be used for genetic improvements and other research purposes. The chemical and physical characteristics of the genotypes related to *D. coccus* resistance mechanisms are an important subject of study.

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Author Contribution

YKB: Collecting genotypes, testing, report preparation, and writing the original draft.
LP: Collecting genotypes, supervision, and reviewing.
MVB: Reviewing and writing the manuscript.

Conflict interests

The authors declared that they have no have conflict interest in this paperwork.