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Evaluation of Six Insecticides for the Control of Potato Whitefly (*Bemisia tabaci*) in Relation to Induced Resistance and Tuber Quality

Farid S. Sabra[1], Mona A. A. Mahmoud[2], Rania S. Ammar[2] and Soad M. Ahmed[1*]
Pesticide Chemistry and technology Department, Faculty of Agriculture, Alexandria University, Elshatby,Alexandria, Egypt
[2]Plant Protection research Institute, Agriculture Research Center (ARC), Alexandria, Egypt

POTATO whitefly, *Bemisia tabaci* (*Homoptera: Aleyrodidae*) is one of the most important pests of potato. Field experiments were carried out during two successive growing winter seasons 2017/2018 and 2018/2019 at the Research Station of Faculty of Agriculture Alexandria University, to evaluate the efficacy of six conventional insecticides , emamectin benzoate + thiamethoxam, imidacloprid, etofenprox, fenitrothion, pymetrozine and thiamethoxam against *Bemisia tabaci* on potato plants (*Solanum tuberosum* L.) of variety sponta, either as direct effect or indirect effect during induced resistance and their relationship with crop yield. Results showed that emamectin benzoate+thiamethoxam, thiamethoxam and imidacloprid achieved high reduction percentage of whitefly adults. Also, fenitrothion, pymterozine and imidacloprid achieved high reduction percentage of whitefly immature. Fortunately, these treatments had a positive effect, both on the measures of induced resistance that were estimated, and at the same time they had a promising effect on the potato yield in terms and quality.

Keywords: *Bemisia tabaci*, Potato plants, Insecticides, Induced resistance, Yield, Quality

Introduction

Potato crop is considered one of the most important vegetable crops, and plays an important role in the Egyptian diet, also as an export vegetable crop. Potato plants *Solanum tuberosum* are attacked by many insect species which cause serious injury and thus the final yield is reduced. Whitefly, *Bemisia tabaci (Gennadius*) is a complex cryptic species and destructive insect pest which is reported to attack and damage about 600 plant species (Nombelaand Muniz, 2010). The damages inflicted by whitefly on its plant hosts result directly from sap sucking and toxin injection, and indirectly from virus transmission and honeydew secretion, which serves as a substrate for the growth of sooty mold fungi upon the leaves (Hirose et al. 2015 and Arnemann et al. 2019). Whitefly is among the most serious pests in cultivation of potatoes, since it has a significant influence on yield (Palumbo 2019 and Bhatnagar, 2007).

Insecticides especially neonicotinoid insecticides are applied to plants in managed landscapes worldwide and it is very likely that the insecticide-mediated disruption of plant defenses that documented is widespread (Szczepaniec et al. 2013; Ford et al. 2010; Karthikeyan et al. 2009). Many plant-protecting compounds have been identified that combine both directaction on the pathogen and priming-inducing activity in the plant, and several have given rise to new commercial formulations such as the insecticide Imidacloprid (Eyles et al., 2010). The enhanced biosynthesis and accumulation of proteins are integral components of the induced chemical defense system against insects (Keeling and Bohlmann 2006; Franceschi et al. 2005).

Phenolic compounds are a major class of inducible defense compoundsin many plants (Witzell and Martin and 2008; Tsai et al. 2006). Recent evidence suggests that correlations between insect performance and concentrations of phenolic

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compounds (Ruuhola et al. 2008). Oxidation of phenolic compounds produces reactive oxygen species, resulting in oxidative stress inmidgut tissues (Barbehenn et al. 2009).It is now generally accepted that plant phenolics are secondary metabolites involved in the defense mechanism of plants against insect (Lattanzio et al., 2006). Pesticide residues may interfere with biochemical and physiological processes in plants retarding the growth and yield of the plant. They may also lower its food quality and prevent its use as food by affecting its quality characteristics (Chauhan et al., 2013).

Induced resistance can be exploited for developing crop cultivars, which readily produce the inducible response upon mild infestation and can act as one of components of integrated pest management for sustainable crop production.Ultimately, to establish an effective management strategy for potato whitefly pest.

Experimental Materials and Methods

Field trials and experimental design for the insecticidal activity

Field experiments were conducted at the Research Station of Faculty of Agriculture, Alexandria University, during two successive growing winter seasons 2017/2018 and 2018/2019 on potato plants (*Solanum tuberosum* L.) of variety Sponta. Treatments were arranged in a randomized complete block design (RCBD). Each treatment was replicated three times (42 m^2 each). The normal agricultural practices were applied. The insecticides were sprayed by Knapsack sprayer equipment (CP3) at the rate of 200 liter per feddan. Control was sprayed only by water. Six insecticides were used in this experiment, trade names, common names, companies and rates were introduced in Table 1.

The inspection samples of whitefly adult individuals were carried out before treatment and 1day (initial effect), 3, 5, 7, 10 days post treatment (residual effect). Counts were done in the early morning when flight activity is minimal according to Bulter et al. (1988). Five leaves of each plot were picked from lower, middle and upper of plant and put in numbered paper bags and transferred to the laboratory for examining the immature stages on the upper and lower surfaces by using stereoscopic binocular microscope. The reduction percentages in numbers of whitefly adults and immature stages were calculated in accordance to Henderson and Tilton's equation (1955). The treatments were compared with each other using onway ANOVA with $LSD_{0.05}$ (CoStat Statistical Software, 1990).

The effect on some induced resistance parameters of potato leaves

Dry matter content

The dry matter content of potato tubers was calculated from the following formula:

$$D.M.C=[100-(F.Wt.-D.Wt.)/20]*100)$$

where: F.Wt. = tuber sample weight before drying, D.Wt. = tuber sample weight after drying on 105ºCuntilthe Constant weight.

Total soluble phenol content assay

Total soluble phenol content of potato leaves, was extracted according to Ahmed (2010) and determined according to Slinkard and Singleton (1997). Total soluble phenol content was standardized against tannic acid and absorbance values were converted to µg of phenols per gram of fresh weight potato leaves.

Total protein assay

Total protein was determined according to method described by Bradford (1976), with slight modification proposed by Dixon (1985). The developed color was measured at 595nm. The reading was related to standard curve of BSA (Bovine Serum Albumin) protein.

TABLE 1. Tested insecticides againstbemisiatabaci on potato plants

Common name	Trade name	Company	Rate/feddan
Etofenprox	Primo® 10% SC	Shanxi Lvhai Agrochemicals, China	188 cm^3
Pymetrozine	Tedo® 50% WDG	Syngenta	50g/100liter
Emamectin benzoate + thiamethoxam	Agriflex® 18.56% Sc	Syngenta	250 cm^3
Thiamethoxam	Vitara® 25%WDG	BR agrotech limited -India	30 g/100liter
Fenitrothion	Sumthion KZ®50% EC	Kafr Elzayat Pesticides &Chemicalss	1 liter
midacloprid	Confidor® 20% OD	Bayer	50 cm/100liter

The effect on potato tuber quality characters

Total tuber yield

In order to determine the side effects of the treatments total yield of potato tuber. All tubers of each plot were harvested. Weighted and recorded as ton /Fadden. Then the percentage of increasing of the total yield was calculated.

Total soluble solid (TSS)

A total soluble solid (TSS) in the fresh potato tubers sap was done using a digital refractometer (Abd El-Latif et al., 2011).

Ascorbic acid in fresh potato tubers

Potato tuber were extracted with 0.4% oxalic acid solution. Spectrophotometric determination of ascorbic acid was carried out according to Sabra 1993, Egoaville et al., 1988 and Burgos et al., 2009.

Total acid of potato tubers

Samples of potato tubers were blended with distilled water (1:2.5). The total acidity as citric acid was determined according Sabra, 1993.

Polyphenols in fresh potato tubers

Extraction of polyphenols was carried out according to Zarzecka and Gugata (2011). The method of determination based on the estimation of the color resulted from the reaction between the FolinCicoalteu reagent and hydroxyl group of phenolic compounds under alkaline condition, according to Sabra (1993), Waterhouse (2002) and Burgos et al. (2013).

Statistical analysis

The data of in vivo experiments were analyzed by Two-way analysis of variance (ANOVA). Mean separations were performed by LSD test and differences at $P < 0.05$ were considered as significant (SAS Software).

Results and Discussion

Efficacy of tested insecticides on whitefly adults

According to insecticides application, emamectin benzoate + thiamethoxam, imidacloprid, etofenprox, fenitrothion, pymetrozine and thiamethoxam in season of 2017/2018, population of whitefly adults were significantly reduced, (Table 2). Data in the first spray showed that there were no significant differences between the six insecticides after 1day post treatment (initial reduction). Concerning to the residual reduction, imidacloprid and thiamethoxam were the most effect recording 79.2% and 73.9%. Etofenprox was the least effect (56.6%).In the second spray, data indicated that emamectin benzoate+thiamethoxam gave the highest initial reduction percentage (96.0%) followed by imidacloprid 83.2%. No significant differences between all insecticides on initial reduction of *b. tabaci* adults. The general mean of the first and second spray indicated emamectin benzoate+thiamethoxam achieved high initial and residual reduction percentage (82.3%, 68.5%) followed by imidacloprid (75.2%, 68.0%). Concerningtoseason 2018/2019, in the first spray, data in (Table 3) indicated that thiamethoxam and emamectin benzoate+thiamethoxam achieved the highest initial and residual reduction percentage (76.9%, 71.0%) and (76.0%, 68.3%). During the second spray emamectin benzoate+thiamethoxam was the most effect achieving 90.4% initial reduction followed by imidacloprid 89.8%. Regarding the residual effect, imidacloprid recorded the highest residual reduction percentage 82.5%, there were no significant differences between the other insecticides. The general mean of the first and second spray showed that emamectinbenzoate+thiamethoxam gave the highest initial reduction percentage 83.2% followed by thiamethoxam 79.2%. Also, imidacloprid gave high residual reduction percentage 73.5%. Pymetrozine and etofenprox recorded low residual reduction percentage 59.9% and 58.4%.

TABLE 2. Mean reduction percentagesof B.tabaci adults on potato plants during season of 2017/2018

Insecticides	% Reduction after different times of treatment											
	1st spray					2nd spray					General mean of 1st and 2nd spray	
	1 day (initial)	Residual			Mean of residual	1 day (initial)	Residual			Mean of residual	1 day (initial)	Residual
		3day	7day	10day			3day	7day	10day			
Etofenprox	43.3 a	50.6	71.6	47.7	56.6 b	72.0 c	54.4	59.1	58.7	57.4 a	57.7 b	57.0 b
Pymetrozine	53.9 a	77.1	75.9	26.4	59.8 ab	78.1 bc	74.8	55.5	61.1	63.8 a	66.0 b	61.8 ab
Emamectinbenzoate+Thiamethoxam	68.6 a	91.5	75.9	42.5	69.9 ab	96.0 a	97.6	51.5	52.2	67.1 a	82.3 a	68.5 a
Thiamethoxam	69.9 a	76.7	82.7	62.4	73.9 a	77.5 bc	62.3	53.7	52.1	56.0 a	73.7 ab	65.0 ab
Fenitrothion	63.4 a	80.5	76.6	43.6	66.9 ab	79.7 bc	55.6	50.0	50.9	52.2 a	71.5 ab	59.5 ab
Imidacloprid	67.2 a	70.3	86.1	81.1	79.2 a	83.2 b	62.5	48.5	59.7	56.9 a	75.2 ab	68.0 ab

Different letters indicate significant differences among treatments within the same column according to least significant difference test (P=0.05).

TABLE 3. Mean reduction percentages of B.tabaci adults on potato plants during season of 2018/2019

Insecticides	% Reduction after different times of treatment											
	1st spray					2nd spray					General mean of 1st and 2nd spray	
	1 day (initial)	Residual			Mean of residual	1 day (initial)	Residual			Mean of residual	1 day (initial)	Residual
		3day	7 day	10 day			3 day	7 day	10 day			
Etofenprox	65.2c	49.7	61.2	49.4	53.4c	84.5bc	65.1	58.0	66.9	63.3b	74.8b	58.4d
Pymetrozine	67.0c	53.6	61.0	57.1	57.3c	83.0c	64.1	53.8	69.9	62.6b	75.0b	59.9cd
Emamectin benzoate+Thiamethoxam	76.0ab	75.2	67.4	62.2	68.3a	90.4a	76.5	75.0	72.6	74.7ab	83.2a	71.5ab
Thiamethoxam	76.9a	69.1	71.6	72.3	71.0a	81.4c	71.3	65.3	65.2	67.3b	79.2ab	69.1ab
Fenitrothion	70.4bc	79.9	57.6	40.1	59.2bc	87.1abc	71.5	69.3	72.4	71.0ab	78.8ab	65.1bc
Imidacloprid	65.2c	53.6	58.5	81.6	64.5ab	89.8ab	82.1	81.4	84.1	82.5a	77.5b	73.5a

Different letters indicate significant differences among treatments within the same column according to least significant difference test (P=0.05).

Efficacy of tested insecticides on whitefly immature stages

Data presented in (Table 4) showed that all insecticides reduced the number of immature stages of *Bemisiatabaci*in season of 2017/2018. In the first spray fenitrothion gave the highest initial and residual reduction percentage (94.8% and 93.4%), imidacopríd gave the least residual reduction percentage 70.4%.In the second spray, initial reduction percentage indicated that the efficacy of the used insecticides on immature stages was not different significantly. The residual effect indicated that pymetrozine was the most effect giving 86.8%, etofenprox was the least effect giving 64.8%.The general mean of the first and the second spray indicated that fenitrothion gave the highest initial reduction percentage 87.3%, no significant differences between pymetrozine, emamectin benzoate+thiamethoxam and imidacloprid which gave moderate reduction 75.4%, 74.4% and 73.0%, respectively. The residual effect showed pymterozine was the best recording 89.4% followed by thiamethoxam 85.2%, fentrothion 85.2%, while etofenprox and imidacloprid was the least effect recording 75.8% and 73.8%.In season of 2018/2019, in the first spray, data in (Table 5) showed that fenitrothion gave the highest initial and residual reduction percentage (91.6% and 90.0%). Also, emamectin benzoate+thiamethoxam gave the least initial reduction percentage 60.1%, etofenprox gave the least residual reduction percentage 72.9%.In the second spray, pymetrozine gave the highest initial percentage 87.0%, fenitrothion was the least effect giving 77.2%. Regarding the residual effect, imidacloprid was the best giving 83.5 %, while etofenprox was the least effect 75.0%.The general mean of the first and second spray, after 1day post treatment, data indicated that fenitrothion recorded the highest initial reduction percentage 84.4% and emamectin benzoate+thiamethoxam was the least effect recording 71.9%, concerning to the residual effect, imidacloprid and fenitrothion gave the highest reduction percentage 85.0% and 83.2%, respectively, while etofenprox gave 73.9%.

Results showed some insecticides were its effect high on adults of *B. tabaci* such as emamectinbenzoate+ thiamethoxam, thiamethoxam and imidacloprid. Some achieved high reduction percentage against immature stages such as fenitrothion, pymterozine and imidacloprid which have different mode of action can use in sequence for controlling *b. tabaci* insects to avoid resistance of insecticides. The obtained results are in agreement with those of several investigators. Nag et al. (2018) found that the treatment Imidacloprid followed by Thiamethoxam at 15 days interval was most effective against whiteflies (1.56 per plant). El-Naggar and Zidan (2013) reported that treatments with imidacloprid and thiamethoxam as foliar applications were highly effective against aphids, up to 14 days in the case of jassids, while the effect was moderate on the whitefly population (mature and immature stages). Imidacloprid had more initial and residual effect than thiamethoxam against jassids. Kim et al. (2000) found that fenitrothion, imidacloprid and pymetrozine among insecticides achieved > 95% larvicidal activity on 3rd nymphal instars and > 95% adulticidal activity. The results are also supported by Preetha et al. (2009) who evaluated Imidacloprid and Thiamethoxam equally effective against whiteflies. Jambulkar et al., (2013) reported Imidacloprid most effective against whitefly. Ghosal and Chatterjee (2013) observed Imidacloprid superior against whitefly with lowest pest population and highest marketable yield. Similar results were reported by Arnemann et al. (2019), Afzal et al. (2014), Chandel et al. (2010) and Ananda et al. (2010).

TABLE 4. Mean reduction percentages of *B. tabaci* immature stageson potato plants during season of 2017/2018

Insecticides	% Reduction after different times of treatment											
	1st spray					2nd spray					General mean of 1st and 2nd spray	
	1 day (initial)	Residual			Mean of residual	1 day (initial)	Residual			Mean of residual	1 day (initial)	Residual
		3 day	7 day	10 day			3 day	7 day	10 day			
Etofenprox	82.2^{b}	92.8	89.3	78.7	86.9^{b}	84.7^{a}	63.1	79.7	51.7	64.8^{c}	83.5^{ab}	75.8^{c}
Pymetrozine	71.1^{b}	91.2	90.2	95.0	92.1^{ab}	79.7^{a}	92.1	93.2	75.0	86.8^{a}	75.4^{b}	89.4^{a}
Emamectin benzoate+Thiamethoxam	71.0^{b}	95.9	86.6	81.1	87.9^{b}	74.4^{a}	90.2	74.2	68.2	77.5^{b}	74.7^{b}	82.7^{b}
Thiamethoxam	81.6^{b}	94.3	79.4	95.4	89.7^{ab}	76.8^{a}	82.9	85.7	73.3	80.6^{b}	79.2^{ab}	85.2^{ab}
Fenitrothion	94.8^{a}	96.4	93.1	90.8	93.4^{a}	79.9^{b}	74.5	82.8	73.4	76.9^{b}	87.4^{a}	85.2^{ab}
Imidacloprid	71.9^{b}	77.4	60.6	73.3	70.4^{c}	74.0^{a}	95.4	64.2	72.0	77.2^{b}	73.0^{b}	73.8^{c}

Different letters indicate significant differences among treatments within the same column according to least significant difference test (P=0.05).

TABLE 5. Mean reduction percentages of B. tabaci immature stages on potato plants during season of 2018/2019

Insecticides	% Reduction after different times of treatment											
	1st spray					2nd spray					General mean of 1st and 2nd spray	
	1 day (initial)	Residual			Mean of residual	1 day (initial)	Residual			Mean of residual	1 day (initial)	Residual
		3 day	7 day	10 day			3 day	7 day	10 day			
Etofenprox	73.1^{bc}	74.2	89.1	55.3	72.9^{c}	79.9^{ab}	66.2	75.6	83.2	75.0^{c}	76.5^{bc}	73.9^{c}
Pymetrozine	79.0^{b}	84.0	76.2	63.0	74.4^{c}	87.0^{a}	84.0	86.2	75.8	82.0^{ab}	83.0^{ab}	78.2^{bc}
Emamectinbenzoate+Thiamethoxam	60.1^{c}	91.0	83.0	83.1	85.7^{ab}	83.7^{ab}	91.7	76.6	74.1	80.8^{ab}	71.9^{c}	83.3^{ab}
Thiamethoxam	72.2^{bc}	85.9	90.4	68.0	81.4^{bc}	84.2^{ab}	78.9	73.9	82.6	78.5^{abc}	78.2^{abc}	79.9^{ab}
Fenitrothion	91.6^{a}	97.9	88.6	83.5	90.0^{a}	77.2^{b}	71.4	72.1	85.7	76.4^{bc}	84.4^{a}	83.2^{a}
Imidacloprid	70.5^{bc}	88.6	89.3	81.8	86.6^{ab}	81.5^{ab}	89.9	77.5	83.0	83.5^{a}	76.0^{bc}	85.0^{a}

Different letters indicate significant differences among treatments within the same column according to least significant difference test (P=0.05).

Effect of tested insecticides on some important plant defense parameters

Most of studies focused on the effects ofpesticides on target and non-target pests but little research has focused on the direct effects of insecticides on plants. Here we demonstrate the effect of applications of insecticides on some important plant defense parameters.

Dry matter content of potato leaves

results of the effect of the six tested insecticides on dry matter percentages of potato leaves were recorded in Table 6. Giving the impact of the tested insecticides, it was found that all treatments reduced the percentage of dry matter in potato leaves, except for a pesticide pymetrozine which had no significant effect, either by increase or decrease, and these effects were for both the first and the second seasons.

Total soluble protein content of potato leaves

Chemical defense against herbivores is of utmost importance for plants. Primary and secondary metabolites, including non-protein amino acids, have been implicated in plant defense against insect pests (Huang et al., 2011 and van Loon et al., 2006). Among the promising results obtained is that all treatments increased the protein content of potato leaves, whether in the first season or in the second season, and the first place in this increase was a compound imidacloprid which provided the protein content by 3470.11µg protein/gm fresh wt. leaves with 132.45% of control and 3516.09 µg protein/gm fresh wt. leaves with 149.67% of control in the first and second season, respectively (Table 7).

Total phenols content of potato leaves

The most commongroup of defensive compounds are phenolic compounds. They are important in the resistance strategy against insects (Sharma et al., 2009 and War et al., 2011).

Table 8 showed that all treatments had a significant increase in the content of potato leaves of phenols, which was estimated as micrograms of tannic acid per gram of fresh potato leaves, and the first place in this increase was the treatment of Emamectin benzoate+Thiamethoxam with an increase of 137.93 and 138.28% of the control, as a general average for the first and second seasons, respectively.

TABLE 6. Effect of tested insecticides on % of dry matter content of potato leaves

Insecticides	% of dry matter content					
	First season			Second season		
	1st Spray	2ndSpray	Mean	1stSpray	2ndSpray	Mean
Etofenprox	31.9bc	40.8b	36.3b	29.2cd	39.7cd	34.5c
Pymetrozine	41.1a	44.2ab	42.7a	41.4a	46.1ab	43.8a
Emamectin benzoate+Thiamethoxam	36.4ab	39.03b	37.7b	36.9b	38.9d	37.9b
Thiamethoxam	31.4bc	41.3b	36.4b	30.8c	41.2cd	35.98bc
Fenitrothion	35.41ab	39.8b	37.6b	35.9b	40.03cd	37.9b
Imidacloprid	27.2c	42.96b	35.1b	26.6d	43.02bc	34.8c
Control	37.52ab	49.4a	43.5a	37.8ab	47.4a	42.6a

Different letters indicate significant differences among treatments within the same column according to least significant difference test (P=0.05).

TABLE 7. Effect of insecticides on total soluble protein as µg protein/gm fresh wt. potato leaves

Insecticides	µg protein/gm fresh wt. leaves					
	First season			Second season		
	1st Spray	2nd Spray	Mean	1st Spray	2nd Spray	Mean
Etofenprox	2374.71c	2555.75b	2465.23c	2066.67e	2944.25bc	2505.46c
Pymetrozine	2612.07bc	3118.39ab	2865.23b	2453.45de	3109.20b	2781.32b
Emamectin benzoate+Thiamethoxam	2862.64b	2725.86b	2794.25b	3016.7abc	2691.38c	2854.02b
Thiamethoxam	2609.77bc	2685.63b	2647.70bc	2883.33bc	2972.99bc	2928.16b
Fenitrothion	2895.98b	3717.24a	3306.61a	3183.33ab	3882.76a	3533.05a
Imidacloprid	3338.51a	3601.72a	3470.11a	3313.22a	3718.97a	3516.09a
Control	2763.79b	2499.43b	2631.61bc	2715.52cd	2097.13d	2406.32c

Different letters indicate significant differences among treatments within the same column according to least significant difference test (P=0.05).

TABLE 8. Effect of insecticides on total phenols as µg tannic acid/gm fresh wt. potatoleaves

Insecticides	µg Tannic acid					
	First season			Second season		
	1stSpray	2ndSpray	Mean	1st Spray	2ndSpray	Mean
Etofenprox	811.9de	1088.6b	950.3a	744.4f	1099.08a	921.8d
Pymetrozine	891.1cd	1005.9c	948.5b	875.1d	996.7b	935.9d
Emamectin benzoate+Thiamethoxam	1145.3a	1180.2a	1162.7a	1135.99a	1089.9a	1112.9a
Thiamethoxam	783.4e	946.2cd	864.8c	721.3f	916.8c	819.03e
Fenitrothion	1011.8b	998.03c	1004.9b	1006.6b	1009.9b	1008.2b
Imidacloprid	963.6bc	997.2c	980.4b	933.98c	1005.3b	969.6c
Control	814.1de	873.1d	843.6c	807.1e	802.50d	804.8e

Different letters indicate significant differences among treatments within the same column according to least significant difference test (P=0.05).

Effect of tested insecticides on quality parameters of potato tubers

Pesticide residues may interfere with biochemical and physiological processes in plants retarding the growth and yield of the plant. They may also lower its food quality and prevent its use as food by affecting its quality characteristics (Chauhan et al., 2013). Hence the possible effect of tested insecticides on some quality control parameters were determined.

Effect on potato tuber yield

Based on the yield performance and efficacy against white fly, tuber yield recorded at harvest was subjected tostatistical analysis after converting it into ton per feddan. It revealed that the largest yield in the first season was awarded to the treatment ofThiamethoxam andFenitrothion with yield 5.69 and 4.69 ton per feddan, respectively. The percentage of control reached to 184.85% for the treatment of insecticide Thiamethoxam. Concerning to the second season, Thiamethoxamretreated to the second place while Imidacloprid occupied the first place, (Figure 1).Our results are consistent with Nag et al., 2018 who found that highest harvested yield of tuber found 129.17 q/ha on treatmentcombination Imidacloprid and Thiamethoxam. Also, Ghosal and Chatterjee, 2013 observed Imidacloprid gave highest marketable yield. Similar resultswere reported by Afzal et al., 2014 and Ananda et al., 2010.

Total soluble solids (%TSS) content of potato tubers

The total soluble solids content of the potato tubers as response of six treatments of insecticides, in comparison with untreated control were shown in Figure (2). The results showed that there were no significant differences between the treatments remember the impact on the total soluble solids content especially in the second season. The largest T.S.S was awarded to the treatment of Etofenprox and Emamectin benzoate+Thiamethoxam with a same value of 5.93% which represents a percentage of control 123.61%.

Ascorbic acid content of potato tubers

Ascorbic acid (vitamin C) is the main vitamin in potato tubers are also one of the richest sources of antioxidants in the human diet. Figure (3) showed the effect of foliar application of insecticides treatments on ascorbic acid content and untreated control.It was obviously seen that, all the treatments of the first season significantly increased ascorbic acid content of potato tubers and the highest amount of ascorbic acid found was the share of Imidacloprid followed by Fenitrothion with values of 671.16 and 629.24 µg/ gm fresh wt. of potato tubers, respectively. It is evident in the same table that the treatments in the second season took the same trend, as all the treatments provided the content of vitamin C with a significant increase, and also both Imidacloprid and Fenitrothion retained the first and second places.It is questionable that some research has shown different results from our resultswhere Chauhan et al., 2013 found that the treatment of insecticides decreased the ascorbic acid content of potato tubers.

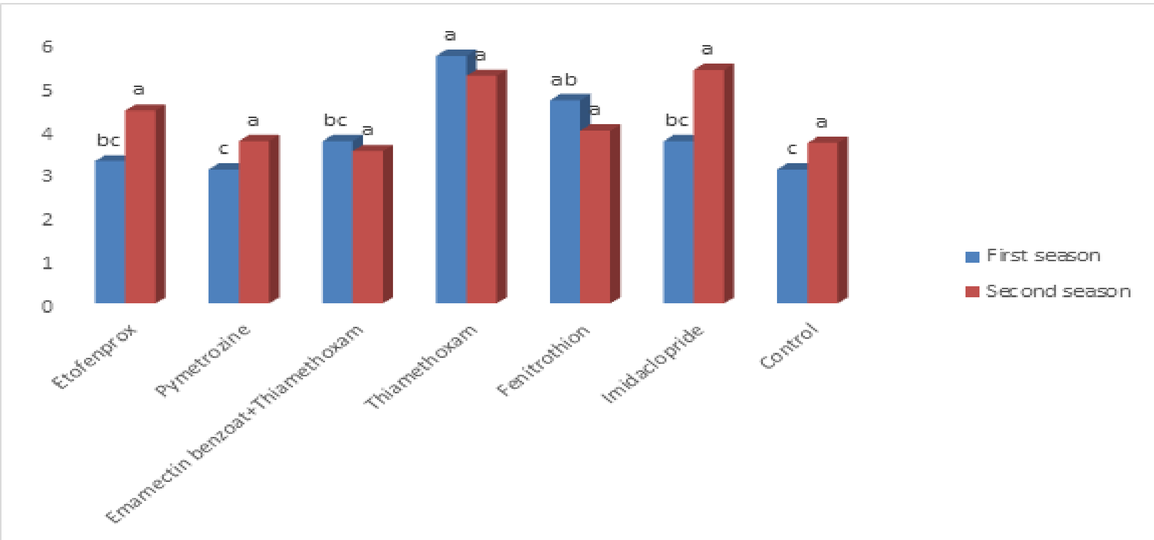

Fig. 1. Effect of tested insecticides on Potato Tuber Yield

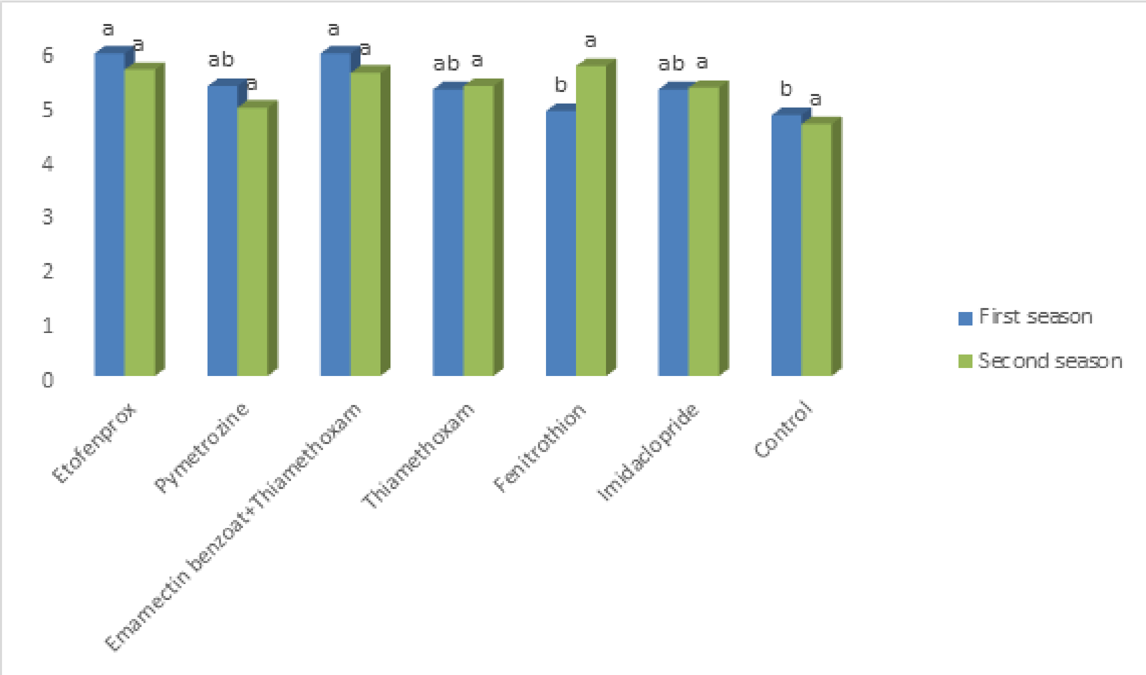

Fig. 2. Effect of tested insecticides on total soluble solids of potato tuber.

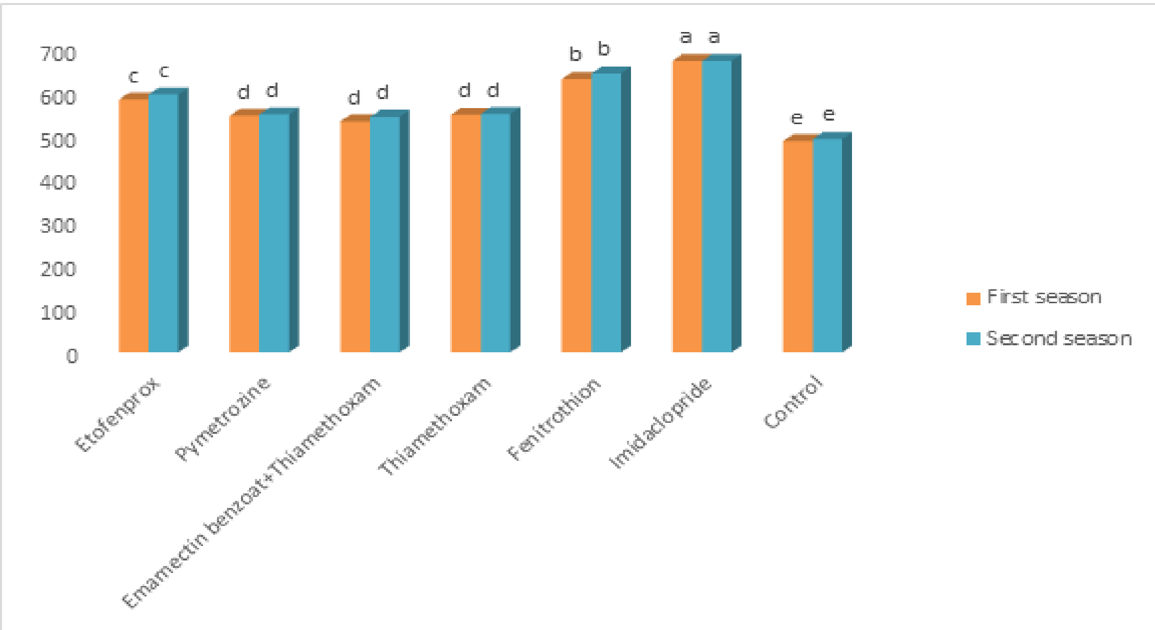

Fig. 3. Effect of tested insecticides on ascorbic acid content of potato tubers

Total acids as citric acid content of potato tubers

Figure 4 shows that all treatments, whether in the first season or in the second season, significantly increased the citric acid content of potato tubers.The highest increase of citric acid percentages in potato tubers were observed in Etofenprox in the first season, Imidacloprid in the second one, since citric acid percentage were 0.187 and 0.182%, respectively.

Total phenol content of potato tubers

The effect of the six treatments of insecticides on the total phenols of potato tubers as µg tannic/gm fresh weightwere shown in Fig. 5. The data revealed that all the treatments either the first season or the second season, significantly increased the total phenol content of the potato. From interestingly, highest total soluble phenols were recorded in Fenitrothionin the two seasons with values of 654.91 and 673.32 µg tannic acid/g fresh wt., respectively.

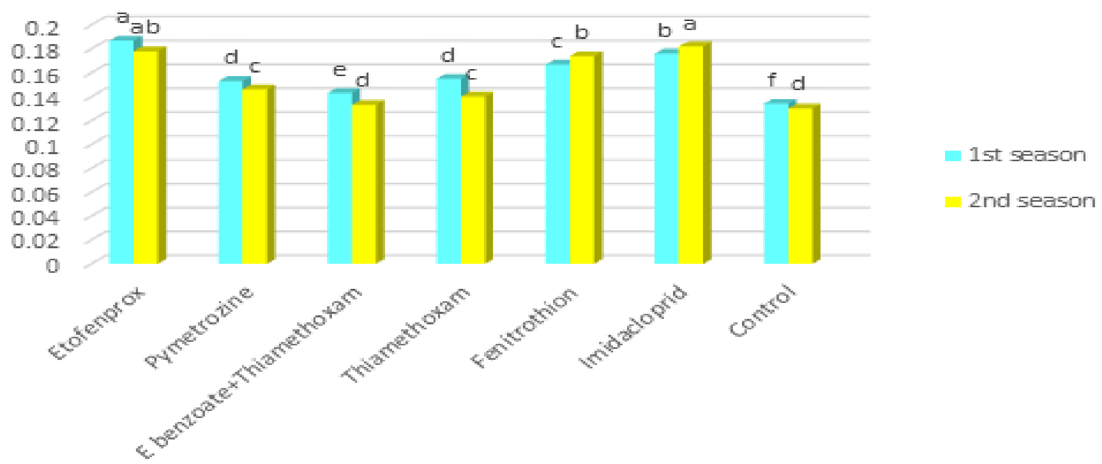

Fig. 4. Effect oftested insecticides on citric acid content of potato tubers.

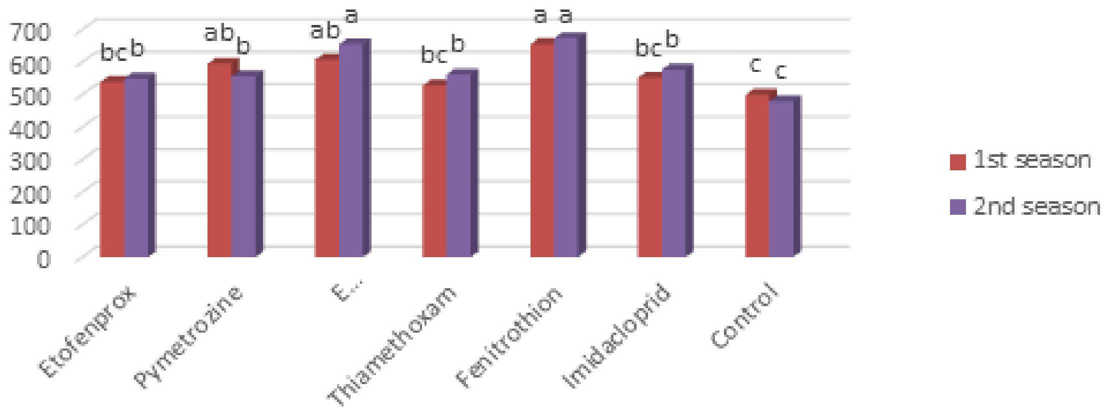

Fig. 5. Effect of tested insecticides on total phenols of Potato Tubers.

Our results differed from some studies since Chauhan et al., (2013) and Hesam et al. (2012) reported a decrease in phenolic content in potatoes by application of pesticide from Iran.

Conclusion

As general results of the two seasons, it may be concluded that all the insecticidal treatments had highly effect against white fly (*Bemisia tabaci*) either on adult stage or immature one. And the immature stage was more sensitive to the pesticides used, (Fig. 6).It is really interesting that these insecticides were not satisfied with their direct effect on the white fly, but rather their good effect that they had indirect effects on the plant, as they improved some components of the potato plant that have a role in inducing resistance to insect infestation, (Fig. 7). The effect of insecticides on the insect is a good thing, but it is not surprising, but what is really surprising is to find that it did not negatively affect the plant, but on the contrary, it positively affected the yield, whether in quantity or quality, (Figure 8). The research is a pure work belonging only to its authors and there is no funding for it from any party, as well as there is no conflict between its authors in any way or another.

Author Contributions

This study was designed and implemented by all authors. They contributed in writing the paper, interpreting information presented and they all have read and agreed to the version of the manuscript.

Conflicts of Interest

The authors declare that there is no conflict of interest.

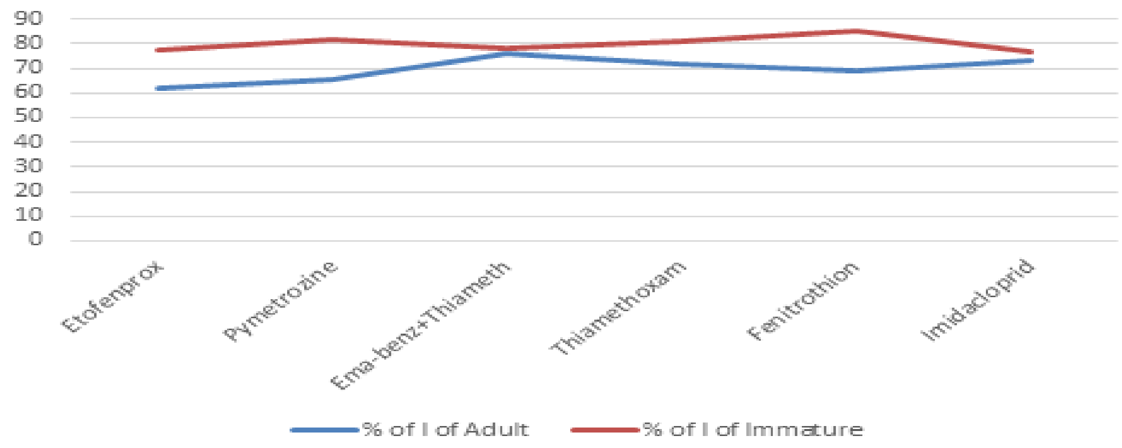

Fig. 6. General mean of Reduction Percentage (%I) of white fly

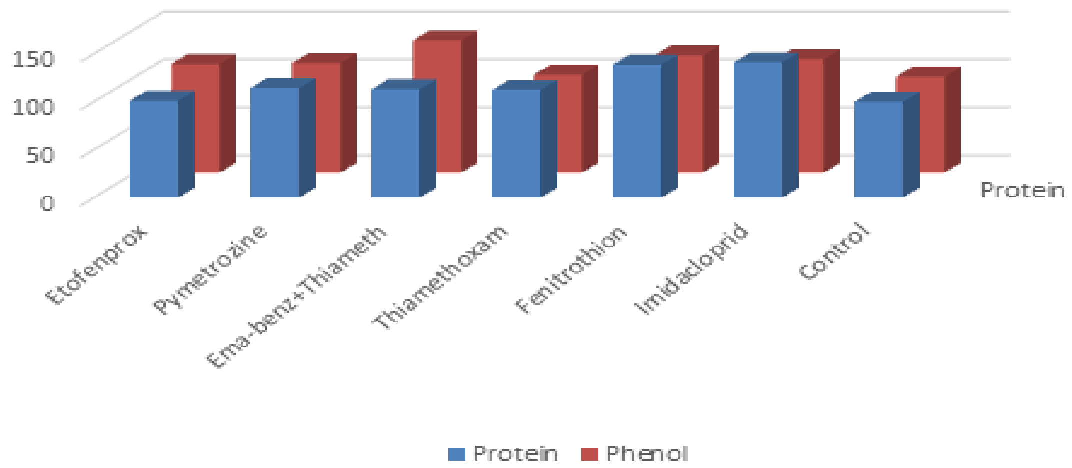

Fig. 7. General effect of Insecticides on Defense Parameters

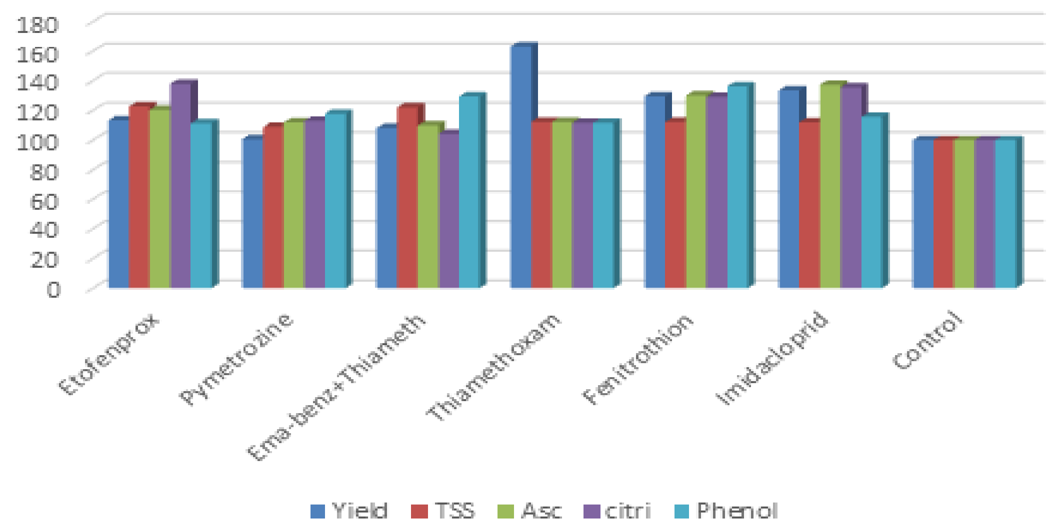

Fig. 8. Effect on Tuber Yield and Quality Parameters

References

Abd El-Latif, K. M., Osman, E. A.M., Abdullah, R., and Abd el Kader, N. (2011) Response of potato plants to potassium fertilizer rates and soil moisture deficit. *Adv. Appl. Sci. Res.,* **2** (2), 388-397.

Afzal, M., Rana, S. M., Barbar, M. H. (2014) Comparative Efficacy ofnew Insecticides against Whitefly, *Bemisiatabaci (Genn.)* and Jassid, *Amrascadevastans (Dist.)* on Cotton,Bt-121. Biologia (Pakistan), **60** (1), 117-121.

Ahmed, S. M. (2010) Impact of foliar applied fungicides on late blight disease, yield and yield components of threevarieties of potatoes. *Journal of Applied Sciences Research,* **6** (8), 994-1001.

Ananda, N., Kotikal, Y. K.and Balikai, R. A. (2010) Managementpractices for major sucking pests of pomegranate.*Karnataka J. Agril. Sci.* **22** (4), 45-49.

Arnemann, J. A.,Bevilaqua, J. G.,Bernardi,L., da Rosa, D. O., da Encarnação,F. A. andPozebon, H. (2019) Integrated Management of Tomato Whitefly Under Greenhouse Conditions. *Journal of Agricultural Science*; Vol. **11**, No. 5, 2019.

Barbehenn, R.V.,Jaros, A., Lee, G.,Mozola, C., Weir, Q. and Salminen, J. P. (2009) Tree resistance to Lymantria dispar caterpillars: importance and limitations of foliar tannin composition. *Oecologia* **159**, 777-788.

Bhatnagar, A. (2007) Incidence and succession of thrips,leafhopper and whitefly in combination of planting datesand potato varieties. *Annals. Pl. Protec. Sci.* **15**,101-105.

Bradford, M.M. (1976) A rapid and sensitive method for the quantification of microgram quantities of protein utilizing the principle of protein-dye binding. *Anal. Biochem.*, **72**, 248-254.

Burgos, G., Amoros, W.,Muñoa, L., Sosa, P.,Cayhualla, E., Sanchez, C., Díaz, C. and Bonierbale, M. (2013) Total phenolic, total anthocyanin and phenolicacid concentrations and antioxidant activity of purple-fleshed potatoes as affected by boiling. *Journal of Food Composition and Analysis.* **30**, 6-12.

Burgos, G., Auqui, S.,Amoros, W., Salas, E. and Bonierbale, M. (2009) Ascorbic acid concentration of native Andean potato varieties as affected by environment cooking and storage. *Journal of Food Composition and Analysis,* **22**, 533-538.

Butler, G. D.,Coudriet, D. L. and Hennebery, T. V. (1988) Toxicity and repellance of soybeans and cotton seed oils to the sweet potato whitefly and the aphids on cotton in greenhouse studies. Southwest, *Entomol*. **13**, 81-96.

Chandel, R. S.,Banyal, D. K., Singh, B. P., Malik, K. and Lakra, B. S. (2010) Integrated Management of Whitefly, *Bemisiatabaci (Gennadius*) and Potato *Apical Leaf Curl Virus in India Potato Research*. **53**, 129-139

Chauhan, S.S., Agrawa, S.and Srivastava, A. (2013) Effect of imidacloprid insecticide residue on biochemical parameters in potatoes and its estimation by HPLC. *Asian J Pharm Clin Res,* Vol 6, *Supp* **l3**, 114-117.

CoStat Statistical Software. (1990) Microcomputer program analysis version 4. 20, Co Hort Software, Berkeley, CA.

Dixon, R.A. (1985) Plant cell culture, a practical approach IRLPRESS. Oxford. Washington DC. 1-235.

Egoaville, M., Sullivan, J.,Kozempel, M. and Jones, W. (1988) Ascorbic acid determination in processed potatoes. *American Potato Journal*. **65**, 91-97.

El-Naggar, J.B. and Zidan, L.T.M. (2013) Field evaluation of imidacloprid and thiamehoxam against sucking insects and their side effects on soil fauna. *J. Plant Protection Research*. **53** (4), 375-386.

Eyles, A., Bonello,P., Ganley, R. and Mohammed, C. (2010) Induced resistance to pests andpathogens in trees. 4,5,6 New *Phytologist,* **185**, 893–908doi: 10.1111/j.1469-8137.2009.03127.x.

Ford, K. A.,Casida, J. E., Chandran, D.,Gulevich, A.G., Okrent, R.A. (2010) Neonicotinoid insecticides induce salicylate-associated plant defense responses. Proceedings of the National Academy of Sciences of the United States of America **107**, 17527-17532.

Franceschi, V.R., Krokene, P., Christiansen, E. andKrekling, T. (2005) Anatomical and chemical defenses of conifer bark against bark beetles and otherpests. *New Phytologist,* **167**, 353-375.

Ghosal, A. and Chatterjee, M. L. (2013) Bioefficacy of Imidacloprid17.8 SL against whitefly, *Bemisiatabaci (Gennadius)* inbrinjal. *J. Pl. Prot. Sci.* **5** (1), 37-41.

Henderson, C. and Tilton, E. (1955) Tests with acaricides against the brown wheat mite. *J. Econ. Entomol.* **48**, 157-161.

Hesam, F., Balali, G.R. and Tehrani, R. T. (2012) Evaluation of antioxidant activity of three common potato (*Solanum tuberosum*) cultivars in Iran. *Avicenna Journal of Phytomedicine.* **2** (2), 79-85.

Hirose, E. Batista, A. S. and Silva, M. S. (2015) Correlação da ocorrência de fumaginaem soja com a população de ninfas de mosca-branca Bemisiatabaci (Hemiptera: Aleyrodidae). Embrapa Soja, Cuiabá, MT: VI Congresso Brasileiro de Soja.

Huang, T., Jander, G. and Martin, V. (2011) Non-protein amino acids in plant defense against insect herbivores: Representative cases and opportunities for further functional analysis. *Hytochemistry,* **72** (13), 1531-7.

Karthikeyan, G., Doraisamy, S. andRabindran, R. (2009) Induction of systemic resistance in blackgram (*Vigna mungo*) against urdbean leaf crinkle virus by chemicals. *Archives of Phytopathology and Plant Protection,* **42**, 1-15.

Keeling, C.I. and Bohlmann, J. (2006) Genes, enzymes and chemicals of terpenoiddiversity in the constitutive and induced defence of conifers againstinsects and pathogens. *New Phytologist,* **170**, 657-675.

Kim, G. Y., Lee, I. L. and Ahn, K. (2000) Susceptibility of sweetpotato whitefly,*Bemisiatabaci* (Homoptera: Aleyrodidae) to commercially registered insecticides in Korea. *The Korean Journal of Pesticide Science.* **4** (1), 51-58.

Lattanzio, V., Lattanzio, V. M. T. and Cardinali, A. (2006) Role of phenolics in theresistance mechanisms ofplants against fungalpathogens and insects. Phytochemistry: *Advances in Research*, 23-67 ISBN: 81-308-0034-9.

Nag, D., Nag, R., Bhargav, P., Kumar, Y. andBisen, M. S.(2018) Relative Efficacy of Insecticides against PotatoAphid (*Myzuspersicae Sulzer*), White Fly (*Bemisiatabaci Genn*.) and Lady Bird Beetle. *International Journal of Chemical Studies*. **6** (1), 1182-1186.

Nombela, G. andMuñiz,M. (2010) Host plant resistance for the management of Bemisiatabaci: a multi-cropsurvey with emphasis on tomato. In: Stansly PA, Naranjo SE (Eds) *Bemisia: bionomicsand management of a global pest.* Springer Science Business Media B.V., pp 357–383.doi:10.1007/978-90-481-2460-2.

Palumbo, J. C. (2019) Impact of Sweet Potato Whitefly Infestation on Yield and Quality of Cantaloupe. http://hdl.handle.net/10150/221467.

Preetha, G., Manoharan, T., Stanley, J. andKuttalam, S. (2009) Evaluation of Imidacloprid against okra jassid, *Amrascabiguttulabiguttula* (Ishida) and whitefly, *Bemisiatabaci (Gennadius)*. *Indian J. Ent.* **71** (3), 209-214.

Ruuhola, T., Yang, S. Y., Ossipov, V. andHaukioja, E. (2008) Foliar oxidases asmediators of the rapidly induced resistance of mountain birch against *Epirritaautumnata*. *Oecologia,* **154**, 725-730.

Sabra, F.S. (1993) Studies on the Chemical Weed Control. Studies on the Efficiency of Certain Herbicides and their Side Effect on Potato Plants and Soil. *Ph.D. thesis,* Faculty of Agric. Alex. University.

Sharma, H. C., Sujana, G., and Rao, D. M. (2009) Morphological and chemicalcomponents of resistance to pod borer, Helicoverpaarmigera in wild relativesof pigeonpea. *Arthropod Plant Interact*. **3**, 151-161. doi: 10.1007/s11829-009-9068-5.

Slinkard, K. and Singleton, V.L. (1997) Total phenol analysis: automation and comparison with manual methods. American Journal of Enology and methods. *American Journal of Enology and Viticulture*, **28**, 49-55. 1997.

Szczepaniec, A., Raupp, M. J., Parker, R. D., Kerns, D. and Eubanks M. D. (2013) Neonicotinoid Insecticides Alter Induced Defenses and Increase Susceptibility toSpider Mites in Distantly Related Crop Plants. *PLoS ONE* **8** (5), e62620. doi:10.1371/journal.pone.0062620.

Tsai, C. J., Harding, S. A., Tschaplinski, T. J., Lindroth, R. L.and Yuan YN. (2006) Genome-wide analysis of the structural genes regulating defense phenylpropanoidmetabolism in Populus. *New Phytologist* **172**, 47-62.

Van Loon,L.C., Rep,M. and Pieterse, C.M.J. (2006) Significance of Inducible Defense-related Proteins in Infected Plants. *Article in Annual Review of Phytopathology*, Vol. **44**, 135-162.

War, A.R., Paulraj, M.G., War, M.Y., and Ignacimuthu, S. (2011) Jasmonicacid-mediated-induced resistance in groundnut (*Arachis hypogaea* L.) against *Helicoverpaarmigera (Hubner)* (Lepidoptera: Noctuidae). *J. Plant GrowthRegul.* **30**, 512-523.

Waterhouse, A.,(2002)Determination of total phenolics. Current Protocols in Food Analytical Chemistry. University of California, U.S.A. I1.1.1-I.1.1.8.

Witzell, J. and Martin, J. A. (2008) Phenolic metabolites in the resistance ofnorthern forest trees to pathogens – past experiences and future prospects.*Canadian Journal of Forest Research* **38**, 2711-2727.

Zarzecka, K. and Gugata, M. (2011) The effect of herbicides and soil tillage systems on the content poly phenols in potato tuber. *Polish J.of Environ. Stud*.vol. **20**, No. 2, 513-517.

تقييم ستة من المبيدات الحشرية لمكافحة ذبابة البيضاء فى البطاطس(Bemisiatabaci) وتأثيرها على مقاومة النباتات وجودة الدرنات

فريد صبره[1]، منى عبدالكريم[2]، رانيا عمار[2] و سعاد محمدين[1]
[1] قسم كيمياء وتقنية المبيدات – كلية الزراعة – الشاطبى- جامعة الأسكندرية
[2] معهد بحوث وقاية النبات ، مركز البحوث الزراعية - الإسكندرية

الذبابة البيضاء (*Bemisia tabaci*) هي واحدة من أهم الآفات التى تصيب البطاطس. أجريت تجارب حقلية خلال موسمي شتاء زراعة متتاليين ٢٠١٨/٢٠١٧ و ٢٠١٩/٢٠١٨ في محطة البحوث بكلية الزراعة جامعة الإسكندرية ، لتقييم فعالية ستة من المبيدات الحشرية وهى : إيمامكتين بنزوات + ثياميثوكسام ، إيميداكلوبريد ، إيتوفينبروكس ، فينيتروثيون ، بيميتروزين. و ثياميثوكسام ضد *Bemisia tabaci* على نباتات البطاطس (*Solanum tuberosum* L) صنف سبونتا. وذلك من خلال تأثيرهاالمباشر على الحشرة أو تأثيرها غير المباشر من خلال المقاومة المستحثة فى النبات وعلاقتها بإنتاجية المحصول. أظهرت النتائج أن إيمامكتين بنزوات + ثياميثوكسام وثياميثوكسام وإيميداكلوبريد حقق نسبة خفض عالية في الذبابة البيضاء وذلك فى حالة الحشرة الكاملة. بينما حقق الفينيتروثيون ، البيمتيروزين والإيميداكلوبريد نسبة خفض عالية وذلك فى الطور الغير بالغ للذبابة البيضاء. ومن حسن الحظ ان لهذه المعاملات من المبيدات الحشرية تأثير إيجابي ، سواء على مقاييس المقاومة المستحثة التي تم تقديرها ، وفي نفس الوقت كان لها تأثير واعد على محصول البطاطس من حيث الكم والكيف.