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Efficacy of new molecules of insecticides against South American tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae)

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ABSTRACT : South American tomato moth, *Tuta absoluta* (Meyrick) is an emerging pest on tomato in India causing extensive damage both under open field and polyhouse conditions. Eleven insecticides were evaluated against the pest for two seasons i.e., *kharif* and *rabi* in 2016 at ICAR-Indian Institute of Horticultural Research, Bengaluru, India under field conditions. The most efficacious insecticides identified effective against *T. absoluta* were spinetoram 12 SC @ 1.25ml/L, cyantraniliprole 10 OD @ 1. 8 ml/L, flubendiamide 480 SC @ 0.3ml/L and spinosad 45 SC @ 0.3ml/L, both on leaf and fruits.

Keywords : Insecticides, tomato, *Tuta absoluta*

INTRODUCTION

Tomato (*Lycopersicon esculentum* L.) is one of the most popular and economically important vegetables in India. It is grown in almost all states of India in an area of 0.767 M hectares with a production of 16.384 M tonnes. In India the major tomato producing states are Bihar, Karnataka, Uttar Pradesh, Orissa, Andhra Pradesh, Maharashtra, Madhya Pradesh, West Bengal and Himachal Pradesh. In Karnataka, tomato is grown in an area of 0.064 M hectares with a production of 2.03M tonnes (Anonymous, 2015).

The tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is native to South America and was detected in Europe for the first time in Spain during 2006. Since then, it has rapidly invaded other European countries and spread throughout the Mediterranean basin, including North Africa, Middle East and further spreading in parts of Asia (Lietti *et al.*, 2005; Sridhar *et al.*, 2014; Urbaneja *et al.*, 2012). Though tomato is the preferred host, it also damages other solanaceous crops like potato, brinjal *etc*. (Sridhar *et al.*, 2015). *T. absoluta* has been reported from different parts of India throughout the year though the incidence levels varies (Sridhar *et al.*, 2014; Sharma and Omkar 2017, Nitin *et al.*, 2017). *T. absoluta* is a pest with high damage potential as it can complete 10–12 continuous generations per year, and females can lay approximately 260 eggs, mainly on the top leaves of tomato plants. After hatching, larvae penetrate the leaf/fruit epidermis and bore galleries in the plant tissues and fruits making fruits unfit for marketing (Siqueira *et al.*, 2011; Roditakis and Seraphides, 2011). Larvae can form extensive galleries in the stems which damage the development of the plant. Severe damage by larvae may result in complete defoliation and drying of plant (IRAC. 2009). Potential yield loss (quantity and quality) is significant and can reach 100% if the pest is not adequately managed (IRAC, 2009).

In general, at least 12 classes of insecticides, including synthetic insecticides, are currently in use to control *T. absoluta* (IRAC, 2009). Organophosphates and pyrethroids have been in use since 1970’s while during 1990s products like abamectin, spinosad, tebufonzide and chlorfenpyr have been tried (Lietti *et al.*, 2005). However, frequent failures to control the pest with organophosphates and pyrethroids in South America (Lietti *et al.*, 2005), has lead to the assessment of new safer insecticides for effective pest control (IRAC, 2009). Indoxacarb, spinosad, imidacloprid, deltamethrin and *Bacillus thuringiensis* var. *kurstaki* have successfully been used against *T. absoluta* larvae in Spain (Russell, 2009). Chlorpyrifos and pyrethrins are frequently used in Italy (Garzia *et al.*, 2009). Abamectin, indoxacarb, spinosad, imidacloprid, thiacloprid, lufenuron and *B. thuringiensis* (*Bt*) have been recommended in Malta (Mallia, 2009). In the Mediterranean basin, the principal control strategy against *T. absoluta* is the use of chemical insecticides which can provide up to 95% control of *T. absoluta* (Urbaneja *et al.*, 2012, Derbalah *et al.*, 2012). However, in India, being a newly invaded pest, information on efficacy of different insecticides against this pest is not available. As the pest is spreading very fast in different states causing severe damage, the present studies were carried out for the management of *T. absoluta* by using few conventional and novel molecules against this pest.

MATERIALS AND METHODS

The present investigation was conducted at ICAR-Indian Institute of Horticultural Research, Bengaluru, India (13°8.12"N, 77°29.45"E, altitude 890 m). Both conventional insecticides used in tomato as well as few new and more IPM-compatible insecticides were used for this study. The trials were laid out during the *Kharif* 2016 and *Rabi* 2016. The experiment was laid out in a randomised block design with 12 treatments including control. Three replications were followed for each treatment. The seedlings (cv. Shivam) were transplanted during second week of June, 2016 for *kharif* season crop and first week of October 2016 for the *rabi* crop. The tomato crop was raised as per the recommended package of practices, except plant protection protocols.

The natural incidence of *T. absoluta* was observed during 4th week after transplanting and first spray was given. There were eleven chemical treatments comprising of spinosad 45 SC @ 0.3ml/L, spinetoram 12 SC @ 1.25ml/L, flubendiamide 480 SC @ 0.3ml/L, indoxacarb 14.5 SC @ 0.75ml/L, chlorantraniliprole 18.5 SC @ 0.3ml/L, cyantrainiliprole 10 OD @ 1. 8 ml/L, Neemazal 1 EC @ 4 ml /L, Neemazal 5 EC @ 2 ml /L, and triazophos 40 EC @ 2 ml/L, emamectin benzoate 5 SG @ 0.4 g/L, imidacloprid 17.8 SL @ 0.5 ml /L. For each spray, insecticide solutions were prepared and sprayed using gutter sprayer up to the point of runoff at fortnightly interval. In a cropping season, a total of four sprays were given and following observations were made.

a. Leaf damage

Observation on live mines of *T. absoluta* (larvae) were recorded on five randomly selected plants, representatively from two leaves each from top, middle and bottom of the plant per replication. Pre count was taken before spraying and observations on the live mines were recorded at 3, 7, 10 and 14 days after the sprays.

b. Fruit damage

Number of fruits damaged by *T. absoluta* were recorded from five selected tomato plants per replication along with healthy fruits. Per cent reduction in fruit damage in different treatments assessed. The observations were recorded on 3, 7, 10 and 14 days after spraying.

The per cent reduction in *T. absoluta* larval damage in leaves and fruits was transformed to arc sine values before subjecting to analysis of variance (P< 0.05%) and DMRT (SPSS v.21).

RESULTS AND DISCUSSION

Bio-efficacy of different insecticides against *T. absoluta*

***Kharif* Season-2016**

On Leaves:

First spray: The highest mortality of *T. absoluta* was observed in the treatments spinetoram @ 1.25 ml/L (89.27 %) followed by cyantraniliprole @ 1.8 ml/L (86.71 %) and flubendiamide @ 0.3 ml/L (82.40 %) on 3rd day after spraying. In general, similar trend was observed up to 14th day after spraying with the mean mortality of larval population in spinetoram (85.89 %) followed by cyantraniliprole (84.78 %) and flubendiamide (83.93 %) (Table 1).

Second spray: On third day after second spraying spinetoram (85.71%), flubendiamide (85.61%) and cyantraniliprole (83.24) treatments recorded highest reduction of leaf damage due to *T. absoluta*. However the mean larval mortality after second spray showed that among the chemicals tested, spinetoram gave highest efficacy in terms of reduction in live mines (87.67 %) followed by cyantraniliprole (84.33 %) and flubendiamide (81.88 %) (Table 1).

Third spray: Similar results were observed in third spray, *i.e*. spinetoram was the best treatment by recording 89.66 % reduction in larval mortality of *T. absoluta* followed by cyantraniliprole (86.33%) and flubendiamide (82.94%) (Table 1).

Thus, when overall reduction of *T. absoluta* was assessed over three sprays, spinetoram was found significantly superior followed by cyantraniliprole and flubendiamide with the tested doses with a mean mortality of 87.74%, 85.15% and 82.92 %, respectively. (Figure 1).

On fruits :

First spray: Among the treatments, spinetoram showed highest efficacy of 93.73 per cent reduction in

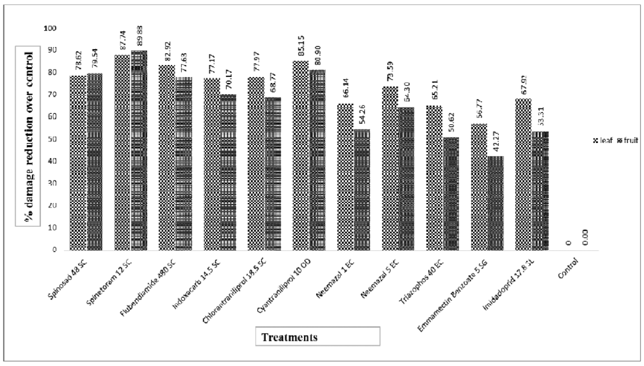

Fig.1. Efficacy of different insecticides against leaf and fruit damage by *T. absoluta* on tomato (*Kharif*, 2016)

fruit damage, followed by cyantraniliprole (79.25%) and flubendiamide (79.24%) on third day after spray which were statistically at par with each other. Average damage over different observations revealed that highest reduction in fruit damage after first spray recorded was in spinetoram (91.54%) followed by spinosad (82.06%), cyantraniliprole (81.41%) and flubendiamide (79.96 %). Other insecticides *viz*., Indoxacarb, chlorantraniliprole and neemazal 5 EC gave overall fruit damage reduction of 70.17 %, 68.77 % and 64.30 %, respectively (Table 2).

Second Spray: on third day after spraying, spinetoram (90.93%) gave higest reduction of fruit damage followed by cyantraniliprole (81.87%) and flubendiamide (80.01%). Similar trend was observed up to 14 days after spraying with highest mean reduction of fruit damage in spinetoram (88.21%) which was significantly superior over all other treatments followed by cyantraniliprole (80.39%), spinosad (77.02%) and flubendiamide (75.30%) (Table 2).

Over two sprays, the treatment, spinetoram was significantly superior followed by cyantraniliprole and spinosad and flubendiamide treatments with mean per cent reduction in fruit damage 89.88 %, 80.90 % and 79.54 % % and 77.63 %, respectively (Figure 1).

Rabi Season-2016

On Leaves:

First spray: The highest mortality of *T. absoluta* was observed in the treatments spinetoram @ 1.25 ml/L (91.45 %) followed by cyantraniliprole @ 1.8 ml/L (90.21 %) and flubendiamide @ 0.3 ml/L (86.55 %) on 3rd day after spraying. Similar trend was observed up to 14th day after spraying with the mean mortality of larvae in spinetoram (89.96 %) followed by cyantraniliprole (86.94 %) and flubendiamide (84.56 %) (Table 3).

Second spray: On third day after spraying, flubendiamide (88.20 %), spinetoram (87.13 %), and cyantraniliprole (85.81) recorded highest reduction of live mines due to *T. absoluta*. However the mean larval mortality after second spray recorded was in the order of spinetoram (87.50 %) followed by cyantraniliprole (85.19 %) and flubendiamide (83.79 %) (Table 3).

Third spray: Similar results were observed in third spray in terms of efficacy against *T. absoluta* larva, *i.e.* spinetoram resulted in 91.03 % larval mortality followed by cyantraniliprole (85.90 %) and flubendiamide (84.62 %). Mean per cent reduction of *T. absoluta* after third spray was in the order of spinosad (90.14 %) followed by cyantraniliprole (86.36 %) and spinosad (82.20 %) (Table 3).

Over three sprays, the treatment, spinetoram was significantly superior followed by cyantraniliprole, flubendiamide and spinosad treatments with mean

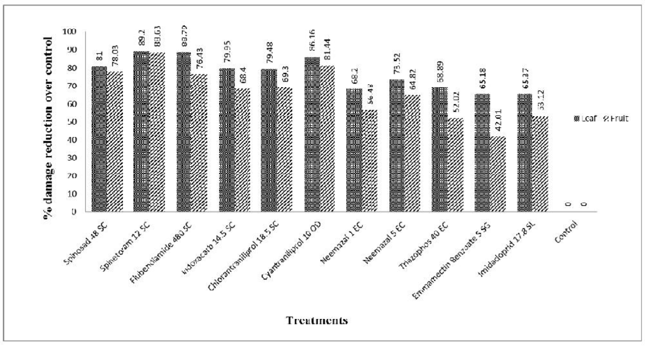

Fig. 2. Efficacy of different insecticides against leaf and fruit damage by *T. absoluta* on tomato (*Rabi,* 2016)

mortality of 89.20 %, 86.16 %, 83.78 % and 81 %, respectively (Figure 2).

On fruits:

First spray: Spinetoram gave highest per cent reduction in fruit damage of 82.13, followed by spinosad (78.32%), cyantraniliprole (75.22%) and flubendiamide (74.82%) on third day after spraying. Highest reduction in fruit damage after first spray recorded was in spinetoram (88.85%) followed by cyantraniliprole (82.47%), spinosad (79.94%) and flubendiamide (78.13%) (Table 4).

Second Spray: On the third day after spraying, spinetoram (83.07%) gave highest reduction of fruit

Table 1. Efficacy of newer molecules against *T. absoluta* on tomato leaf (I season, *Kharif* 2016)

Chemicals and dose	Per cent reduction in live mines of *T. absoluta* over control											
	Days after first spray				Days after second spray				Days after third spray			
	3rd	7th	14th	Mean	3rd	7th	14th	Mean	3rd	7th	14th	Mean
Spinosad 48 SC @ 0.2ml /L	77.27 (61.57)^{ab}	83.65 (66.22)^{bc}	71.35 (57.68)^{abcd}	76.1	76.25 (60.93)^{bcd}	79.72 (63.36)^{bc}	80.03 (63.49)^{ab}	78.66	82.95 (65.60)^{c}	79.25 (62.94)^{bc}	77.22 (61.48)^{cd}	81.09
Spinetoram12 SC@ 1.25ml/L	89.27 (71.05)^{a}	89.92 (71.51)^{a}	83.63 (66.16)^{abc}	85.89	85.71 (68.01)^{a}	88.60 (70.24)^{a}	88.25 (69.96)^{a}	87.67	90.28 (71.85)^{a}	90.79 (72.54)^{a}	86.14 (68.14)^{a}	89.66
Flubendiamide 480 SC @ 0.3ml/L	82.40 (65.37)^{ab}	82.41 (65.34)^{bc}	87.05 (69.37)^{a}	83.93	85.61 (67.79)^{a}	79.72 (63.23)^{bc}	81.18 (64.28)^{ab}	81.88	82.95 (65.60)^{c}	81.59 (64.59)^{bc}	80.14 (63.57)^{bc}	82.94
Indoxacarb 14.5 SC @ 0.75ml/L	78.55 (62.63)^{ab}	78.51 (62.42)^{bcd}	75.97 (60.70)^{abcd}	77.05	78.39 (62.33)^{abc}	74.69 (59.78)^{cd}	74.11 (39.61)^{c}	75.26	76.90 (61.29)^{d}	81.59 (64.87)^{bc}	74.25 (59.49)^{d}	79.15
Chlorantraniliprole 18.5% SC @ 0.3 ml/L	79.60 (63.21)^{ab}	72.24 (58.32)^{de}	75.44 (60.33)^{abcd}	75.89	79.70 (63.20)^{abc}	77.20 (61.51)^{c}	78.79 (62.56)^{ab}	78.57	78.00 (62.01)^{d}	79.29 (62.90)^{bc}	80.20 (63.56)^{bc}	79.27
Cyantraniliprole 10 OD @ 1.8 ml/L	86.71 (68.83)^{a}	84.79 (67.02)^{ab}	85.34 (67.55)^{ab}	84.78	83.24 (65.90)^{ab}	84.80 (67.03)^{ab}	84.71 (66.98)^{ab}	84.33	86.61 (68.54)^{b}	87.34 (69.28)^{ab}	83.17 (65.77)^{ab}	86.33
Neemazal 1 EC @ 4ml /L	67.83 (55.81)^{bc}	69.48 (56.49)^{ef}	69.15 (57.07)^{bcd}	68.96	62.11 (52.02)^{ef}	67.04 (55.04)^{de}	65.98 (54.41)^{abc}	63.71	71.95 (58.00)^{e}	65.61 (54.21)^{ef}	56.42 (48.67)^{f}	65.74
Neemazal 5 EC @ 2ml /L	77.03 (61.55)^{ab}	77.08 (61.45)^{cde}	73.50 (59.00)^{abcd}	74.71	72.79 (58.54)^{cde}	73.36 (59.01)^{cd}	76.50 (61.02)^{ab}	73.24	78.00 (62.01)^{d}	75.96 (60.71)^{cd}	66.34 (54.53)^{e}	72.81
Triazophos 40 EC @ 2ml/L	56.41 (48.70)^{cd}	63.30 (52.71)^{fg}	66.20 (54.77)^{cde}	63.74	65.73 (54.20)^{ef}	67.09 (54.97)^{e}	64.75 (53.59)^{abc}	65.49	67.00 (54.92)^{f}	63.34 (52.78)^{ef}	64.27 (53.31)^{e}	66.41
Emamectin Benzoate 5 SG @ 0.4g /L	52.33 (46.40)^{d}	57.03 (49.02)^{g}	50.59 (45.39)^{e}	55.03	58.74 (50.07)^{f}	55.69 (48.25)^{f}	54.15 (47.36)^{bc}	55.56	58.57 (49.92)^{g}	55.29 (48.05)^{f}	60.34 (50.97)^{ef}	59.7
Imidacloprid 17.8 SL @ 0.3ml /L	70.39 (57.05)^{bc}	13.38 (58.95)^{de}	63.23 (52.74)^{de}	66.66	68.10 (55.60)^{def}	65.76 (54.19)^{de}	70.58 (57.13)^{abc}	68.38	70.67 (57.19)^{e}	68.94 (56.10)^{de}	65.33 (53.93)^{e}	68.73
Control	0 (0)^{e}	0 (0)^{h}	0 (0)^{f}	0	0 (0)^{g}	0 (0)^{g}	0 (0)^{d}	0	0 (0)^{h}	0 (0)^{g}	0 (0)^{g}	0
SEm (±)	3.14	3.05	3.08	—	2.99	2.98	3.36	—	3.04	3.1	2.93	—
CD (0.05)	8.83	4.76	10.33	—	5.51	4.44	17.20	—	2.24	6.14	3.53	—

* Figures in a parenthesis are arc sine transformed values

Treatment values in a column with same alphabets are statistically non-significant (p=0.05)

Table 2. Efficacy of newer molecules against *T. absoluta* on tomato fruits (I season, *Kharif* 2016)

Chemicals and dose	Per cent reduction in fruit damage by *T. absoluta* over control								Yield
	Days after first spray				Days after second spray				
	3rd	7th	14th	Mean	3rd	7th	14th	Mean	(tonnes/ha)
Spinosad 48 SC @ 0.2ml /L	85.50 (67.65)[ab]	81.54 (64.55)[b]	76.15 (61.23)[abc]	82.06	78.16 (62.12)[b]	70.91 (57.65)[bc]	82.51 (65.28)[ab]	77.02	41.30[c]
Spinetoram12 SC@ 1.25ml /L	93.73 (75.47)[a]	90.82 (72.49)[a]	87.29 (69.77)[a]	91.54	90.93 (72.62)[a]	84.95 (67.20)[a]	89.64 (71.52)[a]	88.21	50.80[ab]
Flubendiamide 480 SC @ 0.3ml/L	79.24 (62.89)[ab]	77.73 (61.82)[bc]	81.78 (64.95)[ab]	79.96	80.01 (63.46)[b]	69.36 (56.44)[bc]	77.24 (61.50)[abc]	75.3	46.70[b]
Indoxacarb 14.5 SC @ 0.75ml/L	72.97 (58.66)[bc]	72.16 (58.13)[cd]	72.60 (58.42)[abc]	72.76	70.85 (57.33)[c]	61.99 (51.94)[cde]	71.97 (58.05)[abcd]	67.58	50.00[a]
Chlorantraniliprole 18.5% SC @ 0.3 ml/L	72.85 (58.61)[bc]	68.35 (55.78)[d]	68.79 (56.07)[bcd]	69.49	69.10 (56.22)[c]	65.86 (54.27)[bcd]	70.03 (56.83)[abcd]	68.06	47.70[ab]
Cyantraniliprole 10 OD @ 1.8 ml/L	79.25 (63.22)[ab]	81.33 (64.46)[b]	83.85 (66.40)[ab]	81.41	81.87 (64.80)[b]	77.16 (61.45)[ab]	82.51 (65.28)[ab]	80.39	51.60[a]
Neemazal 1 EC @ 4ml /L	52.00 (45.83)[cd]	55.35 (48.07)[e]	65.13 (54.29)[bcd]	56.82	52.72 (46.54)[e]	50.51 (45.25)[def]	57.82 (49.48)[bcd]	51.69	39.60[c]
Neemazal 5 EC @ 2ml /L	66.60 (54.94)[bc]	66.48 (54.67)[d]	64.97 (53.81)[bcd]	66.01	65.49 (54.01)[cd]	59.85 (50.76)[cde]	68.36 (55.76)[abcd]	62.59	40.60[c]
Triazophos 40 EC @ 2ml/L	37.35 (37.50)[d]	48.14 (43.91)[ef]	57.79 (49.60)[cd]	49.53	54.58 (47.62)[e]	50.69 (45.38)[def]	52.54 (46.44)[bcd]	51.71	38.60[c]
Emamectin Benzoate 5 SG @ 0.4g /L	35.28 (34.73)d	40.82 (39.68) [f]	48.61 (44.15)[d]	43	43.76 (41.36)[f]	36.89 (37.26)[f]	47.27 (43.42)[cd]	41.53	38.30[c]
Imidacloprid 17.8 SL @ 0.3ml /L	54.19 (47.40)[cd]	55.67 (48.24)[e]	48.27 (43.95)[d]	52.78	58.18 (49.69)[de]	48.31 (44.01)[ef]	58.00 (49.59)[bcd]	53.84	39.20[c]
Control	0 (0)[e]	0 (0)[g]	0 (0)[e]	0	0 (0)[g]	0 (0)[g]	0 (0)[e]	0	31.70[d]
SEm (±)	3.43	3.04	3.12	—	3.01	2.86	3.31	—	
CD (0.05)	13.98	4.24	12.08	—	4.35	8.42	16.62	—	

* Figures in a parenthesis are arc sine transformed values
# Treatment values in a column with same alphabets are statistically non-significant (p=0.05)

Table 3. Efficacy of newer molecules against *T. absoluta* on tomato leaf (II season, *Rabi*, 2016)

Chemicals and dose	Per cent reduction in live mines of *T. absoluta* over control											
	Days after first spray				Days after second spray				Days after third spray			
	3rd	7th	14th	Mean	3rd	7th	14th	Mean	3rd	7th	14th	Mean
Spinosad 48 SC @0.2ml /L	84.08 (66.68)ab	85.13 (67.41)bc	74.94 (59.96)cd	80.72	78.86 (62.64)abcd	81.40 (64.57)abc	78.91 (62.64)bc	80.08	84.62 (66.88)bc	78.82 (62.57)c	77.46 (61.66)cd	82.2
Spinetoram12 SC@ 1.25ml/L	91.45 (73.05)a	92.59 (74.14)a	86.34 (68.29)a	89.96	87.13 (69.23)a	88.38 (70.08)a	85.58 (67.67)a	87.5	91.03 (72.62)a	90.60 (72.18)a	87.74 (69.48)a	90.14
Flubendiamide 480 SC @ 0.3ml/L	86.55 (68.62)ab	85.17 (67.33)bc	82.97 (65.66)ab	84.56	88.20 (69.93)a	82.55 (65.29)abc	81.10 (64.22)b	83.79	84.62 (66.88)bc	80.01 (63.43)c	81.61 (64.58)bc	82.98
Indoxacarb 14.5 SC @ 0.75ml/L	82.89 (65.65)abc	80.18 (63.58)cd	80.70 (63.92)abc	80.38	81.08 (64.23)abcd	79.06 (62.75)bcd	75.54 (60.35)c	78.1	80.77 (63.96)cd	84.69 (66.97)bc	76.45 (60.97)d	81.36
Chlorantraniliprole 18.5% SC @ 0.3 ml/L	81.70 (64.65)bc	68.97 (56.28)e	79.51 (63.06)bc	77.25	82.28 (65.16)abc	80.25 (63.60)bc	79.99 (63.40)b	81.46	78.21 (62.16)de	78.82 (62.57)c	80.63 (63.87)cd	79.74
Cyantraniliprole 10 OD @ 1.8 ml/L	90.21 (71.99)ab	86.31 (68.44)b	84.11 (66.50)ab	86.94	85.81 (67.97)ab	84.89 (67.13)ab	84.47 (66.78)a	85.19	85.90 (67.96)b	85.88 (68.00)b	84.67 (66.93)ab	86.36
Neemazal 1 EC @ 4ml /L	71.87 (58.19)cd	69.15 (56.24)e	73.10 (59.01)cd	71.26	69.28 (56.49)d	71.02 (57.55)def	63.27 (52.69)ef	67.04	70.51 (57.10)f	71.72 (57.93)cd	57.01 (49.02)g	66.29
Neemazal 5 EC @ 2ml /L	80.38 (64.12)bc	77.85 (61.93)d	68.30 (55.74)de	74.94	73.92 (59.52)cd	75.66 (60.55)cd	67.75 (55.38)d	71.87	75.64 (60.42)e	78.78 (62.69)c	70.32 (56.99)e	73.76
Triazophos 40 EC @ 2ml/L	62.21 (52.07)d	70.30 (56.99)e	73.98 (59.36)cd	69.91	76.27 (61.03)bcd	74.47 (59.78)cde	64.42 (53.36)de	70.19	67.95 (55.50)f	68.23 (55.69)d	63.15 (52.64)f	66.58
Emamectin Benzoate 5SG @ 0.4g/L	59.74 (50.61)d	70.39 (57.03)e	61.21 (51.50)ef	65.81	71.58 (58.06)cd	66.34 (54.58)ef	62.27 (52.09)ef	66.75	61.54 (51.66)g	61.21 (57.46)d	63.21 (52.64)f	62.97
Imidacloprid 17.8 SL @ 0.3ml /L	71.87 (58.19)cd	70.25 (56.97)e	60.28 (50.92)f	65.27	75.20 (60.16)bcd	64.00 (53.13)f	60.04 (50.78)f	65.67	62.82 (52.45)g	65.85 (51.24)e	66.21 (54.46)ef	65.19
Control	0 (0)e	0 (0)f	0 (0)g	0	0 (0)e	0 (0)g	0 (0)g	0	0 (0)e	0 (0)f	0 (0)g	0
SEm (±)	3.22	3.09	2.98	—	3.09	3.03	2.93	—	3.07	3.05	2.97	—
CD (0.05)	7.17	4.45	4.52	—	7.27	5.29	2.3	—	2.52	4.01	2.87	—

* Figures in a parenthesis are arc sine transformed values
# Treatment values in a column with same alphabets are statistically non-significant (p=0.05)

Table 4. Efficacy of newer molecules against *T. absoluta* on tomato fruits (II season, *Rabi* 2016)

Chemicals and dose	Per cent reduction in fruit damage by *T. absoluta* over control								Yield (tonnes/ha)
	Days after first spray				Days after second spray				
	3rd	7th	14th	Mean	3rd	7th	14th	Mean	
Spinosad 48 SC @ 0.2ml /L	78.32 (66.76)^{a}	74.65 (63.49)^{b}	71.65 (61.38)^{b}	79.94	71.24 (60.62)^{bcd}	68.48 (59.81)^{b}	74.99 (63.52)^{ab}	76.11	41.3^{d}
Spinetoram12 SC @ 1.25ml/L	82.13 (69.89)^{a}	84.88 (72.67)^{a}	81.63 (69.53)^{a}	88.85	83.07 (70.91)^{a}	83.84 (71.70)^{a}	79.47 (67.38)^{a}	88.41	49.4^{a}
Flubendiamide 480 SC @ 0.3ml/L	74.82 (63.77)^{ab}	73.99 (63.39)^{b}	70.46 (60.20)^{b}	78.13	73.09 (61.97)^{bc}	66.13 (56.96)^{bc}	71.66 (61.12)^{ab}	74.72	46.00^{bc}
Indoxacarb 14.5 SC @ 0.75ml/L	63.05 (54.64)^{cd}	64.93 (56.24)^{b}	67.84 (58.09)^{bc}	69.03	66.39 (57.02)^{cde}	60.12 (53.08)^{bcd}	68.92 (37.84)^{c}	67.77	45.40^{c}
Chlorantraniliprole 18.5% SC @ 0.3 ml/L	65.74 (57.27)^{bc}	64.85 (57.33)^{b}	66.30 (57.61)^{bc}	70.53	63.83 (55.91)^{de}	59.61 (53.26)^{bcd}	68.92 (58.91)^{ab}	68.07	46.8^{abc}
Cyantraniliprole 10 OD @ 1.8 ml/L	75.22 (63.66)^{ab}	76.41 (64.79)^{ab}	78.63 (66.85)^{a}	82.47	78.02 (66.08)^{ab}	70.81 (60.63)^{b}	74.99 (63.52)^{ab}	80.4	49.2^{ab}
Neemazal 1 EC @ 4ml /L	53.78 (47.62)^{de}	50.48 (46.44)^{c}	62.61 (54.44)^{c}	56.1	54.95 (49.25)^{f}	49.99 (46.18)^{de}	60.25 (52.75)^{abc}	56.87	41.1^{d}
Neemazal 5 EC @ 2ml /L	63.16 (54.69)^{cd}	63.87 (56.10)^{b}	66.86 (57.87)^{bc}	67.08	59.73 (52.50)^{ef}	56.32 (50.81)^{cd}	67.26 (57.84)^{ab}	62.57	41.8^{d}
Triazophos 40 EC @ 2ml/L	43.68 (40.75)^{ef}	47.72 (44.42)^{c}	53.94 (48.43)^{d}	51.09	53.88 (48.18)^{fg}	51.00 (47.24)^{de}	57.62 (50.82)^{abc}	52.94	39.3^{d}
Emamectin Benzoate 5SG @ 0.4g /L	37.09 (35.78)^{f}	41.63 (40.67)^{c}	47.26 (44.15)^{d}	43.57	45.41 (42.84)^{g}	29.20 (31.94)^{f}	47.62 (44.98)^{bc}	40.45	38.4^{d}
Imidacloprid17.8 SL @ 0.3ml /L	48.00 (44.29)^{e}	50.27 (46.33)^{c}	53.33 (48.96)^{d}	53.24	57.87 (51.40)^{f}	42.74 (41.53)^{e}	52.62 (47.85)^{bc}	52.99	39.3^{d}
Control	0 (0)^{g}	0 (0)^{d}	0 (0)^{e}	0	0 (0)^{h}	0 (0)^{g}	0 (0)^{d}	0	0 (0)^{e}
SEm (±)	3.13	3.12	2.95	—	2.95	3	3.24	—	—
CD (0.05)	6.81	8.42	5.09	—	5.46	7.95	16.67	—	—

* Figures in a parenthesis are arc sine transformed values

\# Treatment values in a column with same alphabets are statistically non-significant (p=0.05) damage by *T. absoluta* followed by cyantraniliprole (78.02%), flubendiamide (73.09%) and spinosad (71.24%). The efficacy of these insecticides lasted up to 14 days after spraying by recording a mean reduction in fruit damage up to 88.41% in spinetoram followed by cyantraniliprole (80.40%), spinosad (76.11%) and flubendiamide (74.72%). Over two sprays, highest reduction of fruit damage recorded was in the order of spinetoram (88.63 %) followed by cyantraniliprole (80.40 %) and spinosad (78.03 %) and flubendiamide (74.72 %) (Figure 2). Highest yield was also recorded in the treatment spinetoram in both the seasons (Table 4).

Hanafy and El-Sayed (2013) evaluated three bio-insecticides and four chemical insecticides for their efficacy against *T. absoluta* and reported that spinetoram exhibited the highest toxic effect in reducing infestation of *T. absoluta* followed by spinosad. In our trial also, among the insecticides tried spinetoram gave highest efficacy throughout the observational period in both the seasons. Studies from others conducted elsewhere revealed that different insecticides were found effective against *T. absoluta* like spinosad (Bratu *et al*., 2015; Samir *et al*., 2015), azadirachtin, emamectin benzoate, spinosad, chlorantraniliprole (Eleonora and Vili, 2014) chlorantraniliprole+abamectin (Ali *et al*., 2014), cyantraniliprole (Patricia *et al.,* 2014), indoxacarb and chlorantraniliprole (Roditakis *et al*., 2013).

From the present trials conducted, it may be concluded that among the insecticides evaluated, the most efficacious insecticides identified to manage *T. absoluta* on tomato are spinetoram 12 SC @ 1.25ml/L, cyantraniliprole 10 OD @ 1. 8 ml/L, flubendiamide 480 SC @ 0.3ml/L and spinosad 45 SC @ 0.3ml/L. As of now only temporary label claims are available in India for few insecticides against *T. absoluta* on tomato and some are in the process of registration with central insecticide board and registration committee. While using these chemicals on tomato, label claims and waiting periods are to be followed as per the recommendations.

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