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Evaluation of bio-efficacy and compatibility of emamectin benzoate with neem based biopesticide against fruit borers of brinjal and okra

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ABSTRACT

Bio-efficacy and physical compatibility of biorational insecticides, viz. emamectin benzoate and Neem Baan® was investigated against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenne and okra shoot and fruit borer, *Earias vittella* Fab. under field conditions during *kharif* 2010 and 2011. Both biorationals were found compatible with each other by using jar test and emulsion stability. The results revealed that in both brinjal and okra there was no phytotoxicity observed due to emamectin benzoate with Neem Baan® combination. The lowest per cent fruit infestation was observed in the treatment of emamectin benzoate combined with Neem Baan® @ 7 ml per litre of water, i e 7.36% and 5.39% on number basis and 8.13% and 5.77% on weight basis in brinjal during *kharif* 2010 and 2011 respectively. Also the highest marketable fruit yield in weight basis was also obtained in the treatment (12.35 tonnes/ha and 16.89 tonnes/ha) during *kharif* 2010 and 2011. Similarly, in okra also it recorded lowest fruit infestation (5.92% and 5.59%) and highest marketable yield (1.62 tonnes/ha and 2.19 tonnes/ha) in 2010 and 2011 on weight basis. Further, it was observed that the plant parameters like shoot length and number of flowers recorded significantly higher in the treatment of emamectin benzoate combined with Neem Baan® than untreated control (T_8) in both the years. The results indicated that the combination of neem formulation with emamectin benzoate was effective in managing *L. orbonalis* and *E. vitella.*

Key words: Compatibility, *Earias vittella*, Emamectin benzoate, *Leucinodes orbonalis*, Neem

Brinjal and okra are two predominant vegetables cultivated in the Indian subcontinent. It is ravaged by numerous insect pests, among them the fruit borer, viz. brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenne and okra shoot and fruit borer, *Earias vittella* Fab. are the major threats to brinjal and okra production respectively. These pests can cause a yield loss as high as 70 to 90 per cent and 50 to 70 per cent in brinjal and okra respectively (Nair 1995, Rosaiah 2001, Pareek and Bhargava 2003). To manage these pests farmers rely on chemical insecticides and undertake up to three sprays a week in Bangladesh (Rashid *et al*. 2003) and up to six to seven in India (Alam *et al*. 2003, Singh and Singh 2001). Indiscriminate use of insecticides resulted in the presence of residues in these vegetables (Arora 2009); on the other hand it also ensued with the resistance development in target insects (Ali 1994, Kabir *et al*. 1996, Satpute *et al*. 2003). New molecules such as emamectin benzoate, spinosad, etc are available now for management of lepidopterous pests. Continuous application of new molecules may also result in resistance development in the target insect pest. One of the resistance mitigation strategies is to use insecticide mixtures which will delay the resistance development as well as extend the longevity of the insecticidal molecule in the market. The neem products with half the dose of conventional insecticide has resulted in more efficient control than insecticide alone (Sinzogan *et al*. 2006). Hence, emamectin a chloride channel activator may perform better when it is combined with a neem product. Keeping this in view the present study was taken to evaluate the compatibility of a neem based biopesticide, Neem Baan® with the emamectin benzoate against the fruit borers of brinjal and okra.

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MATERIALS AND METHODS

Neem formulation, i e Neem Baan® (azadirachtin 1500 ppm) 1.75 ml was taken in a 500 ml beaker. Then the test solution (containing 0.0675 g of emamectin benzoate in 250 ml of water) was added slowly with constant stirring. After adding the solution it was allowed to sit stationary for 15 minutes without any disturbance. This time is referred to as "settling time". If the solution is uniform or homogenous, then the pesticides are compatible; however, if there is clumping or flocculation or separation, then the pesticides are not compatible with each other (Marer 1988).

Neem baan (0.3 ml or 0.5 ml or 0.7 ml) was first diluted with 50 ml of standard hard water and then added with the test solution (containing 0.027 g of emamectin benzoate in 50 ml of water) drop by drop with the help of

burette and conical flask with constant shaking. The emulsion was immediately transferred to a clean and dry 100 ml measuring cylinder and kept in water bath at 30±1°C for one hour without any disturbance. The volume of the creamed matter at the top or sediment at the bottom was observed. The creaming matter and/or the sediment not exceeding 2.0 ml at the top or bottom of 100 ml measuring cylinder was considered as the criteria for the stability of emulsion.

The field trials were conducted at the experimental farm, Division of Entomology, IARI, New Delhi during *kharif* 2010 and 2011 brinjal cv Pusa Kranti was sown in a raised bed nursery. After a month the seedlings were transplanted to the main field of plot size 5 m × 5 m by adopting a spacing of 60 cm × 45 cm. The okra cv Arka Anamika was sown in the main field in rows after germination thinning was done to obtain a spacing of 65 cm × 45 cm. The crops were raised by following the recommended agronomic practices. After the initiation of flowering the field was monitored regularly for fruit borers. Two spraying were given for fruit borers during peak incidence. After seven days of first and second spray the shoot length was measured both in brinjal and okra. Apart from this number of flowers and number of shoots were also counted in brinjal. The data were then subjected to square root transformation and analysed using SAS 9.2 software and significantly different means ($P<0.05$) were separated using Duncan Multiple Range Test (DMRT) at 5% probability.

The field trials were carried out in the research farm, Division of Entomology, Indian Agricultural Research Institute, New Delhi during *kharif* 2010 and 2011. During both the years the brinjal cultivar Pusa Kranti and okra cultivar Arka Anamika was planted in randomized block design in the field plots. For brinjal, seedlings from raised nursery bed were used for transplanting while for okra direct sowing of seeds in the field was done. A good crop was raised by following all the recommended agronomic package of practices for both the crops. For testing the compatibility of emamectin benzoate with Neem baan against the fruit borers, seven treatments with a control were taken as follows, T_1: Neem baan 3 ml per litre, T_2: Neem baan 5 ml per litre, T_3: Neem baan 7 ml per litre, T_4: T_1 + emamectin benzoate @ 5.4 a.i./ha, T_5: T_2+ emamectin benzoate @ 5.4 a.i./ha, T_6: T_3 + emamectin benzoate@ 5.4 a.i./ha, T_7: emamectin benzoate alone @ 5.4 a.i./ha and T_8: control. Each treatment was replicated three times. The insecticides were sprayed once the fruiting was started and repeated after 30 days for brinjal and after fortnight interval for okra. Spraying was done with the help of a hand operated knapsack sprayer. The observations for phytotoxicity were observed on 1, 3, 7, 10 and 14 days after spraying. The phytotoxic symptom observations were recorded as per the protocol of Central Insecticide Board Registration committee (CIBRC) for the phytotoxic symptoms like,

a. Injury to leaf tip and leaf surface
b. Wilting
c. Vein clearing
d. Necrosis
e. Epinasty and hyponasty

Above parameters were recorded based on the following visual rating scale

Rating	Phytotoxicity (%)
0	No phytotoxicity
1	1-10
2	11-20
3	21-30
4	31-40
5	41-50
6	51-60
7	61-70
8	71-80
9	81-90
10	91-100

The per cent leaf injury was calculated using following formula,

Per cent leaf injury= (Total grade points/maximum grade * No. of leaves observed) * 100

Per cent fruit infestation on number basis and weight basis was calculated by using the formula for both the crops after sorting out damaged fruits,

Per cent fruit infestation = (weight of infested fruits/ Total weight of fruits) * 100

The per cent reduction over control and the per cent yield gain over control was calculated by following formula (Pradhan 1969),

Yield gain over control (%) = [(T-C)/C] × 100

where T, Yield from treated plot; C, yield from control plot

All data were subjected to arc sine transformation and subjected to ANOVA by using SAS 9.2 software and significantly different means ($P<0.05$) were separated using Duncan Multiple Range Test (DMRT) at 5% probability.

RESULTS AND DISCUSSION

Physical compatibility

Jar test: After fifteen minutes of standing, it was observed that there was no flocculation or sediment deposit. The mixture of the two biorationals was homogenous, clear, milky white and remained stable.

Emulsion stability test methodology: After one hour of incubation the measuring cylinder was taken out of water bath and the measuring cylinder was wiped with the help of a dry cloth. The creaming was well below two centimetres and no sedimentation behaviour was observed for all the three combination treatments. Hence it provided conclusive evidence that the combination of the two biorationals, viz. emamectin benzoate and Neem baan was compatible.

Biological compatibility with plant parameters

Brinjal shoot length: After first spraying, the brinjal

plant height varied from 74.67 cm to 97.20 cm during 2010 while it varied from 75.67 cm to 98.93 cm during 2011 (Table 1). The plant height after the second spraying varied from 83.27 cm to 106.00 cm during 2010 while it is 85.53 cm to 108.40 cm during 2011. The maximum plant height was recorded from T_6 which differs significantly from all other treatments during both the years. The combination of treatments recorded significantly higher plant height than the untreated control T_8. The similar study was conducted by Sharma and Kaushik (2010) in brinjal. They also found that the insecticide (spinosad, emamectin benzoate, cypermethrin, quinalphos and endosulfan) treated plants recorded higher shoot length than untreated control.

Brinjal number of flowers: After the first spraying the number of flowers varied from 0.67 in untreated control to 4.13 in T_6 during 2010. Similar trend was observed during 2011 as it varied from 0.67 to 4.00 per plant. After second spraying, the number of flowers varied from 1.00 to 2.87 per plant during 2010 and 1.00 to 4.8 per plant during 2011. Here T_6 recorded a significantly higher number of flowers than untreated control.

Brinjal number of shoots: After seven days of the second spraying the number of shoots per plant varied from 3.60 to 6.73 and 4.00 to 7.00 during 2010 and 2011 respectively (Table 1). The highest number of shoots was recorded from T_6 which differs significantly from control (T_8) and emamectin benzoate (T_7) alone treatments. The increase in shoot length and number of shoots in the treatment T_6 is due to lesser infestation by *L. orbonalis*. The present results corroborates with that of Sharma and Kaushik (2010). They reported mean number of shoots in spinosad, emamectin benzoate, cypermethrin and quinalphos treated plants was higher than untreated control.

Okra shoot length: After the first spraying the plant height of okra varied from 45.80 cm to 55.13 cm during 2010 while it is from 48.27 cm to 60.07 cm during 2011 (Table 2). Seven days after the second spraying the plant height varied from 66.07 cm to 74.47 cm during 2010 while it is 63.67 cm to 75.87 cm during 2011. The maximum plant height is recorded from T_6 which is significantly higher than the untreated control, emamectin benzoate alone treatment and Neem baan alone treatments. Thus the combination treatments T_4, T_5, and T_6 recorded a significantly higher plant height than emamectin benzoate alone treatment and Neem baan alone treatments. Similarly, Dhawan *et al*. (2011) found significant higher plant height in insecticidal treatment during 30 days after germination. However, Vethanayagam and Rajendran (2010) didn't found any significant difference with regards to plant height in neem oil treated plants and untreated control.

Phytotoxic symptoms

During both the crop growing seasons in *kharif* 2010 and *kharif* 2011 there was no visual symptom of phytotoxicity recorded from brinjal and okra crops. This

Table 1 Effect of emamectin benzoate and neem oil on plant parameters in brinjal recorded seven days after spraying during *kharif* 2010 and 2011

Treatment	Plant height (cm)				No. of flowers/plant				No. of shoots/plant	
	2010		2011		2010		2011		2010	2011
	83 DAT	100 DAT	85 DAT	106 DAT	83 DAT	100 DAT	85 DAT	106 DAT	100 DAT	106 DAT
T1	78.6 (8.90)^{d,e}	90.67 (9.55)^{d}	78.93 (8.91)^{c,d}	92.4 (9.63)^{c}	2 (1.53)^{b,c}	1.73 (1.45)^{b,c}	1.93 (1.54)^{a,b}	2.53 (1.72)^{a,b}	4.13 (2.15)^{c}	5.67 (2.47)^{a,b}
T2	85.73 (9.28)^{b,c}	96.13 (9.82)^{b,c,d}	86.00 (9.29)^{b,c}	98.4 (9.94)^{b}	1.8 (1.50)^{b,c}	1.53 (1.42)^{b,c}	1.93 (1.55)^{a,b}	1.4 (1.37)^{b}	4.8 (2.28)^{b,c}	5.73 (2.49)^{a,b}
T3	83.07 (9.14)^{c,d}	94.27 (9.73)^{c,d}	84.60 (9.22)^{b,c}	97.13 (9.88)^{b,c}	2.07 (1.60)^{b}	1.73 (1.49)^{b,c}	2.93 (1.83)^{a}	1.4 (1.36)^{b}	4.4 (2.21)^{c}	5.33 (2.40)^{a,b}
T4	92.33 (9.64)^{a}	99.33 (9.99)^{b,c}	92.33 (9.63)^{a,b}	98 (9.92)^{b,c}	2.87 (1.82)^{a,b}	2.13 (1.62)^{a,b}	2.8 (1.71)^{a,b}	2.47 (1.72)^{a,b}	4.8 (2.30)^{b,c}	5.07 (2.35)^{a,b}
T5	91.13 (9.57)^{a,b}	100.67 (10.05)^{b}	91.60 (9.59)^{a,b}	100.53 (10.05)^{b}	3 (1.87)^{a,b}	2.4 (1.70)^{a,b}	3 (1.86)^{a}	2.6 (1.76)^{a,b}	6.07 (2.56)^{a,b}	5.8 (2.50)^{a,b}
T6	97.2 (9.88)^{a}	106 (10.32)^{a}	98.93 (9.97)^{a}	108.4 (10.43)^{a}	4.13 (2.13)^{a}	2.87 (1.82)^{a}	4 (2.09)^{a}	4.8 (2.24)^{a}	6.73 (2.68)^{a}	6.6 (2.66)^{a}
T7	79.67 (8.95)^{d,e}	91.53 (9.59)^{d}	81.53 (9.05)^{c,d}	95.2 (9.78)^{b,c}	1.4 (1.38)^{b,c}	1.6 (1.45)^{b,c}	1.53 (1.43)^{a,b}	2.4 (1.69)^{a,b}	4 (2.12)^{c}	4.2 (2.16)^{b}
T8	74.67 (8.67)^{e}	83.27 (9.15)^{e}	75.67 (8.73)^{d}	85.53 (9.27)^{d}	0.6 (1.05)^{c}	1 (1.22)^{c}	0.67 (1.08)^{b}	1 (1.22)^{b}	3.6 (2.02)^{c}	4 (2.12)^{b}
SEm (±)	0.102	0.086	0.13	0.09	0.15	0.099	0.2	0.17	0.103	0.16
CV	1.9	1.53	2.47	1.58	16.56	11.26	12.75	17.65	7.78	7.66
CD (P<0.05)	0.31	0.26	0.4	0.27	0.47	0.3	0.59	0.5	0.31	0.32

Figures in parenthesis are square root transformed. In a column means followed by same letter are not significant different from each other by DMRT ($P < 0.05$)

Table 2 Effect of emamectin benzoate and neem oil on plant parameters in okra recorded seven days after spraying during *kharif* 2010 and 2011

Treatment	Plant height (cm)			
	2010		2011	
	58 DAS	83 DAS	60 DAS	77 DAS
T1	49.47 (7.07)[b]	68.2 (8.29)[b,c]	51.87 (7.23)[c]	66.4 (8.18)[d]
T2	49.67 (7.08)[b]	69.47 (8.36)[b]	53.07 (7.32)[c]	67.93 (8.27)[c,d]
T3	49.8 (7.09)[b]	70.13 (8.40)[b]	54 (7.38)[c]	68.67 (8.32)[c]
T4	53.53 (7.35)[a]	73.87 (8.62)[a]	57 (7.59)[b]	72.33 (8.53)[b]
T5	54.33 (7.40)[a]	74.67 (8.67)[a]	59 (7.71)[a,b]	74.27 (8.65)[a]
T6	55.13 (7.46)[a]	74.47 (8.65)[a]	60.07 (7.78)[a]	75.87 (8.74)[a]
T7	50.93 (7.17)[b]	70.6 (8.43)[b]	53.6 (7.36)[c]	67.4 (8.24)[c,d]
T8	45.8 (6.80)[c]	66.07 (8.16)[c]	48.27 (6.98)[d]	63.67 (8.01)[e]
SEm (±)	0.042	0.062	0.048	0.033
CV	1.01	1.26	1.11	0.69
CD (P<0.05)	0.13	0.19	0.14	0.1

Figures in parenthesis are square root transformed. In a column means followed by same letter are not significant different from each other by DMRT (P<0.05)

indicated that the emamectin benzoate and Neem baan combination was not phytotoxic to brinjal and okra. This result corroborates with Kumar and Devappa (2006). They also found that emamectin benzoate was not phytotoxic to brinjal.

Brinjal percent fruit infestation

By consolidating the five pickings obtained during 2010 the mean percent fruit infestation in number basis varied from 7.36 to 37.17. It varied from 5.39 to 41.00 during 2011. The treatment T_6 (emamectin benzoate @ 5.4 a.i./ha combined with Neem baan @ 7 ml per litre of water) recorded the lowest per cent fruit infestation 7.36% and 5.39% during *kharif* 2010 and *kharif* 2011 respectively, which was significantly lower than the control and all other treatments (Table 3 and Table 4). Similarly the combination treatments, viz. T_4 and T_5 were recorded lower per cent fruit infestation than control, Neem baan alone and emamectin benzoate alone treatment in both the years. The per cent reduction over control varied from 14.53 to 80.20 during 2010 and from 12.54 to 86.85 during 2011. The Neem baan with lowest dose 3ml per litre T_1 recorded the lowest per cent reduction over control 14.53 and 12.54 during 2010 and 2011 respectively.

The per cent reduction over control was estimated and found to be highest in T_6 80.20 and 86.85 during *kharif* 2010 and *kharif* 2011 respectively. The next best treatments were T_5 (60.34, 65.22) and T_4 (59.39 and 59.61) during

Table 3 Efficacy of emamectin benzoate with neem oil against fruit and shoot borer, *L. orbonalis* infestation brinjal during *Kharif* 2010

Treatment	Total fruit yield per ha		Marketable fruit yield per ha		Damaged fruit yield per ha		Per cent fruit infestation		Percent reduction in infestation over control		Percent increase in yield over control
	Number basis ('000)	Weight basis (T)	Number basis ('000)	Weight basis (T)	Number basis ('000)	Weight basis (T)	Number basis	Weight basis	Number basis	Weight basis	Weight basis
T1	89.07	8.22	60.67	5.46	28.4	2.76	31.77 (34.30) [d,e]	33.54 (35.39) [f]	14.53	18	3.07
T2	91.33	7.51	67.2	5.39	24.13	2.13	26.54 (30.96) [c,d]	28.27 (32.12) [e]	28.61	30.88	1.62
T3	115.2	9.06	89.33	6.66	25.87	2.4	22.46 (28.29) [c]	26.43 (30.93) [d]	39.57	35.39	25.71
T4	127.6	11.46	108.27	9.58	19.33	1.88	15.09 (22.83) [b]	16.68 (24.10) [b]	59.39	59.23	80.75
T5	118	11.64	100.67	9.84	17.33	1.79	14.74 (22.54) [b]	15.41 (23.10) [b]	60.34	62.32	85.75
T6	132.27	13.44	122.53	12.35	9.73	1.09	7.36 (15.72) [a]	8.13 (16.56) [a]	80.2	80.12	132.95
T7	134.4	12.47	102.27	9.59	32.13	2.89	23.96 (29.26) [c]	23.14 (28.76) [c]	35.54	43.41	80.85
T8	120.93	8.9	76.27	5.3	44.67	3.6	37.17 (37.54) [e]	4.9 (39.76) [g]			
SEm (±)	8.51	0.71	7.05	0.52	2.75	0.21	1.19	0.34			
CV	12.69	11.9	13.42	11.12	18.92	15.27	7.44	2.07			
CD (P<0.05)	25.81	2.15	21.38	1.56	8.35	0.62	3.61	1.04			

Figures in parenthesis are arcsine transformed. In a column means followed by same letter are not significant different from each other by DMRT (P < 0.05)

Table 4 Efficacy of emamectin benzoate with neem oil against fruit and shoot borer, *L. orbonalis* infestation brinjal during *kharif* 2011

Treatment	Total fruit yield per ha		Marketable fruit yield per ha		Damaged fruit yield per ha		Per cent fruit infestation		Percent reduction in infestation over control		Percent increase in yield over control
	Number basis ('000)	Weight basis (T)	Number basis ('000)	Weight basis (T)	Number basis ('000)	Weight basis (T)	Number basis	Weight basis	Number basis	Weight basis	Weight basis
T1	215.87	15.99	140	10.88	75.87	5.11	35.86 (36.78)[f]	31.86 (34.36)[f]	12.54	18.38	122.55
T2	209.47	18.39	151.33	13.13	58.13	5.26	27.62 (31.70)[e]	28.48 (32.25)[e]	32.64	27.03	168.47
T3	176	16.12	133.33	12.03	42.67	4.09	24.43 (29.62)[d]	25.52 (30.34)[e]	40.4	34.61	145.92
T4	165.07	15.16	137.73	12.55	27.33	2.61	16.56 (24.00)[b]	17.22 (24.51)[c]	59.61	55.88	156.59
T5	177.87	17.3	152.8	15.11	25.07	2.3	14.26 (22.18)[b]	13.42 (21.48)[b]	65.22	65.61	208.95
T6	173.2	17.93	163.87	16.89	9.33	1.04	5.39 (13.39)[a]	5.77 (13.81)[a]	86.85	85.21	245.49
T7	162	13.97	129.33	11.03	32.67	2.94	20.07 (26.58)[c]	20.94 (27.23)[d]	51.06	46.36	125.62
T8	92.67	8.01	54.53	4.89	38.13	3.12	41 (39.82)[g]	39.03 (38.66)[g]			
SEm (±)	11.7	1.18	9.19	0.88	3.86	0.36	0.66	0.65			
CV	11.85	13.3	11.98	12.56	17.31	18.87	4.08	4.03			
CD (P<0.05)	35.48	3.58	27.88	2.65	11.71	1.09	2.01	1.96			

Figures in parenthesis are arcsine transformed. In a column means followed by same letter are not significant different from each other by DMRT ($P < 0.05$)

both the years (2010, 2011). This is in agreement with findings of Grosman *et al*. (2002). They reported that emamectin benzoate + thiamethoxam combination has recorded highest reduction in overall insect loss (57.7% and 85.7%) caused by cone worm, *Dioryctria* spp and seed bugs, *Leptoglossus corculus* (Say); *Tetyra bipunctata* (Herrich-Schaffer) in loblolly pines.

On weight basis: The data on per cent fruit infestation varied from 8.13 to 40.90 for 2010 and for 2011 it varied from 5.77 to 39.03. The percent fruit infestation is lowest (8.13 and 5.77) in the treatment T_6 (emamectin benzoate @ 0.27g combined with Neem baan @ 7 ml per litre of water) compared to all other treatments during *kharif* 2010 and *kharif* 2011 (Table 3 and Table 4). Interestingly, the other two combination treatments, viz. T_4 and T_5 also recorded lowest per cent fruit infestation (16.68; 17.22 and 15.41; 13.42) than the Neem baan alone (T_1:33.54; 35.86, T_2:28.27; 28.48 and T_3:26.43; 25.52) and emamectin benzoate alone (40.09; 39.03) treatments. This result reveals the increased susceptibility of *L. orobonalis* to the combination treatments. This finding is in accordance with War *et al*. (2011), where the neem oil 1 per cent with endosulfan 0.01 per cent combination increased the susceptibility of *Spodoptera litura* by 2.4 times. They also reported that the reduction of esterase activity is responsible for higher susceptibility of *S. litura* to the combination treatment.

Fruit yield

On number basis: The combination treatments T_4, T_5 and T_6 were significantly superior to the control (76.27 and 54.53 thousands per ha) during both the years 2010 and 2011. The highest number of healthy fruits was recorded from treatment T_6 (122.53 and 163.87 thousands per ha) during *kharif* 2010 and 2011 respectively (Table 3 and Table 4). The number of healthy fruits from T_4 (108.27 and 137.73) and T_5 (100.67 and 152.80) were on par with each other during 2010 and 2011.

On weight basis: The treatment T_6 recorded significantly higher marketable healthy fruits (12.35 tonnes/ha and 16.89 tonnes/ha) than the control (5.30 tonnes/ha and 4.89 tonnes/ha) in both the years. During 2010 the treatments T_4 and T_5 recorded significantly higher (9.58 and 9.84) than T_1 (5.46), T_2 (5.39) and T_3 (6.66). The per cent increase in yield over control was highest in T_6 132.95 and 245.49 for 2010 and 2011 respectively. This is attributed due to reduced infestation in the fruit. Due to combination there may be antifeedancy exhibited against *L. orbonalis*. The antifeedancy against *Spodoptera litura* due to combination of neem and synthetic pyrethroid was already reported by Rao and Dhingra (2000). Similarly, War *et al*. (2011) reported that neem oil in combination with endosulfan resulted in 85.34% antifeedancy against *S. litura*.

Table 5 Efficacy of emamectin benzoate with neem oil against fruit borer, *E. vitella* infestation in okra during *kharif* 2010

Treatment	Percent fruit infestation					
	Number basis			Weight basis		
	After 1st spray	After 2nd spray	Mean	After 1st spray	After 2nd spray	Mean
T1	20.73 (27.06)^{c}	35.34 (36.45)^{e}	28.17 (32.05)^{e}	20.46 (26.89)^{d}	34.27 (35.83)^{g}	26.92 (31.26)^{f}
T2	22.18 (28.09)^{c}	29.16 (32.68)^{c}	25.79 (30.51)^{d,e}	20.95 (27.24)^{d}	31.68 (34.25)^{f}	26.16 (30.76)^{f}
T3	20.87 (27.17)^{c}	25.41 (30.27)^{c,d}	23.40 (28.93)^{d}	19.19 (25.98)^{d}	26.6 (31.05)^{e}	23.13 (28.75)^{e}
T4	12.52 (20.71)^{b}	16.18 (23.72)^{b}	14.53 (22.40)^{c}	9.02 (17.47)^{b}	16.61 (24.05)^{c}	12.82 (20.98)^{c}
T5	9.92 (18.35)^{b}	11.02 (19.29)^{a}	10.51 (18.89)^{b}	8.07 (16.50)^{b}	12.37 (20.58)^{b}	10.25 (18.66)^{b}
T6	6.41 (14.50)^{a}	8.72 (17.13)^{a}	7.55 (15.88)^{a}	3.17 (10.17)^{a}	9.06 (17.48)^{a}	5.92 (14.06)^{a}
T7	12.27 (20.49)^{b}	18.94 (25.78)^{b}	15.59 (23.25)^{c}	11.96 (20.19)^{c}	19.4 (26.13)^{d}	15.36 (23.07)^{d}
T8	37.49 (37.75)^{d}	31.91 (34.38)^{d,e}	34.80 (36.14)^{f}	33.92 (35.62)^{e}	32.97 (35.05)^{f,g}	33.5 (35.36)^{g}
SEm (±)	0.92	1.04	0.72	0.41	0.36	0.3
CV	6.54	6.55	4.81	3.17	2.23	2.03
CD (P<0.05)	2.78	3.15	2.19	1.25	1.1	0.9

Figures in parenthesis are arcsine transformed. In a column means followed by same letter are not significant different from each other by DMRT (P < 0.05)

Table 6 Efficacy of emamectin benzoate with neem oil against fruit borer, *E. vitella* infestation in okra during *kharif* 2011

Treatment	Percent fruit infestation					
	Number basis			Weight basis		
	After 1st spray	After 2nd spray	Mean	After 1st spray	After 2nd spray	Mean
T1	22.92 (28.45)^{c,d}	28.61 (32.32)^{f}	24.7 (29.73)^{e}	24.85 (29.89)^{e}	27.67 (31.73)^{e}	25.75 (30.49)^{e}
T2	24.18 (29.41)^{d}	21.28 (27.45)^{e}	22.89 (28.57)^{d,e}	23.97 (29.31)^{d,e}	23.48 (28.98)^{d}	23.76 (29.16)^{d,e}
T3	22.52 (28.32)^{c,d}	17.85 (24.95)^{d,e}	20.26 (26.73)^{c,d}	22.08 (28.02)^{d}	21.3 (27.48)^{d}	21.74 (27.79)^{d}
T4	10.48 (18.89)^{b}	13.41 (21.48)^{b,c}	11.99 (20.26)^{b}	10.44 (18.85)^{b}	14.03 (22.00)^{b}	12.25 (20.48)^{b}
T5	10.03 (18.45)^{b}	12.9 (21.02)^{b}	11.39 (19.72)^{b}	9.17 (17.62)^{b}	12.96 (21.06)^{b}	11.02 (19.37)^{b}
T6	4.27 (11.82)^{a}	6.22 (14.39)^{a}	5.33 (13.33)^{a}	4.35 (12.01)^{a}	6.93 (15.23)^{a}	5.59 (13.68)^{a}
T7	16.95 (24.20)^{c}	16.88 (24.20)^{c,d}	16.86 (24.20)^{c}	15.32 (23.03)^{c}	17 (24.34)^{c}	16.15 (23.69)^{c}
T8	32.45 (34.73)^{e}	40.73 (39.65)^{g}	36.21 (36.99)^{f}	33.1 (35.12)^{f}	40.99 (39.80)^{f}	36.12 (36.94)^{f}
SEm (±)	1.36	0.98	0.93	0.58	0.67	0.52
CV	9.69	6.6	6.45	4.18	4.43	3.55
CD (P<0.05)	4.12	2.97	2.82	1.77	2.04	1.57

Figures in parenthesis are arcsine transformed. In a column means followed by same letter are not significant different from each other by DMRT (P < 0.05)

Okra per cent fruit infestation

On number basis: The results indicated that after the first and second sprays the lowest per cent fruit infestation was recorded from the T_6 (6.41, 8.72 and 4.27, 6.22) during 2010 and 2011 respectively (Table 5 and Table 6). The mean per cent fruit infestation was 7.55 and 5.33 which was superior to all other treatments. The control has recorded 34.80 and 36.21 per cent fruit infestation during 2010 and 2011 respectively which was the highest among all the treatments. Interestingly, all the combination treatments T_4 (14.53 and 11.99), T_5 (10.51 and 11.39) and T_6 (7.55 and 5.33) were superior to the Neem baan alone treatments T_1 (28.17 and 24.70), T_2 (25.79 and 22.89) and T_3 (23.40 and 20.26) during 2010 and 2011. The Neem baan alone T_1 was least effective treatment. This result is in concordance with the findings of Meena *et al*. (2011) and Ambedkar *et al*. (2000), where azadirachtin 0.03 EC and nimbecidine 0.03 EC were found to be least effective against *E. vitella*.

From the two years results it is evident that the combination treatments (T_5 and T_6) were significantly superior to Neem baan alone and emamectin benzoate alone treatments. The results obtained were in accordance with Mandal (2007) where he has reported the combination of neem oil and endosulfan greatly reduced the jassids number and damage.

On weight basis: Among the eight treatments**,** the lowest per cent fruit infestation was recorded from the combination treatment T_6 (3.17, 9.06 and 4.35, 6.93) during both the years (Table 5 and Table 6). Based on the mean per cent fruit infestation of both the sprays the best four treatments during both the years were T_6 (5.92; 5.59), T_5 (10.25; 11.02), T_4 (12.82; 12.25) as compared to emamectin benzoate alone treatment T_7 (15.36; 16.15). This reveals that combination treatments in the order of T_6, T_5 and T_4 were best over emamectin benzoate alone (T_7) and Neem baan alone (T_1 to T_3). It is evident that the brinjal borer infestation can be effectively managed by the combination of emamectin benzoate and Neem baan in brinjal. The results were in accordance with Jat and Bhardwaj (2005) reported that azadirachtin in combination with half the dose of malathion, decamethrin and *Bacillus thuringiensis* were found effective against *S. litura*.

Fruit yield

On number basis: The fruit yield recorded from 2010 and 2011 revealed that the lowest number of damaged fruits

Table 7 Okra yield recorded from various treatments during *kharif* 2010

Treatment	Total fruit yield per ha		Marketable fruit yield per ha		Damaged fruit yield per ha		Yield gain over control per ha		Percent yield gain over control	
	Number basis ('000)	Weight basis (T)	Number basis ('000)	Weight basis (T)	Number basis ('000)	Weight basis (T)	Number basis ('000)	Weight basis (T)	Number basis	Weight basis
T1	115.07^{c,d}	1.34^{b,c}	82.80^{d,e}	0.98^{c}	32.27^{d}	0.36^{d}	13.2	0.16	18.97	19.45
T2	124.53^{b,c,d}	1.36^{b,c}	92.40^{d}	1.00^{c}	32.13^{d}	0.35^{d}	22.8	0.18	32.76	22.11
T3	127.07^{b,c,d}	1.36^{b,c}	97.33^{c,d}	1.04^{c}	29.73^{d}	0.31^{d}	27.73	0.22	39.85	27.32
T4	136.00^{a,b,c}	1.56^{a}	116.27^{b}	1.36^{b}	19.73^{b,c}	0.20^{b,c}	46.67	0.54	67.05	66.21
T5	144.93^{a,b}	1.57^{a}	128.93^{a,b}	1.41^{b}	15.20^{a,b}	0.16^{b}	59.33	0.59	85.25	71.71
T6	149.20^{a}	1.72^{a}	138.00^{a}	1.62^{a}	11.20^{a}	0.10^{a}	68.4	0.8	98.28	97.11
T7	133.07^{a,b,c,}	1.52^{a,b}	112.27^{b,c}	1.29^{b}	20.80^{c}	0.24^{c}	42.67	0.47	61.3	57.24
T8	106.80^{d}	1.24^{d}	69.60^{e}	0.82^{d}	37.20^{e}	0.42^{e}				
SEm (±)	6.4	0.063	5.56	0.051	1.59	0.014				
CV	8.55	7.46	9.19	7.3	11.07	9.39				
CD (P<0.05)	19.4	0.19	16.85	0.15	4.81	0.04				

Figures in parenthesis are arcsine transformed. In a column means followed by same letter are not significant different from each other by DMRT (P < 0.05)

Table 8 Okra yield recorded from various treatments during *kharif* 2011

Treatment	Total fruit yield per ha		Damaged fruit yield per ha		Marketable fruit yield per ha		Increase in yield over control per ha		Percent increase in yield over control	
	Number basis ('000)	Weight basis (T)	Number basis ('000)	Weight basis (T)	Number basis ('000)	Weight basis (T)	Number basis ('000)	Weight basis (T)	Number basis	Weight basis
T1	145.07^{c,d}	1.43^{b,c}	36.40^{c,d}	0.37^{c,d}	108.67^{d,e}	1.05^{c}	29.6	0.24	37.43	30.14
T2	130.93^{d}	1.44^{b,c}	30.00^{b,c}	0.34^{b,c,d}	100.93^{e}	1.10^{c}	21.86	0.29	27.65	35.23
T3	131.33^{d}	1.47^{b,c}	26.67^{b,c}	0.32^{b,c}	104.67^{d,e}	1.15^{c}	25.6	0.34	32.37	42.3
T4	172.13^{a,b,c}	1.90^{a,b}	20.67^{a,b}	0.23^{a,b}	151.47^{b,c}	1.67^{b}	72.4	0.86	91.56	105.63
T5	186.00^{a,b}	2.09^{a}	21.20^{a,b}	0.23^{a,b}	164.80^{b}	1.86^{a,b}	85.73	1.05	108.42	129.35
T6	208.40^{a}	2.32^{a}	11.07^{a}	0.13^{a}	197.33^{a}	2.19^{a}	118.26	1.38	149.57	170.34
T7	159.20^{b,c,d}	1.92^{a,b}	26.53^{b,c}	0.31^{b,c}	132.67^{c,d}	1.61^{b}	53.6	0.8	67.78	99
T8	124.00^{d}	1.28^{c}	44.93^{d}	0.46^{d}	79.07^{e}	0.81^{c}				
SEm (±)	11.43	0.16	3.38	0.04	9.22	0.12				
CV	12.61	15.86	12.54	12.06	15.97	14.79				
CD (P<0.05)	34.71	0.48	10.26	0.12	27.97	0.37				

Figures in parenthesis are arcsine transformed. In a column means followed by same letter are not significant different from each other by DMRT (P < 0.05)

is recorded from T_6 (11.2 and 11.07) while the control has recorded the highest number of damaged fruits 37.20 and 44.93 (Table 7 and 8). The control T_8 (69.60 and 79.07) has recorded the lowest number of damaged fruits among all other treatments during both the years 2010 and 2011. The T_6 (138.00 and 197.33) has recorded the highest number of marketable healthy fruits during 2010 and 2011. Similarly T_6 recorded highest per cent increase in yield over control (98.128 and 149.57). Neem baan @ 3 ml/L recorded the lowest per cent increase in yield over control 18.97 during 2010.

On weight basis: The treatment T_6 (1.62 and 2.19) recorded the highest marketable yield on weight basis during 2010 and 2011. The total fruit yield per ha was also highest from T_6 1.72 and 2.32 tonnes/ha for both the years which is significantly higher than the control (1.24 and 1.28 tonnes/ha) and Neem baan alone. The per cent increase in yield over control on weight basis was highest for T_6 (97.11 and 170.34) during 2010 and 2011 but emamectin benzoate alone has recorded only 57.24 and 99.00 per cent increase yield over control. Hence it indicated that the combination of emamectin benzoate with Neem baan increases the fruit yield and reduces borer infestation in okra.

CONCLUSION

The combination of emamectin benzoate with Neem baan was safe to brinjal and okra as it doesn't recorded any phytotoxic symptom. Moreover the Bio-efficacy experiment also revealed that the combination has resulted in more per cent reduction in fruit borer infestation in both the crops

than the emamectin benzoate and neem baan spraying alone. Simultaneously the combination treatments recorded the highest marketable yield than all other treatments. This combination will help in avoiding resistance development in the target insect.

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