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In-vivo and Field Evaluation of Spinetoram 12 SC against *Spodoptera litura* Fabricius on Tomato

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***Spodoptera litura* (Noctuidae: Lepidoptera) is a notorious leaf damaging pest on tomato. A new biological insecticide molecule, spinetoram 12 SC was evaluated for acute toxicity on laboratory reared *S. litura* population, and persistence on tomato leaves at laboratory conditions; and effect on *S. litura* on tomato at field conditions during 2011 and 2012 seasons. Acute toxicity studies revealed that LC_{50}`s of spinetoram on third instar larvae after 24, 48 and 72 hours after treatment were 8.56, 5.86 and 3.70 ppm respectively. In persistence studies, there was reduction in the mortality of larvae as the time increased and there was no mortality after 21 DAT in spinetoram 45 and 54 g a.i/ha and after 14 DAT in spinetoram 36 g a.i/ha, novaluron and quinalphos. In the field, spinetoram 12 SC was applied as foliar spray at 36 g a.i./ha, 45 g a.i./ha and 54 g a.i./ha. 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 *S. litura* on tomato plants.**

Key words: Spinetoram, Tomato, Acute toxicity, Persistence, Field efficacy, *Spodoptera litura*

India is the second largest producer of vegetables after China with an average annual production of 87.5 million tonnes from 5.9 million hectares, having a share of 14.4 per cent to world production (Anon., 2010). Tomato (*Lycopersicon esculentum* Mill) is the most popular and remunerative vegetable crop grown around the world for fresh consumption and processing. It was cultivated in an area of 5.1 lakh ha and reaping yields to the extent of 8.8 million tonnes per annum in India during 2010 – 11. It is a rich source of vitamins like A, B_1, B_2 and C and tomato fruit is widely consumed as vegetable, pickles and as a salad. The average productivity is 17.7 q / ha, which is very low due to the attack of number of diseases and insect pests *viz*., tomato fruit borer (*Helicoverpa armigera* Hubner), tobacco caterpillar (*Spodoptera litura*,Fab.) whitefly (*Bemisia tabaci* Gennadius) and leafhopper (*Amrasca devastans* Dist.). Among insect pests, the leaf feeder, *S. litura* is a potential polyphagous pest which attacks cotton, groundnut, rice, tomato, tobacco, citrus, cocoa, potato, rubber, castor, millets, sorghum, maize *etc.,* in India and causes extensive economic damage (Vinod Kumari and Singh, 2009). Synthetic insecticides provide dramatic effect initially, and hence chemical control methods are still largely in use among farmers. Earlier, conventional insecticides like endosulfan (Shivalingaswamy *et al.,* 2008 and Rath and Mukherjee, 2009), malathion and hostothion (Sanjeev Kumar and Gill, 2010), chlorpyriphos (Kuttalam *et al.,* 2008), azadirachtin 1%, phosalone and quinalphos (Anon., 2011), synthetic pyrethroids and endosulfan alternatively with NSKE 4% (Anon., 2009), and fenvalerate, methomyl, azinphos methyl, carbaryl and pyrethrin/rotenone (Anon., 2012) were reported in management of pests on tomato.

In recent times, some new insecticide molecules offer multiple advantages over earlier ones in terms of greater levels of safety, better performance and reduced environmental impact. One such new insecticide molecule is spinetoram, that has shown outstanding efficacy against codling moth (*Cydia pomonella* L.), oriental fruit moth *(Grapholita molesta* Busck *)*, army worms (*Spodoptera spp*), cabbage looper (*Trichoplusia ni* Hubner), thrips such as western flower thrips (*Frankliniella occidentalis* Pergande) and onion thrips (*Thrips tabaci* Lindeman*),* leaf miners (*Liriomyza spp*), chilli thrips (*Scirtothrips dorsalis* Hood), fruit borer (*H. armigera*) and many other pests (Dharne and Bagde, 2011). However, there are no reports on *in vivo* and field evaluation of spinetoram 12 SC against the *S. litura* on tomato. Therefore, this study was undertaken with the objectives to investigate the acute toxicity and persistence toxicity of spinosyn, spinetoram 12 SC and other insecticides against *S. litura* in the laboratory and to evaluate their effectiveness for controlling the pest in the field.

Materials and Methods

Laboratory experiments

Acute toxicity of spinetoram 12 SC against S. litura on tomato

The laboratory culture of *S. litura* was initiated in the Insectary of Agricultural College and Research Institute (AC&RI), Madurai by collecting egg mass and larvae from farmer's field. Mass culturing of *S. litura* was done as per the standard procedure described by Jaglan *et al.* (1996). After rearing for five generations in laboratory (during 2012), the culture was used for experiment. For acute toxicity experiments leaf-dip method was preferred by many researchers, because of its stomach poison action by ingestion. This bioassay was developed by Tabashnik

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and Cushing (1987) and recommended by IRAC (1990). Fresh tomato leaves of uniform size were thoroughly washed with water. Leaves were then dipped into the serial concentration of insecticide solutions (2.4 ppm, 4.8 ppm, 7.2 ppm, 9.6 ppm, 12.0 ppm, 14.4 ppm and 16.8 ppm) for 30 seconds and air dried at room temperature for removing surface water. The treated leaves were transferred to clean plastic containers lined with moistened filter paper at the bottom. In each container, 30 laboratory reared larvae of third instar were released and kept under the normal rearing conditions for observation. For the control, leaves treated with water alone were used. The larvae were considered dead when they became desiccated with shortened body and dark cuticle, and/ or unable to move in a coordinated manner when disturbed with a needle.

In this acute toxicity experiment, observations on larval mortality were fixed till 72 hours of exposure as spinetoram 12 SC tested was lepidoptericide characterized by stomach action showing slower mortality (Ahmad *et al.,* 2003). The cumulative mortality data were observed till 72 h at 24 h intervals and corrected by Abbott's formula.

Persistence of spinetoram 12 SC against S. litura under laboratory condition

Pot culture experiments were conducted in the Insectary of AC&RI, Madurai in order to assess the persistent toxicity of spinetoram against *S. litura* on tomato leaves. Thirty days old potted tomato 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, indoxacarb 14.5 SC 1.04 ml, novaluron 10 EC 1.5 ml and quinalphos 25 EC 2.0 ml in one liter of water which were equivalent to the field doses. Treated tomato leaves were plucked from the plants at different time intervals. 20 starved larvae were released in to each plastic cup which contained treated tomato leaves. Observations on larval mortality were recorded from each treatment at 24 h interval. The per cent mortality was calculated and mortality 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.

Field evaluation of spinetoram 12 SC against S. litura on tomato

Two field experiments with tomato (cv. PKM 1) were laid out to evaluate the effect of spinetoram 12 SC against leaf feeder, *S. litura* on tomato plants. The plot size was 5 X 5 m which accommodated 185 tomato plants. Healthy crop stand was maintained throughout the experimental period by following TNAU recommended agronomic practices. Bio efficacy of spinetoram 12 SC was evaluated at 36 g a.i./ha (300 ml/ha), 45 g a.i./ha (375 ml/ha) and 54 g a.i./ha (450 ml/ha) and compared with indoxacarb 14.5 SC @ 75 g a.i/ha (500 ml/ha), novaluron 10 EC @ 75 g a.i/ha (750 ml/ha), quinalphos 25 EC @ 250 g a.i/ha (1000 ml/ha) and untreated check (water spray) against leaf feeder, *S. litura*. There were three applications at 20 days interval. 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 numbers of *S. litura* were assessed from 10 randomly selected plants on pre-treatment, 1, 3, 7 and 10 DAT after 1st, 2nd and 3rd sprays. The overall mean number of larvae was calculated for each treatment after application. Marketable fruit yield was recorded from 10 harvests and the total fruit yield was represented as quintal/ha.

Results and Discussion

Acute toxicity of spinetoram 12 SC against S. litura on tomato

Toxicity test on a laboratory strain of the third instar larva of the leaf feeder, *Spodoptera litura* was carried out at different concentrations after 24, 48 and 72 hours after treatment. The data in Table 1 indicate that the percentage mortality of larvae showed positive correlation with spinetoram concentrations, which ranged from 13.33, 21.67 and 45.90 to 99.10 per cent after 24, 48 and 72 hours after treatment respectively. The response of larvae to different concentrations was represented by straight regression lines, indicating homogeneity of the population to the tested concentrations and the LC_{50}`s of spinetoram in third instar larvae after 24, 48 and 72 hours after treatment were 8.56, 5.86 and 3.70 ppm

Table 1. Acute toxicity of spinetoram 12 SC against third instar larvae of *S. litura* in tomato

Dose (ml/l)	Concentration (ppm)	After 24 h of treatment		After 48 h of treatment		After 72 h of treatment	
		Mean dead larvae ± SE	Mortality %	Mean dead larvae ± SE	Mortality %	Mean dead larvae ± SE	Mortality %
0.02	2.4	4.00 ± 0.29	13.33	6.50 ± 0.29	21.67	13.77 ± 0.46	45.90
0.04	4.8	8.77 ± 0.46	29.23	11.60 ± 0.35	38.67	17.43 ± 0.23	58.10
0.06	7.2	11.30 ± 0.58	37.67	14.77 ± 0.46	49.23	19.00 ± 0.29	63.33
0.08	9.6	14.70 ± 0.40	49.00	21.53 ± 0.58	71.77	23.00 ± 0.58	76.67
0.10	12.0	20.00 ± 0.29	66.67	25.77 ± 0.46	85.90	25.77 ± 0.46	85.90
0.12	14.4	23.00 ± 0.58	76.67	27.33 ± 0.17	91.10	28.33 ± 0.17	94.43
0.14	16.8	26.33 ± 0.58	87.77	29.00 ± 0.58	96.67	29.73 ± 0.40	99.10
Untreated		1.3	4.33	1.0	3.33	1.33	4.43
LC_{50} and Fiducial limit		8.56 (7.35 - 9.96)		5.86 (4.98 - 6.91)		3.70 (2.74 - 4.99)	
LC_{95} and Fiducial limit		33.41 (22.51- 49.59)		21.69 (14.18 – 33.17)		20.53 (15.44 – 27.30)	
Slope		2.47		2.86		3.04	
Regression equation		Y = 2.656 + 2.475x		Y = 2.826 + 2.858x		Y = 3.847 + 3.045x	

respectively. As for slope values of the regression line, spinetoram had the least slope of 2.47 with 24 hours after exposure, while slope values were 2.86 and 3.04 with 48 and 72 hours after exposure respectively. The results are in rationale with the reports of Elbarky *et al.* (2008) who estimated LC_{50} values of spinetoram 12 SC on fourth instar larvae of *Spodoptera littoralis* (Boisd) as 6.67 and 2.86 ppm after 24 and 48 h after treatment, and Hardke *et al.* (2011) found 0.066 µg/ ml after 96 h exposure. However, LD_{50} was 59.88 µg a.i./g of larval body weight of fourth instar *S. littoralis,* according to Abdu-Allah (2010). Thus the toxic values of spinetoram had significant effect on insects.

Persistence of spinetoram 12 SC against S. litura on tomato

Spinetoram 12 SC was applied at 54 g a.i./ha, cent per cent mortality of third instar of *S. litura* larvae was observed at 1 DAT and 3 DAT, 90.87 at 5 DAT and there was no mortality after 21 DAT Spinetoram at 45 g a.i/ha recorded 100, 93.47 and 81.93 per cent mortality at 1, 3 and 5 DAT respectively. More than 50 per cent mortality was observed in spinetoram at 45, 54 g a.i./ha, novaluron and indoxacarb up to 7 DAT where as that was up to 5 DAT for quinalphos. There was reduction in the mortality of larvae as the time increased and there was no mortality after 14 DAT in spinetoram 36 g a.i/ha, novaluron and quinalphos. The ORE of the insecticides based on PTI values was spinetoram 54 g a.i./ha > spinetoram 45 g a.i./ha > indoxacarb > novaluron > spinetoram 36 g a.i./ha > quinalphos (Table 2).

These results are in accordance with the findings

Table 2. Persistent toxicity of spinetoram 12 SC to *S. litura* on tomato leaves

Treatment (g a.i/ha)	Corrected per cent mortality at intervals (days)								P	T	PTI	RE	ORE
	1	3	5	7	9	11	14	21					
Spinetoram12 SC 36 g a.i/ha	92.28	87.03	70.33	58.97	39.43	21.77	0.00	0.00	11	61.64	678.04	1.19	5
Spinetoram12 SC 45 g a.i/ha	100	93.47	81.93	73.00	42.17	30.00	19.07	0.00	14	62.81	879.34	1.55	2
Spinetoram12 SC 54 g a.i/ha	100	100	90.87	79.33	45.20	32.37	24.93	0.00	14	67.53	945.42	1.66	1
Indoxacarb 14.5 SC 75 g a.i/ha	100	89.37	75.07	60.75	38.53	24.09	17.33	0.00	14	57.88	810.32	1.43	3
Novaluron 10 EC 75 g a.i/ha	63.77	88.95	80.74	69.05	47.27	32.43	0.00	0.00	11	63.70	700.70	1.23	4
Quinalphos 25 EC 250 g a.i/ha	75.33	70.91	62.45	49.13	32.77	19.35	0.00	0.00	11	51.66	568.26	1.00	6

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

of Brevault *et al.* (2009) who reported that the persistence was higher for spinosad 45 SC @ 36 g a.i/ha (8.9 days) and persistence was lower for indoxacarb @ 25 g a.i/ha (5.2 days) and endosulfan @ 750 g a.i/ha (2.7 days) in cotton plants. According to Elbarky *et al.* (2008) spinetoram (Radiant 12 SC) exhibited high mortality in *S. littoralis* (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 was relatively short residual time of spinetoram.

Field evaluation of spinetoram 12 SC against S. litura on tomato

S. litura larval population varied from 5.1 to 6.1 per plant before imposing treatments (Table 3). Data

Table 3. Effect of spinetoram 12 SC against *S. litura* on tomato (2011 and 2012 seasons)

Treatment and doses (g a.i. /ha)	*Spodoptera litura* (larva/plant)					
	I season (Sep 2011- Jan 2012)			II season (Aug 2012 - Dec 2012)		
	Pre count	Over all Mean after treatment	Per cent reduction over control	Pre count	Over all Mean after treatment	Per cent reduction over control
Spinetoram 12 SC 36 g a.i./ha	5.1	3.7_{b}	66.7	3.8	2.5_{c}	66.8
Spinetoram 12 SC 45 g a.i./ha	6.0	2.4_{ab}	78.4	3.2	1.7_{ab}	77.4
Spinetoram 12 SC 54g a.i./ha	5.7	2.1_{a}	81.1	3.3	1.4_{a}	81.4
Indoxacarb 14.5 SC 75 g a.i./ha	5.9	3.6_{b}	67.6	3.7	2.6_{c}	65.4
Novaluron 10 EC 75 g a.i./ha	5.3	3.9_{c}	64.9	3.6	2.8_{cd}	62.8
Quinalphos 25EC 250g a.i/ha	6.1	5.3_{d}	52.3	3.7	3.5_{e}	53.5
Untreated check	5.9	11.1_{e}	-	3.5	7.5_{f}	-
CD (0.05%)	-	0.09	-	-	0.04	-
SEd	-	0.04	-	-	0.02	-

Data are means of three replications. Figures were transformed by square root transformation during analysis. Original values are given in table.
Means followed by the same superscript are not significantly different (P = 0.05) by DMRT.

indicated that larval numbers ranged from 2.1 to 11.1 per plant due to treatments. Spinetoram 54 and 45 g a.i./ha were superior and equally effective in reducing the population to 2.1 and 2.4 per plant and registered 81.1 and 78.4 per cent reduction, respectively over control. The other spinetoram treatment of 36 g a.i./ha (3.7 larvae/plant and 66.7% reduction over control); indoxacarb (3.6 larvae/plant and 67.6% reduction over control); novaluron (3.9 larvae/plant and 64.9% reduction over control) and quinalphos (5.3 larvae/ plant and 52.3% reduction over control) followed in order. Untreated control recorded the highest mean of 11.1 larvae per plant.

Data pertaining to larval population during the second season for 1, 3, 7 and 10 DAT after three sprays indicated that mean larval population observations of 1, 3, 7 and 10 DAT ranged from 1.4 to 7.5 larvae per plant due to treatments. Spinetoram 54 and 45 g a.i./ha were significantly superior and registered the lowest larval population of 1.4 (81.4 % reduction over control) and 1.7 (77.4 % reduction over control) per plant, respectively. Spinetoram 36 g a.i./ ha also contributed moderate reduction in the larval population (2.5 larvae/ plant with 66.8% reduction over control). Indoxacarb and novaluran registered larval population of 2.6 (65.4% reduction) and 2.8

(62.8% reduction) per plant respectively. Quinalphos however registered higher larval population 3.5 larvae per plant with 53.5 per cent reduction over control.

The present results are in line with the findings of Sunilkumar *et al.* (2012) who reported that spinetoram 12 SC at 60 g a.i/ha was highly effective in checking the larvae of *S. litura* in soybean. The most effective insecticides for army worm (*Spodoptera* spp) control were spinetoram, spinosad and indoxacarb; followed by novaluron and metaflumizone. The least effective were pyridalyl (Dakshina Seal *et al.,* 2007). Cook *et al.* (2004) also reported that spinosad, indoxacarb and pyridalyl significantly reduced beet armyworm (*S. exigua*) compared to the control. Similar results of effectiveness of spinosad against *S. exigua* in cotton were documented by Halcomb *et al.* (1998) and Mascarenhas *et al.* (1996).

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