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Compatibility of pheromones of diamond back moth, *Plutella xylostella* (L.) with insecticide sprays in cabbage

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Abstract
The results of experiments conducted in cabbage at Bangalore, South India revealed that Emamectin Benzoate costs the least deterred the moth catches. Chlorantranilirpole and Spinosad plots were also recorded more number of moth catches in water traps. The results also showed that Emamectin Benzoate sprayed in pheromone traps installed plots was significantly superior in terms of DBM management over other insecticides sprayed in pheromone installed plots and also when the same insecticides sprayed alone without pheromone traps. This indicated that there was no interactions of the insecticides for moth catches in pheromone traps at the same time there will be control of DBM population under field conditions.

Keywords: Compatibility, pheromones, *Plutella xylostella*, cabbage

1. Introduction
The chief constraint in the production of cabbage is damage caused by pests complex right from germination till harvest stage. Among them, diamond back moth (DBM), *Plutella xylostella* (L.) has become major limiting factor for successful cultivation of cabbage in India [9, 11]. DBM is known to cause yield loss from 31 to 100 per cent [1, 2]. This insect damages the crop by feeding on the foliage. Attack of a large number of larvae of this pest hinders the health, growth and development of the plant resulting in considerable loss of yields, very young plants may even die.

Commercial consideration of this crop has compelled the growers to go for more frequent and injudicious use of insecticides, for better marketable yield. This has resulted in several problems *viz*., pesticide resistance [12, 8, 5], resurgence [6], residue problems, inefficiency of natural enemies due to effect of chemicals and environmental pollution, *etc.* The growing concern about the risk of use of pesticides to the farmers, consumers and environment has resulted in more emphasis on organic farming and sustainable production of vegetables. The search for alternatives to overcome these problems has led extensive research on use of pheromones for pest management. The use of synthetic sex pheromones for manipulating the behaviour of insect pests has captured worldwide attention today. The trapping of moths by synthetic sex pheromones provide a sound basis for timely pesticides application and for control strategies. Generally cabbage growers in and around Bangalore and adjacent districts do not resist from applying insecticides irrespective of the implementation of other management tools. So, the compatibility of pheromones with insecticide sprays is important.

2. Material and methods
Investigations were carried out under field conditions in cabbage (variety Unnati) fields infested with diamond back moth (DBM), *P. xylostella* at Jinkebacchahalli and Vishwanathpur villages of North Bangalore. The composition of the pheromone components of *P. xylostella* is *Z-11-hexadecenal and Z-11-hexadecenyl acetate*. The pheromone impregnated rubber septa used in these studies were manufactured and supplied by M/s Pest Control India Pvt. Ltd., Bio-control Research Laboratories (BCRL), Sreeramanahalli, Arakere post, Bangalore-561 203, Karnataka.

The traps used for the study were Wota T™ traps. It is a water trap designed by M/s Pest Control India Pvt. Ltd, Bangalore for mass trapping pests such as sugarcane borers, brinjal

Shoot and fruit borer, diamondback moth, etc. Wota-T™ is easy to assemble on a single pole. The trap consists of a plastic bowl (25cm×10cm dia); adapter, basin to hold water mixed with oil or detergent and a lure holder with a canopy. About three fourth of the container is filled with water and oil is poured on the surface of water to hold moths. The pheromone septa are suspended from the lure holder from the centre of the basin. Moths attracted to the trap are killed when they fall into the water containing oil.

To select insecticides for the study, 50 cabbage farmers fields were chosen from Bangalore North and were interviewed using a Proforma. The chemical insecticides sprayed against DBM in cabbage ecosystem were listed. A majority of the insecticides sprayed against DBM were found and three commonly used insecticides in farmer's fields were Chlorantraniliprole 18.5%SC @ 0.3ml/l, Spinosad 45% SC @0.5ml/l and Emamectin benzoate 5 SG @0.5g/l.

These selected insecticides were separately sprayed in pheromone traps installed at fields and in the fields without pheromone traps. The experiment was carried out in different farmer's fields of cabbage in Vishwanthpura and Jinkebacchahalli of Bangalore North. The fields were selected in such a way that there was a minimum distance of 0.5 km between the fields. The crop stage selected was 15 days old after transplanting. Three sprays were given on 10, 20 and 30 days after installation of the traps. Before the first spray, the pre-treatment observations were made on the number of moth catches in traps and number of DBM (larvae and pupae) on 50 selected cabbage plants. Observations were also made on post treatment at 1, 3, 5, 7 and 10 days after each spray. The treatments were replicated 5 times in each field. The data obtained was transformed to $\sqrt{(X + 0.5)}$ transformation before analysis by Two way ANOVA following Randomized Complete Block Design (RCBD).

3. Results and discussion

Generally cabbage growers in and around Bangalore do not resist from applying insecticide irrespective of the execution or implementation of other management tools. So, commonly used insecticides by cabbage growers were selected to determine the compatibility of selected insecticides with the moths in pheromone traps. To know the interaction effects, observations on moth catches in the traps and DBM infestation in the cabbage plants were taken.

3.1 Compatibility of selected insecticides and its influence on the moth catches

Data in Table 1 showed that significant variations in moth catches in the traps among the treatments after the first spray was observed after 3 DAS. The moth catches in pheromone traps alone were higher (8.88 moths / trap) compared with other treatments. The mean number of moth catches in 20 traps + Emamectin Benzoate was 7.94 moths / trap and were more compared to 20 traps + Chlorantraniliprole (7.70 moths / trap) and least in 20 pheromone traps + Spinosad (7.33 moths / trap).

Similar trend was observed after the second spray (Table 2) where the moth catches in pheromone traps alone higher (18.03 moths / trap) compared with all other treatments. However, the moth catches were significantly increased after the 1st spray. There was no reduction in moth catches even after the intervention of the chemical sprays. The mean number of moth catches in 20 traps + Emamectin Benzoate and in 20 traps + Chlorantraniliprole was 16.57 moths per trap and 16.12 moths / trap which was more compared to 20 pheromone traps + Spinosad (15.05 moths / trap).

The data in Table 3 revealed significant differences among the treatments after the third spray. After the third spray also, the same trend was observed where the moth catches in pheromone traps alone were higher (34.12 moths / trap) compared with other treatments. The mean number of moth catches in 20 traps + Emamectin Benzoate was 30.18 moths per trap and were more compared to 20 traps + Chlorantraniliprole (20.03 moths / trap) and the least in 20 pheromone traps + Spinosad (26.29 moths / trap).

The results suggested that the Emamectin Benzoate costs the least and deterred the moths. Chlorantranilirpole and Spinosad plots were also recorded more number of moth catches in water traps. This also indicated that insecticides can be used in pheromone installed traps which will not deter the moth catches in pheromone traps and there will be reduction in the upcoming generation of DBM in the fields.

The study conducted by [3] on effectiveness of combinations of insecticides with pheromones for control of pink boll worm may depend on, among other factors, males freely contacting attracticide sources, insecticide-induced mortality, and sub lethal interference with the mate-locating sequence in poisoned males. In flight-tunnel tests, males readily contacted pheromone sources containing permethrin, fenvalerate or cypermethrin and suffered significant mortality.

3.2 Infestation of DBM on insecticide sprayed cabbage plants

Three promising insecticides commonly used by the cabbage growers *viz*., Chlorantraniliprole, Spinosad and Emamectin Benzoate alone and in pheromone traps installed plots were tested against DBM population (larvae and pupae) on cabbage crop under field conditions during study period. Totally three sprays were given commencing from 15 days after transplanting of the crop with an interval of 10 days.

Pre-treatment count of DBM population at a day before spray revealed that there were no significant differences between the treatments indicating the uniformity in the distribution of pests in the field and DBM population, varied 10.98 to 12.03 DBM per plant (Table 4). The entire tested chemical in pheromone installed plot and also insecticide alone plots shown better control of larvae and pupae of DBM.

From the first spray, the mean number of DBM population observed was the least in 20 pheromone traps + Emamectin benzoate treatment (4.21 DBM/plant) which is superior to the treatments followed by 20 pheromone traps + chlorantraniliprole (4.69 DBM/plant), emamectin benzoate alone (5.39 DBM/plant), chlorantraniliprole alone (5.40 DBM/plant), 20 pheromone traps + spinosad (5.85 DBM/plant) and spinosad alone (7.04 DBM/plant). In control plot, 13.30 DBM/plant was recorded (Table 4).

From second spray, the overall mean number of DBM population recorded the least in 20 pheromone traps + emamectin benzoate (0.47 DBM/plant) plots which significantly superior to the other treatments. It was followed by 20 pheromone traps + chlorantraniliprole which recorded 0.93 DBM per plant. In control, there was an increasing trend which recorded higher number of DBM numbers i.e. 24.97 DBM per plant (Table 5).

From the overall third spray, 20 pheromone traps + emamectin benzoate recorded the least number of DBM population per plant i.e. 0.27 DBM per plant, followed by 20 pheromone traps + chlorantraniliprole (0.62 DBM/plant). The highest number of DBM population was found in control (37.81 DBM/plant) (Table 6).

The results showed that emamectin benzoate sprayed in pheromone traps installed treatment was significantly superior over other insecticides sprayed in pheromone installed plots and also the same insecticides sprayed without pheromone traps installed plots. More number of moth catches resulted from the Emamectin benzoate sprayed plot in pheromone traps at the same time there were reduction in larvae and pupae in the same plot. This indicated that there was no interactions of the insecticides for moth catches in pheromone traps. At the same time there will be control of DBM population under field conditions.

Spinosad works by affecting the nicotinic acetylcholine receptors on the postsynaptic nerve cell [10]. The results from experiments conducted by [7] found that spinosad 2.5 SC a relatively new class of insecticide gave significantly better control of *P. xylostella* when applied @ 15, 20 and 25 g *a.i.* per ha on cabbage at Secunderabad (Telangana), India. Spinosad and emamectin benzoate were the most efficacious at consistently providing excellent control of DBM moth populations and were consistently effective at maintaining moth populations below the economic threshold level in the later stages of field trials, especially when DBM moth larvae averaged more than three per plant [4].

Table 1: Diamond Back Moth catches in pheromone traps after the first spray of insecticides in cabbage fields

Treatments	**No. of moths / trap**						**Mean moth / trap**
	Pre	**1 DAS**	**3 DAS**	**5 DAS**	**7 DAS**	**10 DAS**	
20 Traps + Chlorantraniliprole 18.5SC	4.55 (2.24)	4.75 (2.25)^{a}	5.70 (2.47)^{bc}	8.15 (2.93)^{c}	10.25 (3.26)^{c}	12.8 (3.64)^{b}	7.70
20 Traps + Spinosad 45SC	4.25 (2.17)	4.30 (2.17)^{a}	5.45 (2.42)^{c}	7.85 (2.86)^{c}	10 (3.24)^{c}	12.10 (3.55)^{c}	7.33
20 Traps + Emamectin benzoate 5SG	4.4 (2.21)	5.0 (2.34)^{a}	5.85 (2.52)^{b}	8.65 (3.02)^{b}	10.8 (3.36)^{b}	12.95 (3.67)^{b}	7.94
20 Traps	4.75 (2.27)	5.65 (2.48)^{a}	7.15 (2.76)^{a}	9.35 (3.13)^{a}	12.05 (3.54)^{a}	14.35 (3.85)^{a}	8.88
‘F’ test	NS	NS	*	*	*	*	
SEM±	0.10	0.15	0.09	0.13	0.08	0.08	
CD at P=0.05	-	-	0.27	0.40	0.25	0.25	

DAS: Days after spray; * Significant at P=0.05; NS: Non significant; Values in the parentheses are $\sqrt{X+0.5}$ transformed values; Mean values with same alphabetical superscript within a column are not significantly different.

Table 2: Diamond Back Moth catches in pheromone traps after the second spray of insecticides in cabbage fields

Treatments	**No. of moths / trap**					**Mean moth / trap**
	1 DAS	**3 DAS**	**5 DAS**	**7 DAS**	**10 DAS**	
20 Traps + Chlorantraniliprole 18.5SC	14.15 (3.82)^{ab}	14.9 (3.92)^{b}	15.60 (4.01)^{ab}	15.95 (4.06)^{ab}	20 (4.52)^{ab}	16.12
20 Traps + Spinosad 45SC	13.55 (3.75)^{b}	14.3 (3.84)^{b}	14.75 (3.90)^{b}	15.05 (3.94)^{b}	17.6 (4.24)^{b}	15.05
20 Traps + Emamectin benzoate 5SG	14.75 (3.90)^{ab}	15.15 (3.96)^{ab}	16 (4.06)^{ab}	16.20 (4.08)^{ab}	20.75 (4.60)^{ab}	16.57
20 Traps	16 (4.06)^{a}	16.60 (4.13)^{a}	16.95 (4.18)^{a}	17.45 (4.23)^{a}	23.15 (4.85)^{a}	18.03
‘F’ test	*	*	*	*	*	
SEM±	0.08	0.06	0.07	0.08	0.15	
CD at P=0.05	0.26	0.19	0.20	0.23	0.46	

DAS: Days after spray; * Significant at P=0.05; NS: Non significant; Values in the parentheses are $\sqrt{X+0.5}$ transformed values; Mean values with same alphabetical superscript within a column are not significantly different.

Table 3: Diamond Back Moth catches in pheromone traps after the third spray of insecticides in cabbage fields

Treatments	**No. of moths / trap**					**Mean moth / trap**
	1 DAS	**3 DAS**	**5 DAS**	**7 DAS**	**10 DAS**	
20 Traps + Chlorantraniliprole 18.5SC	22.25 (4.75)^{bc}	24.40 (4.99)^{b}	27 (5.23)^{b}	32.25 (5.71)^{bc}	34.25 (5.89)^{bc}	28.03
20 Traps + Spinosad 45SC	20.10 (4.53)^{c}	22.45 (4.79)^{c}	25.90 (5.13)^{b}	30.05 (5.52)^{c}	32.95 (5.78)^{c}	26.29
20 Traps + Emamectin benzoate 5SG	23.45 (4.89)^{b}	25.25 (5.07)^{b}	29.35 (5.46)^{b}	35.8 (6.02)^{ab}	37.05 (6.13)^{b}	30.18
20 Traps	26.55 (5.20)^{a}	29.45 (5.47)^{a}	33.55 (5.83)^{a}	39.39 (6.31)^{a}	41.8 (6.50)^{a}	34.12
‘F’ test	*	*	*	*	*	
SEM±	0.09	0.05	0.11	0.08	0.09	
CD at P=0.05	0.29	0.15	0.34	0.25	0.28	

DAS: Days after spray; * Significant at P=0.05; NS: Non significant; Values in the parentheses are $\sqrt{X+0.5}$ transformed values; Mean values with same alphabetical superscript within a column are not significantly different.

Table 4: Diamond Back Moth larvae and pupae on cabbage plants after the first spray of insecticides in pheromone traps installed cabbage fields

Treatments	No. of larvae + pupae of DBM / plant						Mean
	Pre	1DAS	3DAS	5DAS	7DAS	10DAS	
20 Traps + Chlorantraniliprole 18.5SC	11.30 (3.43)	7.50 (2.83)^{d}	2.78 (1.81)^{de}	2.10 (1.61)^{d}	1.30 (1.34)^{e}	3.15 (1.91)^{f}	4.69
20 Traps + Spinosad 45SC	12.03 (3.53)	9.13 (3.10)^{c}	3.53 (2.00)^{d}	3.08 (1.89)^{c}	2.35 (1.68)^{d}	4.98 (2.34)^{d}	5.85
20 Traps + Emamectin benzoate 5SG	11.60 (3.48)	7.50 (2.83)^{d}	2.05 (1.59)^{e}	1.50 (1.41)^{e}	0.78 (1.16)^{f}	1.85 (1.53)^{g}	4.21
Chlorantraniliprole 18.5SC	11.10 (3.40)	8.90 (3.06)^{cd}	5.60 (2.46)^{c}	4.08 (2.14)^{b}	2.70 (1.79)^{cd}	5.45 (2.44)^{cd}	6.31
Spinosad 45SC	11.85 (3.51)	9.80 (3.21)^{bc}	6.50 (2.64)^{c}	4.65 (2.14)^{b}	3.05 (1.88)^{c}	6.38 (2.62)^{c}	7.04
Emamectin benzoate 5SG	11.58 (3.47)	9.48 (3.15)^{c}	3.2 (1.92)^{d}	2.38 (2.27)^{b}	1.65 (1.46)^{e}	4.05 (2.13)^{e}	5.39
20 pheromone Traps	11.58 (3.47)	11.15 (3.41)^{ab}	9.18 (3.10)^{b}	9.08 (1.69)^{d}	7.83 (2.88)^{b}	8.38 (2.98)^{b}	9.53
Control (Untrapped & Unsprayed)	10.98 (3.39)	11.70 (3.49)^{a}	12.55 (3.61)^{a}	13.60 (3.75)^{a}	14.20 (4.70)^{a}	17.78 (4.27)^{a}	13.47
'F' test	NS	*	*	*	*	*	
SEM±	0.08	0.08	0.08	0.05	0.05	0.62	
CD at P=0.05	0.22	0.23	0.25	0.15	0.16	0.18	

DAS: Days after spray; * Significant at P=0.05; NS: Non significant; Values in the parentheses are √X+0.5 transformed values; Mean values with same alphabetical superscript within a column are not significantly different.

Table 5: Diamond Back Moth larvae and pupae on cabbage plants after the second spray of insecticides in pheromone traps installed cabbage fields

Treatments	No. of larvae + pupae of DBM / plant					Mean
	1DAS	3DAS	5DAS	7DAS	10DAS	
20 Traps + Chlorantraniliprole 18.5SC	1.18 (1.29)^{f}	0.70 (1.10)^{e}	0.60 (1.04)^{e}	0.40 (0.94)^{e}	1.78 (1.51)^{de}	0.93
20 Traps + Spinosad 45SC	2.90 (1.84)^{cd}	2.10 (1.61)^{c}	1.28 (1.33)^{d}	1.00 (1.22)^{d}	2.40 (1.70)^{c}	1.94
20 Traps + Emamectin benzoate 5SG	0.63 (1.06)^{g}	0.30 (0.89)^{f}	0.18 (0.82)^{f}	0.10 (0.77)^{f}	1.13 (1.27)^{f}	0.47
Chlorantraniliprole 18.5SC	2.43 (1.71)^{d}	2.18 (1.63)^{c}	1.28 (1.32)^{d}	0.90 (1.18)^{d}	2.15 (1.63)^{cd}	1.79
Spinosad 45SC	3.48 (1.99)^{c}	2.55 (1.74)^{c}	1.93 (1.55)^{c}	1.90 (1.55)^{c}	2.38 (1.69)^{c}	2.45
Emamectin benzoate 5SG	1.70 (1.48)^{e}	1.38 (1.37)^{d}	0.80 (1.14)^{e}	0.50 (0.99)^{e}	1.60 (1.44)^{e}	1.20
20 pheromone Traps	8.00 (2.92)^{b}	7.65 (2.85)^{b}	7.30 (2.79)^{b}	6.83 (2.71)^{b}	6.93 (2.72)^{b}	7.34
Control (Untrapped & Unsprayed)	21.93 (4.73)^{a}	23.03 (4.85)^{a}	24.73 (5.02)^{a}	26.75 (5.22)^{a}	28.43 (5.38)^{a}	24.97
'F' test	*	*	*	*	*	
SEM±	0.06	0.06	0.05	0.05	0.05	
CD at P=0.05	0.19	0.18	0.13	0.13	0.15	

DAS: Days after spray; * Significant at P=0.05; NS: Non significant; Values in the parentheses are √X+0.5 transformed values; Mean values with same alphabetical superscript within a column are not significantly different.

Table 6: Diamond Back Moth larvae and pupae on cabbage plants after the third spray of insecticides in pheromone traps installed cabbage fields

Treatments	No. of larvae + pupae of DBM / plant					Mean
	1DAS	3DAS	5DAS	7DAS	10DAS	
20 Traps + Chlorantraniliprole 18.5SC	1.43 (1.39)^{d}	0.55 (1.02)^{e}	0.28 (0.87)^{ef}	0.18 (0.82)^{e}	0.68 (1.08)^{ef}	0.62
20 Traps + Spinosad 45SC	2.18 (1.63)^{cd}	1.40 (1.38)^{d}	1.10 (1.26)^{d}	0.45 (0.97)^{de}	2.00 (1.58)^{c}	1.43
20 Traps + Emamectin benzoate 5SG	0.48 (0.98)^{e}	0.32 (0.88)^{e}	0.08 (0.75)^{f}	0.01 (0.7)^{e}	0.45 (0.96)^{f}	0.27
Chlorantraniliprole 18.5SC	1.83 (1.52)^{cd}	1.25 (1.32)^{d}	0.80 (1.14)^{d}	0.55 (1.07)^{d}	1.10 (1.25)^{d}	1.11
Spinosad 45SC	2.58 (1.74)^{c}	2.20 (1.64)^{c}	1.88 (1.54)^{c}	1.33 (1.35)^{c}	2.15 (1.63)^{c}	2.03
Emamectin benzoate 5SG	1.53 (1.41)^{d}	0.75 (1.11)^{e}	0.35 (0.91)^{e}	0.18 (0.81)^{e}	0.90 (1.18)^{de}	0.74

20 pheromone Traps	6.15 (2.57)[b]	5.60 (2.47)[b]	5.33 (2.41)[b]	5.28 (2.40)[b]	5.00 (2.34)[b]	5.47
Control (Untrapped & Unsprayed)	32.28 (5.72)[a]	34.40 (5.91)[a]	37.80 (6.19)[a]	43.08 (6.60)[a]	41.48 (6.48)[a]	37.81
'F' test	*	*	*	*	*	
SEM±	0.094	0.05	004	0.07	0.05	
CD at P=0.05	0.28	0.15	0.13	0.20	0.14	

DAS: Days after spray; * Significant at P=0.05; NS: Non significant; Values in the parentheses are $\sqrt{X+0.5}$ transformed values; Mean values with same alphabetical superscript within a column are not significantly different.

4. Conclusion
The experiments on compatibility of pheromones of DBM with insecticide sprays revealed that selected insecticides *viz*., Chlorantraniliprole 18.5%SC @ 0.3ml/l, Spinosad 45% SC @0.5ml/l and Emamectin benzoate 5 SG @0.5g/l sprayed separately thrice at 10, 20 and 30 days after installation of the traps and in the fields without pheromone traps. Emamectin Benzoate sprayed in pheromone traps installed plots was significantly superior for DBM management. This indicated that there was no interaction between insecticides and moth catches in pheromone traps under field conditions.

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