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Bio-efficacy studies on selected insecticides against lepidopterous pests in tomato (*Solanum lycopersicum* L.)

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Abstract
A field investigation entitled "Bio-efficacy studies on selected insecticides against lepidopterous pests in tomato (*Solanum lycopersicum* L.)." was carried out during the *Rabi* season of the year 2020-21 at farmer field of Chervupally (village), Madgulapally (Mandal), Nalgonda (District), Telangana State. The experiment was laid out in Randomized Block Design with nine treatments and replicated thrice *viz*., T_1 (Flubendamide 480 SC @ 2.5 ml 10 l^{-1}) T_2 (Emamectin benzoate 5 SG @ 0.4 g l^{-1}) T_3 (Chlorantrinilprole 18.5% W/W SC @ 0.4 ml $acre^{-1}$) T_4 (Novaluron @ 10%EC (1 ml l^{-1})) T_5 (Fluvalinate @ 25% EC (1ml l^{-1})) T_6 (*Beauveria bassiana* @ 2 g l^{-1}); T_7 (*Metarhyzium anisopliae* @ 2 g l^{-1}); T_8 (Neem oil @ 3000ppm); T_9 control. The results revealed that among the selected insecticides T_3 (Chlorantrinilprole 18.5% W/W SC @ 0.4 ml $acre^{-1}$) recorded significantly maximum fruit yield (56.48 T/ha) with the lowest larval population of *Tuta absoluta* (0.73, 0.55), *Helicoverpa armigera* (1.09, 0.70), *Spodoptera litura* (1.93, 1.17), cut worms (0.01, 0.11) per plant and highest number of (natural enemies) Coccinellids (4.70, 5.64), Spiders (5.26, 5.25) observed per plant after first & second sprays.

Keywords: Tomato, lepidopterous pests, insecticides

Introduction
Tomato (*Solanum lycopersicum* L.) is one of the important vegetable crop belongs to the family Solanaceae and has chromosome number 2n=2x = 24. It is a self pollinated crop and originated from Mexico. It is the world's 3rd largest vegetable crop after potato and onion in world. In India, Tomatoes are cultivated in an area of 4.52 lakh ha with production of 36.16 lakh MT (NHB, 2019-20) and in Telangana the crop is grown in an area of 14,087 ha. with a production of 2.82 lakhs MT and productivity of 20 MT (NHB,2019-20). Tomato occupies a prime position in the list of 'Protective Food'. The fruit contains vitamins like 'A' and 'C' and antioxidant in abundance quantity. It is a great source of potassium, foliate, and vitamin K.
About 16 insect and other pest species which caused damage to tomato crop in India. Among the various pests, the tomato fruit borer, *Helicoverpa armigera* (Hub.) (Lepidoptera: Noctuidae) is the most destructive and the crop loss was extent up to 80 per cent. A single larva may destroy 30-40 tomatoes before it reaches maturity stage, they bore circular holes by thrusting only part of its body into fruit and eats the inner content. This pest is highly polyphagous and is reported on nearly 181 host plants. Spodoptera larva bores into the fruit causing irregular holes damaging the fruits leaving excreta inside. It causes around 12-23 per cent damage to tomatoes. A new invasive pest of tomato pinworm, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is recently invaded to India and causing devastation in both open fields and protected crops. It is a Neotropical oligophagous moth, which is associated with solanaceous crops. Spiders and Coccinellids play an important role in regulating pests in agroecosystems in a very effective way.

Material and Methods
The field experiment was laid out in a Randomized Block Design (RBD) with nine treatments including control which was replicated thrice with spacing 60x45 cm, individual plot size of 5x4 m. Raised beds were laid by covering polyethelene mulch with 25 microns thickness. Observations were recorded for morphometric and quality parameters.

Treatment details

Treatment	Selected Insecticides
T_1	Flubendamide 480 SC @ 2.5 ml 10 l^{-1}
T_2	Emamectin benzoate 5 SG @ 0.4 g l^{-1}
T_3	Chlorantrinilprole 18.5% W/W SC @ 0.4 ml $acre^{-1}$
T_4	Novaluron @ 10%EC (1 ml l^{-1})
T_5	Fluvalinate @ 25% EC (1ml l^{-1})
T_6	*Beauveria bassiana* @ 2 g l^{-1}
T_7	*Metarhyzium anisopliae* @ 2 g l^{-1}
T_8	Neem oil @ 3000ppm
T_9	Control

Data Recorded on growth parameters (Plant height, Stem diameter, Number of branches per plant, Number of leaves per plant, Number of fruits per plant, Marketable yield per plant, Yield per plot, Yield per ha), Pest Parameters, Yield loss, population dynamics on five plants at random at weekly intervals.

Results and Discussion

Growth parameters

All the treatments showed non- significant differences on various growth parameters *viz*., plant height, stem diameter, number of branches per plant and number of leaves per plant.

Yield parameters

Among the treatments, T_3 (Chlorantrinilprole18.5% W/W SC @0.4 ml l^{-1}) recorded significantly the highest value (51.55), whereas it was significantly lowest in T_9 (Control) (29.41). All treatments differed significantly with respect to marketable yield per plant. The highest marketable yield per plant was recorded in T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) (1.52 kg) and was on par with T_1 (Flubendamide 480 SC @ 2.5 ml 10 l^{-1}) (1.49 kg), while it was lowest in T_9 (Control) (0.81 kg).

Maximum marketable yield per plot was recorded in T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) (112.89 kg) followed by T_1 (Flubendamide 480 SC @ 2.5 ml 10 l^{-1}) (105.82 kg) and were comparable with each other, whereas minimum marketable yield per plot was recorded in T_9 (Control) (59.80 kg) as compared to others.

Obviously Marketable yield per hectare also higher in T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) and was on par with T_1 (Flubendamide 480 SC @ 2.5 ml 10 l^{-1}) (55.13 t), whereas lowest marketable yield per hectare was recorded in T_9 (Control) (30.13 t). Similar results were in agreement with Kooner *et al.* (2016) [7] in tomato, who reported that the highest yield was recorded in chlorantraniliprole 18.5 SC @ 175 ml ha^{-1} (978.5 q ha^{-1}).

Pest parameters

The data on tomato pin worm larval population were recorded one day before treatment as pre count and post count were of 3, 5, 7, 10 days after spraying of insecticidal treatments.

Number of tomato pin worm (Leaf miner) *Tuta absoluta* larvae per plant

Overall mean (Mean of three replications of 3, 5, 7 and 10days after spraying) efficacies of selected insecticides against tomato pin worm (Table 1&2) larval population after 1st spray revealed that, T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1} @ 0.4 ml l^{-1}) was most effective in controlling larval population (0.73) and (Neem oil 3000 ppm @ 2 ml l^{-1}) was least effective (1.20) and control (1.50). Similarly, after 2nd spray indicated that, T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) was most effective treatment in controlling larval population (0.55) and (Neem oil 3000 ppm @ 2 ml l^{-1}) was least effective (1.15).

The present results are getting support from the findings of Baetan *et al*. (2013) who reported that most efficient product was coragen, which reduced the frequency of attacked plants with 94.4 per cent followed by Affirm which decreased the frequency of attack up to 85 per cent.

Number of *Helicoverpa armigera* larvae per plant

Overall mean (Mean of three replications of 3, 5, 7 and 10days after spraying) efficacies of selected insecticides against *Helicoverpa armigera* larval population (Table 1&2) after 1st spray revealed that, among the insecticidal treatments, T_3 (Chlorantrinilprole 18.5% W/W SC @0.4 ml l^{-1}) was most effective in controlling larval population (1.09) and T_8 (Neem oil 3000 ppm @ 2 ml l^{-1}) was least effective (2.19). After 2nd spray indicated that, T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) was most effective treatment in controlling larval population (0.70) and T_8 (Neem oil 3000 ppm @ 2 ml l^{-1}) was least effective (1.59). These results are in consonant with the Patil *et al.* (2018) in tomato who reported that chlorantraniliprole 18.5 SC (0.055%) was found most effective against tomato fruit borer.

Number of *Spodoptera litura* larvae per plant

Overall mean (Mean of three replications of 3, 5, 7 and 10days after spraying) efficacies of selected insecticides against *Spodoptera litura* larval population after 1st spray revealed that (Table 1&2), T_3 (Chlorantrinilprole 18.5% W/W SC @ 0.4 ml l^{-1}) was most effective in controlling larval population (1.93) and T_8 (Neem oil 3000 ppm @ 2 ml l^{-1}) was least effective (2.95) and control (3.49). Post treatment count after 2nd spray indicated that, T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) was most effective treatment in controlling larval population (1.17) and (Neem oil 3000 ppm @ 2 ml l^{-1}) was least effective (2.24) and control (3.09). The results are in agreement with Abbas *et al.* (2015) [1] reported that in tomato, chlorantraniliprole, flubendiamide and indoxacarb had resulted better as compared with others on the basis of damaged fruits and percent loss of yield.

Number of cut worms per plant

Overall mean (Mean of three replications of 3, 5, 7 and 10days after spraying) efficacies of selected insecticides against cut worms population after 1st spray revealed that (Table 1&2), T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) was significantly most effective in controlling larval population (0.01) and T_8 (Neem oil 3000 ppm @ 2 ml l^{-1}) was least effective (0.49) and control (0.36). After 2nd spray indicated that, T_3 (Chlorantrinilprole18.5% W/W SC 1 @ 0.4

ml l^{-1}) was significantly most effective treatment in controlling larval population (0.11) and (Neem oil 3000 ppm @ 2 ml l^{-1}) was least effective (0.29).

Thus on the basis of overall mean population of cut worms, the order of efficacy of different treatments as follows Chlorantraniliprole >Flubendamide ≥ Emamectin benzoate > Fluvalinate > Novaluron > Metarhyzium anisopliae > Beauveria bassiana > Neem oil > untreated control.

No. of coccinellids per plant

Among the treatments, T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) was most effective in reducing coccinellids population (3.05), whereas (Neem oil 3000 ppm @ 2 ml l^{-1}) was least effective (4.01) at first spray. Post treatment count after 2nd spray indicated that, T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) was significantly most effective treatment in reducing coccinellids population (2.09) and T_8 (Neem oil 3000 ppm @ 2 ml l^{-1}) was least effective (4.49) and control (5.64).

Number of spiders per plant

Overall mean (Mean of three replications of 3, 5, 7 and 10days after spraying) efficacies of selected insecticides against spiders population after 1st spray revealed that, among the treatments, T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) was most effective in reducing spiders population (1.87) and (Neem oil 3000 ppm @ 2 ml l^{-1}) was least effective (4.14) and control (5.26). After 2nd spray indicated that, T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) was significantly most effective treatment in reducing spiders population (2.12) and T_8 (Neem oil 3000 ppm @ 2 ml l^{-1}) was least effective (3.73).

Yield loss

Significantly the highest total number of fruits per plant and number of healthy fruits per plant (Table 3) were recorded in T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) (51.55, 50.89), While the lowest number of fruits were recorded in T_9 (control) (29.41, 27.15). However, among the insecticides, T_8 (Neem oil 3000 ppm @ 2 ml l^{-1}) registered lowest value (32.76, 31.05).

Significantly the lowest number of damaged fruits and lowest Per cent of damaged fruits was recorded in T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) (0.66, 1.28%). The highest value was recorded in T_8 (1.71, 5.23%).While it was significantly highest (2.27, 7.74%) in control. These results are in accordance with Patil *et al.* (2013) reported that lowest fruit damage was recorded in flubendiamide 39.35% SC @ 60 g a.i. ha^{-1} with more yield.

The highest Total yield per plant (kg $plant^{-1}$) and Marketable yield per plant (kg $plant^{-1}$) was recorded in T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) (1.54 kg $plant^{-1}$, 1.52 kg $plant^{-1}$) and it was on par with T_1 (Flubendamide 480 SC @ 2.5 ml 10 l^{-1}) (1.52 kg $plant^{-1}$, 1.49 kg $plant^{-1}$).While the lowest number of fruits were recorded in T_9 (control) (0.88, 0.81 kg $plant^{-1}$). However, among the insecticides, T_8 (Neem oil 3000 ppm @ 2 ml l^{-1}) registered lowest value (0.98 kg $plant^{-1}$, 0.93 kg $plant^{-1}$).

The maximum Yield per ha (t) and Marketable yield per ha (t) was recorded in T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) (57.22 t ha^{-1}, 56.48 t ha^{-1}), followed by T_1 (Flubendamide 480 SC @ 2.5 ml 10 l^{-1}) (56.59 t ha^{-1}, 55.13 t ha^{-1}) and were comparable with each other, while it was minimum in T_9 (Control) (32.65 t ha^{-1}, 30.13 t ha^{-1}), however among the insecticides, T_8 (Neem oil 3000 ppm @ 2 ml l^{-1}) registered lowest value (36.36 t ha^{-1}, 34.46 t ha^{-1}). The present results are coincided with findings of Kooner *et al.* (2016) [7].

The minimum per cent yield loss was recorded in T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) (1.29%), which was on par with T_1 (Flubendamide 480 SC @ 2.5 ml 10 l^{-1}) (2.64%). The maximum yield loss per cent was recorded in T_8 (5.51%).While it was significantly highest in control T_9 (8.34%).

Benefit: cost ratio

Among all the treatments the significantly highest value was recorded in T_3 (Chlorantrinilprole18.5% W/W SC @ 0.4 ml l^{-1}) (3.19), whereas T_8 (Neem oil 3000 ppm @ 2 ml l^{-1}) registered lowest value (1.87).

Table 1: Effect of selected insecticides against lepidopterous pests in tomato after first spray

Treatments (T)/ Insecticides	Dose	*Tuta absoluta*		*Helicoverpa armigera*		*Spodoptera litura*		cut worms		Coccinellids		Spiders	
		A	B	A	B	A	B	A	B	A	B	A	B
T_1	2.5 ml 10 l^{-1}	1.13	0.76^{ab}	2.13	1.37^{ab}	3.13	2.01^{ab}	0.133	0.08^{b}	4.13	3.15^{e}	3.19	2.37^{e}
T_2	0.4 g l^{-1}	1.23	0.84^{ab}	2.23	1.54^{b}	3.23	2.11^{ab}	0.233	0.17^{c}	4.23	3.31^{de}	3.5	2.68^{de}
T_3	0.4 ml l^{-1}	1.03	0.73^{a}	2.03	1.09^{a}	3.03	1.93^{a}	0.033	0.01^{a}	4.03	3.05^{ef}	2.93	1.87^{ef}
T_4	1 ml l^{-1}	1.27	1.00^{bc}	2.27	1.73^{bc}	3.27	2.29^{bc}	0.267	0.20^{e}	4.27	3.51^{d}	3.93	3.35^{c}
T_5	1 ml l^{-1}	1.23	0.95^{b}	2.23	1.63^{bc}	3.23	2.19^{b}	0.233	0.18^{d}	4.23	3.39^{de}	3.6	3.06^{d}
T_6	2 g l^{-1}	1.37	1.15^{c}	2.37	2.05^{cd}	3.37	2.58^{cd}	0.367	0.31^{g}	4.37	3.73^{c}	4.73	3.97^{bc}
T_7	2 g l^{-1}	1.33	1.09^{bc}	2.33	1.89^{c}	3.33	2.48^{c}	0.333	0.27^{f}	4.33	3.62^{cd}	4.35	3.70^{bc}
T_8	2 g l^{-1}	1.43	1.20^{cd}	2.43	2.19^{cd}	3.43	2.95^{d}	0.433	0.36^{h}	4.43	4.01^{b}	4.47	4.14^{b}
T_9	2 ml l^{-1}	1.47	1.50^{d}	2.47	2.49^{d}	3.47	3.49^{e}	0.467	0.49^{i}	4.47	4.70^{a}	5.05	5.26^{a}
CD (0.05%)	-	NS	0.12	NS	0.312	NS	0.21	NS	0.04	NS	0.22	NS	0.63
S.Em±		0.1	0.05	0.1	0.102	0.1	0.07	0.099	0.03	0.1	0.08	0.45	0.26

A: Pre-treatment count - Number of larvae per plant; B: Post treatment count- Number of larvae per plant (Mean of three replications of 3, 5, 7 and 10days after spraying); NS: Non-Significant.

Table 2: Effect of selected insecticides against lepidopterous pests in tomato after Second spray

Treatments (T)/ Insecticides	Dose	*Tuta absoluta*		*Helicoverpa armigera*		*Spodoptera litura*		cut worms		Coccinellids		Spiders	
		A	B	A	B	A	B	A	B	A	B	A	B
T_1	2.5 ml 10 l^{-1}	0.97	0.57^{ab}	1.3	0.86^{ab}	2.3	1.29^{ab}	0.21	0.16^{b}	4.07	2.45^{h}	3.14	2.37^{h}
T_2	0.4 g l^{-1}	1.07	0.64^{ab}	1.37	0.98^{ab}	2.37	1.39^{b}	0.24	0.18^{bc}	4.67	2.85^{fg}	3.28	2.58^{g}
T_3	0.4 ml l^{-1}	0.93	0.55^{a}	1.1	0.70^{a}	2.2	1.17^{a}	0.16	0.11^{a}	3.73	2.09^{i}	3.04	2.12^{i}
T_4	1 ml l^{-1}	1.2	0.84^{bc}	1.53	1.16^{bc}	2.5	1.59^{c}	0.29	0.23^{cd}	4.9	3.38^{e}	3.85	3.15^{de}

T_5	1 ml l^{-1}	1.17	0.75^{b}	1.5	1.08^{b}	2.47	1.49^{bc}	0.24	0.20^{c}	4.77	2.95^{f}	3.51	2.87^{f}
T_6	2 g l^{-1}	1.29	1.07^{d}	1.77	1.40^{c}	2.77	1.96^{e}	0.32	0.27^{d}	5.3	4.08^{c}	4.04	3.54^{c}
T_7	2 g l^{-1}	1.24	0.98^{c}	1.7	1.32^{bc}	2.63	1.82^{d}	0.31	0.25^{de}	5.23	3.70^{d}	3.93	3.37^{d}
T_8	2 g l^{-1}	1.31	1.15^{e}	2.03	1.59^{cd}	2.93	2.24^{f}	0.36	0.29^{de}	5.33	4.49^{b}	4.13	3.73^{b}
T_9	2 ml l^{-1}	1.34	1.38^{f}	2.07	2.09^{d}	3.07	3.09^{g}	0.4	0.43^{e}	5.4	5.64^{a}	4.9	5.25^{a}
CD (0.05%)	-	NS	0.14	NS	0.31375	NS	0.17	NS	0.025	N/A	0.29	N/A	0.17
S.Em±		0.09	0.05	0.21	0.1242	0.19	0.08	0.05	0.016	0.38	0.15	0.42	0.13

A: Pre-treatment count - Number of larvae per plant; B: Post treatment count- Number of larvae per plant (Mean of three replications of 3, 5, 7 and 10days after spraying); NS: Non-Significant.

Table 3: Effect of selected insecticides on different yield parameters and Yield loss of tomato

Treatments (T)/ Insecticides	Total No. of fruits per plant	No. of Healthy fruits per plant	No. of Damaged fruits per plant	Percentage of damaged fruits	Total Yield per plant(Kgs)	marketable Yield per plant (Kgs)	Yield per Ha (Tonnes)	Marketable yield per Ha (Tonnes)	Yield loss%
T_1	50.98^{b}	49.67^{b}	1.31^{de}	2.58^{g}	1.52^{ab}	1.49^{ab}	56.59^{ab}	55.13^{ab}	2.64^{ef}
T_2	41.91^{c}	40.78^{c}	1.13^{e}	2.70^{f}	1.26^{b}	1.22^{b}	46.52^{b}	45.26^{b}	2.78^{e}
T_3	51.55^{a}	50.89^{a}	0.66^{f}	1.28^{h}	1.54^{a}	1.52^{a}	57.22^{a}	56.48^{a}	1.29^{f}
T_4	35.90^{e}	34.56^{cd}	1.34^{d}	3.74^{de}	1.07^{bc}	1.03^{cd}	39.84^{cd}	38.36^{cd}	3.87^{d}
T_5	36.43^{d}	35.11^{c}	1.32^{de}	3.64^{e}	1.09^{bc}	1.05^{c}	40.44^{c}	38.97^{c}	3.77^{de}
T_6	32.61^{g}	31.23^{e}	1.38^{cd}	4.25^{d}	0.97^{cd}	0.93^{cd}	36.20^{d}	34.66^{d}	4.43^{cd}
T_7	34.04^{f}	32.56^{d}	1.48^{c}	4.36^{c}	1.02^{c}	0.97^{cd}	37.78^{cd}	36.14^{cd}	4.55^{c}
T_8	32.76^{h}	31.05^{f}	1.71^{b}	5.23^{b}	0.98^{cd}	0.93^{d}	36.36^{de}	34.46^{de}	5.51^{b}
T_9	29.41^{i}	27.15^{g}	2.27^{a}	7.74^{a}	0.88^{d}	0.81^{de}	32.65^{e}	30.13^{e}	8.34^{a}
CD (0.05%)	0.3	1.05	0.13	0.72	0.19	0.15	3.17	3.27	0.59
S.Em±	0.1	0.35	0.04	0.24	0.06	0.05	1.05	1.09	0.19

The same alphabetical letter(s) across the column are not significantly different ($p < 0.05$).

Table 4: Benefit: Cost ratio of different insecticides used in tomato

Treatments (T)/Insecticides	Yield (t ha-1)	Returns (₹)	Cost of cultivation	Additional cost of Insecticide and sprayings (₹)	Total cost of cultivation (₹)	Net profit (₹)	Benefit: Cost ratio
T_1	55.13	2,75,650.00	73,129.00	15,000.00	88,129.00	187,521.00	3.127801
T_2	45.26	2,26,316.70	73,129.00	10,500.00	83,629.00	142,687.70	2.706198
T_3	56.49	2,82,433.30	73,129.00	15,250.00	88,379.00	194,054.30	3.195706
T_4	38.36	1,91,783.30	73,129.00	8,500.00	81,629.00	110,154.30	2.349451
T_5	38.97	1,94,866.70	73,129.00	8,000.00	81,129.00	113,737.70	2.401936
T_6	34.66	1,73,283.30	73,129.00	6,500.00	79,629.00	93,654.33	2.176133
T_7	36.14	1,80,683.30	73,129.00	7,000.00	80,129.00	1,00,554.30	2.254906
T_8	30.77	1,53,850.00	73,129.00	9,000.00	82,129.00	71,721.00	1.873273
T_9	27.13	1,35,666.70	73,129.00	0	73,129.00	62,537.67	1.855169

Conclusion

It could be concluded from the present investigation that, among the different treatments T_3 treatment (Chlorantrinilprole 18.5% W/W SC @0.4 ml l^{-1}) recorded the best figures with respect to number of larvae incidence, natural enemies reducing and yield and economics over others.

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