Pesticide Research Journal Vol. 23(2): 172-180, December 2011

Evaluation of Eco-Friendly Insecticides against Major Insect Pests of Cabbage

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Field experiments in cabbage c.v. Golden acre were laid out during *rabi* 2009-10 and 2010-11 in the vegetable farm of Division of Entomology, Indian Agricultural Research Institute, New Delhi in Randomised Block Design (RBD) with ten treatments. Each treatment schedule comprised four sprays, except treatment No. 10 which was taken as control. The results showed that in T_9 comprising of acetamiprid-acetamiprid-fipronil-spinosad, showed significantly highest percent reduction over control (PROC) of aphid *Lipaphis erysimi* population (84.65 and 82.92); and (77.88 and 76.04) after 1st spray over two seasons at 3 and 7 DAS respectively. Also acetamiprid in other treatment combination, whether used as 1st or 2nd spray recoded significantly higher PROC of aphids than any other formulation. Chlorantraniliprole (18.5% SC @10 g a.i./ha) showed highest PROC of diamond back moth, *Plutella xylostella* (83.65 and 82.08) and cabbage butterfly, *Pieris brassicae* (84.42 and 84.54) at 3 d after 3rd spray during 2009-10 and 2010-11, respectively in treatment T_4 having acetamiprid-acetamiprid-chlorantraniliprole-emamectin benzoate with corresponding maximum marketable yield (30.6 and 32.17 ton/ha). Neem baan, spinosad, emamectin benzoate and chlorantraniliprole were proved safe to natural enemies in cabbage. High efficacy of chlorantraniliprole in T_4 with emamectin benzoate and acetamiprid as other insecticides could be excellent choice in rotational strategy aimed at prolonging their efficacy by delaying the development of resistance due to diverse mode of action. *Beauveria bassiana* proved significantly superior at 14 DAS as highest PROC in T_5 (64.23 and 71.93) and T_7 (64.37 and 68.94) was recorded during 2009-10 and 2010-11, respectively after 1st spray.

Key words: Cabbage, eco-friendly insecticides, *Lipaphis erysimi* kalt., *Plutella xylostella* L., *Pieris brassicae* L., *Apanteles plutellae*

Cabbage (*Brassica oleracea* var. *capitata* L.) is one of the popular cultivar of the species of the Family Brassicaceae and is used as a leafy green vegetable. In India, cabbage is cultivated in an area of 0.33 million hectares with an annual production of 7.28 million tonnes. At global level, cabbage is cultivated in an area of 3.12 million hectares producing about 69.68 million tones. China is the world leader in context of cabbage production followed by India and Russia[1]. One of the major constraints of not attaining higher yields of crucifers is the damage caused by insect pests. The major insect pests, which cause maximum yield losses in cabbage are cabbage head borer, *Hellula undalis* Fab.; mustard aphid, *Lipaphis erysimi* kalt. and cabbage aphid, *Brevicoryne brassicae* L. at vegetative stage and diamond back moth (DBM), *Plutella xylostella* L.; cabbage butterfly, *Pieris brassicae* L.; Leaf webber, *Crocidolomia binotalis* at curd formation stage. DBM is the most destructive pest of cabbage worldwide and the yield loss up to 52% is reported in India[2]. To mitigate the losses due to these pests, large quantities of pesticides is used in vegetable crops by the farmers[3]. Thus, the intensive and indiscriminate use of pesticides, which is not ecofriendly in nature has changed pest complex and led to many problems like insecticide resistance in insects, development of secondary pests into primary pests, adverse effect on non-target organisms, toxic pesticide residues and health hazards.

In view of the undesirable effects due to unilateral dependence on conventional chemicals, recent advances in research are being directed towards development of safer and effective insecticides i.e. avermectins, microbes, pyrazoles, spinosyns and biopesticides which are relatively safe to natural enemies and reduces pesticide load in environment. It has been reported that these molecules spare good number of coccinellid beetles, spiders and *Chrysoperla*[4]. Considering this, newer pest management schedules comprising insecticides/biopesticides of new groups having different mode of action were evaluated against major insect pests of cabbage.

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MATERIALS AND METHODS

Field experiment was conducted with cabbage variety 'Golden Acre' in Randomized Block Design in the experimental field of Division of Entomology, Indian Agricultural Research Institute, New Delhi during *rabi* seasons of 2009-10 and 2010-11.

The crop was raised with appropriate agronomic practices with plot size of 5m×5m having row to row and plant to plant spacing of 60 cm and 45 cm respectively. There were 10 treatments replicated thrice, each treatment comprised four sprays, Ist spray was given 35 d after transplanting and thereafter at 15 d intervals. As per following:

Treatment	First spraying	Second spraying	Third spraying	Fourth spraying
T1	Neem baan EC 1500 ppm	Neem baan EC 1500 ppm	*M. anisopliae* 1% WP	Emamectin benzoate 5% SG
T2	Vermiwash @ 1:1dilution	Vermiwash @ 1:1dilution	Fipronil 5% EC	Chlorantraniliprole 18.5% SC
T3	Vermiwash@ 1:4 dilutions	Vermiwash@ 1:4 dilutions	Emamectin benzoate 5% SG	Spinosad 45% SC
T4	Acetamiprid 20% SP	Acetamiprid 20% SP	Chlorantraniliprole 18.5% SC	Emamectin benzoate 5% SG
T5	*B. bassiana* 1% WP	*B. bassiana* 1% WP	*M.anisopliae* 1% WP	Chlorantraniliprole 18.5% SC
T6	Neem baan EC 1500 ppm	Neem baan EC 1500 ppm	*B. bassiana* 1% WP	Spinosad 45% SC
T7	*B. bassiana* 1% WP	*B. bassiana* 1% WP	Emamectin benzoate 5% SG	Chlorantraniliprole 18.5% SC
T8	Acetamiprid 20% SP	Acetamiprid 20% SP	Spinosad 45% SC	Emamectin benzoate 5% SG
T9	Acetamiprid 20% SP	Acetamiprid 20% SP	Fipronil 5% EC	Spinosad 45% SC
T10	Control			

Neem baan EC (1500 ppm) @ 3 ml/L, Vermiwash@ 1:1 dilution, Vermiwash@ 1:4 dilutions, Acetamiprid 20% SP @ 20 g ai/ha, *Metarhizium anisopliae* 1% WP @ 2.5 kg/ha, Spinosad 45 SC@ 75 g ai/ha, *Beauveria bassiana* 1% @2.5 kg/ha, Fipronil 5% EC@ 50 g ai/ha, Chlorantraniliprole 18.5% SC @10 g ai/ha, Emamectin benzoate 5 SG @ 10 g ai/ha.

Observations on population of major insect pests were recorded in each plot one d before spraying as pre-treatment count. Post treatment counts were taken at 3, 7, 14 d after each spray and 14th d count formed the pre-treatment count for subsequent spraying. Percent reduction over control (PROC) in pest population was calculated by modified Abbott's formula[5]. Data obtained from all observations was subjected to OPSTAT and MS office excel sheet for statistical analysis after required transformation. The yield per plot was extrapolated into yield per ha.

RESULTS AND DISCUSSION

Efficacy of treatment schedules against aphid, *L. erysimi* (Kalt): Only one species of aphid i.e. *L. erysimi* was observed in the field. The results (Table 1) revealed that reduction in aphid population in all the treatments was noticed 3rd and 7th d after first spray compared to untreated check during both the *rabi* seasons. Three d after first spray, the higher reduction of aphid population was obtained in T_9 (84.65 and 82.92%), T_8 (81.77 and 82.61%) and T_4 (79.41 and 78.15%) where in acetamiprid was common in all of them. The next best treatments were T_1 (50.88 and 51.19%) and T_6 (47.29 and 55.64%) where in Neem baan was common in both of them. T_2 (46.73 and 47.44%) was at par with T_4 and T_6. T_5 with *B. bassiana* (18.35 and 19.67%) and T_7 also with *B. bassiana* (18.89 and 18.37%) were least effective compared to the other treatments. Treatments T_9, T_8 and T_4 did not differ significantly from each other as acetamiprid was common in all of them. The values in parenthesis represent data for first and second year respectively. At seven d after first spraying, T_9 (77.88 and 76.04%), T_4 (75.32 and 76.66%) and T_8 (72.62 and 75.45%) were at par and most effective treatments while T_5 (37.91 and 45.98%) and T_7 (30.53 and 44.19%) were second effective followed by T_1 (29.88 and 31.65%), T_6 (23.73 and 33.80 %). T_2 (19.98 and 23.44%) and T_3 (19.05 and 19.12%) were the least effective treatments. However, on 14th d after first spray, T_5 (64.23 and 71.93%) and T_7 (64.37 and 68.94%) were at par and most effective treatments having *Beauveria* in both of them, while T_9 (48.46 and 47.40 %) and T_8 (38.55 and 35.12%) were second effective treatments followed by T_4 (24.08 and 22.57%), T_6 (21.44 and 24.75%) and, T_1 (18.73 and 20.81%), T_2 (29.62 and 16.86 %). T_3 again was least effective treatment, giving only 14.38 and 14.84 PROC during the consecutive years.

Three d after the second spray (Table 2), the highest aphid population reduction was again obtained in T_4 (84.78 and 78.34 %), T_8 (84.28 and 81.82%) and followed by T_9 (80.39 and 83.51 %) as acetamiprid was common in all of them. T_6 with Neem baan (62.35 and 63.42 %) and T_1 again with Neem baan (55.29 and 53.82%) having azadiractin were at par and second effective treatments followed by T_2 with vermiwash 1:1 (48.39 and 45.58 %), T_3 with vermiwash

Table 1. Effect of different treatments against aphid, *L. erysimi* (Kalt) on cabbage after 1st spray in rabi 2009-2010 and 2010-2011

S.No.	Treatment#	Per cent reduction over control							
		Pre-treatment		3 DAS		7 DAS		14DAS	
		2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
T_1	Neembaan* – *M. anisopliae*-E. benzoate	40.00	39.17	50.88 (45.53)^{c}	51.19 (45.71)^{cd}	29.88 (33.14)^{d}	31.65 (34.25)^{c}	18.73 (25.58)^{ef}	20.81 (27.10)^{e}
T_2	Vermiwash* 1:1-Fipronil- Chlorantraniliprole	35.93	35.60	46.73 (43.14)^{c}	47.44 (43.55)^{d}	19.98 (26.51)^{ef}	23.44 (28.97)^{d}	29.62 (32.94)^{d}	16.86 (24.26)^{f}
T_3	Vermiwash* 1:4 - E. benzoate-Spinosad	41.33	44.33	13.46 (21.52)^{e}	17.15 (24.47)^{e}	19.05 (25.78)^{f}	19.12 (25.94)^{e}	14.38 (22.17)^{f}	14.84 (22.66)^{f}
T_4	Acetamiprid* -Chlorantraniliprole- E. benzoate	28.60	34.00	79.41 (63.08)^{b}	78.15 (62.23)^{b}	75.32 (60.24)^{ab}	76.66 (61.14)^{a}	24.08 (29.28)^{de}	22.57 (28.34)^{de}
T_5	*B.bassiana**-*M. anisopliae*- chlorantraniliprole	39.00	41.63	18.35 (25.34)^{d}	19.67 (26.33)^{e}	37.91 (38.02)^{c}	45.98 (42.71)^{b}	64.23 (53.30)^{a}	71.93 (58.04)^{a}
T_6	Neembaan* - *B. bassiana*- Spinosad	35.80	41.27	47.29 (43.47)^{c}	55.64 (48.26)^{c}	23.73 (29.13)^{e}	33.80 (35.54)^{c}	21.44 (27.58)^{e}	24.75 (29.82)^{d}
T_7	*B.bassiana** – E. benzoate- Chlorantraniliprole	25.67	32.77	18.89 (25.71)^{d}	18.37 (25.33)^{e}	30.53 (33.54)^{d}	44.19 (41.68)^{b}	64.37 (53.39)^{a}	68.94 (56.16)^{a}
T_8	Acetamiprid* - Spinosad- E. benzoate	41.00	44.00	81.77 (64.82)^{ab}	82.61 (65.47)^{a}	72.62 (58.49)^{b}	75.45 (60.33)^{a}	38.55 (38.39)^{c}	35.12 (36.36)^{c}
T_9	Acetamiprid* -Fipronil -Spinosad	31.67	40.00	84.65 (67.02)a	82.92 (65.62)^{a}	77.88 (61.98)^{a}	76.04 (60.73)^{a}	48.46 (44.14)^{b}	47.40 (43.53)^{b}
T_{10}	Control	40.67	44.38		-	-	-	-	-
	S.Em. (±)			1.101	1.058	1.086	0.462	1.248	0.811
	CD (P = 0.05)			3.301	3.173	3.258	1.385	3.743	2.433

#Neembaan EC @ 3 ml/L, Acetamiprid 20% SP@ 20 g/ha, Vermiwash@ 1:1 dilution, Vermiwash @ 1:4 dilution, *M. anisopliae* WP @ 2.5 kg/ha, Spinosad 45 SC @ 75 g ai/ha, *B. bassiana* WP @ 2.5 kg/ha, Fipronil 5% EC @ 50 g ai/ha, Chlorantraniliprole 18.5 SC @ 10 g.ai /ha, E. benzoate 5 sg @ 10 g ai./ha

Figures in parenthesis are arcsine transformed values. *Sprayed twice as First and Second Spray

1:4 (22.16 and 18.77 %). However, T_5 (16.89 and 19.10 %) and T_7 with *B. bassiana* (14.62 and 19.42 %) were less effective treatments compared to others during 2009-10 and 2010-11 respectively. At seven d after second spraying, higher reduction was recorded in T_8 (70.71 and 68.6 %), T_9 (63.74 and 70.01 %) and T_4 (64.81 and 58.67 %). These were followed by T_5 (51.28 and 46.89 %) and T_7 (44.54 and 47.53 %). On 14th d after second spray results were similar to that after 14th days of first spray as *B. bassiana* recorded significantly different from all other treatments. Maximum reduction of aphid population were obtained in T_5 (66.71 and 63.68 %) and T_7 (61.90 and 69.72 %). T_3 treatment schedule was least effective giving only 20.15 and 21.87 per cent reduction during the consecutive years.

Third and fourth sprayings were taken against DBM and *Pieris*. However, data on aphid population was also recorded after 3rd spray.

The above results are in agreement with the findings, who reported that neonicotinoids proved most effective in suppressing the aphid population on cabbage[6]. In our findings also acetamiprid was found significantly effective upto 7 d after spray. The neem seed extracts were highly deterrent to *Beauveria brassicae* and azadirachtin disrupted the aphid feeding on cabbage[7]. In our investigation efficacy of Neem baan was next to acetamiprid. On the 14th d after 1st or 2nd spray highest PROC was recorded with *B. bassiana*. It suggests the use of *B. bassiana* as prophylactic treatment against aphids. Application of vermicompost (2.5 t/ha) with six sprays of vermiwash 1:1 registered significantly lower thrips and mite mean population of 0.35 and 0.64 per leaf, respectively, being at par with the standard check[8]. Three application of neem seed kernel extract were adequate to reduce population of *P. xylostella* on cabbage[9]. Our findings also supported the reduction of aphid population due to the spray of vermiwash (1:1) but the efficacy was moderate. It warrants the use of vermiwash as potential component of aphid control in organic farming as well as one of the tool in IPM programme in cabbage. Quick effect of acetamiprid, medium efficacy of vermiwash or neem and late efficacy of *Beauveria* suggests their use against aphid in an integrated way in cabbage.

Efficacy of treatment schedules against diamond back moth, *Plutella xylostella* L.: First two sprays were undertaken against sucking insect pests while 3rd and 4th spray against lepidopteran pests. Three d after third spray, the maximum reduction of DBM population was obtained in T_4 with chlorantraniliprole (83.65 and 82.08 %), T_2 with fipronil (82.37 and 81.24 %), T_9 again with fipronil (81.11 and 81.25 %), T_8 with spinosad (76.84 and 77.13 %), T_7 with emamectin benzoate (75.59 and 75.56 %), T_3 with emamectin benzoate (75.41 and 73.75 %). T_6 with *B. bassiana* (34.04 and 30.92 %) and T_5 with *Metarhizium anisopliae* (32.10 and 28.48 %) were at par, however T_1 with *M. anisopliae* (21.45 and 20.16 %) was least effective. At seven d after third spraying, treatments T_4 with chlorantraniliprole (82.10 and 81.01 %) was significant and most effective. T_2 with fipronil (78.37and 77.10 %), T_7 with emamectin benzoate (76.36 and 73.19 %) and T_9 with fipronil (75.51 and 74.54 %) were at par. T_8 (73.91 and 72.01 %) and T_3 (73.56 and 70.64 %) were at par. T_5 (59.34 and 54.84 %), T_6 (58.00 and 56.49 %) and T_1 (57.15 and 53.46 %) were at par and moderately effective. At 14 d after third spraying, treatment T_4 (81.34%) was most effective followed by T_9 (80.05%), T_2 (79.21%), T_8 (75.22%), T_7 (73.64%) while T_5 (67.2%), T_6 (66.03%), T1 (65.86%) were at par and second effective during 2009-10. During 2010-11 T_4 (80.11 %), T_2 (78.76%), T_9 (79.46%) were at par with and most effective.The efficacy of chlorantraniliprole continued till 14th days after spray. T_8 (76.95 %), T_7 (74.96 %) were at par with each other and second effective treatments (Table 3).

Three d after fourth spray, the higher population reduction was obtained in T_5 (86.40%), T_2 (85.84%) and T_7 (84.38%) all having chlorantraniliprole. T_9 (81.12%), T_6 both with spinosad (80.40%) were at par and second effective

Table 2. Effect of different treatments against aphid, *L. erysimi* (Kalt) on cabbage after 2nd spray in rabi 2009-2010 and 2010-2011

S.No.	Treatment#	Per cent reduction over control							
		Pre-treatment		3 DAS		7 DAS		14DAS	
		2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
T_1	Neembaan* – *M. anisopliae* -E. benzoate	66.51	64.84	55.29 (48.06)^{d}	53.82 (47.22)^{d}	30.60 (33.59)^{e}	38.68 (38.47)^{d}	27.85 (31.85)^{e}	29.43 (32.86)^{d}
T_2	Vermiwash* 1:1-Fipronil- Chlorantraniliprole	63.05	65.71	48.39 (44.10)^{e}	45.58 (42.48)^{e}	28.62 (32.33)^{ef}	24.13 (29.41)^{e}	25.88 (30.52)^{ef}	26.37 (30.91)^{de}
T_3	Vermiwash* 1:4 - E. benzoate-Spinosad	63.16	70.49	22.16 (28.07)^{f}	18.77 (25.64)^{f}	24.82 (29.88)^{f}	19.95 (26.45)^{e}	20.15 (26.69)^{f}	21.87 (27.87)^{f}
T_4	Acetamiprid* -Chlorantraniliprole- E. benzoate	44.04	42.40	84.78 (67.10)^{a}	78.34 (62.31)^{b}	64.81 (53.66)^{b}	58.67 (50.02)^{b}	48.87 (44.37)^{cd}	45.35 (42.35)^{c}
T_5	*B. bassiana**-*M. anisopliae*- chlorantraniliprole	28.29	65.11	16.89 (24.26)^{g}	19.10 (25.86)^{f}	51.28 (45.76)^{c}	46.89 (43.24)^{c}	66.71 (54.80)^{a}	63.68 (52.97)^{b}
T_6	Neembaan* - *B. bassiana*- Spinosad	55.93	59.27	62.35 (52.18)^{c}	63.42 (52.82)^{c}	33.92 (35.64)^{e}	35.34 (36.47)^{d}	30.28 (33.31)^{e}	24.90 (29.94)^{ef}
T_7	*B. bassiana** – E. benzoate- Chlorantraniliprole	16.03	54.64	14.62 (22.45)^{g}	19.42 (26.07)^{f}	44.54 (41.87)^{d}	47.53 (43.56)^{c}	61.90 (51.92)^{ab}	69.72 (56.65)^{a}
T_8	Acetamiprid* - Spinosad-- E. benzoate	51.59	44.59	84.28 (66.68)^{a}	81.82 (64.80)^{ab}	70.71 (57.27)^{a}	68.60 (55.96)^{a}	55.28 (48.06)^{bc}	46.76 (43.16)^{c}
T_9	Acetamiprid* -Fipronil -Spinosad	34.03	41.12	80.39 (63.76)^{b}	83.51 (66.09)^{a}	63.74 (53.02)^{b}	70.01 (56.84)^{a}	46.43 (42.97)^{d}	45.15 (42.24)^{c}
T_{10}	Control	81.93	86.51		-	-	-	-	-
	S.Em. (±)			0.836	1.159	1.108	1.308	1.381	0.778
	CD (P = 0.05)			2.508	3.476	3.324	3.921	4.142	2.335

#Neembaan EC @ 3 ml/L, Acetamiprid 20%SP@20g/ha , Vermiwash@ 1:1dilution, Vermiwash@ 1:4 dilution, *M. anisopliae* WP@2.5kg/ha, Spinosad 45 SC@75 g ai/ha, *B. bassiana* WP@2.5 kg/ha, Fipronil 5% EC@50 g ai/ha, Chlorantraniliprole 18.5 SC@10 g ai /ha, E. benzoate 5 sg@10 g ai./ha
Figures in parenthesis are arcsine transformed values.*Sprayed twice as First and Second Spray

Table 3. Effect of different treatments against daimond back moth, *Plutella xylostella* on cabbage after 3rd spray in rabi 2009-2010, 2010-2011

S.No.	Treatment#	Per cent reduction over control							
		Pre-treatment		3 DAS		7 DAS		14DAS	
		2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
T_1	Neembaan* – *M. anisopliae* -E. benzoate	6.33	5.67	21.45 (27.49)^{c}	20.16 (26.09)^{b}	57.15 (49.14)^{c}	53.46 (47.03)^{c}	65.86 (54.30)^{c}	64.98 (53.78)^{c}
T_2	Vermiwash* 1:1-Fipronil- Chlorantraniliprole	6.67	5.87	82.37 (65.21)^{a}	81.24 (64.37)^{a}	78.37 (62.32)^{ab}	77.10 (61.61)^{ab}	79.21 (62.91)^{ab}	78.76 (62.60)^{a}
T_3	Vermiwash* 1:4 - E. benzoate-Spinosad	6.80	6.07	75.41 (60.37)^{a}	73.75 (59.49)^{a}	73.56 (59.19)^{b}	70.64 (57.30)^{b}	71.11 (57.62)^{bc}	67.89 (55.59)^{bc}
T_4	Acetamiprid*-Chlorantraniliprole- E. benzoate	5.87	5.53	83.65 (66.19)^{a}	82.08 (65.09)^{a}	82.10 (65.02)^{a}	81.01 (64.22)^{a}	81.34 (64.72)^{a}	80.11 (63.86)^{a}
T_5	*B. bassiana**- *M. anisopliae*-Chlorantraniliprole	6.20	5.67	32.10 (34.46)^{b}	28.48 (32.21)^{b}	59.34 (50.43)^{c}	54.84 (47.83)^{c}	67.28 (55.15)^{c}	66.50 (54.67)^{c}
T_6	Neembaan* - *B. bassiana*- Spinosad	6.53	5.77	34.04 (35.68)^{b}	30.92 (33.70)^{b}	58.00 (49.64)^{c}	56.49 (48.79)^{c}	66.03 (54.40)^{c}	65.79 (54.28)^{c}
T_7	*B. bassiana** -E. benzoate- Chlorantraniliprole	5.93	6.20	75.59 (60.53)^{a}	75.56 (60.49)^{a}	76.36 (61.11)^{ab}	73.19 (58.84)^{ab}	73.64 (59.23)^{abc}	74.96 (60.06)^{abc}
T_8	Acetamiprid* - Spinosad-- E. benzoate	6.40	5.97	76.84 (61.42)^{a}	77.13 (61.47)^{a}	73.91 (59.39)^{b}	72.01 (58.15)^{ab}	75.22 (60.29)^{abc}	76.95 (61.40)^{ab}
T_9	Acetamiprid* -Fipronil -Spinosad	6.50	6.00	81.11 (64.53)^{a}	81.25 (64.58)^{a}	75.51 (60.41)^{ab}	74.54 (59.89)^{ab}	80.05 (63.70)^{ab}	79.46 (63.34)^{a}
T_{10}	Control	6.93	6.27	-	-	-	-	-	-
	S.Em. (±)			2.089	2.541	1.707	2.116	2.144	2.161
	CD (P = 0.05)			6.263	7.619	5.111	6.345	6.428	6.479

#Neembaan EC @ 3 ml/L, Acetamiprid 20% SP@20 g/ha , Vermiwash@ 1:1dilution, Vermiwash@ 1:4 dilution, *M. anisopliae* WP @2.5 kg/ha, Spinosad 45 SC@75 g ai/ha, *B. bassiana* WP @2.5 kg/ha, Fipronil 5% EC@50 g ai/ha, Chlorantraniliprole 18.5 SC@10 g ai/ha, E. benzoate 5 sg@10 g ai./ha
Figures in parenthesis are arcsine transformed values. *Sprayed twice as First and Second Spray

treatments. T_1 (74.29%), T_4 (70.05%) and T_8 all three with emamectin benzoate (69.27%) during 2009-10 were moderately effective. Higher the population reduction was obtained in T_5 (84.35 %), T_2 (84.02%) and T_7 (83.12 %) during 2010-11, which were at par and all most effective treatments. The treatments T_9 (79.43 %), T_6 (79.73 %) and T_3 (80.20%) all with spinosad were at par and second effective treatments. Seven d after fourth spraying, T_7 (84.04%) was significantly superior and most effective treatment, T_7 (84.38%) and T_2 (85.84%) were at par with each other and second effective treatments. T_5 (80.77%) and T_2 (79.07%) were at par and, followed by T_6 (76.58%), T_3 (74.11%) and T_8 (61.54%) during 2009-10. T_7 (82.08%), T_2 (81.06%), T_3 (76.92 %), T_5 (80.20%) were at par and effective treatments during 2010-11 supremacy of chlorantriniprole continued upto 7 days also. Fourteen d after 4[th] spray, the treatments T_7 (75.25 and 76.63 %), T_5 (75.05 and 76.81 %) and T_2 (72.15 and 75.85 %) were most effective treatments and at par with each other. Treatment schedules T_9 (65.35 and 66.05 %), T_6 (63.55 and 64.71 %) and T_3 (62.29 and 65.66 %), were second effective treatments and were at par followed by T_4 (51.91 and 47.47 %), T_8 (50.85 and 49.77 %) and T_1 (46.43 and 48.41 %) (Table 4).

Our results suggest that chlorantraniliprole was most effective insecticide both after 3[rd] and 4[th] spray and its efficacy continued upto 14 days. The next best treatment was spinosad. It appears that relevant literature of chlorantrinipole is not available. It was for the first time registered at Phillippines in 2007 to protect cabbage, aubergines, beans and rice[10]. It was also recommended in Italy for control of the codling moth (*Cydia pomonella*)[11]. Low toxicity of spinosad to most beneficial insects and no phytotoxicity has been demonstrated with this product[12]. Spinosad has a reduced risk to humans compared to

Table 4. Effect of different treatments against daimond back moth, *Plutella xylostella* on cabbage after 4^{th} spray in rabi 2009-2010, 2010-2011

S.No.	Treatment$^{\#}$	Per cent reduction over control							
		Pre-treatment		3 DAS		7 DAS		14DAS	
		2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
T_1	Neembaan* – *M. anisopliae* -E.benzoate	8.23	8.80	74.29 (59.57)^{e}	73.50 (59.15)^{cd}	72.76 (58.57)^{e}	71.18 (57.59)^{bcd}	46.43 (42.97)^{d}	48.41 (44.11)^{c}
T_2	Vermiwash* 1:1-Fipronil- Chlorantraniliprole	7.78	7.63	85.84 (67.93)^{a}	84.02 (66.52)^{a}	79.01 (62.77)^{bc}	81.06 (64.45)^{ab}	72.15 (58.18)^{a}	75.85 (60.64)^{a}
T_3	Vermiwash* 1:4 - E.benzoate- Spinosad	7.33	8.23	77.36 (61.62)^{de}	80.20 (63.62)^{ab}	74.11 (59.45)^{de}	76.91 (61.32)^{abcd}	62.29 (52.15)^{b}	65.66 (54.17)^{b}
T_4	Acetamiprid*-Chlorantraniliprole- E.benzoate	6.31	7.77	70.05 (56.85)^{f}	74.01 (59.38)^{bcd}	67.56 (55.31)^{f}	70.94 (57.41)^{cd}	51.91 (46.12)^{c}	47.47 (43.57)^{c}
T_5	*B.bassiana**- *M. anisopliae*-Chlorantraniliprole	8.07	8.60	86.40 (68.40)^{a}	84.35 (66.74)^{a}	80.77 (64.03)^{b}	81.20 (64.35)^{abc}	75.05 (60.07)^{a}	76.81 (61.26)^{a}
T_6	Neembaan *- *B.bassiana*- Spinosad	8.77	8.10	80.40 (63.78)^{cd}	79.73 (63.30)^{abc}	76.58 (61.12)^{cd}	76.42 (61.32)^{abcd}	63.55 (52.89)^{b}	64.71 (53.60)^{b}
T_7	*B.bassiana** -E.benzoate- Chlorantraniliprole	6.89	8.32	84.38 (66.76)^{ab}	83.12 (65.85)^{a}	84.04 (66.55)^{a}	82.08 (65.01)^{a}	75.25 (60.22)^{a}	76.63 (61.13)^{a}
T_8	Acetamiprid* - Spinosad-- E.benzoate	7.30	8.00	69.27 (56.42)^{f}	72.02 (58.14)^{d}	71.92 (58.04)^{e}	70.29 (57.22)^{d}	50.85 (45.51)^{cd}	49.77 (44.89)^{c}
T_9	Acetamiprid* -Fipronil -Spinosad	7.80	7.83	81.12 (64.28)^{bc}	79.43 (63.10)^{abc}	61.54 (51.70)^{g}	49.13 (44.52)^{e}	65.35 (53.97)^{b}	66.05 (54.39)^{b}
T_{10}	Control	11.41	10.03	-	-	-	-	-	-
	S.Em. (±)			0.857	1.431	0.737	2.347	1.047	1.023
	CD (P = 0.05)			2.569	4.291	2.212	7.038	3.140	3.069

$^{\#}$Neembaan EC @ 3 ml/L, Acetamiprid 20%SP@20g/ha, Vermiwash@ 1:1dilution, Vermiwash@ 1:4 dilution, *M. anisopliae* WP @2.5 kg/ha, Spinosad 45 SC@75 g ai/ha, *B. bassiana* WP @2.5 kg/ha, Fipronil 5% EC@50 g ai/ha, Chlorantraniliprole 18.5 SC@10 g ai/ha, E. benzoate 5 sg@10 g ai/ha

Figures in parenthesis are arcsine transformed values. *Sprayed twice as First and Second Spray

synthetic insecticides and excellent environment profile with reduced risk to fish, birds, earthworms and mammals[13]. Spinosad is used for the control of insect pests on fruit and vegetable crops, cotton, tree and vine crops and ornamentals on a global basis. In our findings spinosad was superior to all the insecticides tested except chlorantraniliprole. However at certain times i.e. 3DAS after 3^{rd} spray it was at par with chlorantraniliprole and at certain occasions after 4^{th} spray. Foliar spray of emamectin benzoate @ 10 g a.i. ha^{-1} and 8.75 g a.i. ha^{-1} doses were effective against *P. xylostella* L. in reducing the larval population by 80.15 and 79.23; 86.23 and 81.33%, respectively after 3 and 7 d after spray[14]. Eight isolates of entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae* indigenous to Benin were screened for virulence against larvae of Diamond backmoth (DBM) *Plutella xylostella.* The isolate Bba5653 caused 94% mortality of DBM larvae and the mortality significantly higher than any isolates[15].

Efficacy against cabbage butterfly, *P. brassicae* L.: Three d after third spray, the maximum PROC of cabbage butterfly larval population was obtained in T_4 with chlorantraniliprole (84.42 and 84.54 %) which was most effective treatment and at par T_2 with fipronil (82.57 and 80.98 %) and T_9 with fipronil (80.91 and 81.33 %). T_7 with emamectin benzoate (72.28 and 77.51 %) was the second effective treatment. Seven d after third spray, the highest PROC of cabbage butterfly larval population was again obtained in T_4 (79.54 and 80.12 %) followed by T_2 (71.06 and 71.94 %) and T_7 (71.83 and 73.71%). On 14^{th} d after third spraying, the maximum reduction of cabbage butterfly larval population was obtained in T_4 (79.39%) and at par with T_8 (76.60 %) and T_2 (75.56 %) during 2009-10. In the year 2010-11, the highest reduction of cabbage butterfly larval population were obtained in T_4 (81.30 %) and T_7 (79.92 %) were most effective treatments and T_8 (75.35 %) were at par. T_3 (71.23 %), T_9 (70.37 %) and T_6 (68.75 %) were at par and second effective treatments. T_1 (66.31 %), T_4 (65.48%) and T_5

Table 5. Effect of different treatments against cabbage butterfly, *P. brassicae* on cabbage after 3rd spray in rabi 2009-2010 and 2010-2011

S.No.	Treatment#	Per cent reduction over control							
		Pre-treatment		3 DAS		7 DAS		14DAS	
		2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
T_1	Neembaan* – *M. anisopliae* -E. benzoate	10.51	10.40	19.65 (26.32)^{d}	17.40 (24.64)^{d}	45.01 (42.16)^{e}	45.40 (42.33)^{d}	63.48 (52.85)^{e}	66.31 (54.56)^{c}
T_2	Vermiwash* 1:1-Fipronil- Chlorantraniliprole	12.23	10.27	82.57 (65.38)^{a}	80.98 (64.23)^{ab}	71.06 (57.49)^{b}	71.94 (58.08)^{ab}	75.56 (60.41)^{ab}	65.48 (54.05)^{c}
T_3	Vermiwash* 1:4 - E. benzoate-Spinosad	9.81	9.68	63.05 (52.62)^{c}	60.10 (50.87)^{c}	59.95 (50.78)^{c}	72.06 (58.20)^{ab}	74.38 (59.65)^{bc}	71.23 (57.61)^{bc}
T_4	Acetamiprid*-Chlorantraniliprole- E. benzoate	11.46	10.30	84.42 (66.79)^{a}	84.54 (67.09)^{a}	79.54 (63.16)^{a}	80.12 (63.58)^{a}	79.39 (63.06)^{a}	81.30 (64.58)^{a}
T_5	*B. bassiana**-*M. anisopliae*-Chlorantraniliprole	11.21	10.25	18.89 (25.63)^{d}	16.96 (24.03)^{d}	53.30 (46.92)^{d}	48.54 (44.17)^{d}	67.19 (55.08)^{de}	64.35 (53.38)^{c}
T_6	Neembaan *- *B. bassiana*- Spinosad	10.81	10.72	17.99 (24.76)^{d}	14.94 (22.49)^{d}	45.53 (42.46)^{e}	49.85 (44.95)^{d}	63.80 (53.05)^{e}	68.75 (56.05)^{bc}
T_7	*B. bassiana** -E. benzoate- Chlorantraniliprole	11.10	9.88	72.28 (58.28)^{b}	77.51 (61.79)^{b}	71.83 (58.02)^{b}	73.71 (59.19)^{ab}	74.80 (59.94)^{b}	79.92 (63.57)^{a}
T_8	Acetamiprid* - Spinosad-- E. benzoate	9.81	10.09	68.47 (55.91)^{bc}	64.78 (53.64)^{c}	58.94 (50.20)^{c}	60.61 (51.16)^{c}	76.60 (61.11)^{ab}	75.35 (60.55)^{ab}
T_9	Acetamiprid* -Fipronil -Spinosad	11.58	10.91	80.91 (64.13)^{a}	81.33 (64.49)^{ab}	69.52 (56.56)^{b}	70.43 (57.09)^{bc}	69.99 (56.85)^{cd}	70.37 (57.09)^{bc}
T_{10}	Control	12.39	10.80		-	-	-	-	-
	S.Em. (±)			1.571	1.712	0.945	2.068	0.959	1.698
	CD (P = 0.05)			4.711	5.134	2.834	6.202	2.875	5.093

#Neembaan EC @ 3 ml/L, Acetamiprid 20% SP@20 g/ha , Vermiwash@ 1:1 dilution, Vermiwash@ 1:4 dilution, *M. anisopliae* WP @2.5 kg/ha, Spinosad 45 SC@75 g ai/ha, *B. bassiana* WP @2.5 kg/ha, Fipronil 5% EC@50 g ai/ha, Chlorantraniliprole 18.5 SC@10 g ai/ha, E. benzoate 5 sg@10 g ai/ha

Figures in parenthesis are arcsine transformed values. *Sprayed twice as First and Second Spray

(64.35%) were at par and less effective compared to the other treatments (Table 5).

Three d after fourth spray the maximum reduction of cabbage butterfly larval population was obtained in T_5 (87.63 %) and was the most effective treatment. T_5, T_7 (83.86 %) and T_2 (83.04 %) all three with chlorantraniliprole were at par; T_3 (73.45 %), T_9 (73.69%), T_6 (73.55 %) all three with spinosad were at par during 2009-10. Almost similar results trend followed during 2010-11. Chlorantraniliprole was also found effective on 7th d after fourth spray. T_5 (85.29 %) was most effective followed by T_7 (79.60 %) and T_2 (78.73 %) in first year. In second year T_2 (78.60%) was most effective treatment followed by T_7 (76.77 %) and T_5 (75.92%). At 14 d after 4th spraying, the maximum reduction of cabbage butterfly larval population was obtained in first year with T_5 (79.16 %), T_7 (68.54 %) and T_2 (67.57%), the efficacy of chlorantraniliprole persisted even after 14 DAS. Spinosad as T_3, T_6 and T_9 was next effective treatment. In second year, T_7 (75.88 %) and T_2 (73.90 %) were most effective treatments (Table 6).

Chlorantraniliprole is used to protect cabbage, aubergines, beans and rice. It exhibits a distinguishing insecticidal activity on the level of 0.01-0.06 ppm, towards the most of species of Lepidoptera order[10]. Four to six applications of spinosad @ 6-96 g/ha were made at 6-10 intervals from 3-7 weeks post transplanting to harvest, it have a high level of control of DBM , *P. brassicae* and leaf miner larvae[16]. Emamectin benzoate (Proclaim 5% SG) is both a stomach and contact insecticide used primarily for the control of lepidopteran pests on cole crops and leaf vegetables[17]. Shortly after exposure, the caterpillar stopped feeding and became irreversibly paralyzed and died within three to four days[18]. Our findings suggest that chlorantraniliprole was most effective against *Pieris* which was closely followed by spinosad. Alternate spray of spinosad and chlorantraniliprole could be an answer to manage DBM and *Pieris* in cabbage.

Effect on yield: Based on yield performance, all the insecticides treated plots were significantly different from

Table 6. Effect of different treatments against cabbage butterfly, *P. brassicae* on cabbage after 4th spray in rabi 2009-2010 and 2010-2011

S.No.	Treatment#	Per cent reduction over control							
		Pre-treatment		3 DAS		7 DAS		14DAS	
		2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
T_1	Neembaan* – *M. anisopliae* -E. benzoate	13.81	12.45	68.86 (56.15)c	70.84 (57.35)cd	61.22 (51.52)fg	62.15 (52.06)cd	54.39 (47.54)e	50.83 (45.50)c
T_2	Vermiwash* 1:1-Fipronil- Chlorantraniliprole	12.18	10.90	83.04 (65.78)ab	82.77 (65.51)ab	78.73 (62.60)b	78.60 (62.58)a	67.57 (55.32)b	73.90 (59.69)a
T_3	Vermiwash* 1:4 - E. benzoate-Spinosad	14.09	10.90	73.45 (59.04)bc	68.29 (55.88)cd	74.97 (60.04)bc	66.23 (54.53)bcd	58.28 (49.79)d	64.32 (53.43)abc
T_4	Acetamiprid*-Chlorantraniliprole- E. benzoate	12.91	11.62	74.28 (59.77)bc	74.99 (60.23)bc	55.92 (48.43)g	60.37 (51.02)cd	44.24 (41.71)f	71.78 (58.50)ab
T_5	*B. bassiana**-*M. anisopliae*-Chlorantraniliprole	14.76	12.59	87.63 (69.45)a	84.84 (67.17)a	85.29 (67.56)a	75.92 (61.30)ab	79.16 (62.89)a	70.98 (57.80)ab
T_6	Neembaan*- *B. bassiana*- Spinosad	14.14	12.45	73.55 (59.39)bc	72.63 (58.53)cd	73.01 (58.75)cd	67.11 (55.10)bcd	58.49 (49.92)d	63.56 (52.98)abc
T_7	*B. bassiana** -E. benzoate- Chlorantraniliprole	10.53	9.46	83.86 (66.56)a	82.36 (65.32)ab	79.60 (63.22)b	76.77 (61.27)ab	68.54 (55.95)b	75.88 (60.69)a
T_8	Acetamiprid* - Spinosad- E. benzoate	14.67	11.29	67.54 (55.38)c	64.79 (53.67)d	65.45 (54.05)ef	55.20 (48.01)d	51.37 (45.81)e	56.91 (49.05)c
T_9	Acetamiprid* -Fipronil -Spinosad	12.54	10.64	73.69 (59.19)bc	68.88 (56.16)cd	68.91 (56.15)de	69.06 (56.31)abc	62.39 (52.20)c	59.38 (50.54)bc
T_{10}	Control	18.33	16.77		-	-	-	-	-
	S.Em. (±)			2.262	1.698	1.125	2.462	0.745	2.814
	CD (P = 0.05)			6.783	5.093	3.373	7.383	2.234	8.436

#Neembaan EC @ 3 ml/L, Acetamiprid 20% SP@20 g/ha, Vermiwash@ 1:1 dilution, Vermiwash@ 1:4 dilution, *M. anisopliae* WP @2.5 kg/ha, Spinosad 45 SC@75 g ai/ha, *Beauveria bassiana* WP @2.5 kg/ha, Fipronil 5% EC@50 g ai/ha, Chlorantraniliprole 18.5 SC@10 g ai/ha, E. benzoate 5 sg@10 g ai./ha
Figures in parenthesis are arcsine transformed values. *Sprayed twice as First and Second Spray

Table 7. Effect different treatments on the yield of cabbage during *rabi* 2010-2011

S.No.	Treatment#	MarketableYield (ton/ha) 2009-10	MarketableYield (ton/ha) 2010-11
T_1	Neembaan* – *M. anisopliae* -E.benzoate	25.2b	26.24cd
T_2	Vermiwash* 1:1-Fipronil- Chlorantraniliprole	24.3bcd	25.40cd
T_3	Vermiwash* 1:4 - E.benzoate-Spinosad	22.9d	23.53e
T_4	Acetamiprid* -Chlorantraniliprole - E.benzoate	30.6a	32.17a
T_5	*B.bassiana** -*M. anisopliae* -Chlorantraniliprole	23.2cd	22.88e
T_6	Neembaan* - *B.bassiana*- Spinosad	25.5b	26.53c
T_7	*B.bassiana* *– E.benzoate- Chlorantraniliprole	24.8bc	25.20d
T_8	Acetamiprid* - Spinosad-- E.benzoate	28.9a	29.97b
T_9	Acetamiprid* -Fipronil -Spinosad	29.01a	31.24a
T_{10}	Control	17.21e	18.07f
S.Em. (±)	0.589	0.390	
CD (P = 0.05)	1.751	1.16	

#Neembaan EC @ 3 ml/L, Acetamiprid 20% SP@20 g/ha, Vermiwash@ 1:1dilution, Vermiwash@ 1:4 dilution, *M. anisopliae* WP@2.5 kg/ha, Spinosad 45 SC@75 g ai/ha, *B. bassiana* WP@2.5 kg/ha, Fipronil 5% EC@50 g ai/ha, Chlorantraniliprole 18.5 SC@10 g ai/ha, E. benzoate 5 sg@10 g ai./ha, *Sprayed twice as First and Second Spray

control by more number of healthy heads, higher average width and weight of heads during both the seasons. The yield gain over control was highest in treatments T_4 (30.6 and 32.17 t/ha) followed by T_9 (29.01 and 31.24 t/ha), T_8 (28.9 and 29.97 t/ha), T_6 (25.5 and 26.53 t/ha) and T_1 (25.2 and 26.24 t/ha) as compared to 17.21 and 18.07 t/ha in control in 2009-10 and 2010-11 respectively (Table 7).

Based on yield performance and efficacy against insect pests *viz*. T_4 (acetamiprid-acetamiprid-chlorantraniliprole-emamectin benzoate), T_8 (acetamiprid-acetamiprid-spinosad-emamectin benzoate) and T_9 (acetamiprid-acetamiprid-fipronil-spinosad) performed extremely well. Use of bio-rational and low dose compounds such as spinosid, acetamiprid, emamectin benzoate will also be more appropriate as compared to conventional broad spectrum, high dose insecticides as they enable to conserve natural enemy fauna and minimize residual load in fruits and environment[19]. In our study vermiwash and *Beauveria* were found effective against aphids. These can be utilised in organic farming. Besides, their compatibility with other insecticides need to be worked and for their possible use in IPM programme. Current public concern about some chemicals in agriculture causing health and environmental problems, and the requirements of some overseas countries for no synthetic chemical residues in agricultural products has reinforced the need to develop techniques to eliminate or reduce the present level of chemical inputs in vegetable growing.

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Manuscript No. PRJ/08/11-01
Received 02 August, 2011; Accepted 08 November, 2011

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