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Bio-efficacy of different insecticides against whitefly (*Bemisia Tabaci*) on Tomato, (*Lycopersicon esculentum* Mill)

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Abstract
The experiment was conducted in 2015-17 to study the bio-efficacy of different insecticides against whitefly (*Bemisia tabaci*) on tomato (*Lycopersicon esculentum* Mill). It was observed that thiamethoxam 25 WG 0.008 percent was the most effective treatment in reducing the whitefly population followed by spiromesifen 22.9 SC 0.028 percent. Dimethoate 30 EC 0.03 percent was ranked third behind thiamethoxam and spiromesifen and was significantly superior over the rest of the treatments. On the other hand, quinalphos 25 EC 0.05 percent was not found effective against the pest and was the least effective treatment at all the intervals after spraying to control the whitefly population.

Keywords: Tomato, insecticides, bio-efficacy, whitefly, *Bemisia tabaci*

1. Introduction
Tomato (*L. esculentum* Mill.) is a profitable vegetable crop, cultivated widely in South Gujarat. It is also a popular vegetable, globally ranked second in importance to potato (Mandaokar *et al*., 2000) [8]. In India, the area under tomato cultivation was 7.67 lakh hectares and its production was 16385.00 MT with average productivity of 21.40 MT/ha during 2014-15 (Anonymous, 2015) [2]. Though it is extensively grown all over the country, still the productivity remains low as compared to other countries mainly due to the prevalence of insect-pests. Amongst various insect-pests reported in India, as many as sixteen have been observed feeding from germination to the harvesting stage which not only reduce its yield but also deteriorate the quality (Butani, 1977) [3]. The major insect pests of tomato in India are whitefly (*Bemisia tabaci*), aphid (*Aphis gossypii*), thrips (*Thrips tabaci*), leaf miner (*Liriomyza trifolii*), red spider mite (*Tetranychus urticae*), fruit borer (*Helicoverpa armigera*) (Anonymous, 2012) [1]. Among them, whitefly is the major pest under the order Hemiptera and carries a piercing and sucking type of mouthparts (David and Ananthakrishnan, 2006) [5]. It cause direct and indirect damage to the tomato, especially in the early growth stage. Both nymphs and adults suck the cell sap from the lower leaf surfaces. When several insects suck the sap from the same leaf, yellow spots appear on the leaves, followed by crinkling, curling, bronzing, and finally drying of leaves. This occurrence is called as "hopper burn" (Das and Islam, 2014) [4]. In case of severe damage, all leaves of the plants become crinkled or twisted with drastic lower down photosynthesis which ultimately reduce yield. Whiteflies transmit gemini viruses known as tomato yellow leaf curl. The spread of this virus is a major threat to tomato production. The honeydew secreted by whiteflies attracts black sooty mold which inhibits photosynthesis thus reducing the yield (Sharma and Chander, 1998)[12]. Keeping in view the importance of sucking insect pests on tomato and use of toxic insecticides for their comparative efficacy, present study was undertaken to compare effect of application of indoxacarb 4.5 SC 0.005%, dimethoate 30 EC 0.03%, lambdacyhalothrin 5 EC 0.003%, spiromesifen 22.9 SC 0.028%, quinalphos 25 EC 0.05%, thiamethoxam 25 WG 0.008% and control on whitefly infestation in tomato.

2. Materials and Methods
2.1 Experimental site
The studies based on field screening of insecticides against whitefly (*Bemisia tabaci*) was carried out under field condition in the Department of Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat during two *Rabi* seasons (2015-

2017) wherein mean annual minimum and maximum temperatures remained 15 and 33 °C, respectively.

2.2 Treatment and management

The field experiment was conducted during two *Rabi* seasons (November 2015 - December 2017) in tomato cv. GT-2. The experiment was laid out in Randomized Block Design (RBD) with 3m x 2m plot size using seven treatments *viz*., T_1: Indoxacarb 4.5 SC 0.005%; T_2: Dimethoate 30 EC 0.03%; T_3: Lambda-cyhalothrin 5 EC 0.003%; T_4: Spiromesifen 22.9 SC 0.028%; T_5: Quinalphos 25 EC 0.05%; T_6: Thiamethoxam 25 WG 0.008% and T_7: control (no pesticide, only normal water) which were replicated four times. Each plot was separated by a gap of 1 m so that drifting of chemicals during spraying was minimized. The experimental field was thoroughly prepared by ploughing followed by repeated harrowing. The field was subsequently cleaned by the removal of stubbles of the previous crop. Healthy disease free 25-day-old seedlings of tomato were planted at a spacing of 60 cm × 45 cm. Gap filling was done 10 days after a uniform plant population in each plot. The application of insecticides was done based on the Economic Threshold Level (ETL) of the insect-pests. For all the treatments, the crop was grown with the same dose of NPK as per state recommendation i.e. 180:60:60 kg N, P_2O_5 and K_2O Kg/ha, respectively. Full quantity of P and K of inorganic fertilization were applied during the time of transplanting. However, half does of nitrogenous fertilizer were applied at thirty days after transplanting and the remaining half of N was applied at 15 days after the first application of N.

2.3 Data collection

The number of adults was counted during the early morning on one randomly selected leaf each on top, middle and bottom canopy of each selected plant and expressed as the total population of a plant. The first count was taken one day before the first spray and post-treatment counts were taken 1, 7 and 15 days after each spray.

2.4 Statistical analysis

The data were compiled and tabulated for statistical analysis. The efficacy of treatments was compared using Analysis of Variance (ANOVA), The analysis of data was done in the Department of statistics, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat.

3. Results and Discussion

3.1 First year (2015-16)

Whitefly population was observed at an early stage (30 days after transplanting or DATP) of tomato seedlings. So, the first spray of insecticide was given at 30 DATP. The results indicated in Table -1 revealed that the insect population before the imposition of treatments was similar in all the experimental plots. All the test insecticides were found significantly superior (except lambda-cyhalothrin and quinalphos) over untreated control. There was similarity or consistency in the order of effectiveness of various treatments at various intervals after spraying wherein lowest whitefly population (irrespective of Days after spraying (DAS)) was observed in thiamethoxam 25 WG 0.008 per cent (1.57/leaf) followed by 2.12 in spiromesifen 22.9 SC 0.028 per cent which in turn was at par with it. Next in the order of effectiveness was dimethoate 30 EC 0.03 percent (3.58). The next group in terms of effectiveness consisted of indoxacarb 14.5 SC 0.005 percent (6.31) followed by 7.40 and 8.14 whiteflies per leaf in lambda-cyhalothrin 5 EC 0.003 percent and quinalphos 25 EC 0.05 percent, respectively which was at par with it. On the other hand, untreated control plot recorded highest whiteflies to the tune of 9.61 per leaf which were at par with lambda-cyhalothrin 5 EC 0.003 percent (7.40) and quinalphos 25 EC 0.05 percent (8.14) (Table 1).

There was similarity or consistency in the order of effectiveness of various treatments at various intervals after second spray indicating lowest whitefly population (irrespective of DAS) in thiamethoxam 25 WG 0.008 percent (1.75/leaf) followed by 2.39 in spiromesifen 22.9 SC 0.028 percent which was at par with it. Next in the order of effectiveness was dimethoate 30 EC 0.03 percent (4.04) followed by indoxacarb 14.5 SC 0.005 percent (6.10), lambda-cyhalothrin 5 EC 0.003 percent (7.40) which was at par with it. Least effective treatment was quinalphos 25 EC 0.05 percent showing 8.80 whiteflies per leaf followed by 7.40 whiteflies per leaf in lambda-cyhalothrin 5 EC 0.003 percent which was at par with it. On the other hand, the control plot indicated highest whitefly population to the tune of 10.99 per leaf (Table 1).

Looking to the results based on pooled whitefly population over periods and sprays during first year (2015-16), similarity or consistency in the order of effectiveness of various treatments was evident indicating lowest whitefly population in thiamethoxam 25 WG 0.008 per cent (1.66/leaf) followed by 2.26 in spiromesifen 22.9 SC 0.028 per cent which was at par with it. Next in the order of effectiveness was dimethoate 30 EC 0.03 percent (3.78) followed by indoxacarb 14.5 SC 0.005 percent (6.21), lambda-cyhalothrin 5 EC 0.003 percent (7.40) which was at par with it. Least effective was quinalphos 25 EC 0.05 percent showing 8.50 whiteflies followed by 7.40 whiteflies per leaf in lambda-cyhalothrin 5 EC 0.003 percent which was at par with it. The control plot had the highest whiteflies (10.26/leaf) (Table 1).

3.2 Second year (2016-17)

The whitefly population before application of treatments was similar or did not differ significantly in any of the experimental plots but after application of treatments, the population was significantly lower in all the treatments (except quinalphos) over untreated control at all the intervals after first spraying during the second year of experimentation (2016-17). The order of effectiveness of various treatments at all the post spray observation intervals after the first spray was found similar indicating lowest population in thiamethoxam 25 WG 0.008 percent (1.49/leaf) followed by 2.16 in spiromesifen 22.9 SC 0.028 percent which was at par with it. Next in the order of effectiveness was dimethoate 30 EC 0.03 percent (3.66) followed by 5.26 whiteflies in indoxacarb 14.5 SC 0.005 percent which was at par with it. The next group indicated effectiveness of indoxacarb 14.5 SC 0.005 percent (5.26) followed by 6.68 whiteflies per leaf in lambda-cyhalothrin 5 EC 0.003 percent which was at par with it. Least effective insecticide treatment was quinalphos 25 EC 0.05 percent (8.50 whiteflies/leaf) which did not differ significantly from lambda-cyhalothrin 5 EC 0.003 percent (6.68) which was at par with it. The untreated control plot indicated highest whitefly population to the tune of 9.74 per leaf which was at par with quinalphos 25 EC 0.05 percent (8.50/leaf) (Table 1).

Table 1: Efficacy of various insecticides against whitefly on tomato during 2015-17

Sr. No.	Treatment with concentration	Whitefly: Adults/plant* (2015-16)											Whitefly: Adults/plant* (2016-17)										
		First spray					Second spray					Pooled over spray	First spray					Second spray					Pooled over spray
		Pre-treat	Post treatment observation at			Mean over DAS	Pre-treat	Post treatment observation at			Mean over DAS		Pre-treat	Post treatment observation at			Mean over DAS	Pre-treat	Post treatment observation at			Mean over DAS	
			1 DAS	7 DAS	15 DAS			1 DAS	7 DAS	15 DAS				1 DAS	7 DAS	15 DAS			1 DAS	7 DAS	15 DAS		
1.	Indoxacarb 14.5 SC 0.005%	3.17 (9.55)	2.74 (7.01)	2.22 (4.43)	2.86 (7.68)	2.61 (6.31)	3.43 (11.26)	2.80 (7.34)	2.38 (5.16)	2.54 (5.95)	2.57 (6.10)	2.59 (6.21)	3.32 (10.52)	2.46 (5.55)	2.21 (4.38)	2.54 (5.95)	2.40 (5.26)	3.02 (8.62)	2.47 (5.6)	1.98 (3.42)	2.68 (6.68)	2.38 (5.16)	2.39 (5.21)
2.	Dimethoate 30 EC 0.03%	3.18 (9.61)	2.27 (4.65)	1.71 (2.42)	2.08 (3.83)	2.02 (3.58)	3.30 (10.39)	2.51 (5.80)	1.69 (2.36)	2.18 (4.25)	2.13 (4.04)	2.07 (3.78)	3.52 (11.89)	2.34 (4.98)	1.79 (2.70)	2.01 (3.54)	2.04 (3.66)	3.18 (9.61)	2.33 (4.93)	1.75 (2.56)	2.26 (4.61)	2.11 (3.95)	2.08 (3.83)
3.	Lambdacyhalothrin 5 EC 0.003%	3.20 (9.74)	2.82 (7.45)	2.70 (6.79)	2.92 (8.03)	2.81 (7.40)	3.18 (9.61)	2.95 (8.20)	2.43 (5.40)	3.05 (8.80)	2.81 (7.40)	2.81 (7.40)	3.32 (10.52)	2.62 (6.36)	2.50 (5.75)	2.93 (8.08)	2.68 (6.68)	3.51 (11.82)	2.74 (7.01)	2.68 (6.68)	2.94 (8.14)	2.79 (7.28)	2.74 (7.01)
4.	Spiromesifen 22.9 SC 0.028%	3.00 (8.50)	2.23 (4.47)	1.04 (0.58)	1.57 (1.96)	1.62 (2.12)	3.31 (10.46)	2.37 (5.12)	1.02 (0.54)	1.69 (2.36)	1.70 (2.39)	1.66 (2.26)	3.11 (9.17)	2.12 (3.99)	1.10 (0.71)	1.66 (2.26)	1.63 (2.16)	3.24 (10.00)	2.18 (4.25)	1.03 (0.56)	1.63 (2.16)	1.61 (2.09)	1.62 (2.12)
5.	Quinalphos 25 EC 0.05%	3.21 (9.80)	2.90 (7.91)	2.84 (7.57)	3.09 (9.05)	2.94 (8.14)	3.17 (9.55)	3.11 (9.17)	2.83 (7.51)	3.21 (9.80)	3.05 (8.80)	3.00 (8.50)	3.37 (10.86)	2.81 (7.40)	2.85 (7.62)	3.33 (10.59)	3.00 (8.5)	3.58 (12.32)	2.84 (7.57)	2.76 (7.12)	3.16 (9.49)	2.92 (8.03)	2.96 (8.26)
6.	Thiamethoxam 25 WG 0.008%	3.14 (9.36)	2.12 (3.99)	0.93 (0.36)	1.28 (1.14)	1.44 (1.57)	3.51 (11.82)	2.29 (4.74)	0.93 (0.36)	1.27 (1.11)	1.50 (1.75)	1.47 (1.66)	3.30 (10.39)	2.05 (3.70)	0.98 (0.46)	1.21 (0.96)	1.41 (1.49)	3.31 (10.46)	1.76 (2.60)	0.94 (0.38)	1.23 (1.01)	1.31 (1.22)	1.36 (1.35)
7.	Control	3.11 (9.17)	3.13 (9.30)	3.15 (9.42)	3.25 (10.06)	3.18 (9.61)	3.06 (8.86)	3.41 (11.13)	3.26 (10.13)	3.49 (11.68)	3.39 (10.99)	3.28 (10.26)	3.63 (12.68)	2.91 (7.97)	3.26 (10.13)	3.44 (11.33)	3.20 (9.74)	3.21 (9.8)	3.13 (9.30)	3.14 (9.36)	3.28 (10.26)	3.19 (9.68)	3.19 (9.68)
S.Em+ (T)		0.13	0.16	0.12	0.12	0.12	0.08	0.15	0.07	0.14	0.11	0.08	0.15	0.15	0.12	0.16	0.13	0.13	0.13	0.11	0.15	0.13	0.08
CD at 5% (T)		NS	0.47	0.34	0.38	0.37	0.25	0.45	0.21	0.42	0.33	0.22	NS	0.43	0.36	0.46	0.38	NS	0.40	0.32	0.46	0.38	0.24
SEm+ (T x D)		-	-	-	-	0.07	-	-	-	-	0.07	0.05	-	-	-	-	0.07	-	-	-	-	0.05	0.07
CD at 5% (Tx D)		-	-	-	-	0.21	-	-	-	-	0.21	0.15	-	-	-	-	0.22	-	-	-	-	0.13	0.23
S.Em+ (T x S)		-	-	-	-	-			-	-	-	0.07	-	-	-	-	-	-	-	-	-	-	0.06
CD at 5% (Tx S)		-				-		-	-	-	-	NS	-	-	-	-	-	-	-	-	-	-	0.18
CV(%) (T)		8.36	12.25	11.13	10.50	17.97	5.27	10.84	6.90	11.37	15.56	16.77	9.10	11.77	11.64	12.77	18.76	8.31	10.84	10.49	12.68	19.20	18.98
CV(%) (T x P)		-	-	-	-	6.17	-	-	-	-	6.09	6.13	-	-	-	-	6.60	-	-	-	-	4.05	5.48

* Total of top, middle and bottom leaves/plant

Figures mentioned in parenthesis are re-transformed values and those outside are √x + 0.5 values

Table 2: Overall efficacy of various insecticides against sucking pest complex of tomato during 2015-17

Sr. No.	Treatment with concentration	Whitefly: Adults/plant*			
		Pre-treat	Post treatment observation (Pooled over sprays)		
			2015-16	2016-17	Overall pooled
1.	Indoxacarb 14.5 SC 0.005%	3.24 (9.97)	2.59 (6.21)	2.39 (5.21)	2.49[d] (5.70)
2.	Dimethoate 30 EC 0.03%	3.30 (10.36)	2.07 (3.78)	2.08 (3.83)	2.08[c] (3.81)
3.	Lambdacyhalothrin 5 EC 0.003%	3.30 (10.41)	2.81 (7.40)	2.74 (7.01)	2.77[e] (7.19)
4.	Spiromesifen 22.9 SC 0.028%	3.17 (9.52)	1.66 (2.26)	1.62 (2.12)	1.64[b] (2.19)
5.	Quinalphos	3.33	3.00	2.96	2.98[ef]

	25 EC 0.05%	(10.61)	(8.50)	(8.26)	(8.37)
6.	Thiamethoxam 25 WG 0.008%	3.32 (10.49)	1.47 (1.66)	1.36 (1.35)	1.42[a] (1.50)
7.	Control	3.25 (10.08)	3.28 (10.26)	3.19 (9.68)	3.24[g] (10.00)
S.Em+ (T)		0.07	0.88	0.13	0.08
CD at 5% (T)		NS	0.22	0.38	0.24
S.Em+ (T x S)		-	0.07	0.06	0.04
CD at 5% (Tx S)		-	NS	0.18	0.10
SEm+ (YxTx S)		-	-	-	0.07
CD at 5% (YxTx S)		-	-	-	NS
CV (%) (T)		7.92	16.77	18.98	17.88
CV (%) (T x P)		-	6.13	5.48	5.83

*Total of top, middle and bottom leaves/plant
Figures mentioned in parenthesis are re-transformed values and those outside are √x +0.5 values
*Treatment ranking as per DMRT

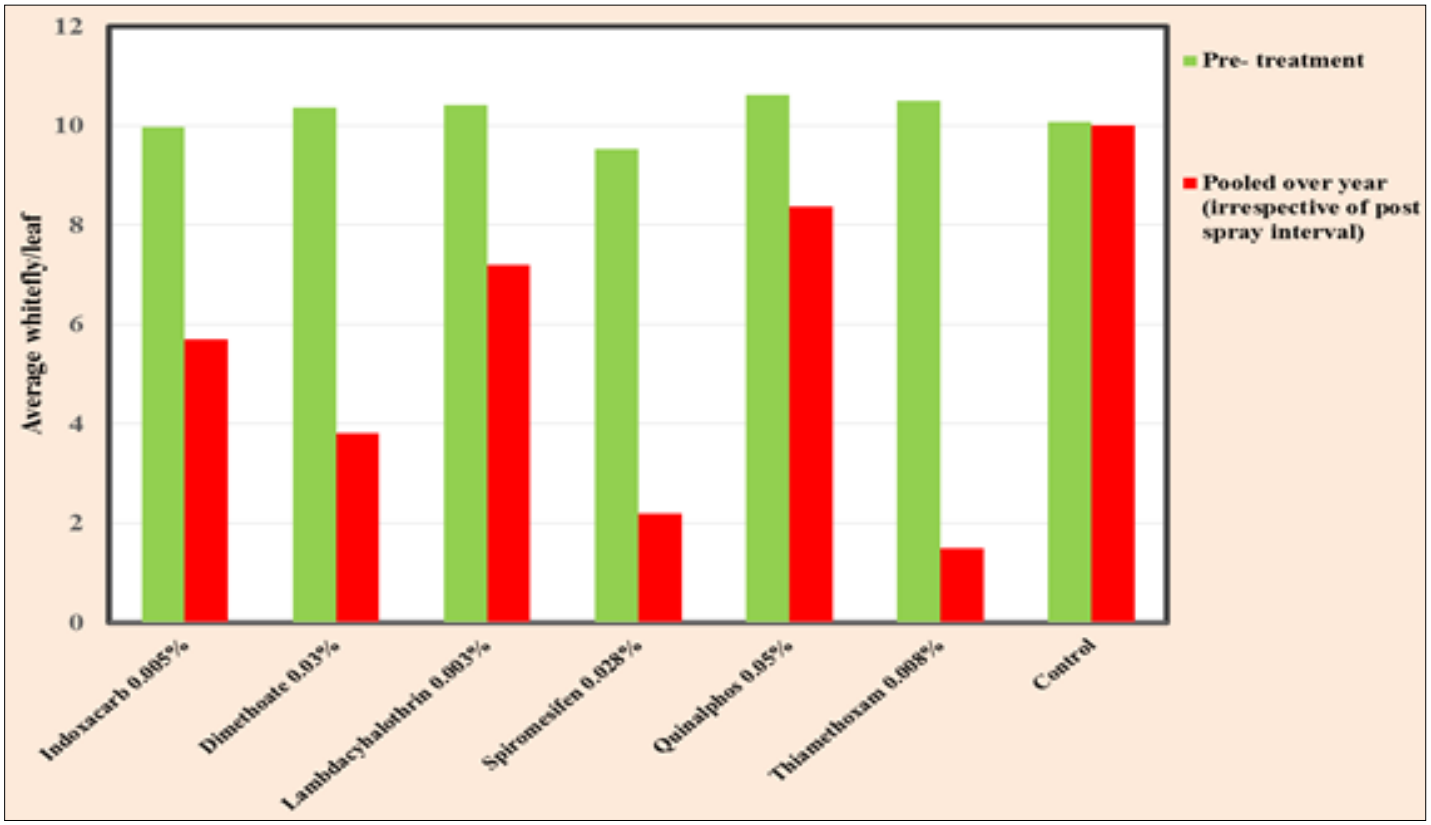

Fig 1: Bioefficacy of various insecticides against whitefly on tomato

The effectiveness during the second spray during the second year of experimentation (irrespective of post spray intervals or DAS) showed significant superiority of all the treatments (except quinalphos) which indicated similarity or consistency in the order of effectiveness at various intervals after spraying. The lowest whitefly population was observed in thiamethoxam 25 WG 0.008 percent (1.22/leaf) followed by 2.09 in spiromesifen 22.9 SC 0.028 percent which was at par with it. Next in the order of effectiveness was dimethoate 30 EC 0.03 percent (3.95) followed by 5.16 whiteflies in indoxacarb 14.5 SC 0.005 percent which was at par with it. Least effective insecticide treatment was quinalphos 25 EC 0.05 percent (8.03 whiteflies/leaf) followed by lambda-cyhalothrin 5 EC 0.003 percent (7.28) which was at par with it. On the other hand, the control plot recorded highest whiteflies to the tune of 9.68 per leaf which in turn was at par with quinalphos 25 EC 0.05 percent (Table 1).

In pooled results, whitefly population irrespective of post spray observation intervals during the second year of experimentation indicated similarity in effectiveness of treatments wherein lowest whitefly population was observed in thiamethoxam 25 WG 0.008 percent (1.35/leaf). Next in the order of effectiveness was spiromesifen 22.9 SC 0.028 percent (2.12) followed by dimethoate 30 EC 0.03 percent (3.83) and indoxacarb 14.5 SC 0.005 percent (5.21). Least effective treatment was quinalphos 25 EC 0.05 percent (8.26 whiteflies/leaf) followed by lambda-cyhalothrin 5 EC 0.003 percent (7.01) which was at par with it. Control plot observed highest whiteflies (9.68/leaf) which was at par with quinalphos 25 EC 0.05 percent (8.26) (Table 1).

3.3 pooled over years (2015-2017)

Looking at the pooled results of two years (2015-17), it was evident that the whitefly population was similar in all the experimental plots before spraying. After spray, all the treatments indicated a significantly lower population than the untreated control. The order of effectiveness of treatments did not differ significantly during 2015 and 2016 and in pooled results (2015-17) which is evident from the non-significant critical difference value of interaction concerning years, treatments and post spray observation intervals when compared or evaluated simultaneously. The lowest whitefly population was observed in thiamethoxam 25 WG 0.008 percent (1.50/leaf) (Table-2 and Fig. 1). Next in the order of effectiveness was spiromesifen 22.9 SC 0.028 percent (2.19) followed by dimethoate 30 EC 0.03 percent (3.81), indoxacarb 14.5 SC 0.005 percent (5.70), lambda cyhalothrin 5 EC 0.003 percent (7.19) which were significantly different from each other. Least effective treatment was quinalphos 25 EC 0.05 percent showing 8.37 whiteflies per leaf which on one hand was at par with lambda-cyhalothrin 0.003 percent and on the other hand was significantly lower than the treatments. On the other hand, the highest whiteflies (10.00/leaf) were observed in the untreated (control) tomato plot (Table-2 and Fig. 1). The efficacy order of treatments in descending order was: thiamethoxam 25 WG 0.008% > spiromesifen 22.9 SC 0.028% > dimethoate 30 EC 0.03% > indoxacarb 14.5 SC 0.005% > lambda-cyhalothrin 5 EC 0.03% > quinalphos 25 EC 0.05% > control.

The present findings are well corroborated with the earlier reports of Mason *et al*. (2000) [9] which in turn revealed that thiamethoxam was significantly superior in the control of whitefly and disease incidence (TYLCV). Nauen *et al*. (2005) [10] reported that nymphal stages of whiteflies are affected more rapidly than the adults and the nymphs treated with spiromesifen did not moult properly and failed to reach adulthood. Gupta *et al*. (2007) [7] showed significant superiority of dimethoate and fenthion in the control of whitefly and disease incidence and provided higher tomato yield. Prabhakar *et al*. (2008) [11] revealed that spiromesifen was significantly more active against early instars of whiteflies. Wafaa and Kherb (2011) [13] observed that thiamethoxam (10 g a.i./ha) had the highest efficiency against tomato whitefly followed by imidacloprid (10 g a.i./ha) and acetamiprid (10 ml a.i./ha). Gorri *et al*. (2015) [6] observed that chlorpyrifos and thiamethoxam were effective against adult whiteflies on tomato. So, thiamethoxam 25 WG 0.008% with good efficacy may be considered as a useful option in the control of the whitefly of tomato.

4. Conclusion

The two years (2015-17) study on whitefly indicated significantly lower population in all the treatments than untreated control wherein the lowest population was observed in thiamethoxam 25 WG 0.008 percent (1.50/leaf). Least effective insecticide treatment was quinalphos 25 EC 0.05 percent showing 8.37 whiteflies which were at par with lambda-cyhalothrin 0.003 percent. The highest whiteflies (10.00) were observed in the untreated (control) tomato plot. The efficacy order of treatments in descending order was: thiamethoxam 25 WG 0.008% > spiromesifen 22.9 SC 0.028% > dimethoate 30 EC 0.03% > indoxacarb 14.5 SC 0.005% > lambda-cyhalothrin 5 EC 0.03% > quinalphos 25 EC 0.05% > control.

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