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Genetic improvement of egg parasitoid *Trichogramma chilonis* Ishii for combined tolerance to multiple insecticides and high temperature*

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ABSTRACT: A strain of *Trichogramma chilonis* Ishii, an effective parasitoid of lepidopteran pests was developed for tolerance to three major groups of insecticides, i. e., endosulfan (organochlorine), monocrotophos (organophosphate) and fenvalerate (synthetic pyrethroid) and to high temperature (32-38°C) through selection. After 81 generations of selection, there was an increase in parasitism from 35% to 90-95% and decrease in mortality from 100% to 57-70% after 6h of constant exposure to three insecticides and high temperature. Interestingly 46.8 and 2.9 fold increase in tolerance was observed in males compared to 18.5 and 1.3 fold increase in females of MITT (multiple-insecticide and temperature tolerant) strain when exposed to endosulfan and fenvalerate sprays, respectively, while in case of monocrotophos, females and males were 465-fold and 25-fold more tolerant, respectively, than susceptible strain. At higher temperatures of 40 and 45°C, the per cent mortality of tolerant adults was 0.0 and 9.2%, respectively, compared to 59.7 and 96.1% in susceptible population after 6h of exposure at these temperatures. At high variable temperature (32-38°C), per cent mortality in MITT was 57.1 compared to 98.5% in susceptible population after 24h of constant exposure. The mean per cent parasitism at 32°C, 36°C, 38°C and at variable temperature of 32-38°C was significantly higher in tolerant strain (46.7, 45.0, 18.3 and 63.3%) compared to susceptible strain (54.0, 6.7, 0.0 and 0.0%), respectively. These studies suggest that the improved strain of *T. chilonis* will provide effective control of the pest even at harsh climatic conditions and under high insecticide pressure in different economically important crops.

KEY WORDS: Egg parasitoid, genetic improvement, high temperature tolerance, multiple insecticide tolerance, *Trichogramma chilonis*

INTRODUCTION

In the recent years, naturally acquired resistance and genetic improvement of various insect pests and natural enemies in annual and perennial crops have been very well recorded. Documentation as far as natural enemies are concerned is confined mostly to predatory mites, braconids and spiders (Hoy, 1990). Egg parasitoids are one of the most promising biological control

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agents released against several lepidopteran and other pests that infest some economically important crops like paddy, cotton, sugarcane, sunflower, maize, vegetables, fruits, etc. (Stinner, 1977; Singh and Jalali, 1994). Endosulfan (organochlorine), monocrotophos (organophosphate) and fenvalerate (synthetic pyrethoid) are used indiscriminately in many commercial crops including vegetables and account for 38% of the total insecticide consumption in India (Singhal, 2003). This has resulted in the development of resistance in several pests, outbreak of secondary pests and reduced efficiency of susceptible natural enemies, especially trichogrammatids. Natural enemies are usually more sensitive to pesticides than the pests they attack. *Trichogramma chilonis* Ishii has a wide host range and is released inundatively against different pests in various agricultural and horticultural crops in most of the Asian and Southeast Asian countries. The efficacy of *Trichogramma* is diminishing due to extensive use of insecticides, as these are generally sensitive to most of the pesticides (Franz *et al.*, 1980; Smith, 1996; Jalali and Singh, 1993). Jalali *et al.* (2003) reported that natural enemies including trichogrammatids were almost absent in pesticide sprayed cotton fields and *Trichogramma* was recorded only in four out of nine cotton growing states in India parasitising *Helicoverpa armigera* (Hübner) eggs to the tune of 0.0 - 21.7%. High temperature conditions in field reduce the survival and performance of trichogrammatids (Smith, 1996). High temperature (>35°C) prevents adult emergence (Lopez and Morrison, 1980; Singh and Jalali, 1994; Scholler and Hassan, 2001), thereby reducing the efficacy of trichogrammatids drastically.

Genetic improvement by artificial selection or hybridization offers a new approach to enhance the sustainability and efficacy of these promising natural enemies under manually altered conditions. Artificial selection of phytoseiid mites for pesticide resistance, temperature tolerance, non-dispause and high searching ability has been documented and releases of multi-resistant (carbaryl – sulfur) strain of *Metaseiulus occidentalis* in almond orchard has resulted in the effective management of spider mites with reduction in number and rate of acaricide application (Hoy, 1990).

Very few reports are available on the genetic improvement of *Trichogramma* despite its wide application. Preliminary attempts on evaluation of endosulfan tolerant strain of *T. chilonis* against *Helicoverpa armigera* on tomato showed promising control results under net house conditions (Jalali *et al.*, 2006). On crops like rice, cotton and vegetables, where several pest problems exist, farmers have to resort to more than one insecticide. In such a scenario, release of multiple-insecticide and temperature tolerant strain of *T. chilonis* will enhance pest management strategies and could be successfully integrated in integrated pest management. Therefore, the present study was taken up to develop a strain of *T. chilonis* through artificial selection for tolerance to three major groups of insecticides and high temperature.

MATERIALS AND METHODS

Corcyra cephalonica (Stainton) eggs were obtained from the mass production unit of PDBC, UV treated and used for maintaining the cultures of different strains of *T. chilonis*. Commercial grades of pesticides, *viz.*, endosulfan, monocrotophos and fenvalerate, were purchased from authorised pesticide dealers. The protocol used for developing the endosulfan tolerant strain of *T. chilonis* was followed for developing the multiple-insecticide and high temperature tolerant strain (Jalali *et al.*, 2006). Initially, a part of the colonies of endosulfan tolerant strain was exposed to monocrotophos and fenvalerate individually at varying concentrations from 180–540ppm and 2-20ppm, respectively. As e"90.0% mortality was observed within 1h of exposure, initial dosages of monocrotophos and fenvalerate were fixed at 180 and 2 ppm, respectively, however exposure to endosulfan was done at 700ppm. The dosages were gradually increased in monocrotophos treatment to 180ppm > 270ppm > 360ppm > 450ppm > 540ppm and in fenvalerate to 2ppm > 5ppm > 10ppm > 15ppm > 18ppm > 20ppm, respectively. When 40% adult survival and 90% parasitization were obtained after

constant exposure for 6h to a particular concentration and high temperature, the treatment was shifted to the subsequent higher concentration. This was continued the tolerance was acquired for the field recommended dosages. The colonies obtained from each of the three insecticides were mixed in each generation and allowed to mate in glass tubes for 1 day before subjecting them to insecticide pressure. The strain development at high temperature started at 32°C by maintaining the colonies in environmental chambers set at required temperature and humidity (60%). In each generation, after subjecting to insecticide sprays, the adults were kept at high temperature for simultaneous acquirement of tolerance high temperature. The parameters set were 50.0% females and 90.0% parasitisation and 90.0% adult emergence before shifting to next higher temperature. The temperature of growth chambers was increased from 32°C >34°C >36°C >38°C >40°C with 60% RH. Later, in order to overcome the genetic trade off problem with exposure to one constant high temperature, the parasitoids were shifted to variable high temperature of 32-38°C till the required parameters were obtained. The multiple insecticide and high temperature tolerant strain was continuously maintained in the laboratory. This was repeated for 81 generations.

Experiments were carried out in the laboratory in a growth chamber maintained at variable temperature for working out the various biological parameters of combined tolerant strain in comparison with susceptible strain. Control batch of the susceptible population was maintained on *C. cephalonica* without exposing them to any insecticide. The LC_{50} and LC_{90} values were calculated by serial dilution of the three insecticides by reducing the dilution by half. The concentrations tested were – endosulfan: 1400ppm, 700ppm, 350ppm, 175ppm, 87.5ppm, 43.75ppm, 21.88ppm; monocrotophos: 1080ppm, 540ppm, 270ppm, 135ppm, 67.5ppm, 33.75ppm, 16.88ppm and fenvalerate: 80ppm, 40ppm, 20ppm, 10ppm, 5ppm, 2.5ppm, 1.25ppm. About 100 adults were released into each vial at each concentration and the mortality was recorded after 2h and 4h of constant exposure. The LC_{50} and LC_{90} values were calculated at 4h after exposure to endosulfan and fenvalerate as at 6h there was 100.0% mortality in susceptible strain and in monocrotophos after 2h of constant exposure as in susceptible strain there was 100.0% mortality.

The developed strain was tested for parasitising ability and survival at different temperatures, *viz.*, 32°C, 36°C, 40°C, 45°C and 32°-38°C in the growth chamber and compared with the susceptible strain. About 100 parasitised eggs were kept in glass vials for emergence with fine streak of honey (50%v/v) provided as adult food. The egg card was provided in each vial @50 eggs / female. The vials were kept at the above temperatures and the experiment at each temperature was replicated 3 times. The data on per cent mortality at the above temperatures was recorded after 6h and 24h of constant exposure. The experiment on parasitism was conducted in insect rearing cages (30 cm^3) placed inside the chambers set at 32°C, 36°C, 40°C, 45°C and 32°-38°C. About 100 parasitised eggs were kept in glass vials for emergence and a fine streak of honey was provided as adult food inside the top of the cages. The egg card was provided in each cage @50 eggs / female. The egg cards were collected back after 24h of exposure and kept in glass vials for observation of parasitism after 6 days of exposure. The susceptible population maintained at the laboratory temperature served as control.

The mortality data recorded was subjected to probit analysis utilising SPSS version 8.0. The data was transformed to log base 10 before probit analysis to obtain LC_{50} and LC_{90}. The fiducial limits, slope and $\div^2$ values were also calculated and tabulated. The data on mortality and percent parasitism recorded at different high temperatures were subjected to arcsine transformation and analysed by one-way ANOVA and the means were separated by CD values.

RESULTS AND DISCUSSION

Studies were conducted to develop tolerance in the endosulfan tolerant strain of *T. chilonis* to multiple insecticides and high temperature by sequentially increasing the dose of monocrotophos

(180 – 540 ppm) and fenvalerate (2 – 20ppm). At the lowest concentration, the adult survival was d" 6.0% and parasitism was 35.0 – 50.0% in the initial generation at 32°C. Gradual reduction in mortality and increase in parasitism was obtained after 15 generations of continuous exposure to this concentration and temperature. The sequential increase in concentration and temperature from the lowest to the next higher took another 15 generations of exposure. The mortality decreased to 65.0 - 70.0% after 6h of constant exposure. After each change in concentration and temperature, the mortality increased drastically for few generations but parasitism remained largely unaffected after 40 generations. After exposing the parasitoids to field recommended dosages of the three insecticides, *i.e.*, endosulfan (700 ppm), monocrotophos (540 ppm) and fenvalerate (20 ppm) and at variable high temperature of 32-38°C in F_{65} generation, the mortality increased to 90.0-95.0%, but % parasitism, % emergence and % females remained unaffected. After 70th generation, the mortality also declined to 57.0-70.0% and remained so for another 11 generations (Table 1) (Fig. 1). It took 70 generations of constant exposure to three insecticides and high temperature to develop a strain tolerant to multiple insecticides and high temperature. At lower concentrations (180 ppm for monocrotophos and 2 ppm for fenvalerate), the parasitoids took a longer time of 20 generations to show adaptability to the next higher dose of multiple insecticides and high temperature treatment simultaneously. However, once adapted, it took 10–15 generations of exposure at each sequential increase. The development of endosulfan tolerant strain had taken a longer time, *i. e.*, 341 generations to acquire tolerance to field recommended dose (Jalali *et al.*, 2006). The present study revealed that a physiologically adapted tolerant strain when artificially selected for other insecticides – monocrotophos, fenvalerate and high temperature tolerance, took 81 generations for its development.

The strain of *T.chilonis* developed for combined tolerance to multiple insecticides and high temperature (MITT) was tested to assess the LC_{50} and LC_{90} values. The females and males of the tolerant population showed 18.5 and 46.8 fold increase in tolerance to endosulfan with LC_{50} values of 3629.5 ppm and 1802.5 ppm, respectively, in comparison to the susceptible strain. Tolerance to monocrotophos was 465 and 25 times higher in female and male, respectively, with LC_{50} values of 334.8 ppm and 180.0 ppm, respectively. Tolerance to fenvalerate was 1.3 and 2.9 times greater with LC_{50} values being 48.0 ppm and 70.0 ppm in females and males, respectively (Table 2). In their study on the development of endosulfan tolerant *T. chilonis* strain, Jalali *et al.* (2006) recorded a 15-fold increase in the LC_{50} values in the tolerant population. Xiong *et al.* (1986) recorded 1.17, 0.94 and 0.32 fold increase in the LC_{50} values (0.8892, 8.6511 and 0.0592ppm) in the resistant populations of *T. japonicum* after exposure to 36-43 generations to methamidofos, fenvalerate and metaphos and 1.92 fold decrease in the LC_{50} values (0.1103 ppm) when exposed to mipcrin. The present study indicates that induction of tolerance to different pesticides by passing through several generations resulted in a better physiologically adapted strain under stress conditions. The response to endosulfan and fenvalerate was observed to be similar in that the males exhibited higher tolerance whereas the females were more tolerant when exposed to monocrotophos.

Laboratory developed tolerant and susceptible strains exhibited differential response to higher temperature during 6 and 24h exposure periods. During 6h exposure at 32°C, 36°C and at variable temperature of 32-38°C, very low mortality was recorded in both strains. However, at 40°C and 45°C, significantly higher mortality was recorded in the susceptible strain compared to the MITT strain. At 32°C, no mortality was recorded for up to 6h exposure, indicating that this temperature is not the higher threshold temperature for survival of *T. chilonis*. However, at 40°C, mortality of the adults was 59.7% in susceptible strain compared to 0.0% in the combined tolerant strain. At 45°C, 96.1% adults of the susceptible strain died within 6h as compared to 9.2% mortality in the tolerant strain. The mean percent mortality recorded when exposed to 6h at 32, 36 and 32 - 38°C (0.0, 2.5 and 0.9, CD = 5.92, P = 0.05) was significantly lower than those at other temperatures (29.8 and 52.7% at 40°C and 45°C,

Table 1. Development of combined tolerant strain of *T. chilonis* to multiple insecticides and high temperature

Concentration (in ppm)	Generations reared at each dosage level / temperature		Adult mortality (% ± SE) after 6h of constant exposure to						% females	% emergence
			Endosulfan		Monocrotophos		Fenvalerate			
	Temperature °C)	Generation	Tolerant strain	Susceptible strain	Tolerant strain	Susceptible strain	Tolerant strain	Susceptible strain		
Endosulfan (700)	32	1st	95.0 ± 1.30	100.0 ± 0.00	100.0 ± 0.00	100.0 ± 0.00	94.0 ± 1.05	100.0 ± 0.00	25.0	60.0
Monocrotophos (180)	32	5th	85.0 ± 1.45	100.0 ± 0.00	100.0 ± 0.00	100.0 ± 0.00	86.0 ± 0.89	100.0 ± 0.00	25.0	60.0
Fenvalerate (2)	32	10th	88.0 ± 0.89	100.0 ± 0.00	95.0 ± 1.00	100.0 ± 0.00	84.0 ± 1.95	100.0 ± 0.00	25.0	65.0
	32	15th	75.0 ± 1.28	100.0 ± 0.00	75.0 ± 0.71	100.0 ± 0.00	63.0 ± 0.89	100.0 ± 0.00	40.0	65.0
Endosulfan (700)	32	20th	77.0 ± 1.41	100.0 ± 0.00	90.0 ± 0.84	100.0 ± 0.00	91.0 ± 0.89	100.0 ± 0.00	50.0	70.0
Monocrotophos (270) Fenvalerate (5)	32	25th	78.0 ± 1.61	100.0 ± 0.00	80.0 ± 0.55	100.0 ± 0.00	70.0 ± 0.71	100.0 ± 0.00	50.0	70.0
Endosulfan (700)	32	30th	75.0 ± 1.64	100.0 ± 0.00	90.0 ± 0.84	100.0 ± 0.00	70.0 ± 1.27	100.0 ± 0.00	55.0	75.0
Monocrotophos (360) Fenvalerate (10)	32	35th	70.0 ± 0.71	100.0 ± 0.00	70.0 ± 0.89	100.0 ± 0.00	70.0 ± 0.63	100.0 ± 0.00	55.0	80.0
Endosulfan (700)	32	40th	65.0 ± 1.27	95.0 ± 1.00	88.0 ± 0.71	100.0 ± 0.00	85.0 ± 0.71	95.0 ± 1.00	55.0	80.0
Monocrotophos (450) Fenvalerate (15)	32	45th	60.0 ± 1.30	95.0 ± 1.00	65.0 ± 0.71	98.0 ± 0.85	63.0 ± 0.89	95.0 ± 1.00	50.0	85.0
Endosulfan (700)	32	50th*	75.0 ± 1.05	100.0 ± 0.00	100.0 ± 0.00	100.0 ± 0.00	95.0 ± 0.63	100.0 ± 0.00	50.0	90.0
Monocrotophos (540)	36	55th	75.0 ± 1.73	100.0 ± 0.00	90.0 ± 0.00	100.0 ± 0.00	90.0 ± 0.89	100.0 ± 0.00	55.0	90.0
Fenvalerate (18)	36	60th	75.0 ± 2.10	100.0 ± 0.00	70.0 ± 1.48	100.0 ± 0.00	70.0 ± 0.71	100.0 ± 0.00	55.0	90.0
Endosulfan (700)	36	65th	70.0 ± 0.71	100.0 ± 0.00	95.0 ± 1.30	100.0 ± 0.00	90.0 ± 1.92	100.0 ± 0.00	55.0	80.0
Monocrotophos (540)	32-38	70th	70.0 ± 1.52	100.0 ± 0.00	80.0 ± 1.38	100.0 ± 0.00	70.0 ± 0.71	100.0 ± 0.00	58.0	85.0
Fenvalerate (20)	32-38	75th	70.0 ± 1.79	100.0 ± 0.00	75.0 ± 0.89	100.0 ± 0.00	57.0 ± 1.27	100.0 ± 0.00	58.0	85.0
	32-38	80th	70.0 ± 1.30	100.0 ± 0.00	75.0 ± 1.27	100.0 ± 0.00	57.0 ± 2.00	100.0 ± 0.00	55.0	95.0
	32-38	81st	70.0 ± 1.27	95.0 ± 1.00	70.0 ± 0.71	95.0 ± 1.00	57.0 ± 0.84	95.0 ± 1.00	55.0	95.0

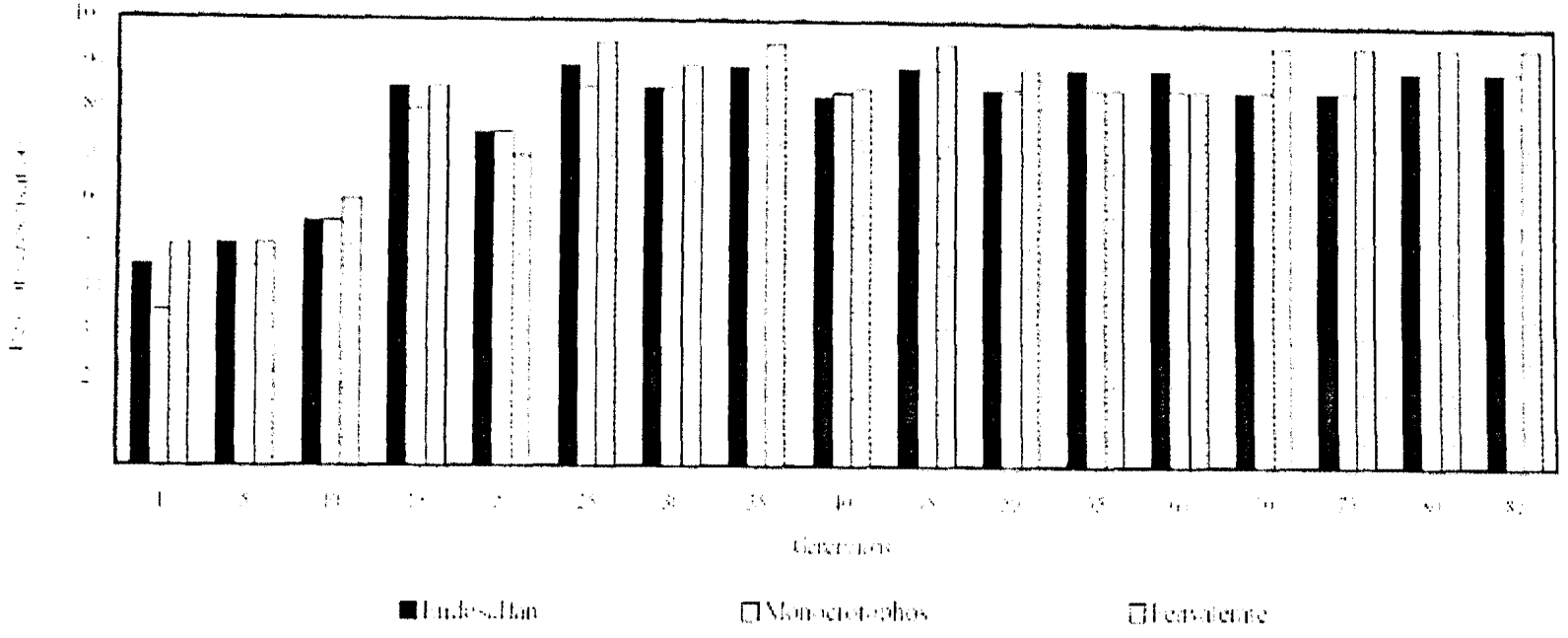

Fig. 1. **Per cent parasitism by multiple insecticide and temperature tolerant strain of *T.chilonis* in different generations under pesticide pressure and high temperature (32°-38°C) during development of tolerant strain**

Table 2. Dose-mortality response (LC) of *T. chilonis* to three insecticides at different time interval exposures

Insecticides	Period of exposure	LC_{50}	95% Fiducial limit		LC_{90}	95% Fiducial limit		Slope ± SE	χ^2
			Lower	Upper		Lower	Upper		
Susceptible strain to Endosulfan 35% EC									
Female	4h	196	126	311.5	549.5	343	1452.5	2.87 ± 0.30	22.37
Male	4h	38.5	-	-	633.5	-	-	1.04 ± 0.19	39.79
Tolerant strain to Endosulfan 35% EC									
Female	4h	3629.5	1732.5	21822.5	46420.5	10601.5	2274352.5	1.16 ± 0.27	3.98
Male	4h	1802.5	1106.0	4361.0	19943.0	7049.0	168444.5	1.23 ± 0.22	3.43
Susceptible strain to Monocrotophos 36% SL									
Female	2h	0.72	-	-	14.4	-	-	1.01 ± 0.53	3.4
Male	2h	7.2	-	-	57.6	-	-	1.39 ± 0.46	46.41
Tolerant strain to Monocrotophos 36% SL									
Female	2h	334.8	165.6	1011.6	4615.2	1339.2	368726.4	1.13 ± 0.19	15.68
Male	2h	180.0	61.2	597.6	4712.4	1062.0	2771762.4	0.90 ± 0.17	14.95
Susceptible strain to Fenvalerate 20% EC									
Female	4h	36.0	-	-	60.0	-	-	5.56 ± 6.34	2.49
Male	4h	24.0	-	-	186.0	-	-	3.52 ± 4.70	0.69
Tolerant strain to Fenvalerate 20% EC									
Female	4h	48.0	-	-	86.0	-	-	4.97 ± 7.40	1.98
Male	4h	70.0	36.0	346.0	622.0	174.0	29470.0	1.34 ± 0.36	7.20

Table 3. Response of MITT and susceptible strains of *T.chilonis* to different temperature regimes

Temperature (°C)	% Mortality (after hours)						% Parasitism		
	6		Mean(B)	24		Mean(B)			Mean(B)
	SS	TS		SS	TS		SS	TS	
32	0.0 (1.3)	0.0 (1.3)	0.0 (1.3)[a]	47.7 (43.7)	45.6 (42.5)	46.6 (43.1)[a]	54.0 (47.3)	46.7 (43.1)	50.4 (45.2)[a]
36	4.1 (11.7)	0.9 (1.9)	2.5 (9.1)[b]	96.9 (79.9)	77.7 (61.8)	97.3 (80.5)[c]	6.7 (15.0)	45.0 (42.1)	25.9 (30.6)[a]
40	59.7 (50.6)	0.0 (0.0)	29.8 (33.1)[c]	100.0 (90.0)	90.7 (72.2)	95.3 (77.5)[c]	0.0 (0.0)	18.3 (25.3)	9.2 (17.6)[b]
45	96.1 (78.6)	9.2 (17.7)	52.7 (46.6)[d]	100.0 (90.0)	97.1 (80.2)	98.6 (78.9)[c]	0.0 (0.0)	2.3 (8.7)	1.2 (6.3)[b]
32 – 38	1.8 (7.7)	0.0 (0.0)	0.9 (5.4)[a]	98.5 (83.0)	57.1 (49.1)	77.8 (61.9)[b]	0.0 (0.0)	63.3 (52.7)	36.1 (36.9)[a]
Mean (A)	32.3 (34.6)[b]	2.0 (8.1)[a]		88.6 (70.3)[b]	73.6 (59.1)[a]		12.1 (20.4)	35.2 (36.4)	
	A factor	B factor	A x B	A factor	B factor	A x B	A factor	B factor	A x B
SEM±	1.26	2.00	2.83	3.40	5.38	7.61	3.34	4.52	7.62
CD at 5%	3.74	5.92	8.37	7.60	15.80	24.40	NS	14.8	19.4

Data in parentheses and arcsine transformed values: SS = susceptible strain, TS = tolerant strain

respectively). Irrespective of the strain, the mean percent mortality recorded when exposed to 32°C was significantly lower (46.6%, CD = 15.80, P = 0.05) than that at 36, 40, 45°C, and at variable range of 32 - 38°C (97.3%, 95.3%, 98.6% and 77.8%). The mean mortality of the combined tolerant population at 6h (2.0%, CD = 3.74, P = 0.05) and 24h (73.6%, CD = 7.60, P = 0.05) was significantly lower than that of susceptible strain (32.3 and 88.6% at 6h and 24h, respectively) irrespective of the temperature (Table 3). Studies on mortality response of the combined tolerant strain suggests that adaptation to variable temperatures must be necessary to enhance the potential of *T. chilonis* in different temperatures as exposure to one constant high temperature results in genetic trade-off (Carriere and Boivin, 2001).

Comparative studies on per cent parasitism by susceptible and MITT strains indicated that in general the efficacy of *T. chilonis* was reduced at high temperatures. At 32°C, parasitism by the susceptible strain was slightly higher compared to the combined tolerant strain, but at all other higher temperatures of 36°C, 40°C, 45°C and at variable temperature of 32-38°C, per cent parasitism by combined tolerant strain was significantly higher. At 40°C and 45°C, very low parasitism was recorded mainly due to desiccation of the host eggs as humidity recorded was <20% at these temperatures. Most surprisingly, at variable temperature, percent parasitism by combined tolerant strain was >63.3% compared to nil parasitism by susceptible strain. The results indicated that though the susceptible strain could survive at temperatures ranging between 32 and 38°C, it failed to parasitise its host. Very few attempts have been made so far to combine insecticide and high temperature tolerance in natural enemies. Most of the studies were oriented towards studying the impact of different temperatures on the biology and related parameters of trichogrammatids like *T. pretiosum*, *T. bournieri* Pintureau and Babault, *T. mwanzai* Schulten and Feijen, *T. evanescens* Westwood and *T. chilonis* (Clavin *et al.*, 1984, Haile *et al.*, 2002). Scholler and Hassan (2001) in their study on comparative biology and life tables of *T. evanescens* and *T. cacaeciae* Marchal on *Cadra* (=*Ephestia*) *cautella* Walker eggs at different constant temperatures of 20, 26, 30 and 35°C reported significantly lower parasitised eggs at 35°C than at lower temperatures. Chihrane and Lauge (1996) recorded loss of parasitisation efficiency when *T. brassicae* Bezdenko was subjected to single temperature shocks (35° and 44°C) at the white pupa (WP) and imago ready to leave a parasitised egg (IRL) stages.

Effective pest control depends on many factors including the quality and fitness of the parasitoid released and the complex interactions between the parasitoid, the target pest, the crop and environmental conditions. Considering the present scenario of very low levels of parasitism recorded during hot summer months (temperature> 35°C) under pesticide pressure, it would be highly advantageous to use a trichogrammatid strain tolerant to multiple insecticides and high temperature conditions. Field evaluation studies on this strain should be done to ascertain its performance in field conditions. The release of such a strain of *T. chilonis* would result in the promising control of lepidopteran pests on economically important crops like cotton, sugarcane, rice and vegetables as it can survive better in a hostile crop environment.

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