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INFLUENCE OF SYLGARD 309 ADJUVANT ON IMIDACLOPRID USED IN CONTROLLING TOMATO LEAF MINOR, *Tuta absoluta* INFESTING TOMATO GROWN IN OPEN FIELD

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ABSTRACT: Tomato is the most widely grown vegetables in the world and also the most important item of the vegetables processing sector. Tomato is important vegetable plant in our agriculture map which used as food in many countries of the world and especially Egypt. It infested with many pests, among of the most serious pest, tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). This study was aimed to investigate efficiency of Imidacloprid applied alone and in a binary mixture with Sylgard 309 adjuvant against this pest under field conditions, effect of Imidacloprid on tomato yield and determination of Imidacloprid residues in tomato fruits and soil. Results illustrated that adding Sylgard 309 adjuvant to Imidacloprid caused increasing mean reduction percentage to 98.02%, recording the first superior treatment. In case of tomato yield during two summer successive seasons 2014 and 2015, results reported that tomato yield increased by adding Sylgard 309 adjuvant to Imidacloprid and recorded superior yield of 600.75 and 613.15 Kg with increasing value of 41.27% and 35.44%, respectively during seasons 2014 and 2015 compared with control. Unfortunately, adding Sylgard 309 adjuvant to Imidacloprid was causation in increasing the half-life ($T_{½}$) values and the quantities of residues in tomato fruits and soil, that were less than the maximum residue level (0.5 mg/kg).

Key words: Tomato, yield, *Tuta absoluta*, imidacloprid, sylgard 309, residues, soil.

INTRODUCTION

Tomato fruit (*Lycopersicon esculentum* Mill.) is one of the most widely grown crops in the world. Egypt is a major producer and consumer of tomatoes, ranking sixth among producing countries with an annual production of 6.7 million tons **(FAOSTAT, 2019)**. It is considered a basic component of the Egyptian diet and is consumed almost daily fresh, cooked or processed as canned product or paste **(Malhat *et al*., 2012)**.

The tomato leaf miner or tomato borer or the South American tomato pinworm *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is one of the most damaging pests in many countries in America, Europe, Africa and Asia **(Santana *et al*., 2019)**. It has been recognized as one of the most serious tomato pests **(Ramadan *et al*., 2016)**. It is an invasive insect pest causing severe loss of tomato production in many countries either in open field or greenhouses **(Erasmus *et al*., 2021)**. The caterpillar feeds on several parts of tomato plants such as leaves, stems and fruits causing direct and indirect damages that could result in 100% yield loss **(Saad *et al*., 2020)**.

Insecticides are used in agricultural production to protect crops and control pests **(Celikler *et al*., 2010)**. Neonicotinoids are widely used in cultivation of vegetables worldwide to control various sucking pests and increase crop production at low cost **(Jeschke and Nauen, 2008)**. They comprise seven commercially marketed active ingredients: imidacloprid, acetamiprid, nitenpyram, thiamethoxam, thiacloprid, clothianidin and dinotefuran. Among this group, imidacloprid is

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the most widely used insecticide in the world **(Elbert *et al*., 2008)**. Imidacloprid ($C_9H_{10}ClN_5O_2$) is a nicotine-based systemic neurotoxin insecticide that acts as a selective agonist at the nicotinic acetylcholine receptors (nAChRs) post-cyanotic in insects. It was initially introduced in the market in 1991 for veterinary usage and crop protection **(Abu Zeid *et al*., 2019)**. It is a largely commercialized first generation neonicotinoid insecticide **(Wu *et al*., 2019)**, which has gastric, thixotropic and systemic activities, as well as high efficiency, low toxicity and broad-spectrum characteristics **(James *et al*., 2016)**. It is found to be widely used for a variety of agricultural including corn, potato, rice and tomato **(Morrissey *et al*., 2015)**. It is an insecticide recommended in Egypt for use on tomato to control sucking pests in open field and greenhouse conditions **(Kumar, 2018)**.

Various adjuvants are being used to increase the penetration of insecticides into target plant foliage and they strongly affect the interactions among pest, pesticide, and crop. They include surfactants, compatibility agents, anti-foaming agents, spray colorants (dyes) and drift control agents **(Ferrell *et al*., 2008)**. They are supplemental substances added to insecticide tank mixtures to enhance their efficacy by altering the dispersing, emulsifying, spreading, sticking and wetting properties of the spray mixture **(Parlakidis *et al*., 2023)**. They are usually much cheaper than insecticides and can decrease the effective insecticide dosage as much as 10 fold, but their effects vary with chemicals and plant species. They may be added to the product at the time of formulation or at treatment time **(Green and Foy, 2003)**. Sylgard 309 is a nonionic surfactant (organosilicon) and specifically designed to enhance the efficacy of insecticide. It is nontoxic to mammals and was found to synergize pymetrozine against insects **(Acheampong and Stark, 2004)**.

Harvesting crops after insecticide application, especially fruit and vegetables, might lead to high levels of insecticide residues in food commodities, which might have chronic effects on human health upon consumption. Therefore, analysis of insecticide residues in food is a key tool for monitoring the levels of human exposure to insecticides **(El-Sheikh and Ashour, 2022)**.

Tomato leaf miner *Tuta absoluta* causes high losses in yield so this study shed light on the efficiency of Imidacloprid applied alone and in binary mixture with Sylgard 309 adjuvant in reduction population of this pest and detection of insecticide residues compared to MRLs in tomato fruits and soil under field conditions.

MATERIALS AND METHODS

Insecticide Used

Imidacloprid (Admir® 20% SC)

(E)–1– (6 – chloro – 3 – pyridylmethyl) – N–nitroimidazolidin-2-ylideneamine). It is produced by Bayer Crop Science, Germany. The basic characteristics of the detected Imidacloprid in tomato fruits and soil are presented in Table 1. The concentration of Imidacloprid used in this study was based on the labeled recommendation rate.

Adjuvant Used

Sylgard 309® (Organosilicon nonionic surfactant)

3-(3-Hydroxypropyl) eptamethyltrisiloxane, Ethoxylated Acetate/125997-17-3, Polyethylene Glycol Monallyl Acetate/27252875, Polyethylene Glycol Diacetate/27252831. It is distributed by Wilbur-Ellis (Fresno, CA, USA). The labeled recommended rate is 25 ml/100 L. water.

Field Experimental

The field experiment was conducted in the present investigation to evaluate the efficiency of Imidacloprid for controlling leaf miner, *Tuta absoluta*, infesting tomato fruits, (*Lycopersicon esculentum* Mill.), under field conditions during the two successive summer seasons of 2014 and 2015, respectively. In this respect, area of about 525 m^2 were selected at a private farm at El-Saleheya El-Gadida district, Sharkia Governorate, Egypt. Tomato plants, (variety, cv 186) were cultivated at field in sandy clay soil with a density of 2 plants/m^2 in the both years, i.e., 2014 and 2015 on first week of May. Mean temperature and relative humidity were (36, 40°C) and (70.14, 71.51%) for the summer seasons of 2014 and 2015, respectively.

Table 1. The trade name, chemical group, field rate and MRL of Imidacloprid.

Common name	Trade name	Chemical group	Field rate	MRL[a] Codex (mg/kg)	MRL[b] EU (mg/kg)
Imidacloprid	Admir® 20 % SC*	Neonicotinoid	50 cm/100 L.	0.5	0.5

a = According to Codex Alimentarius Pesticides Residues in Food Database **(FAO/WHO, 2019)**.
b = According to Commission Amending Regulation, European Commission, EU Pesticide database **(EU, 2019)**.
SC* = Suspension Concentrate – MRL = Maximum Residue Limit.

Effectiveness of Imidacloprid Alone and in Binary Mixture with Sylgard 309 Adjuvant against Tomato Leaf Miner, *Tuta absoluta*

The efficiency of Imidacloprid, applied either alone or in binary mixture with Sylgard 309 adjuvant against tomato leaf miner, *Tuta absoluta,* infesting tomato fruits was studied during two summer seasons in 2014 and 2015. In this respect, the field was cultivated with tomato plants and divided equally into 3 plots (2 treatments of tested insecticides and untreated one as control, each plot consists of four replicates). The experimental area, received routine agricultural practices, was designed as complete randomized blocks. The insecticidal treatments were applied at the recommended dose alone and in binary mixture with Sylgard 309 adjuvant twice when infestation beginning and the nodes and formation with 14 days' interval by using a knapsack hand sprayer fitted with one nozzle boom (20-liter capacity). The applications in the first year, *i.e.,* 2014 was undertaken on May 25th and June 9th during summer season. Also, the chemicals were sprayed in the second year 2015 on the same time. During both seasons Good agricultural practices (GAP) were applied, according to Egyptian Ministry of Agriculture recommendation. The number of certain sucking pests was counted. The effect of different treatments on the reduction percentage in pest population resulted was calculated according to the equation of **Henderson and Tilton (1955)**.

Effect of Imidacloprid Applied Either Alone and in Binary Mixture with Sylgard 309 Adjuvant on Yield of Tomato

For determination the tomato yield, edible fruits were harvested every seven days from each plot and weighted immediately in the field. This procedure was used during the two tested seasons. The yield of each treatment expressed as kilogram of fruits per plot. Data obtained were statistically analyzed according to the method of **Steal and Torrie (1960)**.

Residues Determination of Imidacloprid Alone and in Binary Mixture with Sylgard 309 Adjuvant in Tomato Fruits

Four replicates tomato fruits and soil samples of treated and untreated tomato plants during plantation of 2015 were randomly packed up and placed in paper bags, according to the **FAO/ WHO (1986)**, one hour (initial deposits) after treatments and then 1, 3, 7, 10 and 14 days after spraying for residue analysis. Random samples from the four replicates of each treatment were weighed about 2 kg approx. (half kg for each replicate). Immediately after purchasing, the samples were transported to the laboratory, cut into pieces, packaged separately in marked plastic bags and stored at –20°C. Fruits and soil samples were subjected to extraction and cleaned-up procedures using a quick, easy, cheap, effective, rugged and safe (QuEChERS) methodology according to European Union method, namely EN-15662: 2018 **(EFSA, 2021)**.

Final Determination of Imidacloprid Residues Using HPLC Analysis

Residues determination of tested Imidacloprid was carried out at laboratory of chemical analysis in 10th of Ramadan city by using HPLC system (Agilent, USA) model 0302UC010 series with the flowing conditions, a binary pump and auto sampler, UV (Ultra violet) detector, PAS-5 (Silicycle Ultra column) of 100 mm length, 4.60 mm diameter, 1.80 µm particale size, 1 min void time, maximum pressure 600 bar, maximum pH 9, minimum pH 2 and maximum temperature 60°C. The mobile phase was distilled water and acetonitrile (30:70, v/v), run at a flow rate of 1 ml/min and the injection volume was 10 µl. The tested Imidacloprid was detected at wave length 265 nm and recorded at retenion time 3.211. The residues were calculated according to the equation of **Möllhoff (1975)**. The half-life time ($T_{½}$) for imidacloprid was calculated using the equation of **Moye *et al*. (1987)**.

Statistical Analysis

All data were represented as mean and subjected to the analysis of variance test (ANOVA) and completely randomized block design using the statistical analysis system SPSS (22). The least significant differences (LSD) at 0.05% level were determined according to Duncan's multiple range test **(Litlle and Hills, 1975)**.

RESULTS AND DISCUSSION

The present results will be presented and discussed under the following three main headings:

Effectiveness of Imidacloprid Alone and in Binary Mixture with Sylgard 309 Adjuvant against Tomato Leaf Miner, *Tuta absoluta*

Tomato plants data presented in Table 2 showed efficiency of Imidacloprid after application during two successive seasons 2014 and 2015, respectively. Results concentrated on comparison between treatments, whereat that the statistical analysis of results appeared significant differences between each treatment. Regarding initial effect of adding Sylgard 309 adjuvant to Imidacloprid was causation in increasing mean reduction percentage 98.02% recording the first superior treatment, followed by the other treatment with adding Imidacloprid alone that recorded 96.08% reduction in Table 2. Concerning the residual effect, results illustrate that addition Sylgard 309 adjuvant to Imidacloprid has high effective record reduction (81.02%) while the other treatment with adding Imidacloprid alone recorded 74.68%. The same trend occurs with general mean, where addition Sylgard 309 adjuvant come to at the first score followed by the other treatment with adding Imidacloprid alone as 85.27 and 80.03% reduction, respectively. These finding are in harmony with these recorded by **El-Sherif *et al*. (2009)** who showed that adding surfactant into spray mixtures greatly increased droplet coverage area on the surfaces, while droplet evaporation time was greatly reduced. Therefore, droplet size, surface characteristics of the target (waxy or non-waxy) and chemical composition of the spray mixture (water alone, pesticide, additives) should be included as important factors that can affect the efficacy and efficiency of pesticide applications.

Effect of Imidacloprid Applied Either Alone or in Binary Mixture with Sylgard 309 Adjuvant on Yield of Tomato

Summarized results illustrated that using Imidacloprid alone or in binary mixture with Sylgard 309 adjuvant cause yield increasing compared with control treatment during 2014 and 2015 season., these yields increasing were evidenced in Table 3. In case of first season 2014 season, the results of statistical analysis indicated that there were significant differences among treatments compared with control. The results showed that the yield increased in each treatment, when adding Sylgard 309 adjuvant to Imidacloprid recorded high yield (600.75 Kg) during 2014 season with increasing value 41.27% compared to other treatment with adding Imidacloprid alone that recorded yield (557.40 Kg) during 2014 season with increasing value 31.08%, and control recorded the lowest yield 425.25 kg.

Concerning yield in the second season 2015, results took the same trend and there were significant differences between treatments, whereas, adding Imidacloprid with Sylgard 309 adjuvant recorded the superior treatment (613.15 kg) with increasing value % 35.44 compared with control. Also, adding Imidacloprid alone recorded 505.35 kg tomato fruits with increasing value 11.63%, and control recorded the lowest yield 452.70 kg. Discussing the foregoing results, it could be seen that adding Imidacloprid either alone or in binary mixture with Sylgard 309 induced significant increase in yield of tomato fruits comparing with the untreated check. These results are in full agreement with those obtained by **Ghatwary (2003)** who found that using carbosulfan and pirimiphos-methyl alone or in binary mixtures with caple 2 increased apparently the yield of cucumber fruits comparing with the untreated control.

Table 2. Mean reduction percentage of tomato leaf miner, *Tuta absoluta* population on tomato fruits after application of Imidacloprid under field conditions during 2014 and 2015 season

Tested insecticides	Initial effect (%)*	Residual effect (%)	General mean (%)
Imidacloprid	96.08[a]	74.68[c]	80.03[b]
Imidacloprid + Sylgard 309	98.02[a]	81.02[b]	85.27[b]

Means followed by the same superscript letter(s) are not significantly different at least significant difference 0.05 using the statistical analysis system SPSS (22) according to DMRT.
Initial effect = 3rd day of the application.
Mean residual effect = mean the effect during the period from 7th till 14th day after spraying.
Mean general effect = mean the effect during the period from 3rd till 14th day after spraying.

Table 3. Effect of Imidacloprid alone and in its binary mixture with Sylgard 309 on yield and increasing percentage of tomato under field conditions during 2014 and 2015 season

Treatments	First season (2014)		Second season (2015)	
	Yield (Kg)	Increasing %	Yield (Kg)	Increasing %
Control	425.25[d]	0.0	452.70[d]	0.0
Imidacloprid	557.40[b]	31.08	505.35[c]	11.63
Imidacloprid + Sylgard 309	600.75[a]	41.27	613.15[a]	35.44

Means followed by the same superscript letter(s) are not significantly different at least significant difference 0.05 using the statistical analysis system SPSS (22) according to DMRT.

Impact of Adding Sylgard 309 Adjuvant on Residues of Imidacloprid in Tomato Fruits

The results of the initial deposits, dissipation percentage and half-life values of tested Imidacloprid applied alone and in binary mixture with Sylgard 309 adjuvant in tomato fruits and soil are presented in Table 4. These data were detected after one hour, 1, 3, 7, 10 and 14 days from spraying. The residues in tomato fruits were determined after different intervals of application. They decreased progressively with time irrespective of application rates. Tomato fruits were edible after one hour from spraying where the residues of Imidacloprid were less than the maximum residue level (0.5 mg/kg) as adapted by Eu Pesticide database MRL, (SANTE/10617/2018 N/A), so these tomato fruits can be offered to consumers from the first day of spraying.

In case of adding Imidacloprid alone, the initial deposits (one hour after spraying) in tomato fruits and soil were found to be 0.412 and 0.278 mg/kg, respectively. Fourteen days after application, it reached 0.027 and 0.019 mg/kg, respectively. This indicates considerable rates of Imidacloprid removal amounting to 93.45% and 93.17% of the initial deposits, respectively. Likewise, the corresponding initial deposits of adding Imidacloprid mixed with Sylgard 309 adjuvant in tomato fruits and soil increased to 0.492 and 0.384 mg/kg, respectively, dissipating into the respective reduced levels of 0.041 and 0.028 mg/kg, 14 days after application, respectively. The recorded percentage of dissipation at this period was 91.67% and 92.71%, respectively. The calculated half-life (T½) values were found to be 3.56 and 3.62 days for Imidacloprid and 3.91 and 3.71 days for Imidacloprid mixed with Sylgard 309 adjuvant in tomato fruits and soil, respectively.

As shown in Table 4, it is evident that treated tomato fruits and soil with Imidacloprid plus Sylgard 309 adjuvant reduced considerable relative reductions in residues and greatly increased the amounts of residues compared with untreated tomato fruits and soil. There was negative correlation between the values of Imidacloprid residues and adding Sylgard 309 adjuvant. In the field, the dissipation of insecticide residues in/on crops depends on physical and chemical factors, including climatic conditions, type of application, plant species, dosage, interval between application, growth dilution factor and time of harvest **(Khay *et al*., 2008)**.

Table 4. Residues of tested Imidacloprid alone and in its binary mixture with Sylgard 309 adjuvant in tomato fruits and soil in the field at El-Saleheya El-Gadida region, Sharkia Governorate

Days after application	Imidacloprid**						Imidacloprid*** + Sylgard 309					
	Tomato Fruits			Soil			Tomato Fruits			Soil		
	residues (mg/kg)	loss (%)	Persistence	residues (mg/kg)	loss (%)	Persistence	residues (mg/kg)	loss (%)	Persistence	residues (mg/kg)	loss (%)	Persistence
Initial*	0.412	00.00	100	0.278	00.00	100	0.492	00.00	100	0.384	00.00	100
1	0.319	22.57	77.43	0.215	22.66	77.34	0.405	17.68	82.32	0.312	18.75	81.25
3	0.222	46.15	53.85	0.145	47.84	52.16	0.314	36.18	63.82	0.215	44.01	55.99
7	0.118	71.36	28.64	0.078	71.94	28.06	0.157	68.09	31.91	0.168	56.25	43.75
10	0.072	82.52	17.48	0.054	80.58	19.42	0.131	73.37	26.63	0.077	79.95	20.05
14	0.027	93.45	6.55	0.019	93.17	6.83	0.041	91.67	8.33	0.028	92.71	7.29
T½ in days	**3.56**			**3.62**			**3.91**			**3.71**		
Mean of residues	**0.152**			**0.102**			**0.210**			**0.160**		

Initial* = one hour after application – ** = The recommended dose of tested insecticides.
*** = The half recommended dose of tested insecticides – MRL (Codex and EU) = 0.5 mg/kg.

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تأثير المادة المساعدة سيلجارد 309 على الإميداكلوبرايد المستخدم في مكافحة حفَّار الطماطم الذي يُهاجم نباتات الطماطم المزروعة في الحقول المفتوحة

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تُعَد الطماطم من أكثر الخضروات المزروعة على نطاق واسع في العالم وتُمثل العنصر الأكثر أهمية في قطاع تصنيع الخضروات. وهي تُعتبر أكثر الخضروات أهمية على خريطتنا الزراعية حيث تُستخدم كغذاء في العديد من دول العالم وخاصةً مصر. تُهَاجَم الطماطم من العديد من الآفات والتي من أخطرها حفَّار الطماطم. وهدفت هذه الدراسة إلى التحقق من كفاءة استخدام إميداكلوبرايد بمفرده أو في مخلوط ثنائي مع سيلجارد 309 ضد حفَّار الطماطم تحت الظروف الحقلية وتأثير الإميداكلوبرايد على محصول الطماطم وتقدير متبقياته في ثمار الطماطم والتربة. وأوضحت النتائج أن إضافة سيلجارد 309 إلى الإميداكلوبرايد أدى إلى زيادة متوسط نسبة الخفض إلى 98.02% مسجلة أولى المعاملات تأثيرًا. وفي حالة محصول الطماطم خلال موسمين صيفيين متتاليين 2014 و 2015 ، أشارت النتائج إلى زيادة محصول الطماطم بإضافة سيلجارد 309 إلى الإميداكلوبرايد وسجلت أعلى محصول بلغ 600.75 و 613.15 كجم بنسبة زيادة 41.27% و35.44% على التوالي خلال موسمي 2014 و 2015 مقارنة بالكنترول. ولسوء الحظ فإن إضافة سيلجارد 309 إلى الإميداكلوبرايد كان سبباً في زيادة قيم منتصف العمر (T½) ومتبقيات الإميداكلوبرايد في ثمار الطماطم والتربة والتي كانت أقل من الحد الأقصى للمتبقيات (0.5 ملجم/كجم).

الكلمات الإسترشادية: الطماطم، المحصول، حفَّار الطماطم، إميداكلوبرايد ، سيلجارد 309، المتبقيات، التربة.

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