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Research Article

Phytotonic and Phytotoxic Effect of Newer Insecticide Molecule Spinetoram 12 SC on Okra, Brinjal and Tomato

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Abstract

Field experiments were conducted during kharif season to study the phytotonic and phytotoxic effects of spinetoram 12 SC as three foliar sprays at 20 days intervals in okra, brinjal and tomato. Spinetoram 12 SC at 36, 45 and 54 g a.i/ha treated plants were significantly superior which registered the maximum plant height, chlorophyll content, stem girth and number of fruits per plant on okra, brinjal and tomato and lycopene content in tomato fruits. This clearly indicated that the phytotonic effect was due to the application of spinetoram 12 SC treatments. There was no significant difference among the treatments for crude fiber content in okra and brinjal fruits. Spinetoram 12 SC 54 and 108 g a.i./ha; mixtures of spinetoram 12 SC 54 g a a.i./ha with quinalphos 25 EC 200 g, carbendazim 125 g and urea (2%); and mixtures of spinetoram 12 SC 27 g a a.i./ha with quinalphos 25 EC 100 g, carbendazim 63 g did not result any phytotoxic symptoms like leaf injury, wilting, vein clearing, necrosis, epinasty and hyponasty at any day after treatment on leaves, stems and flowers.

Keywords: Phytotonic, Phytotoxic, Spad meter, Chlorophyll content, Necrosis, Epinasty, Hyponasty

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Introduction

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 the world production. Exported vegetables occupy 1.69 per cent of total vegetable production [1]. Among the vegetables, most popular table vegetables are okra, brinjal and tomato. The chemical insecticides besides controlling the target pests also induce direct and indirect effect on growth and development of crop plants. Previously, [2] reported increase vegetative growth of brinjal and okra plants treated with DDT and this is the first report on phytotonic effects of insecticides.

From the soil sample, a new species of actinomycete (*Saccharopolyspora spinosa* Mertz and Yao) was isolated. Extracts from the fermentation broth of *S. spinosa* showed both contact and ingestion activity against southern armyworm (*Spodoptera eridana* Stoll). Further studies had lead to the identification of a series of new macrocyclic structures later named “spinosyns” [3]. The naturally occurring mixture contained spinosyn A as the major component and spinosyn D as the minor component and named as spinosad, which was the first generation biological insecticide from spinosyn isomers [4].

Techniques such as biotransformation and genetic engineering, as well as screening for organisms had produced new spinosyns and yielded new compounds. The production of second generation innovative compound, spinetoram begins with the naturally occurring mixture of spinosyn J (major component) and spinosyn L (minor component) (XDE-175- J and XDE-175-L) in a ratio of approximately 3:1 (J: L), which have a reactive hydroxyl group at the $3^{/}$ position [5]. The effectiveness of spinosyn insecticides against a broad range of insects like borers, leaf feeders and some sucking insects were more [6-9]. In addition to its effectiveness in pest management, these insecticides as foliar spray have been reported to exert growth promoting effects (phytotonic effects) such as increase in plant height, chlorophyll content and yield in various crops. Basically, no phytotoxicity has been observed in the official spinetoram experiment to date, and thus spinetoram’s high safety toward various types of crops has been confirmed [10]. However, hitherto not much research was made to understand the relationship uniqueness of spinetoram 12 SC on phytotonic and phytotoxic effect in okra, tomato and brinjal. Therefore, present investigations were aimed at with the following objectives.

Experimental

Estimation of phytotonic effects from spinetoram 12 SC treated plants

Field experiments with okra (Hybrid splender No.10), brinjal (cv. CO 2) and tomato (cv. PKM 1) were laid out in randomized block design to evaluate the phytotonic and phytotoxic effect of spinetoram 12 SC on these three plants. Three replications were maintained. Healthy crop stand was maintained throughout the experimental period by following TNAU recommended agronomic practices. Phytotonic and phytotoxic effect of spinetoram 12 SC was evaluated at okra (from the treatments such as spinetoram 36, 45 and 54 g a.i/ha, emamectin benzoate 8.5 g a.i/ha, quinalphos 200 g a.i/ha and cypermethrin 50 g a.i/ha); and brinjal (from the treatments such as spinetoram 36, 45 and 54 g a.i/ha, emamectin benzoate 8.5 g a.i/ha, chlorpyriphos 200 g a.i/ha and thiodicarb 750 g a.i/ha); and tomato (from the treatments such as spinetoram 36, 45 and 54 g a.i/ha, novaluron 75 g a.i/ha, indoxacarb 75 g a.i/ha and quinalphos 250 g a.i/ha).. 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. Various growth parameters like plant height, stem girth, number of fruits, chlorophyll content, crude fiber content and lycopene content (tomato) were assessed from 10 randomly selected plants from each treatment on pre-treatment and 10 DAT after 1^{st}, 2^{nd} and 3^{rd} sprays.

Estimation of chlorophyll content

The chlorophyll content meter or SPAD meter is portable equipment and greenness or relative chlorophyll content can be measured based on optical responses when a leaf is exposed to light that in turn is used to estimate foliar chlorophyll concentrations [11]. Meter readings are given in Minolta Company – defined SPAD (Soil Plant Analysis Development) values that indicate relative chlorophyll contents. Each meter is provided with a calibration disc that is used to ensure the meter is functioning properly.

SPAD meter was used to estimate the chlorophyll content of the leaves of okra, brinjal and tomato collected from various above said treatments. SPAD meter readings were collected by placing a leaf between the sensors and hold the sensors together. Top of the SPAD meter was placed on the top side of the leaf and readings were taken from the same spot of the leaf of plant (halfway down the leaf from the tip to the base and halfway from the leaf edge to the midrib). The youngest fully expanded leaf of 10 tagged plants in each plot was used for SPAD measurement and triplicate readings were taken from each leaf [12].

Estimation of crude fiber content

Okra and brinjal fruits were collected from each treatment with three replications during first picking pooled and subjected to crude fiber analysis. The crude fiber content was determined gravimetrically after chemical digestion and solubilization of other materials present in okra and brinjal fruits using the standard method [13]. The dried sample was taken in a beaker and 200 ml of 1.25 per cent H_2SO_4 was added and boiled for 30 min. The contents were filtered though muslin cloth and washed with distilled water until washings were no longer acidic. The residue was transferred into the same beaker and boiled with 1.25 per cent NaOH for 30 min and filtered through muslin cloth, washed with 50 ml of distilled water and 25 ml of alcohol. The residue was transferred into a pre-weighed silica crucible dried for 2-4 h at 130^0C cooled and weighed. It was ignited and ashed for 30 min at 600^oC cooled and weighed. The loss in weight on ignition was expressed in percentage.

Estimation of lycopene content

Tomato fruits were collected from each treatment during first picking, pooled and subjected to lycopene content analysis. The lycopene content was estimated as per the procedure standardized by [14]. Tomato fruit samples (2 – 3) were taken and pulped well to a smooth consistency in a waring blender. Then took 5-10 g of pulp and extracted repeatedly with acetone using pestle and mortar or a waring blender until the residue was colourless. The acetone extracts were pooled and transferred to a separating funnel which containing 20 ml of petroleum ether and gently mixed that funnel. Then 20 ml of 5% sodium sulphate solution was added and gently shaked the separating funnel. Volume of petroleum ether might be reduced during these processes because of evaporation. Therefore, another 20 ml of petroleum ether was added to the separating funnel for clear separation of two layers. Most of the colour was noticed in the upper petroleum ether layer and two phases were separated. The lower aqueous phase was re-extracted with additional 20 ml of petroleum ether until the aqueous phase was colourless.

All petroleum ether extracts were pooled and washed once with a little distilled water. The washed petroleum ether extract containing carotenoids was poured into a brown bottle containing about 10 g anhydrous sodium sulphate and kept aside for 30 minutes. Then petroleum ether extract was transferred into a 100 ml volumetric flask through a funnel containing cotton wool and sodium sulphate slurry washed with petroleum ether until become colourless. The washings were transferred to the volumetric flask and the volume made up of 100 ml. The absorbance was measured in a spectrophotometer at 503 nm using petroleum ether as blank and calculated mg of lycopene content in 100 g sample by using the formula,

$$\text{mg lycopene in 100 g sample} = \frac{31.206 \text{ X Absorbance}}{\text{Weight of sample (g)}}$$

Field evaluation of spinetoram 12 SC on phytotoxicity on okra, brinjal and tomato plants

Field experiments were conducted to assess the phytotoxic effect of spinetoram 12 SC on okra, brinjal and tomato plants, in two seasons. In all the crops, Spinetoram 12 SC 54 and 108 g a.i./ha; mixtures of spinetoram 12 SC 54 g a a.i./ha with quinalphos 25 EC 200 g, carbendazim 125 g and urea (2%); and mixtures of spinetoram 12 SC 27 g a a.i./ha with quinalphos 25 EC 100 g, carbendazim 63 g were treated. There were five replications and three applications at 20 days interval. The spray fluid used was 500-1000 l/ha based on the age of the crop. Insecticides were sprayed to run off point using a high volume hand operated knapsack sprayer with hydraulic cone nozzle.
Observations on phytotoxic symptoms like leaf injury, wilting, vein clearing, necrosis, epinasty and hyponasty was assessed on pre-treatment and 1, 3, 7, 10 and 15 DAT after 1^{st}, 2^{nd} and 3^{rd} sprays on visual rating basis from 1 to 10. Visual rating of 1 to 10 was made based on per cent leaf injury (0 to 10% - rating 1; 11 to 20% – rating 2; 21 to 30% – rating 3; 31 to 40% – rating 4; 41 to 50% – rating 5; 51 to 60% - rating 6; 60 to 70% - rating 7; 71 to 80% - rating 8; 81 to 90% - rating 9; and 91 to 100% - rating 10).

Results and Discussion

Effect of spinetoram 12 SC on phytotonic observations on okra

The data on the effect of spinetoram 12 SC on plant height, chlorophyll content, stem girth, number of fruits and crude fiber content are presented in the **Table 1**. The plant height before treatment did not vary significantly among treatments. The maximum plant height was recorded in spinetoram 12 SC at 54 g a.i./ha (118.3 cm) followed by spinetoram 12 SC at 45 g a.i./ha (116.5 cm), while it was the shortest in untreated check (109.6 cm) on 10 days after third spray. Spinetoram 12 SC at 36 g a.i./ha as well as emamectin benzoate 5 SG at 8.5 g a.i/ha were on par (116.1 and 115.7 cm) when compared to quinalphos 25 EC 200 g a.i/ha (112.4 cm). The same trend was occurred among treatments 10 days after first and second spray. These results are in conformity with the findings of [15] who reported that thiamethoxam 70 WS seed treatment had an excellent phytotonic effect, as indicated by more number of leaves, plant height and also increased fruiting bodies and yield.

According to [16] newly formulated carbofuran formulation *viz.*, encecap carbofuran and quinalphos treated plots exhibited significant phytotonic effect and well defined superiority over other formulations tested (Carbofuran, phorate, aldicarb and ebuphos). Phytotonic effect of imidacloprid treated plants was observed and was positively correlated with plant height, growth and yield components in cotton [17]. Further, these results also were in accordance with the findings of [18] on chillies and [19] on okra.

Regarding chlorophyll content mean of three sprays observation showed all the three spinetoram 12 SC treated plots (54, 45 and 36 g a.i./ha) recorded maximum leaf chlorophyll content of 63.8, 63.2 and 58.3 SPAD values respectively when compared to 53.6 SPAD value in untreated check. However, emamectin benzoate 5 SG at 8.5 g a.i/ha, cypermethrin 25 EC at 50 g a.i/ha and quinalphos 25 EC at 200 g a.i/ha treated plots achieved 56.6, 56.2 and 55.5 SPAD values.

The maximum stem girth (6.5 cm) was observed with spinetoram 12 SC 54 g a.i/ha, followed by the same insecticide at 45 and 36 g a.i/ha (6.3 cm) and there were no significant difference among the treatments. Spinetoram 12 SC at the higher dose 54 g a.i./ha recorded more number of fruits (12.7/plant) and this was equally effective with spinetoram 12 SC 45 g a.i./ha (12.4/plant). This was followed by the same insecticide at 36 g a.i./ha (12.0/plant) and this was equally effective with emamectin benzoate 5 SG at 8.5 g a.i/ha (11.9/plant) and cypermethrin 25 EC at 50 g a.i/ha (11.7/plant) as against untreated check (10.0/plant).

Spinetoram 36, 45 and 54 g a.i/ha treated okra fruits registered 10.4, 10.4 and 10.6 per cent crude fiber content respectively and 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 registered 10.6, 10.6 and 10.4 per cent crude fiber content respectively. There was no significant difference among the treatments for crude fiber content in okra fruits.

Table 1 Phytotonic effect of spinetoram 12SC on okra (Location: Kokkulam, Madurai)

Treatments and doses (g a.i/ha)	Plant height (cm)*					Leaf chlorophyll content (SPAD Value)*					Stem girth (cm)*	Number of fruits per plant*	Crude fiber content in fruits (%)*
	Before spraying	10^{th} day after 1^{st} spray	10^{th} day after 2^{nd} spray	10^{th} day after 3^{rd} spray	Mean	Before spraying	10^{th} day after 1^{st} spray	10^{th} day after 2^{nd} spray	10^{th} day after 3^{rd} spray	Mean			
Spinetoram 12 SC 36 g a.i./ha	36.5	77.1^{bc}	100.1	116.1^{ab}	97.8^{bc}	51.6	56.2^{ab}	60.1^{ab}	62.5^{b}	58.3^{b}	6.3	12.0^{b}	10.4
Spinetoram 12 SC 45 g a.i./ha	37.1	77.4^{ab}	100.3	116.5^{ab}	98.1^{b}	51.3	58.0^{a}	62.5^{a}	69.0^{a}	63.2^{a}	6.3	12.4^{a}	10.4
Spinetoram 12 SC 54 g a.i./ha	36.9	78.5^{a}	101.8	118.3^{a}	99.5^{a}	52.5	58.4^{a}	63.2^{a}	69.7^{a}	63.8^{a}	6.5	12.7^{a}	10.6
Emamectin benzoate 5 SG 8.5 g a.i./ha	36.3	76.3^{bc}	102.0	115.7^{ab}	98.0^{b}	52.1	54.3^{bc}	57.4^{b}	58.0^{c}	56.6^{c}	6.2	11.9^{b}	10.6
Quinalphos 25 EC 200 g a.i/ha	37.0	74.2^{d}	100.9	112.4^{cd}	95.8^{d}	52.7	53.2^{bc}	56.3^{bc}	57.1^{c}	55.5^{d}	6.2	11.1^{c}	10.6
Cypermethrin 25 EC 50 g a.i/ha	37.4	75.9^{c}	100.2	114.1^{bc}	96.7^{c}	53.0	54.0^{dc}	56.9^{b}	57.8^{c}	56.2^{c}	6.3	11.7^{b}	10.4
Untreated check	36.5	72.4^{e}	99.8	109.6^{d}	93.9^{e}	51.5	52.2^{c}	52.8^{c}	55.9^{d}	53.6^{e}	6.0	10.0^{d}	10.5
CD (0.05%)	-	1.34	NS	3.47	1.75	-	3.36	3.80	3.80	3.52	NS	0.06	NS
SEd	-	0.62		1.59	0.88	-	1.54	1.75	1.75	1.71		0.03	

*Pooled data of 10 tomato plants in each treatment

DAT – Days After Treatment

Figures in the parentheses are $\sqrt{x+0.5}$ transformed values

In a column, means followed by a common letter are not significantly different by DMRT (P = 0.05)

Effect of spinetoram 12 SC on phytotonic observations on brinjal

The data on the effect of spinetoram 12 SC on plant height, chlorophyll content, stem girth; number of fruits and crude fiber content are presented in the **Table 2**. The plant height before treatment did not vary significantly among treatments. In spinetoram 12 SC at 54 g a.i./ha maximum plant height was recorded (82.5 cm) followed by spinetoram 12 SC at 45 g a.i./ha (82.1 cm), while it was the shortest in untreated check (78.3 cm) on 10 days after third spray. Spinetoram 12 SC at 36 g a.i./ha, emamectin benzoate 5 SG at 8.5 g a.i/ha registered plant height of 81.8 and 81.1 cm when compared to chlorpyriphos 20 EC at 200 g a.i/ha (80.4 cm). The same trend was occurred among treatments 10 days after first and second spray.

The chlorophyll content did not vary significantly among treatments before imposing treatments. Mean of three sprays observation showed all the three spinetoram 12 SC treated plots (54, 45 and 36 g a.i./ha) recorded maximum leaf chlorophyll content of 66.3, 65.8 and 64.4 SPAD values respectively when compared to 57.1 SPAD value in untreated check.

The maximum stem girth (3.8 cm) was observed with spinetoram 12 SC 54 and 45 g a.i/ha and there was no significant difference among the treatments. Spinetoram at the higher dose 54 g a.i./ha recorded more number of fruits (18.5/plant) which was followed by spinetoram 45 g a.i./ha (18.0/plant) and this was on par with the lower dose of spinetoram 36 g a.i/ha (17.8/plant). Thiodicarb 75 WP at 750 g a.i/ha (17.8/plant) and chlorpyriphos 20 EC at 200 g a.i/ha (17.7/plant) was the next treatments as against untreated check (15.6/plant). In brinjal experiment, spinosad treated plots registered significantly more plant height, number of shoots, number of flowers and number of fruits per plant than those treated with other insecticides like emamectin benzoate 5 WSG, cypermethrin 10 EC, quinalphos 25 EC, endosulfan 35 EC, lamda Cyhalothrin 5 EC and chlorpyriphos 20 EC [20].

Spinetoram 36, 45 and 54 g a.i/ha treated brinjal fruits registered 10.0, 10.0 and 10.1 per cent crude fiber content respectively and emamectin benzoate 5 SG at 8.5 g a.i/ha, chlorpyriphos 20 EC at 200 g a.i/ha and thiodicarb 75 WP at 750 g a.i/ha registered 10.0, 10.0 and 10.0 per cent crude fiber content respectively. There was no significant difference among the treatments for crude fiber content in brinjal fruits (Table 2).

Table 2 Phytotonic effect of spinetoram 12SC on brinjal (Location: Kokkulam, Madurai)

Treatments and doses (g a.i/ha)	Plant height (cm)*					Leaf chlorophyll content (SPAD Value)*					Stem girth (cm)*	Number of fruits per plant*	Crude fiber content in fruits (%)*
	Before spraying	10th day after 1st spray	10th day after 2nd spray	10th day after 3rd spray	Mean	Before spraying	10th day after 1st spray	10th day after 2nd spray	10th day after 3rd spray	Mean			
Spinetoram 12 SC 36 g a.i./ha	35.4	57.2	77.0	81.8	72.0	55.1	60.7a	65.1a	67.4a	64.4a	3.7	17.8bc	10.0
Spinetoram 12 SC 45 g a.i./ha	34.3	57.6	76.9	82.1	72.2	55.6	61.1a	67.0a	69.3a	65.8a	3.8	18.0bc	10.0
Spinetoram 12 SC 54 g a.i./ha	35.6	58.4	77.4	82.5	72.8	55.2	61.5a	67.3a	70.1a	66.3a	3.8	18.5a	10.1
Emamectin benzoate 5 SG 8.5 g a.i./ha	35.2	57.3	77.1	81.1	71.8	55.7	57.3b	58.0b	60.2b	58.5b	3.7	18.1b	10.0
Chlorpyriphos 20 EC 200 g a.i/ha	34.9	56.1	76.5	80.4	71.0	54.9	55.6b	57.4b	58.6b	57.2b	3.4	17.7c	10.0
Thiodicarb 75 WP 750 g a.i/ha	35.1	57.7	76.7	81.3	71.9	54.8	55.0b	57.9b	60.0b	57.6b	3.6	17.8bc	10.0
Untreated check	34.7	54.8	75.3	78.3	69.5	55.0	56.4b	57.1b	57.9b	57.1b	3.3	15.6d	10.0
CD (0.05%)	-	NS	NS	NS	NS	-	2.69	3.47	3.80	3.53	NS	0.04	NS
SEd	-					-	1.23	1.59	1.75	1.61		0.02	

*Pooled data of 10 tomato plants in each treatment
DAT – Days After Treatment
Figures in the parentheses are $\sqrt{x+0.5}$ transformed values
In a column, means followed by a common letter are not significantly different by DMRT (P = 0.05)

Effect of spinetoram 12 SC on phytotonic observations on tomato

The data on the effect of spinetoram 12 SC on plant height, chlorophyll content, stem girth, number of fruits and crude fiber content are presented in the **Table 3**.

Plant height before imposing treatments did not vary significantly. The maximum plant height was recorded in spinetoram 12 SC at 54 g a.i./ha (50.7 cm) followed by spinetoram 12 SC at 45 g a.i./ha (50.4 cm) and 36 g a.i/ha (50.2 cm) while it was the shortest in untreated check (49.1 cm) on 10 days after third spray. Standard check novaluron 10 EC at 75 g a.i/ha registered plant height of 50.2 and 50.5 cm when compared to indoxacarb 14.5 SC at 75 g a.i/ha (50.0 cm). The same trend was occurred among treatments 10 days after first and second spray. The present study was in consonance with the findings of [20] who inferred that spinosad treated plots recorded more plant height (40.4 cm), more number of shoots (10.6), more number of flowers (18.3) and more number of fruits (14.3) per plant than other insecticides (emamectin benzoate 5 WSG, cypermethrin 10 EC, quinalphos 25 EC, endosulfan 35 EC, lamda cyhalothrin 5 EC and chlorpyriphos 20 EC) and untreated control.

Mean of three sprays observation showed all the three spinetoram 12 SC treated plots (54, 45 and 36 g a.i./ha) recorded maximum leaf chlorophyll content of 53.2, 52.7 and 51.9 SPAD values respectively when compared to 47.4 SPAD value in untreated check. However, indoxacarb 14.5 SC at 75 g a.i/ha, novaluron 10 EC at 75 g a.i/ha and quinalphos 25 EC at 250 g a.i/ha treated plots achieved 48.1, 48.6 and 50.0 SPAD values. According to [21] gerbera flowering plants treated with spinosad and abamectin produced highest quality flowers due to no phytotoxicity, highest chlorophyll content and no thrips damage.

Spinetoram 54 and 45 g a.i/ha treatments were recorded maximum stem girth (2.4 cm), followed by the same insecticide at 36 g a.i/ha (2.3 cm) and this was on par with the novaluron 10 EC at 75 g a.i/ha (2.3 cm) as against untreated control (1.9 cm). Spinetoram at the higher dose 54 g a.i./ha recorded more number of fruits (27.6/plant) and this was followed by spinetoram 45 g a.i./ha (26.5/plant). The next best treatment was spinetoram 36 g a.i./ha (25.0/plant) and this was on par with indoxacarb 14.5 SC at 75 g a.i/ha (24.9/plant). Novaluron 10 EC at 75 g a.i/ha (24.4/plant) and quinalphos 25 EC at 250 g a.i/ha (22.5/plant) were the least effective treatments as against untreated check (19.2/plant). These results corroborate with the findings of [22] on green gram and [23] on cowpea and green gram.

Table 3 Phytotonic effect of spinetoram 12SC on tomato (Location: Pannikundu, Madurai)

Treatments and doses (g a.i/ha)	Plant height (cm)*					Leaf chlorophyll content (SPAD Value)*					Stem girth (cm)*	Number of fruits per plant*	Lycopene content in fruits (%)*
	Before spraying	10th day after 1st spray	10th day after 2nd spray	10th day after 3rd spray	Mean	Before spraying	10th day after 1st spray	10th day after 2nd spray	10th day after 3rd spray	Mean			
Spinetoram 12 SC 36 g a.i./ha	23.6	27.3	35.1	50.2^{a}	37.5	46.3	47.1^{c}	52.7^{a}	56.0^{a}	51.9^{a}	2.3^{ab}	25.03^{c}	2.08^{b}
Spinetoram 12 SC 45 g a.i./ha	24.0	27.0	35.5	50.4^{a}	37.6	45.6	48.0^{b}	53.4^{a}	56.8^{a}	52.7^{a}	2.4^{a}	26.52^{b}	2.01^{c}
Spinetoram 12 SC 54 g a.i./ha	23.2	27.9	35.6	50.7^{a}	38.1	45.9	48.2^{a}	54.0^{a}	57.3^{a}	53.2^{a}	2.4^{a}	27.62^{a}	2.19^{a}
Indoxacarb 14.5 SC 75 g a.i/ha	23.5	27.1	35.2	50.0^{a}	37.4	45.1	46.0^{e}	47.1^{b}	51.3^{b}	48.1^{b}	2.2^{ab}	24.85^{c}	1.75^{f}
Novaluron 10 EC 75 g a.i/ha	24.1	26.8	34.5	50.5^{a}	37.3	46.1	46.5^{d}	47.4^{b}	51.8^{b}	48.6^{b}	2.3^{ab}	24.36^{d}	1.91^{d}
Quinalphos 25 EC 250 g a.i/ha	23.3	26.6	34.1	49.7^{b}	36.8	45.9	47.1^{c}	47.8^{b}	49.0^{b}	50.0^{b}	2.1^{bc}	22.45^{e}	1.37^{g}
Untreated check	23.1	27.3	35.0	49.1^{b}	37.1	45.7	46.0^{e}	47.3^{b}	48.8^{b}	47.4^{c}	1.9^{c}	19.24^{f}	1.82^{e}
CD (0.05%)	-	NS	NS	0.06	NS	-	0.32	3.80	3.47	3.62	0.27	0.02	0.05
SEd	-			0.03		-	0.17	1.75	1.59	1.69	0.12	0.01	0.02

*Pooled data of 10 tomato plants in each treatment
DAT – Days After Treatment
Figures in the parentheses are $\sqrt{x+0.5}$ transformed values
In a column, means followed by a common letter are not significantly different by DMRT (P = 0.05)

Lycopene content was significantly high in spinetoram 12 SC treated plots at 54, 45 and 36 g a.i/ha (2.19, 2.01 and 2.08 mg/100 g fruit). This was followed by novaluron 10 EC at 75 g a.i/ha (1.91 mg/100 g fruit), untreated control (1.82 mg/100 g fruit), indoxacarb 14.5 SC at 75 g a.i/ha (1.75 mg/100 g fruit) and quinalphos 25 EC at 250 g a.i/ha (1.37mg/100 g fruit) (Table 3). The red pigment in tomato fruit, lycopene, is now being considered as the "World's most powerful natural antioxidant" [24]. It is a carotene having the formula $C_{40}H_{56}$. Though it has no nutritional value, its contribution to the colour of tomato has a great role in consumer acceptability. In the present study, lycopene content in tomato fruits was significantly high in spinetoram 12 SC treated plots at 54, 45 and 36 g a.i/ha.

Phytotoxicity of spinetoram 12 SC on okra, brinjal and tomato plants

Spinetoram 12 SC 54 and 108 g a.i./ha; mixtures of spinetoram 12 SC 54 g a a.i./ha with quinalphos 25 EC 200 g, carbendazim 125 g and urea (2%); and mixtures of spinetoram 12 SC 27 g a a.i./ha with quinalphos 25 EC 100 g, carbendazim 63 g did not result any phytotoxic symptoms like leaf injury, wilting, vein clearing, necrosis, epinasty and hyponasty at any day after treatment on leaves, stems and flowers (**Table 4**).

It was evident from the field experiments conducted during two seasons that spinetoram 12 SC 36, 45, 54 g a.i/ha and even two times higher than normal dose (108 g a.i./ha) did not show any phytotoxic symptoms like injury to leaf tip and leaf surface, wilting, vein clearing, necrosis, epinasty and hyponasty on okra, brinjal and tomato. According to (Anonymous, 2012) no phytotoxicity has been observed in the official spinetoram 12 SC experiment to date, and thus spinetoram 12 SC's high safety toward various types of crops has been confirmed. Spinosad and spinetoram 12 SC do not cause phytotoxic effects (leaf burning or discolouration, russetting or other fruit finish effects) on treated plants [25]. Results of the present study are also in accordance with the earlier findings of [26] who stated that application of both spinosad and spinetoram 12 SC for the control of lesser date moth and almond moth on date palm did not show any phytotoxic symptoms on the fruits and foliage. According to [27] on cabbage and cauliflower, they not observed any visual signs of phytotoxicity when the crops were sprayed with spinosad (6-96 g/ha) four to six consecutive applications at 7-10 day interval.

Table 4 Phytotoxic effect of spinetoram 12 SC on okra, brinjal and tomato plants

Treatments and doses (g a.i./ha)	Phytotoxic symptoms	Pre count	Post treatment observation on DAS														
			1st spray					2nd spray					3rd spray				
			1	3	7	10	15	1	3	7	10	15	1	3	7	10	15
Spinetoram	Leaf injury	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12 SC	Wilting	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
54 g a.i./ha	Vein clearing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Necrosis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Epinasty & hyponasty	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Spinetoram	Leaf injury	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12 SC	Wilting	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
108 g a.i./ha	Vein clearing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Necrosis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Epinasty & hyponasty	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Spinetoram	Leaf injury	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12 SC	Wilting	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
54 g a.i./ha +	Vein clearing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Quinalphos	Necrosis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
200 g a.i/ha	Epinasty & hyponasty	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Spinetoram	Leaf injury	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12 SC	Wilting	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
54 g a.i./ha +	Vein clearing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Carbendazim	Necrosis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
125 g a.i/ha	Epinasty & hyponasty	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Spinetoram	Leaf injury	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12 SC	Wilting	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
54 g a.i./ha +	Vein clearing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Urea 2%	Necrosis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Epinasty & hyponasty	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Conclusion

Thus, it can be concluded that the spinetoram 12 SC treated plants were significantly superior which recorded the maximum plant height, chlorophyll content, stem girth, number of fruits per plant and lycopene content (tomato) on okra, brinjal and tomato. This clearly point toward that the phytotonic effect was due to the application of spinetoram 12 SC treatments. There was no significant difference among the treatments for crude fiber content in okra and brinjal fruits. The present findings have indicated that even higher dose of spinetoram 12 SC had no phytotoxic effect on okra, brinjal and tomato plants.

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Reference

[1] Anonymous. Annual Report: Asian Vegetable Research and Development Center (AVRDC), P.O.42, Shanhua, Taiwan, 2016, 741 ROC.

[2] U. Thirumala Rao, K. R. Nagaraja Rao, E. V. Abraham, Science and Culture, 1964, 19,502-503.

[3] W. C. Brown (Ed.), Discovery and identification of a novel fermentation derived insecticide, Vol 32, Developmemt in industrial microbiology series: microbial metabolites, H. A. Kirst, K. H. Michel, J. S. Mynderse, E. H. Chio, R. C. Yao, W. M. Nakatsukasa, L. Boeck, J. L. Occolowitz, J. W. Paschal, J. B. Deeter, G. D. Thompson, Society for Industrial Microbiology, Washington, DC, 1993, Pp 109-116.

[4] G. D. Thompson, Spinosyns: an overview of new natural insect management systems. Proc. Beltwide Cotton Production Conference, San Antonio, TX. 1995, 1039-1043.
[5] Anonymous, Dow Crop Science Spinetoram. Technical Bulletin, 2006, 1-4.
[6] N. Muthukrishnan, M. Visnupriya, W. Babyrani, C. Muthiah, Madras Agric. J., 2013, 100(4-6), 605-608.
[7] N. Muthukrishnan, M. Visnupriya, C. Muthiah, W. Babyrani, Madras Agric. J., 2013, 100(4-6), 601-604.
[8] N. M. Sunilkumar, T. W. Shivanand, V. S. Kukanur, K. Sunil, K. Naveen, B. Patil, Bioinfolet., 2012, 9(3): 378-381.
[9] R. Dakshina Seal, J. David Schuster, W. Klassen, Proc. Fla. State Hort. Soc. 2007, 120, 170-177.
[10] Anonymous, Dow Crop Science Spinetoram. Technical Bulletin 2012, 1-11.
[11] K. Kariya, A. Matsuzaki, H. Machida, Nihon Sakumotsu Gakkai kiji, 1982, 51, 134-135.
[12] A. Gholizadeh, M. S. M. Amin, A. R. Anuar, W. Aimrun, European J. Sci. Res., 2009, 37(4), 591-598.
[13] A.O.A.C. Official method of Analysis. Association of official analytical chemists, food composition, additives natural contaminant. Adrich RC (ed). Assoc. of official analytical chemist Inc. U.S.A. 1990.
[14] S. Sadasivam, A. Manickam, Biochemical methods, II Ed. New Age International Publishers. 1996, pp 20-21.
[15] A. R. Prasanna, M. Bheemanna, B. V. Patil, Karnataka J. Agric. Sci., 2004, 17(2), 334-336.
[16] P. Chandramani, A. Regupathy, N. Chandramohan, Potato Journal, 1993, 20 (3 & 4), 190 - 197.
[17] G. P. Gupta, N. P. Agnihotri, Kirti Sharma, V. T. Gajbhiye, Pestic. Res. J., 1998, 10: 149 - 154.
[18] N. T. Jarande, M. D. Dethe, Plant Protec. Bull., 1994, 46, 43 - 44.
[19] U. N. Mote, R. V. Datkhile, S. A. Pawar, Pestology, 1994, 18, 5 - 9.
[20] S. S. Sharma, H. D. Kaushik. J. ent. Res., 2010, 34 (1), 39 - 44.
[21] J. D. Spiers, F. T. Davies, C. He, Hort. Sci., 2006, 41(3), 701-706.
[22] Manju, Veer Singh, Keshav Mehra, Biotic Environ. Formerly Insect Environ., 2016, 21(4), 66-68.
[23] Mithu Antu, D. M. Korat, The Bioscan, 2016, 11(1), 241-246.
[24] J. J. Jones, In: Tomato plant culture: in the field, greenhouse and home garden. CRC Press, LLC 2000, Boca Raton, Florida, 1999, p.199.
[25] O. Lopez, J. G. F. Bolanos, Green trends in insect control. Royal Society of chemistry (Great Britain), Cambridge, UK, 2011, P. 196.
[26] M. Lysandrou, S. A. Temerak, A. A. Sayed, Acta Hort. (ISHS). 2010, 882, 481-489.
[27] B. M. Harris, B. Maclean, Spinosad: Control of lepidopterous pests in vegetable brassicas. Proc. 52nd N.Z. Plant Protection Conf., 1999, 65-69.

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