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Bioefficacy of insecticides against whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) on cotton

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Abstract : The efficacy of label claimed insecticides was studied against *Bemisia tabacia* adults under field and laboratory conditions and their impact on cotton's natural enemies during 2016-2017. Under field conditions, flonicamid (50% WG) was the most effective insecticide in reducing the whitefly adult population upto seven days after spaying while Fipronil (4%) + acetamiprid (4% W/W) fenpropathrin (30% EC) were least effective. In laboratory trials, flonicamid (50% WG) caused significantly higher adult mortality, (77.8 %), than all other insecticides studied, while buprofezin (25 % EC) caused the least 31 pre cent mortality after 72 hours. The plots treated with Flonicamid (50 % WG) and buprofezin (25 % EC) had a higher population of generalist predators such as chrysoperla and spiders, while the other insecticides were moderate to highly toxic.

Keywords : *Bemisia tabaci*, bioassay, bioefficacy, cotton, label claimed insecticides

Cotton, a major fibre crop, belongs to the family Malvaceae's Genus *Gossypium*, contributing a total of sixty percent fibre globally (Chachral *et al*., 2008). India ranks among the top leading cotton producer in acreage, accounting for one fourth of the total global production. The whitefly *Bemisia tabacia* Gennadius (Homoptera: Aleyrodidae) is the major threatening pest globally which solely causes sixty per cent yield losses (Singh *et al*., 2016). It can damage crops by feeding directly on them and transmitting plant viruses. Whiteflies are known to transmit more than 114 plant viruses majority of them are members of the begomovirus family (Jones 2003). India's north cotton growing zone experienced a whitefly epidemic in 2015-2016, resulting in an approximate loss of 630–670 million US dollars (Anonymous, 2017).

Some of the significant abiotic causes for epidemics were cultivating susceptible hybrids, late sowing, imbalanced fertilizer usages, and spraying insecticidal mixtures (Kranthi, 2015). Insecticides were widely used to manage the whitefly epidemic, resulting in a large scale loss of natural enemies, the emergence of minor pests into major pests, contamination and insecticide resistance build up (Kranti, 2015). As a result, during the following cropping year 2016–2017, the cotton cultivation area was reduced by 40 pre cent in India's north cotton growing zone.

Being highly polyphagous, the management of whitefly has been a challenging task. It has a wide range of host plants which comprises more than 910 host plant species; fibre crops, ornamentals, vegetables, legumes and weeds (Rathore and Tiwari, 2014). The primary strategy used to control whitefly in many cropping systems is the use of insecticides; repeated spray applications had been needed, which has often ended in over use of these chemicals, resulting in the development of resistance to a variety of conventional insecticides across the world (Denholm *et al*., 1996, 1998). The development of insecticide resistance is quite frequent in whitefly due to its biological traits, including multivoltine nature, high reproductive rate, arrhenotokous mode of reproduction, cuticular waxes over the body and ability to migrate (Ellsworth and Jones, 2001; Naranjo, 2001).

Whitefly had developed a high degree of resistance to organophosphates and pyrethroids (Ahmad *et al*., 2000, 2001, 2002) and insect growth regulator; buprofezin and pyriproxyfen (Horowitz *et al*., 2002; Li *et al*., 2003; Ghanim and Kontsedalov 2007). Several new insecticide chemistry classes have recently been developed that selectively control whitefly and provide growers with a varied chemical essential to combat resistance (Horowitz and Ishaaya 1996). As a result, in the present investigation, an attempt to evaluate the efficacy of label claimed insecticides as a critical aspect of pest control to find more effective chemistries to combat whiteflies and eventually safer to the generalist predators.

MATERIALS AND METHODS

Field bioassay: The experiment was conducted during 2016-2017 at Cotton Section, CCS Haryana Agricultural University, Hisar. *Bt* cotton Bollgard II hybrid (NCS 855) was sown with the recommended package of practices with row to row and plant to plant geometry of 67.5 x 60 cm under randomized block design with 14 treatments and control (Table 1) replicated thrice. The cotton crop was monitored weekly to assess the incidence of whitefly, and the sprays were initiated at economic threshold level (ETL), *i.e.*, 6-8 adults/leaves during 27th SMW; after that, three sprays were applied at fortnightly intervals.

Observations: Observations were recorded from 5 randomly selected tagged plants from each treatment. The number of whitefly adults and natural enemies was counted on three leaves from the plant's upper, middle, and lower canopy. Observations were recorded a day before spray and the third and seventh day after spray. Similarly, the generalist predators, lacewing and spiders population were recorded from 5 randomly selected plants after seven days of spray. The dose of insecticides was as per the Central Insecticides Board and Registration Committee (Anonymous, 2016).

Laboratory bioassay: The bioefficacy of insecticides against whitefly adults was assessed using leaf dip assay methodology IRAC No 8 (Anonymous, 2009). Fresh leaves from cotton plants were excised with a long petiole; leaves were rinsed with fresh water and air dried. A slanting cut was made at the petiole end and wrapped with cotton. To maintain turgidity, the petiole was dipped in a micro centrifuge tube containing 10 pre cent sucrose solution and sealed with parafilm. Stock solutions of insecticides mentioned in Table 1 were prepared using distilled water. Air dried leaves were dipped in insecticidal solutions for five seconds, ensuring complete leaf immersions. Treated leaves were dried on blotting paper. These leaves were laid adaxial side down on a layer of agar (2%) in an insect breeding dish. The lid and dish were tapped together sideways off the leaf to trap the adult whiteflies from the field. The procedure was repeated until approximately 50 adults/Petri dish were collected. The number of adults/Petri dish was recorded and kept at constant conditions, 28±2°C. Each treatment was replicated thrice with at least 30 adults/replicate. Leaf dipped in distilled water served as control. Observations were recorded after 24 and 72 hours after treatment. The numbers of dead insects were counted, and the data were subjected to calculate the per cent mortality using the formula mentioned below.

$$\text{Mortality (\%)} = \frac{\text{Number of adults died}}{\text{Total number of adults released}} \times 100$$

Statistical analysis: Data collected from the field trials were subjected to statistical analysis using OPSTAT. To normalize the wide variations among the data and it was subjected to square root transformation. Analysis of Variance (ANOVA) tests was conducted, and means were separated using critical difference (CD) at 5 pre cent significance level. For laboratory assays, mortality percentage was calculated based on pre and post treatment live whitefly and subjected to ANOVA test.

RESULTS AND DISCUSSION

To evaluate the efficacy of label claimed insecticides, cotton crop was monitored regularly, and during 27th SMW, the average

Table 1: Insecticides used as treatments and their dosages

S. No.	Name of the treatments	Dosage/ha formulation	Dilution in water (Litre)
T1	Acetamiprid (20% SP)	100g	500
T2	Dinotefuran (20% SG)	125ml	500
T3	Thiacloprid (21.7% SC)	600ml	500
T4	Thiamethoxam (25% WG)	100g	500
T5	Chlorpyrifos (20% EC)	1250ml	500
T6	Ethion (50% EC)	2000ml	500
T7	Monocrotophos (36% SL)	1250ml	500
T8	Profenofos (50% EC)	1250ml	500
T9	Buprofezin (25% SC)	1000ml	500
T10	Flonicamid (50% WG)	150ml	500
T11	Fenpropathrin (30% EC)	250ml	750
T12	Pyriproxyfen (5% EC) + Fenpropathrin (15% EC)	500ml	500
T13	Indoxacarb (14.5%) + Acetamiprid (7.7% W/WSC)	500ml	500
T14	Fipronil (4%) + Acetamiprid (4% W/W)	1000ml	500

Table 2: Efficacy of insecticides against whitefly adults during first, second and third spray

S. No.	Treatments	Whitefly adults /leaf during the first spray			Whitefly adults /leaf during the second spray			Whitefly adults /leaf during the third spray		
		Before spray	After spray 3rd day	After spray 7th day	Before spray	After spray 3rd day	After spray 7th day	Before Spray	After spray 3rd day	After spray 7th day
T1	Acetamiprid (20% SP)	13.7**(3.8)*	8.0(3.0)	8.0(3.0)	10.1(3.3)*	5.2(2.5)	5.7(2.6)	7.1(2.9)	4.1(2.3)	4.6(2.4)
T2	Dinotefuran (20% SG)	16.0(4.1)	4.5(2.3)	4.1(2.3)	10.5(3.4)	4.7(2.5)	4.4(2.3)	6.9(2.8)	3.4(2.2)	2.8(2.0)
T3	Thiacloprid (21.7% SC)	15.5(4.1)	6.3(2.7)	6.0(2.6)	10.2(3.3)	4.5(2.4)	4.6(2.4)	7.9(2.9)	4.2(2.3)	3.6(2.2)
T4	Thiamethoxam (25% WG)	14.3(3.9)	8.2(3.0)	8.1(3.0)	11.5(3.5)	5.6(2.6)	5.7(2.6)	7.4(2.9)	5.1(2.5)	3.8(2.2)
T5	Chlorpyrifos (20% EC)	13.3(3.8)	6.4(2.7)	6.1(2.6)	10.1(3.3)	4.1(2.4)	5.2(2.5)	7.5(2.9)	3.9(2.3)	4.5(2.4)
T6	Ethion (50% EC)	15.0(4.0)	4.7(2.4)	4.2(2.3)	10.2(3.3)	3.6(2.1)	4.3(2.3)	6.3(2.7)	2.8(2.0)	3.1(2.1)
T7	Monocrotophos (36% SL)	15.8(4.1)	8.4(3.1)	8.6(3.1)	12.0(3.6)	5.7(2.6)	6.8(2.8)	7.7(2.9)	4.8(2.4)	5.3(2.5)
T8	Profenofos (50% EC)	16.7(4.2)	8.2(3.0)	9.0(3.2)	12.4(3.7)	5.8(2.6)	6.8(2.8)	7.3(2.9)	5.3(2.5)	5.1(2.5)
T9	Buprofezin (25% SC)	15.4(4.1)	10.2(3.3)	8.2(3.0)	10.7(3.4)	6.5(2.6)	5.4(2.5)	7.9(2.8)	6.0(2.6)	4.8(2.4)
T10	Flonicamid (50% WG)	14.1(3.9)	4.2(2.3)	3.9(2.2)	7.4(2.9)	3.1(2.0)	2.2(1.8)	5.4(2.4)	2.7(1.9)	2.4(1.8)
T11	Fenpropathrin (30% EC)	15.6(4.1)	12.2(3.6)	11.8(3.7)	13.3(3.8)	7.2(2.9)	7.7(2.9)	8.9(3.1)	7.0(2.8)	7.2(2.9)
T12	Pyriproxyfen (5% EC) C+Fenpropathrin (15% EC)	14.7(4.0)	4.5(2.3)	3.3(2.1)	8.9(3.3)	4.0(2.2)	4.0(2.2)	9.5(3.2)	5.3(2.5)	5.7(2.6)
T13	Indoxacarb (14.5%) + Acetamiprid (7.7% W/W SC)	15.8(4.1)	10.5(3.4)	9.6(3.3)	10.0(3.3)	5.5(2.5)	6.4(2.7)	7.0(2.8)	6.2(2.6)	5.7(2.6)
T14	Fipronil (4%) + Acetamiprid (4% W/W)	17.7(4.3)	12.5(3.7)	13.6(3.8)	14.2(3.9)	8.0(3.2)	8.6(3.1)	9.1(3.2)	7.3(2.9)	8.0(3.0)
T15	Control	15.0(4.0)	15.4(4.1)	16.2(4.1)	18.1(4.4)	20.5(4.6)	16.4(4.2)	13.5(3.8)	18.6(4.4)	20.0(4.6)
	CD (p=0.05)	(NS)	(0.2)	(0.3)	(0.3)	(0.3)	(0.2)	(0.2)	(0.2)	(0.2)

*Figures in parentheses are the square root transformed values (“n+1)
**Mean of five plants

whitefly population in different plots randomized for insecticides application ranged between 13.3-17.7 whitefly/leaf. The counts were sufficient to initiate the first spray applications. After three days of first spray applications, the average whitefly population ranged from 4.2-12.5/leaf. Flonicamid (50% WG) recoded with minimum whitefly counts 4.2, whereas in Fipronil (4%) + Acetamiprid (4% W/W), the highest population (12.5) was observed followed by untreated control 15.4 whiteflies/leaf. After the seventh day of spray, the mean population in treatment ranged from 3.3 whiteflies/leaf in Pyriproxyfen (5% EC) + Fenpropathrin (15% EC) to 13.6

Table 3: Efficacy of insecticides against whitefly adults under laboratory conditions

S. No.	Treatments	Adult whitefly mortality (%)	
		After 24 hrs	After 72 hrs
T1	Acetamiprid (20% SP)	43.5(41.2)*	54.4(45.8)
T2	Dinotefuran (20% SG)	53.0(46.7)	76.6(61.2)
T3	Thiacloprid (21.7% SC)	44.8(42.0)	62.4(52.2)
T4	Thiamethoxam (25% WG)	41.6(40.2)	52.9(46.7)
T5	Chlorpyrifos (20% EC)	46.0(42.7)	60.8(51.3)
T6	Ethion (50% EC)	55.2(47.9)	70.3(56.4)
T7	Monocrotophos (36% SL)	48.3(44.0)	57.0(49.1)
T8	Profenofos (50% EC)	48.2(43.9)	54.6(47.6)
T9	Buprofezin (25% SC)	26.9(31.2)	31.0(33.8)
T10	Flonicamid (50% WG)	61.1(51.5)	77.8(61.9)
T11	Fenpropathrin (30% EC)	46.6(43.1)	60.5(51.1)
T12	Pyriproxyfen (5% EC) + Fenpropathrin (15% EC)	49.2(44.5)	55.8(48.3)
T13	Indoxacarb (14.5%) + Acetamiprid (7.7% W/W SC)	40.2(39.4)	45.9(42.6)
T14	Fipronil (4%) + Acetamiprid (4% W/W)	36.5(37.2)	43.0(40.9)
T15	Control	4.5(12.3)	6.3(14.5)
	CD (p=0.05)	(3.4)	(4.9)

*Figures in parentheses are the angular transformed values

Table 4: Mean population of natural enemies population after 7th day of spray

S. No.	Treatments	Natural enemies/plant after spray					
		Ist spray		2nd spray		3rd spray	
		Chrysoperla	Spider	Chrysoperla	Spider	Chrysoperla	Spider
T1	Acetamiprid (20% SP)	0.3**(1.1)*	0.3(1.1)	0.3(1.0)*	0.6(1.3)	0.6(1.1)*	0.3(1.1)
T2	Dinotefuran (20% SG)	0.3(1.1)	0.5(1.2)	0.8(1.3)	0.4(1.2)	0.6(1.3)	0.7(1.3)
T3	Thiacloprid (21.7% SC)	0.1(1.0)	0.1(1.1)	0.2(1.1)	0.1(1.1)	0.0(1.0)	0.0(1.0)
T4	Thiamethoxam (25%WG)	0.6(1.3)	0.1(1.1)	0.4(1.2)	0.8(1.3)	0.5(1.2)	1.1(1.4)
T5	Chlorpyrifos (20% EC)	0.1(1.0)	0.1(1.0)	0.0(1.0)	0.2(1.1)	0.1(1.0)	0.1(1.1)
T6	Ethion (50% EC)	0.5(1.2)	0.7(1.3)	0.6(1.3)	0.6(1.3)	0.5(1.2)	0.6(1.3)
T7	Monocrotophos (36% SL)	0.1(1.1)	0.2(1.1)	0.1(1.1)	0.0(1.0)	0.1(1.1)	0.2(1.10
T8	Profenofos (50% EC)	0.4(1.2)	0.3(1.1)	0.7(1.3)	0.4(1.2)	0.4(1.2)	0.4(1.2)
T9	Buprofezin (25% SC)	1.6(1.6)	1.8(1.7)	1.7(1.6)	0.8(1.3)	0.9(1.4)	1.5(1.6)
T10	Flonicamid (50% WG)	1.3(1.5)	2.1(1.7)	1.0(1.4)	0.9(1.4)	1.1(1.4)	1.6(1.6)
T11	Fenpropathrin (30% EC)	0.5(1.2)	0.2(1.1)	0.8(1.3)	0.2(1.1)	0.5(1.2)	0.2(1.1)
T12	Pyriproxyfen (5% EC) + Fenpropathrin (15% EC)	0.4(1.2)	0.7(1.3)	0.4(1.2)	0.5(1.2)	0.4(1.2)	0.7(1.3)
T13	Indoxacarb (14.5%) + Acetamiprid (7.7% W/WSC)	0.0(1.0)	0.1(1.1)	0.2(1.1)	0.3(1.1)	0.4(1.2)	0.2(1.1)
T14	Fipronil (4%) + Acetamiprid (4% W/W)	0.0(1.0)	0.1(1.0)	0.0(1.0)	0.0(1.0)	0.1(1.0)	0.1(1.1)
T15	Control	2.0(1.7)	2.1(1.8)	1.1(1.4)	1.1(1.5)	1.6(1.6)	2.0(1.7)
	CD (p=0.05)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)

*Figures in parentheses are the square root transformed values (“n+1)

**Mean of five plants

whiteflies/leaf in Fipronil (4%) + Acetamiprid (4% w/w). In comparison, the control had 16.2 whiteflies/leaf.

For the second round of spray applications, the whitefly population was recorded, and it ranged from 18.1 whiteflies/leaf in the control plot to 7.4 whiteflies/leaf in the Flonicanid (50% WG) applied plot. Three days after spraying, Fipronil (4%) + Acetamiprid (4 % w/w) had the highest whitefly number, *i.e.* 8.0 whiteflies/leaf, while Flonicamid (50% WG) had the lowest 3 whiteflies/leaf. Seven days after spraying, the highest 8.6 whiteflies/leaf in Fipronil (4%) + Acetamiprid (4% W/W) were observed, compared to 2.2 whiteflies/leaf in Flonicanid (50 % WG).

Whitefly populations ranged from 13.5 whiteflies/leaf in the control plot to 5.4 whiteflies/leaf in the Flonicamid (50% WG) treated plots before the third spray. Maximum whitefly population was recorded in Fipronil (4%) + Acetamiprid (4% W/W) after the third and seventh days of spray, *i.e.* 7.3 whiteflies/leaf and 8 whiteflies/leaf, respectively. Maximum control was recorded in Flonicamid (50% WG), *i.e.* 2.7 whiteflies/leaf after the third day and 2.4 whiteflies/leaf after the seventh day of spray.

In leaf dip bioassay studies (Table 3), the insecticidal treatment mortality ranged between 26.9 to 61.1 pre cent after 24 hours and 31 to 77.8 pre cent after 72 hours and out performed the control significantly. Adult whitefly mortality was substantially higher (61.1%) after 24 hours of treatment with flonicamid (50% WG) than all other insecticides. The following effective insecticide was Ethion (50% EC, 55.2% mortality), and it was *at par* with Dinotefuran (20% SG) and Pyriproxyfen (5% EC) + Fenpropathrin (15% EC), which caused 53.0 and 49.2 pre cent mortality, respectively. The remaining insecticides had a modest impact on whitefly adults causing mortality, ranging from 40.2 to 48.3 pre cent, while (Buprofezin 25% SC) had the lowest 26.9 pre cent mortality. After 72 hours of treatment, a similar trend was observed, with maximum whitefly mortality reported in flonicamid (50% WG, 77.8%) and Dinotefuran (20% SG, 76.6%), which were significantly superior to all other treatments, followed by Ethion (50% EC, 70.3%) and thiacloprid (21.7% SC), while lowest mortality recorded in buprofezin (50% SC, 31.0%).

Under field conditions, the population of natural enemies was observed seven days after spraying, and there were substantial differences between the treatments. The majority of insecticides were highly toxic to generalist predators such as chrysoperla and spiders. Control had the highest population of chrysoperla, 2/plant, which was statistically comparable to Buprofezin (25% SC) and Flonicamid (50% WG), which had 1.6 and 1.3 chrysoperla/plant, respectively. Buprofezin (25% SC) and Flonicamid (50% WG) had a similar effect on spider populations with 2.1 and 1.8 spiders/plant, respectively, which was statistically comparable to control (2.1/plant). Other than Flonicamid (50% WG) and Buprofezin (25% EC) all other label claimed insecticide from neonicotinoids, organophosphate, synthetic pyrethroid and their combinations *i.e.*, acetamiprid (20% SP), dinotefuran (20% SG), thiacloprid (21.7% SC), thiamethoxam (25% WG), chlorpyrifos (20% EC), ethion (50% EC), monocrotophos (36% SL), profenofos (50% EC), fenpropathrin (30% EC), fipronil (4%) + acetamiprid (4% W/W), indoxacarb (14.5%) + acetamiprid (7.7% w/w SC) and pyriproxyfen (5% EC) + fenpropathrin (15% EC) were found toxic to both chrysoperla and spider (Table 4). In the second and third sprays, a similar pattern of insecticide toxicity against natural enemies was recorded as in the first spray warrants their usage based on the impacts on natural enemies' fauna.

The findings revealed that new generation insecticides are pretty efficient in the management of whitefly. Among these, flonicamid (50% WG) and dinotefuran (20% SG) were found more effective against whitefly adults after the 3rd and 7th days of spray. The laboratory assays of the insecticide also confirmed the findings of the field trials. Earlier researchers also reported that flonicamid was effective against whitefly (Kontsedalov *et al.*, 2009, Roditalis *et al.*, 2014) and leafhoppers (Kodandaram *et al.*, 2017) in okra. The efficacy of combination product fipronil + acetamiprid of the present study was more or less similar to as reported by Bharpoda *et al.*, (2014), that fipronil

5 EC @ 0.1 pre cent was less effective in managing whitefly, as reported fipronil causes the resurgence of whitefly (Kumar *et al.*, 2019). Buprofezin was less effective in controlling whitefly adults under field and laboratory bioassay as it is a chitin synthesis inhibitor and interferes with cuticle formation only in nymphal stages (Kanno *et al.*, 1981). Buprofezin has little effect on the survival or oviposition of *B. tabacia* dults, but it does limit egg hatch and fecundity in female whiteflies exposed to treated leaves (Ishaaya *et al.*, 1988). The findings of non target effect observations of the present studies confirm with Sabry and Sayed (2011) that buprofezin was least toxic to second instar larvae and adults of *C. carnea* while chlorpyrifos was found to be more toxic. Thus, it can be concluded that theflonicamid (50% WG) is the most effective insecticide to manage whitefly and found eventually safer to natural enemies.

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