Evaluation of Integrated Pest Management in Reducing Insecticide Residues in Plant, Soil and Water*

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Abstract

The impact of integrated pest management (IPM) in reducing insecticide residues at Kothapally (IPM) and Enkepally (non-IPM) villages of Ranga Reddy district, Andhra Pradesh, India was evaluated in two vegetables (tomato and brinjal), besides soil and water samples during 2008-09. Out of the 15 tomato fruit samples analyzed for insecticide residues from IPM fields, only 3 samples (20% contamination) were found contaminated with residues compared to 47% in non-IPM fields. Two soil samples out of the 10 from non-IPM tomato fields, had insecticide residues. In the brinjal fields, 20% of the IPM treated and 47% in non-IPM had insecticide contamination. Twenty per cent of the soil samples in the non-IPM fields had insecticide residues, while none of the soil samples in the IPM fields had residues. Water samples collected either from IPM or non-IPM treated fields contained no residues above the detectable level. Though the contamination levels in crops and soils in the IPM and non-IPM fields indicated substantial differences, the residue concentrations were below the MRLs.

Keywords: Insecticide residues, IPM, non-IPM, vegetables, soil, water, MRLs

Introduction

Integrated pest management (IPM) is the most environment-friendly approach of crop-protection as the practice prescribes the use of chemical pesticides as the last resort. However, most of the farming communities in India are not much aware of these principles of pest management. Therefore, the level of adoption has been quite low. Implementation of the IPM strategies reduces toxic pesticides in agriculture to enhance productivity of healthy products and profitability (Ranga Rao *et al.,* 2009). The inclusion of eco-friendly IPM packages in the plant protection measures is the need of the hour to save the crop losses from the biotic stresses and to sustain and improve the agricultural production, soil health and the overall environmental quality. Several studies in the past clearly indicated that the insecticide residues in the non-IPM vegetable fields were higher than those recorded for the IPM fields (Arora and Singh, 2004; Sardana *et al.,* 2005). The insecticide residues in the IPM vegetable (tomato and cucumber) fields ranged from 0.004-0.027 mg kg^{-1} and 0.005 to 0.106 mg kg^{-1} in the non-IPM fields (Ranga Rao *et al.,* 2009). Hence, the main aim of this study was to assess the impact of IPM practices on insecticide residues in vegetables and soil and water samples as compared to the non-IPM treated farmers' fields.

Materials and methods

Tomato and brinjal were used as the test crops in this study. Five farmers each, growing tomato and brinjal, were selected from Kothapally village to implement the IPM schedule and compared with five each of tomato and brinjal farmers from Enkepally village selected as non-IPM farmers. The plant protection schedule for these crops is summarized in Tables 1 and 2. In the IPM treatment, the sprays of various insecticides were given whenever the pest populations reached the economic threshold levels. Prior to this study, a participatory rapid survey was undertaken to elicit farmers' perception on the plant protection practices in both the villages.

The major chemicals chosen for determining the residues in crop, soil and water samples were monocrotophos, chlorpyriphos, endosulfan and cypermethrin, which represent different insecticide groups widely used and popular among the farmers, as was evident from the survey conducted prior to this study. The samples of tomato and

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Table 1. Integrated pest management (IPM) schedule for the farmers growing tomato in the study area

Name of the chemical	Dose	Time of application
Neem fruit powder extract (NFE)*	5 kg acre^{-1}	30 DAT
Helicoverpa armigera Nuclear polyhedrosis virus (Ha NPV)*	250 LE ha^{-1}	40 DAT
Endosulfan 35EC	2 ml l^{-1}	50 DAT
NFE	5kg acre^{-1}	60 DAT
Cypermethrin 25 EC	1 ml l^{-1}	70 DAT
Ha NPV	250 LE ha^{-1}	80 DAT

NFE= Neem fruit extract; *Prepared at ICRISAT; DAT= Days after transplant

Table 2. IPM schedule for the farmers growing brinjal in the study area

Name of the chemical	Dose	Time of application
NFE*	12 kg ha^{-1}	30 DAT
Endosulfan 35 EC	2 ml l^{-1}	40 DAT
Bacillus thuringiensis (Bt) spray	2 ml l^{-1}	50 DAT
Cypermethrin 25 EC	1 ml l^{-1}	60 DAT
NFE	12 kg ha^{-1}	70 DAT
Endosulfan 35 EC	2 ml l^{-1}	80 DAT
Bt spray	2 ml l^{-1}	90 DAT
Cypermethrin 25 EC	1 ml l^{-1}	100 DAT
NFE	12 kg ha^{-1}	110 DAT
Endosulfan 35 EC	2 ml l^{-1}	120 DAT
Bt spray	2 ml l^{-1}	130 DAT
Cypermethrin 25 EC	1 ml l^{-1}	140 DAT
NFE	12 kg ha^{-1}	150 DAT
Endosulfan 35 EC	2 ml l^{-1}	160 DAT

NFE= Neem fruit extract; *Prepared at ICRISAT; DAT= Days after transplant

brinjal fruits, soil and water samples collected from non-IPM and IPM fields were analysed for insecticide residues. Methods used for the residues extraction from the samples were based on multi-insecticide residues to target several compounds simultaneously. Extraction of insecticide residues from vegetables, soil and water samples was carried out following the procedures of Vicente and Yolando (2004) and Hernandez *et al*. (1993), respectively. Clean up of the extract was done using solid phase extraction (SPE)-FL PR (florisil) cartridges fitted to SPE vacuum manifold, supplied by Phenomenex Company. The eluant was concentrated to 2 ml with nitrogen gas purging and analyzed for the presence of insecticide residues by Gas Chromatography-Mass Spectrometer (GC-MS QP 5050A (Schimadzu Model).

The insecticide reference standards were purchased from Dr.Ehrenstorfer, Augsburg, Germany and their purity ranged from 96% to 99.0%. The standard mixtures of analytes were prepared at 0.5 µg ml^{-1}, 0.2 µg ml^{-1}, 0.1 µg ml^{-1}, 0.05 µg ml^{-1} and 1.0 µg ml^{-1} concentrations by serial dilution technique for preparing the calibration curve. All standards after use were stored in refrigerator at 4ºC. GC-17A Ver.3 equipped with mass spectrometer detector and Zebron Multi residue column ZB -1, with 30 X 0.25 mm i.d. (internal diameter) and 0.25 µm thickness of 100% dimethylpolysiloxane stationary phase was used. The GC operating parameters were as follows: Carrier gas: Helium; Column inlet pressure 130.1 kPa; Column flow: 1.7 ml min^{-1}; Linear velocity: 48.7 cm sec^{-1}; Split ratio: 0; Total flow: 3 ml min^{-1}; Carrier flow: 3 ml min $^{-1}$. The column was initially maintained at 110 °C for 3 min, and then increased at the rate of 15 °C per min up to 280 °C. The column was held at 280 °C for 2 min and then the temperature was increased at the rate of 30 °C per min, and finally increased to 300°C, at the rate of 30°C min^{-1} and held for 4 min to facilitate separation of all the compounds.

The mass spectrometer was calibrated weekly. The individual insecticide standards were run in a scan mode, followed by run in the selected ion monitoring (SIM) mode using two or three reference ions with a total program time of 22.67 min.

Insecticides were identified according to their retention times, the target and qualifier ions and qualifier to target abundance ratios. The target and qualifier abundances were determined by injection of individual insecticide standard mixtures under the same chromatographic conditions using full scan with mass: charge (m/z) ratio ranging from 50 to 600 and also in SIM. A calibration curve or linearity curve was developed using the standard areas and retention times.

In order to obtain the limit of quantification (LOQ), samples were spiked with different known amounts of standard mixtures and the level at which acceptable recovery and Relative standard deviation (RSD) were obtained, was considered as the LOQ.

Spiking was done at LOQ level of 0.005 µg g^{-1} and five times of LOQ in vegetables (tomato and brinjal), at 0.01 µg g^{-1} (LOQ), 0.025 µg g^{-1} (2.5 times of LOQ) in soil and at 0.001 µg ml^{-1} (LOQ) and 0.0005 µg ml^{-1} (five times of LOQ) in water.

The insecticide residues were estimated by injecting 1µl volume of extracted and cleaned samples in GC-MS. Based on the area of peaks obtained at the particular retention time and target and qualifier ions, which matched with those of standards, insecticide residue concentration was calculated.

Results and discussion

The GC-MS response for all analytes was linear in the concentration range (0.05-1.0 µg ml^{-1}) assayed with correlation coefficients >0.998. Recovery experiments exhibited efficacy of the extraction procedures for monocrotophos, chlorpyriphos, alpha endosulfan, beta endosulfan and cypermethrin in all the matrices studied (tomato, brinjal, soil and water) at different spiking levels. The overall relative standard deviation (RSD) for each matrix and the RSD at each fortification level was <20%. The mean recovery at each fortification level for the matrices used was in the range of 70-110%, which are in accordance with the figures reported in the Guidance Document on Pesticide Residue Analytical Methods (OECD, 2007).

The results on insecticide residues are summarized in Tables 3 and 4. Out of the 15 tomato fruit samples analyzed for insecticide residues from IPM fields, only 3 samples (20% contamination) were found to contain cypermethrin residues in the range of 0.01-0.05 ìg g^{-1}. None of the soil and water samples collected from tomato fields with IPM treatment contained insecticide residues. Forty seven per cent of the tomato fruit samples from non-IPM fields were found contaminated with different insecticide residues with concentration ranging from 0.008 to 0.4 ìg g^{-1}. Two soil samples out of the 10 samples analyzed were found to contain residues of alpha endosulfan (0.8 ìg g^{-1}) and cypermethrin (0.04 ìg g^{-1}). No water sample contained the residues above the detectable level from the non-IPM tomato fields. However, the residue levels of insecticides detected from the IPM and non-IPM samples were found to be below the maximum residue limit (MRL).

Monocrotophos, beta endosulfan and cypermethrin residues were detected in 20% of the brinjal fruit samples under the IPM treatment; and the residue concentration ranged from 0.005 to 0.1 ìg g^{-1}. Soil and water samples collected from the brinjal fields with IPM treatment did not contain insecticide residues.

In non- IPM fields, 7 out of the 15 brinjal samples (47% contamination) contained the residues of all insecticides, except for chlorpyriphos. The incidence level of monocrotophos, alpha endosulfan and cypermethrin was detected in three samples, and beta endosulfan was identified in two samples; and the residue concentration ranged from 0.006 to 0.09 ìg g^{-1}. Chlorpyriphos and alpha endosulfan residues were detected in two soil samples (20%), and residue concentration ranged from 0.01 to 0.03 ìg g^{-1}. As in the case of tomato, the residues of none of the insecticides were detected at or above the prescribed MRLs in brinjal in the IPM as well as in non-IPM fields.

Table 3. Insecticide Residues in IPM and Non-IPM tomato fruit, soil and water samples

	No. of samples					
Matrix	Analyzed	Contaminated	Insecticides detected	Frequencies	Residue level (µg g^{-1})	MRL (µg g^{-1})
IPM						
Fruit	15	3	Cypermethrin	3	0.05, 0.02, 0.01	0.5
Soil	10	0	-	-	-	-
Water	10	0	-	-	-	-
Non-IPM						
Fruit	15	7	Monocrotophos	2	0.09, 0.05	0.2
		Alpha endosulfan	1	0.09	2.0	
		Beta endosulfan	2	0.4, 0.03	2.0	
		Cypermethrin	5	0.05, 0.08, 0.008, 0.009, 0.01,		0.5
Soil	10	2	Alpha endosulfan	1	0.8	2.0
		Cypermethrin	1	0.04	2.0	
Water	10	-	-	-	-	-

Table 4. Insecticide residues in IPM and Non-IPM brinjal fruit, soil and water samples

	No. of samples					
Matrix	Analyzed	Contaminated	Insecticides detected	Frequencies	Residue level (µg g^{-1})	MRL (µg g^{-1})
IPM						
Fruit	15	3	Monocrotophos	1	0.005	0.2
		Beta endosulfan	1	0.1	2.0	
		Cypermethrin	1	0.1	0.5	
Soil	10	0	-	-	-	-
Water	10	0	-	-	-	-
Non-IPM						
Fruit	15	7	Monocrotophos	3	0.01, 0.03, 0.09	0.2
		Alpha endosulfan	3	0.07, 0.009, 0.01	2.0	
		Beta endosulfan	2	0.006, 0.08	2.0	
		Cypermethrin	3	0.02, 0.01, 0.04	0.5	
Soil	10	2	Chlorpyriphos	1	0.03	Not available
		Alpha endosulfan	1	0.01	Not available	
Water	10	0	-	-	-	-

The results on the impact of IPM in reducing insecticide residues clearly indicated a demarcation in the insecticide residues between IPM and non-IPM vegetable fields. The recorded contamination per cent of residues from non-IPM fields was almost double to that of IPM fields. It was evident from the survey results that more number of insecticide sprays was applied in the Enkepally village as compared to that in the Kothapally village, which could be the probable reason for the presence of insecticide residues in greater number of samples from Enkepally. The presence of residues in the IPM fields may be due to the left over residues in the soil and water used for the crops before growing vegetables from the contaminated sources and the proximity of non-IPM fields to IPM fields (Ranga Rao *et al.,* 2009). These results are in agreement with the findings of Sardana *et al.* (2004, 2005) who found that the use of neem seed kernel extract (NSKE) intermittently with insecticides and other biological and mechanical practices as a part of IPM package, resulted in increased yield, and the harvested brinjal from the non-IPM package had higher amount (above MRL) of the residues of monocrotophos (1.25 mg kg^{-1}); and the residues of chlorpyriphos, monocrotophos and cypermethrin were 1.54, 6.72, 3.76 µg g^{-1} in the non-IPM fields of okra; and the insecticide residues in the non-IPM fields were higher than those recorded for the IPM fields. Similar findings were reported by Arora and Singh (2004) who reported that the residues of chlorpyriphos and cypermethrin in okra as 0.1 µg g^{-1} and non-detectable from IPM trails compared to 5.75 and 0.63 µg g^{-1} from the non-IPM fields. The incidence of monocrotophos residues in brinjal fruits were found to be non detectable level in IPM fields compared to 1.25 µg g^{-1} of non-IPM fields (Singh *et al.,* 2008). Leandri *et al.* (1996) suggested that IPM strategies generally brought about an improvement in the quality of the tomato fruit with lower insecticide residue levels than in the fields under traditional plant protection schedules based on calendar sprays and the present studies are in conformity of their inference.

As in the case of fruit samples, insecticide residues were detected in a few soil samples from the non-IPM fields which could be due to the cumulative effect of continuous chemical use in these fields. Similar views were presented by Arora and Singh (2004) for interpreting the residues of chlorpyriphos in the soil at sowing as 0.41 µg g^{-1} and 4.22 and 1.14 mg g^{-1} at harvest in samples from non-IPM and IPM okra fields, respectively.

The report of Baker *et al.* (2002) partially negates our findings. They reported that analysis of pesticide residue data performed to describe and quantify differences between organically grown and non-organic fresh fruits and vegetables indicated that IPM/NDR (no detectable residues) category had residues higher than those in organic samples, but lower than those in conventionally grown foods.

Since the implementation of vegetable IPM in various communities, the incidence of pesticide residue maximum tolerance limit(MTL) in sampled vegetables in Kunming city has been continuously reduced from 20.87% in 2003, to 10.2% in 2004 and 2.5% in 2005 (Yang *et al.,* 2005), indicating the importance of community IPM for safe vegetable production by the small holders reflected from their social connectedness and its effects on eliminating vegetable pesticide residues and other pollutions in China (Wu and Pretty, 2004; Fu and Liu, 2006) .

The present study brought out the importance of IPM adoption in effective management of pests as well as natural resources in a sustainable way was explained by previous studies (Chopra, 1993). However, it should be noted that the present IPM strategies are not against chemical use, but the focus is on their judicious use. On the other hand, considering the extent of damage caused to the natural resources in terms of contamination, preference should be given to the implementation of the IPM to provide better food and environmental quality.

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