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Comparative effect of formulated kairomonal dusts on parasitization efficiency of *Trichogramma* spp.

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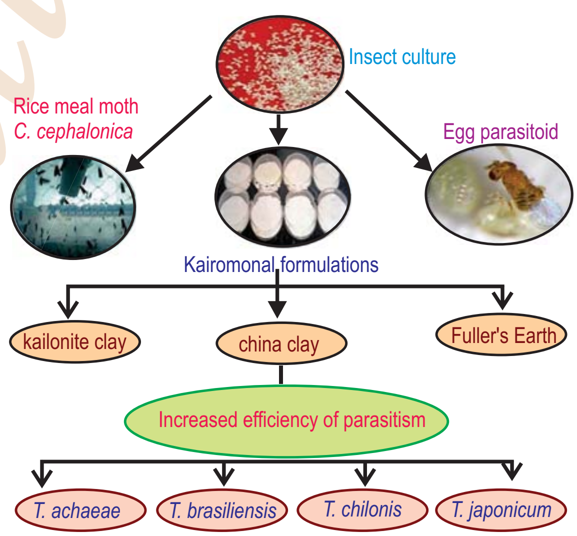
Abstract

Aim: A number of chemicals released by phytophagous insects and plants serve as cues for their natural enemies. Egg parasitoid *Trichogramma* respond towards chemical cues present in the environment for locating their hosts. Formulations are the end user product for pest control because it contains the active ingredient present in it. The main objective of the present study was to understand the effect of different concentrations of kairomones and different clays on various *Trichogramma* spp.

Methodology: The nucleus culture of the host insect used in the present study was maintained on the eggs of rice meal moth *Corcyra cephalonica* on crushed sorghum grains. Culture of the parasitoid was maintained in glass vials of 10x2.5 cm size at 25±1 ºC and 65±5% RH in a culture room on UV sterilized, 0-24 hr old *C. cephlonica* eggs. Twenty different combinations of three straight chain saturated hydrocarbons (Pentacosane, Docosane and Tricosane) used in three different combinations *viz.*,125 ng cm^{-2} (C_1), 250 ng cm^{-2} (C_2) and 375 ng cm^{-2} (C_3), designated as 1, 2 and 3 were tested for their kairomonal response. Three different concentrations of each synthetic kairomone was prepared with HPLC grade hexane. Five kaiomonal dust formulations were prepared using three different clays viz; kailonite, china clay and fuller's earth.

Results: *Trichogramma achaeae* resulted in highest value of PAI (7.19) with kailonite clay, whereas china clay showed highest value of parasitism (9.79 %) and emergence (9.79%) with *T. brasiliensis*. Mean PAI ranged between 2.02 to 7.19 irrespective of *Trichogramma* spp. Maximum parasitization (9.96%) was observed in case of *T. japonicum* as against lowest in *T. chilonis* (6.48%) on kaolinite clay. Similarly, maximum adult emergence (7.42%) in *T. japonicum* was recorded as against lowest in *T. chilonis* (5.15%) on kailonite clay.

Interpretation: Natural enemies including egg parasitoid like *T. chilonis* respond towards chemical cues present in the environment to locate their hosts. Many a times these cues are associated with host and host by product itself. Therefore, it was found that the emission rate of synthetic kairomone was fastest from kailonite clay as compared to china clay and fuller's earth. *T. achaeae* resulted in the highest value of PAI (7.19) with kailonite clay, whereas china clay showed the highest value of parasitism (9.79%) and emergence (9.79 %) with *T. brasiliensis*. *T. brasiliensis* and *T. japonicum* with kairomonal formulation (Tricosane @0.0001 g 10 ml^{-1}) and kailonite clay were found to be the best combination for any integrated pest management programm.



Introduction

Success of natural enemies, particularly well recognized egg parasitoid, Trichogrammatid (Gautam, 1994; Rahman *et al.,* 2003; Balakrishnan *et al*., 2004) in pest management depends upon its host acceptance and searching efficiency in a highly complex crop environment due to release of several volatile compounds termed as allelochemicals (synomones and kairomones). Kairomone is a chemical substance emitted by an organism and detected by another of a different species which gains advantage from this, *e.g* a parasitoid seeking a host. Kairomones, derived from hosts plays a key role in increasing efficiency of natural enemies. Basically, these are present in the body wash, scales, saliva and excreta of an organism. The kairomones from *C. cephalonica* adult moth could stimulate the searching behavior of *Trichogramma* adult. Tricosane, Pentacosane hexacosane, docosane and nonacosane, the components of the scales of lepidopteron moths increased the parasitizing efficiency of Trichogrammatids (Padmavathi and Paul, 1998; Paul *et al*., 2008). The use of a mixture with heneicosane, tricosane, pentacosane, heptacosane and nonacosane increased the upwind regression in the case of *T. brassicae* Bezdeko (Renou *et al*., 1992).

Tondon (2001) highlighted future prospects of kairomones in enhancing the efficiency of natural enemies for the success of biological control of crop pests. Modifying insect behavior in pest management programs through utilization of non-toxic semiochemicals is recognized as a promising alternative to conventional approaches. Foraging entomophages use chemical cues extensively to locate, identify and exploit their hosts as these elicit stimulants from their body (cuticle, excreta and saliva) (Fatouros *et al*., 2008; Colazza *et al*., 2010; Colazza *et al*., 2014). Since the host endeavors to be as inconspicuous as possible, indirect cues to its location are often the only information available to the foraging parasitoid female. The development of efficacious and environmentally acceptable technique for the control of insect pests has received considerable research effort. An appealing potential component of a pest management strategy is the enhancement of activity of insect natural enemies through permeation of the atmosphere with semiochemicals released by the host plants (synomones), as well as kairomones.

Dust formulations can be more effective because the effect of weathering on the release rate would be less than that occurring under field situations (Caro *et al.*, 1981; Jackson *et al*., 2005). It may be noted that the pesticide formulation is a physical mixture of one or more biologically active chemicals and inert ingredients, which provide effective and economical control of the pests, while kairomonal formulation is aimed to enhance the parasitism or predation capacity of a target natural enemy. Long back, the evidence of kairomonal activity present in the hexane body wash of rice meal moth, *C. cephalonica* has been identified. However, concerted efforts on the application aspects of kairomones, especially development of suitable kairomonal formulation against *Trichogramma* spp. is extremely scanty. Therefore, the main objective of the present study was to understand the effect of different concentrations of kairomones and different clays on various *Trichogramma* spp.

Materials and Methods

Insect cultures: The nucleus culture of the host insect used in the present study was maintained on the eggs of the rice meal moth, *C. cephalonica* obtained from Mass Production Laboratory, Division of Entomology, Indian Agricultural Research Institute (Pusa), New Delhi, on crushed sorghum grains as described by Paul and Sreekumar (1998). Culture of the parasitoid was maintained in glass vials of 10x2.5 cm size at 25±1ºC and 65±5% relative humidity in a culture room on UV sterilized, 0-24 hr old *C. cephalonica* eggs following the method by Gautam (1994).

Preparation of different formulations of saturated hydrocarbons: Twenty different combinations of three straight chain saturated hydrocarbons, Pentacosane, Docosane and Tricosane used in three different combinations *viz.,* 125 ng cm^{-2} (C_1), 250 ng cm^{-2} (C_2) and 375 ng cm^{-2} (C_3) designated 1, 2 and 3 were tested for their kairomonal response. Three different concentrations of each synthetic kairomone were prepared using HPLC grade hexane and mixed in equal amount to make 20 different combinations.

Bioassay studies: Bioassay studies were carried out under laboratory conditions at 26±2ºC and 65±5%RH, using glass petridishes of size 150x15 mm size as the arena, the base of which was covered with a Whatman No1 filter paper of 2x2 cm size. Thirty such eggs were pasted equidistantly on each egg card and the extracts of different concentrations were applied on five such egg cards @ 50µl. These five cards along with one control card treated with hexane were arranged equi-distantly in the experimental arena of 150 mm diameter petridish. In each petridish, ten healthy, 0-24 hr old, anesthetized and fast reviving females of *T. chilonis* were released at the centre. The parasitoids were allowed to search in the experimental arena for a total period of 45 min from the time of recovery. Number of parasitoids that visited each egg card was referred as 'Parasitoid Activity Index (PAI)'. The parasitoids were removed carefully after 45 min from each egg card and were kept individually in homeopathic vials for development at 26±2ºC. 0-24 hrs old females of *Trichogramma* were used for all the experiments carried out in this study.

Five kairomonal dust formulations were prepared using three different clays *viz;* kailonite, china clay and fuller's earth. A total of three formulations were prepared using hydrocarbons namely Pentacosane, Docosane and Tricosane in three different combinations *viz.,* 125 ng cm^{-2} (1), 250 ng cm^{-2} (2) and 375 ng cm^{-2} (3). Pentacosane, Docosane and Tricosane used in the present studies were obtained from Sigma, U.S.A. These were then mixed with appropriate quantity of formulations. Formulated products were abbreviated as C_1 (Pentacosane 250 ng cm^{-2} +Docosane 250 ng cm^{-2} + Tricosane 250 ng cm^{-2}, or P_2+D_2+T_2), C_2 (Pentacosane 125 ng cm^{-2} + Docosane 125 ng cm^{-2} + Tricosane 250 ng cm^{-2} or P_1+D_1+T_2), C_3 (Pentacosane 375 ng cm^{-2} + Docosane 250 ng cm^{-2} + Tricosane 250 ng cm^{-2} or P_3+D_2+T_2), C_4 (*C. cephalonica* scale extract (0.2 g 10ml^{-1}), C_5 (Tricosane @ 0.0001 g 10ml^{-1}) and C_6 (Control - *C. cephalonica* eggs washed with hexane). These were tested against five species of *Trichogramma* viz., *T. chilonis* (Ishii), *T. brasiliensis* (Ashmead), *T. achaeae* (Nagarkatti & Nagaraja), *T. exiguum* (Pinto, Platner & Oatman) and *T. japonicum* (Ashmead) for the parasitization efficiency in the laboratory. The dust formulations were prepared by impregnating the respective clay with appropriate concentration of kairomonal solutions @ 2 ml g^{-1}. The slurry was thoroughly mixed, powdered using a pestle and mortar and passed through sieve (60 meshes) and dried overnight.

Tricocard as defined by Gautam (1994) treated with different formulations along with one control card (plain egg card impregnated with the solvent hexane) was arranged equidistantly in the experimental arena, which consisted of a 150 mm diameter glass petridish, the base of which was covered with Whatman No.1 filter paper disc of the same diameter in five replications. UV sterilized 1.0 cm^2 egg cards (6 Nos.) having 30 eggs each of *C. cephalonica* (0-24 hr old) were placed equidistantly on the periphery, which formed the experimental arena (Gautam, 1994). Extracts were applied at different concentrations on five egg cards at the rate of 50 µl. Ten healthy, 0-24 hr old *Trichogramma* females were released at the centre of each petridish. The parasitoids were allowed to search in the experimental arena for a total period of 45 min from the time of recovery. Number of parasitoid that visited the cards was counted at five minutes interval, which is referred as 'Parasitoid Activity Index' (PAI). After 45 minutes, the parasitoids were removed carefully from each egg card and these cards were kept individually in a glass vials for development at 25±1ºC and 65±5% relative humidity. Data on PAI, % parasitism and emergence were recorded in eight replications.

Statistical analysis : All the experiments were conducted in triplicate. The experiment was conducted on Completely Randomized Block Design as described by Padmavathi and Paul (1998) following the method by Gautam (1994). Data were presented as means ± standard deviation and analyzed using SPSS statistical software. The ANOVA was used for comparing different treatments as described by Gomez and Gomez (1986).

Results and Discussion

Data presented in Table 1, 2 and 3 and depicted in Fig. 1 and 2 shows that combination of P_3+ D_2+ T_2 (C_3) indicated maximum value of PAI (6.19), parasitism (9.96%) and emergence (7.42%) with *T. japonicum.* With the same clay, *T. japonicum* showed minimum value of PAI (2.00) with Tricosane formulation (C_5) and minimum value of parasitism (2.75%) and emergence (0.88%) at control (Table 1, 2 and 3), when mean values of species and concentration were compared. Formulation of combination P_3+D_2+T_2 (C_3) recorded maximum mean value of PAI (11.50), whereas scale extract formulation (C_4) showed maximum value of parasitism (18.88%) and emergence (15.25%), irrespective of the *Trichogramma* species studied. *T. japonicum*

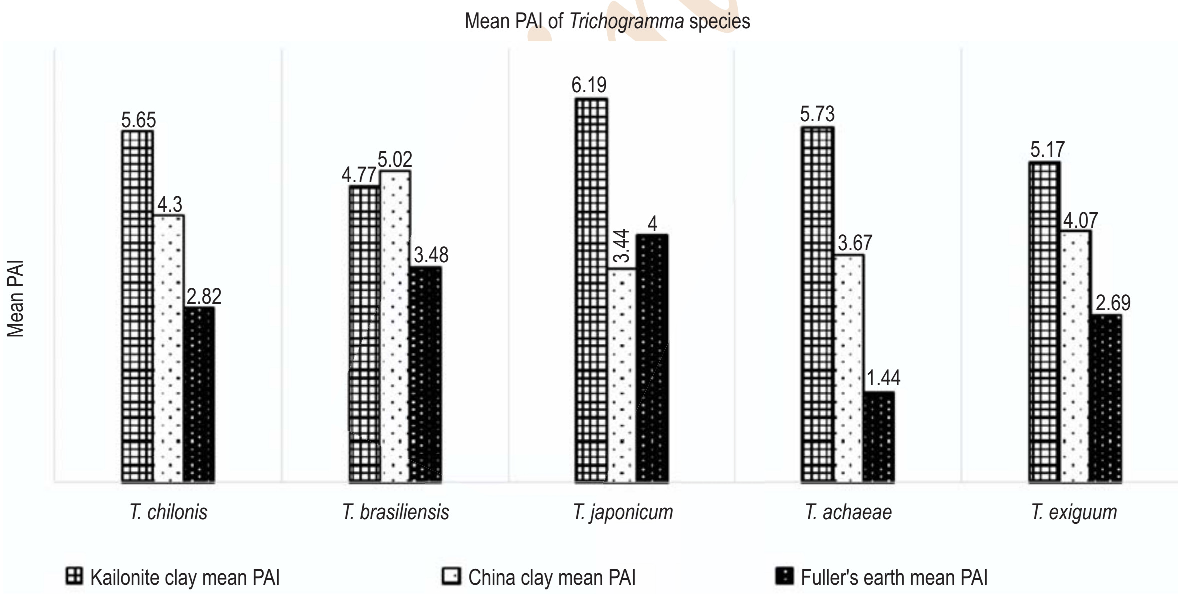


Fig. 1 : Effect of clay on parasitoid activity index (PAI) of *Trichogramma* spp.

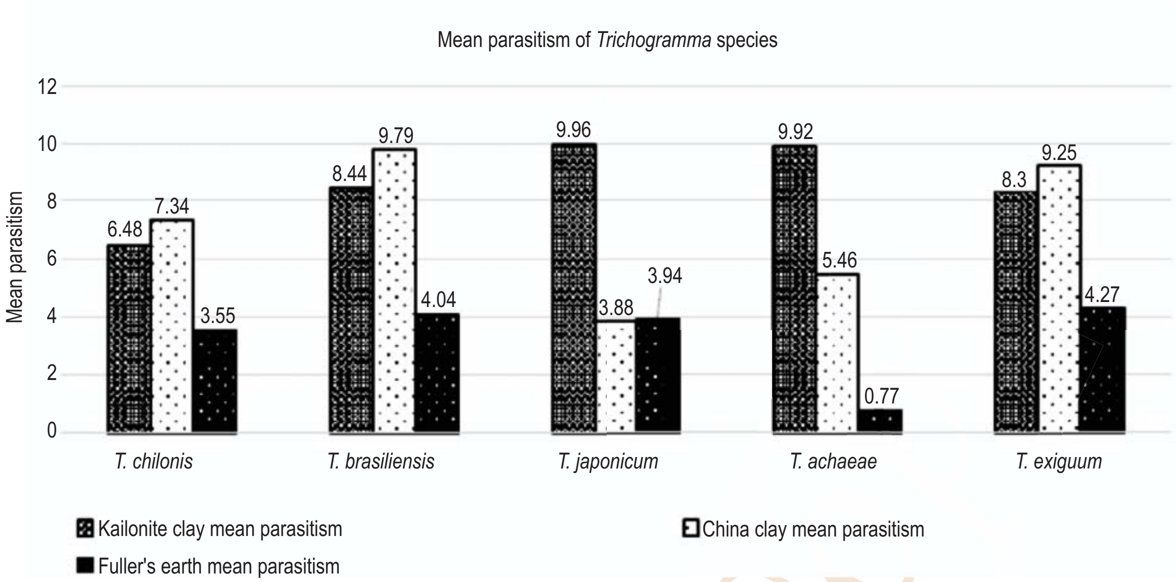


Fig. 2 : Effect of parasitism on *Trichogramma* spp.

elicited maximum value of PAI (6.19), parasitism (9.96%) and emergence (7.42%), irrespective of the combinations studied. During observing the parasitoid activity index, the values of *T. chilonis*, *T. japonicum*, *T. achaeae* and *T. exiguum* were significantly higher than the values of *T. brasiliensis*. In case of parasitism, *T. japonicum* and *T. achaeae* were significantly higher than *T. exiguum*; whereas *T. brasiliensis* and *T. exiguum* were at par with each other and the value of *T. chilonis* was significantly lower than all other species. Emergence in *T. japonicum* and *T. exiguum* was at par with each other and significantly higher than *T. chilonis*, *T. brasiliensis* and *T. achaeae*.

Formulation P_3+D_2+T_2 (C_3) of *T. brasiliensis* showed highest PAI (8.50), however highest parasitism (14.00%) and emergence (14.00%) was shown by scale extract formulation (C_4) in *T. exiguum. T. japonicum* showed least value of PAI (1.13), parasitism (1.13%) and emergence (1.13%) at control (C_6). *C. cephalonica* scale extract (C_4) formulation recorded maximum value of PAI (6.38), however maximum parasitism (14.00%) and emergence (14.00%) was recorded in scale extract formulation (C_4) irrespective of the species studied. Maximum PAI (5.02), parasitism (9.79%) and emergence (9.79%) was recorded in *T. brasiliensis* irrespective of the formulations studied (Table 4, 5 and 6; Fig. 1 and 2).

During observing the Parasitoid Activity Index (PAI) of China clay the species *T. chilonis*, *T. brasiliensis*, *T. japonicum*, *T. achaeae* and *T. exiguum* were significantly higher and were at par with each other, however *T. brasiliensis* recorded significantly higher parasitism than other species. The mean parasitism values of *T. brasiliensis* and *T. exiguum* were also at par with each other. In case of china clay, the parasitism values of *T. chilonis* were significantly lower than the *T. brasiliensis* and *T. exiguum*; whereas the values of *T. achaeae* were still significantly lower than *T. brasiliensis*, *T. chilonis* and *T. exiguum* and the least response was shown by *T. japonicum.* Emergence of *T. brasiliensis*, *T. japonicum*, *T. achaeae* and *T. exiguum* was significantly higher than *T. chilonis*.

T. japonicum at formulation P_1+D_1+T_2 (C_2) showed maximum value of PAI (8.25), *T. brasiliensis* at Tricosane (C_5) showed maximum value of parasitism (9.50%), whereas *T. chilonis* at Tricosane (C_5) showed maximum value of emergence (7.25%). *T. achaeae* at formulation P_2+D_2+T_2 (C_1) showed least value of PAI (0.75) and parasitism (0.25) and *T. chilonis* at control showed least value of emergence (0.13%). Formulation P_1+D_1+T_2 (C_2) in *T. japonicum* showed highest value of PAI (8.25); Tricosane @0.0001g $10ml^{-1}$ (C_5) showed highest value of parasitism (9.50%) in *T. brasiliensis* and highest value of emergence (7.25%) in *T. chilonis* irrespective of the species studied (Table 7, 8 and 9; Fig. 1 and 2). During observing the response the mean Parasitoid Activity Index (PAI) of *T. japonicum* was significantly higher than all the other species, which were at par with each other. The mean parasitism values of *T. chilonis*, *T. brasiliensis*, *T. japonicum* and *T. exiguum* were significantly higher and were at par with each other than the values of *T. achaeae*, whereas the response of emergence of all the species of *Trichogramma* were significantly higher and were at par with each other.

Kairomonal formulations prepared with Tricosane, Docosane and Pentacosane, *C. cephalonica* scale extract and Tricosane at 125, 250, 375,10^6 and 500 ng cm^{-2} respectively, in

Table 1 : Effect of freshly prepared kairomonal dust formulation on Parasitoid Activity Index (PAI) of *Trichogramma* spp.

Parasitoid	Carrier used: Kailonite					
	C_1	C_2	C_3	C_4	C_5	C_6(Control)
T. chilonis	2.88^{c}(1.55)	3.13^{c}(1.57)	6.25^{b}(2.05)	10.63^{a}(3.12)	5.75^{b}(2.37)	5.25^{b}(2.03)
T. brasiliensis	4.38^{b}(1.81)	3.75^{cb}(1.66)	4.50^{b}(1.89)	5.50^{b}(2.09)	6.88^{a} (2.35)	3.63^{cb}(1.60)
T. japonicum	7.38^{c}(2.41)	4.88^{d}(2.18)	11.50^{a}(3.01)	8.75^{b}(2.85)	2.00^{e} (1.38)	2.63^{e}(1.50)
T. achaeae	6.88^{ab}(2.47)	3.88^{c} (1.57)	6.00^{b}(2.35)	5.88^{b}(2.22)	7.63^{aa}(2.79)	4.13^{c}(1.88)
T. exiguum	6.50^{b}(2.12)	2.13^{d}(1.28)	5.00^{c}(1.95)	6.38^{b}(2.28)	8.00^{a} (2.51)	3.00^{d}(1.53)

Figures in parentheses are square root transformed values

	SE (m) ±	C.D. (0.05)
Parasitoid species	0.40	1.20
Conc.	0.46	1.38

Table 2 : Effect of formulation of synthetic kairomones on parasitism of *Trichogramma spp.*

Parasitoid	Carrier used: Kailonite					
	C1	C2	C3	C4	C5	C6Control
T. chilonis	2.88^{d}(1.51)	4.88^{cb}(1.76)	4.75^{d}(1.62)	14.75^{b}(3.66)	6.25^{d}(2.25)	5.38^{a}(1.94)
T. brasiliensis	7.38^{c}(2.29)	6.88^{b}(2.07)	10.75^{b}(2.70)	9.88^{d}(2.74)	11.88^{c}(3.01)	3.88^{a}(1.67)
T. japonicum	10.50^{ab}(2.86)	9.88^{a}(2.85)	12.50^{a}(3.07)	18.88^{a}(3.97)	5.25^{d}(1.86)	2.75^{c}(1.54)
T. achaeae	12.13^{a}(3.12)	5.75^{b}(1.82)	11.88^{a}(3.09)	11.00^{c}(2.91)	15.38^{a}(3.82)	3.38^{bc}(1.67)
T. exiguum	8.13^{bc}(2.34)	2.88^{d}(1.40)	8.25^{c}(2.40)	13.63^{bc}(3.20)	12.88^{b}(3.11)	4.00^{abc}(1.69)

Figures in parentheses are square root transformed values

	SE (m)±	C.D. (0.05)
Parasitoid species	0.60	1.77
Conc.	0.68	1.98

Table 3 : Effect of formulation of synthetic kairomones on emergence of *Trichogramma* spp.

Parasitoid	Carrier used: Kailonite						Mean
	C_1	C_2	C_3	C_4	C_5	C_6Control	
T.chilonis	10.25^{a}(2.63)	10.63^{a}(2.67)	5.88^{bc}(1.75)	7.63^{bc}(2.14)	8.25^{bc}(2.22)	1.38^{ab}(1.04)	7.34^{b}(2.12)
T.brasiliensis	3.88^{c}(1.74)	2.75^{c}(1.38)	3.25^{c}(1.62)	5.25^{b}(1.86)	7.00^{a}(2.17)	1.13^{d}(1.00)	5.46^{b}(1.93)
T.japonicum	9.25^{bc}(2.32)	9.75^{b}(2.37)	10.63^{b}(2.67)	13.00^{a}(2.92)	12.88^{a}(2.91)	3.25^{d}(1.50)	9.79^{a}(2.45)
T.achaeae	4.88^{c}(1.81)	5.13^{b}(1.85)	8.75^{a}(2.47)	7.13^{b}(2.23)	5.38^{c}(2.02)	1.50^{d}(1.20)	3.88^{b}(1.63)
T.exiguum	11.13^{b}(2.74)	6.88^{d}(2.07)	9.38^{c}(2.34)	14.00^{a}(3.25)	12.00^{b}(2.82)	2.13^{e}(1.14)	9.25^{a}(2.39)

Figures in parentheses are square root transformed values

		SE (m)±	C.D. (0.05)
Parasitoid species	0.39	1.17	
Concentration		0.47	1.41

five different concentrations showed significant variations. Kailonite clay showed the maximum value of PAI (6.19), parasitism (9.96%) in *T. japonicum* and maximum value of emergence (9.79%) in *T. brasiliensis* when formulations from all the three clays were compared. These findings are in agreement with Bakthavatsalam and Tondon (2006) who reported that kairomonal compounds present in *C. cephalonica* moth scales fortified with Nonacosane (0.3%), Hexacosane (0.3%), Pentacosane (0.2%) and Tricosane (0.3%) increased significantly the egg parasitism efficiency of *T. chilonis*. Boo and Yang (2000) made similar observations on the effect of male moth scale extract of *H. assulta* on increasing efficiency of *T. chilonis* and reported that the extract contained fractions of saturated hydrocarbons. The dust formulations can be more effective in integrated pest management programmes because of their unique mode of release in field conditions. The choice of formulation type can have an adverse impact on human health and the environment. These studies have demonstrated the utility of formulations in chemical communications and indicated the importance of formulation performance on efficacy. Therefore,

Table 4 : Effect of freshly prepared kairomonal dust formulation on Parasitoid Activity Index of *Trichogramma* spp.

Parasitoid	Carrier used: China clay					
	C_1	C_2	C_3	C_4	C_5	C_6(Control)
T. chilonis	5.13^{a}(1.96)	5.50^{a}(2.03)	3.38^{bc}(1.45)	4.25^{ab}(1.71)	5.63^{a}(1.90)	1.88^{c}(1.23)
T. brasiliensis	3.75^{b}(1.70)	5.00^{b}(1.83)	8.50^{a}(2.26)	6.00^{b}(2.11)	4.88^{b}(1.94)	2.00^{bc}(1.34)
T. japonicum	3.50^{b}(1.71)	2.25^{c}(1.30)	3.38^{ab}(1.74)	4.75^{a}(1.89)	5.63^{a}(2.03)	1.13^{d}(1.00)
T. achaeae	3.13^{b}(1.54)	3.00^{b}(1.51)	4.75^{a}(1.90)	5.13^{a}(1.95)	4.13^{a}(1.82)	1.88^{c}(1.31)
T. exiguum	4.25^{b}(1.90)	2.88^{b}(1.51)	3.25^{b}(1.58)	6.38^{a}(2.28)	6.38^{a}(2.14)	1.25^{c}(1.07)

Figures in parentheses are square root transformed values

	SE(m)$\pm$	C.D. (0.05)
Parasitoid species	0.62	1.86
Conc.	0.71	2.13

Table 5 : Effect of formulation of synthetic kairomones on parasitism of *Trichogramma* spp.

Parasitoid	Carrier used: China clay					
	C_1	C_2	C_3	C_4	C_5	C_6(Control)
T. chilonis	10.25^{a}(2.63)	10.63^{a}(2.67)	5.88^{bc}(1.75)	7.63^{bc}(2.14)	8.25^{bc}(2.22)	1.38^{ab}(1.04)
T. brasiliensis	9.25^{ab}(2.32)	9.75^{a}(2.37)	10.63^{a}(2.67)	13.00^{a}(2.92)	12.88^{a}(2.91)	3.25^{a}(1.50)
T. japonicum	3.88^{c}(1.74)	2.75^{c}(1.38)	3.25^{c}(1.62)	5.25^{c}(1.86)	7.00^{c}(2.17)	1.13^{ba}(1.00)
T. achaeae	4.88^{c}(1.81)	5.13^{b}(1.85)	8.75^{ab}(2.47)	7.13^{b}(2.23)	5.38^{c}(2.02)	1.50^{ab}(1.20)
T. exiguum	11.13^{a}(2.74)	6.88^{b}(2.07)	9.38^{ab}(2.34)	14.00^{a}(3.25)	12.00^{a}(2.82)	2.13^{ab}(1.14)

Figures in parentheses are square root transformed values

	SE(m)$\pm$	C.D. (0.05)
Parasitoid species	0.73	2.09
Conc.	0.81	2.27

Table 6 : Effect of freshly prepared kairomonal dust formulation on emergence of *Trichogramma* spp.

Parasitoid	Carrier used: China clay				C_6(Control)	Mean	
	C_1	C_2	C_3	C_4	C_5		
T. chilonis	2.25^{c}(1.39)	3.88^{b}(1.62)	3.75^{b}(1.51)	11.00^{a}(3.17)	4.88^{b}(2.03)	4.63^{b}(1.82)	5.15^{b} (1.92)
T. brasiliensis	5.50^{c}(2.03)	4.38^{c}(1.75)	7.75^{b}(2.35)	8.13^{b}(2.51)	10.00^{a}(2.79)	2.50^{d}(1.45)	6.38^{a}(2.15)
T. japonicum	8.25^{c}(2.57)	6.75^{d}(2.29)	9.88^{b}(2.75)	15.25^{a}(3.60)	3.50^{e}(1.60)	0.88^{f}(1.03)	7.42^{a}(2.31)
T. achaeae	9.25^{a}(2.69)	4.50^{c}(1.61)	9.88^{a}(2.76)	7.88^{b}(2.50)	10.00^{a}(2.79)	1.50^{d}(1.22)	7.17^{a}(2.26)
T. exiguum	5.88^{b}(2.06)	2.50^{c}(1.34)	6.25^{b}(2.13)	10.50^{a}(2.84)	10.88^{a}(2.88)	3.38^{c}(1.59)	6.57^{a}(2.14)

Figures in parentheses are square root transformed values

	SE(m)$\pm$	C.D. (0.05)
Parasitoid species 0.49	1.47	
Conc.	0.57	1.71

these formulations have been found effective in chemical communications using kairomones and synomones and can withstand wide fluctuations in temperature, rainfall and humidity. The present studies were carried out to identify effective kairomonal compound, optimum concentration and appropriate application technique to increase the parasitizing efficiency of *T. chilonis.* Yadav and Paul (2009) explained the effect of host eggs and scale formulations of *C. cephalonica* on the searching ability in relation to the distance moved by *T. exiguum*. They found that maximum mean parasitism percentage was observed on treatment with unwashed eggs and *Corcyra* scale dust formulations, followed by hexane washed eggs and *Corcyra* scale. Effect of kairomones on *Trichogramma* has been studied by different workers. Paul *et al*. (2008) described the semiochemicals produced by 10 different varieties of tomato obtained in the vegetative and flowering period for their

Table 7 : Effect of freshly prepared kairomonal dust formulation on Parasitoid Activity Index of *Trichogramma* spp.

Parasitoid	Carrier used: Fuller's earth					
	C_1	C_2	C_3	C_4	C_5	C_6(Control)
T. chilonis	2.63^{b}(1.57)	3.00^{b}(1.53)	2.13^{b}(1.51)	3.63^{a}(1.61)	4.25^{a}(1.89)	1.25^{d}(1.09)
T. brasiliensis	4.63^{b}(1.94)	3.25^{c}(1.62)	2.13^{d}(1.28)	2.25^{d}(1.30)	6.00^{a}(2.24)	2.63^{c}(1.60)
T. japonicum	4.00^{c}(1.80)	8.25^{a}(2.35)	5.75^{b}(2.28)	1.25^{e}(1.07)	2.88^{d}(1.59)	1.88^{d}(1.16)
T. achaeae	0.75^{c}(1.01)	1.50^{b}(1.26)	3.25^{a}(1.83)	0.75^{c}(1.03)	1.50^{b}(1.22)	0.88^{c}(0.96)
T. exiguum	2.25^{c}(1.30)	1.88^{c}(1.27)	1.38^{d}(1.14)	3.50^{a}(1.72)	4.25^{a}(1.71)	2.88^{b}(1.56)

Figures in parentheses are square root transformed values

	SE (m)±	C.D.(0.05)
Parasitoid species	0.34	1.02
Conc.	0.39	1.17

Table 8 : Effect of formulation of kairomones on parasitism of *Trichogramma* spp.

Parasitoid	Carrier used: Fuller's earth					
	C_1	C_2	C_3	C_4	C_5	C_6(Control)
T. chilonis	2.00^{b}(1.39)	2.63^{bc}(1.33)	2.63^{b}(1.46)	5.13^{b}(1.85)	8.38^{a}(2.42)	0.50^{b}(0.88)
T. brasiliensis	5.25^{a}(1.95)	2.75^{b}(1.36)	2.25^{b}(1.30)	2.75^{c}(1.38)	9.50^{a}(2.66)	1.75^{ab}(1.19)
T. japonicum	4.50^{ab}(1.87)	7.50^{a}(2.38)	7.75^{a}(2.50)	0.88^{d}(0.96)	1.75^{d}(1.17)	1.25^{ab}(1.02)
T. achaeae	0.25^{c}(0.82)	1.25^{c}(1.14)	1.50^{c}(1.23)	0.25^{d}(0.82)	0.88^{d}(1.03)	0.50^{b}(0.88)
T. exiguum	4.38^{ab}(1.59)	2.88^{b}(1.39)	2.25^{b}(1.30)	6.63^{a}(2.20)	7.00^{b}(2.08)	2.50^{a}(1.41)

Figures in parentheses are square root transformed values

	SE (m)±	C.D.(0.05)
Parasitoid species	0.51	1.42
Conc.	0.58	1.67

Table 9 : Effect of freshly prepared kairomonal dust formulation on emergence of *Trichogramma* spp.

Parasitoid	Kairomonal dust formulation-Carrier used: Fuller's earth						Mean
	C_1	C_2	C_3	C_4	C_5	C_6(Control)	
T. chilonis	1.25^{c}(1.18)	2.00^{c}(1.13)	2.00^{c}(1.33)	4.38^{b}(1.74)	7.25^{a}(2.28)	0.13^{c}(0.77)	2.84^{a}(1.41)
T. brasiliensis	3.25^{a}(1.54)	1.88^{c}(1.22)	1.75^{c}(1.20)	2.50^{b}(1.34)	4.50^{a}(1.88)	1.38^{c}(1.11)	2.54^{a}(1.38)
T. japonicum	4.13^{a}(1.81)	5.38^{a}(2.07)	4.25^{a}(1.83)	0.50^{b}(0.88)	1.38^{b}(1.04)	1.13^{b}(1.00)	2.80^{a}(1.44)
T. achaeae	1.50^{b}(1.23)	1.88^{a}(1.16)	2.00^{a}(1.34)	2.25^{a}(1.30)	2.88^{a}(1.56)	1.25^{b}(1.09)	1.96^{a}(1.28)
T. exiguum	3.50^{b}(1.48)	1.88^{c}(1.23)	1.63^{c}(1.18)	5.63^{a}(2.05)	5.25^{a}(1.86)	1.63^{c}(1.18)	3.90^{a}(1.50)

Figures in parentheses are square root transformed values

	SE (m)±	C.D.(0.05)
Parasitoid species	0.45	1.34
Conc.	0.52	1.56

synomonal response and observed higher response in the flowering period, which could be due to presence of higher relative quantities of tricosane, heneicosane and hexacosane. Srivastava *et al*. (2008) compared the kairomonal response of the three host insects *viz*., *S. litura*, *S. exigua* and *C. auricilius* in both male and female and concluded that the response elicited by the male extract body of *S. litura* was significantly higher, whereas the extract body of male *C. auricilius* elicited least response from *T. chilonis*. Srivastava and Singh (2009) observed that among the seven organic acids (triacontanoic, docosanoic, octosanoic, tricosanoic, pentadeconoic, heptacosanoic and hexacosanoic acid); triacontanoic acid elicited the highest response from *T. chilonis*, followed by docosanoic and octocosanoic acids. Sharma and Aggarwal (2015) evaluated the dispersal ability and parasitisation performance of *Trichogramma* spp in organic Basmati rice. It was found that among the two parasitoid species, *T. chilonis* showed higher parasitism in different distance treatments in comparison to *T. japonicum.*

Natural enemies including egg parasitoid like *Trichogrammatids* respond towards chemical cues present in the environment to locate their hosts. Many a times these cues are associated with host and host byproducts itself. The present study, revealed that the emission rate of synthetic kairomone was fastest from kailonite clay as compared to china clay and fuller's earth in a given limit of time. Therefore, in the present study *T. brasiliensis* and *T. japonicum* with kairomonal formulation (Tricosane @0.0001 g $10ml^{-1}$) and kailonite clay could be recommended for the integrated pest management programme.

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