

Effectiveness of Plant Extracts in the Control of *Bemisia tabaci* Gennadius in Zucchini Squash

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ABSTRACT

Objective: To determine the effectiveness of plant extracts in the control of *Bemisia tabaci* in zucchini squash.

Design/methodology/approach: An open-field experiment was established in zucchini squash using a randomized complete block design with plastic mulch. The incidence of *Bemisia tabaci* adults, nymphs, and eggs was determined through direct monitoring on the underside of leaves treated with different plant extracts at doses of 10 mL and 3 mL. In addition, the percentage efficacy of the extracts was calculated. The incidence of silverleaf symptoms and plants exhibiting viral symptoms was assessed using a visual scale. Finally, zucchini yield was determined by weighing the fruits obtained from each treatment.

Results: Statistically significant differences were detected in the incidence of *B. tabaci* adults, nymphs, and eggs among treatments with plant extracts, with the Mixxert treatment standing out as the most effective in controlling the insect and also producing the highest fruit yield. No differences were observed among the evaluated treatments in the number of silvered leaves or plants with viral diseases.

Limitations on study/implications: The use of some plant extracts affects beneficial fauna in zucchini cultivation.

Findings/conclusions: The Mixxert extract was the most effective for the control of adults, nymphs, and eggs, recording the lowest incidence of *B. tabaci* in zucchini plants, with efficacy values of 54%, 96%, and 95%, respectively.

Keywords: Effectiveness, plant extracts, zucchini.

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INTRODUCTION

Zucchini squash (*Cucurbita pepo* L.) is a highly important vegetable crop in Mexico due to its value as a food source. Commercially, it is commonly known as American squash, zucchini squash, or zucchini (Lira, 2004). In Mexico, zucchini production in 2024 reached 459,005.01 t, generating an economic value of 3,031,430.49 million pesos (SIAP, 2025). Sinaloa ranks third in production, with 54,335.96 t and an average



yield of 28.45 t ha⁻¹ (SIAP, 2025). This crop is affected by various insect pests and diseases that cause considerable reductions in yield, resulting in losses of up to 50% or, in the worst-case scenario, total crop failure. This is mainly due to attacks by insects such as aphids, *Aphis gossypii* Glover and *Myzus persicae* Sulzer; whiteflies, *Bemisia* spp.; and thrips, *Caliothrips phaseoli* Hood (Armstrong, 2012; Díaz-Nájera *et al.*, 2020). This complex of insects causes both direct and indirect damage, as they pierce and suck plant tissues with their piercing-sucking and rasping-sucking mouthparts, extracting sap and cellular contents, which leads to the death of epidermal cells in the leaves. Over time, the affected tissues exhibit necrotic areas that may subsequently be colonized by bacteria and fungi (Johansen and Mojica, 1997). In addition, these insects may transmit viral diseases to the crop (Cambero-Campos *et al.*, 2009; Vargas-Salinas *et al.*, 2019). Among the aforementioned species, the whitefly *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) stands out because of the severe direct and indirect damage it causes in the crop (Hernández-Castro *et al.*, 2022). Direct damage is caused by both nymphs and adults during feeding, as they suck sap from the leaves, inducing yellowing and weakening of the plants, followed by the development of silverleaf symptoms (Nyoike *et al.*, 2008).

Indirectly, through its feeding activity, this insect is an efficient vector of viral diseases belonging to the genus Begomovirus, causing symptoms such as curling, mosaic, chlorosis, fruit deformation (Sobh *et al.*, 2012; Díaz-Nájera *et al.*, 2020; Fontenele *et al.*, 2021), and sooty mold development, which interferes with normal plant growth (Gutiérrez *et al.*, 2013; Gilbertson *et al.*, 2015; Mbata *et al.*, 2024). Consequently, different methods have been used for the eradication or control of this species, mainly relying on chemical products that affect the plant, the environment, and the people who come into direct contact with them. Moreover, this insect has developed resistance to a large number of synthetic molecules (Toscano *et al.*, 2003; García *et al.*, 2014; Carnero *et al.*, 2021). Therefore, it is necessary to implement alternative control methods to produce healthier and more affordable food without harming the environment, plants, water resources, and, above all, consumer health.

The use of plant extracts to prevent and reduce pest populations has gained remarkable relevance in recent years, in addition to being an ancient control method with low environmental impact (Nava-Pérez *et al.*, 2012; Hazir *et al.*, 2017). The prospect of a market for new insecticidal products in the agricultural sector has stimulated a substantial increase in research over the last 30 years. As a result, insecticidal properties have been identified in many plant species, such as *Cymbopogon citratus*, *Lantana camara*, *Lippia alba*, *Citrus paradisi*, *Citrus grandis*, *Hippocratea celastroides*, *Melia azedarach* L., *Azadirachta indica*, *Ricinus communis*, *Allium sativum*, *Satureja laevigata* Standl., *Melia azedarach*, *Solanum lycopersicum*, *Schoenocaulan officinale*, and *Capsicum* sp. Indeed, nearly 3,000 natural plant-derived compounds with fungicidal, nematicidal, bactericidal, and insecticidal activity have been reported (Kagale *et al.*, 2004; Zaker, 2016; Naz *et al.*, 2018; Hernández-Castro *et al.*, 2022). This activity is mainly attributed to the action of secondary metabolites such as alkaloids, tannins, terpenes, albumins, flavonoids, coumarins, monoterpenes, diterpenes, among others (Sepúlveda-Jiménez *et al.*, 2003;

Rojas, 2022; Alba *et al.*, 2022; Kumar *et al.*, 2023). In light of the above, the effectiveness of plant extracts for the control of *Bemisia tabaci* in zucchini squash was evaluated.

MATERIALS AND METHODS

Location of the experiment

The experiment was conducted at the experimental field of the Faculty of Agronomy of the Universidad Autónoma de Sinaloa (UAS), located on the Culiacán-Eldorado highway, km 17.5 (24° 48' 30" N, 107° 24' 30" W, and 38.54 m above sea level) (Google Earth, 2025), during the 2021-2022 growing cycle. The soil at the site is classified as chromic Vertisol, with 64% field capacity, 39% permanent wilting point, and 25% available moisture based on dry soil weight, a pH ranging from 7.5 to 8.0, and electrical conductivity lower than 1 dS m⁻¹. The site has an annual mean temperature of 25.9 °C and an annual mean precipitation of 672 mm (García, 2004).

Establishment of the experiment

The study was carried out under open-field conditions using white plastic mulch to cover the beds. The land was prepared with the aid of a tractor by tilling the soil with plows and harrows. Subsequently, the field was shaped into beds 60 cm wide and 20 m long, with 1.60 m spacing between beds for zucchini establishment. Two beds were left unsown between each block to prevent contact between the applied treatments and the plants in the experimental units. The plant material used was the zucchini variety Nurizeli from the commercial seed company Semillas Fitó. Direct sowing was performed at a depth of 4-5 cm, with 30 cm spacing between seeds. Sowing was carried out in February 2022. Before sowing, drip irrigation tape was installed, and an irrigation depth of 70 mm was applied to ensure adequate soil moisture for planting. Subsequent irrigations were applied every third day with an irrigation depth of 80 mm. All agronomic practices, including fertilization, irrigation, and weed removal, were kept uniform throughout the experiment.

Experimental design. A randomized complete block design was used, with seven treatments (Table 1) and four replications. Each experimental plot consisted of 4 m in length, arranged in a single row with 60 cm spacing between rows and 30 cm between plants.

Application and monitoring

Product applications were carried out using a Hyundai motorized sprayer with a 25 L capacity and a movable outlet nozzle to facilitate spraying from the underside upward. Four applications of the plant extracts were performed during March and April 2022. Direct sampling of whitefly adults, nymphs, and eggs was conducted before and after the application of the plant extracts.

Study variables

Incidence of *B. tabaci* adults in zucchini squash. The incidence of *B. tabaci* adults was determined using the technique proposed by Bernal *et al.* (2008), with slight modifications. Direct sampling was conducted at 24, 48, 72, and 96 h after the application of the plant

Table 1. Commercial plant extracts evaluated for the management of *Bemisia tabaci* in zucchini squash.

Treatment type	Commercial name	Active ingredient	Dose (mL)	Treatment type
Aqueous extract	Aranova	Neem extract (64%), garlic extract (3%), chili oleoresin (3%), cinnamon, and water (30%)	10	Aqueous extract
Aqueous extract	Blend	Derivatives from vegetable oil extraction (55%), plant-derived cinnamaldehyde from cinnamon (15%); inert ingredients: diluents, conditioners, and emulsifiers (30%)	10	Aqueous extract
Absolute control	—	Water	—	Absolute control
Aqueous extract	Mixxert	Quassia amara extract (20%), cinnamon extract (15%), garlic extract (20%), chili extract (15%), emulsifiers and diluents (30%)	10	Aqueous extract
Garlic extract	Escent	Garlic essential oil (5.5%), equivalent to 55% a.i. per liter, diluents and conditioners (94.5%)	10	Garlic extract
Pyrethrum extract	Cridor	Pyrethrum extract (4.5%), emulsifier and surfactants (95.5%)	3	Pyrethrum extract
Fatty acids	Agsoy	Saponified soybean fatty acids (not less than 20%); diluents and related compounds (not more than 80%)	10	Fatty acids

The doses described were used to prepare a proportion of one liter of water.

extracts, for a total of 16 samplings carried out from March 21 to April 4, 2022. Five plants were selected per replication, resulting in a total of 20 experimental units per treatment. The foliage was carefully examined, and observations and counts were performed on the underside of the selected leaves using a manual counter.

Incidence of *B. tabaci* nymphs and eggs in zucchini squash. Two samplings were conducted for these variables using the method proposed by Bernal *et al.* (2008), with slight modifications. The samplings were carried out on March 27 and April 7, 2022. For this purpose, seven leaves were randomly collected, one from each treatment, and observed under a microscope using one square inch as the sampling area. Each leaf was placed with the abaxial surface facing upward, and the designated area was delimited for counting nymphs and eggs.

Efficacy of plant extract applications. The percentage efficacy was determined using Abbott's (1925) formula, where:

$$\% \text{ efficiency} = \frac{B \times 100}{A - 100 \times (-1)}$$

were: *A*=control population taken as 100%; *B*=treatment population; Note: Negative results indicate no efficacy in control.

Incidence of silvered leaves caused by feeding of *B. tabaci* nymphs in zucchini squash

To calculate the incidence of silvered leaves in zucchini plants, the recommendations proposed by Cuellar and Morales (2006) were followed. The total number of plants in each replication per treatment, as well as the number of plants showing symptoms, was recorded, and the percentage was determined using a modified rule-of-three calculation.

Percentage of squash plants with viral symptoms

To determine the percentage of plants with viral symptoms, the methodology proposed by Barrón, Mena, and Garza (2020) was followed, with slight modifications. Plants were considered virus-infected when they exhibited symptoms such as leaf deformation, blistering, mottling, chlorosis, and necrosis. Subsequently, the percentage was calculated by a simple rule-of-three method, in which the total number of plants was considered 100% and the number of plants showing viral symptoms represented the affected proportion. Percentage of virus-infected plants = $B \times K / A$.

Zucchini yield

All fruits were harvested by replication and treatment. Total yield was determined based on the kilograms obtained from the area of each replication, and production was subsequently converted to tons per hectare.

Statistical analysis

The mean values of the evaluated variables were subjected to analysis of variance (ANOVA) and to comparison of means or medians according to data distribution (normality and homogeneity of variances) using the XLSTAT statistical package, through Tukey's test at 99.5% probability.

RESULTS AND DISCUSSION

Incidence of *Bemisia tabaci* adults in zucchini squash

The analysis of variance for the mean number of *B. tabaci* adults obtained from samplings conducted in zucchini showed statistically significant differences among treatments (Table 2). The Mixxert treatment, composed of chili, cinnamon, garlic, and quassia, showed the lowest number of *B. tabaci* adults and was statistically similar to the Aranova treatment (neem, garlic, chili, and cinnamon) and Blend (cinnamon), whereas the absolute control exceeded it by 46.3% (Table 2). In addition, the Mixxert extract was characterized by the highest efficacy in adult control, reaching 54% (Table 3). Plant extracts and oils contain chemical groups and active ingredients with contact, systemic, and repellent action used for the control of insects, fungi, bacteria, and nematodes (Naz *et al.*, 2018; Hernández-Castro *et al.*, 2022). These compounds exert biological effects such as antiseptic and insecticidal activity and may alter the digestive system, induce repellency, and ultimately cause insect mortality. They may also affect the nervous system, preventing the secretion of pheromones involved in insect mating. This activity is attributed to compounds such as terpenes, phenols, alkaloids, organic acids (catechuic and protocatechuic), peptides, polyunsaturated fatty acids, omega-3 group compounds (linoleic, eicosapentaenoic, and dodecahexaenoic acids), alliin, quassin, piperine, capsaicin, cinnamaldehyde, D-limonene, diatoms, caffeine, and nicotine (Acosta, 2021). The results obtained in this study are consistent with those reported by Corrales *et al.* (2018) in Costa Rica, who evaluated the effect of thyme-, hot pepper + garlic-, and cinnamon + clove-based extracts to control whitefly in melon crops. They argued that the treatment providing the best pest control was cinnamon + clove, with a considerable

reduction in the population. Likewise, chili and garlic extracts caused repellency in insects, which is consistent with the low incidence of *B. tabaci* observed in plants treated with Mixxert.

Authors such as Hilje (2001) mention that cinnamaldehyde from cinnamon is associated with deterrent and repellent effects on whitefly adults. Similarly, Pérez-Verdugo *et al.* (2019), when evaluating different plant-derived products for whitefly control, reported a low population density of the insect when treated with an extract prepared from cinnamon and garlic.

Incidence of *B. tabaci* nymphs and eggs in zucchini squash

The lowest incidence of *B. tabaci* nymphs was observed in zucchini plants treated with the Mixxert extract, whereas the absolute control showed a higher incidence, with more than 50 nymphs (Table 2). Regarding the number of *B. tabaci* eggs, the plant extracts Aranova, Mixxert, Escent, and Agsoy were statistically similar, recording the lowest number of eggs oviposited on zucchini leaves (Table 2). This finding is consistent with reports from several studies, such as that of Basedow *et al.* (2002), who demonstrated that neem oil and aqueous neem kernel extract with aloe vera as an adjuvant affect whitefly egg hatching and cause significant mortality in insect nymphs. Derivatives of neem (*Azadirachta indica*) extracts have been reported as repellents and oviposition deterrents against several insect species (Benelli *et al.*, 2017), mainly due to the presence of azadirachtin and other triterpenoids (Copping and Duke, 2007; Marcic, 2012). *Azadirachta indica* exhibited high repellent activity and strong oviposition deterrence in a study conducted by Pérez-Verdugo *et al.* (2019). Likewise, Santiago *et al.* (2009) and Freire *et al.* (2013) reported that neem reduced the population density of *B. tabaci*, attributing its effect probably to high concentrations of alkaloids. This is consistent with what was observed in the present study regarding the number of eggs and adults found on plants treated with the insecticide Aranova (Table 3), which contains 64% neem extract in its formulation. In addition, the cinnamon-based Mixxert extract showed a low density of nymphs and eggs, in agreement with the findings of Pérez-Verdugo *et al.* (2019), who reported a positive effect on the reduction of whitefly nymphs and eggs in

Table 2. Mean number of *B. tabaci* adults, nymphs, and eggs in zucchini squash after four applications of plant extracts.

Treatments	Adults (number)	Nymphs (number)	Eggs (number)
1. Aranova	71.27abc	22.75ab	1.75b*
2. Blend	67.48bc	19.25ab	5.50ab
3. Absolute control (water)	103.50a	57.75a	20.7a
4. Mixxert	47.88c*	3.50b*	2.25b
5. Escent	79.67ab	43.75ab	1.75b
6. Cridor	94.05ab	23.75ab	7.00ab
7. Agsoy	91.16ab	18.75ab	5.00b
PR>F	0.0009	0.0462	0.0157

Means followed by different letters within the same column differ statistically according to Tukey's test ($p \leq 0.05$).

plants treated with an *Allium-Capsicum-Cinnamomum* extract. Regarding treatment efficacy for the control of *B. tabaci* nymphs and eggs in this study, the Mixxert extract was the most effective, reaching 96% and 95%, respectively (Table 3).

Incidence of silvered leaves and virus-infected zucchini squash plants

The analysis of variance for the incidence of silvered leaves and virus-infected zucchini plants showed no statistical differences among treatments with the evaluated extracts (Table 4). However, previous studies have reported that silverleaf damage in squash represents a plant response to whitefly feeding (Robinson, 2011). In the present study, this symptom was observed following the marked increase in whitefly nymph populations. It was detected that, during nymph feeding, the plant initiated a defense response by developing this characteristic silverleaf symptomatology. The direct damage caused by phloem feeding weakens the plant through nutrient extraction, and the disorder most commonly reported is silvering in cucurbits (Cuellar and Morales, 2006; CABI, 2020). Regarding whitefly-transmitted viral diseases, these generate symptoms such as severe yellowing, mottling, chlorotic mosaics, leaf curling, leaf and fruit deformation, flower abortion, and general plant stunting.

Table 3. Efficacy of plant extract applications for the control of *B. tabaci* in zucchini squash.

Treatment	Adult efficacy (%)	Nymph efficacy (%)	Egg efficacy (%)
1. Aranova	31	70	75
2. Blend	37	70	70
3. Absolute control (water)	0	0	0
4. Mixxert	54	96	95
5. Escent	26	48	60
6. Cridor	12	71	70
7. Agsoy	15	70	73

Efficacy percentages were determined using Abbott's formula (1925).

Table 4. Mean number of zucchini squash plants with silvered leaves, viral symptoms, and yield after four applications of plant extracts.

Treatments	Number of silvered leaves	Plants with viral symptoms	Yield (t ha ⁻¹)
1. Aranova	21.75a	7.75a	26.88ab
2. Blend	29.25a	6.50a	23.81ab
3. Absolute control (water)	25.25a	7.50a	23.50ab
4. Mixxert	24.00a	7.25a	37.00a
5. Escent	29.75a	7.00a	13.69b
6. Cridor	30.75a	6.25a	20.56ab
7. Agsoy	22.00a	7.25a	18.75ab
PR>F	0.9242	0.7812	0.2287

Means followed by different letters within the same column differ statistically according to Tukey's test ($p \leq 0.05$).

This insect has been reported as a vector of more than 40 viruses causing disease in diverse crops; in cucurbits alone, more than 35 viruses have been identified, with the principal groups being geminiviruses, carlaviruses, closteroviruses, and potyviruses (Ozaslan *et al.*, 2006; Lugo *et al.*, 2011; Romay *et al.*, 2016; Varsani *et al.*, 2017). Furthermore, several studies have demonstrated that viruses of the genus Begomovirus are transmitted by *Bemisia tabaci* and cause severe losses in cucurbit crops. In this regard, Díaz-Nájera *et al.* (2020) investigated the etiology of the disease caused by squash leaf curl virus (SLCV) and the population dynamics of its vector, confirming that *B. tabaci* transmits SLCV, which reduces plant growth. They also found that both pest incidence and SLCV severity were expressed throughout all phenological stages of the crop and were associated with temperature levels. The highest yield was recorded in zucchini plants treated with the Mixxert extract, which in turn exceeded the absolute control by 13.5 t ha⁻¹ (Table 4). This result may be associated with the low population incidence of *B. tabaci* across the three biological stages of the pest.

CONCLUSIONS

The Mixxert extract, composed of quassia, cinnamon, garlic, and chili, exhibited a suppressive effect on the incidence of *B. tabaci* adults, nymphs, and eggs in zucchini squash under open-field conditions, and showed the highest efficacy, reaching 54%, 96%, and 95%, respectively. Likewise, it produced the highest fruit yield. Regarding the incidence of diseases in zucchini plants caused by direct insect feeding and virus transmission by the pest, similar responses were observed across all treatments evaluated. Therefore, the integration of plant extracts with insecticidal activity into an integrated pest management program is recommended, as this strategy may contribute to the preventive control of whitefly in cucurbits such as zucchini squash, reduce the number of synthetic insecticide applications, and delay the development of resistance to active molecules. Furthermore, this approach helps minimize risks to consumer health by allowing the consumption of fruits free of agrochemical residues.

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