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Influence of Habitats on the Percent Parasitism of Diamondback Moth (Lepidoptera: Plutellidae) Larvae by *Diadegma insulare* (Cresson)(Hymenoptera: Ichneumonidae)

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Abstract: The influence of habitats on the percentage parasitism of diamondback moth larvae, *Plutella xylostella* L. by *Diadegma insulare* was studied. Percent parasitism was significantly different among habitats. Parasitism occurred in all habitats with the exception of centre of the woodland. This suggested that *D. insulare* was very mobile in the heterogeneous habitats. Percent parasitism was high in most crop and non-crop (only when *Daucus carota* L. is present in the majority of plants) habitats, however, it was significantly influenced by the interaction between habitats and times (months or years) of observations conducted. The percentage parasitism decreased as the distance of treatments in corn fields, from the field edge increased, suggesting that the corn field is not the primary habitat for *D. insulare*. The possible effect of polyculture systems on the impact of *D. insulare* in diamondback moth management program is discussed.

Key words: Habitat, *Diadegma insulare*, diamondback moth, percent parasitism, parasitoid

Introduction

Gould & Stinner (1984) defined habitat as the physical area encompassing the resources that support the existence of an individual insect or insect population for a specific time.
Habitats can influence the population size and distribution size of the pest, and its parasitoids (Cromartie, 1975a & b, Hawkin & Sheehan, 1994). Vinson (1985) outlined that habitat preference and the potential of host community location within the habitats are two of the nine steps necessary for successful parasitism. He also suggested that the interactions between the host's habitat and the parasitoid depend on the active behavioral and the physiological aspects of the parasitoids. A study conducted by Landis & Haas (1992) indicates that the microclimate of habitats, particularly in warm years, influences the movement and behaviour of *Eriborus terebrans* (Gravenhost)(Hymenoptera: Ichneumonidae), a parasitoid of European corn borer, *Ostrinia nubilalis* (Hübner)(Lepidoptera: Pyralidae). Dyer & Landis (1997) and Sato & Ohsaki (1987) reported that the effects of habitat on parasitoid's parasitism activity varied as the season progressed. Types of vegetation within or between habitats also affected parasitism by *Cotesia* (= *Apantales*) *glomeratus* L. (Sato & Ohsaki, 1987).
Habitat heterogeneity is defined as the environment being composed of significantly different parts within a particular landscape (Gould & Stinner, 1984). The effects of habitat heterogeneity on the predator-prey dynamics are subjected to specific dispersal behaviour of the predator and prey (Kareiva, 1987). Landis and Haas (1992) reported that the effectiveness of *E. terebrans* was influenced by the local landscape mosaic, including proximity of particular crops or non-crops with the host habitats. The structures of landscape also influence the spatial distribution of adult food resources for this wasp (Landis, 1993). Non-host plants in the heterogeneous habitat of poly-culture agroecosystem can affect the movement of herbivores and their natural enemies (Sheehan, 1986; Andow, 1988; Lawrence & Bach, 1989).
The specialist parasitoids might be less abundant in the structurally complex poly-culture than in structurally simple mono-culture; chemical cues used in host finding will be disrupted and parasitoids will be less able to find hosts, therefore, they are more effective in less diverse agroecosystem (Sheehan, 1986; Andow & Prokrym, 1990). *Diadegma insulare* (Cresson) (Hymenoptera: Ichneumonidae), the major parasitoid of diamondback moth, used nectar sources from certain wildflowers that grew in different habitats (Idris & Grafius, 1995). Differential temperature in habitats may affect *D. insulare*'s fecundity, longevity and day-time flight activity which indirectly determines the parasitism rate (Idris, 1995). The objective of present study was specifically to investigate the influence of habitats on the percentage parasitism of diamondback moth by *D. insulare*.

Materials and Methods

Study was conducted at the Michigan State University Research Field, East Lansing, Michigan, during the summers of 1992 through 1994. The habitats used were; bean, tomato, corn and alfalfa fields, apple orchard, weedy areas, and the center and edge of woodland (Fig. 1). Not all of these habitats were used in each observation because they were not available during the experimental periods. Weedy areas used in 1992, had > 50% *Daucus carota* L. but only two replicates of weedy areas used in 1993, had relatively similar density of *D. carota* as in 1992. Weedy areas were not used as tested habitat in 1994 because there were only two small weedy areas available until August.
Greenhouse grown broccoli plants, *Brassica oleracea* var. *italica* (L.) cav. 'Green Comet' raised in pot were used for the study. At two months age each broccoli plant per plot was infested with 10 second and third diamondback moth instars. Infested plants were kept in the greenhouse for 18 to 20 h before placing in various habitats (= treatments).

Among Habitats: Twenty infested broccoli plants per habitat (five pots of broccoli plant per replicates = 50 larvae) were placed between 0900 and 1000 h on 10, 5 or 12 August of 1992, 1993 and 1994, respectively, for 28 - 30 h. We added new diamondback moth larvae for plants that had less than 10 larvae per plant, when setting out the plants to each habitat. Each treatment was replicated four times. Twenty larvae (per replicate) were collected between 1400 h and 1600h the next day. Larvae were placed in 14.5 cm diam. petri dish with 3 cm diam. screen lid on the cover (20 larvae per dish per

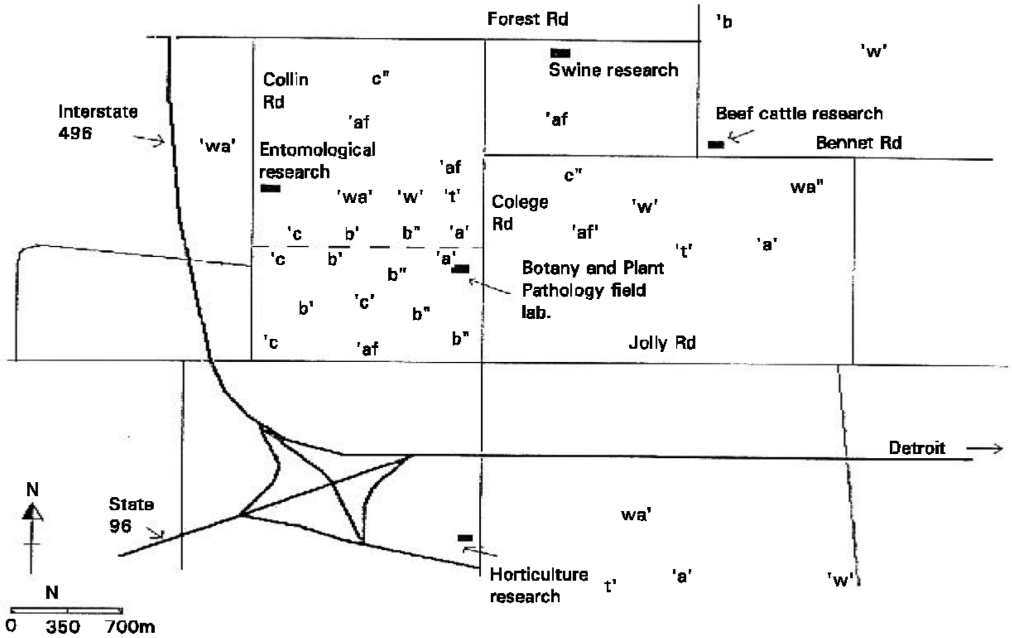

Fig. 1: Location oif habitats (a, apple, af, alfalfa, b, beans, c. Corn, t. Tomato, w, woodland, wa, weedy areas) at Michigan State University Research Farm selected for the study. The habitats used in different years were marked as ---" (1992 and 1993), '_' (1992 to 1994) , _' (1993 and '_ (1194. For example, habitat apple used in 1992 to 1994 was designated as 'a'.

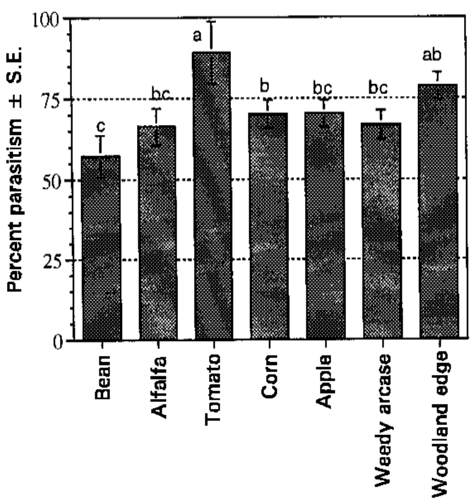

Fig. 2: Percent parasitism of diamondback moth larvae by D. Insulare in various habitats on 11-12 August 1992. In corn field treatment was placed ± 30 m from field edge. Bars with different lertter are significantly different (Fisher's Protected LSD, _<0.05)

replicate) and brought to the laboratory. Larvae were fed broccoli leaf grown in the greenhouse, kept at 25 ± 2°C and a photoperiod of 16: 8 (L : D) h until pupation. The numbers of *D. insulare* and diamondback moth pupae formed were recorded. Diamondback moth larvae were not dissected for parasitism determination because no parasitoid's eggs were encapsulated (Idris, 1995; Bolter & Laing, 1983).

Within habitat of non-host plant (corn fields): To determine within field influence on the parasitism of diamondback moth larvae by *D. insualre* a similar experiment was conducted on the same corn fields as before on 13 -14 August 1994. However, the infested potted broccoli plant was placed inside the corn field at the distance of 50, 100, 200 and 500 m (treatments) from the field edge.

The percentage parasitism of diamondback moth by *D. insulare* was calculated following Idris and Grafius (1993). The percentage of parasitism among habitats, and at different habitats versus months (July - Septembers each year) or years (for apple and corn fields, and woodland edges) were transformed using arcsin before analyzed by 1-way or 2-way ANOVA, respectively. We did not analyze the effect of all habitats on the percentage of parasitism over times (years or months except for apple orchard and woodland edge habitats) because certain habitats were not available in certain years. The Fisher's Protected LSD (Abacus Concepts, 1991) was used to separate means when only main effect was significant. We used simple regression to analyze the percentage of parasitism at different distances from the edge of corn field (Abacus Concepts, 1991).

Results and Discussion

Among habitats: Percentage parasitism was significantly different among habitats in all sampling dates (Fig. 2 to 4). In August 1992, percentage parasitism ranged from 55% (bean) to 89% (tomato)(Fig. 2). Except at the woodland edge, the percentage of parasitism was significantly higher in the tomato than in the other habitats (79%)(Fisher's Protected LSD, $P < 0.05$).

In 1993, parasitism ranged from 3% (woodland edge) to 87% (corn fields)(Fig. 3A to C). The percentage parasitism was somewhat higher in most crop habitats than in weedy areas (Fig. 3A & B). Except on 13 - 14 September, parasitism in

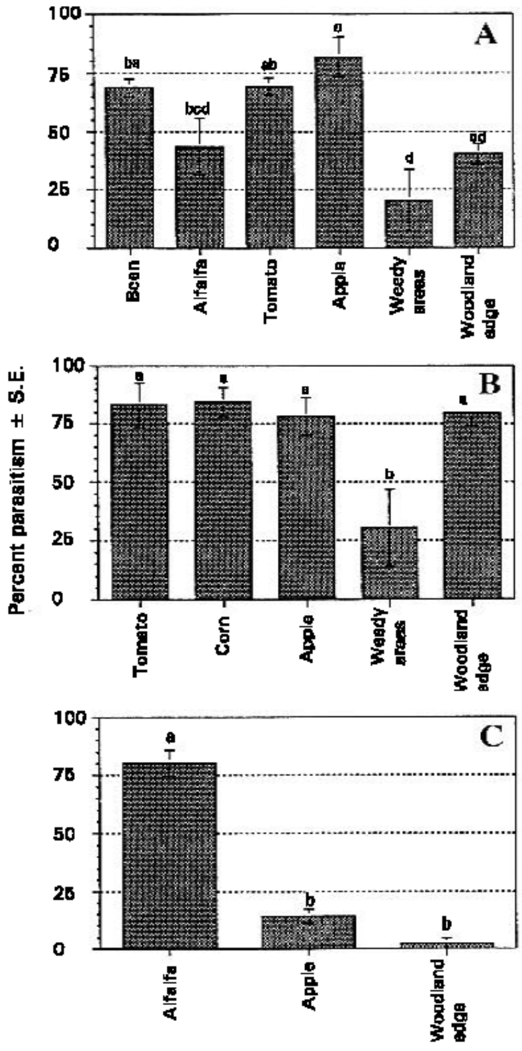

Fig. 3: Percent parasitism of diamondback oth larvae by D. Insulare in various habitats on 23-24 July (A), 15-16 August (B) and 13-14 September 1993 (C). In corn field treatment was placed ± 30 m from field edge. Bars with different letter are significantly different (Fisher's Proteceted LSD, P<0.05)

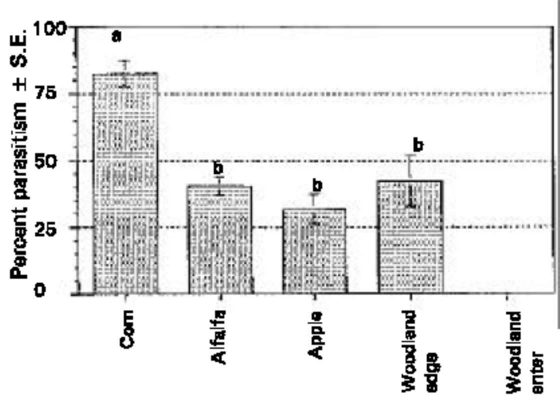

Fig. 4: Percent Parasitism of diamondback moth larvae by D. Insulare in various habitats on 12-13 August 1994. In corn jfield treatment was placed ± 30 m from field edge. Bars with different letter are significantly different (Fisher's Protected LSD, P<0.05)

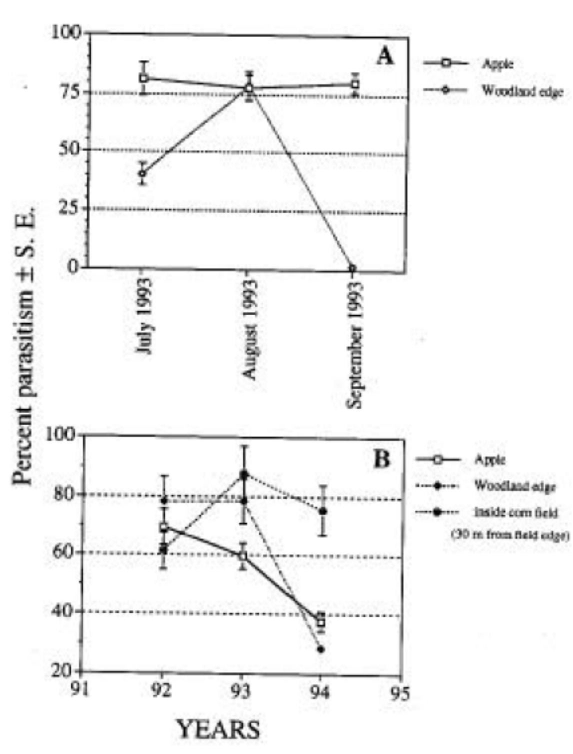

Fig. 5: Percent parasitism of diamondback larvae as affected by the interacetion between habietats and kmonths in 1993 (A) and years (B).

crop habitats registered between 70 to 87% (Fig. 3A to C) which is as high as in the nearby broccoli field (85-93%)(unpublished data), the main habitat of the parasitoids and its host. The apple orchard, the only crop habitats used in three sampling dates, had consistently high rate of parasitism (76-81%). Parasitism rate in the non-crop habitats (woodland edge and weedy areas) was low except on 13-14 September 1993 (Fig. 3B) where parasitism at woodland edge was as high as in the crop habitats.

On 12-13 August 1994, percent parasitism was significantly higher in the corn field (80%) than in the other habitats (0-40%)(Fisher's PLSD, $P < 0.05$)(Fig. 4). There was zero parasitism recorded in the center of the woodlands.

The percentage parasitism was significantly affected by the interaction between habitats and times (month: $F = 24.4$, df = 2 & 8, P = 0.001; year: F = 14.4, df = 4 & 27, $P = 0.001$)(Fig. 5 A & B). Parasitism rate at the woodland edge was significantly lower on July and September than in August 1993 (Fisher's PLSD, $P < 0.001$)(Fig. 5 A). On August 1994, parasitism was generally higher in the corn field than in the other habitats (Fig. 5 B).

Within habitat of non-host plant (corn fields): There was a significant relationship between percentage parasitism of

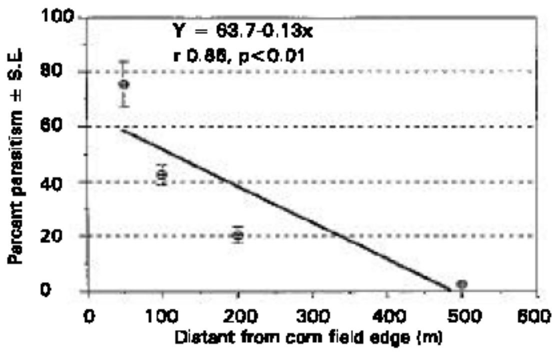

Fig. 6: Relationship between percent parasitism of diamondback moth larvae by D. Insulara and distance from the corn field edge

diamondback moth larvae and the distances of larvae placed in the corn field from field edge (r = 0.86, df = 1 & 14, $P < 0.001$)(Fig. 6). The differences in distant of the treatments explained 74.5% variation in the percentage of parasitism of diamondback moth larvae by *D. insulare* (decreased as the distances of the treatments from the edge into the corn field increased).

As a kionobiont parasitoid, *D. insulare* may have a restricted host range in a simple habitat within a particular landscape (Askew & Shaw 1986). Therefore, it has to be very mobile in the heterogeneous habitats to find its alternate hosts. This explains why the parasitism of diamondback moth larvae by *D. insulare* occurred in all habitats except in the center of the woodland (Fig. 2 to 4).

The percentage parasitism in most crop habitats (corn, tomato, bean, and apple) was consistently high (55 - 80%) for all sampling dates except on 13-14 September 1993 and 12-13 August 1994 for apple, and 12-13 August 1994 for alfalfa (Fig. 2, 3 A to C & 4). This suggests that all crop habitats are not suitable for *D. insulare* parasitism activity. However, parasitism was highly variable in non-crop habitats, woodland edge (3 - 80%) and weedy areas (20-69%). Factors such as the presence of food sources in non-crop habitats in certain years may caused the variation in percentage of parasitism. *D. insulare* diurnal activity such as host and food finding could be optimized in the more suitable habitats that determine the parasitism rate. In addition, there may be an alternate host of *D. insulare* in these habitats. Other diamondback moth parasitoids, *D. semiclausum* and *D. fenestrale* (Holmgren) (Hymenoptera: Ichneumonidae), are reported to parasitized certain tortricids of apple orchard as their alternate host for over wintering (Hardy, 1938). The parasitism of diamondback moth larvae in tested habitats may also depend on the *D. insulare* entering after the placement of the larvae.

Parasitism in woodland edge was highly variable at least in part because of the variability in this habitat. In August 1992 and 1993 when parasitism was high, *D. carota*, one of the best wildflowers for nectar source for *D. insulare* females (Idris & Grafius, 1995), was at peak flowering. In contrast, on July or September 1993, *D. carota* was just begun to flower or started to decline. In August 1994, however, *D. carota* was less abundant in Michigan State University Research Farm including along the woodland edge than in August 1992 and 1993 (Fig. 2, 3B & 4). The low number of *D. insulare* presence in woodland edge with less or no *D. carota* and dependency on the *D. insulare* entering this area after treatment was in placed for parasitism to occur explain why the parasitism was low. A cloudy day on the sampling dates may also cause low parasitism in August 1994 than in August 1992 or 1993, a partially sunny or sunny day. Diurnal flight activity of *D. insulare* is reported to depend on the amount of day light intensity (Idris & Grafius, 1998). The presence of shrubs in the woodland edge may further reduce the light intensity and disrupt *D. insulare* visual cues and parasitism rate during the cloudy day although it may serve as a shelter for the parasitoid during a hot-sunny day.

Parasitism in weedy areas was also highly variable probably due to habitat variability. The weedy areas used for study in August 1992 (Fig. 2) had 50 - 70% *D. carota* (parasitism was 78%). In July and August 1993, there was only one replicate that had a density of *D. carota* similar to August 1992 (Fig. 2, 3 A & B). Whilst other replicates had no *D. carota* but Asteraceae weeds plus grasses (primarily *Agropyron repens* (L.) Beauv). As a result the average parasitism rate in weedy areas was just 28%. The percentage parasitism ranged from 10% in the replicate with *A. repens* to 75% in replicate with 50 - 70% *D. carota*.in July and August 1993 respectively. This variability is shown by the high standard error of the mean for percent parasitism (Fig. 3A & B).

On 12-13 August 1994, percent parasitism in the apple orchard and along the woodland edge is somewhat lower than the parasitism in these habitats in August 1992 and 1993 (Figs. 2, 3 A & B, 4). This is probably due to lack of visual cues for *D. insulare* to locate its host or they were not active in the cloudy day as discussed before. Low light intensity in the center of the woodland may hinder *D. insulare* to fly in as shown by zero catch by the sticky trap (Idris & Grafius, 2001). This partly explains why there was no parasitism recorded when larvae were placed in the center of the woodland as compared with along the woodland edge (Fig. 4). The impact of light intensity on visual cues used by parasitoids, *Diadegma semiclausum* (Hellen) and *Campoletis sonorensis* (Cameron)(Hymenoptera: Ichneumonidae), in host finding and location also reported by Talekar & Yang (1991) and McAuslane *et al.* (1991). In Indonesia, however, Hymenoptera parasitica were found more inside than along the woodland edge (Noyes, 1989).

Fluctuation in day temperature, light intensity and wind speed is reported to influence the diurnal flight activity of *D. insulare* (Idris & Grafius, 1998). The changes in values of particular habitats for *D. insulare* over time, habitat's composition, the presence of wildflowers and over shadows vegetation affected parasitism rate. *Apantales glomeratus* L. (Hymenoptera: Braconidae) responds similarly. *A. glomeratus* female host habitat location is disrupted by overshadowing vegetation on the host plant causing low parasitism of *Pieris rapae* L. (Sato & Ohsaki 1987). Present results suggest that certain habitats are suitable for *D. insulare* parasitism activity. However, their suitability is subjected to the interaction between habitats and the environmental conditions at any particular time of the year.

The decrease of parasitism rate as the distance of treatments from the corn field edge increased indicates that corn field was not a suitable habitat for *D. insulare*. Probably, there was lack or no alternate hosts for *D. insulare* in the corn field. *D. insulare* presence may be associated with food finding activity or for temporary stay during the hotter time of the day especially near the field edge. The need of shelter is also indicated by the high numbers of *D. insulare* caught along the woodland edge with shrub trees than in the weedy areas (Idris & Grafius, 2001).

Of all crop habitats, parasitism was highest in the tomato field, indicating that tomato plants have no adverse effect on *D. insulare* parasitism activity. The parasitism rate of diamondback moth by *Cotesia plutellae* (Kurdjumov) (Hymenoptera: Braconidae), another important larval parasitoid of diamondback moth, was also not affected by the presence of tomato plants in *Brassica* field in Hawaii (Bach & Tabashnik, 1990). Talekar & Yang (1991) reported that the parasitism rate of diamondback moth larvae by *D. semiclausum* in *Brassica* crop planted in poly-culture (soybean, egg plant, corn, sweet potato, garden pea, tomato, garlic, okra and cabbage) was not different from parasitism rate in the mono culture *Brassica*. Their results clearly supported our finding. In view of this fact, Sheehan (1986) and Andow & Prokrym (1990) hypothesized that poly culture systems would restrict natural enemy's movement that cause them to become less effective biocontrol agent is not really true. Interestingly, tomato plants were found to disrupt the long range food plant finding by adult diamondback moth (Buranday & Raros, 1975). This effect can indirectly reduce the numbers of larvae and pupae per plant especially during the first 60 days after *Brassica* crops are transplanted to the field (Talekar *et al.* 1986). Therefore, mixed or poly culture is quite applicable in *Brassica* cropping system and tomato plant can be one of the crops that should be interplanted with *Brassica* crops. Other crops such as corn and apple when mixed with *Brassica* crops could provide refuges for *D. insulare* during the hottest time in the day.

The presence of an Umbelliferae weed (*D. carota*) within any habitat that can harbor *D. insulare* (Idris, 1995), serves as nectar source (Idris & Grafius, 1995) and indirectly would increase its parasitism rate. As such, these weeds could be interplanted within *Brassica* crops in a patch or between rows or around the field. Wild *Brassica*, *Brassica nigra* L. (Indian mustard), planted in one row per 15 rows of cultivated *Brassica* has been used as a trap crop in integrated diamondback moth management in India (Srinivasan & Krishna Moorthy, 1991). However, the techniques of interplanting wild Brassicaceae spp. or other non-Brassicaceae with cultivated *Brassica* crops need to further studied.

D. insulare and probably other parasitoids of diamondback moth may be more abundant at the field edge that normally provide plenty of food to the parasitoid than in the interior field. As such, the effect of field edge and size to the *D. insulare* population abundance, activity and parasitism rate need further investigation.

As a conclusion, the integration of factors that could optimize the impact of *D. insulare* to control diamondback moth should be emphasized in the *Brassica* ecosystem management. It could only be achieved with intelligent modification of the current *Brassica* crops field agroecosystem and field setting within any particular landscape. By doing so, the impact of other biocontrol agents on diamondback moth could also be increased.

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