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Persistence Toxicity and Field Evaluation of Green Insecticide Spinetoram 12 SC w/v (11.7% w/w) against *Helicoverpa armigera* Hubner on Okra

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A B S T R A C T

Fruit borer, *Helicoverpa armigera* (Hubner) is a persistent pest on okra among fruit borer complex throughout India. Experiments were undertaken to investigate the persistence of spinetoram 12 SC against larval stage of *H. armigera* in the laboratory and to evaluate the effectiveness in the field in two seasons. The results of persistence toxicity revealed that there was continuous larval reduction up to 14 DAT under the laboratory condition in different doses of biological green insecticide spinetoram (36, 45 and 54 g a.i/ha). This emphasizes the need to reapply spinetoram 10 – 14 days after the first application (peak of biological activity) for effective control. In field experiments spinetoram 12 SC was significantly effective at 45 and 54 g a.i./ha when sprayed thrice at 15 days interval and minimized the incidence of fruit borer and increased the fruit yield.

Introduction

Okra, [*Abelmoschus esculentus* (L.) Moench] commonly known as lady's finger is cultivated in rainy and summer seasons in an area of 0.36 million hectares with a total annual production of 3.42 million tonnes in India. Although there are larger areas under cultivation, productivity remains low. There are many factors for the stagnant or low productivity, and insect pests are one of the major direct causes for yield reduction. Nearly 72 insect pests attack okra (Mandal *et al.*, 2006). Among these shoot and fruit borer, *E. vittella; Aphis gossypii* Glover; *Amrasca devastans* (Dist.) and *Bemisia tabaci* (Gennadius) are quite serious (Kumar *et al.*, 2008). The damage due to okra fruit borer alone accounts for 48.9 per cent in Tamil Nadu (Uthamasamy and Balasubramanian, 1978), 45 per cent in Karnataka (Srinivasan and Krishna Kumar, 1983), 22.5 per cent in Uttar Pradesh (Verma *et al.*, 1985), from 25.9 to 40.9 per cent in Madhya Pradesh (Dhamdhere *et al.*, 1985) and 54.0 per cent in Rajasthan (Choudhury and Dadheech, 1989).

Generally in vegetable ecosystem due to poor natural enemy complex and concealed nature of the pests, need based insecticide application along with other IPM strategies were developed and used to mitigate pests (Sardana *et al.*, 2004) especially on okra, brinjal and tomato. But these chemicals with varied mode of action due to indiscriminate use carry the danger of resistance development, pest resurgence, outbreaks of secondary pests, reduction in biodiversity of natural enemies, and bio-concentrations of residues in consumable produce at harvest (Mitra *et al.,* 1999; Krishnamurthi, 1999).

These considerations have led to the development of newer insecticide molecules like thiamethoxam, emamectin benzoate, indaxocarb, novaluron, spinosad, chlorantraniliprole, thiodicarb and flumendiamide in recent times, which are reported to be very potent at the lower doses, with novel mode of action and least residue effects on consumables and environment (Moosa *et al.,* 2013).

Biological insecticides are the potential options in IPM of vegetable crops in recent times favouring considerable pest reduction with minimum environmental risks.

Spinetoram (2^{nd} generation spinosyn insecticide) is a fermentation metabolite of naturally occurring soil actinomycetes *Saccharapolyspora spinosa* Mertz & Yoa. Spinetoram 12 SC has been reported as effective biological insecticide for the management of lepidopteran pests of chilli (Dharne and Bagde, 2011), tomato (Visnupriya *et al.,* 2013; Muthukrishnan and Visnupriya, 2013a) and brinjal (Muthukrishnan and Visnupriya, 2013b). However, hitherto research on pests of okra is limited.

Therefore, present investigations were aimed at studying persistence toxicity and field effect of spinetoram 12 SC on *H. armigera.*

Development of spinetoram 12 SC based IPM would be significant in the long run in minimizing the cost of control of pests of okra.

Materials and Methods

Persistence of spinetoram 12 SC against *H. armigera* under laboratory condition

The persistent toxicity was studied against third instar larvae, the most active and damaging stage of *Helicoverpa armigera* on fruits. Laboratory culture of *H. armigera* was initiated by collecting infested fruits from farmer's field. Mass culturing of fruit borer *H. armigera* was done as per the standard procedure described by Guruprasad (2008). After rearing for two to three generations in laboratory, the culture was used for experiment.

Thirty days old potted okra plants were used for the study**.** Insecticidal solutions were prepared by dissolving spinetoram 12 SC 0.6 ml, 0.75 ml and 0.9 ml, emamectin benzoate 5 SG 0.34 g, quinalphos 25 EC 1.6 ml and cypermethrin 25 EC 0.4 ml in one liter of water which was equivalent to the field doses. Potted okra plants were sprayed with the insecticides at the respective concentrations at 30 days after sowing (DAS) by using a hand operated sprayer to the point of run-off. After application, treated tender okra fruits and leaves were collected separately from the plants starting from first day after treatment (DAT) (2h after spray) and continued 3, 5, 7, 9, 11, 14 and till the mortality due to insecticides on *H. armigera* declined to practically negligible level. In each treatment, treated fruit samples were placed in plastic cups separately and laboratory reared third instar larvae of *H. armigera* of 20 numbers were released on treated fruits.

After infestation, the containers were placed in a climatic chamber (temperature 25 ± 1^0C, relative humidity 70 ± 10%). There were three replications for each insect. Larval mortality was assessed 24 hrs after their confinements by cutting open the fruits under a binocular microscope. Moribund larvae were considered as dead. The per cent mortality was calculated and data were corrected by Abbott's (1925) formula. The product (PT) of average residual toxicity (T) and the period (P) for which the toxicity persisted was used as an index of persistent toxicity. The procedure by Saini (1959) and elaborated further by Pradhan (1967) and Sarup *et al.,* (1970) was utilized to calculate the persistent toxicity.

Effect of spinetoram 12 SC against *H. armigera* under field condition

Two field experiments were conducted at farmers' field in Madurai district, Tamil Nadu, India, in the plots of size of 5 X 5 m. The experiments were laid out in a randomized block design at Soorakundu, Melur block and Kokkulam, Chekkanoorani block respectively. Standard agronomic practices as per the recommendations of Tamil Nadu Agricultural University (TNAU) were adopted to maintain healthy okra plants (Hybrid Splender No. 10). Newer green insecticide molecule spinetoram 12 SC was assessed at various doses and compared with standard checks against fruit borer *H. armigera*. There were three applications at 20 days interval based on ETL of target pests (10% fruit damage due to *H. armigera*). Thorough coverage of plants (to a run off point) with the spray fluid of 500 l/ha was ensured by using high volume knapsack sprayer with hydraulic cone nozzle.

Larval population of *H. armigera* per plant, per cent fruit damage (fruits with circular or irregular bore holes and plugged with excreta) due to *H. armigera* were assessed from 10 randomly selected plants on pre-treatment, 1, 3, 7 and 10 days after 1^{st}, 2^{nd} and 3^{rd} sprays/treatments (DAT). Marketable fruit yield was recorded from eight harvests and the total fruit yield was represented as quintal/ha.

Statistical analysis

The data from various field experiments were scrutinized by RBD analysis of variance (ANOVA) after getting transformed into $\sqrt{x+0.5}$, logarithmic and arcsine percentage values where appropriate (Gomez and Gomez, 1984). Critical difference values were calculated at five per cent probability level and treatment mean values were compared using Duncan's Multiple Range Test (DMRT) (Duncan, 1951). The corrected per cent reduction over untreated check in field population was calculated by Henderson and Tilton (1955) formula,

$$\text{Corrected per cent reduction} = \left\{1 - \frac{Ta \times Cb}{Tb \times Ca}\right\} \times 100$$

Where,

Ta - number of insects in the treatment after spraying

Tb - number of insects in the treatment before spraying

Ca - number of insects in the untreated check before spraying

Cb - number of insects in the untreated after spraying

Results and Discussion

Persistence toxicity of spinetoram 12 SC to *H. armigera* on okra

Persistence studies revealed that spinetoram 12 SC when applied at 36, 45 and 54 g a.i./ha, cent per cent mortality of 3^{rd} instar larvae of *H. armigera* was observed at 1 and 3 DAT due to spinetoram 12 SC 45 and 54 g a.i./ha (Table 1). Emamectin benzoate 5 SG at 8.5 g a.i/ha, quinalphos 25 EC at 200 g a.i/ha and cypermethrin 25 EC at 50 g a.i/ha recorded 80.6, 54.3 and 82.1 per cent mortality, respectively at 5 DAT. In the case of quinalphos 25 EC at 200 g a.i/ha, no mortality was observed at 11 DAT.

Persistence for spinetoram 12 SC 36 g a.i./ha was upto 11 DAT and 14 DAT for 45 and 54 g a.i/ha. There was a reduction in the mortality of *H. armigera* larvae as the time increased and the toxicity persisted for 14 days in cypermethrin 25 EC at 50 g a.i/ha, while the same was 11 days for emamectin benzoate 5 SG at 8.5 g a.i/ha. The order of relative efficacy (ORE) of the insecticides based on the persistent toxicity index (PTI) values was spinetoram 12 SC 54 g a.i./ha > spinetoram 12 SC 45 g a.i./ha > cypermethrin 25 EC at 50 g a.i/ha > emamectin benzoate 5 SG at 8.5 g a.i/ha > spinetoram 12 SC 36 g a.i./ha > quinalphos 25 EC at 200 g a.i/ha (Fig. 1). Elbarky *et al.,* (2008) report that spinetoram (Radiant 12 SC) exhibited high mortality (100 % and 95.7 %) after zero and 1 days respectively then decreased gradually to 58.1 per cent after 7 days of treatment which indicated that there is a short residual time of spinetoram.

Field evaluation of spinetoram 12 SC against fruit borer *H. armigera*

Field experiment observations recorded on 1, 3, 7 and 10 days after treatment (DAT) of two seasons were pooled and given in Table 2. Number of larvae of *H. armigera* varied from 10.4 to 13.4 per plant before imposing treatments. In first season experiment, mean data revealed that number of larva ranged from 3.5 to 21.6 larvae per plant due to treatments. Spinetoram 12 SC 54 and 45 g a.i./ha were significantly superior and registered the lowest larval population of 3.5 (83.9% reduction over control) and 4.0 (81.6% reduction over control) per plant, respectively. Spinetoram 12 SC 36 g a.i./ha also contributed moderate reduction in the larval population (6.0 larvae/plant with 72.4% reduction over control). Emamectin benzoate 5 SG at 8.5 g a.i/ha and cypermethrin 25 EC at 50 g a.i/ha registered larval population of 6.4 (70.6% reduction) and 7.0 (67.8% reduction) per plant respectively. Quinalphos 25 EC at 200 g a.i/ha however registered higher larval population 7.9 larvae/plant with 63.7 per cent reduction over control.

In second season field experiment, pooled mean data resulted that number of larva ranged from 2.3 to 14.0 larvae per plant due to all treated experiments. Spinetoram 12 SC 54 and 45 g a.i./ha were equally effective and registered the lowest larval population of 2.3 (83.6% reduction over control) and 2.5 (82.2% reduction over control) per plant, respectively. Lower dose of spinetoram 12 SC 36 g a.i./ha also contributed reasonable reduction in the larval population (3.9 larvae/plant with 72.2% reduction over control).

The insecticides used in the present investigation and their dosages were as follows

S. No	Treatments	Dose (g a.i. ha^{-1})
1	Spinetoram 12 SC	36
2	Spinetoram 12 SC	45
3	Spinetoram 12 SC	54
4	Emamectin Benzoate 5 SG	8.5
5	Quinalphos 25 EC	200
6	Cypermethrin 25 EC	50
7	Untreated check	-

Table.1 Persistent toxicity of spinetoram 12 SC to *H. armigera* on okra

Treatments and doses (g a.i/ha)	Corrected per cent mortality at different intervals (days)								P	T	PTI	RE	ORE
	1	3	5	7	9	11	14	21					
Spinetoram12SC 36 g a.i/ha	93.3	81.6	62.5	52.0	36.5	20.0	0.0	0.0	11	57.7	634.2	1.28	5
Spinetoram12SC 45 g a.i/ha	100	100	80.4	71.6	60.7	37.0	20.8	0.0	14	67.2	941.1	1.90	2
Spinetoram12SC 54 g a.i/ha	100	100	92.6	80.9	66.8	39.4	12.7	0.0	14	70.3	984.8	1.99	1
Emamectin benzoate 5 SG 8.5 g a.i/ha	99.8	88.0	80.6	60.6	43.8	22.0	0.0	0.0	11	65.8	723.9	1.46	4
Quinalphos 25 EC 200 g a.i/ha	89.2	76.4	54.3	38.4	16.9	0.0	0.0	0.0	9	55.0	495.4	1.00	6
Cypermethrin 25 EC 50 g a.i/ha	100	98.2	82.1	69.7	52.5	31.3	19.1	0.0	14	64.7	905.8	1.83	3

P – Period of toxicity persistence (days)
T – Mean per cent mortality
PTI – Persistent toxicity index
RE – Relative efficacy
ORE – Order of relative efficacy

Table.2 Effect of spinetoram 12 SC against fruit borer *H. armigera* on okra – Pooled data of two season experiments

Treatments and doses (g a.i./ha)	Number of larvae per plant on days after treatment					Yield (q/ha)			
	Pre count	1st season		2nd season		1st season			2nd season
		Pooled mean of 3 sprays	Per cent reduction over control	Pooled mean of 3 sprays	Per cent reduction over control	Mean	Per cent increase over control	Mean	Per cent increase over control
Spinetoram 12 SC 36 g a.i./ha	10.7	6.0^{b}	72.4	3.9^{c}	72.2	46.5^{c}	34.9	43.1^{b}	55.16
Spinetoram 12 SC 45 g a.i./ha	11.6	4.0^{ab}	81.6	2.5^{ab}	82.2	50.1^{b}	45.3	48.2^{a}	73.52
Spinetoram 12 SC 54g a.i./ha	10.4	3.5^{a}	83.9	2.3^{a}	83.6	52.2^{a}	51.4	50.5^{a}	81.80
Emamectin benzoate 5SG 8.5 g a.i./ha	12.6	6.4^{bc}	70.6	4.7^{d}	66.4	45.5^{d}	32.0	40.1^{c}	44.36
Quinalphos 25EC 200g a.i/ha	12.3	7.9^{d}	63.7	5.5^{f}	60.7	43.3^{e}	25.6	38.3^{c}	37.88
Cypermethrin 25EC 50g a.i/ha	10.5	7.0^{c}	67.8	5.0^{e}	64.3	45.0^{d}	30.5	39.2^{c}	41.12
Untreated check	13.4	21.6^{e}	-	14.0^{g}	-	34.4^{f}	-	27.8^{d}	-
CD (0.05%)	-	0.02	-	0.02	-	0.17	-	2.69	-
SEd	-	0.007	-	0.008	-	0.08	-	1.23	-

Data are mean values of three replications
Figures were transformed by square root transformation and the original values are given
Means within columns lacking common lower case superscript are significantly different (P<0.05)

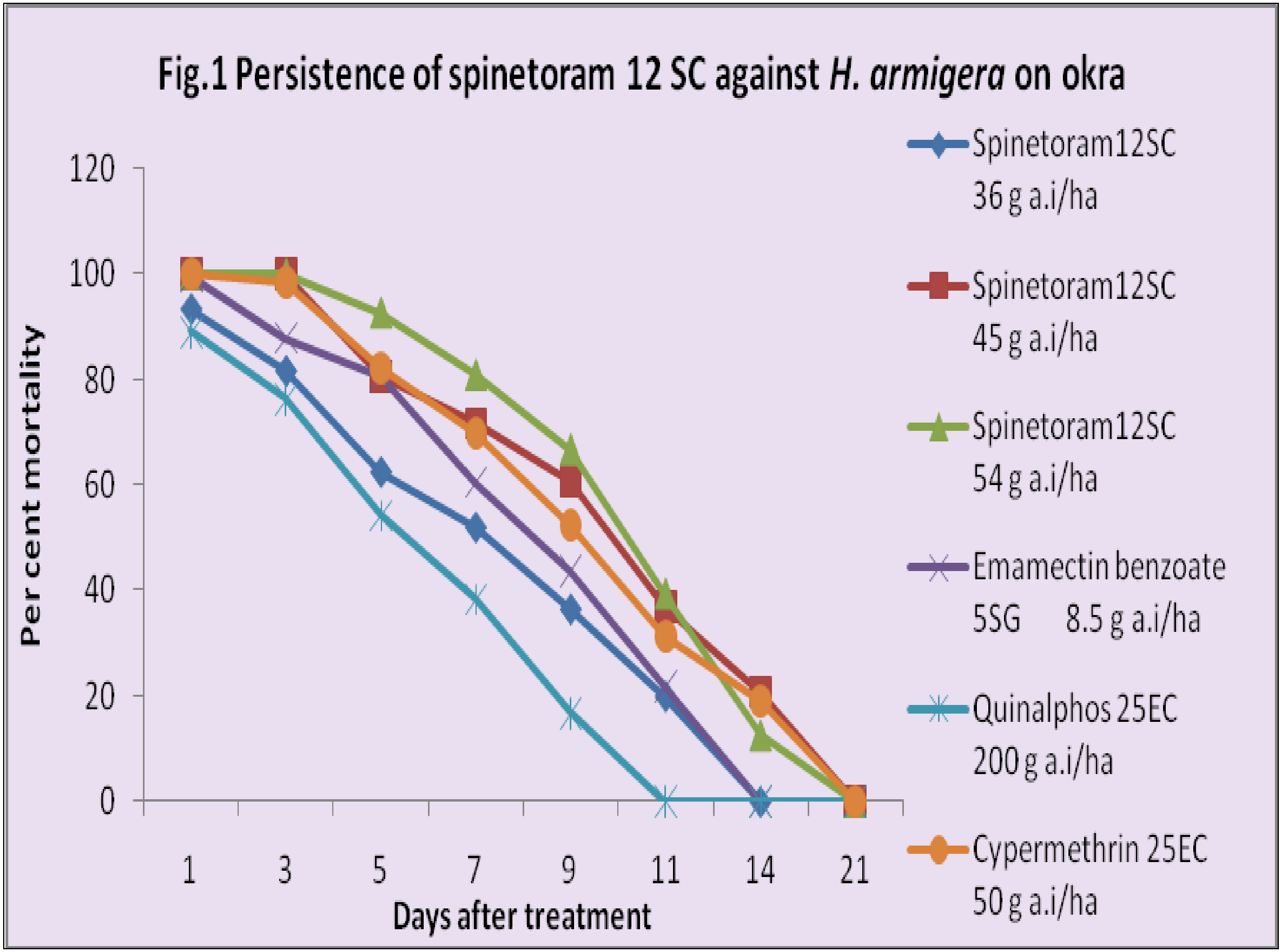
Fig.1 Persistence of spinetoram 12 SC against H. armigera on okra
120
100
80
60
40
20
0
Per cent mortality
1
3
5
7
9
11
14
21
Days after treatment
Spinetoram12SC 36 g a.i/ha
Spinetoram12SC 45 g a.i/ha
Spinetoram12SC 54 g a.i/ha
Emamectin benzoate 5SG 8.5 g a.i/ha
Quinalphos 25EC 200 g a.i/ha
Cypermethrin 25EC 50 g a.i/ha

Standard check treatments viz., emamectin benzoate 5 SG at 8.5 g a.i/ha and cypermethrin 25 EC at 50 g a.i/ha recorded larval population of 4.7 (66.4% reduction) and 5.0 (64.3% reduction) per plant respectively. Larval population of 5.5 per plant with 60.7 per cent reduction over control was registered in the treatment with quinalphos 25 EC at 200 g a.i/ha.

Spinetoram is nicotinic acetylcholine receptor (nAChR) allosteric activator (Salgado, 1997) and the action on the primary site nAChR may be the reason for the quick knock down effect. These findings are in agreement with Muthukrishnan and Visnupriya (2013a) who reported that spinetoram 12 SC at 45 g a.i/ha was the most effective in reducing *Spodoptera litura* and *Thrips tabaci* on tomato and *Leucinodes orbonalis* in brinjal. Spinosad at 75 g a.i/ha and spinosad 45 SC at 0.1% were very effective for the control of *H. armigera* infesting okra as reported by Shinde *et al.*, (2011) and Singh and Gupta (2011) respectively.

The results on the efficacy of spinetoram 12 SC against *H. armigera* revealed that plots treated with spinetoram 12 SC 54 g a.i/ha achieved 83.9 and 83.6 per cent reduction of larval population during first and second season experiments respectively which was on par with spinetoram 12 SC 45 g a.i/ha (81.6 and 82.2 % reduction at first and second season respectively). The results are in accordance with the findings of Singh & Gupta (2011) who found that spinosad 45 SC at 0.1% was effective in suppressing the larval population of *H. armigera* in okra. According to Gosalwad and Kawathekar (2009) spraying with spinosad 45 SC at 45, 60 and 75 DAS recorded most superior in okra fruit borer control. The findings are in accordance with the findings of Jindal *et al.*, (2007) and Bheemanna *et al.*, (2009) who inferred that spinosad 45 SC new A:D ratio @ 100 g a.i/ha resulted in significant reduction of fruiting bodies damage due to bollworms on cotton. While Banajgole (2004) reported that spinosad 90 g a.i/ha was most effective against pigeon pea pod borers in reducing the pod infestation and grain damage. Spinosad @ 75 g a.i/ha recorded lower damage to fruiting bodies and higher seed cotton yield (Bheemanna *et al.*, 2005).

Effect of spinetoram 12 SC on fruit yield

In field experiments, data on marketable yield of okra fruits ranged from 34.4 to 52.2 q / ha and from 27.8 to 50.5 q / ha respectively in all treatments (Table 2). The highest yield in both seasons was registered in spinetoram 12 SC @ 54 g ai/ha (52.2 and 50.5 q/ha) followed by spinetoram 12 SC @ 45 g a.i /ha (50.1 and 48.2 q/ha) and spinetoram 12 SC @ 36 g a.i / ha (46.5 and 43.1 q/ha) respectively. These were followed by emamectin benzoate (45.5 and 40.1 q/ha), cypermethrin (45.0 and 39.2 q/ha) and quinalphos (43.3 and 38.3 q/ha), compared to untreated check which registered only 34.4 and 27.8 q/ha fruit yield in first and second seasons respectively. Sandip Patra *et al.*, (2009) and Sinha and Nath (2011) reported that spraying of spinosad resulted in the highest fruit yield in brinjal compared to other insecticides which was similar to the present observations on fruit yield of brinjal due to application of spinetoram. In conclusion, spinetoram 12 SC was very effective against *L. orbonalis* with enhanced fruit yield in brinjal. Spinetoram 12 SC at 45 and 54 g a.i./ha was significantly more effective against *H. armigera* larval population and fruit damage, enhanced okra fruit yield and caused no phytotoxic effects on plants.

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