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Integration between Salicylic Acid as an Inducer of Plant-Induced Systemic Resistance and Insecticides for Bemisia tabaci Management on Squash (*Cucurbita pepo*, L.)

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Abstract

Salicylic acid (SA), an inducer of systemic acquired resistance (SAR), was foliar applied (0.7 g L^{-1}) on two squash varieties (Alexandrian, and Hollar) to investigate the integration between SAR and insecticides (thiamethoxam or pymetrozine) on *Bemisia tabaci* management. Insecticides were applied at their recommended [FR] and half recommended field [HFR] rates separately or in sequence with SA. The Filed experiments were carried out in September and October during two subsequent successful seasons. In the first season, the sequential treatment SA&thiamethoxam [FR] presented significantly higher initial reduction (24h after treatment) of *B. tabaci* adults on Alexandrian (88.5 %) and Hollar (80.3%) varieties, compared with the other treatments. Conversely, the sequential treatment SA&pymterozine [FR] on Hollar variety was the most effective against the immature stages (82.4%), While on Alexandrian variety the highest reduction was obtained with the sequential treatment of SA&thiamethoxam [FR] (78.7%). Moreover, on both varieties no significant differences were recorded between the sequential treatments of SA&thiamethoxam [HFR] or SA&pymterozine [HFR] and each insecticide alone at the recommended rate. Furthermore, along 10 days of treatment a significant high reduction of adults was recorded with the sequential treatment of SA&thiamethoxam [FR] on both squash varieties. In the second season, similar trend was obtained, the highest reduction of adults was recorded with the treatment of SA&thiamethoxam [FR] on both (Alexandrian 84.1%) and (Hollar 76.3%). As well, the sequential treatments of SA&thiamethoxam [FR] and SA&pymterozine [FR] showed high reduction of adults along 10 days of treatment. Regarding to the immature stages on both squash varieties, high average of initial reduction and reduction along 10 days of treatments were recorded with all the sequential treatments compared with the individual treatments. On Alexandrian, the significant highest reduction recorded with SA&pymterozine [FR] (86.2%), while on Hollar recorded with SA&thiamethoxam [HFR] (60.9%). These results disclose the synergistic effect of SA that affected both tested insecticides efficacy and persistence. Therefore, SA could be recommended in sequence with low rates of insecticides for whiteflies management to reduce both rate and numbers of insecticides application which is in highly demand.

Keywords: Salicylic acid, systemic acquired resistance, thiamethoxam, pymetrozine, whiteflies management, environmentally friendly alternatives.

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1. Introduction

In recent years, whiteflies have risen in notoriety as important pest. Whiteflies especially, *Bemisia tabaci* (Gennadius) cause problems in vegetable production on a global scale [1]. Whiteflies cause their damage either directly or indirectly [2]. Direct damage occurs when whitefly adults pierce the leaves and suck sap that results inchlorosis in plants [3]. The indirect damage occurs due to the accumulation of honey dew that attracts the sooty mold to growth on the leaf surface and disrupts the process of photosynthesis [4]. In addition, whiteflies are known to transmit over 100 plant viruses [5].

Cucurbitaceae are attacked heavily by nymphs and adults of whiteflies [6]. Feeding immature stage of the silver leaf whitefly (B strain) causes a physiological disorder known as squash silver leaf in summer squash, *Cucurbit apepo* L. [7]. Furthermore, whitefly transmits Squash leaf curl virus to squash plants [8]. Using insecticides is the most common approach for the management of whiteflies in vegetable crops. However, the unwise use of insecticides resulted in the development of insecticide resistance and disturbance of agro-ecosystem [9]. Therefore, there is a need for adoption of alternative management methods against whitefly such as plant-induced resistance.

Plant-induced resistance can be achieved physically [10,11,12] or chemically, by organic compounds as salicylic acid [13] or jasmonic acid [14]. Salicylic acid is a natural phenolic compound present in many plants and participates in the regulation of physiological processes in plants. Also, it is an important component in the signal transduction pathway and involved in local and systemic resistance to pathogens [15]. SA induces a range of defense genes, most notably those encoding the pathogenesis-related (PR) proteins, several of which have been shown to possess antifungal or antibacterial properties [16]. In the present study, field studies were carried out to evaluate the integration between salicylic acid and some insecticides for management of nymphs and adults of whiteflies on squash plants.

2. Materials and Methods

a. Insecticides and chemicals:

Formulated thiamethoxam (Actara® 0.15% EC) was produced by Arab company for pesticides and veterinary medicines manufacture. Pymetrozine (Chees 50%WC) was produced by Syngenta Co. Salicylic acid was purchased from El Gomhouria Company for Trading Chemicals and Medical Appliances, Alexandria, Egypt.

Squash varieties:

Two squash varieties were used in the field experiments. Hollar premium was produced by Hollar seeds, Rocky Ford Co, USA. A local squash variety Alexandrian was purchased from a local market.

b. Field experiments:

Two field experiments were conducted during 2017 and 2018 Nile seasons, at Alexandria University Experimental Station, Abees. The mentioned squash varieties were cultivated at September 3, 2017 and September 6, 2018. All cultural practices were carried out according to “good agricultural practice”. Treatments were arranged in a split plot, complete randomized block design. Each treatment was replicated three times (42 m^2 per each). Insecticides were used at their recommended and half recommended field rates alone or in sequence with salicylic acid (table1). Salicylic acid was applied one week before the treatment by insecticides at concentration of 0.7 gm L^{-1}. Treatments were sprayed by Knapsack sprayer equipment (CP3) at the rate of 200 liter per feddan on October 20, 2017 and October 27, 2018, reached the economic threshold (5adults\ plant). Control was sprayed by water. The efficiency of treatments against adult and immature stages of whitefly were determined by counting insects on ten plants per plot (1, 3, 7 and 10 days after treatment). Pre-treatment counts were done just before application. Counts were done in the early morning when flight activity is minimal [17]. Reduction percentages were calculated according to Henderson and Tilton equation 1955, [18]. Treatments were compared with each other using two ways ANOVA with $LSD_{0.05}$ (Costat Statistical Software, 1990, https://www.cohort.com › costat).

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Table (1): Applied insecticides and the sequential treatments

Insecticide, sequence and application rate	Treatment abbreviation
Thiamethoxam at the half field recommended rate	Thiamethoxam [HFR]
Pymterozine the half-recommended rate	Pymterozine [HFR]
Salicylic acid followed by thiamethoxam at the half field recommended	SA&thiamethoxam [HFR]
Salicylic acid followed by pymterozine at the half field recommended rate	SA&pymterozine [HFR]
Thiamethoxam at the field recommended rate	Thiamethoxam [FR]
Pymterozine at the field recommended rate	Pymterozine [FR]
Salicylic acid followed by thiamethoxam at the field recommended rate	SA&thiamethoxam [FR]
Salicylic acid followed by pymterozine at the field recommended rate	SA&pymterozine [FR]

Salicylic acid (SA) was applied one week before insecticides at concentration of 0.7 gm L^{-1}

3. Results

1.1. First season:

Data of 2017 season show that of the all treatments were more effective on *Bemisia tabaci* adults on Alexandrian squash compared with on Hollar variety except for the treatment of pymterozine at the half-recommended rate (HFR) alone (table2). On Alexandrian variety, the sequential treatments of salicylic acid (SA) with the recommended rate (FR) of either thiamethoxam (FR) or pymterozine (FR) were significantly the most effective treatments with initial average reduction percentages of *B. tabaci* adults (88.5 and 84.1%), respectively. Moreover, the sequential treatments of SA&thiamethoxam (HFR) or SA&pymterozine [HFR] significantly enhanced the reduction percentages to (75.3 and 75.6%) compared with the individual treatments of the same rats of both insecticides (62.1% and 53.75%), respectively. Furthermore, no significant differences were recorded between the sequential of SA & thiamethoxam [HFR] or SA &pymterozine (HFR) and each insecticide alone at the recommended rate. Concerning to the residual effects, also the sequential of SA&thiamethoxam [FR] was the most persistent treatment along 10 days of insecticides application with mean reduction percentage of *B. tabaci* adults (81.1%) followed by SA&pymterozine [FR] (79.8%), SA&pymterozine [HFR] (72.6%) and SA&thiamethoxam [HFR] (71.4%).

On with the treatments of SA&thiamethoxam [FR] (80.3%) and SA&pymterozine [FR] (79.9%). Besides no significant differences in average initial reduction of *B. tabaci* adults were observed between the treatments SA&thiamethoxam [HFR] (73.9%), SA&pymterozine [HFR] (70.3%), thiamethoxam [FR] (72.5) and pymterozine [FR] (68.9%). This reveals that, SA enhanced both tested insecticides efficacy. Regarding the residual effect, the treatments SA&thiamethoxam [FR] and SA&pymterozine [FR] were significantly more persistent compared with the other treatments with mean reduction percentage of *B. tabaci* adults (67.3 % and 64.9%), respectively. Comparable the sequential treatments SA&thiamethoxam [HFR] or SA&pymterozine [HFR] remained significantly more effective along 10 days of treatments compared with either thiamethoxam [HFR] or pymterozine [HFR] alone with reduction percentages of (54.0%, 52.1%, 38.9% and 33.2%), respectively. This reveals that SA extended the persistence of both tested insecticides. Hollar squash variety, significant high levels of average initial reduction percentages of *B. tabaci* adults were recorded.

Table (2): Reduction of whitefly adults after field application of certain treatments on two squash varieties during 2017 season.

Variety	Treatment	% Reduction after different times of treatment ±SE				
		Initial (24 h)	Residual			
			3-days	7-days	10-days	Mean residual
Alexandrian	Thiamethoxam (HFR)	62.1±1.3	66.4±5.2	40.9±3.8	26.7±4.6	44.7±3.3
	Pymetrozine (HFR)	53.7±1.9	48.1±3.3	20.4±5.7	17.0±2.2	28.5±2.2
	Thiamethoxam (FR)	77.9±2.8	78.9±7.6	48.4±6.7	41.6±5.2	56.3±3.4
	Pymetrozine (FR)	75.4±1.1	61.6±1.7	48.4±2.2	28.8±5.6	46.3±3.8
	AS*/Thiamethoxam (HFR)	75.3±2.0	84.3±2.8	71.7±4.3	58.3±2.9	71.4±4.2
	SA/Pymetrozine (HFR)	75.6±2.2	88.7±1.3	69.3±3.2	59.8±6.2	72.6±4.9
	AS/Thiamethoxam (FR)	88.5±5.8	91.3±1.9	75.7±4.2	76.2±4.1	81.1±4.7
	SA/ Pymetrozine (FR)	84.1±1.4	86.0±3.9	81.6±2.5	71.8±4.9	79.8±5.0
Hollar	Thiamethoxam (HFR)	54.4±4.8	58.4±3.1	40.4±3.1	18.0±2.0	38.9±2.0
	Pymetrozine (HFR)	52.2±2.9	44.3±3.1	34.3±3.1	21.1±3.2	33.2±2.2
	Thiamethoxam (FR)	72.5±4.4	66.9±4.6	46.9±3.1	35.4±2.9	49.7±4.2
	Pymetrozine (FR)	68.9±3.8	56.9±1.9	46.9±2.5	25.0±1.0	42.9±3.2
	AS/Thiamethoxam (HFR)	73.9±5.3	64.1±4.1	58.5±4.8	39.3±1.3	54.0±3.6
	SA/Pymetrozine (HFR)	70.3±4.8	66.5±4.8	56.5±4.8	33.3±2.3	52.1±4.0
	AS/Thiamethoxam (FR)	80.9±5.3	84.9±5.3	74.1±4.1	43.0±3.3	67.3±5.2
	SA/ Pymetrozine (FR)	79.9±2.7	82.9±3.8	66.9±4.1	45.0±2.8	64.9±4.2

* SA: Salicylic acid ($0.7gmL^{-1}$), was applied one week prior the insecticide treatments

**$LSD_{(0.05)}$ for the initial effect was (4.6)while it was (5.5) for the residual effect

With reference to the immature stages, data present in (Table 3). On Hollar variety, the highest average initial reduction percentage of immature stages of *B. tabaci* was recorded with the sequential treatments, SA&pymterozine [FR] (82.4%) followed by SA&thiamethoxam[FR] (80.3%). Moreover, the sequential of SA& thiamethoxam [HFR] significantly enhanced the average initial reduction percentage to (72.3%) compared with thiamethoxam [FR] alone (61.2%) or pymterozine [FR](62.7%) alone treatments. As well as the sequential of SA&pymterozine [HFR] significantly increased the reduction (70.3%) compared with the same insecticide at the same application rate alone pymterozine [HFR] (52.4%). Similarly, the highest residual effect on the immature stages of *B. tabaci* was obtained with the sequential of SA&thiamethoxam [FR] treatment with mean reduction percentage of (81.7%) followed by SA&pymterozine [FR] (78.3%) and SA& thiamethoxam[HFR] (69.3%) along 10 days of treatments.

On Alexandrian variety, the sequential of SA with either both insecticides at FR or at HFR significantly enhanced both insecticide initial effects. Whereas significant high average initial reduction percentages of the immature stages of *B. tabaci* were recorded with the sequential treatments of SA&thiamethoxam [FR](78.7%), SA&pymterozine [FR] (76.7%) and SA&thiamethoxam [HFR](67.1 %), compared with thiamethoxam [FR] alone (67.2%) pymterozine [FR] alone(67.4). Furthermore, there were no significant differences between both insecticides alone at the recommended rate and the sequential of SA& pymterozine [HFR].

Table (3): Reduction of whitefly immature stage after field application of certain treatments on two squash varieties during 2017 season

Variety	Treatment	% Reduction after different times of treatment ±SD				
		Initial (24 h)	Residual			
			3-days	7-days	10-days	Mean residual
Alexandrian	Thiamethoxam (HFR)	42.3± 3.9	55.9±4.7	52.8± 3.8	45.8± 2.4	51.5± 3.8
	Pymetrozine (HFR)	40.3± 2.5	51.7±4.0	48.7± 2.9	43.5± 2.5	48.0 ± 3.1
	Thiamethoxam (FR)	67.2± 2.6	71.5±2.7	65.3± 2.9	61.6± 2.7	66.1 ±4.8
	Pymetrozine (FR)	67.4± 2.0	71.5±5.1	65.0± 4.5	58.1± 3.5	64.9± 3.6
	AS*/Thiamethoxam (HFR)	67.1±4.5	74.7± 3.8	70.1±2.8	64.5±4.3	69.8± 3.0
	SA/Pymetrozine (HFR)	62.2± 2.4	72.8± 2.1	67.3± 4.2	63.4± 4.0	67.8 ±2.2
	AS/Thiamethoxam (FR)	78.7± 3.6	88.9± 2.6	85.8± 4.7	74.7±2.3	83.1 ±4.3
	SA/ Pymetrozine (FR)	76.7± 2.2	83.3± 2.7	72.8± 3.3	67.3± 3.3	77.5 ± 3.8
Hollar	Thiamethoxam (HFR)	50.9±4.0	59.4±3.1	57.3±2.6	55.2±4.7	57.3±3.3
	Pymetrozine (HFR)	56.9±2.3	62.8± 3.9	52.9±1.1	51.7± 2.0	55.8 ±4.5
	Thiamethoxam (FR)	61.2±2.0	76.2±1.7	72.0± 3.0	63.9± 2.4	70.7 ± 3.9
	Pymetrozine (FR)	62.7±5.4	75.4±2.9	70.1±5.1	66.9± 4.3	70.8± 2.1
	AS/Thiamethoxam (HFR)	72.3±1.7	73.4±2.2	69.7±3.6	64.9± 4.9	69.3 ±3.9
	SA/Pymetrozine (HFR)	63.2± 2.8	68.6±3.6	56.4± 3.2	52.0± 4.3	59.0 ± 4.1
	AS/Thiamethoxam (FR)	80.3± 4.3	85.6± 3.4	80.3±3.0	79.3± 4.1	81.7 ±1.6
	SA/ Pymetrozine (FR)	82.4± 2.4	83.3± 3.4	77.6±3.7	74.0± 2.6	78.3±3.0

* SA: Salicylic acid ($0.7gmL^{-1}$), was applied one week prior the insecticide treatments

**$LSD_{(0.05)}$ for the initial effect was (7.8) while it was (6.7) for the residual effect

1.2. Second season:

In the 2018 season, also the initial reduction of *B. tabaci* adults was higher on Alexandrian squash compared with Hollar variety (table 4). On Alexandrian variety, the sequential of SA significantly enhanced both insecticides efficacy whereas the reduction percentages of *B. tabaci* adults after 24h of treatments with SA&thiamethoxam [FR] and SA&pymterozine [FR]were (84.1% and 80.8%), respectively compared with thiamethoxam [FR] alone (72.9%) and pymterozine [FR] alone (67.3%). Moreover, the sequential of SA with thiamethoxam [HFR] (74.5%) or pymterozine [HFR] (69.9%) achieved efficacy that was insignificantly different compared with thiamethoxam [FR] (72.9%) alone. As well, the sequential of SA with both tested insecticides significantly enhanced their persistence, whereas the mean adults reduction percentage along 10 days of treatment with SA&thiamethoxam [FR] was (66.4%) followed by SA&pymterozine [FR] (55.4%) in comparison with thiamethoxam [FR] alone (55.5%) and pymterozine [FR] alone (43.1%), respectively. Moreover, no significant differences were reordered between the mean reduction percentage with the treatment, SA&thiamethoxam [HFR] (53.4%), and thiamethoxam [FR](55.5%) alone.

Similarly, on Hollar squash, the highest average initial reduction percentages of *B. tabaci* adults were recorded with the combined treatments of SA& thiamethoxam [FR] (76.3%). While no significant differences in reduction were detected between SA&pymterozine (FR) (67.9%), thiamethoxam (FR) (67.7%) and SA&thiamethoxam [HFR] (66.8%). Also, SA&pymterozine [HFR] achieved initial reduction of adults (59.0%) which was significantly equal to pymterozine (FR) alone (58.7%). Concerning the residual effect, SA&thiamethoxam[FR] showed the highest persistence efficacy with mean reduction percentage of *B. tabaci* adults (52.5%) along 10 days of treatment, followed by SA&thiamethoxam [HFR] (47.1%), SA&pymterozine (FR) (46.1), thiamethoxam (FR) (45.7%).

Regarding to the immature stages *B. tabaci*, data present in (table 5). On Alexandria squash, high average of initial reduction was recorded with all sequential treatments; SA&pymterozine [FR] (86.2%) followed by SA&thiamethoxam [FR] (79.6%), SA&thiamethoxam [HFR] (75.7%), and SA&pymterozine [HFR] (75.7%) compared with the individual treatments pymterozine [FR] (69.8%), thiamethoxam [FR] (66.3%), pymterozine [HFR] (36.6%) and thiamethoxam [HFR] (34.0%).

Table (4): Reduction of whitefly adults after field application of certain treatments on two squash varieties during 2018 season.

Variety	Treatment	% Reduction after different times of treatment±SD				
		Initial (24 h)	Residual			
			3-days	7-days	10-days	Mean residual
Alex	Thiamethoxam (HFR)	65.5 ± 3.8	67.1 ± 4.5	32.5 ± 3.4	20.5 ± 1.2	40.0± 2.4
	Pymetrozine (HFR)	58.1 ± 4.9	45.6 ± 3.0	23. 9 ± 1.8	15.3 ± 1.3	28.3± 1.7
	Thiamethoxam (FR)	72.9 ± 4.1	79.2 ± 3.5	56.7 ± 2.2	30.5 ± 2.5	55.5± 3.1
	Pymetrozine (FR)	67.3 ± 3.9	71.7 ± 3.5	38.2 ± 2.2	19.3 ± 2.1	43.1± 2.8
	AS*/Thiamethoxam (HFR)	74.5 ± 4.1	78.3 ± 3.8	52.1 ± 2.2	29.7± 2.1	53.4± 3.9
	SA/Pymetrozine (HFR)	69.9 ± 3.7	75.8 ± 2.3	41.3 ± 2.9	24.8 ± 2.4	47.3± 2.6
	AS/Thiamethoxam (FR)	84.1 ± 3.7	87.3 ± 3.3	65.4 ± 3.2	46.6 ± 1.8	66.4± 2.1
	SA/ Pymetrozine (FR)	80.8 ± 4.0	84.2 ± 2.3	49.0 ± 2.9	32.9 ± 2.6	55.4± 3.4
Hollar	Thiamethoxam (HFR)	56.6 ± 2.2	52.9 ± 2.5	26.8 ± 1.3	15.0 ± 1.2	31.6± 1.5
	Pymetrozine (HFR)	44.0 ± 2.8	38.1 ± 2.5	29.1 ± 2.9	18.3 ± 2.5	28.5± 2.1
	Thiamethoxam (FR)	67.7 ± 3.5	67.2 ± 2.9	44.5 ± 2.4	25.5 ± 1.5	45.7± 3.5
	Pymetrozine (FR)	58.7 ± 2.7	55.6 ± 2.7	33.7 ± 1.6	17.6 ± 1.8	35.6± 1.8
	AS/Thiamethoxam (HFR)	66.8 ± 2.9	70.9 ± 2.5	48.2 ± 1.9	22.2 ± 1.3	47.1± 2.6
	SA/Pymetrozine (HFR)	59.0 ± 2.9	63.7 ± 2.0	41.1 ± 1.7	17.3 ± 2.3	40.7± 2.5
	AS/Thiamethoxam (FR)	76.3 ± 2.8	79.8 ± 2.2	52.7 ± 2.0	24.9 ± 1.9	52.5± 2.9
	SA/ Pymetrozine (FR)	67.9 ± 2.5	72.5 ± 2.7	42.0 ± 2.1	23.9 ± 1.8	46.1± 3.0

* SA: Salicylic acid (0.7gmL^{-1}), was applied one week prior the insecticide treatments

**$LSD_{(0.05)}$ for the initial effect was (4.09) while it was (4.41) for the residual effect

As regards to the residual activity along 10 days of treatments, the same trend was obtained since the mean reduction percentages on the immature stages were higher with the sequential treatments than that with the individual ones. The highest reduction was recorded with SA&thiamethoxam [FR] (88.9%) followed by SA&pymterozine (FR) (83.4%), SA&pymterozine [HFR] (81.8%) and SA&thiamethoxam [HFR] (80.7%).

On Hollar variety, the same trend of *B. tabaci* adult's average initial reduction was observed since the sequential treatments showed significant higher reduction values compared with the individual treatments. The highest reduction was recorded with SA&pymterozine [HFR] (78.5%) follow by SA&thiamethoxam [FR] (77.9%), SA&thiamethoxam [HFR] (77.2%) and SA&pymterozine [FR] (74.6%). The persistence of the sequential treatment SA&thiamethoxam [HFR] was significantly the highest compared with the other treatments with mean reduction percentage of *B. tabaci* immature stages (60.9%) followed by the individual treatment thiamethoxam [FR] (55.3%).

Obviously, all sequential treatments were more effective against adults and immature stages of *B tabaci* compared with the insecticides alone at the same rate on both squash varieties. This elevation of the efficacy was higher on adults of *B. tabaci* on Alexandrian squash compared with the efficacy on Hollar squash with most treatment. Conversely, most treatments were more effective against the immature stages on Hollar verity compared with their efficacy against the same stages on Alexandrian verities. These results disclose the synergistic effect of SA that affected both tested insecticides efficacy and persistence.

Table (5): Reduction of whitefly immature stage after field application of certain treatments on two squash varieties during 2018 season.

Variety	Treatment	% Reduction after different times of treatment ±SD				
		Initial (24 h)	Residual			
			3-days	7-days	10-days	Mean residual
Alexandrian	Thiamethoxam (HFR)	34.0 ± 2.2	38.8± 1.7	20.8 ± 1.7	12.0 ± 2.7	23.9 ± 2.1
	Pymetrozine (HFR)	36.6 ± 2.3	32.2 ± 1.3	24.7± 1.9	19.9 ± 1.2	25.6± 1.8
	Thiamethoxam (FR)	66.3 ± 1.8	71.4 ± 1.5	62.9 ± 4.2	56.5 ± 1. 7	63.6 ± 2.7
	Pymetrozine (FR)	69.8 ± 2.3	75.1 ± 3.4	65.9 ± 2.4	55.8 ± 3.2	65.6± 2.3
	AS*/Thiamethoxam (HFR)	75.7 ± 3.7	85.1 ± 2.3	82.2 ± 0.0	74.7 ± 4.1	80.7± 4.2
	SA/Pymetrozine (HFR)	75.7 ± 3.7	84.4 ± 4.3	84.2 ± 3.0	76.7 ± 1.7	81.8± 2.8
	AS/Thiamethoxam (FR)	79.6 ± 4.6	92.6 ± 4.2	90.2 ± 3.0	83.9 ± 4.9	88.9± 3.9
	SA/ Pymetrozine (FR)	86.2 ± 3.2	92.2± 4.3	81.5 ± 1.6	76.4 ± 2.5	83.4± 3.3
Hollar	Thiamethoxam (HFR)	39.0 ± 5.0	42.2 ± 3.5	34.0 ± 3.0	19.7 ± 1.1	32.0± 1.5
	Pymetrozine (HFR)	42.9 ± 2.7	44.3 ± 3.9	29.4 ± 2.1	18.4 ± 2.9	30.7± 1.8
	Thiamethoxam (FR)	65.8 ± 3.4	69.3± 4.8	55.5 ± 4.7	41.1 ± 1.8	55.3± 2.9
	Pymetrozine (FR)	70.0 ± 2.6	66.3 ± 2.1	50.9 ± 3.5	35.1 ± 2.8	50.8± 3.0
	AS/Thiamethoxam (HFR)	77.2 ± 3.2	75.5 ± 1.3	55.5 ± 2.5	51.8 ± 2.5	60.9± 2.5
	SA/Pymetrozine (HFR)	78.5 ± 3.4	65.5 ± 2.3	45.9 ± 2.1	36.1 ± 2.0	49.2± 2.4
	AS/Thiamethoxam (FR)	77.9 ± 3.9	63.8 ± 1.7	48.2 ± 2.6	40.8± 3.6	50.9± 3.6
	SA/ Pymetrozine (FR)	74.6 ± 2.3	61.0 ± 3.2	47.4 ± 3.9	41.5 ± 4.3	50.0± 4.4

* SA: Salicylic acid ($0.7gmL^{-1}$), was applied one week prior the insecticide treatments

**$LSD_{(0.05)}$ for the initial effect was (4.09) while it was (5.01) for the residual effect

4. Discussion

The integration between different control agents became a necessary tool in the pest management programs. In the present study, field experiments were carried out in 2017 and 2018 to investigate the integration between the plant-induced systemic resistance, two squash varieties and insecticides for whitefly management. Results revealed that, the sequential between salicylic acid and thiamethoxam or pymtrozine on squash variety Alexandrian achieved the highest efficacy against immature and adult stages of whitefly. Previous studies suggested plant induced systemic resistance compounds to provide effective control of many pests [19]. It was reported that, salicylic acid enhanced and prolonged the toxicity of profenofos, cyhalothrin and imidacloprid against the cotton leafworm 4th instar larvae on cotton plants [20]. The mixture of *Azadirachta indica* extract and salicylic acid was the most potent treatment against *B. tabaci* and cotton leaf curl virus disease [21]. On the other hand, it was reported that, tomato plants treated with salicylic acid had a little resistance to the feeding by tobacco hornworm and the plant lost more biomass [22].

Salicylic acid plays important roles in the regulation of responses to biotic and abiotic stress [23]. The vital role of salicylic acid in the regulation of physiological and biochemical processes during the entire life span of the plants and its roles in regulating their growth and productivity attracted the attention of many researchers [24,25]. Researchers mentioned that, treatment of cotton seedlings the elicitors salicylic acid activated the defensive pathway in cotton; the whitefly oviposition was decreased significantly [26].

The limitations and high cost of chemical control, in addition to the toxicological problems such as; insecticide persistence and resistance justify the adoption of alternative management methods including plant resistance against the whitefly. In the present study, most of insecticide treatments achieved higher efficacy against whitefly on the Alexandrian variety compared to Hollar variety. Synergistic interactions between resistant plants and insecticide λ-cyhalothrin against aphid populations on soybean were previously reported. On the other hand, a synergistic interaction with chlorpyrifos-treated plants in one season and an antagonistic interaction occurred in another season against aphids was also reported [27].

Different mechanisms for antagonistic and synergistic interactions between management tools have been suggested. Synergistic effects may be resulted from reducing the insect body weight and availability of physiological resources to detoxify insecticides, due to reduced feeding. Antagonistic effects are thought to be consequence of the up regulation of detoxification mechanism in the insect after exposure to stressors [28,29]. A synergistic effect were reported for some insecticides and antagonistic effects for others against cotton leafworm larvae because of gossypol content in cotton varieties [30].

5. Conclusion

These data bring to a close the utility of salicylic acid incorporation with thiamethoxam or pymetrozine as well as squash varieties to control whiteflies seeing that the sequential treatments increased the insecticides activity and persistent efficacy. Additionally, the squash variety affected the efficacy of the treatments. Increasing demand for integration between environmentally friendly alternatives and traditional pesticides is crucial for designing innovative strategies for crop protection. The present study emphasizes on the integration between the induced plant resistance, plant varieties and insecticides for whitefly management on squash fields.

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