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Evaluation of new molecules against sucking pests of Bt cotton

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Abstract
The present experiment was conducted to evaluate the efficacy of new molecules as well as biopesticides as foliar application against major sucking pests and toxicity against predators of these pests of Bt cotton at Cotton Research Unit Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeth, Akola during 2015-2016 with eight treatment and three replications. Overall, three sprays were carried out and thus, the data obtained revealed that, newer molecule flonicamid 50% WG @ 100 g a.i./ha was found promising to managed the major sucking pests of Bt cotton followed by flonicamid 50% WG @ 75 g a.i./ha, buprofezin 25% SC @ 250 g a.i./ha and diafenthiuron 50% WP 300 g a.i./ha. However, during the present studies no deleterious effect of insecticidal treatments was observed on population of natural enemies. Highest seed cotton yield (1681.02 Kg/ha.) was obtained from flonicamid 50% WG @ 75 g a.i./ha followed by flonicamid 50% WG @ 100 g a.i./ha (1627.31 Kg/ha.). Next effective treatments were diafenthiuron 50% WP @ 300 g a.i./ha, buprofezin 25% SC @ 250 g a.i./ha, NSKE 5 % and *V. lecanii* @ 5 gm/lit.

Keywords: new molecules, biopesticides, Bt cotton, flonicamid, diafenthiuron, buprofezin, sucking pests

1. Introduction
Cotton (*Gossipium hirsutum* L.) is the most important cash crop in India, It also provides 65 per cent raw material to textile industry and contributed 1/3rd of total foreign exchange earning of India [1]. With nearly 12 million hectares under the cotton crop, India ranks first in the world in respect of area and fourth in total production which has reached the level of 31 million bales [2]. India has largest acreage of cotton in the world but productivity is still low. The major biotic constraint in attainment of desired productivity levels in Bt cotton production is the sucking pests. More than 90 per cent area is under Bt cotton and Bt cotton is susceptible to sucking pests [3, 4, 5]. Bt cotton succumb to yield loss due to the sap feeders (i.e. leafhoppers, aphids, thrips, whiteflies, mealy bugs, mirids and stainers) spread throughout the growing season, right from seedling emergence to harvest, as the biotic potential of sucking pests being high, they are a potential threat to Bt cotton [6]. The pest problem in cotton is so complex that about 56 per cent of total insecticides are consumed in India by cotton; while area under this crop is only 5 per cent of the total cultivated area [7, 8]. To protect the crop from the attack of sucking pests, number of insecticides of different groups have been tested and considered under general recommendation for the management of these insects. The repeated use of synthetic chemical insecticides as crop protectants against insect pests has posed serious hazards to environment, humans, resistance in pests to insecticides and natural enemies. In this view, there is a scope of utilizing the newer chemistry molecules such as Pyridincarboxamide and Neonicotinoides which are required in small quantity and economically effective for control of sucking pests in cotton ecosystem [9]. Also, the recent trends in pest management emphasis on nonchemical approaches and there is worldwide demand for organically grown fibre, which is increasing annually in export markets. Therefore, attempts have been made in the present study to find out efficacy of new chemistry molecules and bio pesticides for the management of major sucking pests of Bt cotton.

2. Material and Methods
The present field experiment was carried out at Cotton Research Unit farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* 2015-2016 to evaluate the efficacy of new molecules as well as bio pesticides against sucking pests of Bt cotton. The trial was laid out in a randomized block design (RBD) with eight treatments including untreated control, each replicated thrice.

The treatments namely buperofezin (IGR) 25 SC @ 250 a.i.ha^{-1}, flonicamid 50% WG 75 g a.i. ha^{-1}, flonicamid 50% WG 100 g a.i. ha^{-1}, NSKE 5%, diafenthiuron 50 WP @ 300 g a.i. ha^{-1}, *Verticillium lacanii* @ 5 g liter^{-1} and *Metarhizium anisopliae* @ 3 g liter^{-1} were evaluated. All the treatments had three sprays except untreated control. Bt Cotton hybrid RCH-2 Bt BG II was dibbled at 90 × 60 cm spacing. The plot size was kept 6.30 × 6.00 m. All recommended package and practices was followed to raise the crop as per package and practice except plant protection measures.

2.1 Effect of treatments on abundance of sucking pests
Observations on the population of sucking pests were recorded from five fixed plants plot^{-1} which was tagged after selecting randomly for this purpose. The number of sucking pests namely aphids, leaf hoopers, thrips and whiteflies were recorded from three leaves (top, middle and bottom) per plant. Pre-treatment population was taken just before the application of treatments and post treatment count 7 days after spray. The mean count of sucking pest per 3 leaves is depicted in data. First spray was done at economic threshold level (ETL) and subsequent sprays were given at 15 days interval.

2.2 Effect of treatments on abundance of predators
The observations on predators i.e. lady bird beetles (G&A) chrysopa larvae and spiders were also recorded 7 days after each treatment spray on randomly selected 5 plants from each net plot on whole plant.

2.3 Effect of treatments on yield
The picking wise yield of seed cotton was also recorded. The net plot yield was converted into kg ha^{-1} for analysis and comparison.

2.4 Statistical Analysis
The population count of sucking pests recorded at before treatment application and 7 days after application of treatment was subjected to square root (x+0.5) and square root transformations before analyzing and data subjected to analysis of variance in Randomised Block Design.

3. Results and Discussion
3.1 Efficacy against aphids
The pre-treatment population of aphids was in the range of 0.47 to 1.67 per three leaves and all the treatments are statistically at par whereas, after second spray 0.07 to 0.60 per three leaves range was observed with maximum aphid population in untreated control. All the treatments were significantly superior over untreated control after first spray. Minimum population of aphids (0.00/plant on 3 leaves) was recorded in flonicamid 50% WG @ 75 and 100 g a.i. ha^{-1} and these treatments were found at par with all the other treatments except untreated control. After 2nd spray, non significant results were recorded among the treatments whereas, aphid population was not observed at the time of 3rd spray and this might be due to low pressure of aphid population during the season (Table 1). The present findings are in conformity with [10] who reported effectiveness of flonicamid 0.02 per cent, acetamiprid 0.004 per cent and imidacloprid 0.005 per cent against cotton aphids. Highest aphid mortality was obtained with flonicamid and imidacloprid in the laboratory experiment under controlled conditions [11].

3.2 Efficacy against leaf hoppers
During the present investigation, the pre-treatment population of leaf hoppers did not vary significantly in all the plots before first spray, second spray and third spray with population range of 10.33 to 17.33 and 8.00 to 12.20 and 8.33 to 12.87 per three leaves, respectively. In case of leaf hoppers, significant differences were recorded after 1st spray. All the treatments were significantly superior over untreated control. Flonicamid 50% WG @ 100 g a.i. ha^{-1} was most effective in checking the population of leaf hoppers followed by flonicamid 50% WG @ 75 g a.i. ha^{-1}, diafenthiuron 50% WP 300 g a.i. ha^{-1} and buprofezin 25% SC @ 250 g a.i. ha^{-1}. Maximum leaf hoppers population was recorded in untreated control. Among biopesticides, efficacy sequence of *Verticillium lacanii* followed by *Metarhizium anisopliae* and NSKE 5% was observed. The same above trend of efficacy was recorded after 2nd and 3rd treatment spray (Table 2). The present findings are in agreement with [12, 13] reported that diafenthiuron is very effective in managing cotton leafhopper. Per cent reduction of leafhopper population was found higher with flonicamid @ 75 g a.i. ha^{-1} [14]. Fipronil 5 SC also found very effective and it at par with treatment diafenthiuron 50 WP (0.08%) and imidacloprid 30.5 SL (0.005%) [15]. Neemazol, neem oil and NSKE 5% were also found effective over entamopathogenic fungal against leaf hopper [16]. The present results are comparable with the observations of [17] who reported that flonicamid 50WG was effective against cotton leafhopper.

3.3 Efficacy against thrips
The pre-treatment population of thrips was in the range of 3.60 to 6.00, 2.07 to 4.20 and 0.67 to 1.93 per three leaves in all the treatment plots before first spray, second spray and third spray and all the treatments are statistically at par with each other with maximum thrips population in untreated control. Significant differences between treatments were recorded after 1st spray application. Flonicamid 50% WG @ 75 g a.i. ha^{-1} was found most effective treatment for managing the thrips population followed by flonicamid 50% WG @ 100 g a.i. ha^{-1} and these treatments are at par with each other. Next effective treatment was *Verticillium lacanii* 5 gm

Table 1: Population of aphids after treatment application at different crop stages.

S. No.	Treatment	Dose/ ha (g.a.i.)	Ave. population of aphids/3 leaves at different crop stage											
			First spray				Second spray				Third spray			
			Pre		Post		Pre		Post		Pre		Post	
			OV	TV**	OV	TV**	OV	TV**	OV	TV**	OV	TV*	OV	TV*
1	Buprofezin 25% SC	250	0.73	1.10	0.13	0.79	0.13	0.79	0.07	0.75	0.0	-	0.0	-
2	Flonicamid 50%WG	75	0.60	1.05	0.00	0.71	0.07	0.75	0.00	0.71	0.0	-	0.0	-
3	Flonicamid 50%WG	100	0.47	0.98	0.00	0.71	0.00	0.71	0.00	0.71	0.0	-	0.0	-
4	NSKE	5%	1.07	1.24	0.07	0.75	0.20	0.84	0.07	0.75	0.0	-	0.0	-
5	Diafenthiuron 50%WP	300	0.87	1.16	0.13	0.79	0.13	0.79	0.00	0.71	0.0	-	0.0	-
6	*Verticillium lacanii*	5gms/lit.	1.33	1.35	0.20	0.83	0.13	0.79	0.00	0.71	0.0	-	0.0	-
7	*Metarhizium anisopliae*	3gms/lit.	0.93	1.19	0.27	0.87	0.13	0.79	0.00	0.71	0.0	-	0.0	-

8	Untreated control	------	1.67	1.47	1.80	1.51	0.60	1.05	0.20	0.83	0.0	-	0.0	-
	F test			**NS**		**SIG**		**SIG**		**NS**		-		-
	SE (M±)			0.090		0.053		0.041		0.032		-		-
	CD (P=0.05)			--		0.162		0.124		--		-		-
	CV %			13.00		10.64		8.73		7.52		-		-

** square root (x+0.5) transformed values, OV-Original value, TV-Transformed value

Table 2: Population of leaf hoppers after treatment application at different crop stages

S. No.	Treatment	Dose/ ha (g.a.i.)	Av. Population of leaf hoppers/3 leaves at different crop stage											
			First spray				Second spray				Third spray			
			Pre		Post		Pre		Post		Pre		Post	
			OV	TV*	OV	TV*	OV	TV*	OV	TV*	OV	TV*	OV	TV*
1	Buprofezin 25% SC	250	16.20	4.01	5.53	2.34	9.33	3.05	3.20	1.76	9.73	3.11	2.07	1.42
2	Flonicamid 50%WG	75	12.40	3.49	1.87	1.36	8.40	2.89	1.00	0.97	9.00	2.99	1.13	1.06
3	Flonicamid 50%WG	100	10.33	3.21	1.53	1.23	8.00	2.82	0.60	0.75	8.33	2.88	0.87	0.90
4	NSKE	5%	14.40	3.78	6.73	2.58	9.80	3.13	5.33	2.30	10.87	3.29	3.60	1.88
5	Diafenthiuron 50%WP	300	12.67	3.55	4.00	2.00	9.60	3.10	2.40	1.54	8.73	2.95	2.33	1.51
6	*Verticillium lacanii*	5gms/lit.	14.80	3.82	4.27	2.06	10.53	3.24	4.47	2.11	10.53	3.24	3.27	1.80
7	*Metarhizium anisopliae*	3gms/lit.	17.33	4.15	4.93	2.21	10.87	3.29	5.20	2.27	12.20	3.49	3.80	1.94
8	Untreated control	------	14.67	3.82	13.20	3.63	12.20	3.49	11.93	3.45	12.87	3.58	10.67	3.26
	F test			NS		SIG		NS		SIG		NS		SIG
	SE (M±)			0.246		0.112		0.135		0.136		0.157		0.152
	CD (P=0.05)			--		0.341		--		0.413		--		0.462
	CV %			11.41		8.95		7.94		12.45		8.51		15.33

* square root transformed values, OV-Original value, TV-Transformed value

liter^{-1} whereas, remaining all the treatments were at par with each other. The same above efficacy trend was recorded after 2nd and 3rd treatment spray with thrips population range of 1.33 to 5.67 and 0.60- 3.53 and 0.13 to 1.00 per three leaves, respectively (Table 3). The present results are comparable with [10] who reported that among the insecticidal treatments, application of flonicamid 0.02 per cent, imidacloprid 0.005 and dinotefuran 0.008 per cent resulted in effective control of thrips on Bt cotton.

3.4 Efficacy against white fly

During the evaluation, the pre-treatment population of whiteflies did not vary significantly in all the treatments before first spray, second spray and third spray (3.80 to 4.93 and 5.73 to 7.53 and 5.40 to 8.47 per three leaves, respectively). Significant differences were observed in case of whitefly after 1st, 2nd and 3rd spray. All the treatments were found superior over untreated control. After 1st spray, minimum population was recorded in flonicamid 50% WG @ 75 g a.i. ha^{-1} and it was at par with flonicamid 50% WG @ 100 g a.i. ha^{-1}. Buprofezin 25% SC @ 250 g a.i. ha^{-1} ranked second and it was on par with diafenthiuron 50% WP @ 300 g a.i. ha^{-1}. Similar type of efficacy trend was also observed after 2nd and 3rd spray recording very less whitefly population in flonicamid, diafenthiuron and buprofezin treated plots. Untreated control recorded maximum white fly population during throughout investigation (Table 4). Insecticides performed better than the bio pesticides. The present findings are in close conformity with the findings of [18, 19, 20] who reported that diafenthiuron was highly effective in suppressing the sucking pests viz., *Amrasca biguttula biguttula* (Ishida), *Aphis gossypii* (Glover), *Bemisia tabaci* (Genn.) and *Scirtothrips dorsalis* Hood, and it had no adverse effects on the natural enemies. Effective control of whiteflies was recorded with application of flonicamid 0.02 per cent on Bt cotton [10].

Table 3: Population of thrips after treatment application at different crop stages

S. No.	Treatment	Dose/ ha (g.a.i.)	Av. Population of thrips/3 leaves at different crop stage											
			First spray				Second spray				Third spray			
			Pre		Post		Pre		Post		Pre		Post	
			OV	TV*	OV	TV*	OV	TV*	OV	TV*	OV	TV*	OV	TV*
1	Buprofezin 25% SC	250	5.73	2.39	3.13	1.76	2.13	1.45	1.33	1.15	0.93	0.93	0.27	0.51
2	Flonicamid 50%WG	75	3.87	1.97	1.33	1.15	2.07	1.42	1.13	1.04	0.87	0.92	0.20	0.45
3	Flonicamid 50%WG	100	3.60	1.88	1.67	1.28	2.47	1.54	0.60	0.77	0.67	0.80	0.13	0.30
4	NSKE	5%	4.93	2.18	3.27	1.79	3.47	1.85	2.53	1.58	1.07	1.02	0.67	0.80
5	Diafenthiuron 50%WP	300	6.00	2.44	3.13	1.74	2.80	1.66	2.13	1.45	1.27	1.12	0.20	0.36
6	*Verticillium lacanii*	5gms/lit.	5.27	2.28	1.80	1.33	2.53	1.58	2.00	1.40	1.20	1.08	0.73	0.83
7	*Metarhizium anisopliae*	3gms/lit.	4.20	2.04	3.07	1.74	3.33	1.82	2.33	1.51	1.27	1.11	0.40	0.62
8	Untreated control	------	5.40	2.31	5.67	2.37	4.20	2.04	3.53	1.87	1.93	1.39	1.00	0.99
	F test			NS		SIG		NS		SIG		NS		SIG
	SE(M±)			0.142		0.140		0.144		0.138		0.113		0.128
	CD (P=0.05)			--		0.424		--		0.419		--		0.387
	CV %			11.24		14.73		14.89		17.80		18.62		36.41

* square root values, OV-Original value, TV-Transformed value

Table 4: Population of whitefly after treatment application at different crop stages

S. No.	Treatment	Dose/ ha (g.a.i.)	Av. Population of whitefly/3 leaves at different crop stage											
			First spray				Second spray				Third spray			
			Pre		Post		Pre		Post		Pre		Post	
			OV	TV*	OV	TV*	OV	TV*	OV	TV*	OV	TV*	OV	TV*
1	Buprofezin 25% SC	250	4.93	2.20	2.60	1.60	6.27	2.50	2.27	1.49	7.60	2.75	3.00	1.73
2	Flonicamid 50%WG	75	3.80	1.94	1.00	0.97	5.93	2.43	1.53	1.23	8.27	2.87	2.47	1.56
3	Flonicamid 50%WG	100	4.40	2.09	1.40	1.17	5.73	2.38	1.93	1.38	5.40	2.31	2.07	1.42
4	NSKE	5%	4.47	2.09	4.13	2.03	6.60	2.55	3.33	1.81	7.00	2.64	3.53	1.87
5	Diafenthiuron 50%WP	300	4.00	1.99	3.20	1.78	7.47	2.72	2.07	1.43	7.47	2.72	3.13	1.76
6	*Verticillium lacanii*	5gms/lit.	4.93	2.21	4.27	2.05	7.07	2.65	2.80	1.66	7.00	2.63	4.27	2.06
7	*Metarhizium anisopliae*	3gms/lit.	4.80	2.19	4.20	2.05	6.27	2.50	2.73	1.64	6.27	2.49	3.87	1.96
8	Untreated control	-	4.53	2.13	6.87	2.62	7.53	2.74	7.33	2.70	8.47	2.90	7.40	2.71
	F test			NS		SIG		NS		SIG		NS		SIG
	SE(M±)			0.156		0.126		0.105		0.139		0.133		0.133
	CD (P=0.05)			-		0.382		-		0.421		-		0.404
	CV %			12.81		12.24		7.11		14.42		8.63		12.26

** square root values, OV-Original value, TV-Transformed value

3.5 Effect on natural enemies

The data on the cumulative effect of spraying indicated that there were no significant differences among the treatments in respect to population of natural enemies (i.e. ladybird beetle, chrysopa larvae and spider). However, numerically more number of natural enemies was observed in untreated control plot (Table 5). Effect of flonicamid on natural enemies of aphids, Lady bird beetle, *Coccinella septumpunctata* was studied in laboratory conditionand reported that, flonicamid seem to be promising insecticide for aphid control in term of selectivity for aphid antagonists [21].

3.6 Effect on seed cotton yield

The maximum seed cotton yield of 1681.02 Kg ha^{-1} was obtained from flonicamid 50% WG @ 75 g a.i. ha^{-1} followed by flonicamid 50% WG @ 100 g a.i. ha^{-1} (1627.31 Kg ha^{-1}.) and these treatments were significantly superior over rest of the treatments. Next effective treatments were diafenthiuron 50% WP @ 300 g a.i. ha^{-1}, buprofezin 25% SC @ 250 g a.i. ha^{-1}, NSKE 5 % and *V. lecanii* @ 5 gm liter^{-1}. Lowest yield of 715.28 kg ha^{-1} was recorded in untreated control (Table 6). The influence of new chemistry molecules and bio pesticides in maximizing seed cotton yield has been reported by [22, 23, 24] thus, confirming the present finding.

4. Conclusion

On the basis of present study, it is concluded that three sprays of flonicamid 50 WP@ 100 g a.i. ha^{-1}, flonicamid 50 WP@ 75 g a.i. ha^{-1}, buprofezin 25% SC @ 250 g a.i. ha^{-1} and difenthiuron 50 WP @ 300g a.i. ha^{-1} was found very effective in controlling major sucking pests of Bt cotton and also gave higher yield.

Table 5: Population of predators after third insecticidal application

S. No.	Treatment	Dose/ ha (g.a.i.)	Average population of predators after third insecticidal spray					
			Lady bird beetle/plant		Chrysopa (G&A)/plant		Spider/plant	
			OV	TV**	OV	TV**	OV	TV**
1	Buprofezin 25% SC	250	0.07	0.75	0.20	0.84	0.07	0.75
2	Flonicamid 50%WG	75	0.07	0.75	0.20	0.82	0.13	0.79
3	Flonicamid 50%WG	100	0.13	0.79	0.20	0.84	0.20	0.84
4	NSKE	5%	0.13	0.79	0.33	0.90	0.13	0.79
5	Diafenthiuron 50%WP	300	0.07	0.75	0.20	0.83	0.20	0.84
6	*Verticillium lacanii*	5gms/lit.	0.07	0.75	0.27	0.87	0.13	0.79
7	*Metarhizium anisopliae*	3gms/lit.	0.13	0.79	0.27	0.87	0.20	0.83
8	Untreated control	-	0.47	0.98	0.47	0.98	0.53	1.01
	F test			NS		NS		NS
	SE(M±)			0.052		0.072		0.045
	CD (P=0.05)			-		-		-
	CV %			11.30		14.36		9.46

** square root (x+0.5), OV-Original value, TV-Transformed value

Table 6: Seed cotton yield after treatment application

S. No	Treatment	Dose/ ha (g.a.i.)	Yield of seed cotton (Kg/ha)		
			1st Picking	2nd Picking	Total
1	Buprofezin 25% SC	250	939.97	163.58	1103.55
2	Flonicamid 50%WG	75	1425.62	255.40	1681.02
3	Flonicamid 50%WG	100	1394.29	233.02	1627.31
4	NSKE	5%	964.35	148.92	1113.27
5	Diafenthiuron 50%WP	300	1087.81	135.03	1222.84
6	*Verticillium lacanii*	5 gms/lit.	883.33	171.30	1054.63
7	*Metarhizium anisopliae*	3 gms/lit.	780.86	114.20	895.06
8	Untreated control	------	575.62	139.66	715.28
	F test				SIG
	SE(M±)				95.99

	CD (P=0.05)				291.158
	CV %				14.13

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