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Role of Nozzle Types and Certain Adjuvants in Reducing Application Rates of Imidacloprid; Spirotetramat Against Whitefly, *Bemisia tabaci* (Gennadius) on Zucchini Plant

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Abstract

In Egypt, zucchini squash, *Cucurbita pepo* L., is an important vegetable. Whitefly, *Bemisia tabaci* (Gennadius), has massively infested them. The insect has causes damage by sucking sap or spreading viruses, and it can considerably reduce yield. The widespread usage of traditional insecticides has resulted in a comeback of insecticide resistance. The current study examined the role of the nozzle type (cone nozzle Tx-6, flat fan Ss083), with two adjuvants (Argal (Silwet 408), and Techno oil) in the effectiveness of imidacloprid, and spirotetramat insecticides. Therefore, the recommended dose of these insecticides alone was compared to the recommended dose + adjuvants, ¾ recommended dose + adjuvants, and half recommended dose + adjuvants. The obtained data showed that imidacloprid was superior to spirotetramat. On the other hand, there was no significant difference between the nozzles used. In addition, adjuvants played an essential role in increasing the insecticides' effectiveness. Compared to insecticide alone, the adjuvant increased the efficacy of the insecticides when added to the recommended dose, and the¾ recommended dose of the insecticide. Additionally, adding Argal to the spray tank mixtures was more productive than adding Techno oil. The recommended dose of the target insecticides could be reduced, and the same effect is maintained through the optimal application method, with using adjuvants.
Keywords : Adjuvants , nozzle type , Physical properties, reduction percent of Bemisia tabaci, spirotetramat ,and imidacloprid, spray solution, and zucchini plant

1. Introduction

Food production is one of the most important goals of human activity. Human aim to directed their efforts to produce enough high-quality food for our population, and other countries worldwide [1,2]. Zucchini, *Cucurbita pepo* L. (Cucurbitales: Cucurbitaceae), is an important vegetable with rich content of various nutrients, antioxidants, beta-carotene, phenols ,and vitamin C [3,4] .Zucchini is grown in the tropical ,and subtropical zones [5,6]. The whitefly, Bemisia *tabaci* (Gennadius) (Hemiptera: Aleyrodidae) is a key insect pest for 600 plant species, including zucchini ,and cucumber [7]; it exerts its damage through sucking sap, injecting toxic saliva ,and virus transmission [8–10]. In Egypt, the whitefly has become an increasingly important pest that attacks several vegetables [11]. Insecticide application is the primary control against this pest ,and proved significant reduction in the whitefly population [12–16],and. Unfortunately, extensive insecticide application reduced its efficiency against the pest. As a result, introducing new chemicals with novel modes of action is required. Imidacloprid, a neonicotinoid of the first generation, is a potentially effective alternative insecticide for controlling sucking insects ,and a variety of coleopterans ,and a few Lepidoptera's pests [17]. It acts as a nicotinic acetylcholine receptor (nAChRs) agonist [16,18,19]. Spirotetramat, a tetramic acid derivative with systemic properties, acts as a lipid biosynthesis inhibitor [20,21]. Spirotetramat showed potential efficacy against juvenile stages of the target pests

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such as aphids, and whiteflies [22]. Pesticide efficiency is affected by many factors, including pesticide formulations, tank-mix adjuvants, nozzle type, ,and the droplet spray size [23,24]. Organosilicone adjuvants are substances added to agricultural chemicals such as insecticides to improve wetting ,and droplet spreading. Organosilicone reduces the surface tension of the spray solution, enhancing pesticide penetration to get a uniform distribution of the active ingredient on the plant surface. Moreover, polysorbate 20, L-glutamic acid-based surfactant, is of great interest in novel surfactants research because it is an environmentally biodegradable adjuvant enhancing pesticide activity. Overall, adjuvants modify the physical properties of spray solution, consequently affecting spray coverage, and drift [25–29]. Nozzle type is important in pesticide application, affecting droplet size, spray velocity, and spray drift [30,31]. Consequently, contribute to more excellent coverage, penetration, and increased pesticide efficacy [32–35].

Aim of the work

This study aims to reduce pesticide application rates by maintaining their efficacy by using adjuvants with different nozzle types on *B. tabaci*. This can be achieved by enhancing their penetration of the whitefly, and developing the wetting behavior of their spray solutions with fortifying environmental safety.

2. Experimental

1. **Insecticide used: Bayer CropScience Egypt** supplied **the insecticide used.**
   - Movento 10% SC (Spirotetramat) (cis-3-(2,5-dimethylphenyl)-8-methoxy-2-oxo-1-azaspiro [4.5] dec-3-en-4-yl ethyl carbonate).
   - Confodor 35% SC (imidacloprid) [(2E)-1-[(6-chloro-3-pyridinyl) methyl]-N-nitro-2-imidazolidinimine)].

2. **Tank-mix adjuvant. Adjuvant for tank-mixing obtained from Shoura Chemicals Company**
   - ARGAL (Silwet). It is an aqueous non-ionic surfactant derived from trisiloxane ethoxylate.
   - Techno Oil. It is a non-ionic surfactant with bio activator properties (L-glutamic amino acid).

3. Physicochemical characteristics

The physicochemical properties of formulations; spray solutions of pesticides and adjuvants mixtures were determined to explore the adjuvants' effect.

3.1. Viscosity

Viscosity was determined using a digital viscometer ″Brookfield DV II+ PRO″. (Brookfield, USA). According to the guidelines published during 2015 by the ASTM, a temperature of 25°C was employed using the water bath TC-502 USA.[36]

3.2. Surface Tension

The surface tension was determined using a Force Tensiomate sigma 700 USA and a Whilmy plate prop to comply with the ASTM regulations published during 2014. [37]

3.3. The critical micelle concentration:

The critical micelle concentration: Many researchers determined the critical micelle concentration (CMC) percent for surfactant [38–40].

A stock solution of surfactant was prepared by weighing 2.5 grams of surfactant ,and adding 250 ml of distilled water. Subsequently, concentrations ranging from (0.1 to 1%) were prepared. Their surface tensions were measured using the whilemy plate method until three consecutive fixed surface tension readings were obtained, which CMC recorded.

3.4. pH measurement

The pH value was determined using a Jenway pH meter 3510 – UK HANNA pH electrode with requirements of CIPAC 1999 ,MT 75.3 [41] .

3.5. Free acidity or alkalinity

This test was conducted with the aid of a HANNA 901 automatic titrator using potentiometric endpoint determination according to regulations of CIPAC 2005 ,MT 191 [42] .

3.6. Electrical Conductivity

In agreement with the regulations of CIPAC 1995, MT 32, the conductivity was determined using a Thermo Orion "model 115A+, USA" [43].

3.7. Density and specific gravity

Density and specific gravity measured using a (Rudolph densitometer 2910 USA) as reported in guidelines of ASTM D 4052 , 2011 [44].

3.8. Persistent foam:

Persistent foam is a parameter that indicates the amount of foam in a pesticide spray solution. Moreover, it was accomplished by using WHO-recommended soft ,and hard water [45] . The volume of foam was determined using [43]4.

4. Field experiments

Field experiments were conducted in New Salhyia province, Sharqia Governorate, during the 2019 ,and 2020 growing seasons. The purpose of this study was to determine the efficacy of three different insecticide rates, and two insecticide adjuvant combinations against the Whitefly, B. tabaci. We used a two-feddan area of Zucchini (Egyptian cultivar Shams). The experimental area was divided into 14 treatments with 14 replicates for each insecticide. Each replication included a control plot. Each plot was approximately 1015 m ,and constructed using a completely randomized block design. In July, zucchini was treated after 45 days of cultivation. Twenty-five leaves were randomly selected in an X-shape from each replicate before ,and 3, 7 ,and10 days after pesticide application. The number of whiteflies was counted, and the percentage of reduction in whiteflies was calculated using [46].

Henderson and Tilton formula

$$\text{Corrected}\ \% = \left(1 - \frac{\text{n in Co befor treatment} \times \text{n in T after treatment}}{\text{n in Co after treatment} \times \text{n in T befor treatment}}\right) \times 100$$

Where: n = Insect population, T = treated, Co = control

5. Utilized Ground Equipment:

Knapsack sprayer (Semco) with a ten-liters tank capacity was used with two different nozzle types. The first is the flat fan nozzle Ss083with a flow rate of 0.850 l/min., a swath width of 1m, ,and a spray volume of 89.3 l/fed. The second is the hollow cone nozzle Tx-6 with a flow rate of 0.525 liters per minute, a swath width of 0.75 meters, ,and a spray volume of 73.5 liters per fed. The technical data of the previous nozzles are illustrated in (Table1).

6. Numbers and sizes of droplets

The line is composed of five wires installed on diagonal lines that carry sensitive cards inside each treatment to collect sprayed chemicals. To determine the actual spray coverage ,and ,the number ,and size of droplets on treated plants, water-sensitive cards (2.5–5 cm) were distributed to zucchini plants at three different levels (upper, middle, ,and lower). Each card was labelled, collected, and transported carefully to the laboratory to determine, and calculate the number ,and size of deposited droplets. The size of droplets was then determined using a struben lens ×15 [47] calibrated following [48].

7. Statistical analysis

Calculating reduction percentages based on [46]. was used to determine the effectiveness of various treatments. N – Way ANOVA Analysis of Variance was performed using the statistical software SPSS version 28. (N-way ANOVA). At P=0.05, LSD was used to separate the means of different treatments (least significant difference).

6. Results and Discussion

As shown in Table (2), the adjuvant (Argal) was slightly acidic, whereas Techno oil was strongly alkaline, indicating that it is safe to use in formulations without concern for phytotoxicity. These surfactants had surface tensions of (19.77 ,and 23.1 Dyne/cm) ,and the concentrations at which surface tension could not be further reduced were (0.3 ,and 0.4 wt/v). Argal ,and Techno oils had viscosities of 42.85 ,and167.62, respectively, ,and conductivities of 64.9 ,and451 µs for both Argal ,and Techno oil ,respectively. In addition, both adjuvants had a significant effect on certain physicochemical parameters associated with insecticide efficacy, as previously reported.

The maximum viscosity value obtained with Techno oil ,and a ¾ dose rate of imidacloprid was (534.98 cP), ,and the initial value obtained without adjuvant was (133.62 cP), ,and the lowest value obtained with Argal with ½ dose of insecticide (117.72 cP). Both adjuvants .However, had a significant effect on the viscosity of spirotetramat at all doses, with the full ,and1/2 doses with Argal adjuvant having the greatest effect (747.09, 694.67 cP) compared to the initial without adjuvants (747.09, 694.67 cP) (161.24 cP). The relationship between the application rates with adjuvants on the physical properties of the pesticide under study are shown in Table (3), with viscosity decreasing as the insecticide dose decreases for both insecticides. When both insecticides were used in combination with Techno oil adjuvant ,and the insecticide rate dose was decreased, the viscosity fluctuated.

Table (1): The properties of Semco sprayer with Tx-6 & Ss-83 nozzles

Items	Knapsack (Semco) Sprayer	
	Hollow cone nozzle (Tx-6)	Flat fan SS083
Type of sprayer	Hydraulic	Hydraulic
Spray tank (L)	10	10
Flow rate, (l/min.)	0.5	0.825
Rate of application, (l/fed.)	70	86.63
Spray height, (m)	0.50	0.50
Swath width, (m)	0.75	1
Working speed, (Km/h.)	2.4	2.4
Type of spray used	Target	Target
Productivity, (fed/h.)	0.43	0.57

Rate of performance (fed/day.)	2.29	3.04

Table (2): The physicochemical properties of the tested adjuvants.

Adjuvant	Viscosity (cP)	Surface tension (dyne/cm)	CMC %	pH	Conductivity μs	Acidity/or alkalinity
Argal	42.85	19.77	0.3	7.09	325	0.037 acidic
Techno oil	167.62	23.1	0.4	8.04	451	1.160 alkaline

Adjuvants had a slight effect on the surface tension of imidacloprid. The maximum decrease in surface tension records being (24.652, and 24.708 dyne/cm) for ¾, and½ doses, respectively, with Argal adjuvant. The other records ranged between (25.009 ,and 27.730 dyne/cm). With spirotetramat, a significant effect was observed with both adjuvants. The highest decrease in surface tension was observed with the full dose, ¾ ,and ½ dose of spirotetramat (22.402, 23.154, ,and 23.387 dyne/cm). On the other hand, Techno oil surface tension records had a negligible effect on spirotetramat surface tension records.

Table (4) summarises the physicochemical properties of imidacloprid ,and spirotetramat in hard ,and soft water spray solutions, the obtained data showed that addition adjuvant significantly affects some of the tested insecticide's physical properties while having a negligible effect on others. The surface tensions of a complete dose of imidacloprid gave (32.992 ,and33.522 dyne/cm) ,and spirotetramat (32.992 ,and32.456 dyne/cm). Imidacloprid had a soft water spray solution of (20.954 ,and29.229 dyne/cm) with Argal adjuvant, ,and spirotetramat had a soft water spray solution of (20.869 ,and31.916 dyne/cm) with Argal adjuvant ,and Techno oil adjuvant, respectively. Imidacloprid and spirotetramat at ¾ ,and½ of the recommended dose respectively, resulted in a similar reduction in spray solution surface tension as using the full recommended amount. Based on the aforementioned foundation ,and analysis of the electrical conductivity (EC), adjuvants ,and insecticide doses have a significant effect on the electrical conductivity (EC) of spray solutions. For a full dose of imidacloprid ,and spirotetramat, the (EC) values were (82.3, 664); (87.3, 659); ,and(127.1, 677), respectively. (85.5, 651); (98.6, 649); ,and(120.6, 673).The adjuvants significantly affect the electrical conductivity (EC) of 12 suggested dose spray solutions ,and34 suggested dose spray solutions containing Confidor 35% SC ,and Movento 10% SC, respectively. As a result, electrical conductivity (EC) records (597 ,and 601) (585, 599, 576, 598, 583, 597) for hard water spray solution containing Argal ,and Techno oil were established, as well as (97.0 ,and110.9) (87.8, 109.99) (98.6, 122.1) for soft water spray solution.

Pesticides will be applied via a water spray solution to the target site. The pH of a spray solution is critical because it affects the pesticide's adhesion to the leaf surface ,and penetration of the plant ,and thus its efficacy. The pH of the spray solution varied between 6.23 ,and6.14 for hard water, Argal, ,and Techno oil spray solutions, ,and between 5.60 ,and6.19 for soft water spray solutions containing the recommended dose of imidacloprid. The maximum pH decrease occurs when both insecticides are used at the½ recommended dose ,and the pH record is maintained at the same level of decline. Accordingly , the pH of the soft water spray solution containing ½ recommended dose of imidacloprid ,and spirotetramat with Argal ,and Techno oil were (4.21 ,and5.97) (3.87 ,and5.94), whereas (4.09 ,and6.12) (4.15 ,and5.89), respectively for hard water solutions.

Table (3): The effect of adjuvant on physicochemical properties of Confidor 35% SC and Movento 10% SC .

Insecticide	Dose	Adjuvant	Viscosity (cP)	Surface tension (dyne/cm)	Density g/cm3	Specific gravity
Confidor 35% SC	Full	-----	133.62	27.866	1.0151	1.0182
		Argal	183.06	25.009	1.0157	1.0188
		T. oil	395.52	26.278	1.0379	1.0411
	¾ dose	Argal	145.32	24.652	1.1065	1.0196
		T. oil	534.98	27.198	1.0398	1.0429
	½ dose	Argal	117.72	24.708	1.1062	1.0193
		T. oil	228.45	27.730	1.0476	1.0510
Movento 10% SC	Full	-----	161.24	34.402	1.0734	1.0766
		Argal	747.09	22.402	1.0657	1.0689
		T. oil	651.19	27.486	1.0741	1.0774
	¾ dose	Argal	529.88	23.154	1.0657	1.0689
		T. oil	233.12	28.652	1.0557	1.0563
	½ dose	Argal	397.88	23.387	1.0606	1.0638
		T. oil	694.67	27.752	1.0600	1.0632

Table (4): Effect of adjuvant on physicochemical properties of Confidor 35% SC and Movento 10% SC in the spray solutions of hard (H.W) and soft water (S.W).

Insecticide	Dose	Adjuvant	Surface tension (dyne/cm		pH		Electrical conductivity (µs)	
			H.W	S.W	H.W	S.W	H.W	S.W
Confidor 35% SC	Full	-----	32.992	33.552	6.23	5.60	664	82.3
		Argal	20.696	20.954	4.30	4.39	659	87.3
		T. oil	28.398	29.229	6.14	6.19	677	127.1
	¾ dose	Argal	20.354	20.450	3.90	4.07	585	87.8
		T. oil	32.505	26.778	6.50	6.18	599	109.8
	½ dose	Argal	20.557	20.611	4.09	4.21	597	97.0
		T. oil	32.883	26.635	3.12	5.97	601	110.9
Movento 10% SC	Full	-----	32.992	32.456	5.59	5.29	651	85.5
		Argal	21.079	20.869	4.74	3.88	649	98.6
		T. oil	29.178	31.916	5.80	6.01	673	120.6
	¾ dose	Argal	20.837	20.797	4.09	4.42	583	97.0
		T. oil	29.958	27.587	5.82	5.87	597	118.7
	½ dose	Argal	20.856	20.758	4.15	3.87	576	98.6
		T. oil	30.726	27.736	5.89	5.94	598	122.1

The data in tables (5) illustrated the droplet spectrum (volume ,and number) produced by each nozzle on the plant ,and the droplets that were released onto the land. The results indicate that when both pesticides were used or concentrated in the spray solution, the flat fan Ss083 nozzle produced larger droplets than the hollow cone Tx-6 nozzle. Additionally, they demonstrate that the loss of land caused by Flat fan Ss083 is greater than the loss caused by hollow cone Tx-6 for all treatments used. These findings established a relationship between droplet size ,and pesticide control efficacy, as well as the nozzle types in this operation. Additionally, the results indicated that large droplets are prone to fall, reducing competition ,and increasing contamination.

In the current experiment, Table 6 demonstrates the impacts of the tested factors on volume median droplets, number of droplets, ,and reduction percent. The utilized rate of insecticide ,and the use of adjuvants were affect the volume of median droplets, the number of droplets, ,and decreased percentage. Although nozzle type had a considerable effect on both volume median droplets ,and number of droplets, it had a non-significant effect on reduction percent.

Table (7) show that the tested treatments resulted in a significant reduction in *B. tabacci* after 3, 7, ,and10 days after treatment (DAT) when compared to the control. Argal addition to spirotetramat improved the quality of the spirotetramat applications in the first season. The addition of Argal or techno oil to the recommended dose of spirotetramat significantly increased the mean reduction for whitefly. When argal or techno oil was added to the spirotetramat recommended dose, the mean reduction in whiteflies was significantly greater than when the recommended dose was used alone. The most promising results were obtained when 3/4 recommendations were combined with Argal or Techno oil; the mean reductions were equal to or greater than the recommended dose alone. Although combining the 1/2 recommendation with Argal resulted in a significant reduction in the recommended dose, this treatment was effective. An inversely poor reduction was obtained with 1/2 the recommended amount of Techno oil.

Tables (8) confirmed the first season's findings. While, the second season of spirotetramat performed similarly to the previous season, with the exception of the 1/2 recommendation with Argal, which reduced whitefly numbers equivalent to spirotetramat alone. Regarding imidacloprid, adding Argal ,and Techno oil to the approved dose significantly improved imidacloprid efficiency. Furthermore, combining Argal ,and Techno oil to the 1/2 ,and3/4 of recommendations results in a reduction percentage equal to the full recommended dose. The only exception was Techno oil with a ½ spirotetramat recommendation, which achieved a reduction percent less than the full spirotetramat recommendations.

As demonstrated in Tables 7 ,and8, imidacloprid was more effective than spirotetramat at the recommended dose. Additionally, argal diminishes the effectiveness of insecticides against B. tabaci. By increasing the permitted amount of Argal, the pesticide's efficacy was increased. Surprisingly, combining Argal ,and Techno oil with half of the recommendations resulted the same reduction. Furthermore, ¾ recommendations with Argal surpassed the whole recommendation alone. Although Techno oil showed significant effect with both used pesticides, it showed different manner when mixed with the half rate.

Table (5): Pesticides-adjuvant mixtures affecting reduction % of *B. tabaci* population during the first season.

Pesticide	Rate	Adjuvant	Nozzle	Days after treatments			Mean Reduction %
				3 day	7 day	10 days	
Movento	Recom	no-adj	SS83	74.51±7.13	78.63±6.06	51.94±11.56	75.02±14.51
			TX6	79.05±3.62	75.25±2.98	63.47±12.17	72.59±9.71
		Argal	SS83	90.22±4.02	82.51±0.44	76.06±10.95	82.93±12.16
			TX6	94.77±1.85	81.70±3.01	79.26±5.21	85.24±7.35
		Techno oil	SS83	86.40±2.97	78.83±0.63	74.56±11.97	79.93±9.14
			TX6	83.85±3.87	77.53±5.21	72.61±6.05	77.99±6.11
	0.75	Argal	SS83	85.64±2.75	80.44±2.40	77.54±9.29	81.21± 6.28
			TX6	85.34±5.13	76.17±2.21	74.50±14.79	78.34± 12.14
		Techno oil	SS83	77.10±4.86	75.49±12.26	73.77±13.47	75.45± 10.38
			TX6	76.21± 4.31	72.11± 5.01	70.58±13.03	72.96±11.19
	0.50	Argal	SS83	79.39 ±6.56	77.60± 8.40	69.22± 8.24	75.40± 8.42
			TX6	76.46 ± 5.30	76.11±6.58	59.26±6.05	73.61± 9.98
		Techno oil	SS83	60.69±8.40	55.96±10.52	60.22±6.92	58.95± 8.21
			TX6	46.15±13.32	43.45±0.25	41.04±4.63	43.54±8.10
Confidor	Recom	no-adj	SS83	82.09±7.91	79.19±7.35	79.62±11.13	80.96±0.23
			TX6	77.09±5.82	71.46±6.04	84.09±7.25	77.55±7.91
		Argal	SS83	89.86±5.52	85.18±6.1	81.61±4.70	85.55±6.08
			TX6	78.27±6.69	78.75±7.46	81.19±5.49	79.40±6.11
		Techno oil	SS83	84.99±7.25	80.07±7.75	69.84±13.35	78.30±11.08
			TX6	79.10±6.12	71.70±7.47	76.52±6.26	75.77±6.61
	0.75	Argal	SS83	82.20±6.32	83.19±4.73	72.77±9.33	79.38±8.05
			TX6	80.33±7.25	83.49±5.42	78.23±0.47	80.68±5.24
		Techno oil	SS83	82.73±12.87	84.10±6.76	79.02±11.52	81.95±14.21
			TX6	82.30±10.20	77.89±5.22	75.19±5.48	78.79±7.48
	0.50	Argal	SS83	80.39±6.31	80.71±7.50	76.92±1.65	79.34±5.49
			TX6	74.05±7.41	77.30±10.07	69.32±8.93	73.56±8.72
		Techno oil	SS83	70.25±1.21	70.56±9.63	71.89±4.45	70.57±6.98
			TX6	71.09±9.00	76.83±6.25	70.17±3.43	72.70±6.74
LSD							2.39

Table (6): Pesticides-adjuvants mixtures affecting reduction % of *B. tabaci* population during the second season.

Pesticide	Rate	Adjuvant	Nozzle	Days after treatments			Mean Reduction %
				3 day	7 day	10 days	
Movento	Recom	no-adj	SS83	77.56±5.60	77.54±3.14	66.65±12.85	**73.92±9.22**
			TX6	76.82±5.79	73.61±0.42	73.61±0. .42	**74.68±3.42**
		Argal	SS83	79.57±5.10	86.93±3.46	70.69±5.93	79.06±8.25
			TX6	89.98±6.21	78.44±1.33	63.52±14.75	77.31±14.08
		Techno oil	SS83	83.06±5.02	71.78±2.46	74.15±7.40	76.33±9.48
			TX6	81.54±10.20	76.34±7.02	68.41±9.28	75.43±9.85
	0.75	Argal	SS83	85.25±4.34	82.27±3.78	76.14±4.98	81.22±5.61
			TX6	86.17±5.83	72.39±4.13	76.86±3.50	78.47±7.29
		Techno oil	SS83	81.19±4.61	65.75±13.72	72.21±4.63	73.05±10.33
			TX6	82.69±7.86	61.21±5.16	73.94±6.72	72.61±11.01
	0.50	Argal	SS83	80.30± 3.55	75.76±12.31	68.28±11.30	74.78± 10.31
			TX6	77.21± 3.65	73.62±7.13	67.79± 3.60	72.87± 6.12
		Techno oil	SS83	66.94± 5.14	64.96± 8.06	66.60±10.52	66.17± 7.48
			TX6	51.48± 5.10	50.40± 13.08	78.16± 6.04	60.01± 15.60
Confidor	Recom	no-adj	SS83	86.64±3.36	74.12±8.10	73.30±7.28	78.02±8.72
			TX6	85.75±4.99	75.75±6.66	74.41±5.78	78.63±7.03
		Argal	SS83	86.94±5.20	73.87±9.97	75.29±6.49	78.70±9.13
			TX6	79.74±4.95	81.83±7.47	76.80±5.36	79.46±5.86
		Techno oil	SS83	84.99±7.25	73.51±0.49	79.80±3.90	79.43±8.51
			TX6	79.10±6.12	77.01±7.32	74.23±9.60	76.78±7.37
	0.75	Argal	SS83	87.32±9.41	81.53±9.19	79.73±3.45	82.86±7.86

			TX6	83.43±10.08	78.59±8.01	77.01±6.57	79.68±9.24
		Techno oil	SS83	80.73±12.87	77.64±6.91	73.32±4.79	77.56±9.24
			TX6	79.30±10.20	78.32±7.42	69.61±12.31	75.74±11.49
	0.50	Argal	SS83	85.89±8.25	72.75±10.79	78.34±4.81	78.99±9.39
			TX6	78.23±6.18	78.87±6.73	77.52±7.84	78.20±8.31
		Techno oil	SS83	70.25±1.21	74.20±7.89	77.62±7.54	74.02±6.53
			TX6	71.09±9.00	74.86±5.98	71.32±6.95	72.42±6.95
LSD							2.39

Table (7): The effect of nozzles types used on volume median diameter and number of droplets in the presence of adjuvants with Movento or Comfidor at variable doses.

	Nozzle type							
Pesticide's treatment	SS083				Tx-6			
	Plant		Land		Plant		Land	
	VMD	N/cm2	VMD	N/cm2	VMD	N/cm2	VMD	N/cm2
Spirotetramat								
Rec.Alone	166.33±2.51	62.00±3.60	195.00±4.00	14.33±2.08	153.33±9.86	70.00±5.56	186.33±1.52	12.33±0.57
Rec. + Adj. 1	145.00±5.00	74.00±7.00	186.66±1.52	11.00±0.00	135.00±8.00	90.00±7.54	172.33±2.51	9.66±0.57
3/4Rec. +Adj.1	130.00±10.00	91.66±3.78	176.66±2.08	8.66±0.57	115.00±5.00	104.66±5.13	165.33±4.04	6.00±1.00
½ Rec. +Adj.1	140.00±6.24	86.33±3.21	181.33±1.52	10.33±0.57	129.66±4.50	91.33±1.52	168.66±3.05	8.33±0.57
Rec. + Adj. 2	154.33±6.02	67.66±4.16	190.33±1.52	12.00±1.73	147.33±4.16	81.33±3.05	177.33±1.52	10.66±0.57
3/4Rec.+Adj.2	140.33±8.96	77.00±1.73	181.66±2.08	12.66±1.15	124.33±3.51	87.00±5.00	175.00±2.00	11.66±0.57
½ Rec. +Adj.2	154.66±2.51	67.33±2.51	187.00±2.00	11.66±1.15	141.33±4.04	73.00±2.00	177.00±2.64	12.33±0.57
Imidacloprid								
Rec.Alone	160.00±3.00	72.66±4.04	185.00±4.00	15.33±0.57	141.00±1.00	79.00±1.00	179.66±1.52	13.33±0.57
Rec. + Adj. 1	138.00±2.00	85.33±2.51	180.66±2.08	13.00±1.00	122.66±2.08	104.00±3.60	166.00±3.60	12.00±1.00
3/4Rec.+Adj.1	128.00±1.00	101.00±2.00	172.33±1.52	11.33±1.52	109.00±1.00	114.33±2.08	157.66±2.08	10.33±1.52
½ Rec. +Adj.1	138.00±2.00	93.00±1.00	177.00±1.00	12.33±0.59	119.66±2.51	97.00±1.00	161.33±1.52	9.33±0.57
Rec. + Adj. 2	142.66±3.05	76.66±3.21	185.00±2.00	14.66±0.58	138.33±2.08	91.00±3.60	170.66±2.08	12.66±0.57
3/4 Rec.+Adj.2	126.33±3.05	85.00±3.00	175.66±2.08	15.66±0.57	115.33±3.51	98.66±4.04	165.33±4.04	13.66±0.57
½ Rec. +Adj.2	146.00±3.00	75.00±2.00	180.66±2.08	15.00±1.00	132.00±2.00	79.66±1.52	169.00±2.00	14.66±0.57

Table (8): ANOVA analysis of significant Factors affecting Bemisia tabaci population

Source	df	Volume median droplets Statistics		Number of droplets Statistics		Reduction % Statistics		
		F	Sig.	F	Sig.	df	F	Sig.
Pesticides	1	156.997	<.001	165.738	<.001	1	28.922	.000
Rate	2	135.536	<.001	69.475	<.001	2	26.944	.000
Adjuvants	2	145.434	<.001	118.930	<.001	2	60.949	.000
Nozzle Types	1	416.541	<.001	82.014	<.001	1	2.885	.090

Discussion

Whitefly (*Bemisia tabaci*) (Gennadius) is a widespread insect that infests various agricultural ,and horticultural crops. The pest transfers infectious diseases that induce physiological problems [49]. As a result of the inability of traditional insecticides to control *B. tabaci*, insecticides with novel mechanisms of action have been introduced to achieve successful control [50]. The neonicotinoid, imidacloprid, ,and the spirocyclic tetramic acid derivative, spirotetramat are the most worldwide insecticide used to control *B. tabaci* [20,21,50,51].

Multifunctional, environmentally friendly tank-mix adjuvants are becoming increasingly popular in plant protection. Adjuvants are chemicals added to spray solutions to improve the efficiency, and application of pesticides. Tank mix adjuvants work by influencing the physicochemical properties of spray solution, such as surface tension, pH, viscosity, and electrical conductivity. After application, the spray deposited, and spreading on the plant surface, ,and wetting all parts then penetrate the plant surface easily with suitable amount to be effective. As a result, several advantages can be obtained with adjuvants, including reduced pesticide rate, application cost, and environmental hazard [21,52–56].

In the current study, the used adjuvants significantly increased imidacloprid ,and spirotetramat efficiency. The addition of adjuvants causes a decrease in surface tension ,and pH ,and increased electrical conductivity, which consolidates wetting, spreading deposition, ,and retention on plant surfaces. The present findings are in line with [57]who reported that tank-mix adjuvants led to better application, and reduced surface tension by accumulating molecules at the air-water interface. The surface tension reduction continues with the increasing adjuvant concentration until the interface is saturated with adjuvant molecules. It also reduces spray drift, and droplet size, improving pesticide potency, and lowering the application rate [58,59]. The pH of the spray solution is an important parameter because of the charge difference also affects the adhesion of spray droplets to the leaf surface, keeping the leaves moist for longer [60].

Furthermore, [61] mentioned that a pH range of 3.5–5.5 enhances insecticidal efficacy by slowing the rate of pesticide alkaline hydrolysis. Similarly, decreasing spray solution surface tension improved leaf wetness, retention, and active ingredient absorption by increasing spray droplet spread[62]. Increasing electrical conductivity also improves the adhesion, and dispersion capabilities of the spray solution [63]. All results are agree with [59,64] indicated that reducing the surface tension ,and pH value with increasing electrical conductivity led to an enhancement in wetting, spreading, ,and retention of plant oils used as spray solutions on the treated plants, therefore their toxicity was increased. The findings were also consistent with those of [65]. They discovered that adjuvants could reduce surface tension, pH, pesticide rate of application, and drift. Argal, and Techno oil, on the other hand, had little effect on viscosity, and density. This finding may be explained that adjuvants are typically used in low concentrations in large quantities of spray water [66]. However, these changes may affect droplet size ,and spectrum, which have a direct impact on pesticide performance ,and spray application quality [67].

However, Argal (Trisiloxane surfactants) outperformed Techno oil, (Amino acid-based adjuvant). These findings are consistent with [68], who reported that Trisiloxane surfactants (Argal) improve the spreading of tank-mix spray solution, resulting in 10 – 30 times more leaf coverage than other surfactants. Adjuvants improve insecticide efficiency by modifying spray solution properties such as surface tension, pH, electrical conductivity, ,and viscosity. Similarly, this data is compatible with [69,70] that organosilicone adjuvants (OAs) have an extreme spreading ability to wet the target surface by reducing surface tension, and contact angle of aqueous solution (AS).

Spray nozzles can influence the production, and quality of agricultural spray products [71,72]. The spray nozzle is important because it produces small droplets for optimal coverage, penetration, and deposition on the plant, which increases insecticidal potency [32,33]. According to the current study, nozzle type does not affect spray deposits and, as a result, insecticide potency. Similarly, [73,74] discovered that flat fan, and hollow cone nozzles performed similarly when controlling Stink bugs on soybean. In the meantime, [75] discovered that medium droplet size outperforms both fine, and coarse droplets when applied at the same rate with a flat fan nozzle.

7. Conclusions

The obtained results, in the current study proved that, tank-mix adjuvants were critical for improving the efficacy of imidacloprid ,and spirotetramat **against** B. tabaci. Adjuvants can alter the physicochemical properties of spray solutions in general, such as surface tension, viscosity, pH, ,and electrical conductivity. As a result, the product's coverage ,and spread ability improved during spray application, allowing it to reach its full control potential. As a result, choosing the right adjuvants can lower the rate of pesticides, lowering control costs, crop contamination, and pollution. To control the whitefly B. tabaci, we recommended two pesticides from two different classes, and two different adjuvants based on the current result. On the zucchini crop, imidacloprid with adjuvant outperformed spirotetramat with the same adjuvant, showed no significant differences between hollow cone and flat fan nozzles. In addition, Argal adjuvants outperformed Techno oil adjuvants in terms of its physicochemical properties, and insecticidal potential in the presence of this adjuvant. As a result, application costs are reduced, ,and more protection are given to the environment.

Recommendations

We recommended to use these adjuvant (Argal & techno oil) with ¾ and ½ dose of confidor 35 % SC and Movento 10 % SC to improve insecticidal activity against Bemisia tabaci .These rates can be used with other pesticides that compatible with these adjuvants under study to reduce pesticide application rates while lowering pesticide toxicity on plants, animals, and eventually humans.

8. References

[1] Bhattacharyya, A., Barik, S.R., ,andGanguly, P. (2009) New pesticide molecules, formulation technology ,anduses: Present status ,andfuture challenges. *The Journal of Plant Protection Sciences*.

[2] Schreinemachers, P., Simmons, E.B., ,andWopereis, M.C.S. (2018) Tapping the economic ,andnutritional power of vegetables. *Global Food Security*. 16 36–45.

[3] Brew, B.S., Berry, A.D., Sargent, S.A., Shaw, N.L., Cantliffe, D.J., ,andothers (2006) Determination of optimum storage conditions for’baby’summer squash fruit (Cucurbita pepo). in: Proceedings of the Florida State Horticultural Society, pp. 343–346.

[4] Martínez-Valdivieso, D., Gómez, P., Font, R., ,andDel Rio-Celestino, M. (2015) Mineral composition ,andpotential nutritional

contribution of 34 genotypes from different summer squash morphotypes. *European Food Research ,andTechnology*. 240 (1), 71–81.

[5] Eissa, H.A., Bareh, G.F., Ibrahim, A.A., Moawad, R.K., ,andAli, H.S. (2013) The effect of different drying methods on the nutrients ,andnon-nutrients composition of zucchini (green squash) rings. *J. Appl. Sci. Res*. 9 (8), 5380–5389.

[6] Babayee, S.A., Daneshian, J., Baghdadi, H., ,andYousef, M. (2012) Effect of plant density ,andirrigation interval on agronomical traits of Cucurbita pepo. *Tech. J. Engin. Appl. Sci*. 2 8–258.

[7] Kousik, C.S. ,andAdkins, S. (2020) Detection of cucurbit yellow stunting disorder virus infecting watermelon in South Carolina.

[8] Yokomi, R.K., Hoelmer, K.A., Osborne, L.S., ,andothers (1990) Relationships between the sweetpotato whitefly ,andthe squash silverleaf disorder. *Phytopathology*. 80 (10), 895–900.

[9] Denholm, I., Cahill, M., Byrne, F.J., ,andDevonshire, A.L. (1996) Progress with documenting ,andcombating insecticide resistance in Bemisia. *Bemisia: 1995, Taxonomy, Biology, Damage, Control ,andManagement*.

[10] Wang, X.-W., Li, P., ,andLiu, S.-S. (2017) Whitefly interactions with plants. *Current Opinion in Insect Science*. 19 70–75.

[11] El- Kady, H. ,andDevine, G.J. (2003) Insecticide resistance in Egyptian populations of the cotton whitefly, Bemisia tabaci (Hemiptera: Aleyrodidae). *Pest Management Science*. 59 865–871.

[12] Horowitz, R.A. ,andIshaaya, I. (1994) Managing resistance to insect growth regulators in the sweetpotato whitefly (Homoptera: Aleyrodidae). *Journal of Economic Entomology*. 87 (4), 866–871.

[13] Cahill, M., Gorman, K., Day, S., Denholm, I., Elbert, A., ,andNauen, R. (1996) Baseline determination ,anddetection of resistance to imidacloprid in Bemisia tabaci (Homoptera: Aleyrodidae). *Bulletin of Entomological Research*. 86 (4), 343–349.

[14] Elbert, A., Nauen, R., ,andLeicht, W. (1998) Imidacloprid, a Novel Chloronicotinyl Insecticide: Biological Activity ,andAgricultural Importance. in: Insecticides with Novel Modes of Action, Springer Berlin Heidelberg, Berlin, Heidelbergpp. 50–73.

[15] Jha, S.K. ,andKumar, M. (2017) Relative efficacy of different insecticides against whitefly , Bemisia tabaci on tomato under field condition. *Journal of Entomology ,andZoology Studies*. 5 (5), 728–732.

[16] Thorat, S.S., Kumar, S., ,andPatel, J.D. (2020) Bio efficacy of different pesticides against whitefly (Bemisia tabaci Gennadius) in tomato. *Journal of Entomology ,andZoology Studies*. 8 (4), 1428–1431.

[17] Nauen, R., Elbert, A., Elbert, A., Jeschke, P., ,andTietjen, K. (2003) European monitoring of resistance to insecticides in Myzus persicae ,andAphis gossypii (Hemiptera: Aphididae) with special reference to imidacloprid . *Bulletin of Entomological Research*. 93 (01), 77–105.

[18] Tomizawa, M. ,andCasida, J.E. (2003) Selective toxicity of neonicotinoids attributable to specificity of insect ,andmammalian nicotinic receptors. *Annual Review of Entomology*. 48 (1), 339–364.

[19] Simon-Delso, N., Amaral-Rogers, V., Belzunces, L.P., Bonmatin, J.M., Chagnon, M., Downs, C., et al. (2015) Systemic insecticides (Neonicotinoids ,andfipronil): Trends, uses, mode of action ,andmetabolites. *Environmental Science ,andPollution Research*.

[20] Nauen, R., Bretschneider, T., Elbert, A., Fischer, R., Reckmann, U., ,andVan Waetermeulen, X. (2006) Biological ,andmechanistic considerations on the mode of action of spirotetramat. in: 11th IUPAC Int. Congress of Pesticide Chemistry, pp. 6–10.

[21] Bretschneider, T., Fischer, R., ,andNauen, R. (2007) Inhibitors of lipid synthesis (acetyl-CoA-carboxylase inhibitors). *Modern Crop Protection Compounds*. 3 909–926.

[22] Nauen, R., Reckmann, U., Thomzik, J., ,andThielert, W. (2008) Biological profile of spirotetramat (Movento®)--a new two-way systemic (ambimobile) insecticide against sucking pest species. *Bayer CropScience Journal*. 61 (2), 245–278.

[23] Klein, R.N., Golus, J.A., ,andNelms, K.L. (2009) The effect of adjuvants, pesticide formulation, ,andspray nozzle tips on spray droplet size. *Journal of ASTM International*. 6 (6), 1–7.

[24] Oliveira, R.B. de, Antuniassi, U.R., Mota, A.A.B., ,andChechetto, R.G. (2013) Potential of adjuvants to reduce drift in agricultural spraying. agricultural engineering. 33 986–992.

[25] Infante, M.R., Pérez, L., Pinazo, A., Clapés, P., Morán, M.C., Angelet, M., et al. (2004) Amino acid-based surfactants. *Comptes Rendus Chimie*. 7 (6–7), 583–592.

[26] Acheampong, S. ,andStark, J.D. (2004) Effects of the agricultural adjuvant Sylgard 309 ,andthe insecticide pymetrozine on demographic parameters of the aphid parasitoid, Diaeretiella rapae. *Biological Control*. 31 (2), 133–137.

[27] Nuyttens, D., Baetens, K., De Schampheleire, M., ,andSonck, B. (2007) Effect of nozzle type, size ,andpressure on spray droplet characteristics. *Biosystems Engineering*. 97 (3), 333–345.

[28] Wood, B.W., Tedders, W.L., ,andTaylor, J. (1997) Control of pecan aphids with an organosilicone surfactant. *HortScience*. 32 (6), 1074–1076.

[29] Foy, C.L. (2018) Adjuvants: terminology, classification, ,andmode of action. in: Adjuvants ,andAgrochemicals, CRC Press, pp. 1–15.

[30] Taylor, W.A., Womac, A.R., Miller, P.C.H., ,andTaylor, B.P. (2004) An attempt to relate drop size to drift risk. in: Proceedings of the International Conference on Pesticide Application for Drift Management, pp. 210–223.

[31] Fritz, B.K., Hoffmann, W.C., Bagley, W.E., Kruger, G.R., Czaczyk, Z., ,andHenry, R.S. (2014) Measuring droplet size of agricultural spray nozzles- measurement distance ,andairspeed effects. *Atomization ,andSprays*. 24 (9),.

[32] Yu, Y., Zhu, H., Frantz, J.M., Reding, M.E., Chan, K.C., ,andOzkan, H.E. (2009) Evaporation ,andcoverage area of pesticide droplets on hairy ,andwaxy leaves. *Biosystems Engineering*. 104 (3), 324–334.

[33] da Cunha, J.P.A.R., Farnese, A.C., Olivet, J.J., ,andVillalba, J. (2011) Deposição de calda pulverizada na cultura da soja promovida pela aplicação aérea e terrestre. *Engenharia Agr{\'\i}cola*. 31 (2), 343–351.

[34] Grisso, R., Hipkins, P., Askew, S.D., Hipkins, L., ,andMccall, D. (2013) Nozzles : Selection ,andSizing. *Verginia Corporative Extension*. 12.

[35] Wang, S., Dorr, G.J., Khashehchi, M., ,andHe, X. (2015) Performance of selected agricultural spray nozzles using particle image velocimetry. *Journal of Agricultural Science ,andTechnology*. 17 (3), 601–613.

[36] ASTM (2015) American Society of Testing ,andMaterials Standard Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield viscometer DV+II. pro.).-D2196. .

[37] ASTM (2014) American Society of Testing ,andMaterials Standard Test Methods for Surface ,andInterfacial Tension of Solution of Surface-Active Agents.-D1331. .

[38] Schramm, L.L., Stasiuk, E.N., ,andMarangoni, D.G. (2003) 2 Surfactants ,andtheir applications. *Annual Reports Section" C"(Physical Chemistry)*. 99 3–48.

[39] Osipow, L.I., Rosenblatt, W., ,andSnell, F.D. (1964) Soaps of monohydroxystearic acid in syndet compositions. *Journal of the American Oil Chemists' Society*. 41 (12), 841–842.

[40] Izquierdo, P., Feng, J., Esquena, J., Tadros, T.F., Dederen, J.C., Garcia, M.J., et al. (2005) The influence of surfactant mixing ratio on nano-emulsion formation by the pit method. *Journal of Colloid ,andInterface Science*. 285 (1), 388–394.

[41] CIPAC (1999) Collaborative international pesticides analytical council limited.MT 75.3. .

[42] CIPAC (2005) Collaborative international pesticides analytical council limited.MT 191. .

[43] CIPAC (1995) Collaborative international pesticides analytical council limited. MT 32, 47.1.

[44] ASTM (2011) American Society of Testing ,andMaterials Standard Test Methods for density ,andspecific gravity by Rodulph Densitometer.D-4052. .

[45] WHO: World Health Organization (1979) Specification of pesticides used in public health, Geneva. Switzerland, pp116. 116.

[46] Henderson, C.F. ,andTilton, E.W. (1955) Tests with acaricides against the brown wheat mite. *Journal of Economic Entomology*. 48 (2), 157–161.

[47] Abou-Amer, A.M. (1993) Spray Spectrum of Insecticide deposits on the Cotton Canopy After Using Different Spraying Techniques, Ph. D. Thesis, Fac. of Agric., Cairo University, Egypt, 1993.

[48] Gabir, I., Zidan, Z.H., Attalah, E., ,andHindy, M.A. (1982) Calibration ,andEvaluation of the Performance of Certain Hdraulic Nozzle Types Under Laboratory Conditions. *Res. Bull*. 1738 19.

[49] Razze, J.M., Liburd, O.E., ,andMcsorley, R. (2016) Preference of Bemisia tabaci biotype B on zucchini squash ,andbuckwheat ,andthe effect of Delphastus catalinae on whitefly populations. *Pest Management Science*. 72 (7), 1335–1339.

[50] Palumbo, J.C., Horowitz, A.R., ,andPrabhaker, N. (2001) Insecticidal control ,andresistance management for Bemisia tabaci. *Crop Protection*. 20 (9), 739–765.

[51] Nauen, R., Reckmann, U., Thomzik, J., and Thielert, W. (2007) Biological profile of spirotetramat (Movento)-a new two way systemic (amimobile) insecticide against sucking pests Studies on the susceptibility of Tuta absoluta to novel ,anddiamide insecticides View project Biological profile of spirotetramat (Movento ®. *Bayer CropScience Journal*. 61 (2), 245–278.

[52] Sundaram, A. ,andRetnakaran, A. (1987) Influence of formulation properties on droplet

size spectra ,andground deposits of aerially-applied pesticides. *Pesticide Science*. 20 (4), 241–257.

[53] Green, J.M. ,andBeestman, G.B. (2007) Recently patented ,andcommercialized formulation ,andadjuvant technology. *Crop Protection*. 26 (3), 320–327.

[54] Huang, L.X., Hao, L.F., ,andYuan, J. m. (2010) Research progress on preparation ,andapplication of silicone surfactants for pesticide adjuvants. *Silicone Material*. 24 (1), 59–64.

[55] Zhang, H., Lu, J., ,andWei, D. (2017) Wetting state ,anddynamic spreading behavior of alkyl polyglycoside drop on cucumber leaf surface. *Transactions of the Chinese Society of Agricultural Engineering*. 33 (3), 81–87.

[56] Hilz, Z. ,andVermeer, A. (2013) Spray drift review: the extent to which a formulation can contribute to spray drift reduction. *Crop Protection*. 44 (1), 75–83.

[57] Janků, J., Bartovská, L., Soukup, J., Jursík, M., ,andHamouzová, K. (2012) Density ,andsurface tension of aqueous solutions of adjuvants used for tank-mixes with pesticides. Plant Soil Environment. 58(12), 568–572.

[58] Durigan, J.C. (1993) Efeitos de adjuvantes na aplicação e eficácia dos herbicidas. Funep Jaboticabal, .

[59] Hussein, I.H., Hashim, E.F., Toson, M.G., ,andGnedy, M.M. (2010) Physico-Chemical Studies ,andAphicidal Effect of some Locally Formulated Plant Oils. *Egyptian Journal of Biological Pest Control*. 20 (2),.

[60] Cunha, J.P., Alves, G.S., ,andReis, E.F. (2010) Temperature effect on the physical-chemical characteristics of aqueous solutions with spray adjuvants. *Planta Daninha*. 28 (3), 665–672.

[61] Mueller, T.C. ,andSteckel, L.E. (2019) Spray mixture pH as affected by dicamba, glyphosate, ,andspray additives. *Weed Technology*. 33 (4), 547–554.

[62] Baio, F.H.R., Gabriel, R.R.F., and Camolese, H.D.A.S. (2015) Alteração das propriedades físico-químicas na aplicação contendo adjuvantes. *Brazilian Journal of Biosystems Engineering*. 9 (2), 151–161.

[63] Zandonadi, C.H.S., da Cunha, J.P.A.R., Alves, T.C., ,andSilva, S.M. (2017) Tank mixture of pesticides for Spodoptera frugiperda control in maize with triflumuron. *Bioscience Journal*. 33 (1), 31–40.

[64] El-Khiat, Z.K., El-sayed, W., Abdel-Megeed, M.I., and El-Sayed, M.F. (2016) The Effectiveness of adjuvant on different Formulation of Lambada-Cyhalothrin against cotton leaf Worm. *Middle East Journal of Applied Sciences*, *Res. Bull. Ain Shams Univ*. 6 (3), 541–552.

[65] Bueno, M., Cunha, J., ,and Alves, G. (2013) Lime deposition in aerial ,andground application of phytossanitary in sweet potato culture. Agricultural Engineering. 33(6), 1210–1222.

[66] da Cunha, J. and Alves, G. (2009) Características físico-químicas de soluções aquosas com adjuvantes de uso agrícola. *Interciencia*. 34 (9), 655–659.

[67] Assunção, H.H.T. de, Campos, S.F.B., Sousa, L.A., Lemes, E.M., Zandonadi, C.H.S., ,andCunha, J.P.A.R. da (2019) Adjuvants plus phytosanitary products ,andthe effects on the physical-chemical properties of the spray liquids. *Biosci. j.(Online)*. 1878–1885.

[68] Knowles, A. (2010) The use of surfactants ,andother adjuvants to enhance biological activity of pesticidess. *ISAA Conference*. 11–13.

[69] Stevens, P.J.G. (1993) Organosilicone surfactants as adjuvants for agrochemicals. *Pesticide Science*. 38 (2–3), 103–122.

[70] Singh, M. ,andMack, R.E. (1993) Effect of organosilicone-based adjuvants on herbicide efficacy. *Pesticide Science*. 38 (2–3), 219–225.

[71] Qin, W.-C., Qiu, B.-J., Xue, X.-Y., Chen, C., Xu, Z.-F., ,andZhou, Q.-Q. (2016) Droplet deposition ,andcontrol effect of insecticides sprayed with an unmanned aerial vehicle against plant hoppers. *Crop Protection*. 85 79–88.

[72] Bikram, J., Sinha, J.P., Indra, M., Adarsh, K., ,andothers (2017) Effect of electromechanical properties on spraying quality of electrostatic sprayer. *Environment ,andEcology*. 35 (3B), 2152–2160.

[73] Farias, M.A.G.L., Raetano, C.G., Chechetto, R.G., Ferreira-Filho, P.J., Guerreiro, J.C., Bonini, C.S.B., et al. (2020) Spray nozzles ,anddroplet size effects on soybean canopy deposits ,andstink bugs control in west region of São Paulo state-Brazil. *Phytoparasitica*. 48 (2), 203–213.

[74] Prado, E.P., Raetano, C.G., Christovam, R.S., Aguiar-Júnior, H.O., ,andDal Pogetto, M. (2020) Tecnologias de aplicação de produtos fitossanitários no controle de percevejos pragas na cultura da soja. *Arquivos Do Instituto Biológico*. 77 265–274.

[75] Derksen, R.C., Zhu, H., Ozkan, H.E., Hammond, R.B., Dorrance, A.E., ,andSpongberg, A.L. (2008) Determining the influence of spray quality, nozzle type, spray volume, ,andair-assisted application strategies on deposition of pesticides in soybean canopy. *Transactions of the ASABE*. 51 (5), 1529–1537.