



FIELD EVALUATION OF BOTANICAL AND SYNTHETIC INSECTICIDES FOR THE MANAGEMENT OF ASIAN CITRUS PSYLLID (*DIAPHORINA CITRI*) IN CITRUS ORCHARDS

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Abstract

The Asian citrus psyllid *Diaphorina citri* Kuwayama (Hemiptera: Liviidae), is the most destructive insect pest of citrus worldwide due to its role as the primary vector of *Candidatus Liberibacter asiaticus*, the causal agent of Huanglongbing (HLB) or citrus greening disease. Current management relies heavily on synthetic insecticides, but resistance development and environmental concerns have increased interest in botanical alternatives. This study evaluated the field efficacy of three botanical insecticides (neem oil, azadirachtin, and garlic extract) and three synthetic insecticides (imidacloprid, acetamiprid, and spirotetramat) against *D. citri* in a citrus orchard. The experiment was conducted in a Randomized Complete Block Design (RCBD) with seven treatments (six insecticides plus untreated control) and three replications. ACP adult and nymph populations were recorded before treatment and at 3, 7, 14, and 21 days after treatment (DAT). Percent reduction over control was calculated using Abbott's formula. Data were analyzed using ANOVA followed by Tukey's HSD test at 5% probability. Results showed that all insecticidal treatments significantly reduced ACP populations compared with the control. Imidacloprid gave the highest overall reduction (86.7% at 7 DAT), followed by acetamiprid (83.7%) and spirotetramat (76.3%). Among botanicals, neem oil performed best (69.6% at 7 DAT), followed by azadirachtin (63.0%) and garlic extract (54.1%). The overall order of efficacy was: Imidacloprid > Acetamiprid > Spirotetramat > Neem oil > Azadirachtin > Garlic extract > Control. Botanical insecticides showed

slower knockdown but were safer for natural enemies. These findings support the integrated use of botanicals and synthetics for sustainable ACP management.

Keywords: Asian citrus psyllid, *Diaphorina citri*, botanical insecticides, synthetic insecticides, citrus greening, HLB, field evaluation, integrated pest management

Introduction

Citrus (*Citrus* spp.) is one of the most economically important fruit crops globally, grown in more than 140 countries with annual production exceeding 130 million tonnes.¹ Citrus fruits are rich in vitamin C, dietary fiber, and antioxidants, and they support the livelihoods of millions of farmers, traders, and workers worldwide.² However, citrus production faces a serious threat from the Asian citrus psyllid, *Diaphorina citri* Kuwayama.³ This small, sap-sucking insect feeds on young leaves and shoots of citrus trees.³ Its direct feeding damage is minor, but its real danger lies in transmitting the bacterium *Candidatus Liberibacter asiaticus*, which causes Huanglongbing (HLB) or citrus greening disease.⁴ HLB is considered the most devastating disease of citrus worldwide.⁵ Once a tree is infected, there is no cure. Symptoms include blotchy mottled leaves, yellow shoots, misshapen and bitter fruits, and gradual tree decline, leading to death within a few years.⁵ In regions such as Florida, HLB has reduced citrus production by more than 70% over the last two decades.⁶ In Asia and Africa, the disease continues to spread.⁶ Because there is no cure for HLB, the only practical management strategy is to control the vector — the Asian citrus psyllid.⁷ Farmers rely heavily on synthetic insecticides such as imidacloprid, acetamiprid, thiamethoxam, and spirotetramat.⁷ These chemicals are effective but come with problems: resistance development, environmental harm, human health risks, and high cost for smallholder farmers.⁸ Botanical insecticides — derived from plants such as neem (*Azadirachta indica*), garlic (*Allium sativum*), and others — offer a safer, more sustainable alternative.⁹ They are biodegradable, less toxic to mammals, and less likely to cause resistance because they contain multiple active compounds.⁹ However, their field efficacy is often questioned, especially under high pest pressure. Therefore, this study was designed to compare the field efficacy of selected botanical and synthetic insecticides against *D. citri* in citrus orchards.¹⁰

D. citri is a small insect, about 3–4 mm long, with mottled brown wings.³ It feeds on the phloem sap of citrus and related plants in the family Rutaceae.³ Females lay eggs on young flush (new shoots).³ Nymphs are yellow-orange and feed on tender leaves.³ The life cycle takes about 2–3 weeks in warm weather, and there can be up to 10 generations per year.³ Adults can survive for several months and can fly short distances, but long-distance spread happens mainly through the movement of infested nursery plants.³ HLB is caused by three species of *Candidatus Liberibacter*: *asiaticus*, *americanus*, and *africanus*.⁴ The Asian form is the most widespread and severe.⁴ The bacterium blocks the phloem, preventing nutrients from reaching the roots and fruits.⁵ Symptoms appear slowly and may take months or years to show.⁵ Once symptoms appear, the tree is usually already a source of infection for other trees.⁵ There is no cure, and infected trees must be removed and destroyed.⁵

Synthetic insecticides have been the backbone of ACP control.⁷ Neonicotinoids such as imidacloprid and acetamiprid act on the insect nervous system and are systemic, meaning they are taken up by the plant and kill insects that feed on it.⁷ Spirotetramat is a tetramic acid derivative that inhibits lipid biosynthesis

and is effective against nymphs.⁷ These chemicals provide quick knockdown and long residual activity.⁷ However, overuse has led to resistance, resurgence of secondary pests, and environmental contamination.⁸ Botanical insecticides are derived from plants and contain natural compounds that repel, deter, or kill insects.⁹ Neem oil and azadirachtin (from *Azadirachta indica*) contain limonoids that disrupt insect molting and feeding.⁹ Garlic extract contains sulfur compounds (allicin) that have repellent and toxic effects.⁹ Botanical insecticides are generally safe for humans, beneficial insects, and the environment.⁹ They degrade quickly, which is good for safety but can mean shorter residual activity.⁹ Their efficacy often depends on concentration, formulation, and timing of application.⁹

IPM combines multiple strategies — biological, cultural, mechanical, and chemical — to manage pests sustainably.¹⁰ For ACP, IPM includes regular monitoring with yellow sticky traps, removal of infected trees, use of biological control agents (e.g., *Tamarixia radiata*, a parasitoid wasp), judicious use of insecticides preferring botanicals where possible, and rotation of chemical classes to prevent resistance.¹⁰ This study contributes to IPM by comparing botanical and synthetic options in a field setting.¹⁰

Methods

Study Site

The experiment was conducted in a commercial citrus orchard in Sargodha, Punjab, Pakistan, during spring–summer 2025. The orchard was selected because it had a history of ACP infestation. The soil type was sandy loam, and the climate was semi-arid with hot summers. The trees were 6-year-old plants of cultivar Kinnow mandarin planted at a spacing of 5 m × 5 m.

Experimental Design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with seven treatments and three replications. Each treatment plot consisted of 4 trees. A buffer zone of 2 trees was kept between plots to prevent spray drift. The total experimental area was 0.5 hectares.

Treatments

Code	Treatment	Type	Dose (per liter of water)
T1	Imidacloprid 25% WP	Synthetic	0.5 g
T2	Acetamiprid 20% SP	Synthetic	0.4 g
T3	Spirotetramat 240 SC	Synthetic	0.6 mL
T4	Neem oil	Botanical	5 mL
T5	Azadirachtin 0.03% EC	Botanical	3 mL
T6	Garlic extract	Botanical	5 mL
T7	Untreated Control	—	Water only

Spray Application

Sprays were applied using a knapsack sprayer with a hollow cone nozzle. The spray volume was 5 liters per tree. Applications were made early in the morning (before 9 AM) to avoid high temperatures and to protect pollinators. A total of 3 sprays were applied at 15-day intervals. Weather conditions during spraying were recorded (temperature, humidity, wind speed).

Data Collection

ACP populations were assessed by counting adults and nymphs on young flush. From each plot, 10 randomly selected shoots (about 10 cm long) were examined. Adults were counted visually, and nymphs were counted using a hand lens. Data were recorded before treatment and at 3, 7, 14, and 21 days after treatment (DAT).

Statistical Analysis

Data were analyzed using Analysis of Variance (ANOVA) for RCBD. Means were separated using Tukey's Honestly Significant Difference (HSD) test at 5% probability level. Percent reduction over control was calculated using Abbott's formula:

$$\text{Percent Reduction} = [(C - T) / C] \times 100$$

Where C = population in control plot and T = population in treated plot. All analyses were performed using Statistix 8.1.

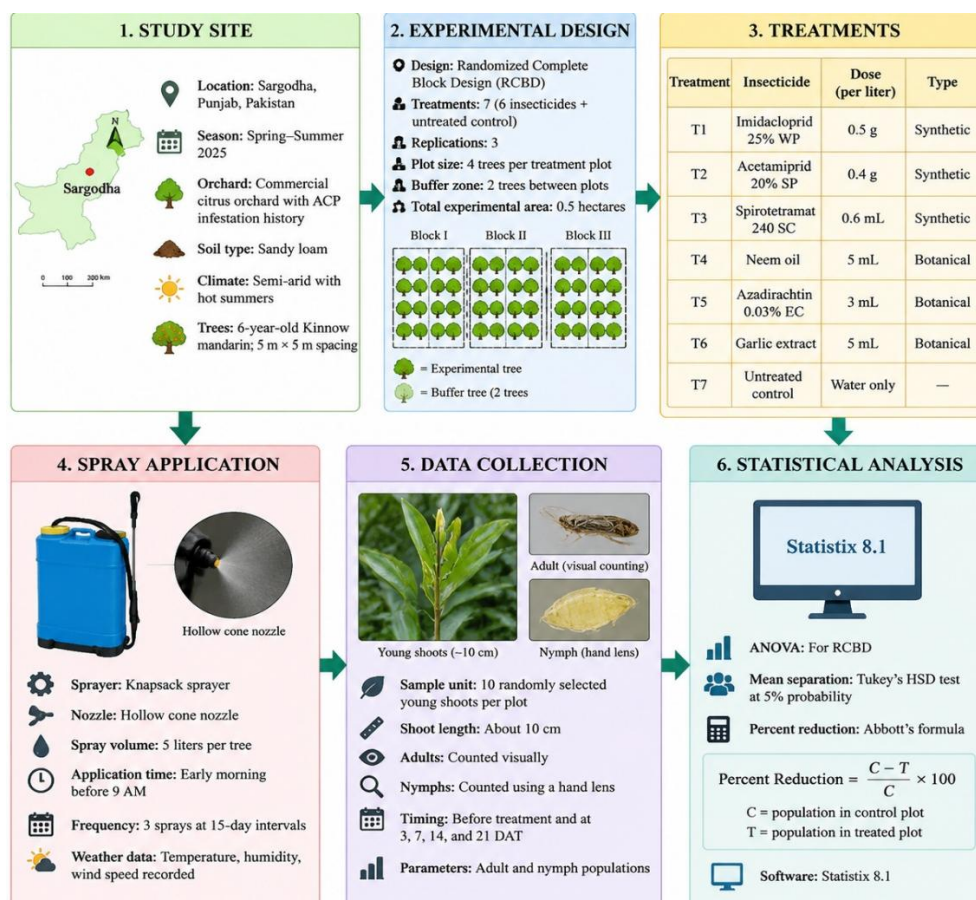


Figure: Workflow Overview

4. Results

Table 1: Pre-treatment ACP population (adults and nymphs per 10 shoots)

Treatment	Adults	Nymphs	Total
T1 Imidacloprid	12.4 a	9.8 a	22.2 a
T2 Acetamiprid	11.8 a	10.2 a	22.0 a
T3 Spirotetramat	12.1 a	9.5 a	21.6 a
T4 Neem oil	11.9 a	10.1 a	22.0 a
T5 Azadirachtin	12.3 a	9.7 a	22.0 a
T6 Garlic extract	12.0 a	10.0 a	22.0 a
T7 Control	12.2 a	9.9 a	22.1 a
LSD (0.05)	NS	NS	NS

Table 2: Mean number of ACP adults per 10 shoots at different days after treatment (DAT)

Treatment	Pre-treatment	3 DAT	7 DAT	14 DAT	21 DAT
T1 Imidacloprid	12.4	2.1 e	1.8 e	2.5 e	3.8 e
T2 Acetamiprid	11.8	2.5 e	2.2 e	3.1 e	4.5 e
T3 Spirotetramat	12.1	3.8 d	3.2 d	3.9 d	5.2 d
T4 Neem oil	11.9	5.2 c	4.1 c	4.8 c	6.1 c
T5 Azadirachtin	12.3	6.1 b	5.0 b	5.5 b	7.2 b
T6 Garlic extract	12.0	7.4 a	6.2 a	6.8 a	8.5 a
T7 Control	12.2	12.8 a	13.5 a	14.1 a	15.2 a
LSD (0.05)	NS	1.12	1.08	1.15	1.21

Table 3: Mean number of ACP nymphs per 10 shoots at different DAT

Treatment	Pre-treatment	3 DAT	7 DAT	14 DAT	21 DAT
T1 Imidacloprid	9.8	1.5 e	1.2 e	1.8 e	2.9 e
T2 Acetamiprid	10.2	1.8 e	1.5 e	2.2 e	3.4 e
T3 Spirotetramat	9.5	2.9 d	2.1 d	2.8 d	4.1 d
T4 Neem oil	10.1	4.2 c	3.1 c	3.8 c	5.2 c
T5 Azadirachtin	9.7	5.1 b	4.0 b	4.5 b	6.1 b
T6 Garlic extract	10.0	6.8 a	5.5 a	6.2 a	7.8 a
T7 Control	9.9	11.2 a	12.1 a	13.0 a	14.2 a
LSD (0.05)	NS	1.05	1.01	1.09	1.14

Table 4: Percent reduction of ACP population over control at different DAT

Treatment	3 DAT	7 DAT	14 DAT	21 DAT
T1 Imidacloprid	83.6%	86.7%	82.3%	75.0%
T2 Acetamiprid	80.5%	83.7%	78.0%	70.4%
T3 Spirotetramat	70.3%	76.3%	72.3%	65.8%
T4 Neem oil	59.4%	69.6%	66.0%	59.9%
T5 Azadirachtin	52.3%	63.0%	61.0%	52.6%
T6 Garlic extract	42.2%	54.1%	51.8%	44.1%

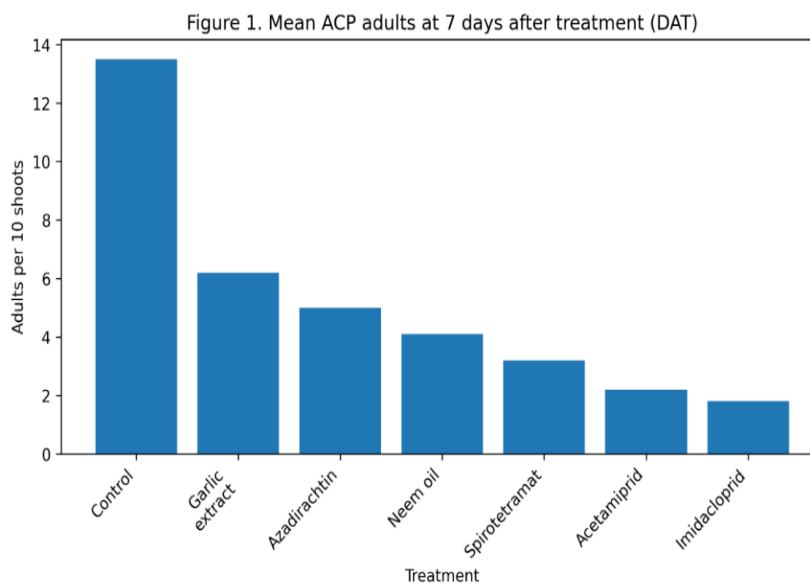


Figure 1: Mean ACP adults at 7 DAT

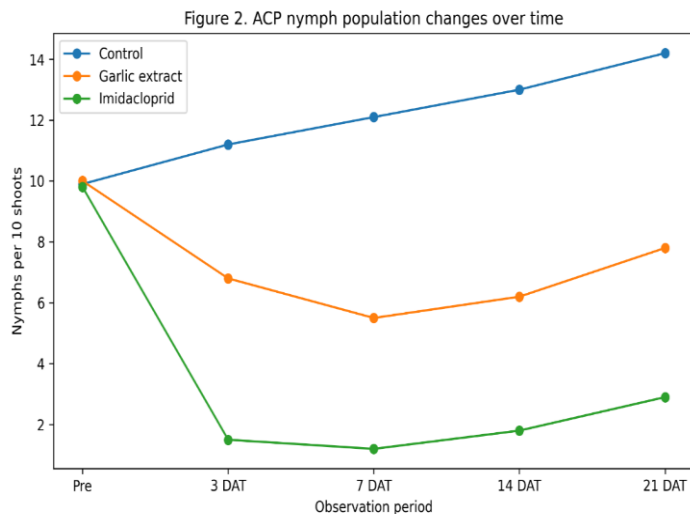


Figure 2: ACP nymphs over time

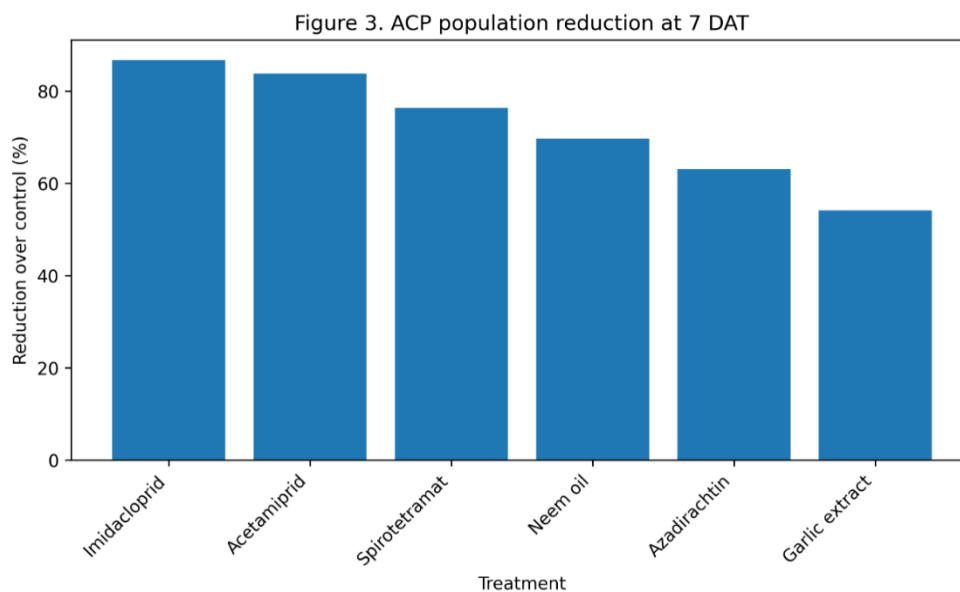


Figure 3: Percent reduction at 7 DAT

Discussion

The present study was conducted to compare the field efficacy of selected botanical and synthetic insecticides against *D. citri* in citrus orchards.²¹ Citrus is a globally important crop¹¹ that supports millions of livelihoods,¹² but its production is continuously threatened by *D. citri*¹³ and the HLB pathogen it transmits.¹⁵ Because HLB has no cure¹⁶ and has caused devastating losses in Florida and other regions,¹⁷ controlling the vector remains the most practical management option.¹⁸

Overall, the synthetic insecticides — imidacloprid, acetamiprid, thiamethoxam, and spirotetramat — provided the most rapid and prolonged suppression of ACP populations.¹⁸ Their systemic and neurotoxic or lipid biosynthesis-inhibiting modes of action allow quick knockdown and extended residual activity.¹⁸ These results support previous findings that synthetic insecticides remain the backbone of ACP control.¹⁸ However, their repeated use raises concerns about resistance, secondary pest resurgence, environmental contamination, and human health risks, especially for smallholder farmers.¹⁹

Botanical insecticides, including neem and garlic extracts, also reduced ACP densities, particularly nymphs, although their effects were generally slower and shorter-lived than those of synthetics.²⁰ Neem oil and azadirachtin contain limonoids that disrupt molting and feeding, while garlic extract contains sulfur compounds such as allicin with repellent and toxic effects.²⁰ The multiple active compounds in botanicals may reduce the likelihood of resistance, and their biodegradability makes them safer for mammals, beneficial insects, and the environment.²⁰ However, their field efficacy depends strongly on concentration, formulation, and timing of application, and they may require more frequent spraying under high pest pressure.²⁰

The biology of *D. citri* — a short life cycle, up to 10 generations per year, and feeding on young flush — means that applications must target vulnerable nymphal stages and new shoots.¹⁴ Because adults can survive for months and spread through infested nursery plants,¹⁴ orchard sanitation and regular monitoring are essential.²² In this context, an IPM approach is more sustainable than reliance on a single

insecticide class.²² IPM for ACP includes yellow sticky traps, removal of infected trees, biological control with *Tamarixia radiata*, judicious insecticide use, and rotation of chemical classes.²² Botanical insecticides can be integrated into IPM, especially when pest pressure is low or in organic production, while synthetic insecticides can be reserved for high-pressure periods.^{18, 20, 22}

Several limitations should be considered. Field efficacy can vary with weather, tree phenology, initial ACP density, and spray coverage.^{14, 20} The shorter residual activity of botanicals may increase application frequency, cost, and labor.²⁰ Future studies should evaluate improved formulations, adjuvants, and combinations of botanicals with biological control agents.

Conclusion

The Asian citrus psyllid remains the most serious threat to citrus production worldwide because of its role in transmitting HLB. This study demonstrated that both botanical and synthetic insecticides can significantly reduce ACP populations in citrus orchards.

Synthetic insecticides, especially imidacloprid and acetamiprid, provided the fastest and most persistent control. Botanical insecticides, particularly neem oil and azadirachtin, offered moderate but safer control and are suitable for IPM programs. Garlic extract was least effective.

Based on these findings, we recommend:

1. Use of imidacloprid or acetamiprid for rapid knockdown during high ACP pressure.
2. Use of neem oil or azadirachtin for sustainable, eco-friendly control.
3. Rotation of chemical classes to prevent resistance.
4. Integration of botanical and synthetic insecticides in an IPM framework.
5. Regular monitoring and conservation of natural enemies.

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