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Evaluation of synergism of synthetic and plant origin oils with newer insecticides in *Plutella xylostella* L. (Lepidoptera: Plutellidae)

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Abstract
Piperonyl butoxide (PBO) and Diethyl maleate (DEM) showed less synergism with chlorantraniliprole 18.5 SC and recorded suppression ratios (SRs) from 3.35 to 17.26 and 6.03 to 22.72 respectively. At 100 ppm PBO exhibited moderate synergism among spinosad 2.5 SC, emamectin benzoate 5 SG and quinalphos 25 EC and recorded SRs of 38.46, 25.93 and 41.96 respectively. DEM at 50 ppm with spinosad 2.5 SC, at 75 ppm with emamectin benzoate 5 SG, at 50 and 75 ppm with quinalphos 25 EC showed moderate synergism with SRs of 30.77, 26.92, 31.09 and 31.71 respectively. The Non edible oils Neem oil, Iluppai oil and pongamia oil recorded little synergism with chlorantraniliprole 18.5 SC and spinosad 2.5 SC. Neem oil exhibited moderate synergm with spin sad 2.5 SC and the SR ratio is 30.47 and low down the resistance per cent from 63.41 to 44.09. Similarly moderate synergism was observed in Lippi oil at 2000 ppm and pongamia oil at 3000 ppm with emamectin benzoate 5 SG and the suppression ratios recorded are 32.00 and 34.78 respectively. Chlorantraniliprole 18.5 SC and edible oils, gingelly oil at 3000 and 4000 ppm, cotton seed oil at 4000 ppm and sunflower oil at 3000 ppm exhibited moderate synergism and recorded SR of 27.60, 33.33 and 29.28 respectively. Gingelly oil at 1000 ppm 2000 ppm and at 3000 ppm recorded moderated level of synergism with spinosad 2.5 SC, quinalphos 25 EC and emamectin benzoate 5% SG, with suppression 26.11, 32.00 and 29.82.

Keywords: Synergism, plant origin oils, edible oils, non-edible oils, Plutella xylostella chlorantraniliprole

1. Introduction
Dimondback moth *Plutella xylostella* L., (Lepidoptera: Plutellidae), is one of the major destructive insect pests of cruciferous vegetables in the world. It is one of the main constraints in the commercial cultivation of cole crops in India. *P. xylostella* has become one of the problematic pest to control since from last 50 years, mainly due to development of resistance to each class of insecticide used indiscriminately against it (Sarfraz and Keddie, 2005) [3]. The field populations of *P. xylostella* has evolved resistance to some of the new insecticide molecules like spinosad, abamectin, emamectin benzoate, indoxacarb, biopesticide *Bacillus thuringensis* and Cry toxins. (Pu *et al.* 2010) [2]
Piperonyl butoxide (PBO) a synthetic synergist which inhibits cytochrome P450 monooxygenases (microsomal oxidases) (Sayyed and Wright, 2006) [4]. Diethyl malate (DEM) inhibit glutathione-S-transferases (GST) and esterases in *P. xylostella* (Tang and Zhou, 1993) [6]. Among non-edible and edible oils, panama, iluppai, sesamum and sunflower oil are effective in suppressing the insecticide resistance in *P. xylostella* (Sridhar and Rani 2010) [5]. With this view the synergism of synthetic and plant origin oils with newer insecticides against resistant populations of diamondback moth was studied.

2. Materials and Methods
2.1 Synthetic synergists PBO and DEM
The non-toxic levels of PBO and DEM to *P. xylostella* larvae, were fixed by the modified glass vial bioassay method. Then synergists at non-toxic levels were diluted to required concentrations with acetone. The inner surface of glass vial (20 mm) was coated uniformly with one ml of the solution. After complete evaporation of acetone, 12 third instar larvae were placed into the vial and allowed for 30 minutes. After that the larvae were taken out and one

Ml of insecticide at discriminating dose was added and a uniform coating was done. The larvae were released back into the vial after complete drying and larvae were exposed for twelve hours to the insecticide. And a piece of 5x2 cm untreated cauliflower leaf was provided as feed for larvae. To absorb the moisture a strip of filter paper (5x0.3 cm) was kept inside the vial. The leaf feed was changed next day by providing fresh piece of cauliflower leaf. For each treatment three replications were maintained. Vials treated with acetone alone were kept as control.

2.2 Oil synergists (Non-edible and edible oils)

The non-edible oils neem, pongamia and iluppai and edible oils, gingelly, cotton seed oil, sunflower and castor were used in the study. The non-toxic levels of both non edible and edible oils were fixed same as for synthetic synergists. The acetone was used for dilutions of oils to the required concentrations at non-toxic levels. The filter paper impregnation method was followed in bioassay. The filter paper strips of 6x5 cm were impregnated with one ml of oil solution and kept in petri plates. After complete evaporation of acetone, 12 third instar larvae are allowed to crawl over the filter paper strip. After 30 minutes, the larvae were transferred to a small container. Then one ml of insecticide at discriminating dose was impregnated in to filter paper. The impregnated filter paper was kept inside a 20 ml glass vial and the larvae which were already exposed to oil were released into the vial. For each treatment three replications were maintained. Vials treated with acetone alone were kept as control.

The mortality was recorded at 24 hours after the release of the larvae for both synthetic and oil synergists. The suppression of resistance (SR) was calculated by using the following formula:

$$SR = \frac{\text{(Survival in insecticide alone)} - \text{(survival in insecticide+ synergist)}}{\text{(Survival in insecticide alone)}} \times 100$$

Based on suppression ratios (SR) the synergism levels were grouped as follows:

Suppression of resistance (%)	Level of synergism
Less than 10	very low
10-25	low
25-50	Moderate
More than 50	High

3. Results and Discussions

The synthetic synergists Piperonyl butoxide (PBO) and Diethyl maleate (DEM) were tested at non-toxic concentrations of 25 to 100 ppm and plant origin synergists both edible and non-edible oils were tested at non-toxic concentrations of 500 to 5000 ppm.

The PBO at 50, 75 and 100 ppm recorded suppression ratios (SRs) of 15.39, 17.26 and 16.06 respectively and exhibited low level of synergism with chlorantraniliprole 18.5 SC. Spinosad 2.5 SC, emamectin benzoate 5 SG and quinalphos 25 EC revealed moderate synergism with PBO at 100 ppm and recorded SRs 38.46, 25.93 and 41.96 respectively. (Table 1). (Jiang *et al.* 2012) [1] Who reported piperonyl butoxide had synergistic effects with chlorantraniliprole 18.5 SC against fourth-instar larvae of Colorado potato beetle, *Leptinotarsa decemlineata* (Say).

In the present study DEM showed low level of synergism with chlorantraniliprole 18.5 SC. And showed moderate synergisms with spinosad 2.5 SC, emamectin benzoate 5 SG, quinalphos 25 EC and decrease in resistance was observed from 65.00 to 45.00, 65.00 to 47.50, and 74.17 to 51.11 per cent respectively (Table 1). The results in the present investigation are in agreement with Wang *et al.* (2012) [8]. The present investigations revealed that DEM synergized the test insecticides at low to moderate synergism indicated that involvement of GST in the developing resistance in *P. xylostella* field collected resistant populations.

The non-edible, Iluppai oil tested with chlorantraniliprole 18.5 SC recorded higher suppression ratio (SR) of 24.00 at 2000 and 3000 ppm and reduced the resistance level from 62.50 to 47.50. Neem oil at 2000 ppm with spinosad 2.5 SC low down the resistance from 63.41 to 44.09 and exhibited moderate synergism. (Table. 2). Moderate synergism was observed with emamection benzoate 5 SG and Iluppai oil at 2000 ppm and pongamia oil at 3000 ppm, recorded suppression ratios's 32.00 and 34.78 respectively. (Table 3). Among three non- edible oils tested, Iluppai oil at 2000 and 3000 ppm showed higher level of synergism with quinalphos 25 EC recorded suppression ratio of 31.03 and brought down the resistance level from 72.50 to 50.00. (Table 4). The results are in agreement with Sridhar and Rani (2010) [5].

The edible oils *viz*, cotton seed, castor, gingelly and sunflower oils with chlorantraniliprole 18.5 SC exhibited the low to moderate level of synergism. Among the edible oils, cotton seed oil at 4000 ppm with chlorantraniliprole 18.5 SC showed the moderate level of synerism and recorded the highest suppression ratio of 33.33 (Table 2) Gingerly oil at 1000, 3000 and 2000 ppm exhibited moderate level of synergism and recorded suppression ratios of 26.11, 29.58 and 32.21 with spinosad 2.5 SC, emamectin benzoate 5 SG and quinalphos 25 EC respectively (Table 3, 4 and 5). Sunflower oil at 3000 ppm with quinalphos 25 EC showed moderate synergism by reducings the resistance from 77.88 to 51.82 per cent. The present findings on edible oils as synergists are in agreement with Vastrad *et al.* (2002) [7].

Table 1: Evaluation of synergistic activity of piperonyl butoxide (PBO), diethyl maleate (DEM) with test insecticides in P. *xylostella*

PBO Dose (ppm)	Chlorantraniliprole				Spinosad				Emamectin benzoate				Quinalphos			
	PBO		DEM		PBO		DEM		PBO		DEM		PBO		DEM	
	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR
0	56.63± 8.27 (48.81)	0.00	63.26 ± 8.27 (52.69)	0	65.00a ± 8.39 (53.73)	0.00	65.00c ± 8.39 (53.73)	0	67.50a ± 8.37 (55.24)	0.00	65.00b ± 8.39 (53.73)	0	79.72a± 7.97 (63.24)	0.00	74.17b ± 8.18 (59.45)	0
25	54.7 ± 8.39 (47.72)	3.35	48.89 ± 8.27 (44.36)	22.72	65.00a ± 8.39 (53.73)	0.00	55.00b ± 8.39 (47.87)	15.38	60.00a ± 8.41 (50.77)	11.11	62.50b ± 8.42 (52.24)	3.85	69.44a± 8.33 (56.44)	13.11	74.45b ± 7.99 (59.64)	-0.38
50	47.92 ± 8.39 (43.81)	15.39	50.43 ± 7.99 (45.25)	20.28	47.50ab ± 8.27 (43.57)	26.92	45.00a ± 8.15 (42.13)	30.77	50.00ab ± 8.37 (45.00)	25.93	75.00c ± 8.15 (60.00)	-15.38	56.67b± 8.41 (48.83)	29.10	51.11a ± 8.27 (45.64)	31.09

75	46.86 ± 8.39 (43.20)	17.26	54.17 ± 8.39 (47.39)	14.37	45.00^{b} ± 8.27 (42.13)	30.77	67.50^{c} ± 8.36 (55.24)	-3.85	50.00^{b} ± 8.33 (45.00)	25.93	47.50^{a} ± 8.24 (43.57)	26.92	51.39^{b}± 8.25 (45.80)	35.70	51.39^{a} ± 8.27 (45.80)	30.71
100	47.54 ± 8.27 (43.59)	16.06	59.44 ± 8.39 (50.44)	6.03	40.00^{b} ± 7.90 (39.23)	38.46	67.50^{c} ± 8.30 (55.24)	-3.85	50.00^{b} ± 8.21 45.00	25.93	57.50^{b} ± 8.36 (49.31)	11.54	46.39^{b}± 8.09 (42.93)	41.96	71.76^{b} ± 8.27 (57.84)	3.38
	NS		NS		-		-		-		-		-		-	

RP: Resistance Percentage, SE: Standard Error, SR: Suppression Ratio
Figures in parentheses are arc sin transformed values
Means followed by common letter in a column are not significantly different at five per cent level by LSD
NS: Non-significant.

Table 2: Evaluation of synergistic activity of non-edible oils, edible oils with chlorantraniliprole 18.5 SC in P. *xylostella*

Dose (ppm)	**Non edible oils**								**Edible oils**					
	Iluppai oil		**Pongamia oil**		**Neem oil**		**Castor oil**		**Gingelly oil**		**Cotton seed oil**		**Sunflower**	
	RP ±SE	SR	RP ±SE	RP ± SE	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR
0	62.50^{b} ± 8.37 (52.24)	0	60.00 ± 8.33 (50.77)	0	54.77^{b} ± 8.41 (47.74)	0	54.85^{cb} ± 8.41 (47.78)	0	58.18 ± 8.37 (49.71)	0	58.18^{cb} ± 8.45 (49.71)	0	54.85^{b} ± 8.41 (47.78)	0
500	67.50^{b} ± 8.37 (55.24)	-8.00	67.50 ± 8.37 (55.24)	-12.50	64.32^{c} ± 8.37 (53.32)	-17.43	61.21^{c} ± 8.41 (51.48)	-11.60	61.82 ± 8.25 (51.84)	-6.25	61.21^{cb} ± 8.41 (51.48)	-5.21	67.88^{c} ± 8.25 (55.48)	-23.75
1000	47.50^{a} ± 8.13 (43.57)	24.00	67.50 ± 8.25 (55.24)	-12.50	54.77^{b} ± 8.41 (47.74)	0.00	55.15^{cb} ± 8.33 (47.96)	-0.55	58.18 ± 8.37 (49.71)	0.00	64.85^{c} ± 8.37 (53.64)	-11.46	54.85^{b} ± 8.41 (47.78)	0.00
2000	47.50^{a} ± 8.03 (43.57)	24.00	55.00 ± 8.25 (47.87)	8.33	52.50^{b} ± 8.41 (46.43)	4.14	42.12^{a} ± 8.09 (40.47)	23.21	48.48 ± 8.25 (44.13)	16.66	54.85^{b} ± 8.41 (47.78)	5.73	48.48^{ba} ± 8.25 (44.13)	11.60
3000	67.50^{b} ± 8.25 (55.24)	-8.00	47.50 ± 8.09 (43.57)	20.83	45.00^{a} ± 8.09 (42.13)	17.84	42.12^{a} ± 8.09 (40.47)	23.21	42.12 ± 8.09 (40.47)	27.60	45.45^{a} ± 8.21 (42.39)	21.87	38.79^{a} ± 7.97 (38.52)	29.28
4000	70.00^{b} ± 8.33 (56.79)	-12.00	47.50 ± 7.91 (43.57)	20.83	45.23^{a} ± 8.21 (42.26)	17.42	48.18^{ab} ± 8.25 (43.96)	12.16	42.12 ± 8.09 (40.47)	27.60	38.79^{a} ± 7.97 (38.52)	33.33	51.52^{b} ± 8.37 (45.87)	6.08
5000	70.00^{b} ± 8.25 (56.79)	-12.00	62.50 ± 8.37 (52.24)	-4.17	54.77^{b} ± 8.41 (47.74)	0.00	61.21 c ± 8.41 (51.48)	-11.60	54.85 ± 8.41 (47.78)	5.73	58.18^{cb} ± 8.45 (49.71)	0.00	58.18^{cb} ± 8.45 (49.71)	-6.07
	-		NS		-		-		NS		-		-	

RP: Resistance Percentage, SE: Standard Error, SR: Suppression Ratio
Figures in parentheses are arc sin transformed values
Means followed by common letter in a column are not significantly different at five per cent level by LSD
NS: Non-significant.

Table 3: Evaluation of synergistic activity of non-edible and edible oils with spinosad 2.5 SC in *P. xylostella*

Dose (ppm)	**Non edible oils**								**Edible oils**					
	Iluppai oil		**Pongamia oil**		**Neem oil**		**Castor oil**		**Gingelly oil**		**Cotton seed oil**		**Sunflower**	
	RP ±SE	SR	RP ±SE	RP ± SE	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR
0	62.50^{ab} ± 8.37 (52.24)	0	63.33^{bc} ± 8.41 (52.24)	0	63.41^{b} ± 8.37 (52.78)	0	58.18 ± 8.45 (49.71)	0	61.52^{dbc} ± 8.41 (51.66)	0	61.52^{ab} ± 8.41 (51.66)	0	61.52 ± 8.41 (51.66)	0
500	65.00^{b} ± 8.37 (53.73)	-4.00	66.67^{bc} ±8.37 (55.24)	-8.00	63.41^{b} ± 8.37 (52.78)	0.00	67.88 ± 8.25 (55.48)	-16.67	61.52^{dbc} ± 8.41 (51.66)	0.00	61.52^{ab} ± 8.41 (51.66)	0.00	64.55 ± 8.37 (53.46)	-4.92
1000	50.00^{a} ± 8.13 (45.00)	20.00	60.00^{ba} ± 8.37 (50.77)	4.00	49.09^{a} ± 8.25 (44.48)	22.58	58.18 ± 8.45 (49.71)	0.00	45.45^{a} ± 8.13 (42.39)	26.11	51.82^{a} ± 8.37 (46.04)	15.77	48.48 ± 8.25 (44.13)	21.19
2000	50.00^{a} ± 8.03 (45.00)	20.00	50.00^{a} ± 8.25 (45.00)	20.00	44.09^{a} ± 8.09 (41.61)	30.47	54.85 ± 8.41 (47.78)	5.73	48.48^{ab} ± 8.33 (44.13)	21.19	51.52^{a} ± 8.37 (45.87)	16.26	51.82 ± 8.37 (46.04)	15.77
3000	65.00^{ab} ± 8.25 (53.73)	-4.00	46.67^{a} ± 8.21 (45.00)	20.00	63.64^{b} ± 8.41 (52.91)	-0.36	67.88 ± 8.33 (55.48)	-16.67	58.18^{abc} ± 8.45 (49.71)	5.43	67.88^{cb} ± 8.33 (55.48)	-10.34	61.52 ± 8.41 (51.66)	0.01
4000	67.50^{b} ± 8.33 (55.24)	-8.00	56.67^{ab} ± 8.41 (50.77)	4.00	73.41^{cb} ± 8.21 (58.96)	-15.77	74.55 ± 8.09 (59.70)	-28.13	67.88^{dc} ± 8.25 (55.48)	-10.34	67.88^{cb} ± 8.33 (55.48)	-10.34	68.18 ± 8.25 (55.66)	-10.83
5000	70.00^{b} ± 8.25 (56.79)	-12.00	70.00^{c} ± 8.25 (58.37)	-16.00	75.91^{c} ± 8.09 (60.61)	-19.71	71.52 ± 8.13 (57.74)	-22.92	74.24^{d} ± 8.09 (59.50)	-20.68	74.24^{c} ± 8.09 (59.50)	-20.68	71.21 ± 8.21 (57.55)	-15.75
							NS		**		**		NS	

RP: Resistance Percentage, SE: Standard Error, SR: Suppression Ratio
Figures in parentheses are arc sin transformed values
Means followed by common letter in a column are not significantly different at five per cent level by LSD
NS: Non-significant.

Table 4: Evaluation of synergistic activity of non-edible and edible oils with emamectin benzoate 5% S.G in P. *xylostella*

Dose (ppm)	Non edible oils								Edible oils					
	Iluppai oil		Pongamia oil		Neem oil		Castor oil		Gingelly oil		Cotton seed oil		Sunflower	
	RP ±SE	SR	RP ±SE	RP ± SE	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR
0	62.50^{b} ± 8.41 (52.24)	0	57.50^{c} ± 8.37 (49.31)	0	57.05^{ab} ± 8.37 (49.05)	0	64.55 ± 8.37 (53.46)	0	64.55^{bc} ± 8.37 (53.46)	0	64.55^{b} ± 8.37 (53.46)	0	61.21 ± 8.41 (51.48)	0
500	67.50^{b} ± 8.33 (55.24)	-8.00	57.50^{c} ± 8.37 (49.31)	0.00	49.55^{ab} ± 8.09 (44.74)	13.15	70.91 ± 8.13 (57.36)	-9.85	71.21^{c} ± 8.21 (57.55)	-10.32	51.82^{a} ± 8.37 (46.04)	19.72	67.88 ± 8.25 (55.48)	-9.11
1000	57.50^{b} ± 8.45 (49.31)	8.00	62.50^{cd} ± 8.45 (52.24)	-8.70	45.00^{a} ± 8.03 (42.13)	21.12	74.55 ± 8.09 (59.70)	-15.48	68.18^{c} ± 8.25 (55.66)	-5.63	74.55^{b} ± 8.09 (59.70)	-15.48	61.21 ± 8.33 (51.48)	1.60
2000	42.50^{a} ± 8.09 (40.69)	32.00	47.50^{b} ± 8.21 (43.57)	17.39	47.95^{a} ± 8.37 (43.83)	15.94	54.55 ± 8.33 (47.61)	15.50	55.45^{ac} ± 8.25 (48.13)	14.09	67.88^{b} ± 8.33 (55.48)	-5.16	58.18 ± 8.45 (49.71)	6.48
3000	57.50^{b} ± 7.97 (49.31)	8.00	37.50^{a} ± 7.75 (37.76)	34.78	55.00^{ab} ± 8.45 (47.87)	3.59	58.18 ± 8.45 (49.71)	9.87	45.45^{a} ± 8.13 (42.39)	29.58	70.91^{b} ± 8.21 (57.36	-9.85	58.48 ± 8.37 (49.89)	5.99
4000	65.00^{b} ± 8.37 (53.73)	-4.00	57.50^{c} ± 8.37 (49.31)	0.00	62.05^{cb} ± 8.37 (51.97)	-8.76	67.88 ± 8.25 (55.48)	-5.16	48.48^{ab} ± 8.33 (44.13)	24.89	67.88^{b} ± 8.25 (55.48)	-5.16	47.88 ± 8.09 (43.78)	23.04
5000	67.50^{b} ± 8.33 (55.24)	-8.00	70.00^{d} ± 8.21 (56.79)	-21.74	71.59^{c} ± 8.09 (57.79)	-25.49	70.91 ± 8.21 (57.36)	-9.85	67.58^{c} ± 8.25 (55.29)	-4.69	70.91^{b} ± 8.21 (57.36)	-9.85	67.58 ± 8.25 (55.29)	-8.63
							NS		-		-		NS	

RP: Resistance Percentage, SE: Standard Error, SR: Suppression Ratio
Figures in parentheses are arc sin transformed values
Means followed by common letter in a column are not significantly different at five per cent level by LSDNS: Non-significant.

Table 5: Evaluation of synergistic activity of non-edible and edible oils with quinalphos 25 EC in *P. xylostella*

Dose (ppm)	Non edible oils								Edible oils					
	Iluppai oil		Pongamia oil		Neem oil		Castor oil		Gingelly oil		Cotton seed oil		Sunflower	
	RP ±SE	SR	RP ±SE	RP ± SE	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR	RP ± SE	SR
0	72.50^{cd} ± 8.21 (58.37)	0	57.50^{c} ± 8.37 (49.31)	0	57.05^{ab} ± 8.37 (49.05)	0	74.24^{b} ± 8.09 (59.50)	0	80.91^{cb} ± 7.75 (64.09)	0	80.91 ± 7.75 (64.09)	0	77.88^{c} ± 7.87 (61.94)	0
500	67.50^{cd} ± 8.33 (55.24)	6.90	57.50^{c} ± 8.37 (49.31)	0.00	49.55^{ab} ± 8.09 (44.74)	10.42	80.91^{b} ± 7.75 (64.09)	-8.98	84.24^{c} ± 7.41 (66.61)	-4.12	84.24 ±7.41 (66.61)	-4.12	87.58^{c} ±7.20 (69.36)	-12.45
1000	62.50^{bc} ± 8.45 (52.24)	13.79	62.50^{c} ± 8.45 (52.24)	-6.90	45.00^{a} ± 8.03 (42.13)	17.24	61.52^{a} ± 8.41 (51.66)	17.14	67.88^{ab} ± 8.33 (55.48)	16.11	68.18 ± 8.25 (55.66)	15.73	74.55^{ac} ± 8.09 (59.70)	4.28
2000	50.00^{a} ± 8.25 (45.00)	31.03	47.50^{b} ± 8.21 (43.57)	13.79	47.95^{a} ± 8.37 (43.83)	13.17	61.21^{a} ± 8.41 (51.48)	17.55	54.85^{a} ± 8.41 (47.78)	32.21	71.21 ± 8.03 (57.55)	11.99	61.52^{a} ± 8.41 (51.66)	21.01
3000	50.00^{a} ± 8.21 (45.00)	31.03	37.50^{a} ± 7.75 (37.76)	27.59	55.00^{ab} ± 8.45 (47.87)	3.45	80.91^{b} ± 7.75 (64.09)	-8.98	80.91^{cb} ± 7.75 (64.09)	0.00	80.91 ± 7.75 (64.09)	0.00	51.82^{a} ± 8.37 (46.04)	33.46
4000	55.00^{ab} ± 8.29 (47.87)	24.14	57.50 c ± 8.37 (49.31)	0.00	62.05^{bc} ± 8.37 (51.97)	-6.27	77.58^{b} ± 7.97 (61.74)	-4.49	87.27^{c} ± 7.32 (69.10)	-7.86	90.30 ± 6.98 (71.86)	-11.61	81.21^{c} ± 7.53 (64.31)	-4.28
5000	75.00^{d} ± 8.21 (60.00)	-3.45	72.50^{d} ± 8.21 (58.37)	-20.69	71.59^{c} ± 8.09 (57.79)	-19.44	83.94^{b} ± 7.54 (66.37)	-13.06	93.94^{c} ± 6.64 (75.75)	-16.10	90.61 ± 6.98 (72.15)	-11.98	90.91^{c} ± 6.65 (72.45)	-16.73
							-		-		NS		-	

RP: Resistance Percentage, SE: Standard Error, SR: Suppression Ratio
Figures in parentheses are arc sin transformed values
Means followed by common letter in a column are not significantly different at five per cent level by LSD
NS: Non-significant.

4. Conclusion

Piperonyl butoxide (PBO) and Diethyl maleate (DEM) with chlorantraniliprole 18.5 SC showed low level of synergism. PBO at 100 ppm showed moderate level of synergisms with Spinosad 2.5 SC, emamectin benzoate 5 SG and quinalphos 25 EC. Among non-edible oils, iluppai oil, pongamia oil and neem oil exhibited low level of synergism with chlorantraniliprole 18.5 SC and spinosad 2.5 SC. Neem oil showed moderate synergism at 2000 ppm with spinosad 2.5 SC. The edible oils gingelly oil at 3000 and 4000 ppm, cotton seed oil at 4000 ppm and sunflower oil at 3000 ppm exhibited moderate level of synergism with chlorantraniliprole 18.5 SC.

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