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Repellent effect of ethanol extracts of balche (*Lonchocarpus oliganthus*) and neem (*Azadirachta indica*) on *Bemisia tabaci* (Gennadius, 1889) in greenhouse assays

Efecto repelente del extracto etanólico de balché (*Lonchocarpus oliganthus*) y neem (*Azadirachta indica*) en *Bemisia tabaci* (Gennadius, 1889) en ensayos de invernadero

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ABSTRACT

The whitefly *Bemisia tabaci* (Hemiptera: Aleyrodidae) (Gennadius, 1889) is one of the most devastating pests in crop production worldwide. The development of insecticide resistance population of *B. tabaci* requieres new alternatives with low environmental impact. The objective of this work was to evaluate the effect of ethanol leaves extracts of balché (*Lonchocarpus oliganthus*) and neem (*Azadirachta indica*), single or in combination, on adult repellency and oviposition deterrence on *B. tabaci*. A polar fraction of extracts was obtained using ethanol as solvent. After evaporation, the extracts of *A. indica* and *L. oliganthus* were dissolved in water and applied by immersion using concentrations of 0.125 % w/v y 0.25 % w/v to Habanero pepper plants. The plants were infested by *B. tabaci* afterwards. The parameters of adult repellency index (RI) and oviposition deterrence index (ODI) were established. The extracts of *L. oliganthus* caused high oviposition deterrence index at 48 h (ODI=-81.576). Furthermore, its effect was also observed after 7 days of extract application, which caused a decrease by 50 % in the population density of eggs. In the case of the use of *A. indica* extracts (0.125 % w/v) a higher value of ODI was observed (ODI=-98.14). The use of ethanol extract of *L. oliganthus* represents a feasible option in the prospection of botanical derivatives for *B. tabaci* management.

KEY WORDS: Insect repellency, agricultural pest, pest control, *Capsicum chinense*, botanical insecticide.

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RESUMEN

La mosquita blanca (*Bemisia tabaci*, Gennadius, 1889, Hemiptera: Aleyrodidae) es uno de los insectos plaga con mayor impacto a nivel global en cultivos agrícolas. La aparición de poblaciones de *B. tabaci* resistentes a insecticidas requiere el desarrollo de nuevas alternativas con menor impacto ambiental. El objetivo de este trabajo fue evaluar el efecto de los extractos etanólicos del balché (*Lonchocarpus oliganthus*) y neem (*Azadirachta indica*), de manera individual y combinados, en la repelencia de adultos y disuasión de la oviposición de *B. tabaci*. Se obtuvo la fracción polar de los extractos de hojas de ambas especies con extracción etanólica. Después de la evaporación del solvente, los extractos de *A. indica* y *L. oliganthus* se disolvieron en agua y se aplicaron a plantas de chile habanero mediante inmersión usando concentraciones de 0.125 % p/v y 0.25 % p/v. Las plantas posteriormente fueron infestadas con *B. tabaci*. Se midieron dos parámetros: índice de repelencia de adultos (RI) y disuasión de la oviposición (ODI). Se observó que el extracto etanólico de *L. oliganthus* causó alta disuasión de la oviposición a las 48 horas (ODI=-81.576), incluso su efecto permaneció por 7 días, disminuyendo la población de huevos en un 50%. Se observó alta disuasión de la ovoposición por efecto de los extractos *A. indica* al 0.125 % (p/v) con un valor ODI de -98.14. El uso de extracto etanólico de *L. oliganthus* representa una opción viable en la prospección de derivados botánicos para el manejo de *B. tabaci*.

PALABRAS CLAVE: Repelencia de insectos, plaga agrícola, control de plagas, *Capsicum chinense*, insecticida botánico**.**

Introduction

Bemisia tabaci (Gennadius, 1889), commonly known as the whitefly, is a species widely found in tropical and subtropical regions world. This insect damages crops by feeding on plant phloem during colonization and transmitting begomoviruses that cause wilting and yellowing (Esquivel-Chí *et al.,* 2024). Indirectly, the excretion of sugary substances on the surface of plants infected by *B. tabaci* promotes the growth of phytopathogenic fungi (Hameed *et al.,* 2023). For more than three decades, it has been recognized in Mexico as a major pest of crops essential for human consumption, with products such as habanero pepper (*Capsicum chinense*) among the most affected, resulting in significant economic losses for the country. Yield losses can reach up to 100 % in some high-value commercial varieties (Carnero-Áviles *et al.,* 2024).

Currently, *B. tabaci* management relies heavily on the widespread use of synthetic insecticides, which harm ecosystems because of their persistence and accumulation in soil, water, and living organisms. Additionally, synthetic insecticides harm beneficial wildlife such as pollinators.

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Over the past decade, most insecticides used against *B. tabaci* have become ineffective as whitefly populations have developed resistance to these synthetic compounds (Ruiz-Jiménez *et al.,* 2024).

Given these issues, attention has increasingly shifted to plant-derived or botanical insecticides, which contain bioactive compounds with a lower environmental impact (Kisiriko *et al.,* 2021). Previous research has demonstrated that plant extracts obtained with solvents such as hexane, alcohols, or water can be effective for biorational pest control, including *B. tabaci* (Cruz-Estrada *et al.,* 2013; Esquivel-Chí *et al.,* 2024). Overall, the biological effects of plant extracts may include repellency, growth inhibition, metabolite-induced sterilization, attraction of natural predators, oviposition deterrence, and feeding inhibition on plant nutrients (Lengai *et al.,* 2020; Hameed *et al.,* 2023).

Lonchocarpus Kunth (Fabaceae, Millettieae) is a genus of plants that includes 150 species distributed throughout the American continent, with one species, *L. sericeus* (Poir.) DC, having a broader distribution in the Neotropics and Africa (da Silva *et al.,* 2012). Numerous studies have reported antimicrobial, anthelmintic, and insecticidal activity in the *Lonchocarpus* genus (Birch *et al.,* 1985; Almeida Filho *et al.,* 2018; Luzuriaga-Quichimbo *et al.,* 2019). This genus contains a wide diversity of biologically active secondary metabolites, including rotenone, deguelin, elliptone, and α-toxicarol, whose insecticidal properties have been previously documented (Birch *et al.,* 1985). The repellency and control of *B. tabaci* infestations using extracts from *Lonchocarpus* species have not been studied previously. Conversely, insecticidal effects of *A. indica* have been reported in various pest species (Kumar & Poehling, 2006; Lynn *et al.,* 2010). This study aimed to evaluate the insecticidal potential of the ethanolic extract of *L. oliganthus*, both alone and in combination with extracts of *A. indica*, against *B. tabaci*, based on the adult repellency index (RI) and oviposition deterrence index (ODI).

Material y Methods

Bemisia tabaci colony

For the repellency and oviposition deterrence assays, a population of *B. tabaci* biotype Q adults was used. This population has been maintained since 2018 on eggplant (*Solanum melongena* L.) plants in the experimental greenhouses at the Tecnológico Nacional de México, Campus Conkal.

Collection of plant material and preparation of ethanolic extract

Leaves from species of the genus *Lonchocarpus* and from *A. indica* were collected from mature trees over 4 m tall during January and February of 2020 and 2021 in Mérida, Yucatán, Mexico, in the gardens of the Instituto Tecnológico de Mérida. Leaves were selected without spots, insect damage, or yellowing. For both species, leaf veins were removed, and the leaves were dried at 50 °C for three days in a drying oven (A&E Laboratories). The dried leaves were then ground using a commercial blender until a fine powder was produced (Super Blender Mill Grater hs-999).

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For both *A. indica* and *Lonchocarpus* specimens, active compounds were released by weighing 15 g of fine leaf powder and adding water to reach a total volume of 450 mL with 96 % ethanol. The solution was stirred for one hour in an Erlenmeyer flask and then left to stand in the dark for 48 hours.

After this period, the extract was filtered twice using pellon fabric. The filtered extract was poured into Pyrex glass trays (21.5 x 31 cm), and the solvent was evaporated under normal atmospheric pressure by exposure to air. The resulting dry paste was collected and stored frozen at -20 °C.

Molecular identification of *Lonchocarpus* through DNA barcoding

Fresh leaves from the plant were collected and ground using liquid nitrogen. DNA extraction was performed following Magaña-Ortiz *et al.* (2013) and Magaña-Ortiz *et al.* (2024). For plant identification, previously reported plant-specific primers were used (Dunning & Savolainen, 2010; Bruni *et al.,* 2015). The primer sequences used were: MatK Kim 3F (5´-CGTACAGTACTTTTGTGTTTACGAG-3´) and MatK - Kim 1R (5´-ACCCAGTCCATCTGGAAATCTTGGTTC-3´).

Polymerase chain reaction was performed using a MultiGene gradient thermocycler (Labnet) and Phusion Taq DNA polymerase (Thermo Fisher Scientific). Amplification temperatures included an initial denaturation at 98 °C for 1 min, followed by 25 cycles of denaturation at 98 °C for 50 s, annealing at 53 °C for 1 min, and extension at 72 °C for 1 minute. Afterward, DNA fragments were analyzed on 1 % (w/v) agarose gels in 1X TAE buffer. For sequencing, amplified gene fragments were recovered with the Zymoclean Gel DNA Recovery Kit (Zymo Research), following the manufacturer's instructions. Purified PCR products were then sent for complete sequencing to the Biotechnology Institute-National Autonomous University of Mexico (IBT-UNAM). Results were evaluated using the Basic Local Alignment Search Tool (BLAST) algorithm from the National Institutes of Health (http://blast.ncbi.nlm.nih.gov/Blast.cgi).

Successfully obtained sequences were submitted to the GenBank database using the BankIt algorithm. Finally, amplicons were analyzed with the Maximum Likelihood method and the Tamura & Nei (1993) model to reconstruct the phylogenetic tree.

Evaluation of adult repellency and oviposition deterrence of *B. tabaci*

The application of *Lonchocarpus* and *A. indica* extracts was carried out using a randomized design as previously reported (Baldin *et al.,* 2015; Esquivel-Chí *et al.,* 2024), with some modifications described below. Before applying to habanero pepper plants, all extracts were dissolved in distilled water and sonicated with a Set Sonics unit (251OR-MT, Bransonic®, USA). Habanero pepper plants var. Jaguar (*C. chinense*) at 32 days after germination were transplanted into 1-liter plastic pots with soil as the substrate. 5 plants were used per treatment, and 5 served as negative controls. The greenhouse experiment was repeated twice with the same number of plants. Two fully developed upper leaves from each plant were dipped in the aqueous extract for 10 seconds.

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The negative control used distilled water, while the experimental treatments included: *A. indica* leaf extract (0.125 % w/v), *L. oliganthus* leaf extract (0.125 % w/v), *A. indica* leaf extract (0.25 % w/v), *L. oliganthus* leaf extract (0.25 % w/v), and a combination of *L. oliganthus* (0.125 % w/v) and *A. indica (*0.125 % w/v). The positive control involved applying a commercial botanical insecticide containing argemonine, berberine, and ricinine (BioDie®, PTI S.A. de C.V.) at a concentration of 4 mL per liter of water.

After treatment application, the plants were randomly placed around *S. melongena* L. plants heavily infested with *B. tabaci*, with the eggplant plants serving as the infestation source. The treated plants were positioned 1 meter away from the infested plants. The total number of eggs and adults on treated plants was recorded 48 hours after exposure. Leaf area of sampled leaves was measured using a stationary optical leaf area meter (LICOR LI-3100C, NE, USA). The number of adults and eggs per square centimeter was calculated for each treatment to determine the adult repellency index (RI) and the oviposition deterrence index (ODI) for *B. tabaci*.

The RI value was calculated using the following equation, where T_a is the total number of adults on plants treated with the extract, and C_a is the total number of adults on plants treated only with water. RI values close to 0 indicate high repellency, while values close to 1 indicate very low repellency (Baldin *et al.,* 2015):

Equation 1. $$RI = \frac{2T_a}{(T_a + C_a)}$$

The ODI value was calculated using a second equation, where T_e is the total number of eggs on extract-treated leaves, and C_e is the total number of eggs on the water-treated controls. ODI values close to -100 indicate strong deterrence, while values near +100 or higher suggest low deterrence or even attraction of pests to the treated leaves (Baldin *et al.,* 2015):

Equation 2. $$ODI = \frac{T_e - C_e}{(T_e + C_e)} \times 100$$

To determine the effect of the extract, reference values previously reported by Baldin *et al.* (2015) were used. For RI, four possible repellency categories were defined: high repellency (RI = 0.00–0.50), intermediate repellency (RI = 0.51–0.80), low repellency (RI = 0.81–1.0), and no repellency (RI > 1.0). For ODI, the reference categories were: high deterrence (ODI = –100 to –80), intermediate deterrence (ODI = –81 to –60), low deterrence (ODI = –61 to –40), and no deterrence (ODI = –39 to 0).

Seven days after the start of exposure, a second assessment of extract effects on adult repellency (RI) was performed, similar to the 48-hour measurement, and egg population density

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on *C. chinense* foliage was also recorded.

Statistical analysis

Data on adult and egg population densities were compared across treatments containing *L. oliganthus* extracts, *A. indica* extracts, the combination of both extracts, and control groups treated with distilled water. The Shapiro-Wilk test was used to determine whether the data followed a normal distribution, and Levene's test was applied to assess homoscedasticity and determine whether ANOVA assumptions could be met. If the data did not meet parametric assumptions, they were transformed as described by Baldin *et al.* (2015), using the following equation.

Equation 3. $x_1 = \sqrt{x + 0.5}$

After transformation, treatment means were compared using Tukey's test in GraphPad Prism version 10.0.0 for Windows (GraphPad Software, Boston, Massachusetts, USA). Statistical significance was set at $p \leq 0.05$.

Results and Discussion

Molecular identification of the *Lonchocarpus* plant

Amplification of the chloroplast genomic molecular marker matK (DNA barcoding) was performed four times to verify the molecular identification of the plant specimen. The amplicons ranged from 700 bp to 800 bp and were of high quality (Figure 1). The sequence's high specificity was confirmed by the observation of a single, well-defined band (Figure 1). The sequences were deposited in GenBank under accession numbers PV594459 and PV712690 after review by the database's technical team, which validated the species' molecular identification.

As shown in Figure 2, the phylogenetic branches clearly identify the study specimen as *Lonchocarpus oliganthus* at the species level. Although previous studies report a high diversity of morphologies and cryptic species within the *Lonchocarpus* genus (da Silva *et al.,* 2012), the DNA barcoding method, widely used in taxonomic systematics, enables efficient discrimination among closely related species (Dunning & Savolainen, 2010; Bruni *et al.,* 2015; Tamura *et al.,* 2021).

The geographic distribution aligns with the molecular identification, as the species ranges from central Mexico to Central America. Similarly, the morphology of the specimens analyzed through DNA barcoding matches the descriptions previously reported in scientific literature. Deskins (2013) and Deskins *et al.* (2014) describe the underside of *L. oliganthus* leaves as rounded, with a small pointed tip and rounded margins. Additionally, *L. oliganthus* produces 3-4 panicles toward the end of the branch, measuring only 6-10 cm in length, which are much shorter than the leaves. The small, purple flowers measure 8-9 mm in length, are slender, spike-shaped, and extend along the branch.

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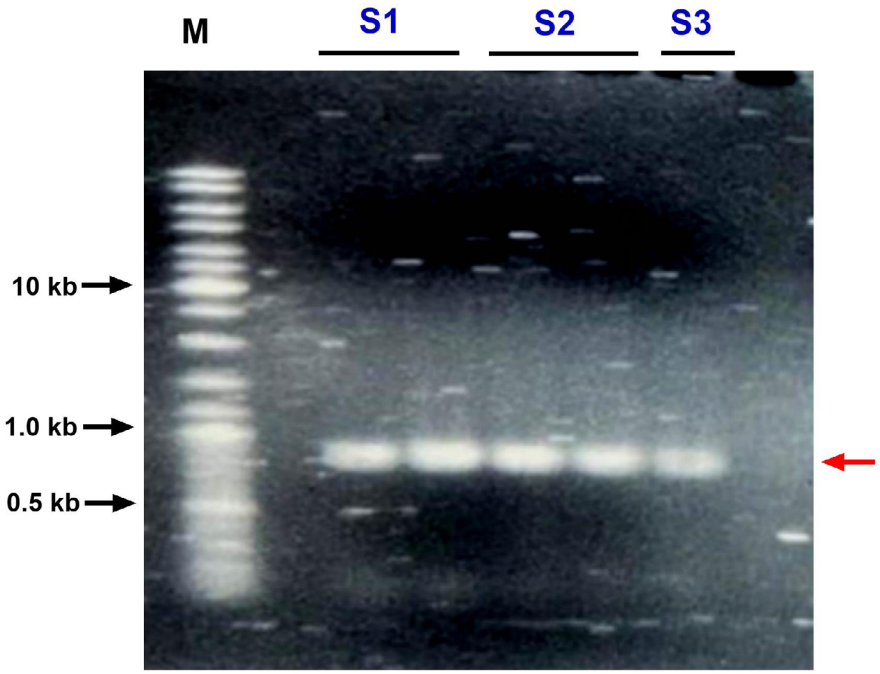

Figure 1. Amplification of the matK gene from *Lonchocarpus oliganthus* using PCR protocols. Matk stands for maturase K, a chloroplast marker. M indicates the Molecular Weight Marker. S1, sample 1; S2, sample 2; S3, sample 3.

All samples were extracted from genomic DNA isolated from leaves. A red arrow shows positive amplification.
Source: Own elaboration based on results obtained in this work.

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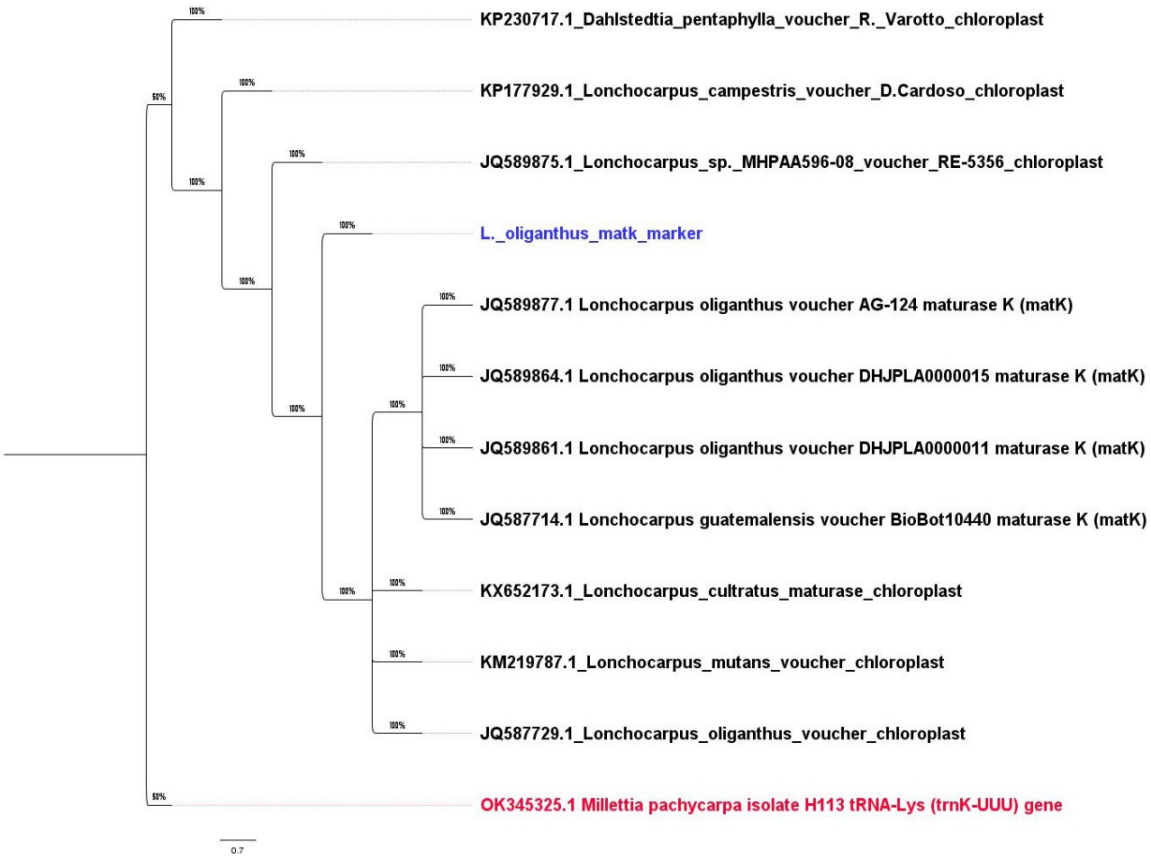

Figure 2. Phylogenetic tree built using matK gene sequences of *Lonchocarpus oliganthus* compared with related plant species.

The matk gene (maturase K) is a chloroplast marker commonly used for phylogenetic research.
Source: Own elaboration based on sequences obtained in this work.

Effect of the extracts on adult repellency (RI) of *B. tabaci*

Application of *A. indica* and *L. oliganthus* extracts showed varying effects on the repellency index (RI) of *B. tabaci* at 48 hours (Table 1). The *A. indica* extract at 0.125 % demonstrated moderate repellency (RI 0.51–0.8), while treatments with *A. indica* 0.25 %, *L. oliganthus* 0.25 %, and the combination of *L. oliganthus* 0.125 % plus *A. indica* 0.125 % resulted in low repellency (RI 0.81–1.0). The *L. oliganthus* extract at 0.125 % and the commercial product BioDie® showed no adult repellency; instead, an increase in the adult population was observed compared to the negative control.

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Seven days after the extract application, adult density on the foliage was reassessed to calculate RI values. The *L. oliganthus* extract at 0.125 % caused a reduction in the adult population on *C. chinense* leaves, with an intermediate RI (RI = 0.58) (Table 1). Similarly, the combination of *L. oliganthus* at 0.125 % plus *A. indica* at 0.125 % slightly reduced the adult population, with an intermediate RI (RI = 0.78). Consistent with these results, the application of *A. indica* at 0.125 % showed a weak repellency effect against *B. tabaci* adults (RI = 0.92) (Table 1). The positive control BioDie® showed effects comparable to the negative control, with no significant repellency against *B. tabaci*.

The results obtained from leaf extracts of *A. indica* (neem) at the concentrations used here did not show the effects reported for *A. indica* seed extracts or for purified compounds like azadirachtin (Kumar & Poehling, 2006). It is important to note that repellency effects from plant extracts are preferable to lethal effects on pest insects, since components responsible for pest lethality can also harm beneficial insects such as bees, predators, and parasitoids (Kumar & Poehling, 2006). Therefore, plant extracts that promote adult repellency are preferable, as they may be safer for the environment and beneficial insects.

Research on plant extracts from species of the genus *Lonchocarpus* has revealed biological activity against pest insects. *L. oliganthus* and closely related species, such as *Lonchocarpus monteviridis* and *Lonchocarpus mutans*, have shown antioxidant and antibacterial effects (Deskins et al., 2014); insecticidal activity has been documented against *Aedes aegypti* (Ioset *et al.,* 2001). In agricultural pests, extracts of *L. salvadorensis* demonstrated activity against *Callosobruchus sp.,* beetles, attributed to the presence of abundant compounds such as rotenone, deguelin, elliptone, and α-toxicarol (Birch *et al.,* 1985). Similarly, compounds in extracts of *L. neuroscapha* were found to influence the feeding behavior of Lepidoptera larvae, specifically *Spodoptera littoralis* and *Spodoptera exempta*, with an effect linked to metabolites derricidine (cordoin), isocordoin, derricin, and lonchocarpin (Simmonds *et al.,* 1990). Secondary metabolites from *Lonchocarpus castilloi*, including the aurones castillene D and castillene E, were also found to affect feeding and reproduction in the termite *Cryptotermes brevis* (Reyes-Chilpa et al., 1995). These findings add to current knowledge by showing that extracts of *L. oliganthus* can moderately repel *B. tabaci* adults. New formulations or the application of fractions obtained with solvents of different polarities might enhance repellency effects using metabolites from *L. oliganthus* or related species.

Tabla 1. Effect of the extracts on the adult repellence of *Bemisia tabaci* using *Capsicum chinense* plants in greenhouse assays

Treatment	[a]RI at 48 h	[a]RI at 7 days
Positive control BioDie® (0.4 % v/v)	1.32	0.99
*A. indic*a leaf ((0.125 % p/v)	0.618	0.92
L. oliganthus leaf (0.125 % p/v)	1.046	0.58

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A. indica leaf (0.25 % p/v)	0.825	[b]NE
L. oliganthus leaf (0.25 % p/v)	0.887	[b]NE
Leaf combination of *L. oliganthus* (0.125 % p/v) + *A. indica* (0.125 % p/v)	0.995	0.78
Negative control (water)	1.0	1.0

[a]RI, repellency index; [b]NE, not evaluated.

Source: Own elaboration using the data obtained in this work.

Oviposition deterrence index in adults (ODI)

Consistent with the adult repellency results, the oviposition deterrence index (ODI) at 48 hours varied across extracts. A high oviposition deterrence was observed for the *A. indica* extract at 0.125 % (w/v), with an ODI of -98.14 (Table 2), followed by the *L. oliganthus* extract at 0.25 % (w/v), with an ODI of -81.6. The *L. oliganthus* extract at 0.125 % (w/v) showed an intermediate ODI value, while the *A. indica* extract at 0.25 % (w/v) had a low ODI (Table 2). Additionally, combining *A. indica* and *L. oliganthus* extracts did not improve oviposition deterrence; instead, the ODI decreased and approached the level of the negative control (Table 2).

In the second evaluation, conducted 7 days after application, egg density on *C. chinense* leaves (number of eggs per cm^2) was measured. Data were normalized using the formula $x_1 = \sqrt{x + 0.5}$ following Baldin *et al.* (2015). In this test, the *A. indica* extract at 0.125 % significantly reduced the number of eggs on the leaves, achieving an 80 % decrease compared to the negative control (Figure 3). Notably, *L. oliganthus* extracts at both concentrations (0.125 % and 0.25 %) also significantly reduced the number of eggs on *C. chinense* leaves compared to the negative control (Figure 3).

It is important to note that the decrease in oviposition observed on day 7 may be linked to an initial disruption of a key physiological process in *B. tabaci*, possibly related to metabolism, reduced mating, or effects on fertility. Furthermore, the extract concentrations used in this study are considered low, as most studies report using concentrations between 0.25 % and 0.5 % (w/v).

Similarly, the results here emphasize the need to explore additional rotation options or to enhance the effectiveness of botanical extracts used to manage *B. tabaci*, since in some cases the repellency or deterrent effect may be moderate or low. To our knowledge, this study is the first to report the impact of ethanolic extracts of *L. oliganthus* on the oviposition rate of *B. tabaci*.

The effects observed with *L. oliganthus* extracts are similar to those reported for the essential oils of *Thymus vulgaris*, *Pogostemon cablin*, and *Corymbia citriodora*, in which a reduction in *B. tabaci* oviposition was observed, and repeated applications decreased pest populations (Yang *et al.,* 2010). Similarly, essential oils of *Ageratum conyzoides* L., *Plectranthus neochilus* Schltr., and *Tagetes erecta* L. have been shown to deter *B. tabaci* oviposition (Baldin *et al.* 2013).

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Compared to essential oil extraction, obtaining ethanolic extracts requires less infrastructure and fewer specialized tools for greenhouse-scale applications (Pérez-Verdugo *et al.,* 2019; Esquivel-Chí *et al.,* 2024). Additionally, using foliage for extract production allows biomass to be harvested without significantly harming trees.

The results of this study contribute to the expanding knowledge about the biotechnological potential of commonly available plant species from the Yucatán Peninsula for pest management in agriculture. Previous research assessing Yucatán Peninsula plants for controlling *B. tabaci* found that extracts from *Croton arboreus* (roots and stems), *Morella cerifera* (roots, stems, and leaves), and *Erythroxylum confusum* (roots, stems, and leaves) had significant effects on repellency and oviposition deterrence (Pérez-Verdugo *et al.,* 2019). However, these studies used higher concentrations, up to 3 % (w/v), than those used here. More recently, ethanolic leaf extracts of *Malpighia glabra* at 1 % (w/v) showed strong repellency and oviposition deterrence against *B. tabaci* under greenhouse conditions (Esquivel-Chí *et al.,* 2024). In combination with this study's findings, these results indicate that plant species from southeastern Mexico have the potential to produce a wide array of botanical products for effective *B. tabaci* control with minimal or no environmental impact.

Hitherto, no previous research has documented the effects of *L. oliganthus* extracts on *B. tabaci*, making this the first record showing that ethanolic leaf extracts from this species can reduce oviposition and aid in controlling *B. tabaci*. Current studies focus on fractionation using hexane, ethyl acetate, and methanol to identify compounds responsible for repellency and oviposition deterrence in this species native to southeastern Mexico.

Tabla 2. Effect of the extracts on the oviposition deterrence of *Bemisia tabaci* using *Capsicum chinense* plants in greenhouse assays

Treatments	[a]ODI
Positive control BioDie® (0.4 % v/v)	+0.113
A. indica leaf ((0.125 % p/v)	-98.148
L. oliganthus leaf (0.125 % p/v)	-66.444
A. indica leaf (0.25 % p/v)	-56.530
L. oliganthus leaf (0.25 % p/v)	-81.576
Leaf combination of *L. oliganthus* (0.125 % p/v) + *A. indica* (0.125 % p/v)	-0.259
Negative control (water)	0

[a]ODI, oviposition deterrence index.

Source: Own elaboration using the data obtained in this work.

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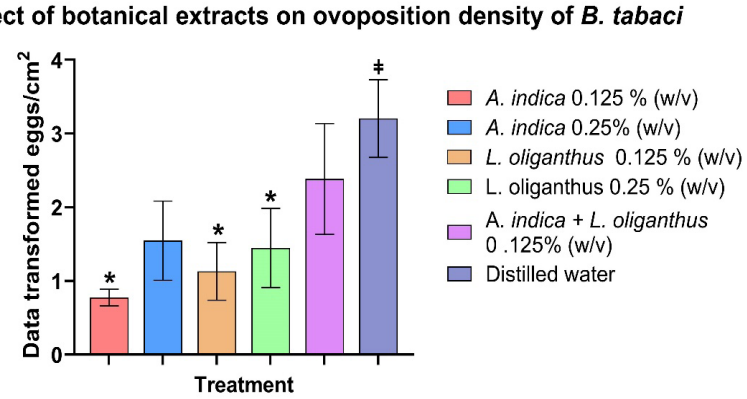

Figure 3. Population density (means ± standard error) of *Bemisia tabaci* eggs on leaves of *Capsicum chinense* treated with leaf extract of *Lonchocarpus oliganthus* and *Azadirachta indica*.

The number of eggs was counted after 7 days of exposure, and the data were transformed using $x_1 = \sqrt{x + 0.5}$. Marks (*) indicate a significant difference between treatment means compared to the negative control (distilled water) according to Tukey's test ($p \leq 0.05$). The negative control is also indicated (ǂ).

Source: Own elaboration based on experimental results obtained in this work.

Conclusions

The use of ethanolic extracts from *L. oliganthus* leaves may provide a low-cost option for controlling *B. tabaci* infestations. This study showed that applying *L. oliganthus* extracts resulted in about a 50 % reduction in egg populations 7 days after application. No consistent or significant effect on adult repellency was observed. *A. indica* extracts consistently deterred oviposition. The combined use of *A. indica* and *L. oliganthus* did not improve protection against *B. tabaci* infestation. The extract can be prepared using basic infrastructure and simple equipment.

Author contributions

Conceptualization, DMO, ERS, and DPC; methodology, ERS, DMO, and DPC; software management, DMO, AFB, and DPC; experimental validation, DPC, AFB, CCB, STR, and JMC; data analysis, DMO, GLU, ERS, and SRA; data curation, AFB, DPC, and DMO; writing-original draft preparation, DMO, ERS; writing-review and editing, DMO, GLU, SRA, and ESR; project administration, DMO, SRA, and GLU; funding acquisition, DMO, GLU, and SRA.

All authors have read and agreed to the published version of the manuscript.

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Ethical statements

The development of this project adhered to the ethical standards of Tecnológico Nacional de México and SEP-PROMEP.

Informed consent statement

Not applicable.

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Conflict of interest

The authors declare that they have no conflict of interest.

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