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Bio-efficacy of spiromesifen 240 SC against whitefly and mites in tomato (*Lycopersicon esculentum*)

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ABSTRACT

The field experiments were carried out for two consecutive *rabi*/summer seasons of 2008-09 and 2009-10 at farmer's fields near Agricultural Research Station, Sankeshwar, Belagavi district, Karnataka, India to study the bio-efficacy of spiromesifen 420 SC against the sucking pests of tomato and its safety to natural enemies. The treatments comprising of two sprays of spiromesifen 240 SC @ 150, 120 and 90 g a.i./ha afforded highest protection against mites and whiteflies over untreated check. All the insecticides recorded significantly higher fruit yield than the untreated check. Two sprays of spiromesifen 240 SC @ 150, 120 and 90 g a.i./ha produced higher fruit yield and were on par with three sprays of acephate 75 SP @ 375 g a.i./ha and four sprays of dicofol 18.5 EC @ 185 g a.i./ha. Hence, the lower dosage of spiromesifen 240 SC @ 90 g a.i./ha (two sprays starting from pest incidence at 21 days interval) could be recommended for the management of mites (*Tetranychus urticae* Koch) and whiteflies [*Bemisia tabaci* (Gennadius)] in tomato. Two sprays of spiromesifen 240 SC @ 90 or 120 or 150 g a.i./ha sustained higher population of coccinellid beetles per plant compared to three sprays of acephate 75 SP @ 375 g a.i./ha and four sprays of dicofol 18.5 EC @ 185 g a.i./ha. None of the insecticidal treatments showed any type of phytotoxic symptoms on tomato plants at 1, 3, 7, 10 and 15 days after spray at the dosages tried *viz*., spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 300 g a.i./ha and spiromesifen 240 SC @ 600 g a.i./ha.

Key words : Natural enemies, phytotoxicity, spiromesifen 240 SC, sucking pests, tomato

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important herbaceous plants belonging to Solanaceae family, which is widely consumed, popular and staple important vegetable crop (Mulatu *et al*., 2019; Tumanyan *et al*., 2020). One of the reasons for its high importance among vegetables is due to its greater nutritional value and reasonably affordable market price (Wahab and Hasan, 2019). Tomato is the rich source of vitamin A and C; besides it also contains lycopene which is an antioxidant that gives protection from cancer (Giovannucci, 1999). In India, the total area and production of various vegetables is 102.59 million hectares and 184.39 million tonnes, respectively, of which tomato is cultivated in an area of 7.89 lakh hectares with a production of 197.59 lakh tonnes (Anonymous, 2018).

There are numerous factors of low yield and one of the most important is sucking pest complex (Kennedy, 2003; Shakoor *et al*., 2010) including foliage and fruit feeding species (Lange and Bronson, 1981). They damage the crop by sucking plant cell sap with the help of their needle-like mouthparts commonly called stylets. The infestation of sucking pests, results in changing leaf morphology that further lead to falling of leaves and earlier fruit dropping which ultimately affects the yield and quality of tomato fruits which fetches low market price (Evans, 1992). The most common sucking pests of tomato are aphid, jassid, whitefly, mites and thrips (Costa and Brown, 1991) throughout the world.

In view of the indiscriminate use of chemical pesticides and public concerns, the rise of new generation insecticides provides an alternative to reduce the ill effects of conventional insecticides. The new insecticides are more tissue-specific, activated in unique ways inside the target cells of insects resulting in a reduced threat to other organisms. Selective toxicity to insects and safety to natural enemies have made the new class of insecticides more user and eco-friendly.

Spiromesifen 240 SC (22.9 % w/w) is a novel foliar contact insecticide/acaricide belongs to the

chemical class of Ketoenols. Oberon has been developed worldwide for the control of mites and whitefly on vegetables, fruits, cotton and tea. The product is active against all the developmental stages of mites and whiteflies resulting in long-lasting control. The efficacy of spiromesifen in reducing chilli mite in India was reported by Kavitha *et al.* (2006) and Nagaraj *et al*. (2007).

MATERIALS AND METHODS

The present field experiment was carried out for two consecutive *rabi*/summer seasons of 2008-09 and 2009-10 at the farmer's fields near Agricultural Research Station, Sankeshwar, Belagavi district, Karnataka, India to study the bio-efficacy of Spiromesifen 240 SC against the sucking pests of tomato and its safety to natural enemies.

Bio-efficacy Trials

The experiment comprised of six treatments replicated four times laid out in randomised block design. The treatments consisted of (1) Spiromesifen 240 SC (Oberon 240 SC) @ 90 g a.i./ha, (2) Spiromesifen 240 SC (Oberon 240 SC) @ 120 g a.i./ha, (3) Spiromesifen 240 SC (Oberon 240 SC) @ 150 g a.i./ha, (4) Acephate 75 SP @ 375 g a.i./ha, (5) Dicofol 18.5 EC @ 185 g a.i./ha (Standard Check), and (6) Untreated check. The spacing followed was 75 × 60 cm with Hanuman variety in a plot size of 5.25 × 5.40 m during both the seasons. The planting was taken up during the last week of December in medium black soils by providing ten irrigations to the crop during the cropping season in both the years.

Spiromesifen 240 SC was sprayed two times at 21 days interval while acephate 75 SP was sprayed three times at 10 days interval and dicofol 18.5 SP was sprayed four times at 10 days interval. These insecticidal applications were given with the help of knapsack sprayer using spray volume of 375-500 L/ha. The insecticidal efficacy was assessed by recording the number of mite nymphs/adults present on five randomly tagged plants from three leaves on the top part of the plant and two leaves on the middle part of the plants using a hand-magnifying lens. For whitefly population, only nymph count was recorded from five randomly tagged plants from three leaves per plant one each from the top, middle and bottom part of the plant. The mean number of mites and whiteflies per leaf was worked out. These observations were made a day before the first spray as pre-treatment count and on 3, 7, 10, 14 and 21 days after each application as post-treatment counts. The observation recorded on 21st day after the first spray served as pre-treatment count for the second spray of spiromesifen. The per cent protection against mites and whiteflies over untreated check was worked out. The fruit yield was harvested separately and fruit yield per hectare was computed. The population of coccinellid beetles was recorded at 5, 10, 20, 30 and 40 days after the first spray of spiromesifen.

Phytotoxicity Trials

One spray was taken up at 40 days after transplanting with knapsack sprayer using 500 litres of water per hectare. The observations on phytotoxicity symptoms (*viz*., leaf chlorosis, leaf tip burning, leaf necrosis, leaf epinasty, leaf hyponasty, vein clearing, wilting and rosetting) were recorded on the first, third, seventh, tenth and fifteenth day after spray by using the score given in Table 1.

Table 1. Scores for judging phytotoxicity symptoms in tomato

Score	Per cent Phytotoxicity
0	No Phytotoxicity
1	1-10
2	11-20
3	21-30
4	31-40
5	41-50
6	51-61
7	61-70
8	71-80
9	81-90
10	91-100

RESULTS AND DISCUSSION

A) Bio-efficacy against red spider mite, *Tetranychus urticae* Koch

First Season

i) During first spray of spiromesifen

At one day before spray, the mite population varied from 13.53 to 16.83 per leaf with non-significant differences among treatments (Table 2). At three days after first spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of mites (1.30 mites/leaf) followed by spiromesifen 240 SC @ 120 g a.i./ha (1.53 mites/leaf) and spiromesifen 240 SC @ 90 g a.i./ha (1.70 mites/leaf) and were significantly

superior to acephate 75 SP @ 375 g a.i./ha and dicofol 18.5 EC @ 185 g a.i./ha with 2.93 and 2.43 mites per leaf, respectively. At seven days after first spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population 0.63 mites per leaf followed by spiromesifen 240SC @ 120 g a.i./ha (0.80 mites/leaf) spiromesifen 240 SC @ 90 g a.i./ha (1.10 mites/leaf) and were highly effective against mites and were at par with each other. At 10 days after spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of mites (0.32 mites/leaf) followed by spiromesifen 240 SC @ 120 g a.i./ha (0.51 mites/leaf), spiromesifen 240 SC @ 90 g a.i./ha (0.75 mites/leaf) and dicofol 18.5 EC @ 185 g a.i./ha (0.90 mites/leaf) and were at par with each other. At 14 days after spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of mites (0.13 mites/leaf) followed by spiromesifen 240 SC @ 120 g a.i./ha (0.43 mites/leaf), spiromesifen 240 SC @ 90 g a.i./ha (0.53 mites/leaf) and dicofol 18.5 EC @ 185 g a.i./ha (0.58 mites/leaf) and were at par with each other. At 21 days after spray, spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha recorded lowest population of mites (1.73, 2.03 and 2.53 mites/leaf, respectively) indicating their higher and equal effectiveness as compared to dicofol 18.5 EC @ 185 g a.i./ha (3.53 mites/leaf) and acephate 75 SP @ 375 g a.i./ha (3.65 mites/leaf) (Table 2).

ii) During second spray of spiromesifen

At one day before second spray (*i.e.,* at 21 days after fist spray), the mite population varied from 1.73 to 9.43 per leaf with significant differences among treatments (Table 2). During second spray of spiromesifen, almost similar trend as noticed after first spray of spiromesifen was observed. At three days after second spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of mites (0.63 mites/leaf), followed by spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen @ 90 g a.i./ha with 0.73 and 0.85 mites per leaf, respectively which were at par with each other. At 7 and 10 days after second spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of mites followed by spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha and were highly effective against mites and were at par with each other. At 14 days after second spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of mites (0.23 mites/leaf) followed by spiromesifen 240 SC@ 120 g a.i./ha (0.33 mites/leaf) and spiromesifen 240 SC @ 90 g a.i./ha (0.53 mites/leaf) indicating their supremacy as compared to any other treatments. At 21 days after second spray, spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha, spiromesifen 240 SC @ 90 g a.i./ha and dicofol 18.5 EC @ 185 g a.i./ha recorded lowest population of mites

Table 2. Efficacy of spiromesifen 240 SC (Oberon 240 SC) against red spider mite, *Tetranychus urticae* during first season

S. No.	Treatments	Dosage		Number of mites per leaf										
		g a.i./ha	Forml/ha (ml/g)	After first spray of spiromesifen						After second spray of spiromesifen				
				1 DBFS	3 DAFS	7 DAFS	10 DAFS	14 DAFS	21 DAFS	3 DASS	7 DASS	10 DASS	14 DASS	21 DASS
1.	Spiromesifen 240 SC (Oberon 240 SC)	90	375	13.78	1.70	1.10	0.75	0.53	2.53	0.85	0.78	0.63	0.53	0.36
2.	Spiromesifen 240 SC (Oberon 240 SC)	120	500	15.63	1.53	0.80	0.51	0.43	2.03	0.73	0.45	0.43	0.33	0.15
3.	Spiromesifen 240 SC (Oberon 240 SC)	150	625	14.25	1.30	0.63	0.32	0.13	1.73	0.63	0.43	0.30	0.23	0.07
4.	Acephate 75 SP	375	500	16.83	2.93	2.10	1.70	1.50	3.65	2.43	2.00	1.70	1.23	0.73
5.	Dicofol 18.5 EC	185	1000	14.90	2.43	1.63	0.90	0.58	3.53	2.33	1.83	1.53	1.00	0.50
6.	Untreated check	-	-	13.53	14.23	14.03	15.33	12.68	9.43	9.23	8.70	7.33	7.20	6.68
	C. V. (%)	-	-	9.74	17.03	17.44	14.24	15.19	13.71	13.30	17.72	13.70	15.98	18.14
	S. Em±	-	-	0.72	0.34	0.29	0.23	0.20	0.26	0.18	0.21	0.14	0.14	0.15
	C. D. (P=0.05)	-	-	NS	1.03	0.89	0.70	0.60	0.79	0.54	0.63	0.41	0.42	0.45

DBFS= Day before first spray, DAFS= Days after first spray of spiromesifen, DASS= Days after second spray of spiromesifen.
Note: Spiromesifen 240 SC was sprayed two times at 21 days interval; Acephate 75 SP was sprayed three times at 10 days interval; Dicofol 18.5 EC was sprayed four times at 10 days interval.

(0.07, 0.15, 0.36 and 0.50 mites/leaf, respectively) indicating their higher and equal effectiveness. Acephate 75 SP @ 375 g a.i./ha with 0.73 mites per leaf was at par with spiromesifen 240 SC @ 90 g a.i./ha and dicofol 18.5 EC @ 185 g a.i./ha with 0.36 and 0.50 mites/leaf, respectively (Table 2).

Second Season

i) During first spray of spiromesifen

At one day before first spray, the mite population varied from 16.08 to 18.50 per leaf with non-significant differences among various treatments (Table 3). At three days after first spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of 1.52 mites per leaf, followed by spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha with 1.87 and 2.84 mites per leaf, respectively and latter two treatments were at par with each other. At 7 and 10 days after first spray also almost similar trend as above was noticed *i.e.*, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of mites followed by spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha and latter two treatments were at par with each other. At 14 days after spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of mites (0.37 mites/leaf) followed by spiromesifen 240 SC @ 120 g a.i./ha (0.58 mites/leaf), spiromesifen 240 SC @ 90 g a.i./ha (0.78 mites/leaf) and dicofol 18.5 EC @ 185 g a.i./ha (0.97 mites/leaf) indicating their effectiveness as compared to acephate 75 SP @ 375 g a.i./ha (1.75 mites/leaf). At 21 days after second spray, spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha recorded significantly lowest population of mites (1.78, 2.10 and 2.87 mites/leaf, respectively) indicating their higher effectiveness as compared to dicofol 18.5 EC @ 185 g a.i./ha (4.40 mites/leaf) and acephate 75 SP @ 375 g a.i./ha (4.62 mites/leaf) (Table 3).

ii) During second spray of spiromesifen

At one day before second spray (*i.e.*, at 21 days after second spray), the mite population varied from 1.78 to 16.43 per leaf with significant differences among treatments (Table 3). At three days after second spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of mites (0.74 mites/leaf), followed by spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha with 0.85 and 0.95 mites per leaf, respectively which were at par with each other. At 7, 10 and 14 days after second spray also almost similar trend as above was noticed *i.e.*, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of mites followed by spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @

Table 3. Efficacy of spiromesifen 240 SC (Oberon 240 SC) against red spider mite, *Tetranychus urticae* during second season

S. No.	Treatments	Dosage		Number of mites per leaf										
		g a.i./ha	Forml/ha (ml/g)	After first spray of spiromesifen						After second spray of spiromesifen				
				1 DBFS	3 DAFS	7 DAFS	10 DAFS	14 DAFS	21 DAFS	3 DASS	7 DASS	10 DASS	14 DASS	21 DASS
1.	Spiromesifen 240 SC (Oberon 240 SC)	90	375	16.80	2.84	2.74	1.70	0.78	2.87	0.95	0.84	0.73	0.55	0.31
2.	Spiromesifen 240 SC (Oberon 240 SC)	120	500	17.32	1.87	1.73	0.90	0.58	2.10	0.85	0.65	0.53	0.38	0.12
3.	Spiromesifen 240 SC (Oberon 240 SC)	150	625	16.55	1.52	1.40	0.73	0.37	1.78	0.74	0.53	0.41	0.25	0.05
4.	Acephate 75 SP	375	500	18.50	4.15	3.48	2.15	1.75	4.62	3.65	2.15	1.81	1.68	0.70
5.	Dicofol 18.5 EC	185	1000	16.08	3.81	2.97	1.67	0.97	4.40	2.85	1.98	1.65	1.40	0.65
6.	Untreated check	-	-	18.50	18.41	17.23	16.83	16.33	16.43	15.53	15.80	16.33	15.20	16.45
	C. V. (%)	-	-	10.42	15.67	17.03	17.44	14.24	13.71	15.40	12.72	16.50	15.98	17.14
	S. Em±	-	-	0.87	0.38	0.35	0.31	0.21	0.41	0.22	0.16	0.15	0.13	0.12
	C. D. (P=0.05)	-	-	NS	1.15	1.04	0.92	0.63	1.22	0.66	0.48	0.45	0.40	0.36

DBFS= Day before first spray, DAFS= Days after first spray of spiromesifen, DASS= Days after second spray of spiromesifen.
Note : Spiromesifen 240 SC was sprayed two times at 21 days interval; Acephate 75 SP was sprayed three times at 10 days interval; Dicofol 18.5 EC was sprayed four times at 10 days interval.

90 g a.i./ha which were at par with each other. At 21 days after second spray, spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha recorded significantly lowest population of mites (0.05, 0.12 and 0.31 mites/leaf, respectively) indicating their higher and equal effectiveness as compared to acephate 75 SP @ 375 g a.i./ha (0.70 mites/leaf). Spiromesifen 240 SC @ 150 g a.i./ha and spiromesifen 240 SC @ 120 g a.i./ha were significantly superior and spiromesifen 240 SC @ 90 g a.i./ha was on par with dicofol 18.5 EC @ 185 g a.i./ha (0.65 mites/leaf) (Table 3).

B) Bio-efficacy against whitefly, *Bemisia tabaci* (Gennadius)

First Season

i) During first spray of spiromesifen

At one day before first spray, the whitefly population varied from 16.51 to 20.08 nymphs per leaf with non-significant differences among treatments (Table 4). At three days after first spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of whitefly (3.12 nymphs/leaf) followed by spiromesifen 240 SC @ 120 g a.i./ha (4.34 nymphs/leaf) and spiromesifen 240 SC @ 90 g a.i./ha (5.46 nymphs/leaf) and latter two treatments were at par with each other. At seven days after first spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of white fly (2.63 nymphs/leaf) followed by spiromesifen 240 SC @ 120 g a.i./ha (3.56 nymphs/leaf) and spiromesifen 240 SC @ 90 g a.i./ha (4.12 nymphs/leaf) which were highly effective against whitefly and were at par with each other. At 10 days after first spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of white fly (2.15 nymphs/leaf) followed by spiromesifen 240 SC @ 120 g a.i./ha (2.74 nymphs/leaf) and spiromesifen 240 SC @ 90 g a.i./ha (3.05 nymphs/leaf) and were at par with each other. At 14 days after first spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of whitefly (1.56 nymphs/leaf) followed by spiromesifen 240 SC @ 120 g a.i./ha (2.08 nymphs/leaf) and spiromesifen 240 SC @ 90 g a.i./ha (2.71 nymphs/leaf) indicating their higher effectiveness as compared to other treatments. At 21 days after first spray also, spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a. i./ha and spiromesifen 240 SC @ 90 g a.i./ha recorded lowest population of white flies (5.77, 6.22 and 7.56 nymphs/leaf, respectively) indicating higher and equal effectiveness as compared to acephate 75 SP @ 275 g a.i./ha (12.75 nymphs/leaf) and dicofol 18.5 EC @ 185 g a.i./ha (14.30 nymphs/leaf) (Table 4).

Table 4. Efficacy of spiromesifen 240 SC (Oberon 240 SC) against whitefly, *Bemisia tabaci* during first season

S. No.	Treatments	Dosage		Number of whitefly nymphs per leaf										
		g a.i./ha	Forml/ha (ml/g)	After first spray of spiromesifen						After second spray of spiromesifen				
				1 DBFS	3 DAFS	7 DAFS	10 DAFS	14 DAFS	21 DAFS	3 DASS	7 DASS	10 DASS	14 DASS	21 DASS
1.	Spiromesifen 240 SC (Oberon 240 SC)	90	375	17.45	5.46	4.12	3.05	2.71	7.56	3.14	2.55	1.75	0.55	0.30
2.	Spiromesifen 240 SC (Oberon 240 SC)	120	500	16.51	4.34	3.56	2.74	2.08	6.22	2.75	2.16	1.45	0.33	0.14
3.	Spiromesifen 240 SC (Oberon 240 SC)	150	625	18.36	3.12	2.63	2.15	1.56	5.77	2.08	1.57	0.76	0.12	0.10
4.	Acephate 75 SP	375	500	20.08	8.50	6.24	5.16	4.54	12.75	7.55	6.53	5.08	4.03	3.24
5.	Dicofol 18.5 EC	185	1000	19.45	10.78	7.38	6.57	5.40	14.30	8.76	7.34	6.20	5.15	4.36
6.	Untreated check	-	-	17.84	17.24	16.40	16.20	15.15	15.04	14.10	14.05	13.70	13.50	13.09
	C. V. (%)	-	-	9.89	10.56	12.78	13.45	15.64	13.56	14.55	15.64	17.8	16.48	17.58
	S. Em±	-	-	8.45	0.42	0.37	0.35	0.31	0.54	0.48	0.41	0.32	0.27	0.16
	C. D. (P=0.05)	-	-	NS	1.27	1.10	1.03	0.94	1.63	1.45	1.22	0.97	0.82	0.49

DBFS= Day before first spray, DAFS= Days after first spray of spiromesifen, DASS= Days after second spray of spiromesifen.
Note : Spiromesifen 240 SC was sprayed two times at 21 days interval; Acephate 75 SP was sprayed three times at 10 days interval; Dicofol 18.5 EC was sprayed four times at 10 days interval.

ii) During second spray of spiromesifen

At one day before second spray, the whitefly population varied from 5.77 to 15.04 nymphs per leaf with significant differences among treatments (Table 4). At three days after second spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of white fly (2.08 nymphs/leaf) followed by spiromesifen 240 SC @ 120 g a.i./ha (2.75 nymphs/leaf) and spiromesifen 240 SC @ 90 g a.i./ha (3.14 nymphs/leaf). Acephate 75 SP @ 375 g a.i./ha and dicofol 18.5 EC @ 185 g a.i./ha with 7.55 and 8.76 nymphs per leaf, respectively were at par with each other and superior to untreated check but inferior to spiromesifen treatments. At seven days after second spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of white fly (1.57 nymphs/leaf) followed by spiromesifen 240 SC @ 120 g a. i./ha (2.16 nymphs/leaf), spiromesifen 240 SC @ 90 g a.i./ha (2.55 nymphs/leaf) and were highly effective against whitefly and were at par with each other. At 10 and 14 days after second spray, spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha recorded significantly lower population of whiteflies than acephate 75 SP @ 375 g a.i./ha and dicofol 18.5 EC @ 185 g a.i./ha. At 21 days after second spray also, spiromesifen 240 SC showed its supremacy where in spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha recorded lowest population of whitefly (0.10, 0.14 and 0.30 nymphs/leaf, respectively) indicating their higher effectiveness as compared to acephate 75 SP @ 275 g a.i./ha (3.24 nymphs/leaf) and dicofol 18.5 EC @ 185 g a.i./ha (4.36 nymphs/leaf) (Table 4).

Second Season

i) During first spray of spiromesifen

At one day before first spray, the whitefly population varied from 19.54 to 22.87 nymphs per leaf with non-significant differences among treatments (Table 5). At three days after first spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of mites (4.25 nymphs/leaf) followed by spiromesifen 240 SC @ 120 g a.i./ha (5.84 nymphs/leaf) and spiromesifen 240 SC @ 90 g a.i./ha (6.87 nymphs/leaf). Acephate 75 SP @ 375 g a.i./ha and dicofol 18.5 EC @ 185 g a.i./ha with 9.58 and 12.68 nymphs per leaf, respectively were at par with each other and superior to untreated check but inferior to all spiromesifen treatments. At 7, 10 and 14 days after second spray also almost similar trend as above was noticed *i.e.,* spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of mites followed by spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha. Acephate 75 SP @ 375 g a.i./ha and dicofol 18.5 EC @ 185 g a.i./ha were at par with each other and superior to untreated check but inferior to all spiromesifen treatments. At 21 days after spray there was a slight increase in the insect population in all the treatments. Spiromesifen 240 SC@ 150 g a.i./ha, spiromesifen 240 SC @120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha recorded lowest population of whitefly (6.14, 7.28 and 8.57 nymphs/leaf, respectively) indicating their higher and equal effectiveness as compared to acephate 75 SP @ 375 g a.i./ha (10.85 nymphs/leaf) and dicofol 18.5 EC @ 185 g a.i./ha (12.45 nymphs /leaf) (Table 5).

ii) During second spray of spiromesifen

At one day before second spray, the whitefly population varied from 6.14 to 20.25 nymphs per leaf with significant differences among treatments (Table 5). At three days after second spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of whiteflies (1.55 nymphs/leaf) followed by spiromesifen 240 SC @ 120 g a.i./ha (2.45 nymphs/leaf) and spiromesifen 240 SC @ 90 g a.i./ha (2.86 nymphs/leaf) and were significantly superior to acephate 75 SP @ 375 g a.i./ha and dicofol 18.5 EC @ 185 g a.i./ha with 6.50 and 7.30 nymphs per leaf, respectively. At seven days after second spray, spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of whiteflies (0.85 nymphs/leaf) followed by spiromesifen 240 SC @ 120 g a.i./ha (1.48 nymphs/leaf) and spiromesifen 240 SC @ 90 g a.i./ha (1.85 nymphs/leaf) which were highly effective against whitefly and at par with each other. At 10 and 14 days after second spray also almost similar trend as above was noticed *i.e.,* spiromesifen 240 SC @ 150 g a.i./ha recorded lowest population of whiteflies followed by spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha which were highly effective against whitefly and at par with each other. At 21 days after second spray, spiromesifen 240SC@ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha recorded significantly lowest population of white flies (0.03,

Table 5. Efficacy of spiromesifen 240 SC (Oberon 240 SC) against whitefly, *Bemisia tabaci* during second season

S. No.	Treatments	Dosage		Number of whitefly nymphs per leaf										
		g a.i./ha	Forml/ha (ml/g)	After first spray of spiromesifen						After second spray of spiromesifen				
				1 DBFS	3 DAFS	7 DAFS	10 DAFS	14 DAFS	21 DAFS	3 DASS	7 DASS	10 DASS	14 DASS	21 DASS
1.	Spiromesifen 240 SC (Oberon 240 SC)	90	375	19.54	6.87	5.62	4.10	3.00	8.57	2.86	1.85	0.50	0.30	0.15
2.	Spiromesifen 240 SC (Oberon 240 SC)	120	500	19.58	5.84	4.41	3.51	2.65	7.28	2.45	1.48	0.35	0.20	0.08
3.	Spiromesifen 240 SC (Oberon 240 SC)	150	625	20.65	4.25	3.15	2.60	2.10	6.14	1.55	0.85	0.15	0.12	0.03
4.	Acephate 75 SP	375	500	21.87	9.58	8.57	6.20	5.00	10.85	6.50	4.50	4.15	3.20	1.50
5.	Dicofol 18.5 EC	185	1000	21.58	12.68	10.25	7.12	6.12	12.45	7.30	5.25	5.00	4.45	2.40
6.	Untreated check	-	-	22.87	21.98	20.25	19.48	19.20	20.25	19.14	19.75	19.50	19.40	18.75
	C. V. (%)	-	-	10.85	13.45	14.52	13.80	14.50	13.50	16.60	17.8	15.45	12.58	17.45
	S. Em±	-	-	5.85	0.61	0.52	0.45	0.36	0.56	0.42	0.35	0.30	0.20	0.15
	C. D. (P=0.05)	-	-	N.S.	1.83	1.55	1.35	1.08	1.68	1.25	1.05	0.90	0.61	0.44

DBFS= Day before first spray, DAFS= Days after first spray of spiromesifen, DASS= Days after second spray of spiromesifen.
Note: Spiromesifen 240 SC was sprayed two times at 21 days interval; Acephate 75 SP was sprayed three times at 10 days interval; Dicofol 18.5 EC was sprayed four times at 10 days interval.

0.08 and 0.15 nymphs/leaf, respectively) indicating their higher and equal effectiveness as compared to acephate 75 SP @ 375 g a.i./ha (1.50 nymphs/leaf) and dicofol 18.5 EC @ 185 g a.i./ha (2.40 nymphs/leaf) (Table 5).

C) Overall efficacy of insecticides and their effect on fruit yield

First Season

Two sprays of spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha afforded highest protection against mites with 98.9, 97.8 and 94.6 per cent, respectively over untreated check. Dicofol 18.5 EC @ 185 g a.i./ha (four sprays) and acephate 75 SP @ 375 g a.i/ha (three sprays) recorded 92.5 and 89.1 per cent protection against mites, respectively over untreated check (Table 6).

Two sprays of spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha afforded highest protection against whiteflies with 99.2, 98.9 and 97.7 per cent, respectively over untreated check. Acephate 75 SP @ 375 g a.i/ha (three sprays) and dicofol 18.5 EC @ 185 g a.i./ha (four sprays) recorded 75.2 and 66.7 per cent protection against whiteflies, respectively over untreated check (Table 6).

All the insecticides recorded significantly higher fruit yield than the untreated check. Two sprays of spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha produced higher fruit yield of 23.02, 22.63 and 22.48 t/ha, respectively but were at par with three sprays of acephate 75 SP @ 375 g a.i/ha (21.90 t/ha) and four sprays of dicofol 18.5 EC @ 185 g a.i./ha (21.78 t/ha) (Table 6).

Second Season

Two sprays of spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha afforded highest protection against mites with 99.7, 99.3 and 98.1 per cent, respectively over untreated check. Dicofol 18.5 EC @ 185 g a.i./ha (four sprays) and acephate 75 SP @ 375 g a.i/ha (three sprays) recorded 96.00 and 95.7 per cent protection against mites, respectively over untreated check (Table 6).

Two sprays of spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha afforded highest protection against whiteflies with 99.8, 99.6 and 99.2

Table 6. Effect of spiromesifen 240 SC (Oberon 240 SC) on mites, whiteflies and fruit yield over two seasons

S. No.	Treatments	Dosage		Per cent Protection against				Fruit Yield (t/ha)	
		g a.i./ha	Forml./ha (ml/g)	Mites		Whiteflies			
				First season	Second season	First season	Second season	First season	Second season
1.	Spiromesifen 240 SC (Oberon 240 SC)	90	375	94.6	98.1	97.7	99.2	22.48	23.24
2.	Spiromesifen 240 SC (Oberon 240 SC)	120	500	97.8	99.3	98.9	99.6	22.63	23.68
3.	Spiromesifen 240 SC (Oberon 240 SC)	150	625	98.9	99.7	99.2	99.8	23.02	24.25
4.	Acephate 75 SP	375	500	89.1	95.7	75.2	92.0	21.90	22.10
5.	Dicofol 18.5 EC	185	1000	92.5	96.0	66.7	87.2	21.78	22.15
6.	Untreated check	-	-	-		-		19.45	20.80
	C. V. (%)	-	-	-		-		9.8	10.4
	S. Em±	-	-	-		-		0.70	0.72
	C. D. (P=0.05)	-	-	-		-		2.10	2.17

Note : Spiromesifen 240 SC was sprayed two times at 21 days interval; Acephate 75 SP was sprayed three times at 10 days interval; Dicofol 18.5 EC was sprayed four times at 10 days interval.

per cent, respectively over untreated check. Acephate 75 SP @ 375 g a.i/ha (three sprays) and dicofol 18.5 EC @ 185 g a.i./ha (four sprays) recorded 92.0 and 87.2 per cent protection against whiteflies, respectively over untreated check (Table 6).

All the insecticides recorded significantly higher fruit yield than the untreated check. Two sprays of spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha produced higher fruit yield of 24.25, 23.68 and 23.24 t/ha, respectively but were on par with three sprays of acephate 75 SP @ 375 g a.i/ha (22.10 t/ha) and four sprays of dicofol 18.5 EC @ 185 g a.i./ha (22.15 t/ha) (Table 6).

D) Effect of Insecticides on Natural Enemies

The data on the effect of insecticides on natural enemies are presented in Table 7. During the first season, the coccinellid beetles varied from 1.17 to 1.42 per plant at one day before the imposition of treatments. The population of coccinellid beetles did not vary among various insecticidal treatments at 5, 10, 20, 30 and 40 days after the first spray. Two sprays of spiromesifen 240 SC @ 90 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 150 g a.i./ha sustained higher population of 1.13, 1.08 and 1.02 beetles per plant as compared to three sprays of acephate 75 SP @ 375 g a.i/ha (0.92 beetle/plant) and four sprays of dicofol 18.5 EC @ 185 g a.i./ha (0.70 beetle/plant).

During the second season, the coccinellid beetles varied from 1.65 to 1.81 per plant at one day before the imposition of treatments. The population of coccinellid beetles did not vary among various insecticidal treatments at 5, 10, 20, 30 and 40 days after the first spray. Two sprays of spiromesifen 240 SC @ 90 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 150 g a.i./ha sustained higher population of 1.35, 1.24 and 1.15 beetles per plant as compared to three sprays of acephate 75 SP @ 375 g a.i/ha (1.18 beetles/plant) and four sprays of dicofol 18.5 EC @ 185 g a.i./ha (1.00 beetle/plant).

The results of the present study are in line with Sekh *et al*. (2007) who revealed that spiromesifen (Oberon 240 SC) @ 300-400 ml/ha gave excellent control of red spider mite (*T. urticae*) of brinjal along with the significant increase in yield and it was very safe to important natural enemies (*Stethorus* sp, *Chrysoperla* sp., *Amblyseius* spp.). Similarly, Varghese and Mathew (2013) reported that spiromesifen 45 SC at 100 g a.i. ha^{-1} was found to be effective in reducing chilli mite [*Polyphagotarsonemus latus* (Banks)] population. Further, spiromesifen was found to be the safest insecticide against natural enemies *viz*. predatory mites, coccinellid beetles, spiders and neutral insects whereas the organophosphate insecticide dimethoate

Table 7. Effect of spiromesifen 240 SC (Oberon 240 SC) on coccinellid beetles in tomato

S. No.	Treatments	Dosage		Number of coccinellid beetles per plant											
		g a.i./ha	Forml/ha (ml/g)	After first spray of spiromesifen (First season)						After second spray of spiromesifen (Second season)					
				1 DBFS	5 DAFS	10 DAFS	20 DAFS	30 DAFS	40 DAFS	1 DASS	5 DASS	10 DASS	20 DASS	30 DASS	40 DASS
1.	Spiromesifen 240 SC (Oberon 240 SC)	90	375	1.42	1.23	1.00	1.21	1.05	1.13	1.65	1.45	1.22	1.42	1.25	1.35
2.	Spiromesifen 240 SC (Oberon 240 SC)	120	500	1.31	1.15	0.94	1.10	1.02	1.08	1.75	1.25	1.12	1.28	1.12	1.24
3.	Spiromesifen 240 SC (Oberon 240 SC)	150	625	1.17	1.01	0.83	1.00	0.97	1.02	1.80	1.18	1.00	1.20	1.02	1.15
4.	Acephate 75 SP	375	500	1.25	1.00	0.75	0.97	0.81	0.92	1.78	1.20	1.10	1.21	1.12	1.18
5.	Dicofol 18.5 EC	185	1000	1.36	1.14	0.71	0.89	0.74	0.70	1.65	1.25	0.90	1.10	0.95	1.00
6.	Untreated check	-	-	1.28	1.30	1.32	1.31	1.40	1.37	1.81	1.74	1.72	1.78	1.62	1.60
	C. V. (%)	-	-	15.71	17.81	18.52	19.37	17.84	16.73	14.74	16.25	14.22	15.74	16.45	17.31
	S. Em±	-	-	0.21	0.18	0.16	0.22	0.15	0.14	0.28	0.24	0.27	0.26	0.23	0.22
	C. D. (P=0.05)	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

DBFS= Day before first spray; DAFS= Days after first spray of spiromesifen.

Note : Spiromesifen 240 SC was sprayed two times at 21 days interval; Acephate 75 SP was sprayed three times at 10 days interval; Dicofol 18.5 EC was sprayed four times at 10 days interval.

30 EC 300 g a.i. ha^{-1} was found to be unsafe to natural enemies.

Spiromesifen was also found highly active against tetranychid mite eggs, all juvenile and quiescent stages and female adults by contact (Nauen *et al*., 2005). Kavitha *et al*. (2006) reported higher efficacy of spiromesifen 240 SC at the rate of 120 g a.i. ha^{-1} against chilli mite, *P. latus*. Halder *et al*. (2015) evaluated the efficacy of different newer molecules against yellow mite (*P. latus*) and thrips (*Scirtothrips dorsalis* Hood) infesting chilli and revealed that maximum reduction in mite population was obtained in treatment with chlorfenapyr @ 1.5 ml/l (69.95%) followed by spiromesifen @ 0.6 ml/l (57.43%). Sharma and Choudhury (2018) recommended the spiromesifen 22.9 SC @ 150 g a.i./ha against whiteflies and mites with a waiting period of 3 days.

Phytotoxicity

The data pertaining to phytotoxicity are presented in Table 8. None of the insecticidal treatments showed any type of phytotoxic symptoms on tomato plants at 1, 3, 7, 10 and 15 days after spray at the dosages tried *viz*., spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 300 g a.i./ha and spiromesifen 240 SC @ 600 g a.i./ha.

Table 8. Phytotoxic effect due to spiromesifen 240 SC (Oberon 240 SC) on tomato recorded at 1, 3, 7, 10 and 15 days after spray (Mean of two seasons)

Tr. No.	Treatments	Dosage		Per cent Leaf chlorosis & leaf tip burning					Per cent Necrosis					Per cent Epinasty & Hyponasty					Per cent vein clearing					Per cent Wilting & Rosetting				
		g a. i./ha	Forml/ha	1	3	7	10	15	1	3	7	10	15	1	3	7	10	15	1	3	7	10	15	1	3	7	10	15
T_1	Spiromesifen 240 SC (Oberon 240 SC)	150	625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T_2	Spiromesifen 240 SC (Oberon 240 SC)	300	1250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T_3	Spiromesifen 240 SC (Oberon 240 SC)	600	2500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T_4	Untreated check (Water spray)	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CONCLUSION

It can be concluded that the new generation insecticide, spiromesifen 240 SC has longer persistence effect as compared to conventional insecticides like dicofol 18.5 EC and acephate 75 SP, as only two sprays of spiromesifen 240 SC @ 150 g a.i./ha, spiromesifen 240 SC @ 120 g a.i./ha and spiromesifen 240 SC @ 90 g a.i./ha can effectively manage mites and whiteflies in tomato as against three sprays of acephate 75 SP @ 375 g a.i/ha and four sprays of dicofol 18.5 EC @ 185 g a.i./ha. Hence, the lower dosage of spiromesifen 240 SC @ 90 g a.i./ha (two sprays starting from pest incidence at 21 days interval) could be recommended for the management of mites (*T. urticae*) and whiteflies (*B. tabaci*) in tomato.

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