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Screening of insecticides against pest complex of tomato and determination of terminal residues

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ABSTRACT: Bio-efficacy of indoxacarb 14.5 SC (0.005 %), λ-cyhalothrin 5 EC (0.003 %), quinalphos 25 EC (0.05%), dimethoate 30 EC (0.03 %), spiromesifen 22.9 SC (0.028 %) and thiamethoxam 25 WG (0.008 %) was assessed against major pests *viz;* whitefly, *Bemisia tabaci*, leaf miner, *Liriomyza trifolii*, aphid, *Aphis gossypii*, fruit borer, *Helicoverpa armigera* and mite, *Tetranychus urticae* on tomato (cv. GT-2) under field condition in comparison to untreated control at Navsari Agricultural University, Navsari, Gujarat during *Rabi* 2017-18. Lowest whitefly (1.50/leaf) and aphid (0.36 grade) populations were observed in thiamethoxam 25 WG 0.008 per cent. Indoxacarb 14.5 SC 0.005 per cent treated plots showed lowest leaf minor damage (4.01 %) while, spiromesifen 22.9 SC 0.028 per cent proved most effective against mite (0.13). Indoxacarb 0.005 per cent was also proved most effective against *H. armigera* indicating lowest larval population (0.46), fruit damage (8.68 %) and highest yield (38.38 t/ha.). Indoxacarb 14.5 SC 0.005 per cent and dimethoate 30 EC 0.03 per cent were found most effective against all pests collectively while, λ--cyhalothrin 5 EC 0.003 per cent was found most economical (ICBR 1:8.39) followed by indoxacarb 0.005 per cent (1:6.87). Terminal residues of most effective insecticides (indoxacarb and dimethoate) were assessed under laboratory condition using QuEChERS method which indicated accurate (70 to 120 %) and precise recovery (< 20 %) and sensitivity (LOQ < MRL) for the determination of terminal residues of indoxacarb (0.101 µg/g) and dimethoate (<LOQ, 0.02 µg/g) in tomato which were below MRL at harvest stage. So, it can be summarized that indoxacarb 14.5 SC 0.005 per cent and dimethoate 30 EC 0.03 per cent did not pose any residue problem when harvested on or after 7th day after application.

Keywords: Bio-efficacy, terminal residue, QuEChERS method and MRL

INTRODUCTION

Tomato is one of the most important vegetable crops due to its immense commercial and nutritive value, wide range of climatic adaptability and continuous demand throughout the year. The estimated area under tomato in India is 8.65 lakh hectares with 168.26 lakh tonnes of fruit production (Choudhary and Kundal, 2015).

There is considerable increase in its area which has led to considerable upsurge in the already reported insect-pests and new invasive insect-pests like tomato leaf miner/south American tomato moth, *Tuta absoluta* (Meyrick) (Sridhar *et al.,* 2014). Amongst various insect-pests reported in India, as many as sixteen have been observed feeding from germination to the harvesting stage which not only reduce its yield but also deteriorate the quality (Butani, 1977). The important insect pests of tomato are fruit borer (*Helicoverpa armigera*), whitefly (*Bemisia tabaci*), leaf hopper (*Amrasca devastans*), leaf miner (*Liriomyza trifolii*), potato aphid (*Myzus persicae*) and Hadda beetle (*Henosepilachna vigintioctopunctata* (Fabricius)) (Sharma *et al.,* 2013[b]).

Insecticide applications though results in increased yield, but are economical up to a certain extent. Their massive overuse and frequent misuse lead to three R^{s} *viz.;* Resistance of pesticides, Resurgence of pest and Residues as well as toxicity hazards to non-target animals. The present study was planned and undertaken to evaluate efficacy and economics of various insecticides such as indoxacarb, dimethoate, lambda-cyhalothrin, spiromesifen, quinalphos, thiamethoxam for the management of major pests of tomato *viz;* fruit borer, leaf miner, whitefly, aphid and mite. Terminal residues of two most effective insecticides have also been assessed. As not much information is available on bio-efficacy of different insecticides for management of major pests of tomato and their terminal residues especially under South Gujarat ago-climatic conditions so, the present study was conducted to test the efficacy of insecticides against pest complex of tomato and estimate the terminal residue of most effective insecticides in/on tomato.

MATERIALS AND METHODS

Experiments were carried out under field as well as laboratory conditions at Navsari Agricultural University

(NAU), Navsari, Gujarat during *Rabi* 2015-17. Six insecticide treatments *viz;* indoxacarb 14.5 SC (0.005%), dimethoate 30 EC (0.03%), lambda-cyhalothrin 5 EC (0.003%), spiromesifen 22.9 SC (0.028%), quinalphos 25 EC (0.05%) and thiamethoxam 25 WG (0.008%) were evaluated under field conditions against major pests (whitefly, leaf miner, aphid, fruit borer and mite) in comparison to control (untreated) on tomato (cv. GT.2). Application of insecticides was initiated at the Economic Threshold Level (ETL) of the insect-pests.

Bio-efficacy of insecticides against pest complex of tomato

The observations for field screening of insecticides against major pests of tomato were recorded at pre-treatment (one day before spray) and post treatment 1, 7 and 15 days after spraying. For this purpose, five plants were selected randomly in each replication of each treatment. Number of adult whiteflies were counted during early morning on one randomly selected leaf each on top, middle and bottom canopy of each selected plant and expressed as total population of the plant. Leaf miner infestation was observed by counting number of mined and healthy leaves on each selected plant and calibrated as per cent damage. Nymph and adult aphids were counted during early morning on selected leaf each on top, middle and bottom canopy of the plant and expressed as total population of plant and converted into aphid infestation index as grade 0 (plants completely free from aphid) grade 1 (inflorescence showing up to 15 aphids but did not show any sign of injury) grade 2 (aphid colonies scattered on leaves and inflorescence) grade 3 (leaves, stems, inflorescence and fruits densely populated by aphids, curling and yellowing of the leaves and fruits are more evident) grade 4 (very heavy population of aphid on plants, leaves, inflorescence and fruits showing symptoms of drying) and grade 5 (completely drying of plants due to heavy infestation of aphid) (Prasad,1978)

Number of fruit borer larvae during pre-harvest stage of the crop was counted on five selected plants of each replication while, during fruiting stage at every picking, damaged and healthy marketable fruits were sampled and counted and per cent damaged fruit was worked out. Mite population (adult and nymph) was counted on one leaf each on top, middle and bottom part of the ear marked plant in each replication and expressed as total population of plant.

Determination of terminal residues in/on tomato

Tomato plants at 50 per cent fruiting stage received two sprays of different insecticides at 15 days interval. After the last spray, the two most effective insecticides i.e. indoxacarb 14.5 SC and dimethoate 30 EC were subjected to estimation of terminal residues.

To assess the insecticide residues, tomato fruit samples weighing approximately 250 g were collected in each treatment along with an untreated control. Analytical grade acetone (2.5 L), Acetonitrile (purity ≥ 99.9 %), anhydrous fine powdered reagent grade magnesium sulphate (≥ 99.5 %) and primary and secondary Amine (Ethylene diamine-N-propyl, particle size 40 µm) were used as solvents.

Analytical method

In order to extract the insecticide residues of indoxacarb and dimethoate in/on tomato fruits, samples collected were subjected to analysis by QuEChERS (Quick, Easy, Cheap, Effective, Rouged and Safe) and AOAC (Official Method 2007.01) methods. Gas Chromatograph Mass Spectrometer (GC-MS) equipped with Ion Trap Detector (ITD) was used for the qualitative and quantitative estimation of dimethoate. Likewise, Liquid Chromatograph Mass Spectrometer (LC-MS) equipped with Photodiode Array Detector was used for the qualitative and quantitative estimation of indoxacarb. Certified reference materials of indoxacarb and dimethoate were obtained from Fluka Analytical (Sigma alolrich) for quantitative analysis.

A linearity study was performed to determine the performance of ion trap detector in GCMS and Photodiode Array Detector in LCMS. To work out the linearity, response (height/area) of the detector *Vs* concentration was plotted. To establish the linearity, different concentrations of the dimethoate standards and indoxacarb standards were injected and their responses on representative instrument were recorded. The volume of the standard used for the injection was 1.0 and 2.0 µl of GCMS and LCMS, respectively. Correlation coefficient and equation was determined.

Information such as accuracy or trueness and precision of the analytical method, the recovery study was carried out in/on tomato fruits before taking up analysis of test sample. Representative tomato samples were fortified with indoxacarb and dimethoate at three levels (0.01, 0.1 and 0.2 µg/g for indoxacarb; 0.05, 0.25 and 0.50 µg/g for dimethoate). The fortified samples were kept at room temperature for 2 hrs and residues were estimated as per the established protocols.

RESULTS AND DISCUSSION

The study based on bio-efficacy of insecticides against major pests infesting tomato and determination of terminal residues of most effective insecticides

Table 1. Bio-efficacy of various treatments against pest complex of tomato under field condition during 2017-18

Treatment with concentration	Whitefly		Leaf miner		Aphid		Mite		Fruit borer				Av. rank index	Overall rank	Yield		ICBR
	Population / plant	Rank	Leaf damage/ plant (%)	RANK	Grade/ plant	RANk	Population/ plant	RANK	No. of Larva/ plant	RANK	Fruit damage (%)	RANK			Pooled(kg/ plot)	Estimated (t/ha)	
Indoxacarb 14.5 SC 0.005%	2.49* (5.70)	**4**	11.55** (4.01)	**1**	1.46* (1.63)	**4**	1.12* (0.76)	**5**	0.98* (0.46)	**1**	17.14** (8.68)	**1**	**2.67**	**1**	23.03^{a}	38.38	**1 : 6.87**
Dimethoate 30 EC 0.03%	2.08 (3.81)	**3**	14.44 (6.22)	**3**	1.11 (0.72)	**2**	0.93 (0.37)	**2**	1.18 (0.89)	**4**	19.83 (11.50)	**4**	**3.00**	**2**	18.64^{cd}	31.07	**1 : 5.29**
Lambdacyhalothrin 5 EC 0.003%	2.77 (7.19)	**5**	13.24 (5.25)	**2**	1.92 (3.18)	**6**	1.06 (0.61)	**4**	1.07 (0.65)	**2**	18.52 (10.09)	**2**	**3.50**	**4**	22.04^{ab}	36.73	**1 : 8.39**
Spiromesifen 22.9 SC 0.028%	1.64 (2.19)	**2**	16.00 (7.59)	**4**	1.37 (1.37)	**3**	0.79 (0.13)	**1**	1.30 (1.20)	**5**	20.74 (12.54)	**5**	**3.33**	**3**	17.40^{de}	29.00	**1 : 0.89 (-)**
Quinalphos 25 EC 0.05%	2.98 (8.37)	**6**	18.25 (9.81)	**5**	1.71 (2.43)	**5**	1.15 (0.82)	**6**	1.16 (0.84)	**3**	19.54 (11.18)	**3**	**4.67**	**6**	20.57^{abc}	34.28	**1 : 4.90**
Thiamethoxam 25 WG 0.008%	1.42 (1.50)	**1**	27.11 (20.77)	**6**	0.93 (0.36)	**1**	1.04 (0.58)	**3**	1.33 (1.26)	**6**	23.00 (15.26)	**6**	**3.83**	**5**	16.16^{def}	26.93	**1 : 2.27**
Control (water spray)	3.24 (10.00)	**7**	30.43 (25.65)	**7**	2.02 (3.60)	**7**	1.30 (1.18)	**7**	1.45 (1.60)	**7**	30.11 (25.17)	**7**	**7.00**	**7**	13.79^{fg}	22.98	**---**
SEm± (T)	**0.08**		**0.86**		**0.04**		**0.03**		**0.02**		**0.70**		**-**	**-**	**0.87**		
CD at 5 % (T)	**0.24**		**2.47**		**0.11**		**0.09**		**0.06**		**2.02**		**-**	**-**	**3.01**		
SEm± (Tx S)	**0.04**		**0.39**		**0.03**		**0.06**		**0.03**		**0.31**		**-**	**-**	**0.41**		
CD at 5 % (Tx S)	**0.10**		**1.13**		**0.10**		**NS**		**0.09**		**2.02**		**-**	**-**	**1.20**		
SEm± (YxTx S)	**0.07**		**0.56**		**0.07**				**0.07**		**0.09**						
CD at 5 % (YxTx S)	**NS**		**1.55**		**NS**				**NS**		**0.26**						
CV(%) (T)	**17.88**		**23.26**		**13.74**		**11.98**		**9.91**		**22.74**		**-**	**-**	**4.46**		
CV(%) (T x P)	**5.83**		**5.99**		**10.45**		**-**		**11.88**		**0.89**		**-**	**-**			

have been carried out in the present investigation. The results on various aspects of this study are presented and discussed under the following heads.

Bio-efficacy of insecticides against pest complex of tomato

Overall comparative effectiveness of various treatments (irrespective of days after spraying) against pest complex of tomato and its impact on yield revealed that all the treatments were found effective over untreated control. The results based on whitefly population revealed significantly lowest adult population in plots treated by thiamethoxam 25 WG 0.008 per cent (1.50/leaf) and was ranked one followed by spiromesifen 22.9 SC 0.028 per cent (2.19) which was ranked two. Quinalphos 25 EC 0.05 per cent on the other hand was the least effective treatment indicating significantly higher whitefly population (8.37). Highest population was recorded in control (10.00) and was ranked seven (Table 1 and Fig. 1).

Indoxacarb 14.5 SC 0.005 per cent and lambdacyhalothrin 5 EC 0.003 per cent treated plots indicated significantly lower leaf miner oriented leaf mining damage to the tune of 4.01 and 5.25 per cent per plant which were significantly different from each other and were thus ranked first and second best treatments, respectively. Thiamethoxam 25 WG 0.008 per cent showed higher leaf damage of 20.77 per cent and was found least effective treatment. Highest leaf damage was observed in control plots (25.65 %/plant) and was thus ranked seventh or last (Table 1).

Significantly lowest adult aphids were observed in plots treated by thiamethoxam 25 WG 0.008 per cent (0.36 Grade/plant) followed by dimethoate 30 EC 0.03 per cent (0.72) and were categorized as first and second most superior treatments, respectively. Lambdacyhalothrin 5 EC 0.003 per cent was the least effective treatment indicating significantly higher aphid population (3.18 grade/plant). Highest population on the other hand was recorded in untreated control (3.60/plant). Significantly lowest mite population was observed in plots treated by spiromesifen 22.9 SC at 0.028 per cent (0.13/plant) followed by dimethoate 30 EC at 0.03 per cent (0.37) and were categorized as two best treatments. Quinalphos 25 EC at 0.05 per cent was the least effective treatment indicating significantly higher mite population (0.82/plant). Highest population was observed in untreated control (1.18/plant) and was ranked seventh (Table 1)

The pooled data presented in Table 1 revealed that all the insecticide treatments remained effective against *H. armigera* over untreated control. Indoxacarb 14.5 SC 0.005 was the most effective indicating significantly lowest larval population (0.46 /plant) followed by lambdacyhalothrin 5 EC 0.003 per cent (0.65) which was at par with each other and stood at first and second positions, respectively. Least effective was thiamethoxam 25 WG 0.008 per cent which recorded as high as 1.26 larvae per plant. Highest larval population of *H. armigera* was observed in untreated control (1.60 /plant).

All the insecticide treatments indicated significantly lower fruit damage of *H. armigera* than control. Indoxacarb 14.5 SC 0.005 remained the most effective indicating significantly lowest fruit damage (8.68 %). This was statistically different from lambdacyhalothrin 5 EC 0.003 per cent (10.09 %) and stood at number two. Least effective was quinalphos 25 EC 0.05 per cent which indicated as high as 15.26 per cent fruit damage. Highest fruit damage was recorded in untreated control (25.17 %) (Table 1)

Impact of various insecticides on tomato yield

The results based on different pickings of tomato fruit yield are presented in Table 1 and Figure 1 which indicate significantly highest fruit yield (23.03 kg/plot) in indoxacarb 0.005 per cent which was at par with lambdacyhalothrin 0.003 per cent (22.04 kg/plot) and quinalphos 25 EC 0.05 (20.57 kg/plot). The lowest (13.79 kg/plot) fruit yield was obtained in control plot.

Economics of insecticides

Economics of different treatments evaluated in this investigation indicated highest incremental income over control in indoxacarb 0.005 per cent (Rs15400/ha.) followed by Rs13750 and 11300 in λ-cyhalothrin 0.003 per cent and quinalphos 0.05 per cent, respectively. The Incremental Cost Benefit Ratio (ICBR) remained highest in lambda cyhalothrin 0.003 per cent (1: 8.39) followed by 1: 6.87 and 1: 5.29 in indoxacarb 0.005 per cent and dimethoate 0.03 per cent, respectively. Quinalphos 0.05 per cent and thiamethoxam 0.008 per cent indicated lower ICBR of 1: 4.90 and 1: 2.27, whereas spiromesifen 22.9 SC 0.028 per cent was not very specific to fruit borer, so failed to provide higher yield and indicated loss in terms of negative ICBR 1: 0.89 (-)

Considering the overall economics of control operation, it was evident that λ-cyhalothrin 0.003 per cent was the most economical treatment in this investigation against leaf miner and *H. armigera* and generated fairly higher gross income (Rs 36730/ha) and Incremental income over control (Rs 13750/ha) due to its excellent quick knock down effect against lepidopteran insects-pests in particular and other pests like leaf miner in general. Next in line was indoxacarb 0.005 per cent

Table 2: Linear dynamic range and co-efficient of determination of indoxacarb and dimethoate

Insecticides	Instrument	Linear dynamic range	Equation	(R^2)
Indoxacarb	LC-MS/MS	0.01-0.2 (ng/kg)	y = 201662x - 594.53	0.9972
Dimethoate	GC-MS	0.05-1.0 (mg/kg)	y = 22015x + 2243.1	0.9949

Table 3: Residue of dimethoate and indoxacarb in/on tomato fruit sample collected on 7 days after last spray

Insecticide	Dose	Sample details	Terminal residue	LOQ (µg/g)	MRL	
					Codex	EU
Indoxacarb 14.5 SC (ng/g)	**0.005 %**	T_1R_0	ND	0.016	0.5	-
		T_1R_1	0.186			
		T_1R_2	0.017			
		Mean	**0.101**			
Dimethoate 30 EC (µg/g)	**0.03 %**	T_2R_0	ND	0.02	-	0.02
		T_2R_1	BDL			
		T_2R_2	BDL			
		Mean	**BDL**			

ND: Not detected, Codex: Codex Alimentarius, EU: European Union

which was found very effective against fruit borer as well as mining insect-pest. This insecticide is reported to be very effective against lepidopteran pests so it might have provided early protection to the crop against borer which often attacks at foliage, flowering and fruiting stages of the crop. Third most economical treatment was dimethoate 0.03 per cent due to its systemic and contact nature, thus observed controlling pest complex of tomato.

Fourth in efficacy order was quinalphos 0.05 per cent which directly reduced fruit borer infestation although it was not effective against sucking whitely, aphid and mite in the investigation. Fifth treatment in sequence was thiamethoxam 0.008 per cent found highly effective against whitefly, aphid and mite but, was found least effective against lepidopteran fruit borer, so its impact on yield was not observed and failed to provide remunerative income.

Last in efficacy was spiromesifen 0.028 per cent which was reportedly very effective against mite and whitefly but was least effective against fruit borer. In the present investigation, all treatments were found varying in effectiveness to control different pests but on the basis of overall ranking indices (2.67 and 3.00), most effective insecticides were indoxacarb 0.005 per cent and dimethoate 0.03 per cent. Brickle *et al.* (1999) reported indoxacarb with lower pod damage and higher grain yield as compared other treatments. Yelshetly (1999) observed that indoxacrab 15 SC at 100 g a.i./ha proved better with lower pod damage and higher grain yield. Wakil *et al.* (2009[a]) recorded maximum seed yield (1203.66 g/plot) in indoxacarb treated plot on chickpea. Babariya *et al.* (2010) reported that indoxacarb (0.0075%) provided highest grain yield (1486 kg/ha). Chandi and Suri (2016) recorded maximum yield (586.67 kg/ha) in indoxacarb @ 500 ml/ha^{-1}. Dhaka *et al.* (2010) showed lowest fruit infestation with highest yield (39.45 q/ha) in plots treated with indoxacarb on tomato.

In the present investigation, indoxacarb 14.5 SC 0.005 was proved most superior treatment against tomato fruit borer thus, responsible for higher yield which resulted in highest efficacy or rank which is also reported in the reports of Brickle *et al.* (1999), Yelshetly (1999), Wakil *et al*. (2009[a]), Babariya *et al.*(2010), Chandi and Suri (2016) and Dhaka *et al.* (2010) who showed similar results against the pest under consideration. Based on these results, the present investigation is said to be in line with the earlier reports and is said to be confirmed.

Insecticide residues

The most effective insecticide treatments obtained in bio-efficacy investigation against major pests of tomato were subjected to residue analysis.

Terminal residues of indoxacarb

The indoxacarb residue determined from the tomato fruit sample collected on 7th day after the last spray was 0.101 µg/g. It indicated much lower value than the MRL value indicated in Codex (0.5 ng/g). Several other investigations performed on indoxacarb on different crops like brinjal (Saimandir and Gopal, 2012) and cauliflower (Takkar *et al*., 2011) reflects that residues of indoxacarb 14.5 SC 0.005 per cent recorded on 7th day were either below the MRL (0.5 ng/g) or equal to that MRL value, which is also detected in the present investigation. Further, the CIBRC has also recommended observation of 5 days as pre-harvest interval to get indoxacarb residue free tomato.

Terminal residues of dimethoate

The data (Table 3) obtained from the study reveals that dimethoate residues detected in/on tomato fruits on 7th day after spraying were BDL (i.e. <0.02 µg/g). Several studies performed on dimethoate on tomato and cucumber (Shiboob, 2012), chilli (Reddy *et al*., 2007, Verghese *et al*., 2011 and Sharma and Parihar, 2013), chilli and okra (Waghulde *et al*., 2011) revealed that residues of dimethoate 30 EC 0.03 per cent recorded on 7th day were either below the MRL (0.02 µg/g) or equal to that MRL value, which is also obtained in present investigation.

On the basis of this investigation, it can be summarized that terminal residues of indoxacarb and dimethoate were below the MRL at the time of harvest i.e. 7 days after last application of insecticides. In the reports of Shiboob (2012), Reddy *et al*. (2007), Verghese *et al*. (2011), Sharma and Parihar (2013) and Waghulde *et al*. (2011) dimethoate applied at different concentrations reported less presence of residue (below MRL). Similarly, Verghese *et al*. (2011) reported residue of dimethoate (0.34 mg/kg^{-1}) at 7 days which prove the residue of the test insecticide after 7 days in the present investigation, thus conforms the in study. Thus, it can be concluded that the results obtained in this investigation are in accordance with those of earlier workers.

Thus, it can be concluded that application of indoxacarb 14.5 SC and dimethoate 30 EC at the rate of 0.005 and 0.03 per cent respectively do not pose any residue problem if harvested on or after the 7th day of their application.

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