

Evaluation of the effectiveness of chemical control agents against *Bemisia tabaci* (Genn.) on cucumber plants

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Abstract

A field trial conducted in Al-Alam, Salah Al-Din (Iraq) evaluated Sivanto Prime (flupyradifurone), azadirachtin, and potassium silicate, applied alone or in combination, against the whitefly *Bemisia tabaci* on cucumber. The three-way mixture T9 (Sivanto Prime + potassium silicate + azadirachtin) was the most reliable option across sampling dates. Adult densities declined to 0.05 insects in⁻² by 28 days after spraying, with corrected mortalities of 98.49% versus the water control and 95.50% versus acetamiprid. For nymphs, the mixture recorded 4.49 nymphs in⁻² at 14 days, with corrected efficiencies of 69.47% and 43.80%, respectively. Sivanto Prime alone produced the fastest early knockdown in nymph counts (6.31 and 5.98 nymphs in⁻² at 1 and 3 days), giving corrected mortalities of 47.81–48.70% (vs. water) and 46.40–48.08% (vs. acetamiprid), and it achieved 97.48% corrected mortality for adults by day 28. Azadirachtin performed weakest on nymphs (36.77% corrected) and reached 88.80% for adults at 28 days. Suppression translated into better crop performance: the three-way mixture raised yield to 1466.11–1489.44 g plant⁻¹ compared with 827.8–851.6 g plant⁻¹ in the two controls, and increased leaf chlorophyll to 12.22 SPAD units versus 7.16 with water. Overall, combining distinct modes of action delivered more durable control than single products and improved both physiological and yield traits. The findings suggest that the T9 mixture (30 mL/100 L (Sivanto), 50 mL/100 L (potassium silicate), 125 mL/100 L (azadirachtin) should be used in the integrated pest management of cucumber. Since these results are from a single location and season, further studies on multi-location, multi-season validation and economic evaluation should be conducted.

Keywords: : Azadirachtin, *Bemisia tabaci*, cucumber, nymphs, potassium silicate, Sivanto Prime, treatments

Introduction

Whiteflies of the *Bemisia tabaci* species complex are among the most damaging pests of cucurbits in both protected and open-field production systems. On cucumber (*Cucumis sativus* L.), they reduce plant vigour through phloem feeding and honeydew contamination, as well as promote sooty mould that lowers marketable yield. *B. tabaci* transmits a set of viruses that infect whiteflies, especially begomoviruses, which lead to more virus-induced losses and management decision complications in integrated programs (Li et al., 2021).

Chemical strategies form a key component of whitefly control. However, extensive use of a narrow range of active ingredients over the long term has led to the development of resistance in various locations. Resistance pressure and benefits from protecting beneficials and delaying resistance evolution have led to interest in chemistries that have distinct structural

characteristics and more favourable ecotoxicological profiles (Nauen et al., 2015). Flupyradifurone is a butenolide insecticide which is a reversible agonist of insect nicotinic acetylcholine receptors (nAChRs) and is not a neonicotinoid. Laboratory and field studies report rapid knockdown of phloem feeders and strong systemic activity via xylem mobility, enabling flexible application methods (Nauen et al., 2015). Splendidly, flupyradifurone treatments lead to reduced transmission of tomato yellow leaf curl virus in a whitefly-infested system. The fast feeding suppression is invaluable along with adult mortality (Roditakis et al., 2017).

At the same time, the focus on “softer” tools, which can be combined with insecticides to enhance crop tolerance and lower pest pressure, is also growing. Botanical products such as azadirachtin and some essential-oil formulations continue to find niches in vegetable IPM programs, although performance is

unpredictable and often context-dependent (Isman, 2020). Another option we can use is silicon-based amendments. Silicon is potentially beneficial for many crops used in protected cultivation. For example, it can reduce feeding success and increase biotic and abiotic resistance by enhancing structural and biochemical defences (for example, strengthening epidermis barriers, modulating defence signalling and secondary metabolites, and so on) when supplied as potassium silicate. Such effects can be pronounced under sustained or recurring infestations. It is likely that tougher leaf tissues and changes to the plant chemistry could lower the fitness and virus acquisition efficiency of whitefly (Ashok et al., 2024).

Evaluations combining novel nAChR modulators with plant-mediated fortification have now become compelling. The practical goal is to achieve season-long suppression without harming natural enemies and delaying resistance development through a range of tactics. Cucumber systems are where tight harvest schedules, fast canopy growth and virus risk converge, making them ideal test cases to evaluate alone versus mixtures or sequences that combine a butenolide insecticide with potassium silicate within spray intervals (Nauen et al., 2015; Roditakis et al., 2017; Ashok et al., 2024).

The study aimed to: (i) quantify the field efficacy of selected chemicals against *B. tabaci* on cucumber, (ii) compare single-product programs versus mixture/sequence programs involving potassium silicate, (iii) assess impact on adult/immature suppression and commercial performance under varying pest loads, and (iv) make IPM-compatible recommendations that balance efficacy with stewardship by combining a modern nAChR-acting butenolide with a potassium silicate.

Materials and methods

Experiment study

A field experiment was set up during the cucumber season in Al Alam District, Salah Al-Din Governorate, Iraq. The hybrid cucumber cultivar 'Ghazir' (Seminis, USA) has been used. Seedlings were raised for 14 days in peat-moss trays and transplanted to plots with drip irrigation. The Iraqi Ministry of Agriculture recommended standard cultural practices such as irrigation, fertilisation, and weeding.

Experimental design and treatments

The piece of land chosen for the agricultural experiment was ploughed, levelled and divided into three rows by keeping a distance of 2 meters per row. In

each row, a tubing system was fitted, and seedlings were planted at a distance of 40 cm per plant. In agricultural tests and studies, the treatments were separated by 1 meter to avoid interference. According to the guidelines of the Iraqi Ministry of Agriculture for planting and maintaining cucumbers, irrigation, weeding, and fertilisation were performed on the studied crops. The trial was performed in a randomised complete block design (RCBD) with three replications. Each of the plots had one row, with 40 cm spacing between the plants. The next treatments were assessed:

T1= Water (untreated control)

T2= Acetamiprid 20% SP (30 mL/100 L water; common farmer practice)

T3= Flupyradifurone (Sivanto Prime, 30 mL/100 L)

T4= Potassium silicate 10% (50 mL/100 L)

T5= Azadirachtin 1% (125 mL/100 L)

T6= Flupyradifurone (Sivanto Prime) + Potassium silicate

T7= Flupyradifurone (Sivanto Prime) + Azadirachtin

T8= Potassium silicate + Azadirachtin

T9= Flupyradifurone (Sivanto Prime) + Potassium silicate + Azadirachtin

Spraying was applied using a 15-L knapsack sprayer in the late afternoon under calm weather to avoid drift. For mixture treatments, products were applied sequentially with careful cleaning of the sprayer between applications, ensuring accurate delivery.

Insect population assessment population assessment

Whitefly populations were recorded one day before spraying and at 1, 3, 7, 14, 21 and 28 days after treatment. Three random plants were selected per plot, and then for each plant, three leaves were chosen for examination. During the time when insects were inactive, adults were counted in the evening, and nymphs in the morning, using a 20× hand lens. The same field methods applied for assessing *B. tabaci* have been validated in recent bioefficacy studies (Issa et al., 2022; Caspary et al., 2023). Drawing on experience from pest studies of vegetables, three plants per plot and three leaves per plant were chosen. The sampling method provides a good representative range of the insect, from the upper leaves and middle leaves to the lower leaves, with enough replication for further statistics. In addition, it does not damage the plant and does not require a lot of labour. According to earlier field studies of *B. tabaci*, this sampling intensity gives reliable estimates of density and unambiguous treatment separation.

Yield and chlorophyll measurements

At harvest, fruit yield was measured per plant from the central row plants. Leaf chlorophyll content was estimated with a SPAD-502 meter (Konica Minolta, Japan) on three fully expanded leaves per plant, following protocols used in recent whitefly impact studies (Lee et al., 2018).

Visual observations

Plants were monitored for visible symptoms (leaf burn, curling, discolouration). No adverse effects were recorded in any treatment. The treated plants were monitored daily throughout the study period, and readings were taken after 1, 3, 7, 14, 21, and 28 days.

Identification of whitefly

Samples were taken from various stages of the insect and were prepared and sent to the Plant Protection Department/College of Agriculture/ University of Tikrit. The results revealed that the species was identified as *Bemisia tabaci*. It belongs to the order Hemiptera, family Aleyrodidae. Identification was done by Prof. Dr Mohammed Shaker Mansor / Department of Plant Protection / College of Agriculture / University of Tikrit.

Data analysis

Mortality data were corrected using the Henderson–Tilton formula, which remains a standard approach in insecticide efficacy trials (Flemings & Ratnakaran, 1985; [Nature, 2025]). Data were analysed using SAS software (Version 9.4, SAS Institute, Cary, NC, 2016). Analysis of variance (ANOVA) was performed, and means were compared using Duncan's Multiple Range Test at a significance level of $p \leq 0.05$.

the results of Duncan's multiple range test. The triple treatment, which included all study factors Azadirachtin + Potassium silicate + Sivanto Prime (T9), recorded the lowest average numbers of whitefly nymphs during the counting periods of 7, 14 and 21 days after treatment, reaching 6.29, 4.49 and 7.04 nymphs/inch², achieving the highest killing rates, which reached (69.05 and 44.4%) and (69.47 and 43.8%) compared to the water T1 and Acetamprid treatments T2, respectively, and with a significant difference from other treatments according to Duncan's test.

The effect of treatments on the adult *B. tabaci*

Table 2 shows the average numbers of whitefly adults after treatment with study factors and their various combinations, and the corrected mortality rates compared to the water and acetamiprid treatments. The results showed that all study factors affected the insect population density, but to varying degrees. It was observed that the quadrilateral combination (which included the three factors) Azadirachtin + Potassium silicate + Sivanto Prime achieved the best results, with averages of 0.41, 0.36, 0.3, 0.19, 0.07, and 0.05 insects/inch² during all counting periods: 1, 3, 7, 14, 21, and 28 days after control. The highest mortality rates reached (87.09 and 81.6%), (82.68 and 81.5%), (76.92 and 81.1%), and (90.99% and 84.9%), (97.01 and 94.3%) and (98.49 and 95.5%) compared to water (T1) and acetamprid pesticide (T2) for each of them, respectively and with significant differences from all other treatments according to Duncan's test.

The results of the present study are consistent with those of Zewain et al. (2018) when testing the efficiency of Closer pesticide at concentrations of 3.5, 7, 10 and

$$\text{Rate of correction} = \left\{ \left(1 - \frac{\text{P. D. in comparative before spray} \times \text{P. D. in treatment after spray}}{\text{P. D. in comparative after spray} \times \text{P. D. in treatment before spray}} \right) \times 100 \right\}$$

P.D.= Population density of insect.

Results and Discussion

Effect of treatments on *B. tabaci* nymphs

The results of **Table 1** indicate that the best results were recorded for the Sivanto Prime pesticide (T3) treatment after one and three days of control. Average nymph numbers during these treatments were 6.31 and 5.98 nymphs/inch², achieving mortality rates of (47.81 and 48.7%) and (48.08 and 46.4%) compared to the water (T1) and Acetamprid pesticide (T2) treatments, respectively. These results showed significant differences from the kill rates recorded by other treatments, according to

14 ml/30 litres of water compared to Radiant 240SC pesticide at a concentration of 15 ml/30 litres of water on the dubas bug. Very good control results were shown for the numbers of nymphs and adults of the dubas bug at different concentrations of Closer pesticide after 35 days of control, as the concentration of 3.5 ml/30 liters of water achieved a corrected control efficiency of 89.3%, while the concentrations of 7, 10 and 14 ml/30 liters ranged between 93.3-94.6% during the same period after spraying, while Radiant 240SC pesticide at a concentration of 15 ml/30 liters achieved an efficiency of 91.5%.

The poor performance of potassium silicate

Table 1. Effect of treatments on the average numbers of whitefly nymphs with mortality rate.

Treatments	The average number of whitefly nymphs with a mortality rate						
	After 1 day	After 3 days	After 7 days	After 14 days	After 21 days	After 28 days	Average
T3 Sivanto Prime	6.31 (a 47.81) (a 48.7)	5.98 (a 48.08) (a 46.4)	5.98 (a 48.08) (a 46.4)	7.93 (e 51.54) (e 10.7)	8.51 (c 54.77) (c 16.7)	9.13 (c 51.71) (c 30.1)	7.11 (a 54.1) (a 33.5)
T4 Potassium silicate	11.71 (g 10.68) (g 12.3)	9.4 (i 24.73) (i 22.3)	9.4 (i 24.73) (i 22.3)	9.53 (l 46.28) (l 1.1)	10.82 (h 46.96) (i 2.4)	12.2 (f 40.49) (f 13.9)	10.33 (i 38.5) (i 11)
T 5 Azadirachtin	10.91 (h 6.03) (h 7.8)	9.09 (j 17.81) (j 15.2)	9.09 (j 17.81) (j 15.2)	8.2 (j 47.81) (j 3.9)	9.47 (g 47.58) (h 3.5)	11.48 (j 36.77) (j 8.5)	9.45 (l 36.5) (l 8)
T 6 Potassium silicate + Siva.	9.53 (f 16.67) (f 18.2)	8.07 (g 25.93) (g 23.6)	8.07 (g 25.93) (g 23.6)	7.47 (d 51.73) (d 11.1)	9.58 (j 46.17) (k 0.9)	10.67 (g 40.34) (g 13.7)	8.49 (f 42.1) (f 16.1)
T7 Aza.+ Siva.	9.13 (e 18.77) (e 20.2)	8.04 (h 24.91) (h 22.5)	8.04 (h 24.91) (h 22.5)	7.89 (i 48.13) (i 4.5)	9.44 (k 46.02) (l 0.6)	11.58 (l 34.11) (l 4.7)	8.56 (g 40.6) (g 14)
T8 Aza.+ Potassium silicate	8.95 (c 26.22) (c 27.6)	8.18 (e 29.22) (e 27)	8.18 (e 29.22) (e 27)	8.22 (f 49.93) (f 7.8)	9.42 (e 50.1) (e 8.1)	11.47 (i 39.54) (i 12.5)	8.76 (e 43.7) (e 18.4)
T9 Aza.+ Potassium silicate + Siva.	9.71 (g 10.66) (g 12.3)	6.29 (c 39.25) (c 37.3)	6.29 (c 39.25) (c 37.3)	4.49 (a 69.47) (a 43.8)	7.04 (b 58.37) (b 23.4)	8.13 (b 52.16) (b 30.8)	6.66 (b 52.2) (b 30.8)

The values followed by the same letter are not significantly different from each other; each value represents the average of three replicates.

Table 2. Effect of control factors on the average number of whitefly adults with the corrected mortality rate compared to water and the pesticide Acetamiprid

Treatments	The average number of whitefly nymphs with the corrected mortality rate						
	After 1 day	After 3 days	After 7 days	After 14 days	After 21 days	After 28 days	Average
Sivanto Prime	0.82 (c 69.14) (c 56.1)	0.37 (b 78.72) (b 77.2)	0.36 (c 71.44) (c 76.6)	0.26 (d 85.26) (d 75.3)	0.13 (b 93.36) (b 87.4)	0.07 (b 97.48) (b 92.5)	+
Potassium silicate	2.31 (m 32.42) (m 4)	1.61 (l 27.88) (l 22.9)	1.52 (m 6.27) (m 23.2)	0.74 (l 67.4) (l 45.3)	0.32 (g 87.3) (g 76)	0.29 (j 91.89) (j 76)	1.13 (m 56.7) (m 34.6)
Azadirachtin	1.41 (k 48.41) (k 26.7)	1.07 (j 40.18) (j 36.1)	1.01 (k 22.11) (k 36.2)	0.56 (k 69.15) (k 48.3)	0.32 (h 84.11) (h 70)	0.32 (m 88.8) (m 66.8)	0.78 (k 62.6) (k 43.6)
Potassium silicate + Siva.	1.01 (f 65.41) (f 50.8)	0.98 (g 48.72) (g 45.2)	0.47 (e 66.07) (e 72.2)	0.47 (i 75.76) (i 59.3)	0.41 (j 80.95) (j 64)	0.15 (d 95.08) (d 85.4)	0.58 (f 73.8) (f 60.5)
Aza.+ Siva.	0.57 (b 79.19) (b 70.4)	0.48 (d 73.23) (d 71.4)	0.35 (b 76.77) (b 80.9)	0.26 (c 85.71) (c 76)	0.22 (f 89.1) (f 79.4)	0.13 (c 95.46) (c 86.5)	0.33 (b 84.2) (b 76.2)
Aza.+ Potassium silicate	1.17 (j 51.27) (j 30.8)	0.83 (h 47.18) (h 43.5)	0.75 (j 34.16) (j 46)	0.38 (h 76.17) (h 60)	0.35 (k 80.22) (k 62.6)	0.21 (k 91.63) (k 75.2)	0.62 (i 66.3) (i 49.2)
Aza.+ Potassium silicate + Siva.	0.41 (a 87.09) (a 81.6)	0.36 (a 82.68) (a 81.5)	0.3 (a 76.92) (a 81.1)	0.19 (a 90.99) (a 84.9)	0.07 (a 97.01) (a 94.3)	0.05 (a 98.49) (a 95.5)	0.23 (a 88.86) (a 86.48)

The values followed by the same letter were not significantly different from each other; each value represents the average of three replicates.

growth regulator, alone or in combination with the studied control agents, as demonstrated in the study, may be attributed to the development of resistance in the insect to this type of compound. Horowitz and Ishaaya (1994) demonstrated that resistance in the insect was not limited to chemical pesticides alone, but also included growth regulators. They observed the emergence of resistance in the insect after three successive sprays of the growth regulators Buprofezin and Pyriproxyfen in greenhouses

and cotton fields. They recommended the need to follow an insecticide resistance management (IRM) strategy by using growth regulators once during the season and during the peak insect period. Al-Rubaie (2005) used the growth regulators Trigard, Insegas, Admiral, and Cascade to reduce the incidence of black bean aphid (*Aphis fabae scopolia*). Al-Rubaie et al. (2000) observed that Neem extract was more effective than Sabha extract against *B. tabaci* nymphs when used at a concentration

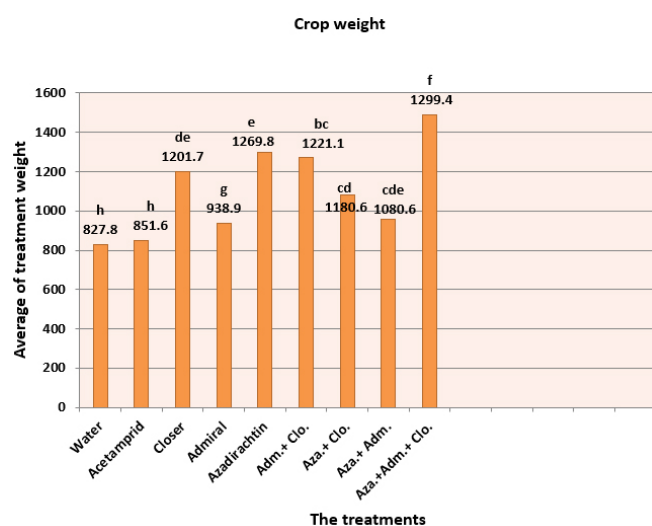


Figure 1. The effect of treatments on the average yield weight trait

of 10%, with the former achieving 100% mortality while the latter achieved 90% after 72 hours of treatment. The mortality rate of whitefly nymphs reached 93.7% when Neem seed extract was used (Nauen, R., 2014). Issa et al. (2022).

The effect of treatments on the yield trait of cucumber crops infested with *B. tabaci*

The result shows the yield trait averages for cucumber crops infested with the whitefly, indicating the impact of different control treatments under study on the cucumber crop. It was observed that the triple treatment T9 (Azadirachtin + Potassium silicate + Sivanto Prime) achieved the highest average in yield of cucumber, reaching 1299.4 g/plant (**Figure 1**). The lowest yield trait averages were 827.8 and 851.6 g/plant for the two control treatments, water and Acetamprid, respectively. There was no significant difference between them, but a significant difference from the averages of the other treatments, according to the results of Duncan's test.

The study of Ndiaye and Doumma (2006) which involved the release of *B. tabaci* (Gennadius) at densities of 0 adults for control and 5, 10, 20, 40, 80 and 160 adults per plant protected in cages at two-leaf age of soybean plants showed that soybean pod weights on mature plants of the control group were significantly higher than in the infested treatments, but no significant differences were recorded among the infested treatments. The results of regression analysis indicated that pod weight was significantly and negatively correlated with the infestation levels. Based on the regression analysis, 36.23% loss of pod weight was predicted at an infestation density of five adults, resulting in a pod weight of 18.55 g compared to the control pod weight of 29.09 g. These

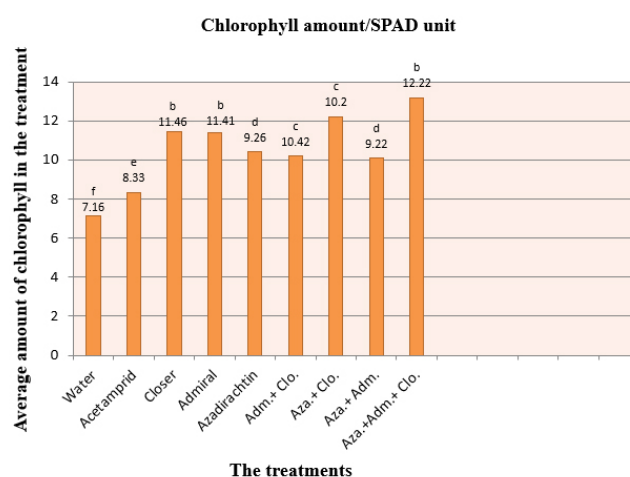


Figure 2. Effect of control factors on the average chlorophyll content.

results demonstrate that *B. tabaci* can cause significant losses in soybean production and quality when it infests the crop at an early stage. Even at a high level of low infestation, when infested with 20 *B. tabaci* adults, the seeds were smaller and had lower weight compared to those with no or light infestation. Enhanced yield performance is likely the result of reduced feeding injury and lower virus transmission, which enabled plants to allocate more resources to fruit development. Similar relationships between effective whitefly management and improved yield have been reported in soybean (Ndiaye & Doumma, 2006) and cassava (Caspary et al., 2023).

The effect of treatments on the chlorophyll content of cucumber leaves infested with whiteflies

The chlorophyll content of cucumber leaves infested with whiteflies showed that the combined treatment of T9 (Azadirachtin + Potassium silicate + Sivanto Prime) was superior in achieving the highest average chlorophyll amount, with a value of 12.22 SPAD units and a significant difference from the averages of the remaining treatments, according to the results of the Duncan multiple range test. Meanwhile, the water treatment achieved the lowest chlorophyll content, reaching 7.16 SPAD units (**Figure 2**).

Maintaining higher chlorophyll values reflects better photosynthetic capacity and healthier foliage. Whitefly feeding normally reduces chlorophyll through sap extraction and honeydew deposition, which encourages sooty mould and impairs gas exchange (Shannag & Freihat, 2009). Effective suppression in this study prevented chlorophyll decline and preserved physiological function, in agreement with previous reports in cucumber and

tomato (Lee et al., 2018). Whiteflies feed by sucking plant sap, reducing plant vitality and productivity (Ghimire, 2023). Whitefly secretions on the leaf surface stimulate the growth of fungi and moulds, which reduces the efficiency of leaf respiration and photosynthesis (Arun et al., 2021). Whitefly infestations have been found to reduce chlorophyll pigments in the leaves of many plants, such as tomato and cucumber (Shannag & Freihat, 2009).

Conclusion

The combined application of flupyradifurone, potassium silicate, and azadirachtin (T9) provided the most consistent control of *Bemisia tabaci* on cucumber. Flupyradifurone alone showed the fastest initial effect on nymphs, while T9 maintained greater suppression over time and also resulted in higher yield and chlorophyll content. These findings indicate that combining compounds with complementary modes of action may improve whitefly management in cucumber. Further studies under different locations and growing seasons are needed to confirm the consistency and economic feasibility of this strategy.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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