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Short communication

Management of *Helicoverpa armigera* (Hübner) on tomato using insecticide resistance egg parasitoid, *Trichogramma chilonis* Ishii in farmers' field

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ABSTRACT

A multiple insecticide tolerant strain of beneficial egg parasitoid, *Trichogramma chilonis* with several folds of tolerance to six different insecticide groups was developed for suppression of Lepidopteran insect pests on vegetable crops. Tolerant strain parasitized significantly more pest eggs and survived long compared to the susceptible strain under sprayed condition. The tolerant strain could parasitize more eggs during winter (50.8%) compared to summer (39.0%), whereas no parasitism was recorded by susceptible strain under sprayed system in net-house. The activity of detoxifying enzymes, *viz.*, glutathione *S*-transferases and carboxylesterase was significantly high by 2.13-fold and 1.5 to 9.0-fold in tolerant strain. Field evaluation of the strains in different geographical locations in India, on tomato resulted in increased yields by 816, 2400 and 1500 kg / acre and reduced insecticidal application by 20-65% and per cent benefit of Rs. 9,000 to 20,000 / acre to farmers.

Key words: *Helicoverpa*, insecticide resistance, intergrated pest management, natural enemies, *Trichogramma*.

Tomato, *Solanum lycopersicum* (L.), one of the most important vegetable crops originated in South America and spread throughout the world. In India, the major tomato producing states are Bihar, Karnataka, Uttar Pradesh, Odisha, Andhra Pradesh, Maharashtra, Madhya Pradesh and West Bengal. Insecticides are widely used by the farmers for the control of variety of insect pests occurring on tomato. In India, about 10% of insecticides are used on vegetable crops and more than 15 insecticides are used on tomato alone (Kodandaram *et al*., 13).

Intensive use of insecticides is widespread and increasing despite historically well recognized consciousness of the costs and hazards. The benefits from insecticides in suppressing the insect pests and increasing crop yield may further lead to development of insecticide resistance and resurgence in certain insect pests and elimination of beneficial natural enemies (Bommacro *et al*., 2), over a period of time. Our studies for the past six years have resulted in development of strain of beneficial egg parasitoid tolerant to multiple insecticides and its utilization for the suppression of fruit borer, *Helicoverpa armigera* (Hübner) on tomato across India. Trichogrammatids are important egg parasitoids used as key beneficial natural enemies for suppression of moth pests of various crops. Among them, *Trichogramma chilonis* Ishii, native to Asian, Indo-China and Indo-Australian region, is the most widely used species in integrated pest management (IPM) in India, China, Korea, Taiwan, Japan, Pakistan, Nepal and Reunion Island, and as an exotic species in Kenya, Spain, South Africa and Australia (Jalali *et al*., 12). However, most of the trichogrammatids are known to be highly susceptible to broad spectrum insecticides and reduced parasitism has been reported (Campbell *et al*., 4; Jalali and Singh, 10). Similarly, the drift of insecticides even a mile away is known to reduce the efficacy of trichogrammatids (Stinner *et al*., 14; Bull and House, 3).Under such a scenario, it is extremely unlikely that biocontrol agents will exert any pressure on the population of insects or can survive on crops, which receives 10-30 rounds of spray per cropping season. This may be the major reason for the failure of field released biological control agents against insect pests.

Insecticide tolerant strain has potential to suppress the insect pests under insecticide stressed conditions and can be used by the farmers, who do not take up releases of any natural enemies on insecticide sprayed crops as suggestion of waiting period between them is not acceptable. Therefore, it is believe that such new technology, which sort itself out with farmers' conviction, will be of enormous use against insect pest of tomato and significantly reduce the insecticide load.

The population of an egg parasitoid was collected from tomato fields in and around Bengaluru city. About 100 eggs of tomato fruit borer (*H. armigera*) were collected, at least from 10 fields. The eggs were transferred to the laboratory and were observed for parasitism by the egg parasitoids. On emergence, the identity of the parasitoid was determined and was multiplied on laboratory host rice moth eggs (*Corcyra*

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cephalonica) to obtain sufficient adults for screening against insecticides. The insecticides screened for tolerance of parasitoids were, *viz*., organochlorine (endosulfan), organophosphate (monocrotophos, acephate, dichorvos and dimethoate), synthetic pyrethroids (λ-cyhalothrin, fenvalerate, cypermetrin and deltamethrin), oxadizine (indoxacarb), spinosyn (spinosad), neonicotinoid (imidacloprid) and insect growth regulator (IGR) (novaluron) that are used on vegetable crops in India. Each insecticide was diluted 6-times and compared with untreated check. About 100 adults were released in each treated glass vial. The mortality data was recorded after 6 h of exposure and LC_{50} was calculated based on probit analysis (Finney, 7). The per cent parasitism was also recorded.

Based on their tolerance ability, one insecticide from each group, *viz*., endosulfan, monocrotophos, λ-cyhalothrin, indoxacarb, spinosad, imidacloprid and novoluron were selected for development of a strain tolerant to multiple insecticides for field evaluation and determination of their ability to survive to suppress the pest. A strain of *T*. *chilonis* was developed for its tolerance to multiple insecticides (MITS) as reported by (Jalali, 9). Insecticide tolerant strain that can be used in integration with farmers' practice of plant protection practices, without suffering adverse effects on them by insecticide used by farmers. In order to determine the mechanism of insecticide resistance, quantification of detoxification of enzymes, *viz*., glutathione *S*-transferases (GSTs) and carboxylesterase was done by following standard protocols (Devonshire, 5; Devonshire *et al*., 6). Field evaluation was carried out in three states of the country, *viz*., Dharmapuri (Tamil Nadu), Patiala (Punjab) and Saharanpur, Varanasi, Mirzapur and Meerut (Uttar Pradesh), to assess potential of tolerant (MITS) strain by releasing at flowering initiation stage of tomato at the rate of 50,000 parasitoids/ acre, 6 times during the cropping season as advocated by (Jalali *et al*., 11) and was compared with farmers practice in each region, about 6 to 15 rounds of different insecticides during the season at three places.

Field-collected population showed some degree of tolerance to various insecticides. Lethal concentration (LC_{50}) values recorded for the insecticides, *viz.,* endosulfan, monocrotophos, acephate, dichlorvos, dimethoate, fenvalerate, cypermethrin, deltamethrin, λ-cyhalothrin, indoxacarb, spinosad, imidacloprid and novaluron were 0.30, 0.45, 0.67, 0.28, 0.32, 0.017, 0.085, 0.026, 0.12, 0.24, 0.19, 0.12 and 1.83 ml/ litre of water, respectively. No such egg parasitoids are at this time available in India or anywhere in the world. The existing susceptible egg parasitoids are not effective in farmer's field as they are not compatible with insecticides, whereas multiple insecticide tolerant strain was effective against harmful insect pests, parasitizing ≥ 60% eggs compared to ≤ 5% by the susceptible strain and survived for 1 day compared to > 3 h by the susceptible strain in insecticide sprayed condition (Jalali *et al*., 10).

After selecting the insecticide tolerant strain in the laboratory for 40 generations, which is 1 year (8-9 days/ generation), enhanced tolerance was recorded for different groups of insecticides (Fig. 1). The resistance-ratio, *i.e.*, number of folds more tolerance over initially collected population, was 18.4-fold for organochlorine, 4.1- to 13.39-folds for organophosphates, 3.75- to 14.23-fold for synthetic

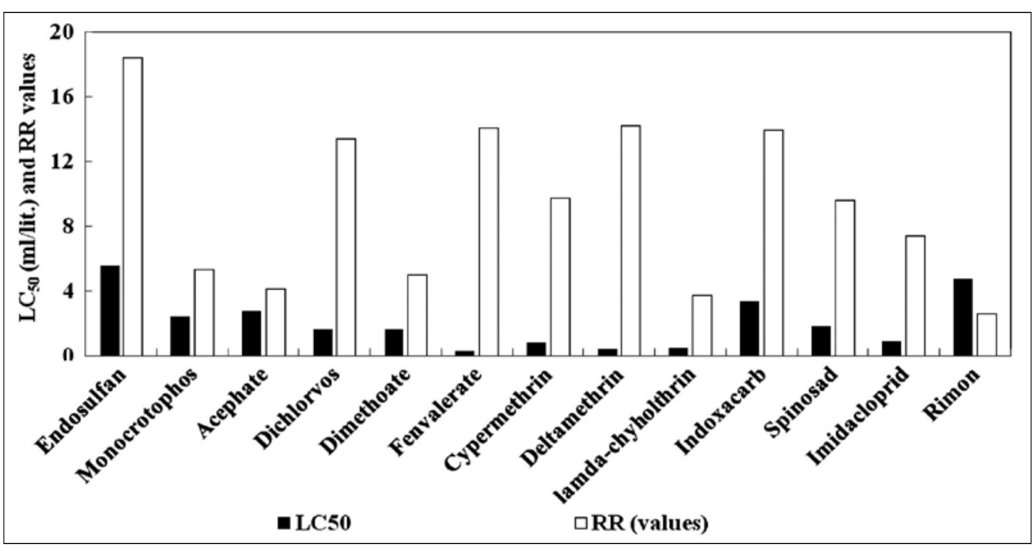

Fig. 1. Toxicity data (LC_{50} ml / lit of water) and resistance ratio (LC_{50} = lethal concentration required to kill 50% of the population; RR = LC_{50} of tolerant strain / LC_{50} of susceptible strain).

Table 1. Nethouse study on parasitizing ability tolerant and susceptible strain of egg parasitoid under insecticide sprays against *H. armigera* on tomato.

Treatment	Summer		Winter	
	% egg parasitism	No. of larvae / 10 plants	% egg parasitism	No. of larvae / 10 plants
Tolerant egg parasitoid	39.0[a]	2.1[a]	50.8[a]	1.9[a]
Susceptible egg parasitoid	0.0[b]	8.8[b]	0.0[b]	10.7[b]
$LSD_{0.01}$	1.2	0.6	2.45	0.4
CV (%)	2.0	16.7	3.3	9.0

The letter followed by the different letter in the columns are significantly different at P = 0.01

Table 2. Field efficacy of tolerant egg parasitoid in multi-location trials.

Natural enemy	Province	Area covered (in acres)	Increase in yield (kg / acre)	% reduced insecticide application	% benefit over farmers' practice (Rs. / acre)
Trichogramma chilonis – multiple insecticide tolerant strain	Patiala (Punjab) (North-West India)	10	816	25	13,872
	Dharmapuri (Tamil Nadu) (South India)	20	2,400	65	20,000
	Saharanpur, Varanasi, Mirzapur and Meerut (Uttar Pradesh) (Central India)	10	1,500	20	9,000

pyrethroids, 13.95-fold for oxadizine, 9.63-fold for spinosyn, 7.41-fold for neonicotinoid and 2.6-fold for IGR. Such tolerant parasitoids were evaluated under net house conditions on tomato infested with fruit borer (*H. armigera*) eggs to establish its efficacy under sprayed system during summer and winter (November to February).

Evaluation of tolerant and susceptible strains in the net-house against fruit borer on tomato revealed that egg parasitism was significantly higher (50.8%) in winter 2013-14 (mean max temp. 26°C), as compared to 39.0% in summer (March to May, 2013) (mean max temp. 35°C) (39.0%) in tolerant strain. However, there was no parasitism recorded by susceptible strain under sprayed system. There were 4.2 and 5.63-times more larvae per 10 plants in susceptible strain released net-house, which indicates efficacy of tolerant strain to survive and parasitize its host eggs in sprayed system (Table 1).

Glutathione S-transferase (GST) and carboxylesterase play a significant role in detoxification of insecticides in different organisms (reference may be quoted). GST-conjugative activity in tolerant strain (MITS) was significantly higher (2.13-fold) than that of susceptible strain. Similarly, carboxylesterase activity in the tolerant strain was significantly higher (1.5- to 9-fold) as compared to susceptible strain.

Efficacy of the tolerant strain was demonstrated against fruit borer on tomato during summer, *Kharif* and winter seasons of 2013-2014 (covering 40 acres) in Tamil Nadu, Punjab and Uttar Pradesh. Release of tolerant strain resulted in increasing the tomato yield by 816, 2,400 and 1,500 kg / acre, respectively and reduction in insecticide application from 20-65% in different locations. This resulted in % net benefit of Rs. 9,000 to 20,000 / acre to farmers (Table 2). Indirect ecological benefits of using such tolerant egg parasitoid such as conservation of beneficial fauna, reduced pesticide pressure on the environment, *etc.*, cannot be measured in monetary terms. Very rare examples of use of resistant natural enemies in insect pest control are documented, mainly due to obvious incompatibilities (Tabashnik and Johnson, 15; Hoy, 8). In a study on cabbage damage by diamondback moth, the increased leaf damage in insecticide-treated field was attributed to a combined consequence of insecticide resistance in the pest, and of lower predation and parasitism rates that are suppressed by the insecticide applications (Bommacro, 2). It was also documented that tolerant strain of an egg parasitoid performs better in insecticide sprayed crops as compared to susceptible strain (Ballal *et al*., 1; Xu *et al*., 17).

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