Biological Forum – An International Journal **15(6): 565-572(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Bio-efficacy of the Combination Product Emamectin benzoate 4% + Alfamethrin 9% against Tomato Fruit Borer (*Helicoverpa armigera* Hübner) (Noctuidae: Lepidoptera) and their Safety to Natural Enemies

N. Aswathanarayana Reddy[1&2*], Raghunatha, R.[3], B. Subramanyam[2], Ramachandra R.K.[2] and Manjunathareddy T.B.[1]

[1]Department of Entomology, College of Horticulture, Tamaka, Kolar (Karnataka), India.
[2]Horticultural Research and Extension Centre, Hogalagere -563 138, Kolar District (Karnataka), India.
[3]Department of Entomology, College of Horticulture, Sirsi,-581401, Uttara Kannada district (Karnataka), India.

(Corresponding author: N. Aswathanarayana Reddy)*
(Received: 24 March 2023; Revised: 02 May 2023; Accepted: 18 May 2023; Published: 20 June 2023)
(Published by Research Trend)

ABSTRACT: Tomato (*Solanum lycopersicum*) is one of the most important and remunerative vegetable crops grown around the world for fresh market and processing. Tomato is plagued with several insect pests mainly due to the tenderness and softness as compared to other crops and devastated by an array of pests. Of which, the fruit borer (*Helicoverpa armigera* Hübner) is the polyphagous pest causes considerable losses in quantity as well as the quality of tomato fruits. Hence the field experiment was conducted to determine the bio-efficacy of combination product Emamectin benzoate 4% + Alfamethrin 9% against tomato fruit borer and its safety to natural enemies at Horticultural Research and Extension Centre, Hogalagere during 2019-20. The results revealed that the treatment emamectin benzoate 4% + alfamethrin 9% @1000 ml/ha was found superior in reducing the *H.armigera* population and increased marketable fruit yield in tomatoes, which was followed by the treatment emamectin benzoate 4% + alfamethrin 9% @ 500 ml/ha and emamectin benzoate 5SG @ 220g/ha. Emamectin benzoate is one of the microbial origin insecticide molecule produced by the fermentation of the soil actinomycete, *Streptomyces avermitilis*, and is safer to non target organisms. Hence, the tested combination product emamectin benzoate 4% + alfamethrin 9% was found to be non-toxic to important predators like *Menochilus sexmaculatus, Bracon* sp., and *Chrysoperla carnea* at all the concentrations.

Keywords: alfamethrin, bio-efficacy, emamectin benzoate, fruit borer, *Helicoverpa armigera*, natural enemies, tomato.

INTRODUCTION

Tomato (*Solanum lycopersicum*) is one of the most extensively grown and remunerative vegetable crops in tropical and subtropical regions of the world for fresh market and processing, constituting an important part of our human diet (Talekar *et al*., 2006). It is a rich source of vitamins, minerals, and lycopene. Lycopene is a phytochemical that protects us from cancer (Sharma *et al*., 2011). Globally, the consumption of tomatoes ranked second and is next to Potato (Mandaokar *et al*., 2000). In India, it is cultivated in an area of 865 thousand ha with an average annual production of 16826 thousand tonnes and productivity of 19.50 t ha^{-1}. Andhra Pradesh ranks first in area (296.30 thousand ha) and production (5926.2 thousand tonnes), while Karnataka ranks first in productivity with 34.30 t ha^{-1} (Anon., 2011), but the productivity is still very low compared to the average of the world's yield of 26.29 t ha^{-1}. There are several production constraints for the poor yield of tomatoes. The important reason can be contributed to the substantial losses due to heavy infestation of insect pests due to the tenderness and softness as compared to other crops (Aswathanarayanareddy and Ashok Kumar 2004; Raghunatha *et al*., 2023).

Among them, the fruit borer, *Helicoverpa armigera* Hübner is a polyphagous and most destructive pest attacking several crops throughout the world as well as in India and forms one of the major key pests of tomato for lowering the fruit yield (Atwal, 1976; Aswathanarayanareddy, 1999; Talekar *et al*., 2006). The larva feeds initially on leaves, flowers, buds, and while matured larval instars bore into developing fruits resulting in the reduction of marketable fruit yield (Gajete *et al*., 2004) from 20 to 60 per cent (Tewari and Krishnamoorthy 1984; Lal and Lal 1996; Selvanarayanan, 2000; 55 per cent (Pareek and Bhargava 2003; Gadhiya *et al*., 2014) and up to 90 per cent (Reddy and Reddy, 1999). The fourth instar larva feeds on the developing fruits with the whole body inside the fruit, whereas, only the apical half portion of the 5th instar larvae remains inside the fruit (Aswathanarayanareddy and Ashok Kumar 2004). Globally, *H. armigera* causes an annual crop loss of nearly 5 billion US dollars (Sharma *et al*., 2001; Raghunatha *et al*., 2023) and in India. It has been estimated that crops worth Rs.1000 crores are lost annually by this pest (Jayaraj *et al*., 1994).

In tropical and subtropical areas, tomato production has been seriously affected in recent years by populations that have developed resistance to a wide range of insecticides (Bhusan *et al*., 2012). The presence of high reproductive potential, wider host range, multiple generations, and migratory behavior of this pest has led to indiscriminate use of synthetic pesticides by the farmers for its management, which accounts for the consumption of half of the total insecticide used in India for protection of different crops besides development of resistance (Armes *et al*., 1994) and harmful pesticide residues on fruits. It becomes very problematic pest to tackle with any single potent toxicant for a long time (Hussain *et al*., 1991; Ahmed *et al.,* 2000). Therefore, the use of new insecticide combination product of Emamectin benzoate and alphamethrin could help in preventing development of insecticide resistance. Emamectin benzoate is one of the new microbial origin insecticides produced by the fermentation of the soil actinomycete, *Streptomyces avermitilis*, and is safer to natural enemies. Keeping this in view, the present studies were conducted under field conditions to evaluate the bio-efficacy of the combination product emamectin benzoate 4% + alfamethrin 9% against *H. armigera* to develop sound management strategy and its safety to natural enemies.

MATERIALS AND METHODS

Field experiments were conducted to evaluate the bio-efficacy of a combination product emamectin benzoate 4% + alfamethrin 9% against *H. armigera* in tomato and its safety to natural enemies at Horticultural Research and Extension Centre (HREC), Hogalagere (13°20’06.3” N & 78°17'35.6" E with an elevation of 836m above mean sea level and average normal rainfall of 720mm) located in Srinivaspur Tehsil of Kolar district in Karnataka (India) during 2019-20. The experiment was laid out in Randomized Completely Block Design (RCBD) with seven treatments (Table 1) including untreated control replicated thrice with an individual plot size of 8m × 5m (40m^2). The tomato crop was grown with raised beds of 15cm height with inline drip irrigation (with bore well water) and beds are covered with polythene mulch sheet (40 gauge) for water conservation and weed control. Transplanting of 25days old tomato seedlings of hybrid ‘Charita’ (F_1 hybrid of Sankranti Seeds Pvt. Ltd) obtained from a commercial nursery was taken up with spacing of 90cm x 60cm by following all the recommended package of practices for tomato crop (Anon., 2017). Treatments were imposed as foliar sprays when the *H. armigera* population reached ETL level. Three spray applications were taken up preferably in morning hours at 10 days intervals by using a high volume sprayer with a spray volume of 500 l/ha.

Table 1: Treatment details.

Treatments	Concentration (per ha)	Spray water volume (litre/ha)
T_1- Emamectin benzoate 4% + Alfamethrin 9% EC	300 ml	500
T_2- Emamectin benzoate 4% + Alfamethrin 9% EC	500 ml	
T_3 - Emamectin benzoate 4% + Alfamethrin 9% EC	1000 ml	
T_4- Alfamethrin 10% EC	280 ml	
T_5- Emamectin benzoate 5% SG	220 g	
T_6- Chlorpyriphos 20 EC (RPP)	1250 ml	
T_7 - Untreated Control	-	

Data Recording: Observations on the number of *H. armigera* larva/plant and number of natural enemies like ladybird beetles (eggs, grubs, and adults), green lacewing (eggs, grubs, and adults), *Bracon* sp, and *Cotesia* sp (pupae) were recorded on 10 randomly selected and tagged plants per plot on apical shoots, leaf lets, flowers, flower calyses as well as fruits at a day before spraying as pre-treatment count (Aswathanarayanareddy and Ashok Kumar 2004; Raghunatha *et al.,* 2023). Post treatment count was taken at five, ten and fifteen days after each spray. Further, the mean number of larvae per plant and percent reduction in fruit borer population over control was calculated by using Henderson and Tilton formula (Reddy and Kumar, 2004):

$$\%\ \text{Reduction in population over control} = 100\left\{1 - \frac{(T_a \times C_b)}{(T_b \times C_a)}\right\}$$

Where,
T_a = Number of insects after treatment
T_b = Number of insects before treatment
C_a = Number of insects in untreated check after treatment
C_b = Number of insects in untreated check before treatment.

The data on percentage infestation of tomato fruits by borer was calculated at each picking by counting the total number of fruits and number of damaged fruits. The mean per cent fruit damage was calculated using formula (Reddy and Kumar 2004):

$$\%\ \text{Fruit damage} = \frac{\text{Number of damaged fruits}}{\text{Total number of fruits observed}} \text{X}100$$

Later per cent reduction in fruit damage over untreated control and percent increase in marketable fruit yield per treatment was calculated. Finally, marketable fruit yield per hectare (t/ha) was worked out.

The total marketable fruit yields obtained from all plots were computed on hectare basis. The increase in fruit yield was calculated as yield increase in treated plots compared to untreated plots as follows (Reddy and Kumar 2004):

$$\text{Percent Increase in Yield} = \frac{\text{Increased yield in treated plot}}{\text{Yield in untreated plot}} \times 100$$

Data analysis. All the recorded data were subjected to the analysis of variance by following the RCBD technique (Snedecor and Cochran 1967; Gomez and Gomez 1984). Larval counts were analyzed with original as well as square root transformation. Data on per cent damaged fruits was analyzed be in terms of original as well as angular transformation. Yields of marketable fruits was analyzed by simple RBD with original figures in terms of tons/ha.

EXPERIMENTAL RESULTS

The results of field experiments conducted during 2019 on bio-efficacy, phytotoxicity, and its effect on natural predators and parasitoids of combination product - Emamectin benzoate 4% + Alfamethrin 9% against fruit borer on tomato and percent reduction of in target pest populations were presented in Tables 2-5.

1. Bio-efficacy of combination product Emamectin benzoate 4% + Alfamethrin 9% against *Helicoverpa armigera* Hübner in tomato

First spray

The fruit borer, *H. armigera* population in tomato appeared from the vegetative stage (three weeks after transplanting) to till maturity of the crop. The population was distributed uniformly in experimental plots and differs non-significantly among different treatments tested. The population ranged from 0.96 to 3.03 larva/plant a day before the first spray.

At five days after the first spray, all the treatments differ significantly in reducing the larval population of *H. armigera*. The treatment Emamectin benzoate 4% + Alfamethrin 9% @1000 ml/ha was found to be significantly superior over the remaining other treatments with a minimum *H. armigera* population (0.24 larva/plant). This treatment was on par with Emamectin benzoate 4% + Alfamethrin 9% @ 500 ml and Emamectin benzoate 4% + Alfamethrin 9% @ 300 ml with 0.29 and 0.86 larva/plant, respectively. The maximum larval population of fruit borer was recorded in untreated control and Chlorpyriphos 20 EC @ 1250 ml/ha with 3.38 and 1.37 larvae/plant (Table 2).

The larval population of fruit borer was ranged from 0.29 to 4.10 larvae/plant at ten days after first spray. All the treatments tested were found to be significantly superior over untreated control. The lower larval population of *H. armigera* was noticed in treatment Emamectin benzoate 4% + Alfamethrin 9% @ 1000 ml/ha (0.29 larvae/plant) and Emamectin benzoate 4% + Alfamethrin 9% @ 500 ml/ha (0.41 larvae/plant). The next best treatments were Emamectin benzoate 4% + Alfamethrin 9% @ 300 ml/ha (0.76 larvae/plant) and Emamectin benzoate 5 SG @ 220 g/ha (1.06 larvae/plant). The higher larval population was observed in untreated control (4.10 larva/plant) and Chlorpyriphos 20 EC @ 1250ml/ha (1.54 larva/plant) (Table 2). Similar trend was also noticed at fifteen days after first spray (Table 2).

Second spray. All the treatments were found to be significantly superior over the untreated control five days after the second spray. The larval population of fruit borer ranged from 0.29 to 3.19 larvae/plant. The minimum larval population of *H. armigera* was noticed in the treatment of Emamectin benzoate 4% + Alfamethrin 9% @1000 ml/ha (0.29 larvae/plant). This treatment was on par with Emamectin benzoate 4% + Alfamethrin 9% @ 500 ml/ha (0.35 larvae/plant). The maximum larval population was observed in untreated control (3.19 larva/plant), Chlorpyriphos 20EC @ 1250 ml/ha (1.36 larvae/plant) and Alfamethrin 10% @280 ml/ha (1.31 larvae/plant) (Table 2).

All the treatments were found to be significantly superior over the untreated control ten days after the second spray. The larval population of fruit borer ranged from 0.29 to 3.41 larvae/plant. The lower larval population of *H. armigera* was noticed in treatment Emamectin benzoate 4% + Alfamethrin 9% @ 1000 ml/ha (0.29 larvae/plant), followed by Emamectin benzoate 4% + Alfamethrin 9% @ 500 ml/ha (0.35 larvae/plant). These treatments were on par with each other. The higher larval population was observed in untreated control (3.41 larva/plant), Alfamethrin 10% @ 280 ml/ha (1.52 larvae/plant) and Emamectin benzoate 5 SG @ 220 g/ha (1.30 larvae/plant) (Table 2).

All the treatments were found to be significantly superior over the untreated control at 15 days after the second spray. The larval population of fruit borer ranged from 0.24 to 3.80 larvae/plant. The lower larval population of *H. armigera* was noticed in treatment Emamectin benzoate 4% + Alfamethrin 9% @ 1000 ml/ha (0.24 larvae/plant), followed by Emamectin benzoate 4% + Alfamethrin 9% @ 500 ml/ha (0.37 larvae/plant) and were on par each other. The higher larval population was observed in untreated control (3.80 larva/plant) and Chlorpyriphos 20EC @ 1250 ml/ha (1.31 larvae/plant) (Table 2).

Third spray. All the treatments were found to be significantly superior over the untreated control five days after the third spray. The larval population of fruit borer ranged from 0.27 to 3.44 larvae/plant. The lower larval population of *H. armigera* was noticed in treatment Emamectin benzoate 4% + Alfamethrin 9% @1000 ml/ha (0.27 larvae/plant), followed by Emamectin benzoate 4% + Alfamethrin 9% @ 500 ml/ha (0.42 larvae/plant) and were on par each other. The higher larval population was observed in untreated control (3.44 larva/plant), Chlorpyriphos 20EC @ 1250 ml/ha (1.42 larvae/plant) and Emamectin benzoate 5 SG @ 220 g/ha (1.26 larvae/plant) (Table 2).

All the treatments were found to be significantly superior over the untreated control ten days after the third spray. The larval population of fruit borer ranged from 0.25 to 3.91 larvae/plant. The lower larval population of *H. armigera* was noticed in treatment Emamectin benzoate 4% + Alfamethrin 9% @ 1000 ml/ha (0.25 larvae/plant), followed by Emamectin benzoate 4% + Alfamethrin 9% @500 ml/ha (0.37 larvae/plant) and were on par each other. The higher larval population was observed in untreated control (3.91 larva/plant), Chlorpyriphos 20EC @ 1250 ml/ha

(1.45 larvae/plant) and Emamectin benzoate 5 SG @ 220 g/ha (1.26 larvae/plant) (Table 2).

All the treatments were found to be significantly superior to the untreated control at 15 days after the third spray. The larval population of fruit borer ranged from 0.24 to 3.95 larvae/plant. The lower larval population of *H. armigera* was noticed in treatment Emamectin benzoate 4% + Alfamethrin 9% @1000 ml/ha (0.24 larvae/plant), followed by Emamectin benzoate 4% + Alfamethrin 9% @ 500 ml/ha (0.31 larvae/plant). The higher larval population was observed in untreated control (3.95 larva/plant), Chlorpyriphos 20EC @ 1250 ml/ha (1.62 larvae/plant) and Alfamethrin 10% @ 280 ml/ha (1.33 larva/plant) and (Table 2).

On an average, all the treatments differ significantly in reducing *H. armigera* larval population. The fruit borer population ranged from 0.26 to 3.66 number of larva/plant. The Emamectin benzoate 4% + Alfamethrin 9% @1000 ml/ha was found significantly superior over remaining other treatments with minimum *H. armigera* population (0.26 larvae/plant), followed by Emamectin benzoate 4% + Alfamethrin 9% @ 500 ml/ha (0.36 larvae/plant) and both were on par each other (Table 2). The Emamectin benzoate 4% + Alfamethrin 9% @ 300 ml/ha (0.78 larvae/plant), Emamectin benzoate 5 SG @ 220 g/ha (1.11 larvae/plant), Alfamethrin 10% @ 280 ml/ha (1.18 larvae/plant) and Chlorpyriphos 20 EC @ 1250 ml/ha (1.38 larvae/plant) was found to be on par each other and significantly superior over untreated control (3.66 larvae/plant) (Table 2).

Table 2: Bio-efficacy of combination product Emamectin benzoate 4% + Alfamethrin 9% against fruit borer, *Helicoverpa armigera* Hübner on tomato.

Treatments	I Spray				II Spray			III Spray			Pooled Mean	% reduction in population over control
	Mean No. of larvae per plant at diff. days after spray											
	DBS	5	10	15	5	10	15	5	10	15		
T_1- Emamectin benzoate 4% + Alfamethrin 9% @ 300ml/ha	1.71 (1.31)	0.86 (0.93)	0.76 (0.87)	0.69 (0.83)	0.93 (0.96)	0.66 (0.81)	0.88 (0.94)	0.67 (0.82)	0.73 (0.85)	0.83 (0.91)	0.78	78.69
T_2- Emamectin benzoate 4% + Alfamethrin 9% @ 500ml/ha	0.97 (0.98)	0.29 (0.54)	0.41 (0.64)	0.41 (0.64)	0.35 (0.59)	0.35 (0.59)	0.37 (0.61)	0.42 (0.65)	0.37 (0.61)	0.31 (0.56)	0.36	90.16
T_3 - Emamectin benzoate 4% + Alfamethrin 9%@1000ml/ha	0.96 (0.98)	0.24 (0.49)	0.29 (0.54)	0.21 (0.46)	0.29 (0.54)	0.29 (0.54)	0.24 (0.49)	0.27 (0.52)	0.25 (0.50)	0.24 (0.49)	0.26	92.90
T_4- Alfamethrin 10% @ 280ml/ha	2.23 (1.49)	1.02 (1.01)	1.13 (1.06)	1.33 (1.15)	1.31 (1.14)	1.15 (1.07)	1.31 (1.14)	0.92 (0.96)	1.07 (1.03)	1.33 (1.15)	1.18	67.76
T_5- Emamectin benzoate 5 SG @ 220g/ha	1.92 (1.39)	0.99 (0.99)	1.06 (1.03)	1.14 (1.07)	1.07 (1.03)	1.30 (1.14)	0.89 (0.94)	1.26 (1.12)	1.26 (1.12)	1.01 (1.00)	1.11	69.67
T_6- Chlorpyriphos 20 EC @ 1250ml/ha	2.2 (1.48)	1.37 (1.17)	1.54 (1.24)	1.24 (1.11)	1.36 (1.17)	1.13 (1.06)	1.31 (1.14)	1.42 (1.19)	1.45 (1.20)	1.62 (1.27)	1.38	62.30
T_7 - Untreated Control	3.03 (1.74)	3.38 (1.84)	4.10 (2.02)	3.70 (1.92)	3.19 (1.79)	3.41 (1.85)	3.80 (1.95)	3.44 (1.85)	3.91 (1.98)	3.95 (1.99)	3.66	-
SEm ±	-	0.09	0.09	0.06	0.07	0.15	0.14	0.10	0.11	0.09	-	-
CD @ 5%	NS	0.28	0.27	0.19	0.23	0.46	0.43	0.30	0.33	0.28	-	-
CV	-	13.61	11.57	8.67	10.49	21.72	19.35	14.14	14.36	11.83	-	-

The percent reduction in the fruit borer population over control ranged from 62.30% to 92.90% among different treatments. The maximum percent reduction in fruit borer population over control was observed in the treatment of Emamectin benzoate 4% + Alfamethrin 9% @1000 ml/ha (92.90%), followed by Emamectin benzoate 4% + Alfamethrin 9% @ 500 ml/ha (90.16%) and were on par each other. The minimum percent reduction in fruit borer over control was recorded in Chlorpyriphos 20 EC @ 1250 ml/ha (62.30%) and Alfamethrin 10% @ 280 ml/ha (67.76%) (Table 2).

The percent of fruit damage due to fruit borer was ranged from 52.81 to 67.29% a day before spray application and damage found uniform and differed non significantly among different treatments. At first harvest, the minimum percent fruit damage was noticed in treatment Emamectin benzoate 4% + Alfamethrin 9% @1000 ml/ha (7.18%), followed by Emamectin benzoate 4% + Alfamethrin 9% @ 500 ml/ha (8.80%). The maximum percent fruit damage was observed in untreated control (60.11%), Alfamethrin10% @ 280 ml/ha (15.66%) and Chlorpyriphos 20EC @ 1250 ml/ha (15.19%). These treatments were found to be on par with each other and significantly superior to untreated control (60.11%). A similar trend was noticed in the remaining second, third, fourth, and fifth pickings (Table 3).

The mean percent fruit damage was found to be lower in treatment Emamectin benzoate 4% + Alfamethrin 9% @1000 ml/ha (7.44%) and Emamectin benzoate 4% + Alfamethrin 9% @ 500 ml/ha (8.35%). These two treatments were differing non significantly among themselves and significantly superior over remaining other treatments. The next best treatments were Emamectin benzoate 4% + Alfamethrin 9% @ 300 ml/ha (11.69%) and Emamectin benzoate 5 SG @ 220 g/ha (13.47%). The higher mean fruit borer damage was found in untreated control (62.22%), Chlorpyriphos 20 EC @ 1250 ml/ha (17.35%) and Alfamethrin 10% @ 280 ml/ha (16.54%) (Table 3).

Fruit Yield. The marketable fruit yield was ranged from 13.71 to 30.86 t/ha among different treatments. The treatments Emamectin benzoate 4% + Alfamethrin 9% @1000 ml/ha and Emamectin benzoate 4% + Alfamethrin 9% @ 500 ml/ha recorded maximum marketable fruit yield (30.86 t/ha & 28.89 t/ha) with 125.09% and 110.72% increase in fruit yield over untreated control, respectively and both were on par each other. The Alfamethrin 10% @ 280 ml/ha (19.99 t/ha & 45.81% increase in fruit yield over untreated control), Emamectin benzoate 4% + Alfamethrin 9% @300 ml/ha (19.72 t/ha & 43.84% increase in fruit yield over untreated control), Chlorpyriphos 20 EC @ 1250 ml/ha (19.20 t/ha & 40.04% increase in fruit yield over untreated control) and Emamectin benzoate 5 SG @ 220g/ha (18.78 t/ha & 36.98% increase in fruit yield over untreated control) was found to be on par each other and significantly superior over untreated control (13.71t/ha) (Table 4).

Safety of combination product Emamectin benzoate 4% + Alfamethrin 9% to natural enemies in tomato: Natural enemies observed in the tomato experimental plot were adults of coccinellid beetles (*Coccinella* spp., *Menochilus sexmaculata*) and adults of green lacewing (*Chrysoperla zastrowi*). The study revealed that the natural enemies population in all the treatments an average found to be almost similar and uniform (Table 5). While in untreated control a few more populations were recorded indicating that all the tested treatments are safer for natural predators.

DISCUSSION

The maximum percent reduction in the *H. armigera* population over control was observed in the treatment of emamectin benzoate 4% + alfamethrin 9% @1000 ml/ha (92.90%), followed by Emamectin benzoate 4% + Alfamethrin 9% @ 500 ml/ha (90.16%) and were on par each other. The mean percent fruit damage was also found to be lower in treatment emamectin benzoate 4% + alfamethrin 9% @1000 ml/ha (7.44%) and emamectin benzoate 4% + alfamethrin 9% @ 500 ml/ha (8.35%) at different pickings. These two treatments were differing non-significantly among themselves and were significantly superior to the remaining other treatments. The treatments emamectin benzoate 4% + alfamethrin 9% @1000 ml/ha and emamectin benzoate 4% + alfamethrin 9% @ 500 ml/ha recorded maximum marketable fruit yield (30.86 t/ha & 28.89 t/ha) with 125.09% and 110.72% increase in fruit yield over untreated control, respectively and both were on par each other. The present results are in agreement with the findings of Murugraj *et al.* (2006) who reported that emamectin benzoate (Proclaim 5 SG) @11g ai/ha were highly effective against the larval population of *H. armigera* in tomatoes. Suganya Kanna *et al.* (2005) revealed that emamectin benzoate significantly reduced the population of *H. armigera* in tomatoes. Raghunatha *et al.* (2023) reported that the treatment Novaluron 9.45% + Lambda-cyhalothrin 1.9% EC @ 90g.a.i./ha was found to be most effective in reducing the population of *Helicoverpa armigera* (Hübner) in tomato and recorded higher fruit yield with maximum cost-benefit ratio. Patil *et al*. (2007) observed the superiority of emamectin benzoate 5% SG against *H. armigera* on chickpea with a higher yield of 2256 kg/ha. Two applications of emamectin benzoate 5% SG @220g ai/ha reduced the larval population of *H. armigera* on cotton (Murali Baskaran *et al*., 2010). Similarly, several workers reported the efficacy of emamectin benzoate against bollworm complex (*H. armigera*, *E. vittella*, and *P. gossypiella*) on cotton (Duraimurugan *et al*., 2007; Gupta *et al.*, 2005; Raghuraman *et al*., 2008; Uddikeri *et al*., 2011). Anil Sharma (2010) reported that emamectin benzoate reduced the shoot and fruit infestation of *Leucinodes orbonalis* on brinjal. Patra *et al*. (2007) recorded the less larval populations of shoot and fruit borer, *Earias vittella* on okra.

The tested combination product emamectin benzoate 4% + alfamethrin 9% was found to be less harmful to beneficial insects population with all concentrations under field conditions. These findings are confirmed by the results of Bade *et al*. (2017) who reported that emamectin benzoate 5 SG (0.001%) was found to be safer to coccinellid (*Coccinella* sp. & *Menochilous sexmaculatus*) population as compared to other insecticides. Govindan *et al*. (2013) recorded a maximum population of ladybird beetles with emamectin benzoate 5% SG at 7g ai/ha followed by emamectin benzoate 5% SG at 11g ai/ha. All the tested concentrations of emamectin benzoate1.9 EC were found to be safer to coccinellid beetles and a greater number of beetles was recorded in treatment emamectin benzoate 1.9 EC at 5g ai/ha (Karthikeyan *et al*., 2017). Emamectin benzoate 5% WG was harmless to natural enemies like ladybird beetles (*Coccinella* sp. & *Menochilous sexmaculatus*) and *Chrysoperla* (Kailash *et al*., 2017).

Table 3: Bio-efficacy of combination product Emamectin benzoate 4% + Alfamethrin 9% against fruit borer, *Helicoverpa armigera* Hübner on tomato.

Treatments	Percent fruit damage (Picking wise)						Mean fruit damage (%)
	DBS	I	II	III	IV	V	
T_1- Emamectin benzoate 4% + Alfamethrin 9% @ 300ml/ha	62.34 (38.6)	10.28 (5.9)	10.76 (6.2)	14.04 (8.1)	13.05 (7.5)	10.31 (5.9)	11.69
T_2- Emamectin benzoate 4% + Alfamethrin 9% @ 500ml/ha	52.73 (31.8)	8.80 (5.1)	8.52 (4.9)	9.14 (5.2)	8.82 (5.1)	6.48 (3.7)	8.35
T_3- Emamectin benzoate 4% + Alfamethrin 9% @ 1000ml/ha	54.38 (32.9)	7.18 (4.1)	8.59 (4.9)	8.10 (4.7)	6.95 (4.0)	6.37 (3.6)	7.44
T_4- Alfamethrin 10% @ 280ml/ha	61.79 (38.2)	15.66 (9.0)	15.66 (9.0)	15.60 (9.0)	20.31 (11.7)	15.46 (8.9)	16.54
T_5- Emamectin benzoate 5SG @ 220g/ha	52.81 (31.9)	13.97 (8.0)	13.91 (8.0)	11.19 (6.4)	11.68 (6.7)	16.60 (9.6)	13.47
T_6- Chlorpyriphos 20 EC @1250 ml/ha	62.58 (38.7)	15.19 (8.7)	21.63 (12.5)	18.84 (10.9)	15.20 (8.7)	15.89 (9.1)	17.35
T_7 - Untreated Control	67.29 (42.3)	60.11 (36.9)	69.43 (44.0)	52.09 (31.4)	75.61 (49.1)	53.87 (32.6)	62.22
SEm ±	-	1.91	2.48	0.99	1.00	1.22	-
CD @ 5%	NS	5.88	7.63	3.06	3.07	3.76	-
CV	-	17.62	20.22	9.33	7.98	11.83	-

Table 4: Bio-efficacy of combination product Emamectin benzoate 4% + Alfamethrin 9% against fruit borer on tomato.

Treatments	Fruit yield (Picking wise) (kg/plot)						Fruit yield (t/ha)	% increase in yield over control
	I	II	III	IV	V	Total		
T_1- Emamectin benzoate 4% + Alfamethrin 9% @ 300ml/ ha	80.86 (9.0)	85.33 (9.2)	69.30 (8.3)	88.70 (9.4)	70.19 (8.4)	78.87	19.72	43.84
T_2- Emamectin benzoate 4% + Alfamethrin 9% @ 500ml /ha	106.65 (10.3)	109.38 (10.5)	103.59 (10.2)	117.00 (10.8)	141.26 (11.9)	115.57	28.89	110.72
T_3 - Emamectin benzoate 4% + Alfamethrin 9% @1000ml/ha	132.34 (11.5)	112.51 (10.6)	127.85 (11.3)	140.74 (11.9)	103.72 (10.2)	123.43	30.86	125.09
T_4- Alfamethrin 10% @ 280ml/ha	75.60 (8.7)	85.32 (9.2)	89.29 (9.5)	81.67 (9.0)	67.85 (8.2)	79.94	19.99	45.81
T_5- Emamectin benzoate 5 SG @ 220g/ha	67.57 (8.2)	84.25 (9.2)	70.08 (8.4)	81.42 (9.0)	72.19 (8.5)	75.10	18.78	36.98
T_6- Chlorpyriphos 20 EC @ 1250 ml/ha	81.88 (9.1)	70.51 (8.4)	83.62 (9.1)	80.46 (9.0)	67.48 (8.2)	76.79	19.20	40.04
T_7 - Untreated Control	49.19 (7.0)	60.10 (7.8)	64.11 (8.0)	56.27 (7.5)	44.44 (6.7)	54.82	13.71	-
SEm ±	6.06	4.67	4.29	8.54	6.31	-	-	
CD @ 5%	18.68	14.40	13.22	26.32	19.43	-	-	
CV	12.37	9.33	8.56	16.02	13.48	-	-	

Table 5: Effect of combination product - Emamectin benzoate 4% + Alfamethrin 9% on natural predators in tomato.

Sr. No.	Treatments	Mean no./plant after 2 sprays		
		Coccinellids	Green lacewing	*Bracon* sp
T_1	Emamectin benzoate 4% + Alfamethrin 9% @ 300 ml/ha	1.07	0.88	1.00
T_2	Emamectin benzoate 4% + Alfamethrin 9% @ 500 ml/ha	1.13	0.95	1.16
T_3	Emamectin benzoate 4% + Alfamethrin 9% @ 1000 ml/ha	1.06	0.92	1.25
T_4	Alfamethrin 10% @ 280 ml/ha	1.16	1.13	1.0
T_5	Emamectin benzoate 5 SG @ 220g/ha	1.04	0.80	0.75
T_6	Chlorpyriphos 20 EC@1250ml/ha (RPP)	1.97	0.89	0.65
T_7	Untreated Control	1.87	0.89	0.70
	F - test	NS	NS	NS

CONCLUSIONS

The treatment emamectin benzoate 4% + alfamethrin 9% @1000 ml/ha was found superior in reducing the *H.armigera* population and increased the marketable fruit yield in tomatoes, which was followed by the treatment emamectin benzoate 4% + alfamethrin 9% @ 500 ml/ha.

Acknowledgements. The authors are grateful to the University of Horticultural Sciences, Bagalkot, Karnataka, India, and M/s Dhana Crop Sciences Limited, No. 15, MS Nilayam, HACP Colony, Kharkana, Secunderabad – 500 009, Telangana, India for financial assistance and timely facilities.
Conflict of Interest. None.

REFERENCES

Ahmed, K., Qureshi, A. S. and Khalique, F. (2000). Effect of environmental factors on pheromone trap catches of chickpea pod borer, *Helicoverpa armigera* (Hub.) from 1983 to 1998. In: Proc. *Pakistan Acad. Sci.*, *37*, 227-238.

Anil Sharma, P. C. (2010). Bio-efficacy of insecticides against *Leucinodes orbonalis* on brinjal. *Journal of Environmental Biology*, *31*, 399-402.

Anonymous (2017). *India Agristat* (2017) (www.indiastat.com/table/agriculture/tomato/dada.aspx).

Anonymous (2011). *National Horticulture Production database*, 2011.

Anonymous (2017). *Package of Practices: tomato*. University of Horticultural Sciences, Bagalkot, Karnataka, India Pp., 57-60.

Armes, N.J., S. K. Banergee, K. R. De Souza, D. R. Jadhav, A. B. S. King, K. R. Kranthi, A. Regupathy, T. Surulivelu and Rao Venugopal (1994). Insecticide resistance in *Helicoverpa armigera* in India: recent developments. *Brighton Crop Protection Conference - Pests and Diseases*. Pp. 437-442.

Aswathanarayanareddy, N. (1999). Studies on the incidence of insect pests of tomato and management of tomato fruit borer *Helicoverpa armigera* (Hub.). *M.Sc. (Ag) thesis* submitted to University of Agricultural Sciences, Bangalore. Pp 135.

Aswathanarayanareddy, N. and C. T. Ashok Kumar (2004). Studies on the seasonal incidence of insect pests of tomato in Karnataka, *Pest Management in Hort. Ecosystems*, *10*(2), 27-29.

Atwal, A. S. (1976). *Agricultural Pests of India and South East Asia*. Kalyani Publishers, New Delhi., Pp. 528.

Bade, B. A., Kharbade, S. B., Kadam, M. B. and Patil, A. S. (2017). Bio-Efficacy of Novel Pesticides against Shoot and Fruit Borer, *Leucinodes orbonalis* (Guen.) on brinjal. *Trends in Biosciences*, *10*(4), 1179-1182.

Bhushan, S., Singh, R. P. and Shanker, R. (2012). Biopesticidal management of yellow stem borer, *Scirpophaga incertulas* Walker in rice. *The Bioscan*, *7*(2),317-319.

Butani, D.K. (1977). Insect pest of vegetables-tomato. *Pesticides*, *11*, 33-36.

Duraimurugan, P., Suganya kanna, S., Chandrasekaran, S. and Regupathy, A. (2007). Field evaluation of emamectin 5 SG against cotton bollworm, *Helicoverpa armigera* (Hübner). *Pesticide Research Journal*, *19*(2), 186-189.

Gadhiya, H. A., Borad, P. K. and Bhut, J. B. (2014). Effectiveness of synthetic insecticides against *Helicoverpa armigera* (Hübner) and *Spodoptera litura* (Fabricius) infesting groundnut. *The Bioscan*, *9*(1), 23-26.

Gajete, T. D., Gajete, L. B., Irabagon, J. R. and Tiburcio, E. B. (2004). Technoguide for tomato production. In: *Technoguides for Agric. Production and Livelihood Projects*. CLSU Res. Office, RET, Science City of Muñoz, Nueva Ecija 58-65.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for agricultural research. Second edition. Wiley, J., Sons. A Wiley International Publication. New York. Pp. 680.

Govindan, K., Gunasekaran, K. and Kuttalam, S. (2013). Emamectin Benzoate 5 SG: A safer insecticide to coccinellids predators in a cotton ecosystem. *Afr. J. Agric. Res*., *8*(21), 2455-2460.

Gupta, G. P., Raghuraman, M. and Ajanta, B. B. S. (2005). Field efficacy of newer insecticides against bollworms in cotton. *Indian Journal of Entomology*, *67*(1), 16-20.

Hussain, T., Talpur, M. A. and Tunio, G. D. (1991). Relative toxicity of pyrethroid insecticides to gram pod borer. Proc. *11th Pakistan Cong. Zool*., *11*, 119-122.

Jayaraj, S., Ananthakrishnan, T. N. and Veeresh G. K. (1994). Biological pest control in India: Progress and perspective. RGICS Project No.2, Rajiv Gandhi Institute of Contemporary Studies, New Delhi. Pp 101.

Kailash, C., Bhowmick, A. K., Marabi, R. S., Das, S. B., Tomar, V. S., Mastkar, A., (2017). Evaluation of Bio-efficacy of emamectin benzoate against gram pod borer, *Helicoverpa armigera* Hübner and natural enemies on chickpea (*Cicer arietinum*). *Env. Pharmacol. Life Sci*., *6*(3), 402-406.

Karthikeyan, R. and Ayysamy, R. (2017). Safety evaluation of Emamectin benzoate 1.9 EC against predatory coccinellid in okra eco-system. *Journal of Entomology and Zoology Studies*, *5*(6), 2494-2497.

Korycinska, A. and Moran, H. (2009). South American tomato moth, *Tuta absoluta*. *The Food and Environment Research Agency* (Fera). www.defra.gov.uk/fera/plants/plantHealth

Lal, O. P. and Lal, S. K. (1996). Failure of control measures against *H. armigera* infesting tomato in heavy pesticide application areas in Delhi and satellite towns in Western Utter Pradesh and Haryana (India). *J. Entomol. Res*., *20*, 355-364.

Mandaokar, A. D., Goyal, R. K., Shukla, A., Bisaria, S., Bhalla, R. and Reddy, V. C. (2000). Transgenic tomato plants resistant to fruit borer (*Helicoverpa armigera* Hübner). *Crop Protection*, *19*, 307-312.

Murali Baskaran, R. K., Rajavel, D. S., Suresh, K., Manisegaran, S. and Palanisamy, N. (2010). Evaluation of emamectin benzoate 5% SG (New source) against *Helicoverpa armigera* (Hübner) of cotton. *Pestology*, *34*(5), 20-22.

Murugaraj, P., Nachiappan, R. M. and Selvanarayanan, V. (2006) Efficacy of emamectin benzoate (Proclaim 5 SG) against tomato fruit borer, *Helicoverpa armigera* (Hübner). *Pestology*, *30*(1), 11-16.

Pareek, P. L. and Bhargava, M. C. (2003). Estimation of avoidable losses in vegetables caused by borers under the semi-arid condition of Rajasthan. *Insect Environment*, *9*, 59-60.

Patil, S. K., Ingle, M. B. and Jamadagni, B. M. (2007) Bio-efficacy and economics of insecticides for management of *Helicoverpa armigera* (Hüb) in chickpea. *Annals of Plant Protection Sciences*, *15*(2), 307-311.

Patra, S., Mondal, S., Arunava, Chatterjee, S. M. L. (2007). Bio-efficacy of some new insecticides against the okra shoot and fruit borer, *Earias vittella* (F.). *Pest Management and Economic Zoology*, *15*(1), 53-56.

Raghuraman, M., Ajanta, B. and Gupta, B. S. G. P. (2008). Bio-efficacy of a newer insecticide emamectin benzoate 5% EC against cotton bollworms. *Indian Journal of Entomology*, *70*(3), 264-268.

Raghunatha, R., N. Aswathanarayana Reddy, Suvarna Patil, R.B. Hirekurubar, Dileep Kumar N.T., C.G. Yadava and Chandan K., 2023, Bio-Efficacy of Combination Product Novaluron 9.45% + Lambda Cyhalothrin 1.9% ZC (GPI 1316) against Tomato Fruit Borer, *Helicoverpa armigera* (Hübner) in Western Ghats Region of Karnataka. *Biological Forum – An International Journal*, 15(6): 60-65.

Reddy, M. R. S. and Reddy G. S. (1999). An eco-friendly method to combat *Helicoverpa armigera* (Hub.). *Insect Environment*, *4*, 143-144.

Reddy, N. A. and A. Kumar (2004) A study on correlation between abiotic factors and incidence of tomato fruit borer, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae). *Mysore Journal of Agricultural Sciences*, *38*(3), 417-421.

Reddy, K.V.N., A. Vyas, Lekha and Chhangant, G. (2019). Bio-efficacy of insecticides against fruit borer, *Helicoverpa armigera* (Hübner) infesting tomato (*Solanum lycopersicum* L.). *Indian Journal of Applied Entomology*, *33*(1), 24-28.

Selvanarayanan, V. (2000). Host plant resistance in tomato against fruit borer, *Helicoverpa armigera (*Hub.). *Ph.D. a thesis submitted to Annamalai University*, Annamalainagar, Tamil Nadu, India.

Sharma, K. C., Bhardwaj, S. C. and Sharma, G. (2011). Systematic studies, life history and infestation by *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) on tomato in the semi-arid region of Rajasthan. *Biological Forum-An International Journal*, *3*(1), 52-56.

Snedecor, G.W. and W.G. Cochran (1967). *Statistical methods* 6th Edition, Oxford and LBH Publishing Co., New Delhi

Suganya Kana, S., Chandra Bekaran, S., Raghupathy, A. and Stanly, J. (2005). Field efficacy of emamectin benzoate 5% SG against tomato fruit borer, *Helicoverpa armigera* (Hübner). *Pestology*, *29*, 21-24.

Talekar, N. S., Open, R. T. and Hanson, P. (2006). *Helicoverpa armigera* management: A review of AVRDC research on host plant resistance in tomato. *Crop Protect*., *5*, 461467.

Tewari, G. C. and Krishnamoorthy, P. N. (1984). Yield loss in tomato caused by fruit borer. *Indian Journal of Agricultural Sciences*, *54*, 341-343.

Uddikeri, S. S., Patil, S. B., Vandal, N. B., Guruprasad, G. S. and Hirekurubar, R. B. (2011). Bio-efficacy of emamectin benzoate (1% ME) against bollworm complex of cotton. *Journal of Cotton Research and Development*, *25*(1), 98-101.

How to cite this article: N. Aswathanarayana Reddy, Raghunatha, R., B. Subramanyam, Ramachandra R.K. and Manjunathareddy T.B. (2023). Bio-efficacy of the Combination Product Emamectin benzoate 4% + Alfamethrin 9% against Tomato Fruit Borer (*Helicoverpa armigera* Hübner) (Noctuidae: Lepidoptera) and their Safety to Natural Enemies. *Biological Forum – An International Journal, 15*(6): 565-572.