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Activity of novel insecticides against different life stages of whitefly (*Bemisia tabaci*)

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ABSTRACT

Whitefly, *Bemisia tabaci* (Gennadius), in North Cotton Growing Zone of India adversely affect cotton yield. Both the nymphal and adult stages of whitefly cause damage by sucking the sap from leaf tissue and honey dew secretion. In this study, the efficacy of new generation insecticides, viz. pyriproxyfen 10EC@1250 ml/ha, spiromesifen 22.9SC @500 ml/ha, flonicamid 50WG @200g/ha, and diafenthiuron 50WP @ 500g/ha were evaluated against different stages of whitefly under confined as well as field conditions in Bt cotton.The experiment conducted in screen house revealed significantly higher per cent reduction of whitefly nymphs in spiromesifen 22.9SC (49.36, 75.17) followed by pyriproxyfen 10EC (33.26, 75.07) in comparison to all other treatments after 5 and 7 days of spray, respectively. Under field conditions, pooled analysis of six experiments showed that flonicamid 50WP was more effective, being at par with pyriproxyfen 10EC, diafenthiuron 50WP, spiromesifen 22.9SC after 10 days of spray as compared to standard check, ethion 50EC and control against whitefly adults. It is concluded that pyriproxyfen10EC and spiromesifen 22.9SC have good nymphicidal action while flonicamid 50WP and diafenthiuron 50WP have adulticidal action.Therefore, for its effective management, these novel insecticides can be rotated alternatively depending upon the stage of pest dominating in the cotton field.

Key words: Bt cotton, Diafenthiuron, Flonicamid, New generation insecticides, Pyriproxifen, Spiromesifen, Whitefly

Cotton crop known as white gold is cultivated on an area of 118.77 lakh ha with a production of 484 kg lint/ha in India (Anonymous 2017). After the introduction of Bt cotton, bollworm incidence decreased, however, sucking pest incidence increased. In Punjab, whitefly, *B. tabaci* has assumed the status of a serious pest of cotton in the recent past and during *kharif* 2015, it appeared in epidemic form in Punjab and Haryana. Due to the attack of whitefly, the crop productivity of Punjab state fell substantially from 574 kg/ha of lint in 2014–15 to 197 kg/ha in 2015-16 (Dhillon and Sidhu 2016).

Use of insecticides to manage insect pests always remained as preferred tactics. Many new generation insecticides are being used worldwide which are comparatively safer to environment and continuous efforts are needed to evaluate the new eco-friendly insecticides against this pest. The pyriproxyfen and flonicamid are among the new chemistry with novel mode of action. Pyriproxyfen (4-phenoxyphenyl (RS)-2- (2-pyridyloxy) propyl ether) is a potent juvenile hormone analog that acts by suppressing embryogenesis, metamorphosis and inhibit adult formation. It has been found to be effective against variety of insect pests including whiteflies (Qureshi *et al.* 2009), aphids (Liu and Chen 2001).

Flonicamid (IK1220; *N*-cyanomethyl-4-trifluoromethylnicotinamide) is a selective insecticide which belongs to the pyridine carboxamide group (Hancock 2003, Hancock *et al.* 2003). It inhibits feeding behaviour of aphid and other sucking insect pests (Morita *et al.* 2014). Spriromesifen, a spirocyclic tetronic acids, acts by inhibiting the lipid synthesis, was found effective against whiteflies (Bretschneider *et al.* 2003, Nauen *et al.* 2005, Nauen and Konanz 2005). Diafenthiuron is another potent insecticide which inhibits the oxidative phosphorylation and disrupts the ATP formation. Diafenthiuron and flonicamid were also found effective for management of jassid and whitefly in Bt cotton (Kalyan *et al.* 2017). Some novel insecticides have shown specific activity against different life stages of insect pests. Keeping in view the above facts, new generation insecticides, viz. pyriproxyfen, flonicamid, diafenthiuron and spiromesifen having novel mode of action were evaluated against nymphs and adults of whitefly on Bt cotton.

MATERIALS AND METHODS

Test insecticides: Pyriproxyfen 10EC (Lano) @1250

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ml/ha of M/s Sumitomo Chemical India Pvt Ltd, flonicamid 50WG (Ulala) @200 g/ha of M/s United Phosphorus Ltd**,** spiromesifen 22.9SC (Oberon) @500 ml/ha of M/s Bayer Crop Science and diafenthiuron 50WP (Polo) @500 g/ha of M/s Syngenta India Pvt Ltd and ethion 50EC (Fosmite) of PI Industries Pvt Ltd. (standard check) were evaluated against whitefly under screen house and field conditions**.**

The experiment on effect of novel insecticides on nymphal population of whitefly was conducted in screen house at Ludhiana, during *kharif* 2016. The field efficacy was evaluated at experimental area of PAU Regional Station at Bathinda and Abohar.

Under screen house conditions: The whitefly culture was maintained on cotton plants in screen house at Entomological Research Farm, PAU, Ludhiana. The leaf cages were prepared from 50 ml centrifuge tubes (3.1 cm diameter × 2.5 cm length). Six circular holes (0.75 cm diameter) were made on sides of tube at equal distance from each other. On the cutting edge of the tube, a fine transparent sheet was glued with fevicol so that the side holes are not covered by this sheet. Muslin cloth was pasted on five holes while the sixth hole was kept uncovered for releasing the whitefly adults into the cage, which was later plugged with a cotton swab. The other end of the tube was fastened on the lower surface of the leaf which was supported from the upper side of leaf by means of a foam piece (10 mm thickness) measuring 3.5 cm × 3.5 cm, pasted on a thin sunmica piece. These leaf cages were attached to the lower surface of cotton leaves and 10 pairs of whitefly were released in the leaf cages. After 24 h, the whiteflies were removed from leaf cages and the number of eggs laid was observed under stereo zoom microscope (40X). In each cage, 50 eggs were retained and other was removed using camel hair brush. The egg development was observed daily. At second or third instar nymphs, the insecticides selected for testing were sprayed on the plants using knapsack sprayer with three replicates. The nymphal population was recorded 5, 7 and 10 days after spray. The per cent reduction of whitefly nymphs over control was calculated.

Under field conditions: The test insecticides were evaluated for their efficacy against whitefly nymphs in field conditions at PAU Regional Station, Bathinda and Abohar. The whitefly nymphal population was recorded in 150 m^2 plot area before spray of insecticides. There are four replications for each treatment. The insecticides were sprayed in each plot in completely randomized block design. The nymphal population was observed in a unit area of leaf (1 cm^2) after 3, 7 and 10 days of spray from 3 leaves of 10 randomly selected plant from each plot.

Effect of novel insecticides on adult whitefly population under field conditions: Six experiments were conducted, viz. one at Bathinda and five in Abohar to test efficacy of insecticides against adults of whitefly. The Bt cotton hybrid (RCH773BGII) was grown in the field at each location following recommendations of PAU Package of Practices (Anonymous 2016). The plot size for each treatment was 150 m^2 with four replications in randomised block design. The insecticides at selected dosages were sprayed using knapsack sprayer, using 375 l of water/ha. The population of whitefly adults was recorded before spray and after 3, 7 and 10 days of insecticide application. The data on number of whitefly adults per three fully opened leaves from upper canopy were recorded from 10 randomly selected plants per replication. The seed cotton yield was also recorded on whole plant basis.

Data Analysis: The data were subjected to ANOVA using arc sine transformation for per cent mortality and square root transformation for population count. The data was analysed using Completely Randomised Block (CRD) and Randomized Block Design (RBD) for screen house and field experiments, respectively. The treatment means were compared using least significant difference (LSD) at 5% probability.

RESULTS AND DISCUSSION

Effect of novel insecticides on whitefly nymphal population

Under screen house conditions: Number of whitefly nymphs did not differ significantly under the leaf cage before spray (Table 1). The population varied from 49.05–55.97 nymphs in each leaf cage. After 5 day of spray, per cent reduction of whitefly nymphs over control was significantly higher in spiromesifen 22.9SC @500 ml/ha (49.36) followed by pyriproxyfen 10EC @1250 ml/ha (33.26), diafenthiuron 50WP (28.10) and flonicamid 50WG (27.71) which were statistically at par with each other. After 7 days of spray, per cent reduction of whitefly nymphs over control was significantly higher in spiromesifen 22.9SC @500 ml/ha (75.17), being at par with pyriproxyfen 10EC @1250 ml/ha (75.07) followed by diafenthiuron 50WP (61.39). After10 days of spray, it was significantly higher in pyriproxyfen

Table 1 Efficacy of novel insecticides against whitefly nymphs on Bt cotton under screen house conditions at PAU, Ludhiana

Treatment	Dose (g/ml/ ha)	Number of whitefly nymphs/ cm 2 area (Before spray)	Reductionof whitefly nymphs over control (%)		
			5 DAS	7 DAS	10 DAS
Pyriproxyfen 10 EC (Lano)	1250 ml	55.97	33.26 (35.20)	75.07 (60.02)	85.04 (67.22)
Spiromesifen 22.9SC (Oberon)	500 ml	49.05	49.36 (44.62)	75.17 (60.10)	77.08 (61.39)
Flonicamid 50 WG (Ulala)	200 g	50.42	27.71 (31.74)	34.92 (36.21)	40.42 (39.46)
Diafenthiuron 50 WP (Polo)	500 g	54.05	28.10 (31.98)	61.39 (51.56)	71.60 (57.79)
Control	-	51.42	-	-	-
LSD (P=0.05)	-	NS	(3.64)	(3.44)	(3.57)

Figure in parenthesis are arc sine transformation; pooled of two experiments; DAS: Days after spray

Table 2 Field efficacy of novel insecticides against whitefly nymphs on Bt cotton at Bathinda and Abohar

Treatment	Dose (g/ml/ha)	Reduction of whitefly nymphs over control (%)					
		Abohar			Bathinda		
		3 DAS	7 DAS	10 DAS	3 DAS	7 DAS	10 DAS
Pyriproxyfen 10EC (Lano)	1250 ml	14.07 (21.85)	56.27 (48.59)	70.60 (57.15)	15.78	54.21 (47.40)	71.50 (57.77)
Spiromesifen 22.9SC (Oberon)	500 ml	24.20 (29.41)	67.63 (55.31)	68.03 (55.90)	15.33	42.35 (40.57)	64.26 (53.28)
Flonicamid 50WG (Ulala)	200 g	17.43 (24.65)	28.43 (32.21)	47.64 (43.60)	16.24	27.03 (31.27)	30.21 (33.27)
Diafenthiuron 50WP (Polo)	500 g	29.97 (33.12)	43.97 (41.48)	41.56 (40.10)	21.01	33.20 (35.09)	41.77 (40.22)
LSD (P=0.05)	-	(5.77)	(6.14)	(8.41)	NS	(6.01)	(6.82)

Figure in parenthesis are arc sine transformation, DAS: days after spray

10EC (85.04) followed by spiromesifen 22.9SC (77.08) and diafenthiuron 50WP (71.60). The flonicamid was found to be least effective against nymphs of whitefly as compared to all other treatments.

Under field conditions: At Abohar, after 3 days of spray, per cent reduction of whitefly nymphs was significantly higher in spiromesifen 22.9 SC (24.20) followed by pyriproxyfen 10EC (14.07). Similarly, it was significantly higher in spiromesifen 22.9 SC (67.63) followed by pyriproxyfen 10EC (56.27) after 7 days of spray. However, after 10 DAS, it was significantly higher in pyriproxyfen 10EC (70.60) being at par with spiromesifen 22.9 SC (68.03) (Table 2).

At Bathinda, after 3 days of spray, non-significant differences were recorded in all test insecticides (Table 2). Whitefly nymphal population reduction was significantly higher in pyriproxyfen 10EC (54.21%) as compared to all other treatments after 7 days of spray. It was followed by spiromesifen 22.9SC (42.35%), diafnethiuron 50WP (33.20%) and flonicamid 50WG (27.03%). However, after 10 days of spray, the maximum reduction of nymphs was recorded in pyriproxyfen 10EC (71.50%) being at par with spiromesifen 22.9 SC (64.26%). Daifenthuiuron 50WP (41.77%) and flonicamid 50 WG (30.21%) were found to be least effective against nymphal population and were statistically at par with each other.

Effect of novel insecticides on adult whitefly population under field conditions

Bathinda: Whitefly adults per three leaves did not differ significantly before spray (Table 3). After three days of spray, population was significantly lower in diafenthiuron 50WP (2.31/3 leaves) being at par with spiromesifen 22.9SC (2.98/3 leaves), flonicamid 50WG (3.68/3 leaves), pyriproxyfen 10EC (3.96/3 leaves) followed by ethion 50EC (4.71/3 leaves). After 7 days of spray, it was significantly lower in diafenthiuron 50WP (2.71/3 leaves) being at par with pyriproxyfen 10EC (2.76/3 leaves), flonicamid 50WG (4.40/3 leaves) followed by spiromesifen 22.9SC (6.31/3 leaves) and ethion 50EC (7.02/3 leaves).

After 10 days of spray, it was significantly lower in diafenthiuron 50WP (3.02/3 leaves) being at par with pyriproxyfen 10EC (3.20/3 leaves), flonicamid 50WG (3.20/3 leaves) followed by spiromesifen 22.9SC (6.53/3 leaves) and ethion 50EC (15.69/3 leaves). However, all the treatments were significantly better than control.

Abohar: At all five experimental locations in Abohar, no significant differences were observed before treatment (Table 4). However, after 3 days of spray, the lowest population was recorded in flonicamid 50WG at all the five locations. The population was again minimum in flonicamid 50WG treatment after 7 days of spray except location IV. Similar, results were observed after 10 days of spray except in experiment no 5. In all experiments, the whitefly adult population was significantly higher in control. The flonicamid 50 WG was significantly at par with pyriproxyfen 10EC after 10 days of spray except in location I.

Pooled analysis: Whitefly adult population data for Bathinda and Abohar experiment was pooled (Table 5). Before treatment, there were non-significant differences ranges from 25.92–31.50 per 3 leaves. After 3 days of spray, the whitefly adults were significantly lower in flonicamid 50WG (8.25/3 leaves) which was at par with diafenthiuron 50WP (10.91/3 leaves) and ethion 50EC (10.45/3 leaves) as

Table 3 Field efficacy of novel insecticides against whitefly adults on Bt cotton at Bathinda

Treatment	Dose (g/ml/ha)	Whitefly adults per 3 leaves			
		Before spray	3 DAS	7 DAS	10 DAS
Pyriproxyfen 10EC (Lano)	1250 ml	12.53	3.96 (2.23)	2.76 (1.94)	3.20 (2.04)
Spiromesifen 240 SC (Oberon)	500 ml	13.33	2.98 (1.99)	6.31 (2.67)	6.53 (2.74)
Flonicamid 50WG (Ulala)	200 g	13.33	3.68 (2.16)	4.40 (2.32)	3.20 (2.04)
Diafenthiuron 50WP (Polo)	500 g	13.10	2.31 (1.82)	2.71 (1.92)	3.02 (2.00)
Ethion 50 EC (Fosmite)	2000 ml	13.20	4.71 (2.34)	7.02 (2.78)	15.69 (4.06)
Control	-	13.50	14.40 (3.90)	16.44 (4.17)	15.25 (4.03)
LSD (P=0.05)	-	NS	(0.50)	(0.58)	(0.63)

Figure in parenthesis are square root transformation, DAS: days after spray

Table 4 Field efficacy of novel insecticides against whitefly adults on Bt cotton at different locations of Abohar during 2016

Treatment	Dose (g/ml per ha)	Whitefly adults per 3 leaves																			
		Location 1				Location II				Location III				Location IV				Location V			
		Before spray	3 DAS	7 DAS	10 DAS	Before spray	3 DAS	7 DAS	10 DAS	Before spray	3 DAS	7 DAS	10 DAS	Before spray	3 DAS	7 DAS	10 DAS	Before spray	3 DAS	7 DAS	10 DAS
Pyriproxyfen 10EC (Lano)	1250 ml	31.50	21.92 (4.78)	12.72 (3.70)	10.42 (3.37)	32.73	22.17 (4.80)	10.69 (3.40)	12.95 (3.73)	24.56	20.64 (4.65)	7.14 (2.84)	6.14 (2.66)	15.67	15.60 (4.07)	10.80 (3.43)	10.33 (3.37)	20.13	10.27 (3.36)	8.20 (3.03)	2.73 (1.93)
Spiromesifen 240 SC(Oberon)	500 ml	25.92	18.33 (4.36)	12.94 (3.71)	13.83 (3.84)	31.33	21.29 (4.70)	8.83 (3.10)	13.67 (3.83)	22.67	15.83 (4.10)	11.53 (3.53)	15.56 (4.07)	21.93	13.00 (3.74)	7.87 (2.98)	10.80 (3.43)	20.87	13.73 (3.83)	9.13 (3.18)	3.87 (2.21)
Flonicamid 50WG (Ulala)	200 g	29.37	10.97 (3.45)	8.08 (3.01)	6.20 (2.68)	36.9	11.89 (3.52)	3.36 (2.07)	9.94 (3.31)	22.06	9.44 (3.23)	4.44 (2.33)	5.72 (2.58)	15.67	5.47 (2.54)	10.67 (3.41)	10.20 (3.34)	21.87	8.07 (3.0)	4.07 (2.25)	7.00 (2.83)
Diafenthiuron 50WP (Polo)	500 g	26.05	14.44 (3.92)	8.20 (3.01)	10.67 (3.41)	34.95	12.83 (3.71)	8.58 (3.04)	11.22 (3.48)	23.5	14.31 (3.90)	9.33 (3.20)	8.22 (3.04)	16.27	10.67 (3.42)	11.80 (3.58)	12.87 (3.72)	20.13	10.87 (3.44)	8.27 (3.04)	9.67 (2.26)
Ethion 50 EC (Fosmite)	2000 ml	28.67	14.83 (3.97)	8.67 (3.11)	17.39 (4.28)	33.39	5.42 (2.51)	7.85 (2.96)	14.11 (3.89)	21.03	10.56 (3.39)	8.22 (3.01)	9.55 (3.24)	18.00	14.40 (3.92)	13.93 (3.86)	11.67 (3.56)	20.93	12.80 (3.71)	8.07 (3.01)	9.73 (3.27)
Control	-	29.22	30.25 (5.59)	32.61 (5.79)	38.17 (6.25)	32.06	33.72 (5.89)	36.55 (6.12)	38.33 (6.26)	25.58	27.92 (5.35)	29.89 (5.55)	32.72 (5.81)	19.53	18.20 (4.38)	18.93 (4.46)	20.73 (4.66)	24.80	26.07 (5.20)	28.60 (5.44)	28.93 (5.47)
LSD (P=0.05)	-	NS	(0.66)	(0.59)	(0.65)	NS	(0.80)	(0.95)	(0.45)	NS	(0.63)	(0.57)	(0.40)	NS	(0.20)	(0.27)	(0.24)	NS	(0.35)	(0.24)	(0.25)

Figure in parenthesis are arc sine transformation, DAS: days after spray

Table 5 Field efficacy of novel insecticides against whitefly adults on Bt cotton and seed cotton yield of Bt cotton (pooled data of Bathinda and Abohar)

Treatment	Dose (g/ml/ ha)	Whitefly adult per 3 leaves				Seed cotton yield (q/ha)
		Before spray	3 DAS	7 DAS	10 DAS	
Pyriproxyfen 10EC (Lano)	1250 ml	22.85	15.76 (3.99)	8.72 (3.06)	7.63 (2.86)	24.51
Spiromesifen 240 SC (Oberon)	500 ml	22.68	14.19 (3.80)	9.44 (3.21)	10.71 (3.36)	23.84
Flonicamid 50 WG (Ulala)	200 g	23.20	8.25 (3.00)	5.84 (2.57)	7.04 (2.80)	24.52
Diafenthiuron 50WP (Polo)	500 g	22.33	10.91 (3.37)	8.15 (2.98)	9.28 (3.16)	24.53
Ethion 50 EC (Fosmite)	2000 ml	22.54	10.45 (3.32)	8.96 (3.14)	13.02 (3.72)	22.83
Control	-	24.11	25.09 (5.06)	27.17 (5.26)	29.02 (5.42)	19.80
LSD (P=0.05)	-	NS	(0.57)	(0.49)	(0.57)	0.45

Figures in parentheses are arc sine transformation, DAS: days after spray, Pooled data of six experiments

compared to all other treatments. The whitefly population is also minimum in flonicamid 50WG (5.84/3 leaves) being at par with pyriproxyfen 10EC (8.72/3 leaves) and diafenthiuron 50WP (8.15/3 leaves) after 7 days of spray. Flonicamid 50WP (2.80/3 leaves) was again found most effective after 10 days of spray and at par with pyriproxyfen 10EC (7.63/3 leaves), diafenthiuron 50WP (9.28/3 leaves) and spiromesifen 22.9SC (10.71/3 leaves). All the treatments were significantly better than standard check ethion 50EC (13.02/3 leaves) and control (29.02/3 leaves).

Seed cotton yield: The pooled seed cotton yield data of Bathinda and two location at Abohar was significantly higher in pyriproxyfen 10EC (24.51 q/ha), flonicamid 50WG (24.52 q/ha) and diafenthiuron 50WP (24.53 q/ha), being at par with each other as compared to all other treatments. However, all the treatments were better than control.

The results showed that new generation insecticides are quite effective in management of whitefly. Among these, flonicamid 50WG and diafenthiuron 50WP were found more effective against adults of whitefly after 3, 7 and 10 days of spay. However, these did not show significant decrease in nymphal population. In contrast to these, pyriproxyfen 10EC and spiromesifen 22.9SC proved more effective against nymphs of whitefly, while these insecticides lowered the adult whitefly population after 10 days of spray. Hence, it is imperative from the data that pyriproxyfen 10EC and spiromesifen 22.9SC has good nymphicidal and flonicamid 50WP and diafenthiuron 50WP has adulticidal action. It has been reported that pyriproxyfen does not possess direct toxicity against whitefly adults, however, it exhibits juvenoidal activity

by disrupting normal hormonal balance, resulting in the suppression of embryogenesis, metamorphosis and adult formation (Ishaaya and Horowitz 1995, Kontsedalov *et al.* 2009, Roditalis *et al.* 2014). Earlier researchers also reported that flonicamid was effective against whitefly (Kontsedalov *et al.* 2009, Roditalis *et al.* 2014) and leaf hoppers (Kodandaram *et al.* 2017) in okra. Diafenthiuron and flonicamid were also reported to be effective against whitefly in Bt cotton (Kalyan *et al* 2017). Treatment with spiromesifen @5 mg/l caused 40% whitefly adult mortality and reduced the fecundity by more than 80% (Kontsedalov *et al.* 2009). Further number of ovarioles in female was also significantly reduced. Therefore, in integrated pest management programme, these novel insecticides can be rotated alternatively depending upon the stage of whitefly dominating in the fields.

REFERENCES

Anonymous. 2016. *Package of Practices for Crops of Punjab Kharif 2016*. Punjab Agricultural University, Ludhiana.

Anonymous. 2017. Annual Reports 2016-17. All India Coordinated Cotton Improvement Project. CICR Coimbatore. www.aiccip.cicr.org.in/main_aiccip_reports.html

Bretschneider T, Benet-Buchhol J, Fischer R and Nauen R. 2003. Spirodiclofen and spiromesifen – novel acaricidal and insecticidal tetronic acid derivatives with a new mode of action. *Chimia* **57**: 697–701.

Dhillon B S and Sidhu R S. 2016. Successful management of whitefly incidence in cotton through joint efforts of farm experts and farmers. *Progressive Farming* **52**(9): 5–7.

Hancock H G, Fustaino M L and Morita M. 2003. 'Flonicamid (2003) (F1785, IKI-220): novel insecticide chemistry for cotton and other crops', pp 83–8. '*Proceedings of Beltwide Cotton Conference*, National Cotton Council of America, Nashville, TN.

Hancock H G. 2003. 'Field performance of flonicamid (F1785) in cotton', pp. 1629–36. *Proceedings of Beltwide Cotton Conference*, National Cotton Council of America, Nashville, TN.

Ishaaya I and Horowitz AR. 1995. Pyriproxyfen, a novel insect growth regulator for controlling whiteflies: mechanism and resistance management. *Pesticide Science* **43**: 227–32.

Kalyan RK, Saini DP, Meena BM, Pareek A, Naruka P, Verma S and Joshi S. 2017. Evaluation of new molecules against jassids and whiteflies of Bt cotton. *Journal of Entomology and Zoology Studies* **5**(3): 236–40.

Kodandaram MH, Kumar YB, Banerjee K, Hingmire S, Rai AB and Singh B. 2017. Field bioefficacy, phytotoxicity and residue dynamics of the insecticide flonicamid (50 WG) in okra [*Abelmoschus esculenta* (L) Moench]. *Crop Protection* **94**: 13–9.

Kontsedalov S, Gottlieb Y, Ishaaya I, Nauen R, Horowitz R and Ghanim M. 2009. Toxicity of spiromesifen to the developmental stages of *Bemisia tabaci* biotype B. *Pest Management Science* **65**: 5–13.

Liu TX and Chen TY. 2001. Effects of a juvenile hormone analog pyriproxyfen on apterous form of *Lipaphis erysimi* (Homoptera:Aphididae). *Entomologia Experimentalis et Applicata* **98**: 295–301.

Morita M, Yoneda T and Akiyoshi N. 2014. Research and development of a novel insecticide, flonicamid. *Journal of Pesticide Sciences* **39**(3): 179–80.

Nauen R and Konanz S. 2005. Spiromesifen as a new chemical option for resistance management in whiteflies and spider mites. *Pflanzenschutz-Nachrichten Bayer* **58**: 485–502.

Nauen R, Schnorbach H J and Elbert A. 2005. The biological profile of spiromesifen (Oberon) – a new tetronic acid insecticide/acaricide. *Pflanzenschutz-Nachrichten Bayer* **58**: 417–40.

Qureshi M S, Midmore D J, Syeda S S and Reid D J. 2009. Pyriproxyfen controls silver leaf whitefly, *Bemisia tabaci* (Gennadius), biotype B (Homoptera: Aleyrodidae) (SLW) better than buprofezin in bitter melons *Momordica charantia* L. (Cucurbitaceae). *Australian Journal of Entomology* **48**: 60–4.

Roditakis E, Fytrou N, Staurakaki M, Vontas J and Tsagkarakou A. 2014. Activity of flonicamid on the sweet potato whitely *Bemisia tabaci* (Homoptera: Aleyrodidae) and its natural enemies. *Pest Management Science* **70**(10): 1460–7.