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Full Length Research Paper

Field and laboratory evaluation of biological compatibility of Emamectin benzoate 5 SG with agrochemicals against okra fruit borer (*Helicoverpa armigera* Hubner)

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In the context of complex field problems compatibility of an efficacious insecticide with other agrochemicals normally used in the field is essential. In this view emamectin benzoate 5 SG 11 g a.i. ha^{-1} was tested with commonly used insecticide, fungicide and fertilizers. Studies were conducted in both laboratory (physical and phytotoxcity experiment) and field experiments (bio efficacy and phytotoxcity) to evaluate the biological compatibility of emamectin benzoate 5 SG recommended dose at 11 g a.i. ha^{-1} with commonly used other agrochemicals against okra fruit borer, *Helicoverpa armigera* Hubner was tested. Emamectin benzoate 5 SG at 11 g a.i. ha^{-1}, Urea (2%), Carbendazim 50 WP (0.1%), Endosulfan 35 EC (350 g a.i.) for the control of okra fruit borer, *H. armigera* at farmers fields. Two field experiments were conducted, first season at Deenampalayam during (January 2009 - March 2009) and second season at Udayampalayam during April 2009 – June 2009). The new formulation of emamectin benzoate 5 SG at 11 g a.i. ha^{-1} and combination treatments were highly effective and reduced the okra fruit borer, *H. armigera* and fruit damage when compared to other agrochemicals. Emamectin benzoate 5 SG at 11 g a.i. ha^{-1} was physically compatible with endosulfan, carbendazim and urea which did not produce any sedimentation. When emamectin benzoate 5 SG was sprayed as tank mix on okra plants, in combination with urea, carbendazim and endosulfan it did not exhibit any phytotoxic symptoms on okra plants and was effective in controlling *H. armigera* and their damage to fruits. Similarly, emamectin benzoate 5 SG at 11 g a.i. ha^{-1} was physically and biologically compatible with endosulfan, carbendazim and urea and effective against fruit borer and reducing their damage on okra plants.

Key words: Laboratory and field biological compatibility, emamectin benzoate 5 SG, agrochemicals , *Helicoverpa armigera* – Okra, experiments.

INTRODUCTION

India is the second largest producer of vegetables in the world with an estimated production of about 90 million tonnes and average productivity of 15 tonnes per hectare. India shares about 14.4 percent of the world output of vegetables from about 2.8 per cent cropped area in the country (Roseleen et al., 2011). Among several vegetable crops cultivated in India, Okra, *Abelmoschus esculentus* (L.) Moench is one of the important vegetables and the tender fruits are the rich sources of vitamins (A, B and C), iron, calcium, and magnesium and also certain other minerals and tender fruits of okra are used as vegetables (Roseleen et al., 2012). Besides various reasons for low productivity, heavy damage is inflicted by fruit borer inflicts direct losses in yield of marketable fruits and vitality of plant resulting In 54.04 percent net yield loss (Sivakumar *et al.,* 2003).

Combinations of pesticides spray are economical and convenient to apply a mixture of two or more pesticides when wide ranges of pests are to be controlled. Incompatibility may cause loss of effectiveness, poor application and also phytotoxicity, physical incompatibilities usually show up as a precipitation of in the spray solution. Chemical incompatibility occurs when the materials breaks down in to different compounds or when the products chemically combine to produce another which involves deactivation and may result in complete or partial failure. Emamectin benzoate, one of the newer compounds is synthesized from the naturally occurring insecticide/acaricide of avermectin family. This was discovered in 1984 as a broad spectrum lepidoptericide. Emamectin benzoate product is a mixture of emamectin benzoate B1a and emamectin benzoate B1b that are extracted from *Streptomyces avermitilis* Burg. (Patil and Rajanikantha, 2004). It interferes with neurotransmitters of target pests which results in disruption of nerve impulses. It is used primarily for the control of lepidopteran pests in foliage and fruity vegetables (Ishaaya et

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Table 1. Physical and Biological compatibility of emamectin benzoate 5 SG with other agrochemicals on okra (Laboratory and field experiments).

	Dose (g a.i. ha^{-1})	Sediment at the bottom (ml)	Phytotoxicity rating*					
			Leaf tip injury	Wilting	Vein clearing	Necrosis	Epinasty	Hyponasty
Emamectin benzoate 5 SG	11	Nil	0	0	0	0	0	0
Urea	1%	Nil	0	0	0	0	0	0
Carbendazim 50 WP	0.1%	Nil	0	0	0	0	0	0
Endosulfan 35 EC	350	Nil	0	0	0	0	0	0
Emamectin benzoate 5 SG + urea	11+ 1%	Nil	0	0	0	0	0	0
Emamectin benzoate 5 SG + carbendazim 50 WP	11+ 1+ 0.1%	Nil	0	0	0	0	0	0
Emamectin benzoate + endosulfan 35 EC	11+ 350	Nil	0	0	0	0	0	0
Emamectin benzoate 5 SG + carbendazim 50 WP + endosulfan 35 EC	11+ 1+ 0.1%	Nil	0	0	0	0	0	0
Emamectin benzoate 5 SG + urea + endosulfan 35 EC	11+ 1% +350	Nil	0	0	0	0	0	0
Emamectin benzoate 5 SG + urea + carbendazim	11+ 0.1% + 350	Nil	0	0	0	0	0	0
Emamectin benzoate 5 SG + endosulfan 35 EC + carbendazim + urea	11+ 1%+ 0.1% + 350	Nil	0	0	0	0	0	0
Untreated control	-		0	0	0	0	0	0

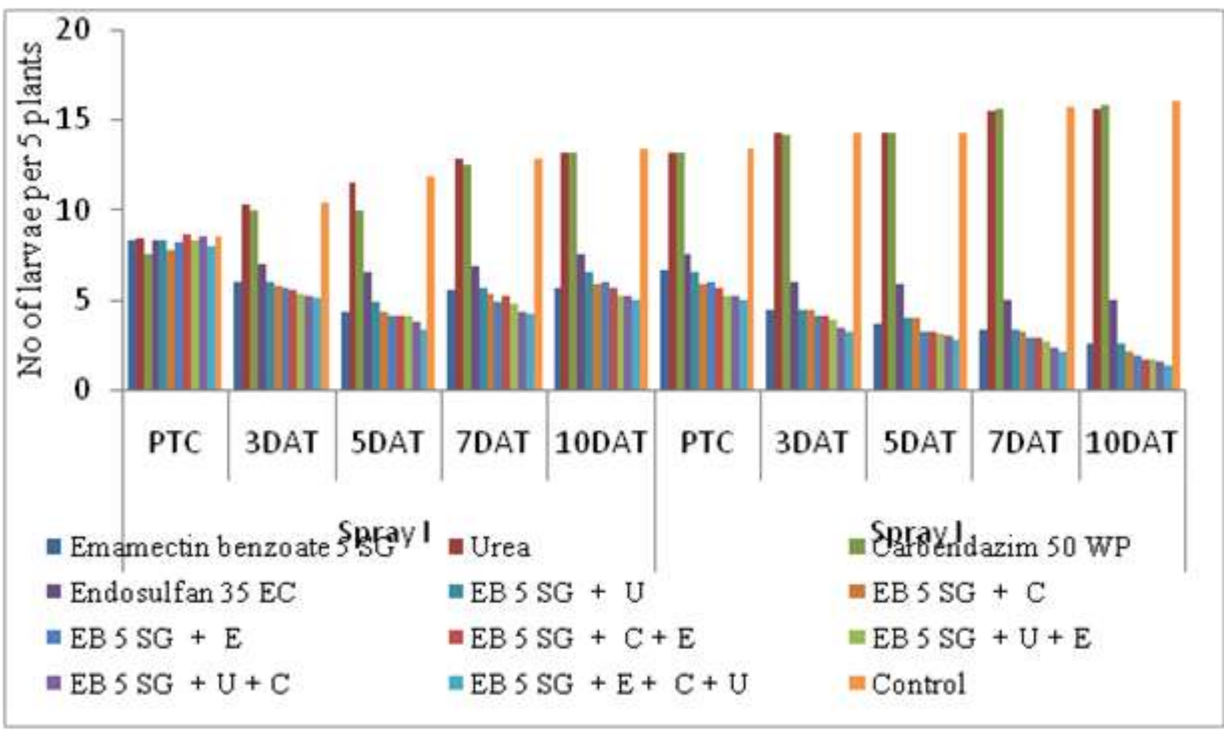

Figure 1. Biological compatibility of Emamectin benzoate 5 SG on larval population of *H. armigera* in okra (Location: Deenampalayam - I season).

al., 2002). It has been reported to possess excellent performance against pests cotton (Govindan et al., 2010) and vegetables (Govindan et al., 2011; Sharma and Kausik, 2010). Combination of insecticide with fungicide and nutrients may save time energy and labour in case of complex field problems (Jasmine *et al.,* 2007). The present study was undertaken to field and laboratory to evaluate the biological compatibility of emamectin benzoate 5 SG with other agrochemicals against okra fruit borer, *H.armigera* and presented in this chapter.

Materials and Methods

Physical compatibility of emamectin benzoate 5 SG with agrochemicals

Laboratory experiments were carried out at toxicology laboratory, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore during 2009– 2010. The Physical compatibility of emamectin benzoate 5 SG with fungicides (carbendazim), macronutrient (urea) and insecticides (endosulfan) were studied in the laboratory condition. Physical stability of emamectin benzoate 5 SG was studied individually and in combination with agrochemicals as detailed below.

Preparation of standard hard water

Standard hard water was prepared by dissolving 0.302 g calcium chloride ($CaCl_2$) and 0.139 g magnesium chloride ($MgCl_2$) in one litre of distilled water. This solution had hardness equivalent of 342 ppm calcium carbonate. To 30 ml of the formulated chemical suspension (emamectin benzoate) prepared, 30ml of the combination chemical (urea, carbendazim and endosulfan) was added separately and transferred to a clean dry graduated cylinder and the volume was made upto 100 ml with standard hard water, shaken well and kept in a thermostat at 30±1°C for 1 h without any disturbance. The sediment, if any, at the bottom was observed. The sediment not exceeding 2.0 ml was considered as the criteria on for the compatibility.

Pot culture experiment

For observing the visible phytotoxic effects of the combination products, okra variety -Thulasi was grown in pots. The experiment with the following treatments was conducted in a completely randomized design and replicated thrice. The treatment details were as follows. The recommended level of emamectin benzoate 5 SG (11 g a.i. ha^{-1}) was mixed with water and to this solution, the fungicide, insecticides, nutrients at recommended concentrations were added and mixed thoroughly. The potted okra plants were sprayed with these solutions on 30th day after planting at the rate of 15 ml plant^{-1}. The plants were observed on 3, 5, 7 and 10 days after spraying and phytotoxicity symptoms likes injury, wilting, vein clearing, necrosis, epinasty and hyponasty were recorded.

Field experiments

Two field experiments were conducted in farmer fields, first season at Deenampalayam during (January 2009 - March 2009) district of Coimbatore and second season at Udayampalayam during (April 2009 – June 2009) district of Erode with above mentioned emamectin benzoate individual and combination 12 treatments. The experiments were carried out in plots of 4 × 5 m size using the Thulasi cultivar in a randomized block design (RBD) with twelve treatments replicated thrice to study the biological compatibility of emamectin benzoate 5 SG with commonly used agrochemicals in okra ecosystem. The recommended effective dose of emamectin benzoate 5 SG (11 g a.i. ha^{-1}) was mixed with water and to this solution, the insecticide, fungicide and nutrients at recommended concentrations were added and mixed thoroughly. Treatments were imposed twice: one at 30th day after planting and the second, 10 days later with pneumatic knapsack sprayer using 500 litres of spray fluid per hectare and observations on larval population of *H. armigera* and fruit damage on okra fruits were recorded on five randomly tagged plants per plot before insecticide application and at 3, 5, 7 and 10 days after spraying. Observations on phytotoxic symptoms like leaf injury, wilting, vein clearing, necrosis, epinasty and hyponasty at any day after treatment on, 3, 5, 7 and 10 days after treatment.

Statistical analysis

The corrected percent reduction of pests over control in the field population was worked out by using the formula given by Henderson and Tilton (1955). The data on percentage reduction were transformed into square root in numbers and percentage in arc sine values before statistical analysis. The data obtained from laboratory and pot culture experiments were analysed in completely randomized design, while the same from field experiments were analysed in randomized block design (RBD) (Gomez and Gomez, 1984). The mean values were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1951).

RESULTS AND DISCUSSION

The results (Table 1) of the investigations on the physical compatibility to assess the compatibility of emamectin benzoate 5 SG at (11 g a.i. ha^{-1}) with carbendazim 50 WP (0.1%), urea (2 %) and endosulfan 35 EC (350 g a.i. ha^{-1}) revealed that no sediment was observed at the bottom which was considered as the criterion for compatibility. The results confirmed that emamectin benzoate 5 SG is physically compatible with the agrochemicals used in the present study. The results of laboratory and field (Deenampalayam and Udayampalayam) experiments conducted to assess the biological compatibility of emamectin benzoate 5 SG at 11 g a.i. ha^{-1} with endosulfan 35 EC (350 g a.i. ha^{-1}), urea (2%) and carbendazim 50 WP (0.1%) as foliar application on okra variety - Thulasi showed that none of the combination treatments caused any phytotoxic symptoms such as injury to leaf tip and leaf surface, wilting, vein clearing, necrosis, epinasty and hyponasty (Table 1) and it was in agreement with the report of Aiswariya, (2010) who reported that plots treated with emamectin 5 WSG and combination with endosulfan + carbendazim + urea recorded no phytotoxic symptoms in okra plants.

Larval population (first season)

The efficacy of emamectin benzoate 5 SG in combination with other agrochemicals commonly used in okra ecosystem in reducing the larval population of *H. armigera* is presented in Figure 1 and Table 2. The results of first season field experiments conducted at Deenampalayam revealed that the larval populat-

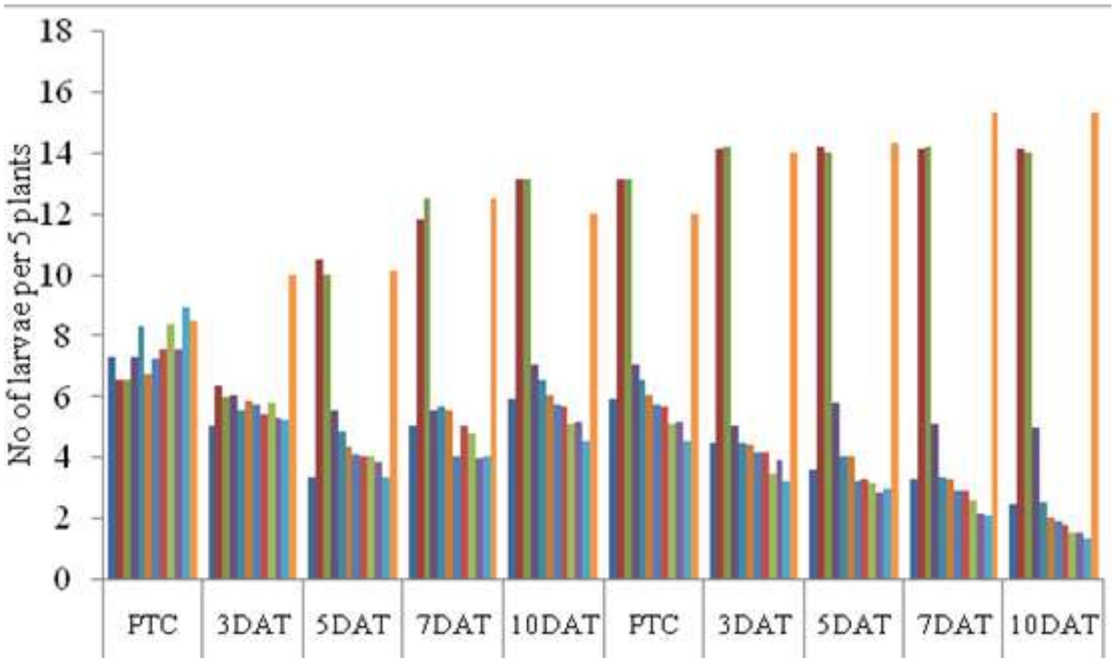

Figure 2. Biological compatibility of Emamectin benzoate 5 SG on larval population of *H. armigera* in okra (Location: Udayampalayam - II season).

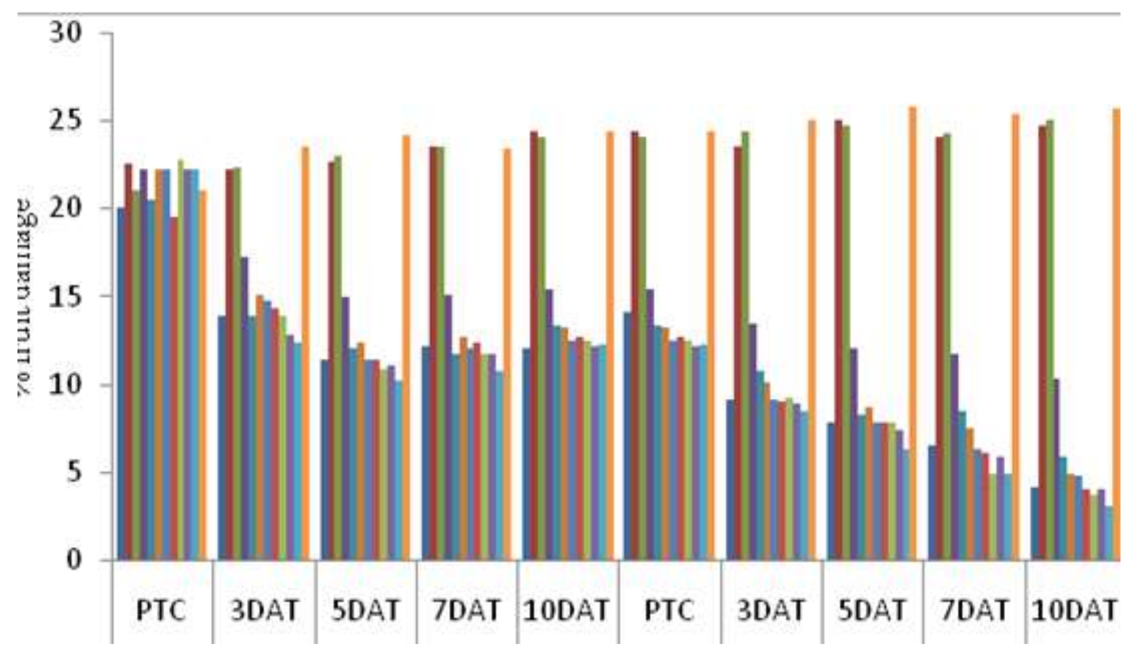

Figure 3. Biological compatibility of emamectin benzoate 5 SG against fruit borer damage on okra (Location: Deenampalayam- I season).

ion of *H. armigera* before imposing treatments ranged from 7.53 to 8.57 larvae per five plants. After the first application of emamectin benzoate 5 SG combinations, there was significant reduction of larval population of *H. armigera* compared to untreated check. At 5 DAT, emamectin benzoate 5 SG alone and emamectin benzoate in combination treated plots recorded **<** 5.00 larvae per five plants, while the highest larval population of *H. armigera* was noticed in untreated plots, urea and carbendazim **>** 10.00 larvae per five plants. This is supported by Singh and Kumar, (2012) emamectin benzoate 5 SG at 0.15 kg / ha was found effective reducing the population of *H. armigera* in chick pea. Earlier report of Kuttalam et al. (2008)

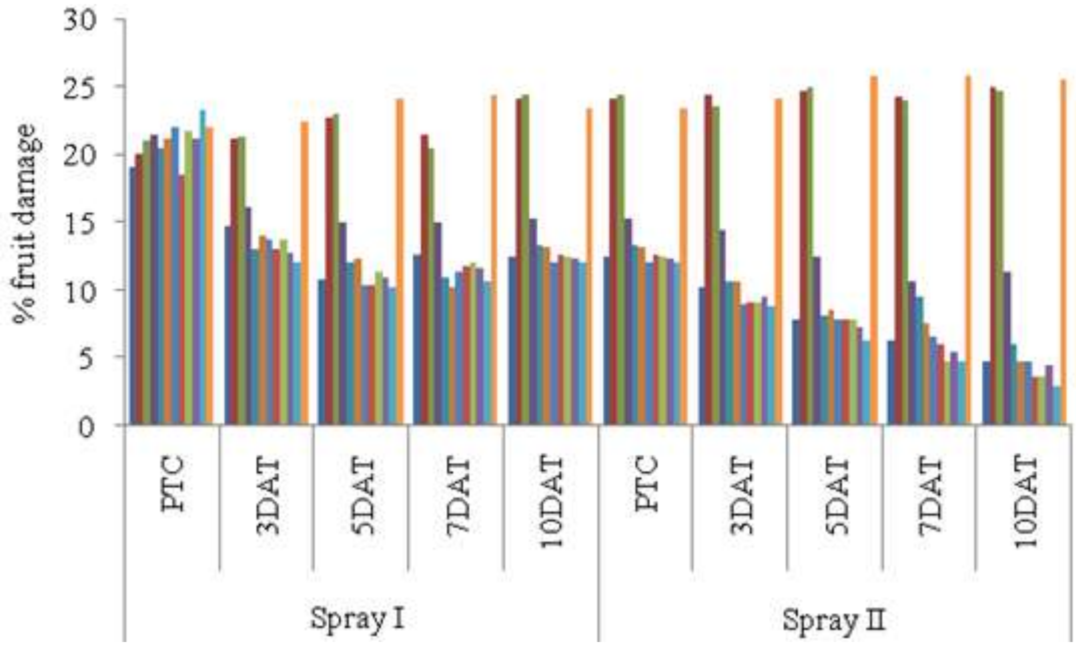

Figure 4. Biological compatibility ofemamectin benzoate 5 SG against fruit borer damage on okra (Location: Udayampalayam II season).

also found emamectin benzoate 5 SG @ 13 and 15 g a.i ha^{-1} effective in suppressing the larval population of *E. vittella* in okra and also these results are in line with Bheemanna *et al.* (2005) who found that foliar application of emamectin benzoate 5 SG 5 SG @ 11 g a.i. ha^{-1} recorded lower fruit damage, against okra fruit borers. The lowest mean larval population of *H. armigera* was recorded by emamectin benzoate alone and its combination treatments effecting > 58.58 per cent (52.52 – 63.58 %) reduction over untreated check. Where as endosulfan alone (42.52 %), lower efficacy showed in carbendazim (6.02) and urea (1.23). The present findings are in tune with the earlier reports of Ahmed *et al*., (2003) who reported that ULV application of Novaster® 56 EC (abamectin + bifenthrin) at 500 ml ac^{-1} was the best for controlling I, II and III instars of *H. armigera* (Figure 1). At 10 DAT, the lowest larval population was recorded in plots sprayed with emamectin benzoate + urea + carbendazim + endosulfan, emamectin benzoate + urea + endosulfan, emamectin benzoate + carbendazim + endosulfan and emamectin benzoate + urea effecting 84.28, 81.35 80.23, and 76.37 per cent reduction, respectively while the highest larval population per five plants was observed in the plots treated with urea (14.90) and carbendazim (14.94), untreated check (16.00). This is supported by Rui (2001) who found that abamectin (1.5% + *Bt* WP) at a dilution rate of 1:750 and 1500 effected a control of 90.9 per cent in *Plutella xylostella* (L.) on 7 DAT.

Second season

At Udayampalayam, the pre treatment population ranged from 6.55 to 8.90 larvae per five plants (Figure 2 and Table 3). Application of combination of emamectin benzoate + urea + carbendazim + endosulfan resulted in reducing larval population to 3.31 larvae per five plants which were on par with emamectin benzoate alone (3.33) and emamectin benzoate + urea + carbendazim (3.81) followed by emamectin benzoate + carbendazim + endosulfan (4.00) which were on par with emamectin benzoate + urea + carbendazim (4.00) and emamectin benzoate + endosulfan (4.10). All the emamectin benzoate with combination treatments were significantly superior to untreated control recorded (10.10 larvae per five plants). These findings are in conformity with the results of Sontakke *et al.,* (2007) observed that emamectin benzoate 5 SG @ 11 g a.i. ha^{-1} alone was effective in controlling the fruit borer and frit damage in okra and tomato (Singha and Nath, 2011). This increase in larval population at 10 DAT is due to the new younger fruits growth that dilutes the non- systemic insecticide deposits on the fruit surface and also that the new fruit act as insecticide free refuges to the insects that decrease the mean efficacy of insecticides, as reported by (Wilson *et al.,* 1983).

Fruit damage (First season)

The damage percentage due to fruit borers before imposing treatments ranged from 19.50 to 22.78 per cent (Figure 3 and Table 4). he results revealed that emamectin benzoate + endosulfan + carbendazim + urea combination was highly effective and reduced the fruit damage (10.73%) which was on par with emamectin benzoate + urea + carbendazim (11.73%), emamectin benzoate + urea + endosulfan (11.67%), emamectin benzoate + endosulfan (12.07%), emamectin benzoate + carbendazim (12.67%) and emamectin benzoate + urea (11.67%) at 7 DAT. Untreated plot as well as urea and carbendazim alone treated plots recorded higher damage (>23.00 %) than combination after seven days of first spray. It was in agreement with the report of Aiswariya, (2010) who stated that plots treated with emamectin 5 WSG combination with endosulfan + carbendazim + urea recorded reducing the fruit borer, *H. armigera* in okra. The lowest mean percent

Table 2. Biological compatibility of emamectin benzoate 5 SG on larval population of *H. armigera* in okra (Location: Deenampalayam - I season).

Treatments	Dose (g a.i.ha^{-1})	Number of larva per five plants *													
		First application							Second application						
		PTC	3DAT	5DAT	7DAT	10DAT	Mean	ROC (%)	PTC	3DAT	5DAT	7DAT	10DAT	Mean	ROC (%)
Emamectin benzoate 5 SG	11	8.27	6.00 (2.55)^{ab}	4.33 (2.20)^{b}	5.50 (2.45$^{)bc}$	5.68 (2.49)^{ab}	5.38	55.58	6.67	4.40 (2.21)^{cd}	3.67 (2.04)^{bc}	3.28 (1.95)^{d}	2.50 (1.73)^{de}	3.46	77.04
Urea	1%	8.37	10.32 (3.20)^{d}	11.50 (3.40)^{e}	12.80 (3.63)^{e}	13.20 (3.80)^{e}	11.96	1.23	13.20	14.20 (3.95)^{f}	14.28 (3.97)^{e}	15.50 (4.00)^{f}	15.60 (4.04)^{f}	14.90	1.12
Carbendazim 50 WP	0.1%	7.53	9.90 (3.20)^{d}	10.00 (3.10)^{e}	12.50 (3.60)^{e}	13.10 (3.10)^{de}	11.38	6.02	13.10	14.10 (3.85)^{f}	14.28 (3.96)^{e}	15.55 (4.03)^{f}	15.83 (4.04)^{f}	14.94	1.00
Endosulfan 35 EC	350	8.27	7.00 (2.74)^{c}	6.50 (2.64)^{d}	6.83 (2.71)^{d}	7.50 (2.83)^{cd}	6.96	42.52	7.50	6.00 (2.54)^{e}	5.83 (2.52)^{d}	5.00 (2.34)^{e}	4.97 (2.34)^{e}	5.45	63.83
EB 5 SG + U	11+ 1%	8.27	6.00 (2.55)^{ab}	4.83 (2.30)^{c}	5.67 (2.48)^{c}	6.50 (2.64)^{bc}	5.75	52.52	6.50	4.44 (2.24)^{cd}	4.01 (2.04)^{c}	3.27 (1.94)^{d}	2.50 (1.73)^{de}	3.56	76.37
EB 5 SG + C	11+ 0.1%	7.73	5.80 (2.51)^{ab}	4.34 (2.20)^{b}	5.33 (2.41)^{bc}	5.87 (2.52)^{ab}	5.34	55.91	5.87	4.40 (2.21)^{cd}	4.00 (2.03)^{c}	3.23 (1.93)^{d}	2.13 (1.62)^{cd}	3.44	77.18
EB 5 SG + E	11+ 350	8.20	5.67 (2.48)^{ab}	4.10 (2.17)^{ab}	4.88 (2.39)^{ab}	6.00 (2.54)^{ab}	5.16	57.40	6.00	4.14 (2.15)^{bc}	3.23 (1.93)^{ab}	2.90 (1.84)^{cd}	1.87 (1.54)^{bc}	3.04	79.83
EB 5 SG + C + E	11+ 0.1% +350	8.57	5.50 (2.45)^{ab}	4.08 (2.15)^{ab}	5.17 (2.38) ^{bc}	5.67 (2.48)^{ab}	5.11	57.81	5.67	4.13 (2.15)^{bc}	3.23 (1.93)^{ab}	2.87 (1.83)^{cd}	1.70 (1.48)^{abc}	2.98	80.23
EB 5 SG + U + E	11+ 1% +350	8.30	5.30 (2.41)^{ab}	4.07 (2.14)^{ab}	4.77 (2.29)^{ab}	5.17 (2.38)^{a}	4.83	60.11	5.17	3.87 (2.09)^{ab}	3.10 (1.90)^{ab}	2.60 (1.76)^{bc}	1.67 (1.47)^{abc}	2.81	81.35
EB 5 SG + U + C	11+ 1% + 0.1%	8.53	5.23 (2.39)^{ab}	3.80 (2.07)^{ab}	4.33 (2.20)^{a}	5.17 (2.38)^{a}	4.63	61.77	5.17	3.43 (1.98)^{ab}	2.97 (1.86)^{a}	2.30 (1.67)^{ab}	1.60 (1.44)^{ab}	2.58	82.88
EB 5 SG + E + C + U	11+ 350 + 0.1% + 1%	7.93	5.13 (2.37)^{a}	3.33 (1.96)^{a}	4.17 (2.16)^{a}	5.00 (2.34)^{a}	4.41	63.58	5.00	3.23 (1.93)^{a}	2.80 (1.82)^{a}	2.10 (1.61)^{a}	1.33 (1.35)^{a}	2.37	84.28
Untreated control	-	8.47	10.42 (3.30)^{d}	11.83 (3.51) ^{e}	12.87 (3.66)^{e}	13.33 (3.84)^{e}	12.11	-	13.33	14.30 (3.98)^{f}	14.30 (3.98)^{e}	15.67 (4.02)^{f}	16.00 (4.15)^{f}	15.07	-

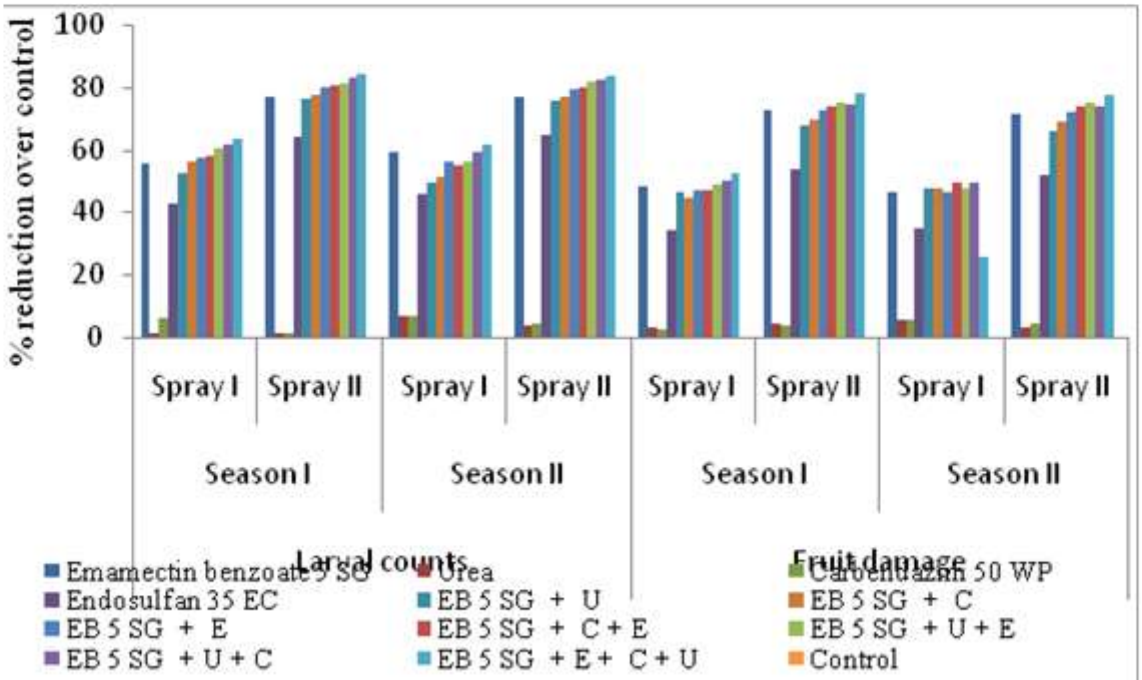

Figure 5. Percent reduction over control for larval and fruit damage for season I and season II.

damage was recorded by emamectin benzoate alone (12.34 %), emamectin benzoate + endosulfan + carbendazim + urea (14.41 %), emamectin benzoate + urea + endosulfan (12.21%), emamectin benzoate + urea + carbendazim (11.93%) and emamectin benzoate + urea (12.73%). This observation is similar to that of Jasmine *et al.* (2007) reported that abamectin was physically and biologically compatible with carbendazim and mancozeb and no phytotoxicity was observed in cotton and cabbage.

After second spray data, there was significant reduction in fruit damage caused by fruit borer. At 5 DAT, the lowest fruit damage was recorded by combination treatments *viz*., emamectin benzoate + endosulfan + carbendazim + urea (6.33%), emamectin benzoate + urea + carbendazim (7.33%), emamectin benzoate + carbendazim + endosulfan (7.80%), emamectin benzoate + endosulfan (7.83 %), emamectin benzoate + carbendazim (8.67 %) and emamectin benzoate + urea (8.18 %) (Figure 3).

All the combination treatments recorded 6.33 to 8.67 per cent damage as against 25.83 per cent damage in untreated check. Results reported by Birah *et al.* (2010) plots treated with emamectin benzoate causing highest larval mortality of *H. armigera* in okra. The highest per cent reduction was recorded by emamectin benzoate + urea + carbendazim + endosulfan (77.76%) combination followed by emamectin benzoate + urea + endosulfan (74.93%), emamectin benzoate + urea + carbendazim (74.49 %) and emamectin benzoate + carbendazim + endosulfan (73.67%). This is supported by Suganthi (2003) reported that emamectin benzoate (0.3 g l^{-1}) was highly compatible with azoxystrobin (1 ml l^{-1}), wettable sulphur (2 g l^{-1}), carbendazim 50 WP (1 g l^{-1}), spiromesifen 240 SC (0.3 ml l^{-1}), dicofol 18.5 EC (2 ml l^{-1}), neem oil (5 ml l^{-1}), neem seed kernel extract (50 ml l^{-1}) and imidacloprid (17.8% SL) at 25 g a.i. ha^{-1} resulted reduced the fruit borer damage and it did not cause any phytotoxic symptoms on the potted plants of okra.

Fruit damage (second season)

The per cent damage due to fruit borers before imposing treatments ranged from 19.00 to 23.22 per cent per ten plants (Figure 4 and Table 5). There was a significant reduction in damage after first round of application, lowest mean percentage of fruit damage reported by emamectin benzoate + urea + carbendazim + endosulfan (11.23 %) followed by emamectin benzoate + carbendazim + endosulfan (11.93%), emamectin benzoate + urea + carbendazim (11.94%), emamectin benzoate + endosulfan (11.88 %) and emamectin benzoate + urea (12.33%), whereas urea, carbendazim and untreated check registered 22.34, 22.29 and 23.41 per cent fruit damage, respectively. All the combination treatments recorded mean of 11.23 to 12.43 per cent damage as against 23.59 per cent damage in untreated check. The per cent fruit damage reduced due to the fact that the insecticide efficacy depends on the initial activity of the active ingredient on the target pest and its residual activity (persistence) as reported by Mulrooney and Elmore (2000). After second spray, the highest per cent reduction was recorded by emamectin benzoate + urea + carbendazim + endosulfan (77.36%) followed by with emamectin benzoate + urea + endosulfan (74.87 %), emamectin benzoate + car bendazim + endosulfan (73.80 %), emamectin benzoate + urea + carbendazim (73.48%) and emamectin benzoate + endosulfan (72.17%) (Figure 4). This increased efficacy might be due to penetration of emamectin benzoate through leaf tissues by translaminar movement delaying its degradation under field conditions as reported by Tomlin (2003). The fruit yield (Table 6) was significantly higher in all the emamectin benzoate 5 SG combination treatments compared to untreated check, urea and carbendazim 50 WP in field experiment I (Deenampalayam) and emamectin benzoate 5 SG at 11 g a.i. ha^{-1} yielded the 9117 kg ha^{-1} which were on par with all emamectin benzoate 5 SG combination treatments,

Table 3. Biological compatibility of emamectin benzoate 5 SG on larval population of *H. armigera* in okra ,(Location: Udayampalayam - II season).

Treatments	Dose (g a.i.ha^{-1})	Number of larva per five plants *													
		First application							Second application						
		PTC	3DAT	5DAT	7DAT	10DAT	Mean	ROC (%)	PTC	3DAT	5DAT	7DAT	10DAT	Mean	ROC (%)
Emamectin benzoate 5 SG	11	7.28	5.00 (2.50)^{ab}	3.33 (1.20)^{a}	5.00 (2.10)^{bc}	5.87 (2.52)^{ab}	4.55	59.19	5.87	4.44 (2.24)^{cd}	3.60 (1.97)^{bc}	3.27 (1.94)^{d}	2.47 (1.70)^{de}	3.45	76.61
Urea	1%	6.50	6.32 (3.00)^{d}	10.50 (3.00)^{e}	11.80 (3.63)^{e}	13.10 (3.70)^{e}	10.43	6.45	13.10	14.10 (3.85)^{f}	14.20 (3.89)^{e}	14.10 (3.85)^{f}	14.10 (3.85)^{f}	14.12	3.54
Carbendazim 50 WP	0.1%	6.55	5.95 (3.20)^{d}	10.00 (3.10)^{e}	12.50 (3.00)^{e}	13.10 (3.10)^{de}	10.39	6.81	13.10	14.20 (3.95)^{f}	14.00 (3.69)^{e}	14.20 (3.95)^{f}	14.00 (3.69)^{f}	14.10	4.10
Endosulfan 35 EC	350	7.25	6.00 (2.70)^{c}	5.51 (2.30)^{d}	5.55 (2.35)^{d}	7.00 (2.23)^{cd}	6.02	46.00	7.00	5.00 (2.05)^{e}	5.80 (2.49)^{d}	5.10 (2.44)^{e}	4.97 (2.34)^{e}	5.22	64.61
EB 5 SG + U	11+ 1%	8.27	5.50 (2.25)^{ab}	4.81 (2.35)^{c}	5.67 (2.48)^{c}	6.55 (2.59)^{bc}	5.63	49.50	6.55	4.45 (2.26)^{cd}	4.00 (2.03)^{c}	3.30 (1.97)^{d}	2.50 (1.73)^{de}	3.56	75.86
EB 5 SG + C	11+ 0.1%	6.70	5.85 (2.55)^{ab}	4.30 (2.12)^{b}	5.51 (2.30)	6.00 (2.54)^{ab}	5.42	51.39	6.00	4.40 (2.21)^{cd}	4.01 (2.04)^{c}	3.23 (1.93)^{d}	2.00 (1.10)^{cd}	3.41	76.88
EB 5 SG + E	11+ 350	7.20	5.68 (2.49)^{ab}	4.10 (2.17)^{ab}	4.00 (2.14)^{a}	5.68 (2.49)^{ab}	4.87	56.32	5.68	4.13 (2.15)^{bc}	3.20 (1.90)^{ab}	2.87 (1.83)^{cd}	1.87 (1.35)^{bc}	3.02	79.52
EB 5 SG + C + E	11+ 0.1% +350	7.50	5.40 (2.35)^{ab}	4.00 (2.14)^{ab}	5.00 (2.10)^{bc}	5.67 (2.48)^{ab}	5.02	54.97	5.67	4.15 (2.16)^{bc}	3.23 (1.93)^{ab}	2.90 (1.84)^{cd}	1.75 (1.52)^{abc}	3.01	79.60
EB 5 SG + U + E	11+ 1% +350	8.35	5.80 (2.81)^{ab}	4.00 (2.14)^{ab}	4.77 (2.29)^{ab}	5.10 (2.28)^{a}	4.92	55.87	5.10	3.43 (1.98)^{ab}	3.15 (1.95)^{ab}	2.60 (1.70)^{bc}	1.50 (1.30)^{ab}	2.67	81.89
EB 5 SG + U + C	11+ 1% + 0.1%	7.50	5.24 (2.20)^{ab}	3.81 (2.07)^{a}	3.96 (1.95)^{a}	5.17 (2.38)^{a}	4.55	59.19	5.17	3.87 (2.09)^{ab}	2.80 (1.82)^{a}	2.15 (1.67)^{a}	1.50 (1.30)^{ab}	2.58	82.50
EB 5 SG + E + C + U	11+ 350 + 0.1% + 1%	8.90	5.18 (2.38)^{a}	3.31 (1.90)^{a}	4.00 (2.14)^{a}	4.50 (2.30)^{a}	4.25	61.88	4.50	3.20 (1.90)^{a}	2.97 (1.86)^{a}	2.10 (1.61)^{a}	1.30 (1.25)^{a}	2.39	83.80
Untreated control	-	8.45	10.00 (3.10)^{d}	10.10 (3.20)^{e}	12.50 (3.50)^{e}	12.00 (3.40)^{e}	11.15	-	12.00	14.00 (3.58)^{f}	14.30 (3.98)^{e}	15.30 (4.00)^{f}	15.30 (4.00)^{f}	14.75	-

Table 4. Biological compatibility of emamectin benzoate 5 SG against fruit borer damage on okra (Location: Deenampalayam - I season).

Treatments	Dose (g a.i.ha^{-1})	Per cent fruit damage per five plants* First application							Second application						
		PTD	3DAT	5DAT	7DAT	10DAT	Mean	ROC (%)	PTC	3DAT	5DAT	7DAT	10DAT	Mean	ROC (%)
Emamectin benzoate 5 SG	11	20.00	13.87 (21.86)^{bcd}	11.33 (19.66)^{ab}	12.17 (20.36)^{a}	12.00 (20.23)^{a}	12.34	48.25	14.13	9.10 (17.55)^{abc}	7.84 (16.26)^{ab}	6.50 (14.60)^{b}	4.10 (11.62)^{abc}	6.88	72.66
Urea	1%	22.50	22.17 (28.08)^{g}	22.67 (28.43)^{d}	23.50 (29.00)^{c}	24.33 (29.56)^{c}	23.17	2.85	24.33	23.50 (29.00)^{f}	25.00 (30.00)^{d}	24.00 (29.33)^{f}	24.67 (29.78)^{f}	24.29	4.55
Carbendazim 50 WP	0.1%	21.05	22.33 (28.20)^{g}	23.00 (28.65)^{d}	23.50 (29.00)^{c}	24.08 (29.38)^{c}	23.23	2.59	24.08	24.33 (29.56)^{f}	24.67 (29.78)^{d}	24.30 (29.53)^{f}	25.00 (30.00)^{f}	24.57	3.45
Endosulfan 35 EC	350	22.22	17.17 (24.47)^{f}	15.00 (22.78)^{c}	15.05 (22.82)^{b}	15.33 (23.05)^{b}	15.64	34.42	15.33	13.40 (21.46)^{e}	12.00 (20.23)^{c}	11.67 (19.97)^{e}	10.33 (18.72)^{e}	11.85	53.43
EB 5 SG + U	11+ 1%	20.50	13.90 (23.94)^{bc}	12.00 (20.26)^{ab}	11.67 (19.95)^{a}	13.33 (21.41)^{a}	12.73	46.62	13.33	10.67 (19.06)^{d}	8.18 (16.61)^{b}	8.50 (16.93)^{d}	5.83 (13.96)^{d}	8.29	67.42
EB 5 SG + C	11+ 0.1%	22.22	15.03 (22.81)^{de}	12.33 (20.54)^{b}	12.67 (20.84)^{a}	13.17 (21.27)^{a}	13.30	44.23	13.17	10.07 (18.50)^{cd}	8.67 (17.11)^{bc}	7.50 (15.89)^{c}	4.84 (12.71)^{bc}	7.77	69.46
EB 5 SG + E	11+ 350	22.22	14.73 (22.57)^{cde}	11.33 (19.66)^{ab}	12.07 (20.33)^{a}	12.43 (20.65)^{a}	12.64	47.00	12.43	9.05 (17.50)^{bc}	7.83 (16.25)^{ab}	6.33 (14.56)^{b}	4.80 (12.63)^{bcd}	7.00	72.49
EB 5 SG + C + E	11+ 0.1% +350	19.50	14.33 (22.24)^{cd}	11.33 (19.67)^{ab}	12.40 (20.57)^{a}	12.67 (20.84)^{a}	12.68	46.83	12.67	9.00 (17.45)^{bc}	7.80 (16.22)^{ab}	6.03 (14.20)^{b}	4.00 (11.52)^{abc}	6.70	73.67
EB 5 SG + U + E	11+ 1% +350	22.78	13.87 (21.86)^{bcd}	10.83 (19.20)^{ab}	11.67 (19.93)^{a}	12.47 (20.68)^{a}	12.21	48.80	12.47	9.17 (17.61)^{bc}	7.84 (16.24)^{ab}	4.84 (12.71)^{a}	3.67 (11.02)^{ab}	6.38	74.93
EB 5 SG + U + C	11+ 1% + 0.1%	22.22	12.83 (20.99)^{ab}	11.07 (19.42)^{ab}	11.73 (19.95)^{a}	12.10 (20.35)^{a}	11.93	49.97	12.10	8.83 (17.29)^{ab}	7.33 (15.69)^{ab}	5.80 (13.93)^{b}	4.00 (11.52)^{abc}	6.49	74.49
EB 5 SG + E + C + U	11+ 350 + 0.1% + 1%	22.22	12.40 (20.61)^{a}	10.23 (18.66)^{a}	10.73 (19.11)^{a}	12.27 (20.50)^{a}	11.41	52.15	12.27	8.50 (16.95)^{a}	6.33 (14.51)^{a}	4.83 (12.70)^{a}	3.00 (9.95)^{a}	5.66	77.76
Untreated control	-	21.05	23.50 (29.00)^{g}	24.17 (29.44)^{d}	23.41 (28.94)^{c}	24.33 (29.56)^{c}	23.85	-	24.33	25.00 (30.00)^{f}	25.83 (30.55)^{d}	25.33 (30.22)^{f}	25.67 (30.44)^{f}	25.45	-

Table 5. Biological compatibility of emamectin benzoate 5 SG against fruit borer damage on okra (Location: Udayampalayam II season).

Treatments	Dose (g a.i.ha^{-1})	Per cent fruit damage per five plants*													
		First application							Second application						
		PTD	3DAT	5DAT	7DAT	10DAT	Mean	ROC (%)	PTC	3DAT	5DAT	7DAT	10DAT	Mean	ROC (%)
Emamectin benzoate 5 SG	11	19.00	14.73 (22.57)^{cde}	10.83 (19.20)^{ab}	12.67 (20.84)^{a}	12.43 (20.65)^{a}	12.67	46.30	12.43	10.20 (18.63)^{bc}	7.83 (16.25)^{ab}	6.33 (14.56)^{b}	4.80 (11.82)^{bc}	7.29	71.19
Urea	1%	20.00	21.10 (27.00)^{g}	22.67 (28.43)^{d}	21.50 (27.00)^{c}	24.08 (29.38) ^{c}	22.34	5.30	24.08	24.33 (29.56)^{f}	24.67 (29.78)^{d}	24.30 (29.53)^{f}	25.00 (30.00)^{f}	24.58	2.85
Carbendazim 50 WP	0.1%	21.00	21.33 (27.20)^{g}	23.00 (28.65)^{d}	20.50 (26.00)^{c}	24.33 (29.56)^{c}	22.29	5.51	24.33	23.50 (29.00)^{f}	25.00 (30.00)^{d}	24.00 (29.33)^{f}	24.67 (29.78)^{f}	24.29	3.99
Endosulfan 35 EC	350	21.50	16.10 (23.40)^{f}	15.00 (22.78)^{c}	15.05 (22.82)^{b}	15.33 (23.05) ^{b}	15.37	34.84	15.33	14.40 (22.46)^{e}	12.50 (20.73)^{c}	10.60 (18.97)^{e}	11.33 (17.72)^{e}	12.21	51.74
EB 5 SG + U	11+ 1%	20.50	13.00 (23.90)^{bc}	12.00 (20.26)^{ab}	11.00 (18.55)^{a}	13.33 (21.41) ^{a}	12.33	47.74	13.33	10.67 (19.06)^{d}	8.18 (16.61)^{b}	9.50 (16.93)^{d}	6.00 (14.17)^{d}	8.59	66.00
EB 5 SG + C	11+ 0.1%	21.22	14.03 (21.81)^{de}	12.33 (20.54)^{b}	10.17 (17.86)^{a}	13.17 (21.27) ^{a}	12.43	47.31	13.17	10.67 (19.06)^{d}	8.60 (17.10)^{bc}	7.50 (15.80)^{c}	4.80 (12.63)^{bc}	7.89	68.81
EB 5 SG + E	11+ 350	22.00	13.80 (21.79)^{bcd}	10.33 (18.66)^{ab}	11.40 (18.57)^{a}	12.00 (20.23)^{a}	11.88	46.63	12.00	9.00 (17.45) ^{bc}	7.80 (16.22)^{ab}	6.55 (14.60)^{b}	4.80 (12.63)^{bc}	7.04	72.17
EB 5 SG + C + E	11+ 0.1% +350	18.50	13.00 (21.00)^{cd}	10.33 (18.67)^{ab}	11.73 (19.95)^{a}	12.67 (20.84) ^{a}	11.93	49.43	12.67	9.05 (17.50) ^{bc}	7.80 (16.20)^{ab}	6.00 (14.17)^{b}	3.67 (11.02)^{ab}	6.63	73.80
EB 5 SG + U + E	11+ 1% +350	21.78	13.80 (21.80)^{bcd}	11.33 (19.66)^{ab}	12.07 (20.33)^{a}	12.47 (20.68)^{a}	12.42	47.36	12.47	9.18 (17.60)^{bc}	7.80 (16.20)^{ab}	4.80 (12.67)^{a}	3.67 (11.02)^{ab}	6.36	74.87
EB 5 SG + U + C	11+ 1% + 0.1%	21.22	12.80 (20.94) ^{ab}	11.00 (19.40)^{ab}	11.67 (19.93)^{a}	12.27 (20.50)^{a}	11.94	49.39	12.27	9.50 (17.95)^{a}	7.33 (15.69)^{ab}	5.50 (13.53)^{b}	4.50 (11.12)^{ab}	6.71	73.48
EB 5 SG + E + C + U	11+ 350 + 0.1% + 1%	23.22	12.00 (19.97)^{a}	10.20 (18.63)^{a}	10.60 (19.00)^{a}	12.10 (20.35) ^{a}	11.23	25.40	12.10	8.80 (17.26)^{ab}	6.30 (14.48)^{a}	4.80 (12.60)^{a}	3.01 (9.98)^{a}	5.73	77.36
Untreated control	-	22.05	22.50 (28.00)^{g}	24.10 (29.34)^{d}	24.33 (29.56) ^{c}	23.41 (28.94)^{c}	23.59	-	23.41	24.10 (29.34)^{f}	25.80 (30.52)^{d}	25.80 (30.52)^{f}	25.50 (30.01)^{f}	25.30	-

Table 6. Effect of biological compatibility of emamectin benzoate 5 SG with agrochemicals on the fruit yield of okra

Treatments	Dose (g a.i.ha^{-1})	Field experiment I (Deenampalayam)		Field experiment II (Udayampalayam)	
		Fruit yield (kg ha^{-1})	% IOC	Fruit yield (kg ha^{-1})	% IOC
Emamectin benzoate 5 SG	11	9117^{a}	77.03	9300^{a}	86.08
Urea	1%	5240^{c}	1.75	5206^{c}	4.16
Carbendazim 50 WP	0.1%	5292^{c}	2.71	5250^{c}	5.04
Endosulfan 35 EC	350	7760^{b}	50.67	7425^{b}	48.55
EB 5 SG + U	11+ 1%	8997^{a}	74.69	9095^{a}	81.98
EB 5 SG + C	11+ 0.1%	9065^{a}	76.02	9250^{a}	85.08
EB 5 SG + E	11+ 350	9095^{a}	76.61	9295^{a}	85.98
EB 5 SG + C + E	11+ 0.1% +350	9100^{a}	76.70	9311^{a}	86.30
EB 5 SG + U + E	11+ 1% +350	9115^{a}	76.80	9325^{a}	86.58
EB 5 SG + U + C	11+ 1% + 0.1%	9110^{a}	76.90	9315^{a}	86.38
EB 5 SG + E + C + U	11+ 350 + 0.1% + 1%	9125^{a}	77.18	9335^{a}	86.98
Untreated control	-	5150^{c}	-	4998^{c}	-

emamectin benzoate + urea + carbendazim + endosulfan (9125 kg ha^{-1}), emamectin benzoate + urea + endosulfan, (9115 kg ha^{-1}), emamectin benzoate + urea + carbendazim (9110 kg ha^{-1}), emamectin benzoate + carbendazim + endosulfan (9100 kg ha^{-1}), emamectin benzoate + endosulfan (9095kg ha^{-1}) and emamectin benzoate + carbendazim (9165 kg ha^{-1}), This clearly indicates the effectiveness of emamectin benzoate 5 SG in controlling the fruit borer, (*H. armigera*) of okra which results in higher fruit yield. Among the insecticidal treatments the lowest yield was recorded carbendazim recorded 5150, 5240 and 5292 kg ha^{-1}, respectively. Hence, the recommended dose of emamectin benzoate 5 SG at 11 g a.i. ha^{-1}, with combination treatments showed good efficacy against okra fruit borer, (*H. armigera*) and also recorded higher fruit yield could be considered appropriate and economical. The effectiveness of emamectin benzoate 5 SG on yield increase is in agreement with Bheemanna *et al.*,2005 and Sontakke *et al.*,2007 on okra and Jyoti and Basasvangoud, 2012 on brinjal. In second field trial conducted at Udayampalayam (Table 6) emamectin benzoate 5 SG at 11 g a.i. ha^{-1} which was on par with all emamectin benzoate combination treatments and their all combination treated plots recorded the highest fruit yield ranging from 9095 to 9335 kg ha^{-1} with an increase of 81.98 to 86.98 per cent over untreated check, while in the untreated check the okra fruit yield was 4998kg ha^{-1}. The present findings are in tune with the earlier report of Kuttalam *et al*. (2008) who found that foliar application of emamectin benzoate 5 EC alone at 11 g a.i. ha^{-1} treated okra plots recorded 7215 kg ha^{-1}. Therefore, the application emamectin benzoate 5 SG at 11 g a.i. ha^{-1} was physically and biologically compatible with endosulfan, carbendazim and urea and effective against fruit borer and reducing their damage on okra plants.

Per cent reduction for larval population and fruit damage for (first season and second season)

Plots treated with all emamectin benzoate combination treatments ,there was significant reduction of larval population of *H. armigera* compared to untreated check. After two spray highly reduced larval population and fruit damage emamectin benzoate 5 SG alone and combination treatments caused more than 80 per cent larval population and fruit damage (Figure 5).

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