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EVALUATION OF EFFICACY OF SELECTED BOTANICAL EXTRACTS FOR CONTROL OF TOMATO WHITEFLY

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ABSTRACT

Tomato (*Solanum lycopersicum* L.) is essential globally for nutrition and income purposes, particularly in sub-Saharan Africa (SSA). The crop faces significant challenges from whiteflies, which damage plants by feeding on leaf sap and transmitting tomato leaf curl virus, leading to reduced crop yields. Synthetic insecticides have been effective, but pose environmental and health risks. The objective of this study was to evaluate the efficacy of selected botanical extracts, for controlling whiteflies (*Bemisia tabaci* Gennadius,1889) in tomato production in Central and Rift valley regions, in Kenya. The study was conducted over two growing seasons. Treatments included extracts from Tithonia, Neem, and Datura leaves and their mixtures. Confidor WG 70 was a positive control. The whitefly-susceptible tomato variety, Kilele F1, was used in this study. Neem extract was the most effective botanical (5.4 ± 5.56), followed by Neem+Datura (8.5 ± 8.59) and Datura (10.1 ± 9.46). Confidor WG 70 (4.4 ± 4.45) was the most effective overall. Leaf curl management was best with Confidor WG 70 (0.33±0.12), followed by Neem extract (1 ± 0.45), with the untreated plot showing the most severe damages (3.5± 1.45). The highest yield was correspondingly obtained from the Confidor WG 70 treatment (30.0 ± 0.50 metric tonnes ha^{-1}), followed by Neem extract (26.7 ± 0.50 t ha^{-1}); while the lowest yield was in the untreated plot (8.3 ± 1.75 t ha^{-1}). Neem and Neem+Datura mixtures showed high potential for controlling tomato whiteflies, and could be out-scaled for this purpose.

Key Words: *Azadirachata indica*, *Datura stramonium*, *Tithonia diversifolia*

RÉSUMÉ

La tomate (*Solanum lycopersicum* L.) est essentielle au niveau mondiale pour la nutrition et les revenus, en particulier en Afrique subsaharienne (ASS). La culture est confrontée à des défis importants liés aux aleurodes, qui endommagent les plantes en se nourrissant de la sève des feuilles et en transmettant le virus de la cloque de la tomate, ce qui entraîne une réduction des rendements. Les insecticides synthétiques se sont révélés efficaces, mais présentent des risques environnementaux et sanitaires. L'objectif de cette étude était d'évaluer l'efficacité d'extraits botaniques sélectionnés pour lutter contre les aleurodes (*Bemisia tabaci* Gennadius, 1889) dans la production de tomates dans les régions de la vallée centrale et de la vallée du Rift, au Kenya. L'étude a été menée sur deux saisons de croissance. Les traitements comprenaient des extraits de feuilles de Tithonia, de Neem et de Datura et leurs mélanges. Confidor WG 70 était un témoin positif. La variété de tomate sensible aux aleurodes, Kilele F1, a été utilisée dans cette étude. Français L'extrait de Neem était le produit botanique le plus efficace (5,4 ± 5,56), suivi de Neem+Datura (8,5 ± 8,59) et Datura (10,1 ± 9,46). Confidor WG 70 (4,4 ± 4,45) était le plus efficace dans l'ensemble. La gestion de la cloque était la meilleure avec Confidor WG 70 (0,33 ± 0,12), suivi de l'extrait de Neem (1 ± 0,45), la parcelle non traitée présentant les dommages les plus graves (3,5 ± 1,45). Le rendement le plus élevé a été obtenu avec le traitement Confidor WG 70 (30,0 ± 0,50 tonnes métriques ha^{-1}), suivi de l'extrait de Neem (26,7 ± 0,50 t ha^{-1}); tandis que le rendement le plus faible a été obtenu dans la parcelle non traitée (8,3 ± 1,75 t ha^{-1}). Les mélanges Neem et Neem+Datura ont montré un potentiel élevé pour lutter contre les aleurodes de la tomate et pourraient être largement utilisés à cette fin.

Mots Clés: *Azadirachata indica*, *Datura stramonium*, *Tithonia diversifolia*

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is the most popular vegetable crop, accounting for 29.4% of the value of exotic vegetables and 12.7% of the total value of horticultural crops grown in Kenya (FAOSTAT, 2018; HCDA, 2020). It is a source of revenue for government and offers employment opportunities to millions small scale farmers in the country (Mukholi *et al.,* 2023). Although the area under intensive tomato production has increased over the years (HCDA, 2020); the country continues to record low productivity of around 410,000 metric tonnes ha^{-1} annually (FAOSTAT, 2022). This is partly attributed to intensified whitefly infestation (Ochilo *et al*., 2019).

Whitefly is a tomato pest widely distributed in the medium and high altitude agro-ecological zones in Kenya, where the crop is mostly grown (Mwangi *et al.,* 2015). Whiteflies have direct effects on tomato plants, as they suck sap from the lower leaf surface; which leads to yellow spots on the leaves; and crinkling, curling and drying of the entire plant (Chatterjee *et al*., 2023). Moreover, the insect pest acts indirectly as a vectors of tomato yellow leaf curl disease, which alone causes up to 50% of the crop yield loss (Chatterjee *et al.,* 2023). The pest, additionally, excretes honey dew on the leaf surface, that results in black sooty mold, which inhibits photosynthesis reducing tomato yield (Mabou Tagne *et al.,* 2018). Moreover, whitefly has the ability to attack new host plants located in new geographical environments (Mabou Tagne *et al.,* 2018).

Tomato farmers in Kenya mostly rely on synthetic pesticides to control whitefly, for they believe they are the most effective and accessible materials, compared to other alternative approaches (Ddamulira *et al.,* 2021). However, continuous use of synthetic pesticides in crop production, is associated with various negative attributes, including toxic residues, insect pest resistance and resurgence; and elimination beneficial organisms as well as environmental pollution (Ochilo *et al*., 2019). This ushers in the need for increased exploitation of other more environmentally friendly control alternative options, such as use of botanical extracts.

The efficacy of botanical extracts, also referred to as biopesticides is attributed to their active ingredients, which are mainly composed of phytochemical like tannins, alkaloids and pyrethroid that have insecticidal properties (Ddamulira *et al.,* 2021). The main advantage of these biopesticides is that they are easily degraded under most tomato production conditions (Ochilo *et al*., 2019); they oxidise quickly, and leave no traceable toxic residues on the targeted plants and the surrounding environment after application. Additionally, their continued use does not result in development of insect pest resistance, as is the case with most synthetic pesticides (Ochilo *et al*., 2019).

A number of plant species has been characterised for their bio-pesticide properties. For instance, leaves of *Tithonia diversifolia* contain compounds such as flavonoid, alkaloids and tannins that act as botanical insecticide ingredients (Mabou Tagne *et al.,* 2018). Similarly, *Azadirachta indica* plants contain compounds known as *azadirachtin*, which act as insect repellants; inhibit their feeding and yet disrupt their growth, metamorphosis and reproduction (Chatterjee *et al.,* 2023). *Datura stramonium*, on the hand, is a common weed containing flavonoids compound that can also act as biopesticides against agricultural insect pests (Singh *et al.,* 2023). The objective of this study was to evaluate the efficacy of selected botanical extracts and their mixtures for control of whitefly in tomato production in Kenya.

MATERIALS AND METHODS

Study site. This study was carried at Kandara Subcounty in Murang'a county, in Kenya (0° 59'S and 37° 04' E), and at altitude 1548 m above sea level. The site experiences a bimodal pattern of rainfall, with an annual mean of 1000 mm. This study was conducted for two consecutive tomato growing seasons; August to December 2023 and January to April, 2024. The mean annual maximum and minimum temperatures are 25.1 and 13.7 °C, respectively; with relative humidity of 68% (Barrett *et al.,* 2020). The soils are classified as sandy loam to clay, with varying depths and with good drainage.

Plant extracts. Leaves of *Tithonia diversifolia, Datura stramonium,* and *Azadirachta indica* were collected from Ngararia Ward and Kandara Subcounty in Kenya. Middle green leaves, known for their high phytochemical content (Mara *et al.,* 2014), were collected and washed with running water to remove dirt and then dried following the method described by Sen and Batra (2012). The dried leaf samples were minced into small pieces (approx.10 mm long). Approximately 100 g of the material was placed in a perforated bag fitting into a 20-liter container filled with 500 ml of distilled water (100 g in 500 ml). Twenty-five milliliters of detergent soap were added to the sample to ensure complete extraction.

The bag was suspended in a container filled with water, attached to a pole placed across the top of the container cover. The mixture was stirred every 3-5 days by partially lifting the bag in and out of the water several times. After 2-3 weeks, the extract turned dark, indicating that most of the contents had dissolved. The extracts were filtered in two stages: (i) pre-filtration using muslin cloth to remove large particles; and (ii) Buchner filtration. The filter was intermittently flushed clean between samples to prevent contamination.

For field application, bio pesticide alongside with the positive and negative controls were prepared for application. The plant extracts were diluted at a ratio of 1:3 (extract: distilled water) as described by Maindargikar *et al.* (2022). This was transferred into container and left for one day before application (Rwegoshora *et al*., 2023). The positive control (Confidor WG 70) it was prepared as manufacturer protocol to manage whiteflies.

Experimental procedure. The treatments included botanical extracts made from Neem, Tithonia, and Datura, as well as mixtures of paired extracts in ratios of 1:3 extract to water. These were extracted through soaking - a simple but effective method suitable for producing a potent, cost-effective pesticides. This method effectively extracts pesticide ingredients such as tannins, anthocyanin, terpenoids, and saponins (Rasul, 2018). The treatments were further prepared in a ratio of one-part extract to three parts distilled water during application, as described by Maindargikar *et al.* (2022). Confidor WG 70, a synthetic pesticide, was used as the positive control; while distilled water was used as the negative control.

The experiment was laid out in a randomised complete block design (RCBD), with eight treatments namely; control, Tithonia, Tithonia+Datura, Tithonia+Neem, Datura, Datura± Neem, Neem and Confidor WG 70 and they were replicated three times. Plot size was 4 m x 3 m, with 1 m alleys between plots and 1.5 m alleys between blocks. Four-week-old tomato seedlings of Kilele F1 variety, were used as the test crop. The hardened seedlings were transplanted to the field plots at a spacing of 90 cm by 45 cm. Diammonium phosphate (18% N, 46% P_2O_5) was applied at the rate of 10 g per hole, and was thoroughly mixed with the soil before transplanting.

All recommended agronomic practices were followed, except for plant protection measures against the whitefly. The botanical extracts were foliarly applied, two weeks after transplanting, with weekly intervals for 3 weeks. This was for biopesticide application, along with the positive and negative controls. The plant extracts were diluted at a ratio of 1:3 (extract: distilled water) as described by Maindargikar *et al.* (2022).

The experiment was laid out in a randomised complete block design (RCBD), consisting of eight treatments, with three replicates each. Plot size was 4 m x 3 m, with 1 m alleys between plots and 1.5 m alleys between blocks. Four-week-old tomato seedlings of the Kilele F1 variety were used as the test crop. The hardened seedlings were transplanted into field plots at a spacing of 90 cm by 45 cm.

Data collection. Data on the adult whitefly population were collected weekly for 42 days after the first spraying (DAFS). Five plants were selected for direct leaf counts, ensuring that the data collected were representative of the entire treatment plot. By sampling multiple plants, researchers were able to account for variability within the plot, such as differences in plant health, microclimate, sunlight exposure, soil composition and water availability. This approach provides a more accurate and reliable estimate of the whitefly population across the treatment area (Craig *et al.,* 2024).

The selection of plants followed a zig-zag sampling design, with a distance of 1 meter between each selected plant. The plants were intensively sampled per plot to assess the whiteflies' damage across all three replicate treatment plots, making the total number of sampled plants per treatment 15 tomato plants. This sampling was conducted from weeks 6 to 8 after the application of the first botanical extract.

Symptom development was evaluated based on the symptom severity scale, with leaf curl damage determined on a 0-5 scale/grade and presented as an average disease score, as described by Friedmann *et al*. (2002) (Table 1).

Tomato yield. Tomato yield was recorded per treatment, by harvesting tomato fruits at

TABLE 1. Leaf curl symptom scoring rate scale (0-5) under whitefly infestation

Scale	Symptoms	Description
0	No symptoms	Immune
1	Slightly yellowing and curl	Resistant
2	Moderate leaf curling and yellowing	Moderate resistant symptoms
3	Moderate yellowing, curling and cupping	Moderate susceptible
4	Severe stunting, curling and cupping; plant stop growth	Susceptible
5	All above and sudden death	Highly susceptible

their physiological maturity, when they exhibited an orange to pink colour (Moneruzzaman *et al.,*2008). Harvesting was conducted once a week from all remaining plants, in separate plots, for two weeks. The samples were weighed using a top pan calibrated weighing scale.

Data analysis. Data on whitefly populations, leaf curl symptoms, and tomato fruit yields were analysed using analysis of variance (ANOVA). Normality was tested using the Shapiro-Wilk test. Mean differences among treatments were determined using Fischer's Least Significant Difference (LSD) test at a 95% confidence level, conducted in R Statistical Software Version 4.3.1. Data were collected at 7-day intervals, and these time intervals were included as a parameter in the analysis.

RESULTS

Adult whitefly population. There were significant differences ($P<0.05$) among treatments at 21 days after first foliar spraying (DAFS) (Table 2). The lowest number of adult whiteflies was recorded in the positive control plot treated with Confidor WG 70 (5.7 ± 3.30). Neem extract treatment followed (5.9 ± 3.32), which also showed significant difference with other extracts. In contrast, the highest whitefly infestation was observed in the untreated plots (27.9 ± 6.65).

The results from the mixed treatments showed no significant differences ($P>0.05$) overall; except at first 28 DAS (Table 2). The mixture of Datura and Neem was the most effective among the biopesticide regimes, in managing the pest population throughout the study period. This was followed by the mixture of Tithonia and Neem, and lastly by Tithonia plus Datura.

At the 42 DAFS, the lowest number of adult whiteflies was observed in the Confidor treatment (2.3 ± 1.88) and Neem extract treatment (Table 2). In contrast, the highest number of adult whiteflies was recorded in

TABLE 2. Whitefly population under selected botanicals extracts and their mixture at different interval durations

Treatment	Days after spraying						Mean white fly population
	7	14	21	28	35	42	
Control	11.1±2.73a	13.7±16.88a	27.9±6.65a	27.4±7.30a	30.7±7.68a	31.7±4.85a	17.8±12.09a
Tithonia	10.5±12.98a	7.8±8.15ab	16.4± 7.21b	15.5±13.77b	18.8±4.66b	17.8±4.67b	11.9±11.57ab
Tithonia+Datura	10.5±13.01a	10.4±14.55ab	13.8±10.61bc	14.2±11.52bc	14.5±4.05cd	13.5±4.05cd	10.5±10.88bc
Tithonia+Neem	12.0±13.67a	8.6±10.41ab	11.2± 7.21bc	10.2±8.62bc	10.9±6.22de	10.9±3.40d	10.3±10.42bc
Datura	10.2±12.39a	8.1±8.98ab	13.7±11.17bc	11.0±7.50bc	17.8±4.99bc	16.3±4.29bc	10.1±9.46bc
Datura± Neem	11.2±13.43a	8.6±10.46ab	9.9±6.36bc	8.1±2.96bc	8.8±3.23e	7.8±1.81e	8.5±8.59bc
Neem	9.2±10.51a	4.6±6.27ab	5.9±3.32c	5.9±3.20c	3.4±3.18f	2.3±1.83f	5.4±5.56bc
Confidor WG 70	3.7±13.15a	4.3±5.23b	5.7±3.30c	5.7±3.30c	3.2±3.11 f	2.3±1.88f	4.4±4.45c
CV	37.51	47.88	29.01	32.8	12.08	10.26	28.23
LSD 0.05	8.68	9.34	8.95	9.49	3.86	3.11	6.59
Pr(>F)	0.5	0.45	0.009 **	0.01 *	8.97e-06 ***	1.43e-06 ***	0.03 *

The means bearing the same letter(s), in the same column, are statistically identical at Fisher's $LSD_{0.05}$

the control plots (31.7 ± 4.85), followed by the Tithonia treatment (17.8 ± 4.67). Among the sole extracts, Neem performed the best throughout the research period, followed by Datura; while Tithonia was the least effective.

The interactions of the mixtures revealed their synergistic effects, showing greater efficacy compared to the sole extracts (Table 2). The mixture of Datura and Neem performed better in managing whitefly populations than to the sole extracts of Tithonia and Datura. Additionally, the mixtures of Tithonia and Neem, and Tithonia and Datura, were more effective than the sole Tithonia extract in managing whiteflies (Table 2).

The study monitored leaf curl symptoms for 42 days after the first spraying (DAFS). By week 21 DAFS, significant differences emerged between the treatments, with Confidor WG 70, a synthetic pesticide, being the most effective, showing the lowest symptom score (0.33±0.12) on a 0-5 scale (Fig. 1).

Neem extract was the second most effective treatment among the sole extracts, with a symptom curl score of 1.5 ± 0.45; demonstrating its natural insecticidal properties. The untreated plot had the highest symptom curl score (3.5 ± 1.45).

Tomato fruit yield. There were significant differences at ($P<0.05$) in tomato yield, among the botanical extracts (P=1.77; CV=4.76) The highest yield of tomato crop was recorded in the plot treated with Confidor (30.0±0.50 metric tonnes ha^{-1}); followed by neem extract (26.7±0.50 t ha^{-1}); Datura (10.6 ±0.76 t ha^{-1}) and Tithonia treated plots (11,8±0.76 t ha^{-1}).

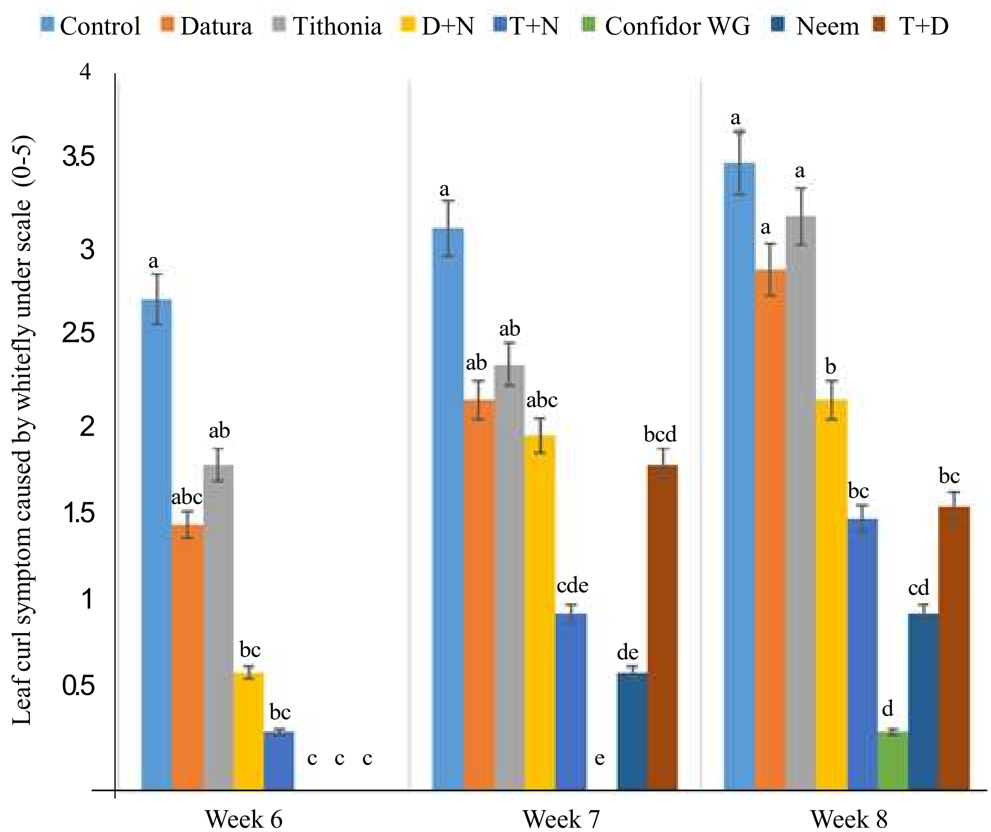

Figure 1. Scores of leaf curl symptoms on tomato under management of whitefly by selected botanic extracts and their mixtures at scoring rate of 0-5 scale of two season pooled data.

TABLE 3. Effect of selected botanical extracts and their mixtures on yield of tomato crop pooled data for two growing seasons

Treatments	Yield (t ha^{-1})
Confidor WG 70	30.0±0.50a
Neem	26.7±0.50b
Neem+Datura	22.5±1.50c
Neem+Tithonia	17.1±0.50d
Datura+Tithonia	13.2±0.58e
Datura	10.6±0.76f
Tithonia	11.8±0.76f
Control	8.3±1.75g
CV	4.38
LSD 0.05	1.56
Pr(>F)	9.47e-16 ***

Means bearing the same letter(s) in the same column, are statistically identical at Fisher's $LSD_{0.05}$

The lowest tomato yield was recorded in untreated plot (8.3 ±1.75 t ha^{-1}) (Table 2).

For the mixtures of bio-pesticides, there were significant differences at (P<0.05). The highest tomato yield was recorded in the positive control. This was closely followed by Neem +Datura (22.5±1.50 t ha^{-1}); Neem +Tithonia (17.1±0.50 t ha^{-1}) and lastly by Datura+Tithonia (13.2 ±0.58 t ha^{-1}). The control plots recorded the least tomato fruit yields (Table 3).

DISCUSSION

Adult whitefly populations. Data on whitefly populations was recorded a day before applying plant extracts and synthetic insecticides, with subsequent observations at 7, 14, 21, 28, 35 and 42 days after spraying (DAFS). Neem extract emerged as the most effective botanical treatment against whitefly populations (Table 1), likely due to the presence of *Azadirachtin*, a potent insecticidal ingredient. This result is consistent with the findings by Adhikari *et al.* (2017), which reported Neem's high efficacy in controlling various pests in tomatoes.

The most notable effectiveness was observed at 42 DAFS, with Neem maintaining lead in efficacy (2.3±1.83). This was followed by a mixture of Datura and Tithonia extracts (7.8±1.81). The least effective was the untreated plot (31.7±4.85).

Significant reduction in whitefly populations was noted three weeks after the first Neem extract application, likely due to the bioavailability of the extracts in the whiteflies' metabolic system. Additionally, the time factor contributed to the extracts' adaptability in controlling whiteflies. Adhikari *et al.* (2017) reported that Neem effectively controled various food crop pests at different concentrations, noting that its physiological effects, such as interfering with molting, growth and reproduction were more consistent than its antifeedant effects. The extract of *Azadirachta indica* at a concentration ratio of 1part Neem extract to 3 parts distilled water, was found to be the most effective in managing the whitefly population by the maturity stage of tomatoes (Moneruzzaman *et al.,* 2008). This effectiveness is attributed to the bioactive alkaloids, including tannins, anthocyanins, terpenoids, and saponins (Rasul, 2018).

The present study has demonstrated that the effectiveness of botanical extracts is time dependent not instantaneous (Table 1). Time influences the efficaciousness of the plant extracts used as pesticide. In the first three weeks, the extracts showed inconsistent results due to their slow adaptability to the environment and their reaction at the target site (Table 1). This observation is supported by the findings of Mabou Togne *et al.* (2018), who studied the time taken for pests to respond to plant extracts.

Data examined at different tomato growth intervals revealed that whitefly populations depended on both the bio-extract formulation and the time of its application (Table 1). The effectiveness of botanical extracts varied based on the plant source and insecticidal active ingredients composition. Mabou Togne *et al.* (2018) found that Datura contained scopolamine, which is highly volatile and quickly enters insect organs. However, scopolamine degrades rapidly under sunlight and heat, losing its potency. Similarly, Shagal *et al*. (2022) reported that Datura contains insecticidal compounds such as hyoscyamine and scopolamine, potent at different stages of plant growth and from various parts of *Datura* spp.; but these compounds lose effectiveness when exposed to light, heat, and air.

Tithonia contains toxic alkaloids, and according to Mabou Togne (2018), its mature seeds and vegetative leaves have the highest concentration of alkaloids, specifically phenols and terpenoids. These compounds target and destroy the nervous system of insect pests, but lose effectiveness when exposed to acids and oxygen, which break the aromatic rings. Our results revealed similar sudden death rates when pests were first exposed to Datura extracts (Table 1). Consistent and prolonged exposure to Neem extract resulted in the highest mortality rates. Shahidi (2015) observed similar findings for the pest, *Callosobruchus maculatus.*

The results consistently showed that from 21 DAFS, Confidor WG 70 maintained a low whitefly population, comparable to that of synthetic pesticides for both physiological and behavioral processes in insects. Among the plant extracts, neem was the most effective in managing whitefly populations due to its alkaloids, which affect cellular processes in insect pests. This finding aligns with Singh *et al*. (2023), who reported that neem contains stable aromatic compounds such as *azadirachtin*, gedunin, nimbinate, and quercetin. These ingredients independently impact the nervous system and biological functions, leading to paralysis and weakening of the insect's body. The alkaloids inhibit feeding, disrupt metamorphosis, and impair reproduction. This pattern of events helps to explain the consequential significant reduction in the whitefly population. Recent studies have shown that botanical extracts, such as neem and datura, are highly efficient in managing leaf damage caused by whiteflies. These natural extracts significantly reduce the whitefly population and the severity of leaf damage, leading to improved plant health and yield. The effectiveness of these botanicals makes them a promising alternative to synthetic pesticides, offering an eco-friendly solution for pest management in agriculture though performing differently. These differences in symptom scores can be attributed to the varying disintegration rates of the extracts and their effectiveness in managing whitefly infestation (Singh *et al*., 2023).

CONCLUSION

Plant extract of *Azadirachta indica* (neem), prepared by soaking and applied at a ratio of 1-part neem extract to 3 parts distilled water, was most effective in managing whitefly populations. Its application led to reduced damage on tomatoes and resulted in the highest yield. Synergism also played a significant role in improving management; for instance, the mixture of Datura and Neem performed better than Datura alone, indicating the compatibility of compounds in mixtures.

The effectiveness of the extracts varied over time due to the adaptability of the alkaloids to the environment and their disintegration strength upon exposure. These extracts reduced pest population infestation, thereby mitigating tomato leaf curl damage and increasing overall yield.

Further studies are needed to optimise the best plant compounds and concentrations for managing whitefly populations to enhance tomato yield under appropriate concentrations of plant extracts.

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