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MANAGEMENT OF INSECT PESTS OF CABBAGE WITH A NEWER ANTHRANILIC DIAMIDE INSECTICIDE, CYANTRANILIPROLE 10% OD

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ABSTRACT
Evaluation of the cyantraniliprole 10% OD against insect pests of cabbage was undertaken during Rabi 2009-10 and 2010-11. The new insecticide, cyantraniliprole 10% OD was tested at four dosages *viz*., 20, 40, 60 and 80 g *a.i.* per ha against insect pests of cabbage. Among them, cyantraniliprole 10% OD @ 60 g *a.i.*/ha was quite effective dosage for the management of sucking pests like aphids, *Lipaphis erysimi* and *Brevicoryne brassicae* and whiteflies, *Bemesia tabaci* during both the years (0.79 and 0.10/ leaf; 0.55 and 1.18 /leaf; and 0.51 and 0.0 whiteflies /leaf, respectively). In addition, cyantraniliprole 10% OD @ 60 g *a.i.*/ha has been found promising in reducing lepidopteran pests like diamond back moth, *Plutella xylostella*, tobacco caterpillar, *Spodoptera litura* and head borer, *Hellula undalis* during both the years (0.03 and 0.0 larva/ plant; 0.22 and 0.33 larva/plant and 0.15 and 0.32 larva/plant, respectively). Further, cyantraniliprole 10% OD @ 60 g *a.i.*/ha has recorded higher cabbage marketable yield of 43.59 and 42.18 tonnes/ha during 2009-10 and 2010-11, respectively. So, cyantraniliprole 10% OD may be used @ 60 g *a.i.*/ha for the management of both sucking and lepidopteran pests and for obtaining higher marketable yield in cabbage.

INTRODUCTION

Cabbage is most important and widely grown vegetable prone to attack by several insect pests. Several workers have reported more than 35 insect pests causing damage on the crop. However, the major insect pests include diamondback moth, *Plutella xylostella* (L), head borer, *Hellula undalis* Zeller, white butterfly, *Pieris brassicae* (L.), leaf webber, *Crocidolomia binotalis* Zeller, and aphid, *Brevicoryne brassicae* L (Srivastava and Butani, 1998; Pajmon, 1999; Kumar and Singh., 2014 and Rabari *et al*., 2016). Among all, diamond back moth, *Plutella xylostella* (L.) is the most destructive insect pest of cruciferous plants throughout the world.

The pest has shown to develop resistance against most groups of insecticides necessitating repeated application of insecticides and of-late sucking pests like aphids and whiteflies are also causing significant reduction in cabbage yield. So, evaluation of novel insecticides with alternative mode of action is inevitable for suppression of pest and prevention of resistance development. Recently a new molecule, cyantraniliprole, a second generation anthranilic diamide insecticide, having a unique mode of action targeting the ryanodine receptors (RyR) in insect muscle cells (Sattelle *et al.,* 2008; IRAC, 2012) has been developed. Cyantraniliprole is shown to have a broad spectrum on both chewing (Lepidoptera) and sucking (Hemiptera) pests (Anon., 2012) and even reported to have anti-feedant properties (Gonzales-Coloma *et al.,* 1999) also. So, the present investigation was taken up to evaluate the bioefficacy of cyantraniliprole against both sucking insects and lepidopteran caterpillar on cabbage.

MATERIALS AND METHODS

Evaluation of the cyantraniliprole 10% OD against insect pests of cabbage was undertaken in an experimental block at Agricultural Research Station, Bheemarayanagudi, Karnataka during Rabi 2009-10 and 2010-11. The experiment was laid out in a randomized block design (RBD) with seven treatments and three replications. The test chemical, cyantraniliprole 10% w/v OD (Cyazypyr ™) is a second-generation ryanodine receptor (RyR) activator belongs to anthranilamide insecticide class (supplied by E.I. DuPont India Pvt Ltd, Haryana) was tested at four different dosages *viz*., 20, 40, 60 and 80 g *a.i.* per ha along with two standard checks *viz*., spinosad 45 SC @ 73 g *a.i.*/ha against lepidopterans and imidacloprid 17.8 SL @ 25 g *a.i.* per ha against sucking pests and an untreated control (Facknath and Kawol, 1996). Treatments were imposed four times based on pest population build-up (above ETL). All the agronomic packages were followed as per recommended package of practices of University of Agricultural Sciences (UAS), Dharwad. Observations were recorded at pre-treatment and 3, 7 and 10 days after each application on ten tagged plants per plot. Observations on sucking pests like aphids, whiteflies were recorded from three leaves per plant. Larval populations of diamond back moth (DBM), *Plutella xylostella*, tobacco caterpillar, *Spodoptera litura* and head borer, *Hellula undalis* were recorded on whole plant basis. The data

collected from four sprays was averaged and expressed on per leaf basis for aphids and whiteflies and per plant basis for DBM, tobacco caterpillar and head borer.

The natural enemy population of lady bird beetle, *Menochilus sexmaculatus* was recorded by counting the number of beetles per plant on a whole plant basis. The yield data was collected from each plot and extrapolated on per hectare basis. Also per cent marketable heads were worked out per plot.

The treatments were subjected to statistical analysis by single factor ANOVA and means were compared by following Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Pre-treatment count on number of aphids and whiteflies and lepidopteran pests like diamond back moth, *Spodoptera litura* and head borer was non-significant among the treatments showing uniformity in the incidence of the pests in the experimental plots.

Efficacy against sucking pests

The data revealed that aphid species, *Lipaphis erysimi* predominated during the crop season. The aphid population, at 3 DAS was significantly lowest in cyantraniliprole 10% OD @ 80 g *a.i.*/ha (0.29 and 0.03/leaf, respectively) which was statistically at par with its lower dose @ 60 g *a.i.*/ha (0.79 and 0.10/ leaf, respectively) both during 2009-10 and 2010-11 (Table 1 and 2). The next best dose of cyantraniliprole 10% OD was @ 40 g *a.i.*/ha (1.88 and 1.14 /leaf, respectively) which was statistically at par with standard check, imidacloprid 17.8 SL @ 25 g *a.i.*/ha (2.07 and 1.54/ leaf, respectively). Aphid population at 7 and 10 DAS in cyantraniliprole 10%OD @ 60 g *a.i.*/ha (1.00 and 1.43 and 0.96 and 0.95/ leaf, respectively) was statistically at par with its higher doses *i.e.*, @ 80 g *a.i.*/ha (0.51/leaf) but significantly superior compared to its lower doses and also standard check, imidacloprid 17.8 SL @ 25 g *a.i.*/ha.

Later in the season, (during the fourth spray) incidence of *Brevicoryne brassicae* was noticed. Cyantraniliprole 10% OD showed significant efficacy against, *Brevicoryne brassicae* @ 60 g *a.i.*/ha (0.55 and 1.18 aphids/leaf, respectively) which was statistically at par with its higher dose @ 80 g *a.i.*/ha (0.45 and 1.10 aphids/ leaf, respectively) but significantly superior compared to its lower dose @ 40 g *a.i.*/ha (2.23 and 3.26 aphids/leaf, respectively) at 3 days after fourth application (Table 1 and 2).

Cyantraniliprole 10% OD @ 80 g *a.i.* recorded significantly

Table 1: Efficacy of cyantraniliprole 10% OD on the incidence of sucking pests on cabbage during 2009-10

Sl No	Treatment	Dose	No of aphids/leaf				No of whiteflies/leaf			
		(g *a.i.*/ha)	*Lipaphis erysimi*				*Bemisia tabaci*			
			DBS	3DAS	7DAS	10DAS	DBS	3DAS	7DAS	10DAS
1	Cyantraniliprole 10% OD	20	14.32	3.92	3.15	5.96	7.13	2.31	3.61	4.75
2	Cyantraniliprole 10% OD	40	14.53	1.88	2.8	2.85	7.15	1.21	1.2	2.15
3	Cyantraniliprole 10% OD	60	15.08	0.79	1	1.43	6.98	0.51	0.41	1.61
4	Cyantraniliprole 10% OD	80	14.26	0.29	1.07	1.51	7.24	0.27	0.37	1.29
5	Spinosad 45% SC	73	14.53	11.26	12.79	15.79	7.09	5.12	5.45	6.56
6	Imidacloprid 17.8% SL	25	15.11	2.07	2.46	2.18	7.34	1.95	1.76	2.11
7	UTC	-	14.41	16.64	20.97	21.71	7.13	6.79	8.36	8.72
	CD @5%		NS	0.6	1.24	1.08	NS	0.69	0.7	0.61
	SEm±			0.19	0.4	0.35		0.23	0.23	0.2
	CV (%)			13.25	12.56	14.23		9.42	13.07	8.94

DBS = day before spray, DAS = days after spray; Each observation is an average of 3 sprays for aphids and two sprays for whiteflies

Table 2 : Efficacy of cyantraniliprole 10% OD on the incidence of sucking pests on cabbage during 2010-11

Sl No	Treatment	Dosage	No of aphids/leaf								No of whiteflies/leaf			
		(g *a.i.* /ha)	*Lipaphis erysimi*				*Brevicoryne brassicae*							
			DBS	3DAS	7DAS	10DAS	DBS	3DAS	7DAS	10DAS	DBS	3DAS	7DAS	10DAS
1	Cyantraniliprole 10% OD	20	10.21	2.56	2.98	3.04	8.65	4.16	4.67	4.62	2.81	0.55	0.47	0.88
												1.24	1.18	1.44
2	Cyantraniliprole 10% OD	40	10.59	1.14	1.34	2.43	8.71	3.26	4.56	4.34	2.64	0.12	0.27	0.46
												0.83	1.02	1.18
3	Cyantraniliprole 10% OD	60	9.97	0.1	0.96	0.95	9.2	1.18	1.25	1.89	2.37	0	0.14	0.17
												0.5	0.88	0.9
4	Cyantraniliprole 10% OD	80	10.23	0.03	0.51	0.51	8.95	1.1	1.01	1.72	2.8	0	0.11	0.01
												0.5	0.81	0.55
5	Spinosad 45 %SC	73	10.23	4.85	4.84	5.45	8.99	7.89	9.04	9.62	2.29	1.44	1.62	1.73
												1.7	1.77	1.81
6	Imidacloprid 17.8% SL	25	9.88	1.54	1.16	1.63	9.11	2.35	2.24	2.63	2.65	0.61	0.54	0.53
												1.28	1.24	1.23
7	UTC	-	10.54	8.93	9.09	9.41	9.53	9.5	9.97	10.25	2.58	2.47	2.09	2.15
												2.07	1.95	1.97
	CD @5%		NS	0.52	0.63	0.64	NS	0.62	0.63	0.54	NS	0.14	0.16	0.2
	SEm±			0.17	0.21	0.21		0.21	0.21	0.17		0.04	0.05	0.07
	CV (%)			10.74	11.64	11.32		12.76	12.24	12.34		6.92	6.96	13.44

DBS = day before spray, DAS = days after spray; Figures in the paranthesis are $\sqrt{}$ + 0.5 transformed values; Each observation is an average of 4 sprays except for *Brevicoryne brassicae* which is an average of one spray

Table 3: Efficacy of cyantraniliprole 10% OD on the incidence of lepidopteran pests on cabbage during 2009-10

Sl No	Treatment	Dose (g *a.i.*/ha)	No. of larvae / plant *Plutella xylostella*				*Spodoptera litura*				*Hellula undalis*			
			DBS	3DAS	7DAS	10DAS	DBS	3DAS	7DAS	10DAS	DBS	3DAS	7DAS	10DAS
1	Cyantraniliprole 10% OD	20	4.13	0.53	0.91	1.01	3.25	1.44	1.14	1.83	0.8	0.51	0.62	0.68
				1.21	1.45	1.51					1.38	1.2	1.28	1.33
2	Cyantraniliprole 10% OD	40	3.52	0.16	0.26	0.64	3.09	0.73	0.79	0.98	0.76	0.3	0.5	0.54
				0.89	1.01	1.3					1.37	1.05	1.2	1.23
3	Cyantraniliprole 10% OD	60	3.76	0.03	0	0.12	3.14	0.22	0.16	0.32	0.77	0.15	0.32	0.24
				0.61	0.5	0.83					1.37	0.91	0.97	0.98
4	Cyantraniliprole 10% OD	80	4.08	0	0	0.04	3.75	0.13	0.18	0.29	0.82	0.05	0.18	0.2
				0.5	0.53	0.66					1.41	0.72	0.82	0.94
5	Spinosad 45% SC	73	4.12	0.96	0.99	1.25	3.39	0.84	1.12	1.67	0.79	0.28	0.38	0.35
				1.48	1.5	1.62					1.39	1.03	1.12	1.09
6	Imidacloprid 17.8% SL	25	4.32	2.18	2.75	2.99	3.8	2.84	3.2	3.43	0.83	0.68	0.76	0.8
				1.97	2.16	2.23					1.41	1.33	1.37	1.39
7	UTC	-	3.5	3.59	3.55	3.44	3.46	3.37	4.07	3.6	0.81	0.85	0.81	0.92
				2.39	2.38	2.35					1.4	1.42	1.4	1.46
	CD @5%		NS	0.19	0.14	0.19	NS	0.5	0.42	0.41	NS	0.18	0.17	0.2
	SEm±			0.06	0.04	0.06		0.16	0.14	0.14		0.06	0.06	0.07
	CV (%)			8.46	5.5	6.92		10.65	10.23	11.06		7.05	7.11	8.09

DBS = day before spray, DAS = days after spray;Each observation is an average of 4 sprays.;Figures in the paranthesi are$\sqrt{}$ + 0.5 transformed values

Table 4: Efficacy of cyantraniliprole 10% OD on the incidence of lepidopteran pests on cabbage during 2010-11

Sl No	Treatment	Dosage (g *a.i.*/ha)	No. of larvae / plant *Plutella xylostella* DBS	3DAS	7DAS	10DAS	*Spodoptera litura* DBS	3DAS	7DAS	10DAS	*Hellula undalis* DBS	3DAS	7DAS	10DAS
1	Cyantraniliprole 10% OD	20	4.62	0.69	0.49	0.7	6.31	1.87	1.99	2.31	1.94	0.75	0.61	0.89
				1.33	1.2	1.51						1.37	1.28	1.44
2	Cyantraniliprole 10% OD	40	5.09	0.21	0.36	0.53	5.9	0.83	1.18	1.57	2.06	0.31	0.46	0.54
				0.96	1.1	1.22						1.06	1.18	1.23
3	Cyantraniliprole 10% OD	60	5.11	0.04	0.12	0.22	6.03	0.33	0.58	0.77	2.13	0.01	0.16	0.22
				0.66	0.85	0.97						0.59	0.89	0.97
4	Cyantraniliprole 10% OD	80	4.96	0.05	0.06	0.07	6.2	0.2	0.4	0.6	1.9	0.02	0.01	0.09
				0.72	0.73	0.75						0.62	0.57	0.76
5	Spinosad 45 %SC	73	4.57	0.57	0.69	1.08	6.32	0.91	1.14	1.88	1.97	0.5	0.6	0.93
				1.25	1.51	1.54						1.2	1.27	1.46
6	Imidacloprid 17.8% SL	25	4.4	3.19	2.92	3.9	6.14	5.52	4.93	4.94	1.88	1.06	1.48	1.89
				2.28	2.21	2.47						1.53	1.71	1.87
7	UTC	-	5.03	4.01	3.98	4.81	6.19	6.77	6.87	5.89	1.96	1.61	2.02	2.33
				2.5	2.49	2.69						1.77	1.92	-2.02
	CD @5%		NS	0.18	0.19	0.17	NS	0.49	0.49	0.88	NS	0.16	0.19	0.2
	SEm±			0.06	0.06	0.05		0.16	0.16	0.28		0.05	0.06	0.07
	CV (%)			6.96	4.58	5.91		13.04	12.52	12.31		7.36	8.57	8.18

DBS = day before spray, DAS = days after spray;Each observation is an average of 4 sprays;Figures in the paranthesis are $\sqrt{x}$ + 0.5 transformed values.

Table 5 : Effect of cyantraniliprole 10% OD on population of natural enemies on cabbage during 2009-10 and 2010-11

Sl. No	Treatment	Dose (g *a.i.*/ha)	No of coccinellid predatory beetles (Adults + Grubs) /plant 2009-10 DBS	3DAS	7DAS	10DAS	2010-11 DBS	3DAS	7DAS	10DAS
1	Cyantraniliprole 10% OD	20	1.97	1.07	1.45	1.24	1.52	1.42	1.45	1.62
2	Cyantraniliprole 10% OD	40	1.68	0.98	1.31	1.26	1.5	1.34	1.39	1.52
3	Cyantraniliprole 10% OD	60	1.88	0.96	1.17	1.22	1.49	1.38	1.47	1.55
4	Cyantraniliprole 10% OD	80	1.9	0.37	0.68	1.11	1.58	1.3	1.4	1.6
5	Spinosad 45% SC	73	1.91	0.95	1.1	1.36	1.5	1.35	1.45	1.56
6	Imidacloprid 17.8% SL	25	1.62	0.93	1.28	1.11	1.55	1.29	1.4	1.61
7	UTC	-	1.31	1.65	1.73	1.7	1.6	1.45	1.58	1.57
	CD @5%		NS	0.21	0.39	NS	NS	NS	NS	NS
	SEm ±			0.07	0.13		-	-	-	-

DBS = day before spray, DAS = days after spray;Each observation is an average of 4 sprays, *Menochilus sexmaculatus* and *Coccinella septempunctata* were major coccinelids recorded

lowest whitefly population (0.27 /leaf) at 3 DAS which is statistically at par with cyantraniliprole 10% OD @ 60 g *a.i.* (0.51/leaf), but significantly superior compared to its lower dose @ 40 g *a.i.* during 2009-10, whereas during 2010-11 whitefly population were statistically at par and recorded zero population at 3 DAS (Table 1 and2). In general, cyantraniliprole 10% @ 60 g *a.i.* was statistically superior compared to standard check, imidacloprid 17.8 SL @ 25 g *a.i.* and lower dosages of test chemical. Similar trend continued on 7 and 10 DAS, indicating superiority of cyantraniliprole 10% OD @ 60 g *a.i.*/ ha over standard check for more than 10 days after spray.

Overall results indicated that, cyantraniliprole 10% OD @ 60 g *a.i.*/ha is quite effective dose for the management of sucking pests like aphids and whiteflies for more than 10 DAS and is

Table 6 : Efficacy of cyantraniliprole 10% OD on marketable yield and yield parameters in cabbage during 2009-10 and 2010-11

Sl No	Treatment	Dose (g *a.i.*/ ha)	2009-10		2010-11	
			% Marketable heads	Marketable Yield (t/ha)	%Marketable heads	Marketable Yield (t/ha)
1	Cyantraniliprole 10% OD	20	86.54 (68.53)	38.15	85.44 (67.49)	37.43
2	Cyantraniliprole 10% OD	40	92.18 (77.49)	41.29	94.97 (76.9)	40.14
3	Cyantraniliprole 10% OD	60	97.27 (82.1)	43.59	97.23 (80.36)	42.18
4	Cyantraniliprole 10% OD	80	98.6 (84.34)	43.78	97.04 (80.18)	41.66
5	Spinosad 45% SC	73	91.33 (72.79)	37.64	90.55 (72.18)	38.13
6	Imidacloprid 17.8% SL	25	78.99 (62.04)	31.69	69.1 (56.14)	31.25
7	UTC	-	70.99 (56.99)	26.19	57.78 (49.41)	21.3
	CD @5%		4.02	1.57	5.08	1.45
	SEm ±		1.35	0.51	1.65	0.47
	CV (%)		11.46	2.34	4.14	2.25

Figures in the paranthesis are arcsine transformed values

statistically superior compared to standard check, imidacloprid 17.8 SL @ 25 g *a.i.*/ha.

Similar results of effectiveness of cyantraniliprole (90 and 105 g *a.i.*/ha) was also reported against whitefly on okra, brinjal and tomato as reported by Patel *et al*. (2011), Patel and Kher (2012a; 2012b).

The present findings are in conformity with the findings of Govindappa *et al*. (2013) who reported among the different concentrations of new molecule cyantraniliprole (Cyazypyr 10 OD) (45, 60 and 75 g *a.i.*/ha) tested, cyantraniliprole 10 OD at 60 and 75 g *a.i*. were found more effective in reducing both whitefly and disease incidence at first and final observation with the least whitefly population and leaf curl disease incidence in tomato. Correspondingly, the yields were high in cyantraniliprole 10 OD 75 g *a.i.*/ha (32.5tons/ha) and significantly superior over the standard check, triazophos (23.5 tonnes/ha.) followed by cyantraniliprole 10 OD at 60 g *a.i.*/ha (29.2 tonnes/ha).

Balikai and Mallapur (2015) evaluated the bioefficacy of cyantraniliprole 10 OD, along with carbaryl 50 WP and malathion 50 EC as standard checks against pests complex of gherkins. Three sprays of cyantraniliprole 10 OD @ 90 g *a.i.*/ ha afforded highest protection against white fly, thrips, serpentine leaf miner, fruit fly, red pumpkin beetle and fruit borer over untreated check and produced higher marketable fruit yield.

Patel *et al*. (2014) evaluated the field bio-efficacy of a newer molecule, cyantraniliprole 10% OD @ 45, 60, 75, 90 and 105 g *a.i.*/ha along with indoxacarb 14.5 SC and endosulfan 35 EC as standard checks against the cotton aphid, *Aphis gossypii* Glover; thrips, *Thrips tabaci* Lindeman and whitefly, *B. tabaci*. The two higher doses of cyantraniliprole 10% OD *i.e.* 90 and 105 g *a.i.*/ha was found highly effective in managing the population of aphid, thrips and whitefly during both the year compared to endosulfan and indoxacarb.

Efficacy against lepidopteran pests

Diamond back moth (DBM), *Plutella xylostella* population on cabbage ranged from 0.0 to 3.59 and 0.04 to 4.01 larva/ plant at 3 DAS during 2009-10 and 2010-11 (Table.3and 4). Among the different treatments, cyantraniliprole 10% OD @ 60 g *a.i.* and @ 80 g *a.i.* were statistically at par and recorded significantly lowest population at 3 DAS during both the years (0.03 and 0.00 and 0.04 and 0.05 larva/ plant, respectively). The next best dosage was cyantraniliprole 10% OD @ 40 g *a.i.*/ha which recorded 0.16 and 0.21 larva per plant, respectively which was significantly superior compared to its lower dosage, cyantraniliprole 10% OD @ 20 g *a.i.* (0.53 and 0.69 larva/ plant, respectively) and also standard check, spinosad 45 SC @ 73 g *a.i.* (0.96 and 0.57 larva/ plant, respectively). Similarly cyantraniliprole 10% OD at both @ 60 g *a.i.* and @ 80 g *a.i.* performed significantly superior in recording negligible population of DBM upto 10 DAS (0.04 – 0.12 larva/plant) while, its lower dose @ 40 g *a.i.* being the next best treatment both at 7 and 10 DAS (0.26 and 0.64 larva/plant, respectively). However, dosage of cyantraniliprole 10% OD @ 40 g *a.i.* was statistically superior compared to its lower dose @ 20 g *a.i.*/ha and standard check, spinosad 45 SC @ 73 g *a.i.* at 7 and 10 DAS.

It is evident from the results that test chemical cyantraniliprole 10% OD @ 60 g *a.i.* and @ 80 g *a.i.* per ha were at par and significantly superior to other lower dosages and spinosad 45 SC @ 73 g *a.i.* and reduced DBM population below ETL even beyond 10 DAS, while DBM in untreated control was always above ETL (3.44 – 3.59 larva/plant).

Tobacco caterpillar, *Spodoptera litura* population at 3 DAS was significantly lowest in cyantraniliprole 10% OD @ 80 g *a.i.* during 2009-10 and 2010-11 (0.13 and 0.20 larva/plant, respectively) (Table 3 and 4) which was at par with its lower dose @ 60 g *a.i.*/ha (0.22 and 0.33 larva/plant respectively) but significantly superior compared cyantraniliprole 10% OD @ 40 g *a.i.* (0.73 and 0.83 larva/plant, respectively). Test chemical @ 40 g *a.i.* was intern statistically at par with standard check, spinosad 45 SC @ 73 g *a.i.* (0.84 and 0.91 larva/plant respectively) and significantly superior compared to HGW86 10%OD @ 20 g *a.i.*/ha (1.44 and 1.87 larva/plant, respectively

cyantraniliprole 10% OD @ 60 g *a.i.* was excellent and significantly superiority to its lower dosages and standard check even at 7 and 10 DAS.

Infestation of cabbage head borer, *Hellula undalis* was noticed at later stages of the crop growth. At 3 DAS, cyantraniliprole 10% OD @ 80 g *a.i.*/ha recorded significantly lowest head borer larva (0.05 and 0.02 larva/plant, respectively) which was statistically significant compared to its lower dose @ 60 g *a.i.* (0.15 and 0.32 larva/plant, respectively) both during 2009-10 and 2010-11. The next best treatment was cyantraniliprole 10% OD @ 40 g *a.i.* (0.30 and 0.31 larva/plant, respectively) which intern was statistically at par with standard check, spinosad 45 SC @ 73 g *a.i.* (0.28 and 0.50 larva/plant). At 7 DAS and 10 DAS, cyantraniliprole 10% OD @ 60 g *a.i.* has proved best and was significantly superior compared to standard check, spinosad 45 SC @ 73 g *a.i.* So, test chemical @ 60 g *a.i.* was most effective dose among all the treatments at all observation periods (Table 3 and 4).

Overall, test chemical cyantraniliprole 10% OD @ 60 g *a.i.* was quite effective and was at par with its higher dosages @ 80 *g a.i.* against diamond back moth, *S. litura* and head borer.

Stansly and Kostyk (2012) reported a significant decrease in the number of larvae and damage of the diamondback moth in a cauliflower crop using foliar applications of cyantraniliprole 10 OD. Similarly, cyantraniliprole at the rate of 70 and 80 g *a.i.*/ha was most effective and at par with spinosad in reducing *S. litura* population in grapes. The present findings are in line with Yadav *et al*. (2012).

Natural enemy population

Natural enemy population comprising coccinellids beetles, *Menochilus sexmaculatus* and *Coccinella septempunctata* ranged from 0.37-1.65 and 1.10-1.45 per plant respectively at 3 DAS during 2009-10 and 2010-11. (Table 5). All the treatments except cyantraniliprole 10% OD @ 80 g *a.i.* (0.37/ plant) recorded significantly higher and at par natural enemy population at 3 DAS. However natural enemy population increased slowly and showed non-significant difference among all the treatments on subsequent days of observation (7 and 10 DAS). So, reduction in the natural enemy population in treated plots compared to untreated control at 3 and 7 DAS can be attributed to reduction of pest (prey) population. Which indicates that, cyantraniliprole 10% OD at varied dosages is quite safer to natural enemies.

Several workers reported safety of anthranillic diamide group of insecticides, like cyantraniliprole to coccinellid predators which are in line with the present findings (Misra, 2011; Misra and Mukharjee, 2012; Misra, 2013b; Rachappa *et al*., 2014) and Chlorantraniliprole to coccinellids in specific and even to most of natural enemies in general general (Mandal, 2012).

Contrararily, Balikai and Mallapur (2015) recorded slight decrease in population of coccinellid beetles in cyantraniliprole treated plots compared to untreated check in gherkin was attributed to reduction in pest population.

Cabbage yield and marketable heads

Highest marketable heads of more than 97 per cent was recorded in cyantraniliprole 10% OD @ 80 g *a.i.* which was statistically at par with its lower dose @ 60 *g a.i.* both during 2009-10 and 2010-11 but were significantly superior than and its lower dose of 40 g *a.i.* (92.18% and 89.97% respectively) (Table 6) and standard check, spinosad 45 SC @ 73 g *a.i.*/ha. On the other hand, per cent marketable head was significantly lowest in untreated control (70.99% and 57.78 % respectively).

Highest cabbage marketable yield of 43.78 tonnes per ha was recorded in cyantraniliprole 10% OD @ 80 g *a.i.*/ha which was statistically at par with its lower dose @ 60 g *a.i.*/ha (43.59 t/ha) in 2009-10 and highest marketable yield of 42.18 t/ha was recorded in cyantraniliprole @ 60 g *a.i.*/ha which was statically at par with its higher dose @ 80 g *a.i.*/ha (41.66 t/ha during 2010-11). The next best treatment with respect to head yield was recorded in cyantraniliprole 10% OD @ 40 g *a.i.*/ha (41.29 and 40.12 t/ha respectively), which intern was statically at par with spinosad 45 SC @ 73 g *a.i.*/ha but significantly superior compared to imidacloprid 17.8 SL @ 25 g *a.i.*/ha.

Overall, cyantraniliprole 10% OD @ 60 g *a.i.*/ha is highly effective treatment because it has recorded higher per cent marketable heads and marketable cabbage yield at par with its higher dosage but superior when compared to both the standard checks.

Misra (2013a) also reported significantly highest fruit yield in cyantraniliprole 10 % OD at 90 and 105 g *a.i.*/ha registering 93.08 to 97.69 per cent increase in fruit yield over untreated control, respectively followed by spinosad 45 SC at the rate of 56 g *a.i.*/ha (90.77%) in gherkin.

Cyantraniliprole 10% OD at higher doses *i.e.* 90 and 105 g *a.i.*/ha was found highly effective in managing the population of aphid, thrips and whitefly in cotton and recorded significantly higher cotton yield (31.97 and 33.33 q/ha, respectively). So, cyantraniliprole 10% OD @ 90 g *a.i.*/ha was recommended for control of sucking pests on cotton (Patel *et al*., 2014). But in the present study, lower dosage of cyantraniliprole 10OD proved promising because of relative low pest pressure on cabbage.

New insecticide molecule, cyantraniliprole 10% OD @ 60 g *a.i.*/ha is quite effective dosage for the management of both sucking pests and lepidopteran pests, and is safer to natural enemies. Hence, an anthranilamide insecticide, cyantraniliprole 10% OD @ 60 g *a.i.*/ha with broad spectrum activity is ideal for harvesting higher marketable cabbage heads.

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