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Research Article

Comparative Assessment of Toxicity of Selected Insecticides against Key Sucking insect Pests of Cotton

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ABSTRACT

Sucking insect pests, including *Bemisia tabaci* (whitefly), *Amrasca devastans* (jassid), and *Thrips tabaci* (thrips), cause substantial yield losses in cotton, with reported reductions of up to 40%. To evaluate effective management options, a field experiment was conducted in Muzaffargarh, South Punjab, Pakistan, to assess the toxicity of five insecticides, Nitenpyram, Acephate, Amidecloprid, Buprofezin, and Diafenthiuron, against Bt cotton (*Gossypium hirsutum* L. cv. IUB-B). The experiment was laid out in a randomized complete block design with three replications, and pest populations were recorded at 24, 48, and 72 h after insecticide application. The results revealed that all insecticidal treatments significantly reduced pest populations compared with the untreated control ($p < 0.05$). Among the tested insecticides, Acephate exhibited the highest overall efficacy, reducing *B. tabaci* populations to 3.64 individuals at 48 h compared with 15.56 individuals in the control, and completely suppressing *T. tabaci* populations by 72 h (control: 4.02 individuals). Diafenthiuron was particularly effective against *A. devastans*, reducing its population to zero within 48 h, compared with 14.9 individuals in the untreated plots. Nitenpyram and the remaining insecticides also caused significant population reductions, though to a comparatively lesser extent. These findings demonstrate the strong field efficacy of Acephate and Diafenthiuron against major cotton sucking pests. However, prolonged reliance on chemical insecticides may accelerate resistance development and pose environmental risks. Therefore, the integration of these insecticides into an Integrated Pest Management framework, incorporating insecticide rotation, biological control agents, and reduced chemical inputs, is strongly recommended to ensure sustainable and long-term pest management in cotton production systems.

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Introduction

Industrialization in agriculture has led to a substantial transformation in global farming systems. Milestones such as the Green Revolution have driven major breakthroughs in crop production. These advances include the extensive use of synthetic pesticides, genetically engineered crops, chemical fertilizers, and novel crop breeding methods (Hamdan et al., 2022). Cotton (*Gossypium hirsutum* L.) has been directly influenced by these innovations and is one of the major

crops cultivated in Pakistan (Shahzad et al., 2022). Pakistan is the world's fourth-largest cotton producer and the third-largest consumer and exporter of raw cotton (Anwar et al., 2022). The cotton sector plays a critical role in the national economy by supporting the textile industry, generating foreign exchange, creating employment, and contributing to overall economic development (Tariq et al., 2023).

Pakistan's predominantly tropical and subtropical climate, especially in Punjab and Sindh, supports extensive cotton cultivation. Cotton grows optimally at temperatures ranging from 21°C to 30°C, which provide favorable conditions for achieving high yields (Arshad et al., 2021). Despite its importance, cotton production is severely threatened by numerous insect pests and diseases. More than 1,326 insect species have been reported to attack cotton, making it the crop with the highest number of associated pests (Belachew et al., 2024). Among these, the most destructive are the sap-sucking insects, including *Bemisia tabaci* (whitefly), *Aphis gossypii* (aphid), and *Amrasca devastans* (jassid). These pests cause significant economic damage, leading to annual yield losses estimated between 20% and 40%.

The cotton industry has increasingly relied on chemical insecticides to suppress pest populations, placing additional financial pressure on the agricultural economy. One of the major advancements in pest management was the introduction of Bt cotton, genetically engineered to resist bollworms and reduce losses from lepidopteran pests. However, Bt cotton does not protect against sucking pests, which continue to pose major challenges for cotton growers (Razzaq et al., 2023). This limitation highlights the need for complementary pest management strategies, including targeted chemical controls.

Although genetically modified crops were introduced to enhance pest management, the release of Bt cotton was followed by a rapid increase in sucking pest populations, leading to heavier reliance on traditional insecticides. Excessive pesticide use has accelerated the development of insecticide resistance in many pest species (Araujo et al., 2013). The emergence of resistance further complicates pest management by reducing insecticide efficacy, requiring higher application rates, and aggravating environmental and economic consequences.

The aim of the present study was to determine the toxicity of five commercial insecticides, Nitenpyram, Acephate, Amideclubrid, Buprofezin, and Diafenthiuron, against the most prevalent sucking pests of cotton. The study provides essential data on the efficacy of these insecticides under field conditions. The findings will support farmers in making informed decisions regarding pest control, helping to maintain high yields and reduce losses caused by sucking insects. Furthermore, this research contributes to integrated pest management (IPM) by promoting more sustainable and environmentally sound cotton production practices.

Material and methods

Experimental site and crop establishment

Field experiments were conducted during 2020 cotton-growing season at a farm area, in district Muzaffargarh under World Wildlife Foundation (WWF) in South Punjab, Pakistan, to evaluate the efficacy of selected insecticides against major sucking insect pests of cotton. The experimental site lies within a semi-arid agro-ecological zone, characterized by hot summers and conditions favorable for the proliferation of sucking insect pests. Prior to sowing, the field was prepared through standard tillage operations to achieve a fine seedbed. Uniform agronomic practices, including fertilizer application, irrigation scheduling, and weed management, were maintained across all experimental plots to eliminate confounding effects due to cultural practices.

An approved cotton variety, NIAB-9242, widely cultivated in the region for its yield potential, was sown on 6 May 2020 following recommended row spacing and plant population guidelines applicable to Bt and non-Bt cotton production systems. Fertilizers were applied at regionally recommended rates to ensure optimal crop growth and uniform plant vigor across treatments.

Experimental design and treatments

The experiment was laid out in a randomized complete block design (RCBD) with three replications to minimize environmental variability and improve the precision of treatment comparisons. Each replication contained all insecticide treatments along with an untreated control. Five commercially available insecticides representing different Insecticide Resistance Action Committee (IRAC) mode-of-action groups were evaluated at their label-recommended doses: Acephate 75% WP at 0.3% a.i. (organophosphate; IRAC Group 1B), Nitenpyram 10% SL at 0.2% (neonicotinoid; Group 4A), Imidacloprid 15% SP at 0.1125% (neonicotinoid; Group 4A), Buprofezin 25% SC at 0.125% (chitin synthesis inhibitor; Group 16), and Diafenthiuron 50% WP at 0.375% (thiourea derivative;

Group 12A). An untreated control plot was maintained to assess natural pest population dynamics.

Insecticide application

Sucking pest infestation in the region typically initiates during the early vegetative stage of cotton; therefore, foliar insecticide applications were initiated approximately 15 days after sowing, when early pest incidence was observed. All treatments were applied using a manually operated hand sprayer that was carefully calibrated prior to spraying to ensure uniform spray volume and consistent coverage across the plant canopy. Applications were carried out under calm weather conditions to minimize spray drift and maximize deposition efficiency.

Pest monitoring and data collection

Population densities of the major sucking insect pests, whitefly (*Bemisia tabaci*), onion thrips (*Thrips tabaci*), and cotton jassid (*Amrasca biguttula biguttula*), were recorded from 10 randomly selected plants per plot. Observations were taken immediately before insecticide application (0 h) and subsequently at 24, 48, and 72 h after spraying to evaluate both immediate knockdown effects and short-term residual activity of the tested insecticides. Visual counts were conducted following standard entomological procedures during early morning hours to minimize diurnal variation in insect activity and improve data consistency.

Statistical analysis

The collected data were tested for normality and homogeneity of variance prior to analysis. Where necessary, appropriate data transformations, including square-root or logarithmic transformations, were applied to meet the assumptions of parametric analysis. A two-way analysis of variance (ANOVA) was performed using SAS statistical software (version 9.4), considering insecticide treatments and sampling time as main factors. Treatment means were separated using Duncan's Multiple Range Test (DMRT) at a 5% probability level. In tables and figures, means followed by different letters indicate statistically significant differences ($p < 0.05$) among treatments within each observation interval.

Results

All tested insecticides exhibited significant efficacy against the major sucking insect pests of cotton compared with the untreated control. Pest populations declined markedly following application, with clear treatment-specific differences observed within 48-72 h after spraying.

Whitefly

All insecticidal treatments resulted in a significant reduction in whitefly populations compared with the control (Figure 1). At 48 h after application, Acephate produced the lowest mean whitefly density (3.64 individuals per sampling unit), which was significantly lower than that recorded in the untreated plots (15.56 individuals; ANOVA, $p < 0.01$). Amidecloprid and Diafenthiuron were also highly effective, reducing whitefly populations to approximately 4.5-5.5 individuals per unit, corresponding to a reduction exceeding 60% relative to the control (DMRT, $p = 0.05$).

Buprofezin and Nitenpyram provided moderate but still significant suppression, with mean populations of approximately 7-8 individuals per unit. Based on mean whitefly densities at 48 h, the overall efficacy of insecticides against *B. tabaci* followed the order: Acephate > Amidecloprid ≈ Diafenthiuron > Buprofezin ≈ Nitenpyram. All treatments differed significantly from the control, and statistically significant differences among insecticides were evident (Figure 1).

Thrips

Thrips populations were significantly reduced by all insecticidal treatments compared with the untreated control (Figure 2). In the control plots, thrips densities remained relatively high, reaching an average of approximately 4.0 individuals per plant at 72 h after spraying. In contrast, Acephate induced a rapid and complete suppression of thrips, with population levels declining to zero within 48 h and remaining at zero through 72 h ($p < 0.01$).

Diafenthiuron and Amidecloprid also provided near-complete control, reducing thrips densities to approximately 0.1-0.2 individuals per plant at 48 h. Nitenpyram and Buprofezin significantly lowered thrips populations as well, with mean densities of approximately 0.8-1.5 individuals per plant at 48 h, which were still significantly lower than those observed in the control plots (DMRT, $p < 0.05$). Overall, all five insecticides achieved more than 75% reduction in thrips populations within 48 h, with Acephate showing the fastest and most pronounced knockdown effect (Figure 2).

Jassid

All insecticides caused a pronounced reduction in jassid populations relative to the control (Figure 3). At 48 h post-treatment, Diafenthiuron-treated plots recorded almost complete suppression of jassids (mean ≈ 0.0),

which was significantly lower than the untreated control (mean 14.9; $p < 0.01$). Acephate and Amidecloprid were similarly effective, reducing jassid populations to approximately 0.8-1.2 individuals per plant.

Buprofezin and Nitenpyram resulted in moderate but significant control, lowering jassid densities to approximately 3.0-3.5 individuals per plant, which remained significantly lower than the control ($p < 0.05$). Based on mean jassid counts at 48 h, the relative efficacy of treatments followed the order: Diafenthiuron ≈ Acephate > Amidecloprid > Buprofezin ≈ Nitenpyram.

Analysis of variance revealed a highly significant effect of insecticidal treatments on pest populations across all three species (ANOVA, $p < 0.01$). Mean separation using Duncan's Multiple Range Test (DMRT) at the 5% probability level confirmed significant differences among treatments (Figures 1-3).

In summary, all five insecticides significantly suppressed populations of whiteflies, thrips, and jassids during the 3-day observation period. Acephate (organophosphate) and Diafenthiuron (metabolic inhibitor) consistently resulted in the lowest pest densities, while Amidecloprid, Nitenpyram, and Buprofezin also provided effective, though comparatively moderate, control. In contrast, untreated control plots maintained consistently high pest populations throughout the monitoring interval.

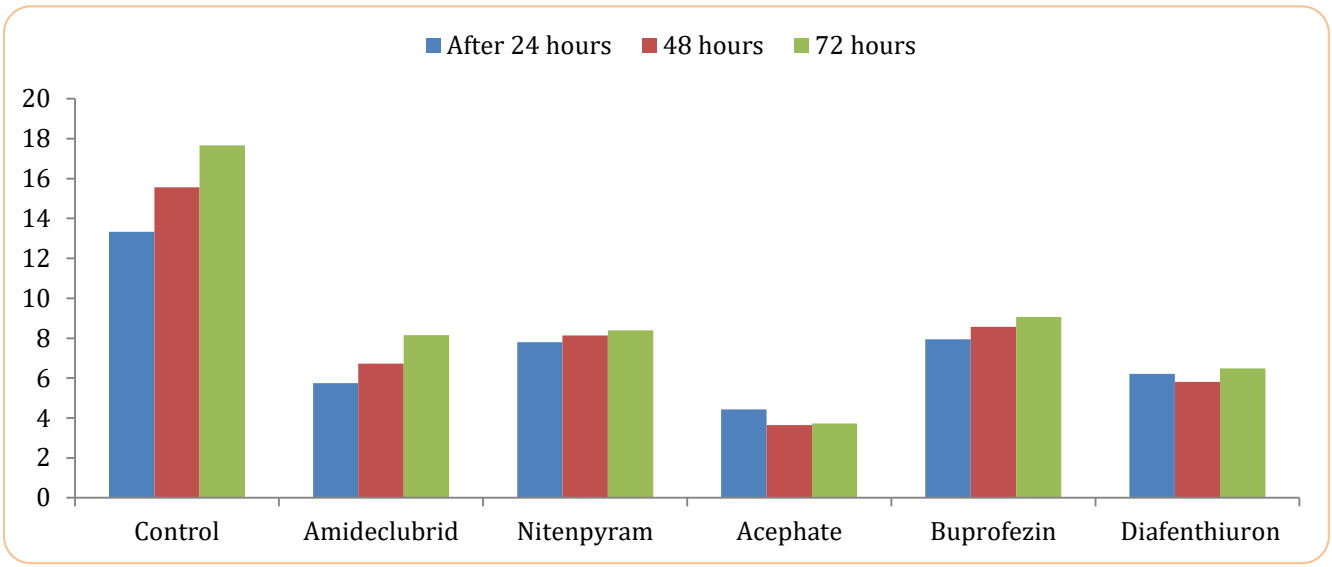


Figure 1. Mean population-level efficacy of the tested insecticides against cotton whitefly.

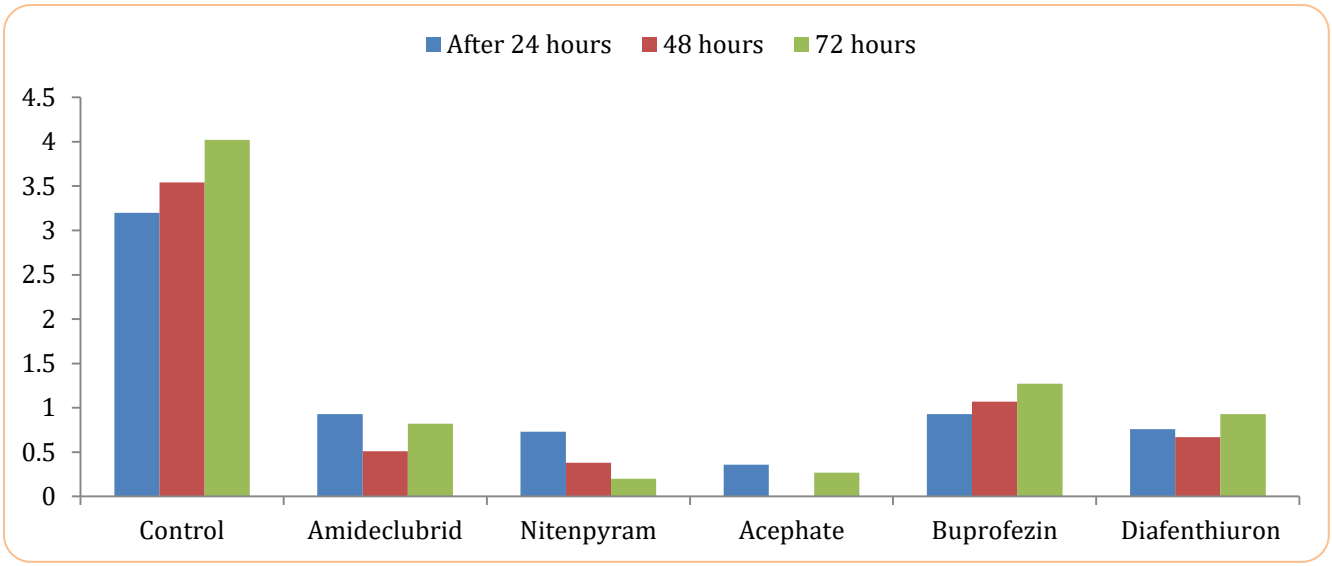


Figure 2. Mean efficacy of the tested pesticides against cotton thrips.

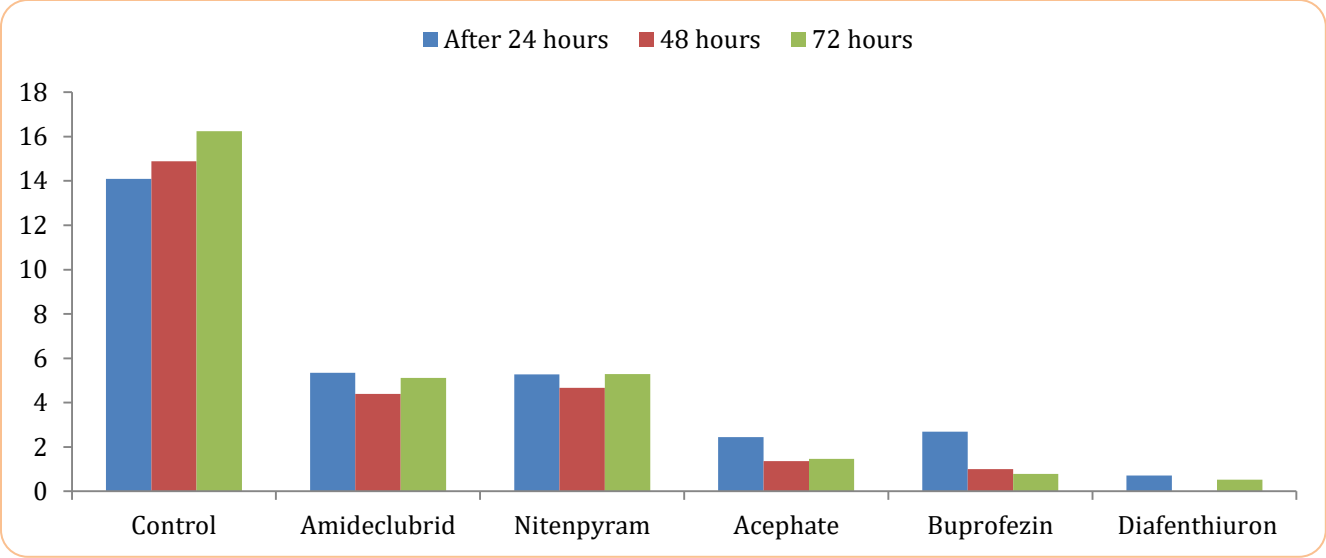


Figure 3. Mean population reduction efficiency of the tested pesticides against cotton jassid.

Discussion

The present study clearly demonstrates the effectiveness of commonly used broad-spectrum and systemic insecticides in suppressing major sucking insect pests of cotton, including *Bemisia tabaci* (whitefly), *Thrips tabaci* (thrips), and *Amrasca devastans* (jassid). Among the tested compounds, Acephate and Diafenthiuron consistently produced the highest levels of pest mortality and the most rapid population decline. These findings corroborate earlier reports indicating that such insecticides are capable of achieving near-complete knockdown of sucking pest populations under field conditions (Hemalatha, 2019).

Acephate, an organophosphate insecticide, exerts its toxic effects by inhibiting acetylcholinesterase (AChE), a key enzyme involved in terminating nerve impulses at synaptic junctions. Inhibition of AChE leads to the accumulation of acetylcholine, resulting in continuous nerve stimulation, neuromuscular hyperexcitation, paralysis, and eventual death of the insect (Oyugi et al., 2024). The rapid reduction in whitefly and thrips populations observed in this study is consistent with the irreversible inhibition of AChE and explains the fast-acting nature of Acephate reported by Chandraleka et al. (2024). However, the similarity of Acephate's mode of action to that of other organophosphates and carbamates increases the risk of cross-resistance, which has been widely documented in sucking insect pests (Abobakr et al., 2022).

Diafenthiuron exhibited strong and sustained toxicity against all three pest species, particularly *A. devastans* and *T. tabaci*. This compound acts by inhibiting mitochondrial oxidative phosphorylation, thereby disrupting ATP synthesis and depriving insect cells of metabolic energy. Although its mode of action is relatively slower than that of neurotoxic insecticides, the resulting energy deficiency ultimately leads to irreversible cellular dysfunction and death, particularly in actively feeding and developing tissues (Schmitt et al., 2021). The pronounced reduction in pest populations observed at later observation intervals supports this delayed yet highly effective mechanism.

Nitenpyram and Amidecloprid, both neonicotinoid insecticides, function as agonists of insect nicotinic acetylcholine receptors (nAChRs), causing persistent neuronal excitation and paralysis (Lu et al., 2022; Thany et al., 2023). Their efficacy against whiteflies and thrips in the present study reflects their rapid systemic action during feeding. However, increasing evidence of neonicotinoid resistance, driven by mutations in nAChR subunits (e.g., the R81T mutation) and enhanced detoxification mediated by cytochrome P450 monooxygenases, poses a serious challenge to their long-term effectiveness (Zhang et al., 2022). These resistance mechanisms emphasize the necessity for judicious use and rotation of neonicotinoids within pest management programs.

Buprofezin, an insect growth regulator, interferes with chitin synthesis during molting and primarily affects immature stages rather than adults. Its comparatively

slower onset of action observed in this study is consistent with its requirement for ingestion and its dependence on the molting process (Pan et al., 2025). Nonetheless, the significant reduction in whitefly and jassid populations by the third day after application indicates its effectiveness against nymphal stages. Resistance to Buprofezin has been associated with metabolic detoxification and target-site alterations, further reinforcing the importance of resistance management strategies (Al-Naggar et al., 2025).

Despite the high efficacy of Acephate and Diafenthiuron, excessive reliance on broad-spectrum insecticides carries substantial ecological risks. Resistance associated with mutations in the *ace-1* gene and increased activity of detoxifying enzymes such as esterases and cytochrome P450s has been reported in whiteflies, thrips, and aphids (Samal et al., 2022; Renault et al., 2023). Moreover, the non-selective nature of these insecticides can adversely affect non-target organisms, including natural enemies and pollinators such as bees and ladybird beetles, thereby disrupting agroecosystem balance (Naz et al., 2023).

The findings of this study strongly support the adoption of Integrated Pest Management (IPM) strategies to mitigate resistance development and minimize environmental harm. IPM offers a sustainable framework by integrating chemical control with non-chemical approaches, including biological control using predators and parasitoids, cultural practices, and host plant resistance. Rotating insecticides with different modes of action, optimizing application timing and frequency, and reducing unnecessary foliar sprays can significantly delay resistance development. Moreover, alternative approaches such as seed treatments and targeted systemic applications may reduce overall pesticide load and exposure of non-target organisms.

Conclusion

In conclusion, the present study demonstrated that all five evaluated insecticides significantly suppressed populations of major sucking insect pests of cotton. Acephate and Diafenthiuron provided the most rapid and effective control, while Amidecloprid, Nitenpyram, and Buprofezin also achieved substantial reductions in pest densities. These results confirm that chemical insecticides remain an important component of cotton pest management when used responsibly.

However, prolonged reliance on a single insecticide or mode of action can accelerate resistance development and increase ecological risks. Therefore, it is recommended that cotton pest management programs adopt insecticide rotation, integrate chemical and non-chemical control measures, and routinely monitor pest susceptibility. Maintaining unsprayed refuges and incorporating safer alternatives, such as botanical insecticides and entomopathogenic organisms, will further enhance sustainability. Future research should focus on developing eco-friendly pest management strategies that effectively suppress pest populations while preserving beneficial organisms and maintaining long-term agroecosystem health.

Authors' Contributions

MAB and MN conceptualized and designed the study. AA performed the field experiment, analyzed the data and drafted the original manuscript. MAB and MN provided critical guidance, constructive feedback, and valuable suggestions to improve the content and clarity of the manuscript. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work, ensuring accuracy and integrity in reporting.

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Conflict of Interest

The authors declare no conflict of interest.

Sustainable Development Goals Targeted

SDG 2: Zero Hunger
SDG 12: Responsible Consumption and Production
SDG 15: Life on Land

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