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Original Article

Determination of thiamethoxam residues and dissipation kinetic in tomato plants and its efficacy against *Bemisia tabaci* under open field eco system

Determinação de resíduos de tiametoxam e cinética de dissipação em plantas de tomate e sua eficácia contra Bemisia tabaci em ecossistema de campo aberto

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Abstract

Whitefly, *Bemisia tabaci* cause important losses for many crops especially tomato, therefore farmers often use many chemical insecticides which had dangerous side effects on human beings and environment, thus there are need to determine the residues of these chemicals in plant . The dissipation of thiamethoxam in tomato leaves and fruits followed the first order kinetics; Half-lives were 2.91 and 3.15 days for fruits and leaves, respectively. The residues of thiamethoxam were determined using a QuEChERS method with HPLC–DAD and it was 0.14 mg/ kg in fruits after 7 days of treatment and less than the maximum residue limit (MRL 0.2 mg/kg. The residue in leaves was more than in fruits. Seedlings produced from treated seeds were more resistant to different stages of the whitefly population and protect tomato plants from whitefly infestation for 6-10 weeks after transplanting. The three sprays of thiamethoxam increased the reduction percentage of *B. tabaci* stages and the highest increase was recorded after the third spray in egg, nymph, and adult stages. It could be recommend that Thiamethoxam is considered an unconventional insecticide appropriate for *B. tabaci* control and safe for humans and the environment.

Keywords: *Bemisia tabaci*, thiamethoxam residues, treated seeds, tomato.

Resumo

Bemisia tabaci, também conhecida como "Mosca-branca" causam perdas importantes para muitas culturas, especialmente tomate, por isso, os agricultores costumam usar muitos inseticidas químicos que têm efeitos colaterais prejudiciais aos seres humanos e ao meio ambiente. Nesse sentido, observa-se a necessidade de determinar os resíduos desses produtos químicos na planta. A dissipação do tiametoxam nas folhas e frutos do tomateiro seguiu a cinética de primeira ordem: As meias-vidas foram de 2,91 e 3,15 dias para frutos e folhas, respectivamente. Os resíduos de tiametoxam foram determinados pelo método QuEChERS com HPLC-DAD e foi de 0,14 mg/kg nos frutos após 7 dias de tratamento e inferior ao limite máximo de resíduos (LMR 0,2 mg/kg). O resíduo nas folhas foi maior do que nas frutos. Mudas produzidas a partir de sementes tratadas mostraram-se mais resistentes a diferentes estágios da população de mosca-branca e protegeram os tomateiros da infestação por mosca-branca por 6-10 semanas após o transplante. As 3 pulverizações de tiametoxam aumentaram a porcentagem de redução dos estágios de *B. tabaci* e o maior aumento foi registrado após a terceira pulverização nos estágios de ovo, ninfa e adulto, assim, é possível considerar o tiametoxam como um inseticida não convencional apropriado para o controle de *B. tabaci* e seguro para humanos e meio ambiente.

Palavras-chave: *Bemisia tabaci*, resíduos de tiametoxam, sementes tratadas, tomate.

1. Introduction

Tomato, *Solanum lycopersicum* L. is considered one of the most widespread and usually used vegetables in the world (Dorais et al., 2008). Many pests and diseases infested tomato plants such as aphids and white fly. Large numbers of new pesticide compounds such as neonicotinoids developed as an alternative to conventional insecticides due to the extensive use of conventional insecticides which induced the development of resistance by the target insects Pawar et al. (2016).

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Thiamethoxam was used in soil, foliar and, seed treatments in most crops around the world and was active as contact, systemic activity (Maienfisch et al., 1999). Wettstein et al. (2016), Zhang et al. (2016) found that thiamethoxam was effective in sucking pests control such as aphids, mirids, thrips and, whiteflies. The sucking insect, *Bemisia tabaci* was controlled effectively on vegetables using neonicotinoids (Li et al., 2021). Also, Pandey (2018) found that thiamethoxam 25 WG was effective against aphids, leaf hopper and, whitefly. Maurya et al. (2015) found that Thiamethoxam 70% WS as tomato seed treatment protected tomato from aphid and thrips with significant increase in the fruit yield. Abdelatef et al. (2022) found that both spray ultra-low volume (ULV) and low volume (LV) techniques with thiamethoxam reduced Whitefly *B. tabaci* infestation and significantly increased cucumber fruit quality yield. Hafez and Singh (2016) reported that the initial residue of thiamethoxam was equal to the MRL after the 7th day of application at the recommended dose on tomato. Reddy et al. (2022) found that thiamethoxam at the recommended rate was safe for crops and the environment. Also, Yang et al. (2022) reported that thiamethoxam was safe and suitable for spinach under field conditions.

From the previous review, this study was conducted to throw light on the best method of applying thiamethoxam to achieve effective whitefly control, minimize the spraying numbers, reduce environmental pollution & human toxicity, as well as to compare seed treatment and foliar spraying, furthermore, to determine pesticide residues in leaves and fruits.

2. Materials and Methods

2.1. Tested insecticide and chemicals

Thiamethoxam: 3- (2- chloro - thiazol -5- yl methyl) -5- methyl-[1, 3, 5] oxadiazinan-4-ylidene-*N*-nitro-amine (Actara 25% WG) was provided by Syngenta at Cairo, Egypt.

The standard of thiamethoxam (98% purity) was provided by Central Agricultural Pesticides Laboratory (CAPL) Giza, Egypt. Solvents, anhydrous magnesium sulfate and sodium chloride of analytical grade were supplied by Merck Ltd. Primary Secondary Amine (PSA) and Graphitized Carbon Black (GCB) was obtained from M/s Supelco, Bellefonte, PA, USA.

2.2. Field experiments and sampling procedure

Experiments were conducted at a private farm of Elbehira Governorate, Egypt from April 2022 to October 2022.

Thirty three plots of cultivation land were prepared, each plot (20 m^2) was divided into four rows of 10 m length and 0.5 m width. Twenty gram of tomato seeds, *Solanum lycopersicum*, and Variety Castle rock were sown in the nursery. Thirty days later, the growing seedlings were planted at requested plots, where each row was cultivated on both sides at 20 cm distance. Thirty days from planting, 35 g sodium sulfate + 12 g potassium sulfate + 47 g superphosphate/plot were added. One month later, 47 g sodium sulfate + 24 g potassium sulfate/plot were added. Moreover, 3 months later, 35 g ammonia nitrate + 24 g potassium sulfate/plot were supplied. Finally, after the first fruit appearance, 35 g ammonia nitrate/plot was added as fertilizer regime.

2.3. Seed treatment with thiamethoxam

Ten grams of tomato seeds Castle rock was mixed in 20 ml solution of water + 0.2 g of thiamethoxam 25% WG and vigorously shaken for 10 minutes and left in shadow until dried. Three plots (20 m^2) were planted with seedlings produced from treated tomato seeds as mentioned above, while 3 plots were planted with seedlings produced from untreated tomato seeds as control.

Fifteen days after planting, weekly samples of twenty five tomato leaves were randomly collected early in the morning from each replicate, and transported to the laboratory for examination. The numbers of whitefly adults were counted in the field in the early morning before flight activity, while whitefly egg and nymph stages were counted in the laboratory using a dissecting microscope. Reduction percentages were calculated using Abbott Formula 1 (Abbott, 1925):

$$\begin{gathered} Corrected\ R\ \% = \\ \left(1 - n\ in\ T\ after\ treatment \,/\, n\ in\ Co\ after\ treatment \times 100\right) \end{gathered} \tag{1}$$

R **=** Reduction, T= treatment Co = Control
n.=number of insect stage

2.4. Foliar spraying with thiamethoxam

To determine the efficacy of thiamethoxam 25% WG on *B. tabaci* stages, six plots (each 20 m^2) were cultivated with tomato seedlings, and sprayed three times with thiamethoxam (20 g/100 L water) at 21 days interval starting from 30 days after planting, using a calibrated hand-held compression sprayer (Kwazar), while other three plots were sprayed with water and left as control. Samples of 25 leaves per replicate were randomly collected before spraying 0 time and 1, 3,5,7,9,11,13,15 & 21 days after pesticide spraying. Numbers of whitefly eggs, nymphs,, and adults were counted as previously mentioned. The reduction % of white fly stages was determined according to the Equation 2 of Henderson and Tilton (1955).

$$\begin{gathered} Corrected\ R\ \% = \\ (1 - \frac{n\ in\ Co\ before \times n\ in\ T\ after}{n\ in\ Co\ after \times n\ in\ T\ before}) \times 100 \end{gathered} \tag{2}$$

Co =control,
T=treatment

The experiments were arranged in a complete randomized block design (RCBD) with three replicates.

2.5. Residues and dissipation of thiamethoxam in tomato leaves and fruits

Three plots each 20 m^2 were cultivated with 30 days old tomato seedlings prepared as previously mentioned and sprayed with thiamethoxam (25% WG) with field recommended rate (20 g/100 L water) at fruiting period (one spray only) using the calibrated Hand-Held compression sprayer. All agricultural practices were conducted as usual during the experimental period.

One kg of tomato fruits and 100 leaves were randomly collected from each treatment at one hour (0 time), 1, 3, 5, 7, 9, 15 and 21 days after spraying the insecticide, and transferred to the laboratory where it was subjected to determine thiamethoxam residues.

2.6. Processes of pesticide analysis

QuEChERS methodology was used to extract and clean up tomato samples (Anastassiades et al., 2003). Homogenized tomato samples of leaves and fruits (15 g) were shaken with 15 ml of acetonitrile 1% acetic acid in a polyethylene tube 50 ml for 1 min., then the mixture was shacked vigorously for 5 min and a centrifuged for 10 min at 3000 rpm with 6 g of anhydrous magnesium sulfate and 1.5 g of sodium chloride. One ml of supernatant was transferred to centrifuge tube (15 ml) which contain 50 mg PSA, 25 mg graphitized carbon black and 150 mg Magnesium sulfate, then samples were mixed vigorously by vortexing for one minute and centrifuged for10 minutes at 6000 rpm. The final volume (2 ml) concentrated to dryness.

2.7. HPLC conditions

Agilent 1100 series HPLC system with a quaternary pump, thermostat compartment for the column and photodiode array detector was used. An ODS C18 HPLC column (250 × 4.6 mm, 5 µm) was used as the separation column. The mobile phase consisted of acetonitrile and water (60:40) with a flow rate of 0.8 ml/min. The retention time was 4.05 min.

2.8. Validation procedure

The performance of the analytical methods validation parameters on tomato was evaluated using the following parameters: linearity, the limit of quantification (LOQs), accuracy, and precision. Recovery experiments were carried out by spiking untreated tomato leave and fruit samples with thiamethoxam at 0.25, 0.5 and, 1 mg/kg, processed as previously described, and analyzed by HPLC three times for each fortified concentration to establish the reliability and validity of the analytical method adopted. The calibration curve was drawn by plotting the mean peak area against the corresponding concentration ranging from 1 to 100 mg/kg of the target analysts in the mobile phase. Tomato -fortified samples were prepared using standard solutions. The precision of the method was determined based on the relative standard deviations (RSD). The limit of detection (LOD mg/kg) and limit of quantification (LOQ mg/kg) were evaluated based on 3:1 (LOD) while LQD was determined based on signal to noise ratio of 10:1 (Sahoo et al., 2012; Gao et al., 2014). The method which gave recovery of thiamethoxam in the range of 70-120% with a relative standard deviation < 20 was considered to be the ideal method and the lowest spiking level was considered as LOQ.

2.9. Statistical analysis

The obtained data were statistically analyzed using an analysis of variance (ANOVA) at 5% probability. The measurements were divided using Duncan's Multiple Range Test through the Costat software program (Version 6.400) 1989-2008.

3. Results

3.1. Effect of tomato seed treatment with thiamethoxam on the population density of whitefly, Bemisia tabaci stages in the field

Regarding to the effect of seed treatment with thiamethoxam 25% WG, at the rate of 5g a.i /kg seeds , on the population density of whitefly, *Bemisia tabaci* stages in the field , the obtained results in Table 1 and Figure 1 revealed that there were significant decrease in white fly stages along more than 8 weeks compared with control.

Table 1. Effect of tomato seed treatment with thiamethoxam on white fly,*Bemisia tabaci* stages under open field conditions.

Period after sowing (week)	Seeds 5g a.i /kg seeds			control			Reduction %		
	Mean numbers of white fly stages / 25 leaves								
	egg	nymph	adult	egg	nymph	adult	egg	nymph	adult
0	21 k	12 ijk	35 hi	28 j	15hij	52 gh	-	-	-
2	2 k	2 k	5 j	36 ij	23 gh	66 fg	92.59	89.13	88.74
4	10 k	5 jk	12 j	50 hi	39 ef	84 ef	73.33	83.97	78.78
6	25 ij	7 jk	20 ij	72 f	49 de	91 e	53.70	82.14	67.35
8	36 gh	20 hi	34 hi	93de	60 c	115 cd	48.39	58.33	56.07
10	48 fg	33 fg	51 gh	115c	74 b	132 c	44.35	44.26	42.60
12	70 ef	41 ef	68 gh	135b	89 a	157 b	30.86	42.42	35.65
14	98 d	54 cd	97 de	156a	98 a	198 a	16.24	31.12	27.22
Grand mean	38.8	21.8	40.3	85.6	55.9	111.9	51.40	61.60	56.60
LSD 5%	for eggs = 15.3 for nymphs = 10.7 for adults =18.3								
F value 0.05%	for eggs = 76.44 for nymphs = 70.91 for adults = 72.85								

Means followed by different letters for each stage means significant difference at 5%. Reduction % according to Henderson and Tilton (1955). LSD =Least Significant Difference.

Statistical analysis of the obtained data revealed that there were significant differences in the numbers of eggs, nymphs and, adults between control and treated seeds along sampling periods.

The highest grand mean reduction percentage of *B. tabaci* was achieved with nymph stage (61.6%) followed by the adult stage (56.6%) and the egg stage (51.4%).

3.2. Effect of three sprays of thiamethoxam 20%WG (20 g/100 L water) against Bemisia tabaci infesting tomato seedlings under open field conditions

The obtained data in Tables 2, 3 and 4 and Figures 2, 3, and 4 indicated that there were significant differences in the mean number of whitefly egg, nymph, and adult stages between the treatment of three sprays with thiamethoxam25% WG and control. The highest grand mean reduction percentages after the first spray Table 2 and Figure 2 were achieved with the eggs stage (89.73%), followed by nymphs (80.33%), and adult stages (63.60%). The highest grand mean reduction percentages after the second spray Table 3 and Figure 3 were achieved with the eggs stage (97.10%), followed by nymphs (93.23%), and adult stages (74.30%). The highest grand mean reduction percentages after the second spray Table 4 and Figure 4 were achieved with the eggs stage (98.68%), followed by nymphs (97.07%), and adult stages (78.13%).

From the obtained results it could be reported that, the three sprays of thiamethoxam highly decreased *B. tabaci* stages, and the highest decrease in egg, nymph, and adult stages were achieved after the 3rd spray with thiamethoxam at field recommended rate.

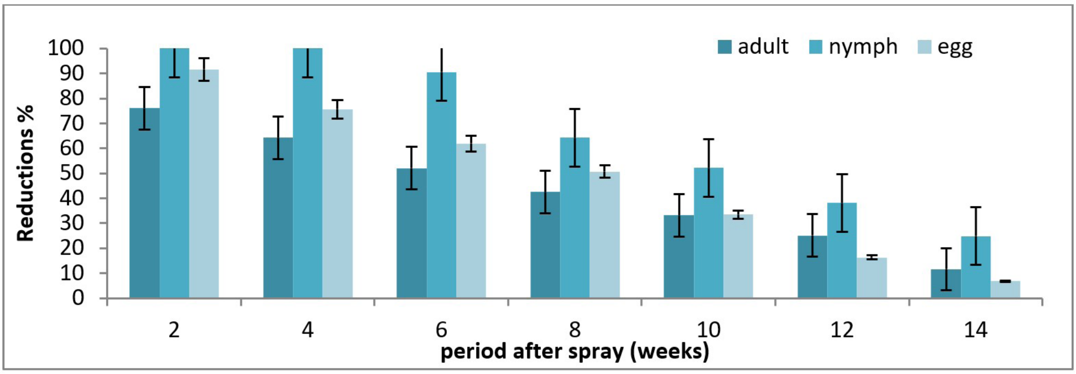

Figure 1. Effect of tomato seed treatment with field recommended rate of thiamethoxam on *B. tabaci* stages ± SE infecting tomato plants under open field conditions.

Table 2. Effect of the 1st spray on tomato plants with field recommended rate of thiamethoxam 25%WG on *B. tabaci* stages under open field conditions.

Period after spray (days)	1st spray (20 g/100 L water)			Control			Reduction %		
	mean numbers of white fly stages / 25 leaves								
	egg	nymph	adult	egg	nymph	adult	egg	nymph	adult
Pre treatment	25 j	18klm	54 lm	28 ij	26 kl	64 l	-	-	-
1	0 k	0 m	10 o	28 ij	37 jk	116 hi	100	100	89.78
3	0 k	0 m	16 no	42 i	51 ij	118ghi	100	100	83.93
5	0 k	2 m	22 no	68 gh	81 gh	125 gh	100	96.43	79.14
7	0 k	6 lm	36 mn	77fgh	99 f	168 e	100	91.25	74.60
9	1 k	12 lm	56 lm	92 f	110 f	210 d	98.78	84.24	68.40
11	4 k	13 lm	76 kl	125 e	140 e	222 cd	96.42	86.59	59.43
13	14 jk	20klm	90 jk	181 d	195 d	239 c	91.34	85.19	55.37
15	22 j	35 jk	102 ij	198 c	225 c	268 b	87.56	77.53	54.89
17	44 i	63hi	112hij	213 c	245 bc	281 ab	76.86	62.86	52.76
19	65 h	85 g	139 fg	245 b	264 b	290 ab	70.29	53.49	43.19
21	82 fg	109 f	155ef	269 a	292 a	297 a	65.86	46.08	38.15
Grand mean	21.4	30.3	72.3	130.5	147.1	199.8	89.73	80.33	63.60
LSD 0.05%	for eggs = 16.8 for nymphs = 21.4 for adults =22.8								
F value 0.05%	for eggs = 203.6 for nymphs = 148.6 for adults = 130.5								

Means followed by different letters for each stage means significant difference at 5%. LSD =Least Significant Difference. Reduction % according to Henderson and Tilton (1955).

Table 3. Effect of the 2nd spray on tomato plants with field recommended rate of thiamethoxam 25%WG on *B. tabaci* stages under open field conditions.

Period after spray (days)	2nd spray (20 g/100 L water)			Control			Reduction %		
	mean numbers of white fly stages / 25 leaves								
	egg	nymph	adult	egg	nymph	adult	egg	nymph	adult
Pre treatment	18 lmn	20 jkl	55 n	24klm	28 ijk	58 mn	-	-	-
1	0 o	0 m	6 p	35 jk	35 hij	106 kl	100	100	94.03
3	0 o	0 m	10 p	44 ij	46 gh	110 jkl	100	100	90.41
5	0 o	0 m	15 op	56 hi	78 f	135 ij	100	100	88.22
7	0 o	0 m	22 op	69 h	89 ef	184 g	100	100	87.39
9	0 o	1 m	40 no	88 g	99 e	212 f	100	98.69	80.01
11	1 o	3 m	63 mn	120 f	135 d	275 e	98.81	97.11	75.84
13	3 o	6 lm	85 lm	164 e	189 c	291 de	97.56	95.87	69.20
15	5 no	10 lm	99 kl	180 d	210 b	311 cd	96.03	93.81	66.43
17	11 mno	19 kl	124 jk	266 c	223 b	332 bc	94.49	88.07	60.61
19	18 lmn	40 hi	155 hi	289 b	264 a	340 b	91.07	78.86	51.93
21	26 kl	56 g	174gh	310 a	271 a	369 a	88.82	73.14	50.27
Grand mean	6.8	12.9	70.7	137.1	138.9	247.6	97.10	93.23	74.30
LSD 0.05%	for eggs = 14.7 for nymphs = 15.6 for adults = 27.1								
F value P > 0.05%	for eggs = 359.0 for nymphs = 267.9 for adults = 147.4								

Means followed by different letters for each stage means significant difference at 5%. LSD =Least Significant Difference. Reduction % according to Henderson and Tilton (1955).

Table 4. Effect of the 3rd spray on tomato plants with field recommended rate of thiamethoxam 25%WG on *B. tabaci* stages under open field conditions.

Period after spray (days)	3rd spray (20 g/100 L water)			Control			Reduction %		
	mean numbers of white fly stages / 25 leaves								
	egg	nymph	adult	egg	nymph	adult	egg	nymph	adult
Pre treatment	22 ijk	24 ij	58 kl	27 hij	25 ij	61 jkl	-	-	-
1	0 l	0 k	0 n	30 hi	35 hi	106 gh	100	100	100
3	0 l	0 k	0 n	39 gh	46 h	86 hij	100	100	100
5	0 l	0 k	0 n	51 g	78 g	117 fg	100	100	100
7	0 l	0 k	11 n	74 f	101 f	136 ef	100	100	91.49
9	0 l	0 k	24 mn	86 f	116 ef	158 de	100	100	84.02
11	0 l	0 k	42 lm	116 e	125 e	175 cd	100	100	74.76
13	0 l	2 k	56 kl	134 d	169 d	198 c	100	98.77	70.25
15	1 l	8 jk	77 ijk	157 c	215 c	234 b	99.22	96.12	65.39
17	4 l	14 jk	88 hi	186 b	260 b	246 ab	97.56	94.39	62.38
19	8 kl	24 ij	105 gh	199 b	284 a	257 ab	95.07	91.20	57.03
21	12 jkl	37 hi	117 fg	229 a	302 a	268 a	93.57	87.24	54.09
Grand mean	3.9	9.1	48.2	110.7	146.3	170.2	98.68	97.07	78.13
LSD 0.05%	for eggs = 15.1 for nymphs = 19. for adults = 26.4								
F value P >0.05%	for eggs = 190.3 for nymphs = 214.4 for adults = 82.5								

Means followed by different letters for each stage means significant difference at 5%. LSD =Least Significant Difference.

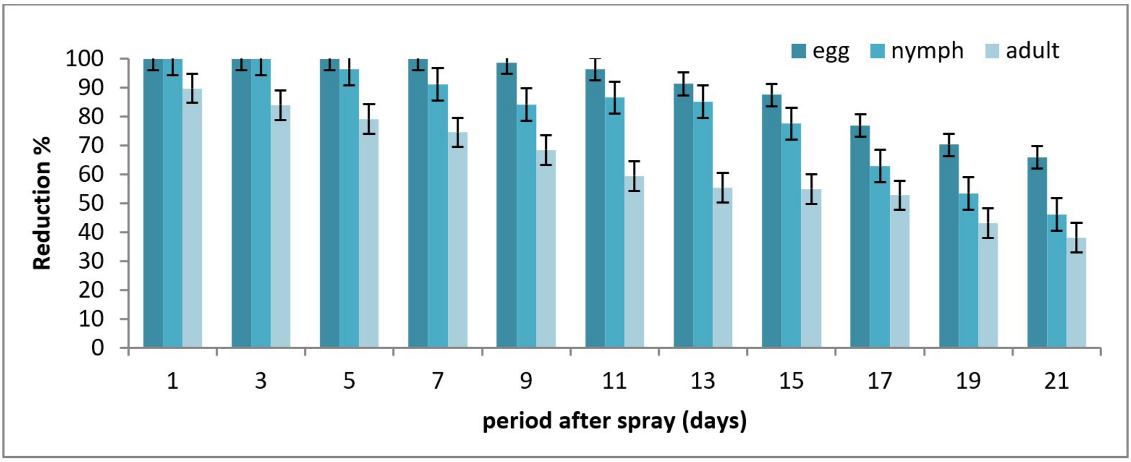

Figure 2. Effect of the first spray on tomato plants with field recommended rate of thiamethoxam on *B. tabaci* stages ± SE under open field conditions.

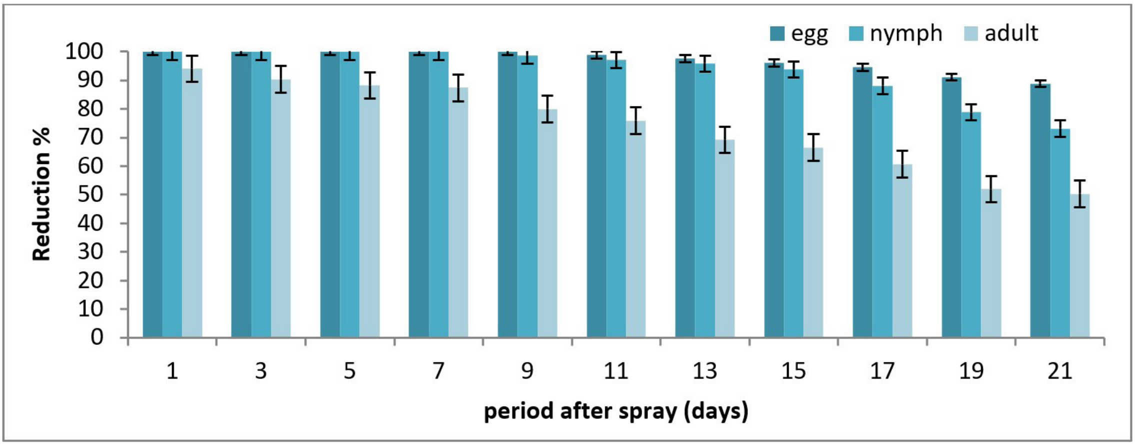

Figure 3. Effect of the second spray on tomato plants with field recommended rate of thiamethoxam on B. *tabaci* stages ± SE under open field conditions.

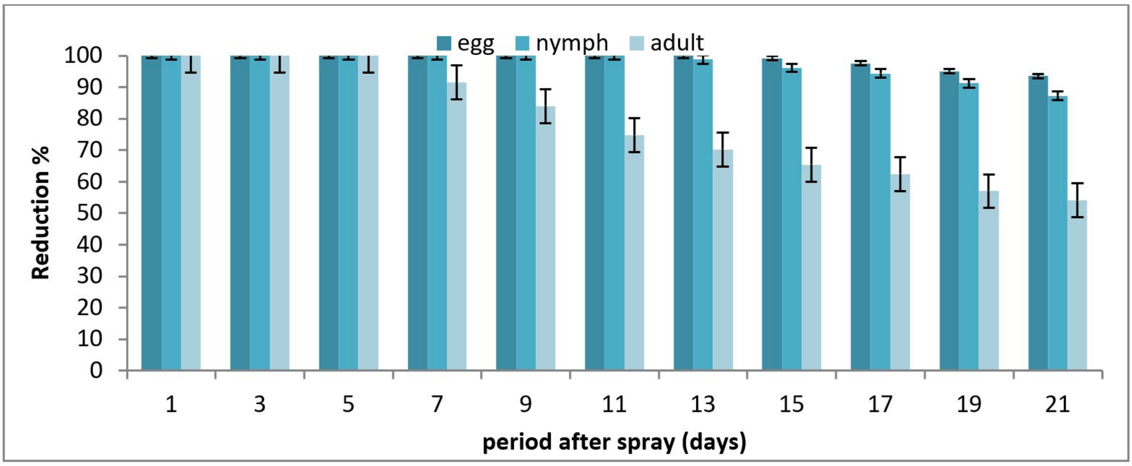

Figure 4. Effect of the third spray on tomato plants with field recommended rate of thiamethoxam on *B. tabaci* stages ± SE under open field conditions.

3.3. Residues of thiamethoxam in tomato leaves and fruits sprayed with field recommended rate:

3.3.1. Linearity of the thiamethoxam insecticide

The calibration curve of thiamethoxam (Figure 5) shows good linearity and strong correlation between concentrations and peak area in the studied range (0–100 mg/kg) (r2 = 0.9886). The LOD and LOQ were 0.02 and 0.06 mg/kg at a signal to noise ratios of 3:1 and 10:1, respectively. These limits are below the maximum residue limits (MRLs) of 0.2 mg/kg for tomato fruits (Europe Union, 2005).

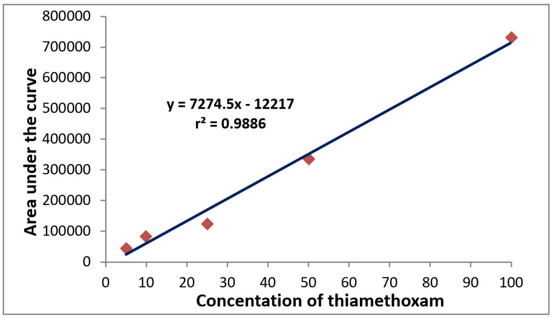

Figure 5. Standard curve of thiamethoxam.

3.3.2. Recovery test

The mean recoveries of thiamethoxam in tomato fruit and leaf samples have been presented in Table 5. The achieved recoveries for thiamethoxam in spiked tomato fruits and leaves were ranged from 98.4 to 103.6% for fruits and from 96.4 to 102.7% for leaves. The (Relative Standard Deviation % RSD) value was ranged from 2.232 to 4.32 and 1.27 to 8.53 for tomato fruits and leaves, respectively.

3.3.3. Kinetic study

The thiamethoxam disappearance kinetics in tomato fruit and leaves were evaluated by plotting thiamethoxam residues against time. The dissipation kinetics of thiamethoxam followed the first-order rate Equation 3:

$$Ct = C_0 e - kt \tag{3}$$

Where Ct is the total amount of pesticide concentration at time t, C_0 is the initial residues (the total amount of pesticides present at time t = 0) and k is the rate constant on day-1. The half-life time was determined from the k value for each experiment,$t_{1/2}$ = ln 2/k. Half-life time ($t_{1/2}$) in days was calculated according to Equation 4 (Moye et al., 1987).

$$t_{1/2} = ln\ 2\ /\ k\ =\ 0.693\ /\ k\ ,\ k \\ \left(apparent\ rate\ constant\right)\ =\ 1\ /\ t\ x\ ln\ a\ /\ m \tag{4}$$

Where t = time in days, m = residue at x time, and a = initial residue.

3.3.4. Thiamethoxam residues and disappearance % in tomato leaves

The obtained results in Table 6 and Figure 6a & b show the residues and disappearance % of thiamethoxam in tomato leaves. The initial residue was 0.91 mg/kg one hour after the application of the field recommended rate and the residues dissipated to 48.89% after 3 days of treatment.

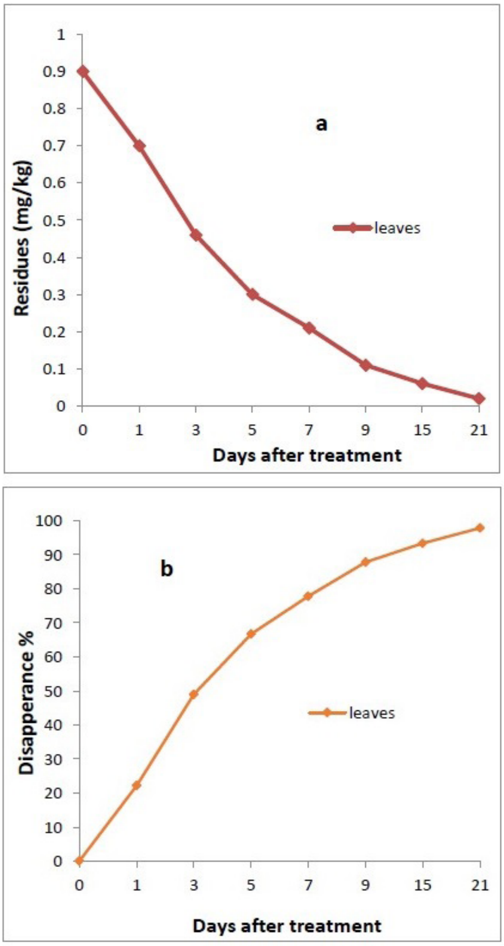

Figure 6. (a) Residues and (b) disappearance % of thiamethoxam in leaves of tomato plants after different periods of treatment.

Table 5. Recovery percentages and %RSD of thiamethoxam from spiked leaves and tomato fruits samples.

Fortified level (mg/kg)	recovery% in leaves ±SE	RSD%	recovery% in fruits ±SE	RSD%
0.25	96.4±0.007	4.98	98.4±0.006	4.32
0.50	101.6±0.005	1.27	102.8±0.007	2.33
1.00	102.7±0.06	8.53	103.6±0.14	2.32

RSD =Relative Standard Deviation; SE = Standard Error.

After that, the residual dissipated by 66.67 and 97.77% after 5 and 21 days, respectively. The Half-life value (t½) for degradation of thiamethoxam was 3.15 days and the dynamics described by the equation C = 0.90 e −0.220 t, with R2 = 0.86385. The RSD% value ranged from 2 to 9.1%.

3.3.5. Thiamethoxam residues and disappearance in tomato fruits

The obtained results in Table 6 and Figure 7a & b show the residue and disappearance % of thiamethoxam in tomato fruits, where the initial residue in fruits was 0.645 mg/kg one hour after the application of the field recommended rate. The residues were dissipated to 52.74% after 3 days showing residues of 0.23 mg/kg. Furthermore, the residual amount of thiamethoxam dissipated calculated in Table 2 and Figure 4 a was 66.18 and 99.85% after 5 and 21 days, respectively. The relative standard deviations RSD% value ranged from 1.43 to 8.82%. The residue of thiamethoxam in tomato fruits was below MRL 0.2 mg/ kg after 7 days of its application at the recommended rate. Half-life time value (t½) for degradation of thiamethoxam in tomato fruits was 2.91 days, after the application of recommended dose and the dynamics could be described by the equation C = 0.680 e −0.238 t, with R2 = 0.86385.

From the previous results, it could be concluded that the average residues in tomato fruits were less than the leaves, and thiamethoxam dissipated in fruits more than in leaves. The residues of thiamethoxam in tomato fruits were below its established MRL 0.2 mg kg-1 after 7 days of its application at the recommended rate.

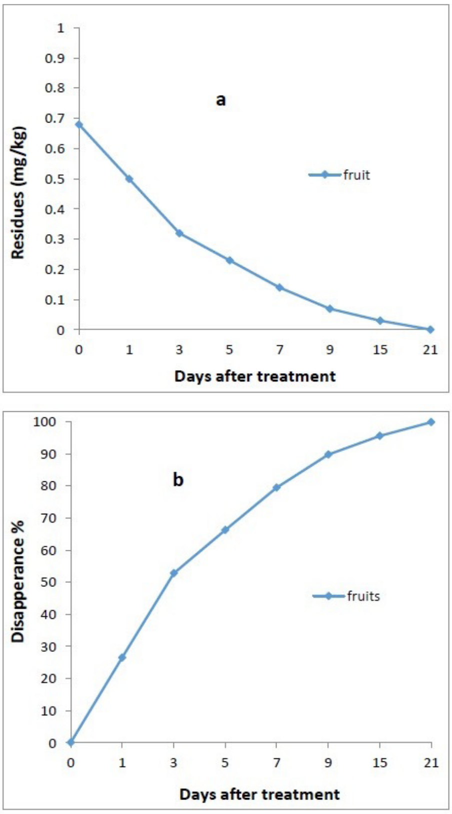

Figure 7. (a) Residues and (b) disappearance% of thiamethoxam in fruits of tomato plants after different periods of treatment.

Table 6. Residues of thiamethoxam and loss % in the leaves and fruits of tomato plants cultivated under field conditions.

Days after spraying	Conc. ±SE (mg/ kg)	RSD%	Disappearance%	persistence%
		Leaves		
1 hr.	0.90 a ± 0.115	3.33	-	100
1 day	0.70 b ± 0.02	7.14	22.22	77.78
3 day	0.46c ± 0.03	4.35	48.89	51.11
5 day	0.30 d ± 0.01	3	66.67	33.33
7 day	0.21 e ± 0.006	4.8	77.76	22.24
9 day	0.11 f ± 0.006	9.1	87.78	12.22
15 day	0.06 g ± 0.0007	2	93.33	6.67
21 day	0.01 h ± 0.0006	5	97.77	2.23
LSD 5%	0.392			
t ½ (day)	3.15			
		Fruits		
1 hr.	0.68 a ± 0.35	8.82	-	100
1 day	0.50 b ± 0.02	6	26.47	73.53
3 day	0.32 c ± 0.01	6.25	52.74	47.26
5 day	0.23 d ± 0.01	8.70	66.18	33.82
7 day	0.14 e ± 0.006	7.14	79.41	20.59
9 day	0.07 f ± 0.0006	1.43	89.71	10.29
15 day	0.030 fg ± 0.002	6.67	95.56	4.44
21 day	0.001 g ± 0	0	99.85	0.15
LSD 5%		0.045		
t ½ (day)		2.91		
PHI (day)		7		

Means followed by different letters for each stage means significant difference at 5%. RSD =Relative Standard Deviation; SE = Standard Error.

4. Discussion

The obtained results are in agreement with Naveed et al. (2010) who reported that cotton seed treated with thiamethoxam kept the population of *B. tabaci* below the economic threshold level (6 $leaf^{-1}$) up to 50 days after sowing seed compared with the control. Also, Maurya et al. (2015) found that tomato seed treated with Thiamethoxam 70% WS at 4.2 g a.i /kg of seed reduced the early season insect pests (aphids and thrips) as well as significantly increased the fruit yield. Recently, Ding et al. (2018) treated successfully corn seeds with thiamethoxam against early-season thrips and reduced yield losses under field conditions. In addition, (Wettstein et al., 2016, Zhang et al., 2016) reported that thiamethoxam is highly effective in the control of piercing-sucking pests (aphids, mirids, trips and whiteflies).The present findings are in harmony with those of El-Naggar (2006) who reported that thiamethoxam was effective against thrips for 7 weeks after planting. Furthermore, El-Zahi and Aref (2011) reported that thiamethoxam was very effective against cotton aphids under field conditions and Patil et al. (2014) reported that, foliar spray of thiamethoxam 25 WG @ 0.006% was effective against whitefly population and achieved the highest fruit yield (126.14 q/ha). Also, Liang et al. (2015) found that thiamethoxam significantly reduced the average number of aphids on plants. On okra, Pawar et al. (2016) reported that thiamethoxam was effective in aphids, jassids, and whiteflies control. Pandey (2018) found that thiamethoxam 25 WG @ 0.006% was effective against aphids, leaf hoppers, and white fly on okra plants. Also, Karthik et al. (2020) found that thiamethoxam 25% WG at 25 g a.i. /ha was highly effective against whitefly after the first and second spray and minimized the spraying numbers, so that, it reduces environmental pollution and human hazards, as well as to compare seed treatment and foliar spraying. Recently, Abdelatef et al. (2022) sprayed thiamethoxam to control *Bemisia tabaci* on cucumber plants and found that it reduced *B. tabaci* infestation and caused a significant increase in cucumber fruit quality yield. Naveed et al. (2010) who reported that cotton seed treated with thiamethoxam kept the population of *B. tabaci* below the economic threshold level (6 $leaf^{-1}$) up to 50 days after sowing seed compared with the control. Also, Maurya et al. (2015) found that tomato seed treated with Thiamethoxam 70% WS at 4.2 g a.i /kg of seed reduced the early season insect pests (aphids and thrips) as well as significantly increased the fruit yield. Recently, Ding et al. (2018) treated successfully corn seeds with thiamethoxam against early-season thrips and reduced yield losses under field conditions. In addition, (Wettstein et al., 2016, Zhang et al., 2016) reported that thiamethoxam is highly effective in the control of piercing-sucking insects.El-Naggar (2006) who reported that thiamethoxam was effective against thrips for 7 weeks after planting. Furthermore, El-Zahi and Aref (2011) reported that thiamethoxam was very effective against cotton aphids under field conditions and Patil et al. (2014) reported that, foliar spray of thiamethoxam 25 WG @ 0.006% was effective against whitefly population and achieved the highest fruit yield (126.14 q/ha). Also, Liang et al. (2015) found that thiamethoxam significantly reduced the average number of aphids on plants. Recently, Karthik et al (2020) found that thiamethoxam 25% WG at 25 g a.i. /ha was highly effective against whitefly after the first and second spray and minimized the spraying numbers, so that, it reduces environmental pollution and human hazards. In addition, Abdelatef et al. (2022) successfully control *Bemisia tabaci* infested cucumber plants by spraying thiamethoxam resulting a significant increase in cucumber fruit quality yield.

According to DG SANCO (2013), the obtained recovery of thiamethoxam was in the range of 70-120% with a relative standard deviation (RSD %) value within the acceptable range of ≤ 20% so, the values show that the method was a good performance, sensitive and suitable for the determination of thiamethoxam residues in tomatoes. As for thiamethoxam residues, Hafez and Singh (2016) found that the residue of thiamethoxam in tomato fruits was declined progressively with time, where more than 36% of initial residues of thiamethoxam were dissipated one day after pesticide application with the recommended rate, raised to 90.91% on the 7th day of application. Also, Wang et al. (2013) reported that the residues of thiamethoxam declined progressively in tomato fruits with time, the initial deposits were found to be equal to the MRL on the 7th day at the recommended rate, furthermore, the half-life time values of thiamethoxam ranged from 3.9 to 4.4 days in tobacco leaves, and added that the use of thiamethoxam at low effective rate does not cause any hazard to the consumers up to 7 days of treatment. Karmakar and Kulshrestha (2009) found that the thiamethoxam residues were dissipated to 59 and 73% in 5 and 7 days and were not detected at 15 days, the half-life value was 3.5 days when thiamethoxam applied at 140 g a.i. /ha and reported waiting 8 days safe consumption of treated tomato. Hafez and Singh (2016) found that the initial deposits of thiamethoxam on tomatoes were found to be equal to the MRL on the 7th day at the recommended rate. Ramadan et al. (2016) revealed that the initial deposits of thiamethoxam in tomato plants were 0.647 mg kg-1, and residue levels decreased to 0.03 mg kg-1 after 15 days from application indicating that 95.4% of thiamethoxam dissipated. Abd El-Zaher et al. (2011) reported that kidney bean horns could be safely consumed after 7 days of thiamethoxam application according to the recommended maximum residue limit for thiamethoxam in kidney bean (0.2 ppm). Also, Rabea et al. (2018) found that the half-life period of thiamethoxam on pepper fruits was 3.11 days. In addition, Abd-Alrahman (2014) reported that the recovery was 99.4% for potato tubers and that the terminal residues of thiamethoxam were below the maximum residue limit (MRL 0.2 mg/ kg) after 6 days, and safe for human consumption, in addition, the half-life time value ($t½$) of thiamethoxam was 2.92 days, after spraying recommended rate. Yang et al. (2022) considered that thiamethoxam is the safe and proper application for spinach grown in field conditions.

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