International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; SP-8(3): 09-15

Received: 13-03-2020
Accepted: 16-04-2020

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Bio-efficacy of different insecticides against leaf miner and whitefly on tomato

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DOI: https://doi.org/10.22271/chemi.2020.v8.i4k.9780

Abstract
Investigations were carried out on management of leaf miner and whitefly on tomato, which was conducted at Instructional Farm, College of Agriculture, Junagadh Agricultural University, Junagadh during the year 2016-17. The treatment of profenofos + cypermethrin 44 EC (0.044%) was found to be more effective for the control of leaf miner (*Liriomyza trifolii*) and the treatment of dimethoate 30 EC (0.03%) was found to be more effective for the control of whitefly (*Bemisia tabaci*) on tomato. The fruit yield of tomato was significantly highest in profenofos + cypermethrin 44 EC (0.044%) (21722.22 kg/ha).

Keywords: Tomato crop, *Liriomyza trifolii* (Burgess), *Bemisia tabaci* (Gennadius), insecticides

Introduction
Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetable crops of the globe due to its immense commercial and nutritive value and wide range of climatic adaptability. The tomato popularly called as “poor man’s orange” is an important solanaceous vegetable fruit originated from tropical America (Thompson and Kelly, 1957) [13]. Tomato is a good source of vitamin ‘A, B’ and excellent source of vitamin ‘C’. It can be eaten as a fresh fruit and as a salad vegetable. It is used for culinary purpose and also used in preparation of pickles, ketchup, sauces and many products. The estimated area under tomato in India is about 6.33 lakh hectares with a production of 124.25 lakh tonnes of fruits. It was grown in an area of 46,397 hectares with the production of 13,19,113 tonnes and a productivity of 28.43 tonnes per hectare in Gujarat (Anon., 2016) [1]. The production and quality of tomato fruits are considerably affected by many pests infesting at different stages of crop growth. Amongst various pests reported in India, as many as sixteen of different groups have been observed feeding from germination to the harvesting stage which not only reduce yield but also deteriorate the quality (Butani, 1977) [4]. Among the various insect pest, whitefly (*Bemisia tabaci*) and leaf miner (*Liriomyza trifolii*) are major insect pest causing considerable damage to the crop by attacking the different plant parts of tomato in Gujarat state (Brust, 2008; Sharma *et al.*, 2013) [3, 10]. So, it is prime need to find out such insecticides which was effective against leaf miner and whitefly on tomato under field condition for management.

Materials and Methods
Insecticidal management of leaf miner and whitefly on tomato
To study the efficacy of various chemical insecticides, a field experiment was conducted at Instructional Farm, Department of Agronomy, College of Agriculture, JAU, Junagadh during *Rabi* season of 2016-17. The tomato variety GT-1 was sown in a Randomized Block Design with a spacing of 75 cm x 60 cm with gross and net plot size of 4.80 m × 3.00 m and 3.60 m × 1.50 m, respectively. All the recommended agronomical practices were adopted for good growth of the crop. Details of insecticidal treatments are given in Table 1. Eight treatments including control with three replications were evaluated against leaf miner (*Liriomyza trifolii*) and whitefly (*Bemisia tabaci*) on tomato.

Methodology for insecticidal management of leaf miner (*Liriomyza trifolii*) and whitefly (*Bemisia tabaci*) on tomato
All the insecticides under study for their efficacy were applied after appearance of the pest in

the field by using knapsack sprayer. The sprayer was washed thoroughly prior to the application of subsequent treatment. The care was taken to have uniform coverage of the crop with insecticidal spray fluid. Two insecticidal applications were carried out, first at 50% flowering and second at 15 days of first application.

Observations recorded

Five plants were selected randomly from each net plot and tagged for observations and count number of mined leaves per plant and number of mines per five leaves per plant for leaf miner and count the number of adult whitefly on tomato. Number of damaged leaves of leaf miner and adult whitefly were recorded 24 hours before spraying and 1, 3, 5 and 7 days after spraying from each treatment. The yield was recorded from each net plot. The data was subjected to statistical analysis for drawing conclusion. Statistical analysis was carried out using ANOVA technique given by Panse and Sukhatme (1985) [6].

Table 1: Treatment details

Sr. No.	Technical Name	Concentration (%)	Dose/10 lit.	Trade name
1.	Profenofos + Cypermethrin 44 EC	0.044%	10 ml	Polytrin-C
2.	Chlorantraniliprole 18.5 SC	0.006%	3.2 ml	Coragen
3.	Deltamethrin + Triazophos 36 EC	0.036%	10 ml	Sun-Delta
4.	Emamectin benzoate 5 SG	0.0025%	5 g	EM-1
5.	Thiodicarb 75 WP	0.15%	20 g	Larvin
6.	Diafenthiuron 50 WP	0.05%	10 g	Polo
7.	Dimethoate 30 EC	0.03%	10 ml	Tafgor
8.	Control	-	-	-

Results and Discussion

Insecticidal management of leaf miner and whitefly on tomato

Leaf miner (*Liriomyza trifolii*)

Mined leaves/plant

Before first spray: The results based on mined leaves per plant caused by leaf miner are presented in Table 2. All the experimental plots showed non-significant variation with respect to the mined leaves per plant or it may be said that the mined leaves per plant was homogeneous or statistically similar amongst all the experimental plots before spraying.

Table 2: Bio-efficacy of various insecticides against leaf miner in tomato after spray

Sr. No.	Treatment	Concentration (%)	Mean leaf damage (Number of mined leaves/plant)									
			First Spray					Second Spray				
			Before Spray	1 DAS	3 DAS	5 DAS	7 DAS	Before Spray	1 DAS	3 DAS	5 DAS	7 DAS
1	Profenofos + Cypermethrin 44 EC	0.044%	2.63 (6.91)	1.65^{d} (2.72)	1.57^{d} (2.45)	1.23^{c} (1.52)	1.52^{c} (2.32)	1.96 (3.85)	1.30^{d} (1.70)	1.17^{d} (1.37)	1.08^{e} (1.16)	1.23^{d} (1.52)
2	Chlorantraniliprole 18.5 SC	0.006%	2.60 (6.77)	1.69^{cd} (2.86)	1.61^{cd} (2.58)	1.28^{bc} (1.65)	1.57^{bc} (2.45)	1.96 (3.86)	1.39^{cd} (1.94)	1.27^{cd} (1.60)	1.18^{de} (1.39)	1.32^{cd} (1.75)
3	Deltamethrin + Triazophos 36 EC	0.036%	2.72 (7.39)	1.95^{bc} (3.78)	1.87^{bc} (3.51)	1.56^{b} (2.43)	1.84^{b} (3.37)	2.06 (4.25)	1.63^{bcd} (2.64)	1.59^{bc} (2.52)	1.50^{bcd} (2.25)	1.59^{bc} (2.52)
4	Emamectin benzoate 5 SG	0.0025%	2.61 (6.83)	1.96^{bc} (3.84)	1.89^{bc} (3.58)	1.54^{bc} (2.37)	1.86^{b} (3.45)	2.00 (4.00)	1.65^{bc} (2.71)	1.58^{bc} (2.50)	1.51^{bc} (2.29)	1.60^{bc} (2.57)
5	Thiodicarb 75 WP	0.15%	2.73 (7.45)	2.20^{ab} (4.85)	2.17^{ab} (4.72)	1.89^{a} (3.59)	2.19^{a} (4.79)	2.11 (4.44)	1.84^{ab} (3.38)	1.80^{ab} (3.24)	1.74^{ab} (3.04)	1.82^{ab} (3.31)
6	Diafenthiuron 50 WP	0.05%	2.68 (7.18)	2.29^{a} (5.25)	2.25^{a} (5.05)	1.96^{a} (3.86)	2.26^{a} (5.12)	2.08 (4.32)	1.96^{ab} (3.86)	1.91^{ab} (3.64)	1.86^{a} (3.45)	1.93^{a} (3.72)
7	Dimethoate 30 EC	0.03%	2.68 (7.17)	1.71^{cd} (2.91)	1.65^{cd} (2.71)	1.31^{bc} (1.72)	1.58^{bc} (2.51)	2.00 (3.99)	1.46^{cd} (2.13)	1.39^{cd} (1.93)	1.31^{cde} (1.72)	1.41^{cd} (2.00)
8	Control (water spray)	-	2.67 (7.12)	2.31^{a} (5.32)	2.32^{a} (5.40)	2.05^{a} (4.20)	2.28^{a} (5.19)	2.13 (4.52)	2.02^{a} (4.06)	1.95^{a} (3.80)	1.90^{a} (3.60)	2.00^{a} (4.00)
S.Em ±	-	-	0.12	0.09	0.09	0.10	0.09	0.08	0.10	0.10	0.10	0.09
C.D. at 5%	-	-	NS	0.28	0.29	0.29	0.28	NS	0.29	0.30	0.31	0.28
C.V.%	-	-	7.62	8.21	8.55	10.28	8.56	7.17	10.02	10.81	11.81	9.76

DAS = Days after Spray. Figures in the parenthesis indicate retransformed values, while outside are square root transformed values.
DNMRT was used for treatment comparison

One day after first spray

The mean leaf damage by leaf miner per plant recorded 24 hours after application (Table 2) revealed that profenofos + cypermethrin 0.044% proved to be the most effective treatment, which gave 2.72 mean leaf damage. However, it was statistically at par with chlorantraniliprole 0.006% (2.86) and dimethoate 0.03% (2.91). Deltamethrin + triazophos 0.036% (3.78) and emamectin benzoate 0.0025% (3.84) were next effective treatments. Control plot (5.32) found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (5.25) and thiodicarb 0.15% (4.85).

Three days after first spray

The mean leaf damage per plant three days after application of insecticides (Table 2) indicated that profenofos + cypermethrin 0.044% was found the most effective treatment, which gave 2.45 mean leaf damage of leaf miner. However, it was statistically at par with chlorantraniliprole 0.006% (2.58) and dimethoate 0.03% (2.71). Deltamethrin + triazophos

0.036% (3.51) and emamectin benzoate 0.0025% (3.58) were next effective treatments. Control plot (5.40) found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (5.05) and thiodicarb 0.15% (4.72).

Five days after first spray

Perusal of data on mean leaf damage per plant by leaf miner (Table 2) revealed that profenofos + cypermethrin 0.044% and chlorantraniliprole 0.006% were found to be the most toxic and gave 1.52 and 1.65 mean leaf damage per plant, respectively, at fifth day after first spray. However, it was statistically at par with dimethoate 0.03% (1.72). Emamectin benzoate 0.0025% (2.37) and deltamethrin + triazophos 0.036% (2.43) were next effective treatments. Control plot (4.20) found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (3.86) and thiodicarb 0.15% (3.59).

Seven days after first spray

The mean leaf damage per plant seven days after application of insecticides (Table 2) indicated that profenofos + cypermethrin 0.044% was found the most effective treatment, which gave 2.32 mean leaf damage. However, it was statistically at par with chlorantraniliprole 0.006% (2.45) and dimethoate 0.03% (2.51). Emamectin benzoate 0.0025% (3.45) and deltamethrin + triazophos 0.036% (3.37) were next effective treatments. Control plot (5.19) found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (5.12) and thiodicarb 0.15% (4.79).

Second spray

Before second spray

The results based on mined leaves per plant caused by leaf miner are presented in Table 2. All the insecticidal treatments were effective than control. All the experimental plots showed non-significant variation with respect to the mined leaves per plant or it may be said that the mined leaves per plant was homogeneous or statistically similar amongst all the experimental plots before second spraying.

One day after second spray

The mean leaf damage per plant by leaf miner, 24 hours after application (Table 2) revealed that profenofos + cypermethrin 0.044% proved to be the most effective treatment, which gave 1.70 mean leaf damage. However, it was statistically at par with chlorantraniliprole 0.006% (1.94) and dimethoate 0.03% (2.13). Emamectin benzoate 0.0025% (2.71) and deltamethrin + triazophos 0.036% (2.64) were next effective treatments. Control plot (4.06) found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (3.86) and thiodicarb 0.15% (3.38).

Three days after second spray

The mean leaf damage per plant after three days of application (Table 2) indicated that profenofos + cypermethrin 0.044% was found to be the most effective treatment, which gave 1.37 mean leaf damage. However, it was statistically at par with chlorantraniliprole 0.006% (1.60) and dimethoate 0.03% (1.93). Emamectin benzoate 0.0025% (2.50) and deltamethrin + triazophos 0.036% (2.52) were next effective treatments. Control plot (3.80) found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (3.64) and thiodicarb 0.15% (3.24).

Five days after second spray

Perusal of data on mean leaf damage per plant by leaf miner (Table 2) revealed that profenofos + cypermethrin 0.044% and chlorantraniliprole 0.006% were found to be the most toxic and gave 1.16 and 1.39 mean leaf damage per plant, respectively, by leaf miner at fifth day after first spray. However, it was statistically at par with dimethoate 0.03% (1.72). Deltamethrin + triazophos 0.036% and emamectin benzoate 0.0025% (2.29) were next effective treatments. Control plot (3.60) found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (3.45) and thiodicarb 0.15% (3.04).

Seven days after second spray

The mean leaf damage per plant at seven days after application (Table 2) indicated that profenofos + cypermethrin 0.044% was found to be the most effective treatment, which gave 1.52 mean leaf damage of leaf miner. However, it was statistically at par with chlorantraniliprole 0.006% (1.75) and dimethoate 0.03% (2.00). Emamectin benzoate 0.0025% (2.57) and deltamethrin + triazophos 0.036% (2.52) were next effective treatments. Control plot (4.00) found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (3.72) and thiodicarb 0.15% (3.31).

Mines/five leaves/plant

Before first spray

The results based on number of mines per five leaves per plant caused by leaf miner are presented in Table 3. It indicated that all the experimental plots showed non-significant variation with respect to the number of mines.

Table 3: Bio-efficacy of various insecticides against leaf miner in tomato after spray

Sr. No.	Treatment	Concentration (%)	Mean leaf damage (Number of mines/five leaves/plant)									
			First Spray					Second Spray				
			Before Spray	1 DAS	3 DAS	5 DAS	7 DAS	Before Spray	1 DAS	3 DAS	5 DAS	7 DAS
1	Profenofos + Cypermethrin 44 EC	0.044%	0.91 (0.82)	0.60^{f} (0.36)	0.55^{f} (0.30)	0.50^{d} (0.25)	0.54^{d} (0.29)	0.73 (0.53)	0.47^{d} (0.23)	0.42^{c} (0.17)	0.34^{c} (0.12)	0.38^{d} (0.14)
2	Chlorantraniliprole 18.5 SC	0.006%	0.89 (0.80)	0.61^{ef} (0.37)	0.56^{ef} (0.32)	0.51^{d} (0.26)	0.56^{d} (0.32)	0.72 (0.51)	0.50^{d} (0.25)	0.43^{c} (0.18)	0.36^{c} (0.13)	0.39^{d} (0.16)
3	Deltamethrin + Triazophos 36 EC	0.036%	0.87 (0.76)	0.70^{cde} (0.49)	0.66^{cde} (0.44)	0.64^{bc} (0.41)	0.68^{c} (0.46)	0.73 (0.53)	0.63^{c} (0.40)	0.58^{b} (0.33)	0.55^{b} (0.31)	0.60^{c} (0.36)
4	Emamectin benzoate 5 SG	0.0025%	0.87 (0.76)	0.71^{bcd} (0.51)	0.67^{bcd} (0.45)	0.63^{c} (0.40)	0.69^{bc} (0.48)	0.71 (0.50)	0.64^{bc} (0.41)	0.59^{b} (0.34)	0.54^{b} (0.29)	0.61^{bc} (0.37)
5	Thiodicarb 75 WP	0.15%	0.86 (0.74)	0.77^{abc} (0.60)	0.73^{abc} (0.53)	0.69^{abc} (0.48)	0.75^{abc} (0.56)	0.75 (0.56)	0.70^{abc} (0.49)	0.66^{ab} (0.44)	0.63^{ab} (0.40)	0.66^{abc} (0.44)
6	Diafenthiuron 50	0.05%	0.89	0.81^{ab}	0.77^{ab}	0.74^{ab}	0.78^{ab}	0.75	0.74^{ab}	0.70^{a}	0.67^{a}	0.71^{ab}

	WP		(0.78)	(0.65)	(0.60)	(0.55)	(0.61)	(0.56)	(0.55)	(0.49)	(0.45)	(0.51)
7	Dimethoate 30 EC	0.03%	0.87 (0.76)	0.62^{def} (0.39)	0.58^{def} (0.33)	0.53^{d} (0.28)	0.58^{d} (0.33)	0.75 (0.56)	0.51^{d} (0.26)	0.45^{c} (0.20)	0.38^{c} (0.15)	0.42^{d} (0.17)
8	Control (water spray)	-	0.90 (0.81)	0.85^{a} (0.73)	0.81^{a} (0.66)	0.77^{a} (0.60)	0.82^{a} (0.68)	0.72 (0.52)	0.76^{a} (0.57)	0.73^{a} (0.53)	0.70^{a} (0.49)	0.76^{a} (0.57)
S.Em ±	-	-	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
C.D. at 5%	-	-	NS	0.10	0.10	0.10	0.10	NS	0.09	0.08	0.08	0.09
C.V.%	-	-	7.26	8.02	8.87	9.44	8.68	7.99	8.42	8.45	9.25	8.62

DAS = Days After Spray. Figures in the parenthesis indicate retransformed values, while outside are square root transformed values.
DNMRT was used for treatment comparison.

One day after first spray

The number of mines per five leaves per plant by leaf miner at 24 hours after application of different insecticides (Table 3) revealed that profenofos + cypermethrin 0.044% proved to be the most effective treatment, which gave 0.36 number of mines by leaf miner. However, it was statistically at par with chlorantraniliprole 0.006% (0.37) and dimethoate 0.03% (0.39). Deltamethrin + triazophos 0.036% (0.49) and emamectin benzoate 0.0025% (0.51) were next effective treatments. The control (0.73) was found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (0.65) and thiodicarb 0.15% (0.60).

Three days after first spray

The number of mines per five leaves per plant at three days after application (Table 3) indicated that profenofos + cypermethrin 0.044% was found the most effective treatment, which gave 0.30 number of mines by leaf miner. However, it was statistically at par with chlorantraniliprole 0.006% (0.32) and dimethoate 0.03% (0.33). Deltamethrin + triazophos 0.036% (0.44) and emamectin benzoate 0.0025% (0.45) were next effective treatments. The treatment control (0.66) was found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (0.60) and thiodicarb 0.15% (0.53).

Five days after first spray

Perusal of data on number of mines per five leaves per plant by leaf miner (Table 3) revealed that profenofos + cypermethrin 0.044% and chlorantraniliprole 0.006% were found to be the most toxic and gave 0.25 and 0.26 number of mines, respectively, by leaf miner at fifth day after first spray. However, it was statistically at par with dimethoate 0.03% (0.28). Emamectin benzoate 0.0025% (0.40) and deltamethrin + triazophos 0.036% (0.41) were next effective treatments. The treatment control (0.60) was found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (0.55) and thiodicarb 0.15% (0.48).

Seven days after first spray

The number of mines per five leaves per plant after three days of application (Table 3) indicated that profenofos + cypermethrin 0.044% was found the most effective treatment, which gave 0.29 number of mines by leaf miner. However, it was statistically at par with chlorantraniliprole 0.006% (0.32) and dimethoate 0.03% (0.33). Deltamethrin + triazophos 0.036% (0.46) and emamectin benzoate 0.0025% (0.48) were next effective treatments. The control (0.68) was found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (0.61) and thiodicarb 0.15% (0.56).

Before second spray

The results based on number of mines per five leaves per plant caused by leaf miner are presented in Table 3. It indicated that all the experimental plots showed non-significant variation with respect to the number of mines.

One day after second spray

The number of mines per five leaves per plant by leaf miner at 24 hours after application (Table 3) revealed that profenofos + cypermethrin 0.044% proved to be the most effective treatment, which gave 0.23 number of mines by leaf miner. However, it was statistically at par with chlorantraniliprole 0.006% (0.25) and dimethoate 0.03% (0.26). Deltamethrin + triazophos 0.036% (0.40) and emamectin benzoate 0.0025% (0.41) were next effective treatments. The control (0.57) was found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (0.55) and thiodicarb 0.15% (0.49).

Three days after second spray

The number of mines per five leaves per plant at three days after application (Table 3) indicated that profenofos + cypermethrin 0.044% (0.17) was found the most effective treatment. However, it was statistically at par with chlorantraniliprole 0.006% (0.18) and dimethoate 0.03% (0.20). Deltamethrin + triazophos 0.036% (0.33) and emamectin benzoate 0.0025% (0.34) were next effective treatments. The treatment control (0.53) was found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (0.49) and thiodicarb 0.15% (0.44).

Five days after second spray

Perusal of data on number of mines per five leaves per plant by leaf miner (Table 3) revealed that profenofos + cypermethrin 0.044% and chlorantraniliprole 0.006% was found to be the most toxic and gave 0.12 and 0.13 number of mines, respectively, by leaf miner at fifth day after first spray. However, it was statistically at par with dimethoate 0.03% (0.15). Emamectin benzoate 0.0025% (0.29) and deltamethrin + triazophos 0.036% (0.31) and were next effective treatments. The treatment control (0.49) was found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (0.45) and thiodicarb 0.15% (0.40).

Seven days after second spray

The number of mines per five leaves per plant at three days after application (Table 3) indicated that profenofos + cypermethrin 0.044% was found the most effective treatment, which gave 0.14 numbers of mines by leaf miner. However, it was statistically at par with chlorantraniliprole 0.006% (0.16) and dimethoate 0.03% (0.17). Deltamethrin + triazophos 0.036% (0.36) and emamectin benzoate 0.0025% (0.37) were next effective treatments. The treatment control (0.57) was found least effective against tomato leaf miner which was statistically at par with diafenthiuron 0.05% (0.51) and thiodicarb 0.15% (0.44).

Rai *et al.* (2017) [8] observed that profenophos 40% + cypermethrin 4% was found to be the most effective over control against *Liriomyza trifolii* in tomato. Sharma *et al.* (2003) [11] observed dimethoate 30 EC 0.5% as highly effective in controlling leaf miner. In the present investigation, emamectin benzoate 0.004% was found next in the order of effectiveness against leaf miner which was also reported by Variya and Patel (2012) [14].

In the present investigation, profenofos + cypermethrin 0.044%, chlorantraniliprole 0.006% and dimethoate 0.03% remained most effective treatments against leaf miner and suppressed the pest population which is also reported in the above reports thus, it confirms the present investigation.

Whitefly (*Bemisia tabaci*)

Mean adult whitefly/3 leaves

Before first spray: The results based on mean adult whitefly population are presented in Table 4. It indicated that all the experimental plots showed non-significant variation with respect to the mean adult whitefly population or it may be said that the mean adult whitefly population was homogeneous or statistically similar amongst all the experimental plots before spraying.

Table 4: Bio-efficacy of various insecticides against whitefly in tomato after spray

Sr. No.	Treatment	Concentration (%)	Mean adult whitefly/3 leaves									
			First Spray					Second Spray				
			Before Spray	1 DAS	3 DAS	5 DAS	7 DAS	Before Spray	1 DAS	3 DAS	5 DAS	7 DAS
1	Profenofos + Cypermethrin 44 EC	0.044%	2.81 (7.92)	1.57^{cd} (2.45)	1.46^{cde} (2.12)	1.33^{cde} (1.78)	1.40^{cd} (1.97)	2.57 (6.59)	1.43^{de} (2.04)	1.35^{cde} (1.83)	1.28^{cde} (1.63)	1.36^{d} (1.84)
2	Chlorantraniliprole 18.5 SC	0.006%	2.79 (7.78)	1.80^{bc} (3.25)	1.71^{bc} (2.92)	1.63^{bc} (2.65)	1.75^{b} (3.05)	2.54 (6.46)	1.71^{cd} (2.92)	1.65^{bc} (2.73)	1.53^{bcd} (2.33)	1.67^{c} (2.80)
3	Deltamethrin + Triazophos 36 EC	0.036%	2.71 (7.32)	1.74^{bcd} (3.04)	1.64^{cd} (2.69)	1.56^{cd} (2.43)	1.67^{bc} (2.78)	2.54 (6.44)	1.73^{cd} (2.98)	1.62^{bcd} (2.64)	1.56^{bc} (2.43)	1.62^{c} (2.64)
4	Emamectin benzoate 5 SG	0.0025%	2.71 (7.32)	2.03^{ab} (4.12)	1.96^{ab} (3.86)	1.91^{ab} (3.66)	2.00^{ab} (3.98)	2.50 (6.25)	1.98^{bc} (3.91)	1.91^{ab} (3.64)	1.82^{ab} (3.32)	1.94^{b} (3.78)
5	Thiodicarb 75 WP	0.15%	2.73 (7.45)	2.19^{a} (4.79)	2.11^{a} (4.45)	2.06^{a} (4.25)	2.14^{a} (4.59)	2.52 (6.37)	2.13^{ab} (4.53)	2.08^{a} (4.33)	2.02^{a} (4.06)	2.11^{ab} (4.46)
6	Diafenthiuron 50 WP	0.05%	2.70 (7.30)	1.53^{cd} (2.33)	1.39^{de} (1.93)	1.29^{de} (1.66)	1.36^{cd} (1.85)	2.47 (6.12)	1.41^{e} (1.99)	1.34^{de} (1.79)	1.23^{de} (1.52)	1.31^{d} (1.72)
7	Dimethoate 30 EC	0.03%	2.79 (7.78)	1.48^{d} (2.19)	1.34^{e} (1.78)	1.23^{e} (1.52)	1.33^{d} (1.77)	2.55 (6.52)	1.38^{e} (1.91)	1.28^{e} (1.64)	1.17^{e} (1.38)	1.23^{d} (1.52)
8	Control (water spray)	-	2.70 (7.28)	2.26^{a} (5.12)	2.17^{a} (4.72)	2.13^{a} (4.52)	2.22^{a} (4.93)	2.50 (6.25)	2.29^{a} (5.26)	2.19^{a} (4.79)	2.11^{a} (4.46)	2.22^{a} (4.92)
S.Em ±	-	-	0.11	0.09	0.09	0.09	0.10	0.11	0.09	0.09	0.09	0.08
C.D. at 5%	-	-	NS	0.26	0.27	0.29	0.29	NS	0.27	0.28	0.27	0.26
C.V.%	-	-	7.22	8.20	9.10	9.96	9.51	7.30	8.80	9.60	9.83	8.67

DAS = Days After Spray. Figures in the parenthesis indicate retransformed values, while outside are square root transformed values. DNMRT was used for treatment comparison.

One day after first spray

The mean adult whitefly population at 24 hours after application of different insecticides (Table 4) revealed that dimethoate 0.03% proved to be the most effective treatment, which gave 2.19 mean adult whitefly population. However, it was statistically at par with diafenthiuron 0.05% (2.33), profenofos + cypermethrin 0.044% (2.45) and deltamethrin + triazophos 0.036% (3.04). Chlorantraniliprole 0.006% (3.25) was next effective treatment. The treatment control (5.12) was found least effective against tomato whitefly which was statistically at par with thiodicarb 0.15% (4.79) and emamectin benzoate 0.0025% (4.12).

Three days after first spray

The mean adult whitefly population after three days of application of insecticides (Table 4) indicated that dimethoate 0.03% was found the most effective treatment, which gave 1.78 mean adult whitefly population. However, it was statistically at par with diafenthiuron 0.05% (1.93) and profenofos + cypermethrin 0.044% (2.12). Deltamethrin + triazophos 0.036% (2.69) and chlorantraniliprole 0.006% (2.92) were next effective treatments. The treatment control (4.72) was found least effective against tomato whitefly which was statistically at par with thiodicarb 0.15% (4.45) and emamectin benzoate 0.0025% (3.86).

Five days after first spray

Perusal of data on mean adult population of whitefly (Table 4) revealed that dimethoate 0.03% and diafenthiuron 0.05% was found to be the most toxic and gave 1.52 and 1.66 mean adult population, respectively, of whitefly at fifth day after first spray. However, it was statistically at par with profenofos + cypermethrin 0.044% (1.78). Deltamethrin + triazophos 0.036% (2.43) and chlorantraniliprole 0.006% (2.65) were next effective treatments. The treatment control (4.52) was found least effective against tomato whitefly which was statistically at par with thiodicarb 0.15% (4.25) and emamectin benzoate 0.0025% (3.66).

Seven days after first spray

The mean adult whitefly population at seven days after application of insecticides (Table 4) indicated that dimethoate 0.03% was found the most effective treatment, which gave 1.77 mean adult whitefly population. However, it was statistically at par with diafenthiuron 0.05% (1.85) and profenofos + cypermethrin 0.044% (1.97). Deltamethrin + triazophos 0.036% (2.78) and chlorantraniliprole 0.006% (3.05) were next effective treatments. The treatment control (4.93) was found least effective against whitefly which was statistically at par with thiodicarb 0.15% (4.59) and emamectin benzoate 0.0025% (3.98).

Before second spray

The results based on mean adult whitefly population are presented in Table 4. It indicated that all the experimental plots showed non-significant variation with respect to the mean adult whitefly population or it may be said that the mean adult whitefly population was homogeneous or statistically similar amongst all the experimental plots before spraying.

One day after second spray

The mean adult whitefly population at 24 hours after application of different insecticides (Table 4) revealed that dimethoate 0.03% proved to be the most effective treatment, which gave 1.91 mean adult whitefly population. However, it was statistically at par with diafenthiuron 0.05% (1.99) and profenofos + cypermethrin 0.044% (2.04). Chlorantraniliprole 0.006% (2.92), deltamethrin + triazophos 0.036% (2.98) and emamectin benzoate 0.0025% (3.91) were next effective treatments. The treatment control (5.26) was found least effective against whitefly which was statistically at par with thiodicarb 0.15% (4.53).

Three days after second spray

The mean adult whitefly population after three days of application of insecticides (Table 4) indicated that dimethoate 0.03% was found the most effective treatment, which gave 1.64 mean adult whitefly population. However, it was statistically at par with diafenthiuron 0.05% (1.79) and profenofos + cypermethrin 0.044% (1.83). Deltamethrin + triazophos 0.036% (2.64) and chlorantraniliprole 0.006% (2.73) were next effective treatments. The treatment control (4.79) was found least effective against whitefly which was statistically at par with thiodicarb 0.15% (4.33) and emamectin benzoate 0.0025% (3.64).

Five days after second spray

Perusal of data on mean adult population of whitefly (Table 4) revealed that dimethoate 0.03% and diafenthiuron 0.05% was found to be the most toxic and gave 1.38 and 1.52 mean adult population, respectively, of whitefly at fifth day after first spray. However, it was statistically at par with profenofos + cypermethrin 0.044% (1.63). Chlorantraniliprole 0.006% (2.33) and deltamethrin + triazophos 0.036% (2.43) were next effective treatments. The treatment control (4.46) was found least effective against tomato whitefly which was statistically at par with thiodicarb 0.15% (4.06) and emamectin benzoate 0.0025% (3.32).

Seven days after second spray

The mean adult whitefly population at seven days after application of insecticides (Table 4) indicated that dimethoate 0.03% was found the most effective treatment, which gave 1.52 mean adult whitefly population. However, it was statistically at par with diafenthiuron 0.05% (1.72) and profenofos + cypermethrin 0.044% (1.84). Deltamethrin + triazophos 0.036% (2.64), chlorantraniliprole 0.006% (2.80) and emamectin benzoate 0.0025% (3.78) were next effective treatments. The treatment control (4.92) was found least effective against tomato whitefly which was statistically at par with thiodicarb 0.15% (4.46).

Razaq *et al.* (2003) [9] concluded that diafenthiuron 500 SC treated plots had the lowest population (1.4 per leaf) of whitefly. Bharpoda *et al.* (2014) [2] revealed that among the different insecticides, diafenthiuron 50 WP @ 0.05% found more effective against whitefly and safer to the natural enemies. Gupta *et al.* (2007) [5] revealed that dimethoate and fenthion were significantly superior in the control of whitefly and disease incidence and lastly recorded higher yield. Similarly, Singh *et al.* (2010) [12] revealed that dimethoate 30 EC (0.03 %) was most effective against whitefly.

In the present investigation, dimethoate 0.03%, diafenthiuron 0.05% and profenofos + cypermethrin 0.044% remained most effective treatments against whitefly and suppressed the pest population which is also reported in the above reports thus, confirms the present investigation.

Yield of tomato fruit

The data on yield of tomato fruits obtained in various insecticidal treatments are summarized in Table 5.

The yield of tomato fruits in different treatments varied from 12641 to 21722 kg/ha. The highest yield of tomato fruits (21722.22 kg/ha) was recorded in the treatment with profenofos + cypermethrin 0.044%. However, it was statistically at par with chlorantraniliprole 0.006% (20469.14 kg/ha), dimethoate 0.03% (19956.79 kg/ha) and deltamethrin + triazophos 0.036% (19827.16 kg/ha). The moderate yield of tomato fruit was obtained from treatments of diafenthiuron 0.05% (18814.81 kg/ha), emamectin benzoate 0.0025% (17962.96 kg/ha) and thiodicarb 0.15% (17111.11 kg/ha). Whereas, significantly low yield i.e. 12641.98 kg/ha was recorded from the untreated control plot.

Looking to the per cent increase in yield over control, it was varied from 35.35 to 71.82 per cent (Table 5). The maximum increase in yield of tomato fruit (71.82 per cent) over control was recorded in the treatment of profenofos + cypermethrin 44 EC (0.044%). The treatments found next in order in respect of per cent increase in yield of tomato fruits over control were chlorantraniliprole 18.5 SC (0.006%), dimethoate 30 EC (0.03%), deltamethrin + triazophos 36 EC (0.036%), diafenthiuron 50 WP (0.05%), emamectin benzoate 5 SG (0.0025%) and thiodicarb 75 WP (0.15%) as they registered 61.91, 57.86, 56.83, 48.82, 42.08 and 35.35 per cent increase in yield of tomato fruit over control, respectively. According to Rai *et al.* (2013) [7] profenofos + cypermethrin 44 EC (0.044%) gave maximum yield over other insecticides. Thus, the present findings are more or less in agreement with the results reported by earlier workers.

Looking to the overall results and considering the insecticidal efficacy and yield, the most effective treatments are profenofos + cypermethrin 44 EC, chlorantraniliprole 18.5 SC and dimethoate 30 EC which were sprayed at 4 to 6 weeks after transplanting. They may be recommended for better management of leaf miner and whitefly and to obtain higher yield of tomato fruits.

Table 5: Impact of various insecticides on tomato yield

Sr. No.	Treatment	Fruit yield (kg/ha)	Percentage increase in yield over control
1	Profenofos + Cypermethrin 44 EC	21722.22^{a}	71.82
2	Chlorantraniliprole 18.5 SC	20469.14^{ab}	61.91
3	Deltamethrin + Triazophos 36 EC	19827.16^{abc}	56.83
4	Emamectin benzoate 5 SG	17962.96^{bc}	42.08
5	Thiodicarb 75 WP	17111.11^{c}	35.35

6	Diafenthiuron 50 WP	18814.81[abc]	48.82
7	Dimethoate 30 EC	19956.79[abc]	57.86
8	Control	12641.98[d]	-
S.Em ±	-	882.96	-
C.D. at 5%	-	2678.52	-
C.V.%	-	8.24	-

DNMRT was used for treatment comparison.

Conclusion

The treatment of profenofos + cypermethrin 44 EC (0.044%) was found to be more effective for the control of leaf miner and the treatment of dimethoate 30 EC (0.03%) was found to be more effective for the control of whitefly on tomato. The fruit yield of tomato was significantly highest in profenofos + cypermethrin 44 EC (0.044%) (21722.22 kg/ha).

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