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## Temporal and Spatial Dispersal of Laboratory-Reared *Trichogramma chilonis* Ishii in Open Field

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### ABSTRACT

Laboratory-reared *Trichogramma chilonis* Ishii was assessed for its ability to move in open field through parasitism on sentinel cards of *Corcyra cephalonica* placed at distances of 1, 3, 5, 7, 10, 15, 20, 25 and 30 m, from the point of release of parasitoids at eight cardinal directions. Sentinel cards were recovered from the field after 1-7 days time at 24 h interval to observe parasitism and adult emergence. The dispersal rate was affected significantly by the time allowed as well as by the distances from the release point while the impact of direction was not significant. The overall dispersal rate was found to increase from 23.56% at 24 h to 37.07% on the completion of third day, irrespective of the distance or direction at which the cards were kept. The mean dispersal rate over the seven time periods tested was quite high at 1-10 m distance (73.78 to 32.05) which decreased to 7.67 at 30 m. Adult emergence did not show a definite influence by the interactive elements. High rates of adult emergence was observed (77.72-92.44%) in the cards that were left in the field for 1-7 days. Overlapping but significant variations in the emergence rates (76.06-91.9%) were observed in the cards kept at different distances from the release point. Results indicated that three days of time stabilized parasitoid dispersal and that at least 13 release points are required per acre of release area for ensuring uniform dispersal.

**Key words:** *Trichogramma chilonis*, dispersal, time, distance, wind

### INTRODUCTION

The egg parasitoid *Trichogramma chilonis* Ishii is used throughout India for management of many lepidopterous pests across the crops through inundative releases. Field fitness of such parasitoids mass reared for biological control is generally evaluated by assessing parasitization rates of pest eggs in the target crop (Kolliker-Ott *et al.*, 2004) and efficient dispersal is a key factor in the host searching leading to high parasitization. Dispersal capacity and host location ability in the field are important quality attributes in biological control, but are difficult to estimate in the laboratory (Kölliker-Ott *et al.*, 2004). In field, being small, Trichogrammatids are believed to disperse to short distances and the rates of such dispersal of the *Trichogramma* species is reduced in direct relation to the distance from the point of release (Geetha and Balakrishnan, 2010; Wright *et al.*, 2001). The factors that influence the dispersal ability of a parasitoid may either be of parasitoid origin: physiological state of female and wing size (Reznik and Klyueva, 2006; Kolliker-Ott *et al.*, 2004) or of host: egg density (Sarkar *et al.*, 1999) or of host plant: crop age or growth (Geetha and Balakrishnan, 2010; Muhammad *et al.*, 2004) and plant architecture

(Gingras *et al.*, 2003, 2008; McDougall and Mills, 1997; Wang *et al.*, 1997), or climatic: wind (Yu *et al.*, 1984), rain (Chapman, 2007) and temperature (Singh and Shenhmar, 2008; Sohi *et al.*, 1996; Suverkropp *et al.*, 2001) or strategical: density of parasitoid (Ayvaz *et al.*, 2005; Pfannenstiel *et al.*, 1996; Singh and Jalali, 1992; Taylor, 1978) or number of release points (Wang and Shipp, 2004) or the size of the experimental area (Canto-Silva *et al.*, 2006). Mostly, these studies have been done to assess the ability of the *Trichogramma* sp. to move every 24 h but at least the *T. chilonis* adults live up to 11.6 days (Nadeem *et al.*, 2009) ovipositing up to six days (Baitha *et al.*, 2005) and survive in the field for many days though it is reported that the parasitoid lays most of its eggs on the first two days after emergence in the laboratory (Baitha and Verma, 2003) when the host is readily available.

Hence, in the present study, the ability of the parasitoid to move from the point of release as influenced by time allowed since release from 1-7 days is assessed in the open field and the use of such results on deciding the number of release points during inundative releases is discussed.

## MATERIALS AND METHODS

The present study was undertaken in the fields of Sugarcane Breeding Institute, Coimbatore (77°E longitude and 11°N latitude in Southern India) during 2008. The factitious host *Corcyra cephalonica* Stainton eggs were used as sentinel cards to observe the parasitism by the dispersing parasitoids instead of its native host, sugarcane inter node borer *Chilo sacchariphagus indicus* (Kapur) eggs since mass-culturing technique for the latter is unavailable. However, in the inundative release strategy, UV-sterilized *C. cephalonica* eggs are used as a factitious host for mass rearing *T. chilonis*.

The *T. chilonis* parasitoids were derived from the culture maintained in the laboratory of insectary (28±2°C, 52±4% RH) at Sugarcane Breeding Institute (Coimbatore, Tamil Nadu). The *Trichogramma* cards were used at the stage when the adults had emerged, were less than 24 h old and mated. The parasitoids were used at the rate of Ca. Eight thousand for each of 3 replicates (the dose per unit area derived -30 m radius circle of 2825 m<sup>2</sup> area was corresponding to field dosages of 2 ccl/ac suggested (Geetha *et al.*, 2009) for management of inter node borer in sugarcane).

The sentinel cards were thick chart paper sheets of 8×1 cm size with at least 100 UV-inactivated and unparasitized eggs of *C. cephalonica*. The fresh sentinel cards were positioned at 1, 3, 5, 7, 10, 15, 20, 25 and 30 m, from the point of release of parasitoids at eight cardinal directions along the straight radius lines forming a ring around the release point at every distance studied as per the protocol used by Geetha and Balakrishnan (2010). The *Tricho cards* (with fresh mated *T. chilonis* adults) used for the study were held in glass vials till release and the cards were placed in the sugarcane field in a small circle with the central point of the circle serving as release site of the parasitoid. Both the parasitoid cards and sentinel cards were tied onto the bamboo pegs placed at point of release and at specified distances, respectively.

At a single point seven such sentinel cards were placed simultaneously and at the interval of 24 each card was collected for determination of incidence of parasitism. Thus one of the seven cards at each monitoring point was collected after 24 h followed by one on day 2 and so on. The study was conducted for a period of seven days during 12.8.08-18.8.2008. When the sentinel cards were collected the distance and direction from the release points were noted. Records of weather parameters were obtained from the Meteorological Laboratory located at Sugarcane Breeding Institute, Coimbatore.

The recovered cards were maintained at the ambient temperature of 28-30°C for 1-7 days depending on the day of recovery, to observe the percentage of parasitized eggs. When there was

complete destruction of a sample by predators, the data was construed as missing data (and replaced with mean of surrounding replication). The natural population of *T. chilonis* at the trial site was assessed by placing sentinel cards only, a week prior to experimentation as well as during the experiments at 100 m distance.

In an earlier study done in 2004-2005, the effect of plant age and distance on the dispersal of the parasitoid was found to be distinct (Geetha and Balakrishnan, 2010). So in the present study, to eliminate the effect of crop cues and architecture, the study was undertaken in a crop-free field. Thus the results would reveal the effect of wind direction, distance of from the point of release and the time allowed for the parasitoids to move sans crop architecture and chemical cues.

The percentage data were transformed using arc-sine square root transformation. Treatment means of percent parasitism and emergence were analyzed through a nested split-split plot analysis of variance and means were separated by least significant difference (LSD) values at  $p = 0.05$  level.

## RESULTS

The weather parameters existed in the field during the experiments are given in Table 1. The temperature to some extent was higher than the optimal temperature required by *T. chilonis* for parasitism which is reported to be 28°C (Nadeem *et al.*, 2009). The temperature ranged from 30-33°C during the day and 19-22°C during night. RH was 87-95% in the morning and 51 to 60% in the afternoon (Table 1). The natural parasitism rates in sentinel cards prior to and during the experiments were 0.0-0.05% and thus were not considered for analysis.

Dispersal as influenced by the time, distance, direction:

**Parasitism:** The dispersal rate was influenced significantly by the time allowed as well as by the distances from the release point while the impact of direction on dispersal was insignificant (Table 2). The parasitoid was able to move up to farthest distance (30 m) tested in the present study

Table 1: Weather parameters during the conduct of experiment

Days of experimentation	Temperature		RH (%)		Wind direction
	Max.	Min	a.m.	p.m.	
1	29.6	22.0	91.0	60.0	NE
2	31.0	21.5	91.0	56.0	NW
3	31.6	19.0	87.0	55.0	N
4	33.0	20.6	89.0	55.0	NE
5	31.0	20.5	91.0	51.0	N
6	30.0	21.0	87.0	53.0	N
7	30.5	20.5	95.0	59.0	N

Table 2: ANOVA table for parasitism (using angular values)

Source	DF	Mean SS	F-value
Main plots (time)	6	3348.58	53.92 S
Subplots (direction)	7	45.39	0.37 N.S
Interaction			
Main×sub plots	42	72.15	0.58 N.S
Sub-sub plots (distance)	8	485551.63	534.72 S
Main×sub-sub plots	48	91.88	1.01 N.S
Sub plots×sub-sub plots	56	90.38	1.00 N.S
Main×sub plots×sub-sub plots	336	85.76	0.94 N.S

Significance at  $p = 0.05$

Table 3: Percent parasitism: time x distance

Time lapsed (days)	Distance (m)									Mean
	1*	3	5	7	10	15	20	25	30	
1	68.29g	57.38f A	38.38e A	21.92d A	12.63c A	6.13b A	4.13b A	2.25abA	0.96aA	23.56A
2	75.83f	64.42e AB	45.29d AB	40.25d B	26.25c B	18.63bc B	12.08ab B	10.33a B	8.21a B	33.48BC
3	76.25f	68.17e B	50.38d B	48.79d B	36.38c C	20.17b B	11.88a B	12.54a B	9.08a B	37.07BC
4	74.21f	65.67e AB	52.38d B	46.29c B	38.29c C	20.58b B	12.38a B	12.50a B	9.00a B	36.81C
5	73.17g	67.17f B	52.38e B	46.79d B	36.38c C	19.58b B	13.08abB	12.13abB	8.98a B	36.63CD
6	73.33e	71.71e B	52.69d B	45.60cd B	36.85c C	20.13b B	12.83a B	11.21a B	7.88a B	36.91CD
7	75.38e	70.27e B	52.50d B	47.88d B	37.60c C	20.33b B	11.88a B	12.25a B	9.56a B	37.52D
Mean*	73.78h	66.40 g	49.14f	42.50e	32.05d	17.93c	11.18b	10.46b	7.67a	34.57

\*No significant differences among mean values were found among the mean parasitism at different days at 1m distance. Mean values in a column (upper case) and in a row (lower case) followed by the same letter are not significantly different (LSD,  $p = 0.05$ ). Analysis conducted on arcsine- transformed data; Interaction effect of Days (Time) x Distance was insignificant ( $p=0.05$ )

(Table 3). The overall dispersal rate was found to increase from 23.56% at 24 h to 37.07% on the completion of third day, irrespective of the distance or direction at which the cards were kept. After 72 h the dispersal rate was stabilized (Table 3). With in each time period tested, the impact of distance was categorically observed. For example, at 24 h after release the dispersal steadily and proportionally decreased from 68.29% at 1 m distance to 12.63% at 10 m distance. However when compared across the days, the impact of lapse of time was found to have a positive significant effect till 72 h after release at most of the distances tested, with the average percent parasitism across the distances increasing from 23.5 (on day 1) to 37.07 (on day 3). The latter was on par with the parasitism levels by parasitoid allowed for still longer periods (4-7 days) in the field.

Distance had a visible direct impact on the dispersal. The mean dispersal rate over all the time periods tested, was quite high at 1-10 m distance as indicated by the percent parasitism ranging from 73.78 to 32.05 which decreased to 7.67 at 30 m (Table 3). The effect of time allowed on the dispersal was not observed in the shortest distance tested (1 m) though for all other distances tested, with passage of time significantly more dispersal was found. For example, at distances of 20, 25, 30 m, the percent parasitism observed on day 3 was 3-10 fold more than what was observed within 24 h time (Table 3).

Dispersal at any distance from the point of release was not influenced by the direction of wind (Table 4). On the other hand, within each wind direction, the movement of the parasitoid was found to be affected by the distance from the release point (Table 5). The mean parasitism over all the time periods tested was not found to vary significantly from 33.27 (North) to 35.63 (North East) though, the wind flow during the experimental period was mostly North or North East. Within each direction of wind, the impact of time allowed (days) on dispersal ability was found with overlapping significance (Table 4).

**Interaction effects:** Interaction effects of time allowed (days) x directions, time allowed x distances and direction x distance were found to be insignificant showing no effect on the dispersal rate of the *T. chilonis* (Table 2). Similarly there was no significant effect of three way interaction of time x direction x distance on dispersal ability (Table 2).

**Emergence:** The percent emergence of the parasitoid, *T. chilonis* was very high in the open field ranging from 77.72 to 92.44 with the highest on day 2 and the lowest on day 4. Though the climatic

Table 4: Percent parasitism: time x direction

Time lapse (days)	Directions*								
	East	West	South	North	NorthEast	NorthWest	SouthEast	SouthWest	Mean
1	21.07a	23.07a	25.56a	25.00a	22.96a	20.74a	23.67a	26.41a	23.56A
2	35.70b	33.41b	33.93b	31.44b	34.52b	33.96b	31.67b	33.19bc	33.48BC
3	36.93b	34.81b	39.56b	39.19b	37.30b	33.11b	38.26b	37.41bc	37.07BC
4	32.07b	36.33b	39.67b	35.37b	36.81b	39.74b	40.52b	33.96b	36.81C
5	37.06b	35.26b	34.20b	33.48b	40.24b	39.17b	34.39b	39.22c	36.63CD
6	35.91b	38.46b	34.44b	33.87b	39.52b	37.69b	36.69b	38.74bc	36.91CD
7	35.93b	40.98b	38.59b	34.56b	38.07b	37.06b	37.96b	36.98bc	37.52D
Mean*	33.52	34.67	35.13	33.27	35.63	34.49	34.74	35.13	34.57

\*Over all means of parasitism across the directions are not significantly different; overall means of parasitism across days (last column) followed by same letters are not significantly different; Means in a column followed by same letter (lower case) are not significantly different (LSD, p = 0.05); analysis conducted on arc sine transformed data

Table 5: Percent parasitism: direction x distance

Direction	Distance in meters*									
	1	3	5	7	10	15	20	25	30	Mean*
East	71.67e	63.43e	44.71d	41.81d	31.29c	17.86b	9.00a	12.95ab	9.00a	33.52
West	78.19f	64.19e	51.60d	47.88d	31.50c	17.14b	8.57a	5.88a	6.62a	34.62
South	74.71e	69.24e	50.31d	43.29d	32.81c	17.43b	10.62ab	10.43ab	7.38a	35.13
North	70.86e	65.10e	46.50d	35.95c	29.14c	20.86b	12.50a	10.45a	8.10a	33.27
Northeast	73.40d	66.43d	52.60c	48.33c	29.00b	16.43a	13.19a	13.31a	8.00a	35.63
Northwest	74.10e	66.81e	51.40d	39.00c	33.43c	15.90b	12.62b	9.86ab	7.33a	34.49
Southeast	72.31e	68.64e	47.24d	36.71c	36.55c	19.48b	12.38b	12.79b	6.52a	34.74
Southwest	75.00f	67.33f	48.76e	47.05d	32.71c	18.38b	10.55a	8.00a	8.38a	35.13
Mean	73.78H	66.40G	49.14F	32.05E	32.05D	17.93C	11.18B	10.46B	7.67A	34.57

\*Over all means of parasitism in different directions were not significantly different; Means of percent parasitism across the directions in a single distance, were not significantly different; Means in a row followed by same letters (lower case) and overall means at different distances as shown in the last row (upper case) are not significantly different (LSD, p = 0.05); analysis conducted on arc sine transformed values

Table 6: ANOVA table for emergence (using angular values)

Source	df	Mean SS	F-value
Main plots (Time)	6	3641.33	27.53S
Subplots (Direction)	7	338.21	1.16NS
Interaction			
Main×sub plots	42	177.55	0.61NS
Sub-sub plots (Distance)	8	2636.19	8.96S
Main×sub-sub plots	48	1343.01	4.56S
Sub plots×sub-sub plots	56	354.55	1.20NS
Main×sub plots×sub-sub plots	336	292.15	0.99NS

factors were almost the same on day 2 as in other days, the temperature on day 3 was the highest among the days of test. In all the directions at which the sentinel cards were kept, irrespective of the day and distance, the percent emergence was high (84.19 to 87.5%) with no significant differences (Table 6). With respect to distances, the emergence was more than 80% up to 20 m distances with overlapping levels of significance (Table 7).

Table 7: Percent emergence as influenced by individual effects of time, direction and distance

Time (days)	Emergence (%)	Direction	Emergence* (%)	Distance (m)	Emergence(%)
1	82.20b	East	84.93	1	86.00d
2	92.44d	West	85.43	3	91.90cd
3	84.06b	South	84.30	5	90.68cd
4	77.72a	North	86.80	7	88.35c
5	89.49c	Northeast	87.50	10	89.73cd
6	86.69b	Northwest	85.33	15	83.68b
7	86.54b	Southeast	84.19	20	84.11bc
		Southwest	86.26	25	79.83ab
				30	76.06a

\*Means are not significantly different; Means in a column followed by similar alphabets are not significantly different (LSD,  $p = 0.05$ ); Interaction effects of Time×Direction, Direction×Distances, Days×Direction×Distances were insignificant ( $p = 0.05$ ) while Time (days)×distance effect was significant

The lower rate of emergence in the distances beyond 20 m could probably due to the lower (smaller values) of % parasitism at farthest distances where in the impact of even few failures to emerge were seen magnified in calculations. Significance of time lapse since release, i.e., days for which the sentinel cards were left in the field on the emergence was also overlapping (Table 7) and not proportionate.

Interaction between either any of the two factors or among all the three elements tested did not have a significant effect on the emergence (Table 6).

## DISCUSSION

The high rates of parasitization in the cards placed up to 3 m distance show concentrated pattern of dispersal closer to the point of release, which however declined progressively with increase in distance. At 10 m distance from release point the percent parasitism was only 12.63 in 24 h time, though by seventh day it increased to 37.6. This is in contrast with the earlier study wherein the dispersal in 45 days old sugarcane crop by *T. chilonis* was 28.96% in 24 h at 10 m distance from the release point (Geetha and Balakrishnan, 2010) indicating the role of plant cues and possibly the cooler microclimate in the field, in better dispersal. However, when more time was allowed to lapse after release, increased percent parasitism was observed at most of the distances tested which was more pronounced in the farthest distances from release point. This may be because after settling in a point on the day one, the parasitoid might have started dispersing again further on the consecutive day. Stabilization in parasitization after 72 h indicates either that the parasitoids had perished in the field by then, or they have off-loaded all their eggs within this time frame. Faster decline in parasitization due to time lapse has been observed earlier where in intensity of parasitization by *T. chilonis* was reduced at 48 h post release of parasitoids compared to 24 h time (Muhammad *et al.*, 2004).

Similar trend of increased dispersal with time was observed in a two year study on *Trichogramma ostrinae* Pang and Chen from release point, the greatest number of wasps recaptured occurred from 3-4 days after emergence (Chapman, 2007). However, the majority of the newly-emerged adults of *Trichogramma pretiosum* Riley remained around the release point during days 1 and 2 post-release, resulting in the highest parasitoid-induced mortality of 38 and 45% on the release plant (Wang and Shipp, 2004).

Distance had influenced the rate of dispersal which is in line with the findings in earlier work by several authors in many *Trichogramma* sp. (Bigler *et al.*, 1988; Geetha and Balakrishnan, 2010;

Mills, 2003; Wang *et al.*, 1996, 1997; Wright *et al.*, 2001). Though for other species of *Trichogramma* high dispersal ability has been reported, *T. chilonis* dispersal is reported to be limited (Anonymous, 1995; Muhammad *et al.*, 2004; Singh *et al.*, 1994). Brar *et al.* (2000) observed that *T. chilonis* could disperse up to 9 m in search of its host and maximum parasitization was observed up to 2 m. Conversely, the study by Sohi *et al.* (1996) did not show any significant differences in the parasitization rates by *T. chilonis* between 2-10 m distances. Similar low levels of parasitization in sentinel cards by *T. chilonis* in proportion to the distance tested has been established by Singh and Shenhmar (2008) where the maximum parasitization was recorded at 1 m and the least at 10 m from the release point. Thomas and Rainer (2009) found parasitism by *Trichogramma brassicae* to be the highest in the close vicinity of the release point, i.e., 86%, whereas 6.5 m away the mean parasitization rate decreased to 3% though the parasitoids persisted in the field for 9 days. In open field conditions, *Trichogramma* sp., seem to have low ability to disperse on their own which may probably be because they lose their ability for directed flight and a similar phenomenon was observed in case of *T. pretiosum* (Smith, 1996; Wang and Shipp, 2004).

These declines in parasitism are likely to reflect wasp density, as in these experiments wasps are released at a single point in the field and there is a decrease in parasitoid density with increasing distance from the release point (Kolliker-Ott *et al.*, 2004). Further, *Trichogramma* females concentrate their search for hosts close to the release point (Gingras *et al.*, 2003). Due to the small size of *Trichogramma* the exact physiological or environmental reasons behind the characteristic dispersal ability are difficult to segregate.

On the contrary, Parsons and Ullyett (1936) concluded that dispersal of *Trichogramma* sp. was rapid, extending from the centre to the outer part of 5-acre fields within 24 h. Similar quick movement of *T. ostriniae* adults to 45 m from the release point was observed with high rates of parasitization (20-50%) at this distance, but the levels decreased with increasing distance from the release point (Chapman *et al.*, 2009).

There are several reasons for the findings on the level of parasitism observed in the present study. Dispersal leading to parasitism was dependent on release rate with the proportion of parasitized egg masses and eggs per mass increasing with the number of *Trichogramma platneri* Nagarkatti released (Pfannenstiel *et al.*, 1996). However in the present study, absence of crop cues could have been an hindrance in directed host location and thus increase in the parasitoid density (8000 parasitoids) at the release point as compared to the release rate (4000 parasitoids) and the increase in the host density (seven times more) from those used in the earlier study (Geetha and Balakrishnan, 2010) has not really altered the resultant parasitism. Combined with host plant attraction, it could have been still higher.

It was thought the parasitoid would disperse downwind due to its small size. But in the present study no association of the dispersal was found with wind direction was observed. This kind of independence from wind is reported in the study of Chapman (2007) where in the effect of drift was negligible in the dispersal of the *T. ostriniae*. However, Saavedra *et al.* (1997) had observed that the low wind speed on the release days allowed uniform *T. pretiosum* dispersal in experimental area while Singh *et al.* (1994) found higher parasitism by *T. chilonis* in the direction of wind. In another study with the latter, dispersal of the parasitoid was found to be influenced by both distance and wind direction (Anonymous, 1995).

There were non-significant differences in parasitoid emergence pattern with respect to directions in any distance or on any day while unexpectedly the time allowed as well as distances significantly affected though the emergence rates were overlapping. Among the days, the



emergence on day four was the lowest, corresponding to the highest temperature (33°C) recorded in the open field during experimentation. In a cropped- field though, the microclimate would have been optimal at this temperature. Comparable results on the emergence of parasitoids have been reported by Geetha and Balakrishnan (2010). Wind speed which was not recorded or the number of hours spent by the parasitized sentinel cards in the experimental tropical climate could have had an impact on the adult emergence rate by causing loss of moisture in the open field. Environmental conditions, primarily temperature has been shown to affect the movement activity of *Trichogramma* sp. (Fournier and Bovin, 2000; Suverkropp *et al.*, 2001). Temperature has a profound influence on the survival and dispersal of *T. chilonis* in the field and seasonal variation in parasitism rates due to change in temperature has been reported by many workers (Brar *et al.*, 2000; Muhammad *et al.*, 2004; Nadeem *et al.*, 2009; Singh and Shenhmar, 2008; Sohi *et al.*, 1996).

Importance of this study in the light of inundative releases Insect dispersal has been and will always be a study under the realm of ecologists. However, this knowledge of insect dispersal may be of greater importance in the insect management tactics (Stinner *et al.*, 1983) and for a biocontrol advocate, it becomes a prerogative as well as a prerequisite while formulating an inundative release program. As narrated in the text there are several factors affecting the movement of this parasitoid in the field. Understanding the dispersal capacity and dynamics is important in terms of developing effective release techniques and for predicting the efficacy of releases (Wright *et al.*, 2001). While inundative releases rely on rapid dispersal and uniform coverage of the target area (Chapman, 2007), limited dispersal ability may be an impediment for parasitization efficacy but fine-tuning of release rates and number of release points might adequately compensate that. Mills (2003) had suggested that either more frequent releases, or an extended period of emergence of adult parasitoids from each release, could increase the efficacy of *Trichogramma* inundation to compensate the lower dispersal. Based on the findings from the current study, we understand that the released parasitoid move only up to 10 m effectively and restrict their parasitization up to 3 days in the field though the presence of host plant cues and complexity of architecture could have either added or diminished these results further. Because host location by *Trichogramma* sp., is influenced by structural complexity but with time they seem to be nullified. So with the present results, it can safely be assumed that the number of the release points is to be at least 13 per ac for uniform high distribution resulting in good dispersal and thus host parasitization. Release of parasitoid cards containing differential emergence of adults would be another efficient alternative for ensuring presence of parasitoid in a temporal continuum for efficient pest management.

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