
*Journal of Biological Control*, 24 (1): 22–27, 2010

**Research Article**

# Differential parasitism by *Cotesia plutellae* (Kurdjumov) on *Plutella xylostella* (L.) in artificially infested host plants

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**ABSTRACT**: The parasitic potential of *Cotesia plutellae* (Kurdjumov) on diamondback moth larva was studied under laboratory and field conditions. The results revealed that the parasitism under field conditions was 27% lower than the caged laboratory conditions. Cauliflower, cabbage and mustard plants were more attractive to the gravid females establishing 56%, 53% and 45% parasitism, respectively, compared to other tested host plants. These were followed by Brussels sprout and broccoli. Lowest level of parasitism was recorded in knol-khol and kale under both field and caged laboratory conditions. The role played by host plants, herbivore induced volatiles and larval byproducts as well as the phyllotaxy of host plants in sheltering the host larvae are implicated for the observed variation in parasitism and discussed in a tri-trophic context.

**KEY WORDS**: *Cotesia plutellae*, larval parasitoid, parasitism, *Plutella xylostella*, field efficiency, host plant volatiles, biological control

(Article chronicle – Received: 23.11.2009; Sent for revision: 25.01.2010; Accepted: 07.02.2010)

## INTRODUCTION

The diamondback moth, *Plutella xylostella* (L.), is one of the most serious pests of cruciferous crops in many parts of the world. In India, cultivation of winter vegetables of the family Cruciferae such as cabbage, cauliflower, knol-khol, broccoli, Brussels sprout, kale and oil seed crops like mustard and rape is threatened by diamondback moth infestation with varied levels of incidence from season to season. Generally the incidence of *P. xylostella* on these crops occurs during the months from October to January depending upon the availability of host plants, accompanied by the specialist parasitoid, *Cotesia plutellae* (Kurdjumov) in Delhi region. Sachan and Gangwar (1990) have reported damage to an extent of 52% on these crops in Shillong region by this pest alone. In Southeast Asia, major outbreaks of *P. xylostella* reportedly caused more than 90% crop losses (Verkerk and Wright, 1996). In Punjab Kandoria *et al*. (1996) have reported varying levels of parasitism of DBM larvae by *C. plutellae*.

Volatile semiochemicals are known to mediate various interactions between organisms belonging to different trophic levels, which include phytophagous insects, their parasitoids and predators (Vet and Dicke, 1992). Several parasitoids and predators are known to use volatile infochemicals that are emitted by herbivore–plant complexes while searching for their host and prey (Takabayashi and Dicke, 1996; Turlings and Fritzsche, 1999). The behaviour of natural enemies is greatly influenced by the diverse semiochemicals present in a given ecosystem. Plant genotype alters the quality and quantity of allelochemicals released in any ecosystem by the plant and also the infochemicals released by host insects (Paul and Yadav, 2002; Paul, 2003).

Valuable information is available on various aspects of foraging behaviour of *C. plutellae* in individual host plant-herbivore-systems (Bogahawatte and Van Emden, 1996; Potting *et al*., 1999; Shiojiri *et al*., 2000; Jiang *et al*., 2001; Shiojiri *et al*., 2001; Wang and Keller, 2002; Liu and Jiang, 2003). However, the parasitic potential and foraging behaviour of *C. plutellae* on diamondback moth on a series of artificially infested host plants under open field conditions have not been reported earlier. Further, the literature on the tri-trophic interaction of this specialist parasitoid in an ecosystem comprising several host plants is very limited. Hence, the objective of the present study was to compare and assess the parasitism inflicted by *C. plutellae* on its host larvae infesting various host plants under laboratory and field conditions. The results could be useful in the formulation of control strategies against the diamondback moth.

## MATERIALS AND METHODS

*Host plants and host insects*

The cruciferous host plants of diamondback moth were grown in the research farm of Indian Agricultural Research Institute, during Oct-Jan season 2004-05. Breeder seeds of host plants selected for this study were obtained from National Seeds Corporation, New Delhi, Horticultural Research Station - Katrain [HP] and Division of Vegetable Science, IARI, New Delhi. The seedlings of most suitable local varieties – cabbage (Golden acre), cauli-flower (Pusa snowball- K-1), broccoli (Pusa KTS-1), knol-khol (White Vienna), Brussels sprout (Hilds ideal), kale (Red Russian kale) and mustard (Pusa bold) were grown in a nursery for 25-30 days and transplanted in discrete experimental plots of 4 x 4m size with the application of recommended fertilizers suitable for local conditions. The diamondback moth, *P. xylostella* was maintained on cabbage / cauliflower leaves in the culture room at 27 ± 1°C and 60-70% RH, 10L:14D photoperiod in open trays at the Biological Control Laboratory, IARI, New Delhi, as per Seenivasagan (2001). The host plant leaves were picked at active vegetative stage to maintain the diamondback moth culture.

*Parasitoids*

The nucleus culture of *C. plutellae* was obtained from the Project Directorate of Biological Control (PDBC), Bangalore. Two/three pairs of parasitoid wasps were kept overnight for mating in a Perspex glass cage (30 x 30 x 30 cm size) and offered with second and third instar larvae of diamondback moth for parasitization for about 24–48 hours as described by Potting *et al*. (1999), with slight modifications. The adult parasitoids were fed with 10% glucose / honey solution, pollen and opened raisins. Parasitized larvae were transferred to new trays after 48 hrs and reared following normal rearing procedure till the formation of parasitoid pupae in silken cocoons on the leaf surface. The pupae thus formed were collected and stored in a refrigerator at 10°C till further use. Upon emergence, the adults were examined under a binocular microscope for the segregation of the females and males for further multiplication and use in experiments.

*Laboratory experiments on parasitism*

The parasitic potential of *C. plutellae* was studied in Perspex glass (30 x 30 x 30cm size) cages and in each cage, two pairs of freshly emerged male and female parasitoids were left overnight for mating. After 24 hrs, the gravid females were offered a fixed number of uniformly grown second and third instar larvae which were fed on different host plants for parasitism for 24 hours. In each experimental day approximately 135-150 larvae sandwiched between two/three leaves were offered to the parasitoids and this constituted one replicate. The petiole was soaked in wet cotton wrapped with aluminum foil to maintain the turgidity of leaves. The next day, parasitized larvae along with leaves were removed from the cage and transferred to rearing trays. The experiment was repeated for three days with different wasps to obtain three replicates for each host plant. The parasitoids which were utilized in one trial were not used in subsequent experiments and the new trial was set again with naïve individuals under a similar set up. Similar experiments were carried out on the other host plants with a fresh set of parasitoids to assess the parasitic potential on different host plants. The per cent parasitism for a particular host plant in a replicate was calculated by using the formula.

$$\%\ \text{parasitism} = \frac{\text{Number of parasitoid pupae recovered}}{\text{Total number of host larvae offered}} \times 100$$

*Field experiments on parasitism*

The host plants were transplanted in discrete blocks in three replicates with 45 x 30cm spacing in plots of 2 x 2m size in a randomized block design with the application of recommended fertilizers suitable for local conditions. Each block contained all the seven host plants transplanted in discrete plots in a randomized manner in such a way that no two plots of adjacent blocks had the same host plants in a row. Mustard was sown in the field with 30 x 15cm spacing; and the plants were thinned during the experiments. In an experimental day to obtain one replicate, one plant each in three discrete blocks from each host plant was selected for artificial infestation. The stem of each plant selected for the study was encircled by placing a paper underneath the foliage on the ground to mark the infested plants as well as to observe the fallen larvae. Host plants in the growing stage with 5-7 leaves after transplanting were artificially infested with approximately 100-125 numbers of second and /or third instar larvae of DMB released onto the foliage of plant at 0800 hrs for parasitism by the field population of *C. plutellae*. After 24 hrs the larvae present on the artificially infested plants were collected and observed for parasitism (measured in terms of formation of parasitoid pupa) by rearing the larvae under normal laboratory conditions. The emerging adults were examined for identification and confirmation as *C. plutellae*. Three repetitions of the experiment were performed and the per cent parasitism was calculated from the number of parasitoid pupae recovered from the field collected larvae in the designated host plants.

*Statistical analysis*

The per cent parasitism values recorded in the laboratory and field experiments were subjected to square root transformation for one-way ANOVA using SPSS 10.0 software. The differences between mean parasitism by *C. plutellae* observed on different host plants were separated by least significant difference (LSD) test. Subsequently, paired t-test was used to compare the parasitism on DBM larvae on individual host plants under laboratory and field conditions.

## RESULTS AND DISCUSSION

The mean parasitism by *C. plutellae* in cage experiments ranged from 50 to 86% with an average of 69%, which was 27% higher than the parasitism observed under field conditions. The mean parasitism by *C. plutellae* differed significantly ($F = 25.3$, $df = 20$, $P < 0.001$) on different host plants under laboratory conditions. A maximum of 85% host larvae were parasitized by *C. plutellae* on mustard and cauliflower leaves followed by Brussels sprout and cabbage with 78% and 71% parasitism of DBM larvae. As per Fig. 1, the parasitism, on broccoli and knol-khol was on par. The parasitism on knol-khol and kale was on par. Kester and Barbosa (1994) presumed that host diet may influence the long-range foraging behaviour of parasitoids; however, this contradicts the studies of Geervliet *et al*. (1996) who reported that the preferences of *Cotesia glomerata* were independent of the food plant on which the host had been feeding.

In the present study because of limited space in the laboratory cage experiment, the movement of the host larva was restricted due to which the foraging ability of the parasitoid could have improved to the highest possible extent. The specific host environment in which the parasitoid developed could have influenced the behavioral responses of the adult. In addition, the concentration of volatiles released from the host plants into the cage by herbivore feeding and the preference of *C. plutellae* for its host related odors could have resulted in increased amount of parasitism inside the cages.

We observed that the gravid females upon release into the cages quickly oriented toward the host damaged sites and upon reaching the herbivore damaged sites gravid females exhibited rapid antennation and vigorous searching at the feeding site. In many instances, herbivore produced chemicals are obviously the most reliable source of information about herbivore presence and identity but this information is presumably not detectable at a distance (Steinberg *et al*., 1993). Further the availability of host larvae per unit area enhanced the parasitic potential of the parasitoid by which the giving-up time (i.e. the time spent by the parasitoid for searching the host in its habitat) in a patch of host larvae on the leaf surface also increased.

In general, the overall parasitism of DBM larvae by *C. plutellae* under field conditions was 27.0% lower than caged conditions. Significant differences were observed ($F = 10.1$, $df = 20$, $P < 0.001$) in the field parasitism on different host plants. Under field conditions, the parasitization of diamondback moth larvae by *C. plutellae* was highest on cauliflower, cabbage and mustard (56.0, 53.0 and 45.0%, respectively) compared to other host plants. Parasitism values on Brussels sprout and broccoli were on par with those on cabbage and mustard, while knol-khol and kale recorded lowest level of parasitism (Fig. 2). The observed difference was possibly due the phyllotaxy of host plant species selected, their leaf characteristics, and the ability of larva to move from one

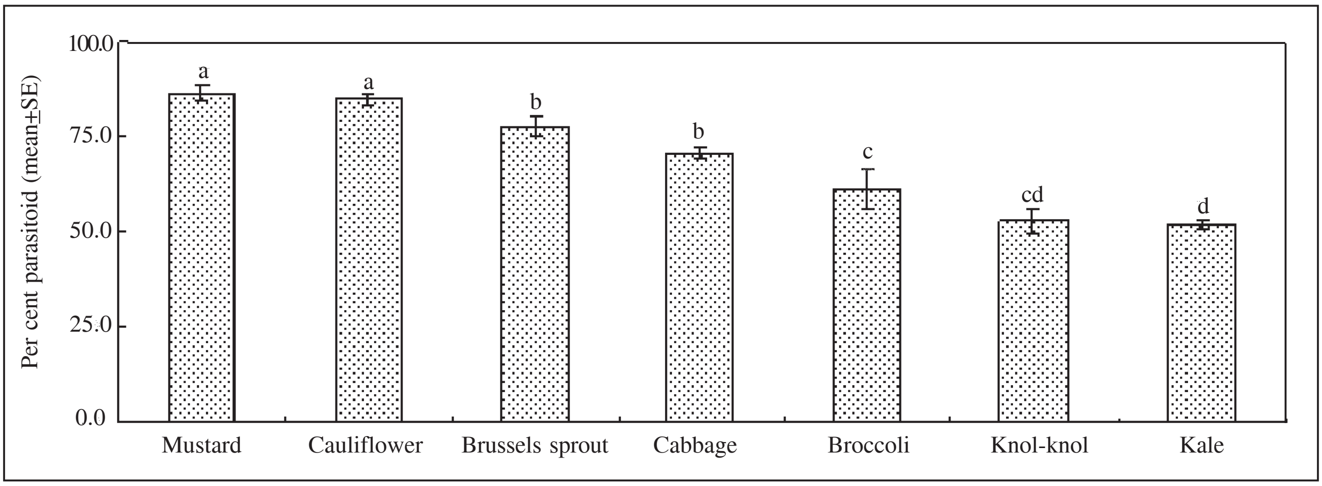


**Fig. 1. Parasitic potential (mean ± SE) of *Cotesia plutellae* on diamondback moth larvae under laboratory conditions arranged in descending order of parasitism. Data are mean values of three replicates for each host plant. Bars marked by different letters are statistically significant (n = 3, P < 0.001)**

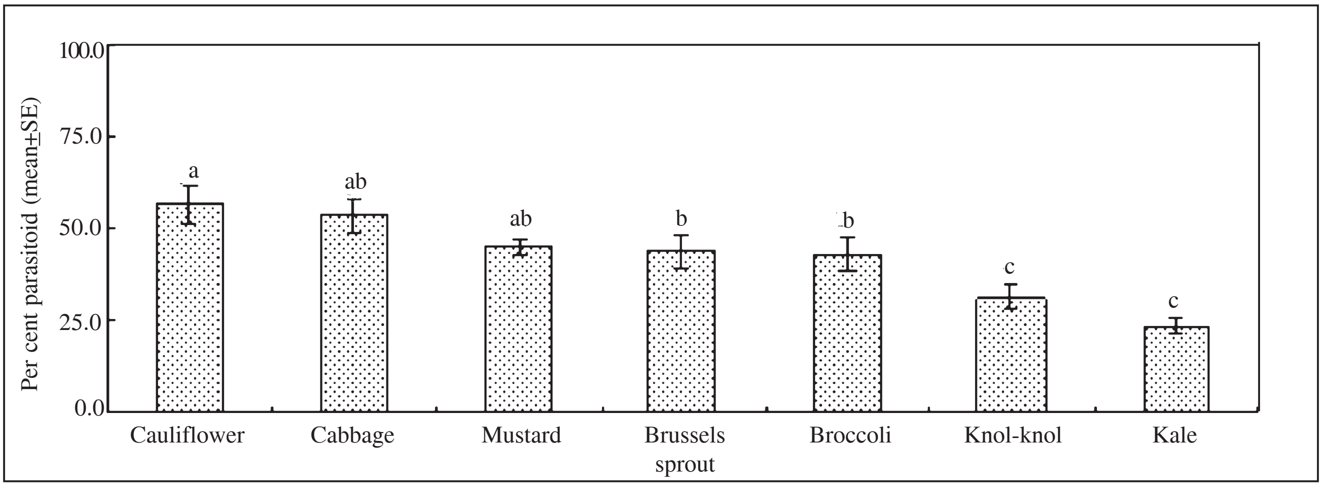


**Fig. 2. Parasitic potential (mean ± SE) of *Cotesia plutellae* on diamondback moth larvae under field conditions arranged in descending order of parasitism. Data are mean values of three replicates for each host plants. Bars marked by different letters are statistically significant (n = 3, P < 0.001)**

plant to another plant by hanging down using silk thread at the time of parasitoid attack. Further, the distribution of larvae, host density per unit area of leaves in selected plants and other associated mortality factors also play a role in the parasitoid efficiency.

Parasitoids may use non-specific plant volatiles as long-range cues to lead them to the general area where they are likely to find the herbivore feeding on a plant. Once they have located such an area, wasps may rely on more specific cues such as host frass, mandibular secretions, larval exudates, etc. to find their hosts (Turlings *et al*., 1991; Cortesero *et al*., 1997). The increased level of parasitism observed on cabbage and cauliflower is presumably due to the arrangement of leaves in a closed manner compared to other host plants which possess relatively open leaf arrangement. The escape of larvae from a plant having closed/ encircled leaves is expected to be minimum compared to the plants having open type. Further, the varying level of parasitism in the field can also be attributed to the number of parasitoids foraging over the test plant, interference by attractive volatiles from other host plants and the decision of the parasitoid to land on a most profitable host patch. However, the artificial introduction of host larvae in huge numbers on a single plant projected the profitability of that particular plant among others.

In addition to these factors the ability of *C. plutellae* to learn odors that are associated with hosts may help the parasitoids in general to detect subtle differences between these cues and other non-profitable cues (Turlings *et al*., 1995). It is evident from our results that on cabbage and broccoli there was no significant difference (t = 3.13,

**Table 2. Comparison of parasitism by *Cotesia plutellae* on *Plutella xylostella* larvae in caged laboratory and open field experimental conditions**

| Host Plants | Laboratory parasitism (LP) % | Field parasitism (FP) % | Difference in parasitism (LP-FP) % | t-value | P Value |
|---|---|---|---|---|---|
| Cabbage | 70.8 ± 1.4 | 53.3 ± 4.3 | 17.6 ± 5.6 | 3.125 | 0.09NS |
| Cauliflower | 85.0 ± 1.5 | 56.3 ±5.2 | 28.6 ± 5.7 | 5.040 | 0.04* |
| Broccoli | 61.2 ± 4.9 | 42.8 ± 4.6 | 18.4 ± 6.8 | 2.715 | 0.11NS |
| Knol-khol | 52.8 ± 3.1 | 31.0 ± 3.3 | 21.8 ± 5.1 | 4.293 | 0.05* |
| Brussels sprout | 77.7 ± 2.7 | 43.5 ± 4.6 | 34.3 ± 3.7 | 9.271 | 0.01** |
| Kale | 51.9 ± 1.3 | 23.4 ± 2.1 | 28.5 ± 3.1 | 9.184 | 0.01** |
| Mustard | 86.3 ± 1.9 | 44.9 ± 2.3 | 41.4 ± 2.9 | 14.134 | 0.01** |

Values are mean ± SE of three replicates, compared by paired *t-test*; treatments are significant (*P < 0.05, **P < 0.01, NS-not significant) df = 1, P > 0.05) between parasitism by *C. plutellae* under laboratory and field conditions (Table 2), whereas cauliflower and knol-khol recorded 28% and 21% reduced parasitization ($P < 0.05$), respectively, in the field. Although, mustard was the most preferred host plant for DBM, a highly significant 41% reduction in field parasitism by *C. plutellae* was noticed. Similarly parasitism in Brussels sprout and kale plants was significantly reduced ($P < 0.01$) compared to laboratory conditions.

The present study documents certain evidence for the apparent influence of host plant cues on the parasitic potential of *C. plutellae*. The significant difference in the level of parasitism in both laboratory and field condition reveals the ability and foraging preference of this wasp on its host. Nevertheless, the role of stimuli from different trophic levels in various phases of the host searching process is determined by the parasitoid's degree of specialization on the first and second trophic level as well as its ability to learn and associate the cues of most profitable plant–herbivore complex to effect maximum damage on the pest population. The behaviour of specialist wasps may be better adapted to specific stimuli from the plant–host complex as a result of close association with their hosts to improve their parasitic efficiency.

## ACKNOWLEDGEMENTS

We are grateful to IARI and CSIR for granting Merit Scholarship & Senior Research Fellowship, respectively, during the period of study. We thank all the members of the Biological Control Laboratory for their help in maintaining cultures of host insects and parasitoids. The help received from NCIPM for statistical analysis of research data is sincerely acknowledged. We are thankful to the Director, IARI and Head, Division of Entomology for providing the required facilities.

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