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Development and validation of Integrated Pest Management modules against South American tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in India: Blending non-insecticidal, nature friendly tools

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ABSTRACT: Field experiments were conducted to evaluate the nine different Integrated Pest Management (IPM) modules including standard check and control against South American tomato moth, *Tuta absoluta* on *cv*. 'NS-501' of tomato. Module 7 (Pheromone traps @20/ha, *Metarhizium anisopliae* @3ml/L, Spinosad (45% SC) @0.2ml/L and Azadirachtin (1% EC) @ 2ml/L) followed standard check (*Indoxacarb* (14.5SC)@0.75ml/L, Flubendiamide (480SC) @0.2ml/L, Cyantraniliprole (10.26 OD)@0.3ml/L, Spinetoram (11.7 SC)@0.75ml/L) and Module 6 (Pheromone traps @20/ha, *M. anisopliae* @3ml/L, Azadirachtin (1% EC) @ 2ml/L and Spinosad (45% SC) @0.2ml/L) were found effective in reducing *T. absoluta* population. The highest yield (59.31 t) was obtained from Module 7 compared to farmer's practice i.e., standard check (52.92 t) and control (20.61 t). Highest Cost-Benefit ratio were obtained from Module 7 (1:3.25) compared to standard check (1:2.72) and control (1:1.47).

Keywords: *Tuta absoluta*, IPM, eco-friendly methods, farmers practices

INTRODUCTION

Tomato, *Solanum lycopersicum* L. is one of the most important and largest produced vegetable crops around the world for fresh market consumption and processing. India is the second largest producer of tomato, next to China (FAO, 2016) Recently, in 2014 end, it was invaded by a new invasive pest *i.e*., South American tomato moth, *Tuta absoluta* (Meyrick). It is spreading rapidly all over the world from its first report at South America (Muszinski *et al.,* 1982) to India (Sridhar *et al.,* 2014; Sankarganesh *et al.,* 2017), Nepal (Bajracharya, 2016), Bangladesh (Hossain *et al.,* 2016), South Africa (Visser *et al.,* 2017). It is oligophagous pest preferring tomato (Sridhar *et al.,* 2015). Besides tomato the pest attacks potato, eggplant, pepino (Notz, 1992; Desneux *et al.,* 2010; Unlu, 2012; Caparros Megido *et al.,* 2013) and recently, in India it was reported on French beans, *Phaseaolus vulgaris* (Nitin *et al.,* 2017a). In India, this pest potentially occur throughout the year on tomato (Nitin *et al.,* 2017b). It has the potential to cause 80-100% crop loss (Apablaza, 1992) in the absence of appropriate management practices. Initially it makes small holes in the fruit near the calyx and makes the fruit not suitable for marketing. Spraying of insecticides was the main method used against *T. absoluta* (Galarza and Larroque, 1984). In recent times, the pest had developed resistance against many insecticides in different countries around the world (Siqueira *et al.,* 2000a; Siqueira *et al.,* 2000b; Siqueira *et al.,* 2001; Lietti *et al.,* 2005; Silva *et al.,* 2011; Reyes *et al.,* 2012). The use of synthetic pesticides against *T. absoluta* resulted in catastrophic effects and also toxicity to non-target organisms. Now a days, in India use of synthetic pesticides against *T. absoluta* have caused acute and chronic poisoning to farm workers, applicators and extending even consumers. Thus it is important that farmers adopt safer alternative management strategies against *T. absoluta* (Chaudhary *et al.,* 2017). As yet, studies on pheromone traps based threshold feral have not been established in India for *T. absoluta*. So that interventions, whether insecticidal or non-insecticidal are timed. In order to decrease the indiscriminate use of hazardous insecticides in tomato fields against *T. absoluta* and keeping the economic importance of this vegetable in mind, nine eco-friendly IPM modules with farmers practices were evaluated and validated on tomato and cost-benefit ratio were worked out. The modules embraced newer and safer molecules and tools.

MATERIALS AND METHODS

By taking best controlling formulations among the botanicals, entomopathogenic fungi and eco-friendly insecticides nine IPM modules were evaluated in the farmers field at Shivakote village of Bengaluru rural district, Karnataka, in *rabi* (2015-16 and 2016-17) and *kharif* season (2015-16 and 2016-17) against standard check and control. The popular variety of tomato (*cv*:

NS-501) was grown in approximately 1500 m^2 plots for each module in randomized block design (RBD) with three replications. Row to row spacing of 75 cm and plant to plant spacing of 45 cm was maintained during the study. Plants were grown according to the recommended package of practices without using any recommended pesticides. From the study area, ten plants/replication were randomly selected for assessing the pest population (Amutha and Manisegaran, 2006).

The different treatments used were pheromone trap (PCI™), Azadirachtin (Econeem plus-1% EC), Spinosad (Tracer-45.1 SC), *M. anisopliae* (Green meta), Indoxacarb (Kingdoxa- 14.55 SC), Flubendiamide (Fame- 39.35 m/m SC), Cyantraniliprole (Benevia- 10.26 w/w O.D) and Spinetoram (Delegate- 11.7 SC) (Table. 1).

Pheromone traps were installed in the field as soon as the transplanting was done. Module treatments were initiated as soon as the pest population noticed on the crop. The pre- and post- larval populations were counted on five randomly selected plants from all the replications. The pre-count of larval population were taken just before the spray and for post- treatments counts were taken 3 after the spray of each treatment. The damage by *T. absoluta* was identified by the feeding holes on leaves and fruits. Total number of leaves and fruits and the number of damaged leaves and fruits were counted and per cent fruit damage was worked out using Henderson and Tilton (1955) equation:

Reduction (%) = 1−[(T_a × C_b) X (T_b × C_a)] X 100

Where,

T_a and T_b = The numbers of infested plants in treatments after and before insecticide use;

C_a and C_b = The numbers of infested plants in control after and before insecticide use.

During harvest time, both the damaged and undamaged tomato fruits were collected manually at weekly intervals commencing from fruit ripening stage and the total yield was recorded and reported in t/ha. The yield obtained in different IPM modules tested were recorded. Income derived from each module was worked out. Total cost / benefit ratio was worked out for all modules.

Damage control and yield data obtained were subjected to DMRT analysis in SPSS (version. 21)

RESULTS

Damage control during vegetative stage

Among the nine different IPM modules tested including standard check and untreated control against *T. absoluta* on tomato, during vegetative stage, all the modules were statistically at par with each other in reducing *T. absoluta* population, except module 3, 1 and control. Module 7 (pheromone traps + sprays of *M. anisopliae* @3ml/L + Spinosad (45% SC) + Azadirachtin

Table 1. Different IPM modules validated against *T. absoluta*

Module	Trap/ Spray I	Spray II	Spray III	Spray IV
1	Pheromone traps @20/ha	Azadirachtin (1% EC) @2ml/L	Azadirachtin (1% EC) @ 2ml/L	Azadirachtin (1% EC) @ 2ml/L
2	Pheromone traps @20/ha	Spinosad (45%SC) @0.2ml/L	Spinosad (45%SC) @0.2ml/L	Spinosad (45%SC) @0.2ml/L
3	Pheromone traps @20/ha	*M. anisopliae @3ml/L*	*M. anisopliae @3ml/L*	*M. anisopliae @3ml/L*
4	Pheromone traps @20/ha	Azadirachtin (1% EC) @ 2ml/L	*M. anisopliae @3ml/L*	Spinosad (45%S C) @0.2ml/L
5	Pheromone traps @20/ha	Azadirachtin (1% EC) @ 2ml/L	Spinosad (45%SC) @0.2ml/L	*M. anisopliae @3ml/L*
6	Pheromone traps @20/ha	*M. anisopliae @3ml/L*	Azadirachtin (1% EC) @ 2ml/L	Spinosad (45%SC) @0.2ml/L
7	Pheromone traps @20/ha	*M. anisopliae @3ml/L*	Spinosad (45%SC) @0.2ml/L	Azadirachtin (1% EC) @ 2ml/L
8	Pheromone traps @20/ha	Spinosad (45%SC) @0.2ml/L	Azadirachtin (1% EC) @ 2ml/L	*M. anisopliae @3ml/L*
9	Pheromone traps @20/ha	Spinosad (45%SC) @0.2ml/L	*M. anisopliae @3ml/L*	Azadirachtin (1% EC) @ 2ml/L
10	*Indoxacarb (14.5SC)@0.75ml/L*	*Flubendiamide (480SC) @0.2ml/L*	*Cyantraniliprole (10.26 OD)@0.3ml/L*	*Spinetoram* (11.7 SC)@0.75ml/L
11	Control	Control	Control	Control

Table 2. Efficacy of IPM modules on larval population during vegetative and reproductive stage of plant.

Module	Vegetative stage		Reproductive stage	
	Pre-count (Number of larvae/plant)	Damage Control	Pre-count (Number of larvae/plant)	Damage Control
1	10.80	44.63 (40.99)[c]	12.33	45.10 (42.13)[e]
2	11.87	74.91 (61.75)[a]	14.33	76.23 (61.56)[c]
3	11.60	62.11 (52.08)[b]	14.6	66.23 (54.75)[d]
4	10.33	78.11 (62.47)[a]	11.47	79.54 (63.31)[c]
5	11.73	74.46 (60.12)[a]	13.53	77.20 (61.95)[c]
6	12.33	79.02 (62.92)[a]	11.93	81.89 (65.32)[bc]
7	14.33	85.34 (67.63)[a]	15.07	89.46 (71.28)[a]
8	14.07	75.49 (60.72)[a]	15.2	77.72 (62.27)[c]
9	14.67	78.20 (62.75)[a]	14.47	79.57 (63.63)[c]
10	12.87	83.44 (66.54)[a]	13	84.89 (67.61)[b]
11	18.27	16.47 (23.92)[d]	12.4	17.81 (24.95)[f]
S.Em		0.81		0.36
CD@0.05%		2.37		1.04

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

Table 3. Efficacy of IPM modules on yield and Cost-Benefit Ratio in tomato

Modules	Yield (t/ha)	Cost incurred for the module	Benefit incurred in the module	C-B ratio
1	30.19[h]	63700	105653.95	1:1.66
2	36.08[fg]	67600	126283.06	1:1.87
3	32.98[gh]	61900	115422.39	1:1.86
4	42.74[e]	64400	149573.74	1:2.32
5	37.26[f]	64400	130419.19	1:2.03
6	49.51[bc]	64400	173281.32	1:2.69
7	59.31[a]	63900	207569.85	1:3.25
8	45.98[de]	64400	160913.03	1:2.50
9	48.44[cd]	64125	169535.52	1:2.64
10	52.92[b]	67989	185202.59	1:2.72
11	20.61[i]	49000	72151.263	1:1.47

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

(1% EC)) had highest damage control potential (85.34%) followed by standard check (Indoxacarb (14.5SC)@0.75ml/L, Flubendiamide (480SC) @0.2ml/L, Cyantraniliprole (10.26 OD)@0.3ml/L, Spinetoram (11.7 SC)@0.75ml/L)) which reduced *T. absoluta* population by 83.44% (Table. 2).

Damage control during reproductive stage

As soon as the tomato started setting up the fruits, the *T. absoluta* larvae started attacking the fruits. So during that time once again these nine IPM modules were evaluated. During reproductive stage of tomato Module 7 consisting of pheromone traps followed by sprays of *M. anisopliae* @3ml/L, Spinosad (45% SC) and Azadirachtin (1% EC) found more effective (89.46%) followed by standard check, consisting of sprays of *Indoxacarb* (14.5SC)@0.75ml/L, Flubendiamide (480SC) @0.2ml/L, Cyantraniliprole (10.26 OD) @0.3ml/L, Spinetoram (11.7 SC) @0.75ml/L), which reduced *T. absoluta* infestation by 84.89% and Module 6 consisting of Pheromone traps @20/ha followed by sprays of *M. anisopliae* @3ml/L, Azadirachtin (1% EC) @ 2ml/L and Spinosad (45% SC) @0.2ml/L) were found effective in reducing *T. absoluta* population (81.89%). But in untreated control reduction of *T. absoluta* population was only 17.81% (Table. 2).

Yield and Cost-Benefit ratio

All the IPM modules evaluated gave significantly higher yield than the control (20.61 t/ha). Module 7 gave highest yield of 59.31 t/ha, followed by standard check (52.92 t/ha) and Module 6 (49.51 t/ha). By considering the economics, the Module 7 had recorded higher C:B ratio (1:3.25) and ranked first among all the trials, followed by standard check (1:2.72) and Module 6 (1:2.69). But the Control gave cost-benefit ratio of 1:1.47 only (Table. 3).

DISCUSSION

An effective eco-friendly IPM for the management of *T. absoluta* is badly needed as it is spreading rapidly and causing nuisance. For the management of this pest, we employed combination of various already proven successful strategies like use of botanicals, microbials, pheromone traps and eco-friendly molecules. As soon as the infestation noticed in the crop, we installed pheromone traps in the field. Catches of male adults started as soon as we installed the trap, which is similar to the observations of Sihem ziri and Mouhouche (2014) and Nitin *et al.,* (2017b). *T. absoluta* larvae bored inside the fruits making it unsuitable for marketing. As we used green coloured trap in the open field, it attracted more number of adults (Uchôa-Fernandes *et al.,* 1994; Ferrara *et al.,* 2001). Singh *et al.,* (2009) also demonstrated successfully use of pheromone trap @20/ha in their IPM modules to manage *Helicoverpa armigera* (Hubner) in chickpea. Our standard check consisting of chemicals was also found effective in the management of *T. absoluta*, which is similar to Sihem ziri and Mouhouche (2014) observations where they found Spinetoram was effective in the management of *T. absoluta* populations in Algeria. Roditakis *et al.,* (2015) reported for the first time about the development of diamide resistant in *T. absoluta*, but in this module Flubendiamide in combination with other insecticides found effective in suppressing *T. absoluta.* Entomopathogenic fungal isolates like *M. anisopliae* are given promising results in Chile and Brazil, (Pires *et al.,* 2009; 2010) and in this study also, *M. anisopliae* alone was not able to suppress *T. absoluta* population to that extent, where as in combination with other treatments it was highly successful in controlling the *T. absoluta* population (Table. 2). Sabbour (2014) had also reported effectiveness of *M. anisopliae* in the controlling of *T. absoluta* in Egypt. Jamshidnia (2018) was also reported efficacy of spinosad in manageing *T. absoluta* when it is used in combination with *Bacillus thuringiensis*, a entomopathogenic fungal similar to *M. anisopliae*.

CONCLUSION

T. absoluta, a devastating invasive pest spreading rapidly in many parts of the world, posing severe threat to tomato and other solanceous crops. In many other countries, it has already developed resistance against several insecticides. So, we evaluated different eco-friendly IPM modules against it and found promising results. Module 7 consisting of Pheromone traps @20/ha, *Metarhizium anisopliae* @3ml/L, Spinosad (45% SC) @0.2ml/L and Azadirachtin (1% EC gave very good results in terms of managing the *T. absoluta* population as well as in terms of yield and Cost-Benefit ratio, compared to chemicals for the management of *T. absoluta.*

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