DIAMONDBACK MOTH (LEPIDOPTERA: PLUTELLIDAE) INFESTATION AND PARASITISM BY *DIADEGMA INSULARE* (HYMENOPTERA: ICHNEUMONIDAE) IN COLLARDS AND ADJACENT CABBAGE FIELDS

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ABSTRACT

Two rows of collard greens (*Brassica oleracea var. acephala* L.) were planted between two cabbage fields in Bunnell, Flagler County, Florida in spring 1995. More larvae of the diamondback moth (DBM), *Plutella xylostella* (L.), were found on collard plants than on cabbage plants in the adjacent fields. The parasitism rate of DBM larvae collected from the collard plants reached 72% in early May and was higher than for larvae collected from the cabbage plants in adjacent fields. Parasitoids recovered from DBM larvae were mainly *Diadegma insulare* (Cresson). The damage to collard plants caused by DBM larvae was greater than on cabbage plants. At harvest, there was no significant difference in damage ratings of cabbage heads sampled near the middle of the field and damage to heads on rows nearest the collards. The results suggest that collard may have potential as a trap crop of DBM in cabbage fields, and that collard can play an important role in maintenance of the natural enemy, *D. insulare*.

Key Words: *Plutella xylostella, Conura side, Spilochalcis,* population regulation, *Brassica oleracea*

RESUMEN

Fueron plantadas dos hileras de acelga, *Brassica oleracea* var. *acephala*, entre dos campos de col en Bunnell, condado de Flagler, Florida, en la primavera de 1995. Fueron encontradas más larvas de *Plutella xyllostella* (L.) en las acelgas que en las coles de los campos adyacentes. Las tasas de parasitismo de las larvas de *P. xylostella* en la acelga alcanzaron el 72% a principios de mayo y fueron más altas que en la col. Los parasitoides recuperados fueron principalmente *Diadegma insulare* (Cresson). El daño causado por *P. xylostella* fue mayor en las plantas de acelga. En el momento de la cosecha, no hubo diferencia significativa en el daño de las coles muestreadas junto a las acelgas o en el centro del campo. Los resutados sugieren que la acelga podría tener potencial como cultivo trampa para *P. xylostella* en campos de col y puede jugar un papel importante en el mantenimiento de *D. insularis*.

The diamondback moth (DBM), *Plutella xylostella* (L.), is the most destructive pest of cabbage and other crucifers throughout the world. The annual cost for control of this pest is estimated to be U.S. $1 billion (Talekar & Shelton 1993). This pest typically has been controlled with pesticides (Shelton et al. 1993a). The diamondback moth, however, has become resistant to synthetic insecticides used against it in many countries (Shelton et al. 1993a, Talekar & Shelton 1993). In the USA, control failures have occurred in several states including Florida, Georgia, North Carolina, Texas, Wisconsin, and New York (Shelton et al. 1993b). Therefore, other control tactics, including biological control, cultural control and the use of pheromones (McLaughlin et al. 1994), should be integrated in the management strategy for this pest.

Cultural practices can be efficient and ecologically sound methods for control of DBM. Successful use of Indian mustard [*Brassica juncea* (L.) Czern] as a trap crop for management of DBM on cabbage has been recorded from India (Srinivasan & Krishna Moorthy 1992). Intercropping cabbage with garlic or tomato has been reported in Central America (Andrews et al. 1992), but substantial reduction of DBM infestation in cabbage has not been reported. In Hawaii, however, interplanting cabbage with tomato has shown significant reduction of larval density of DBM in cabbage (Bach & Tabashnik 1990). The objective of this study was to compare DBM densities, damage to cabbages, and larval parasitism on collard plants and cabbage plants in adjacent fields.

MATERIALS AND METHODS

Experimental Location

The cabbage fields used in the study were located in Bunnell, Flagler County, Florida. Cabbage seedlings (*Brassica oleracea var. capitata* L.) were planted into two adjacent fields 4 January (field B) and 20 January (field A), 1995, respectively. Two rows of collard seedlings (*Brassica oleracea var. acephala* L.) were planted between these two fields 27 January. Field B (5.26 ha) was on the north side of the collard rows, and field A (5.06 ha) was on the south side (Fig. 1). Cabbage and collard plants were planted in rows 0.76 m apart with 0.23 m plant spacing. The length of each row was 275 m.

Insect Sampling

DBM larvae (1st to 4th instars) on cabbage were sampled weekly beginning 17 January for field B and 9 February for field A; and the larvae and cocoons on collard plants were sampled beginning 13 March. The collards were sampled at 10 different sites, each 20 m apart along the rows. Six sites in a grid pattern were sampled in each cabbage field (Fig. 1). Three sites in a row were in each outer third (35 m from the edge) of the cabbage field, with 3 sites next to the collards and 3 sites at the opposite side of the field (away from the collards). The number of plants sampled at each site decreased as their size increased, from 65 cabbage plants the first wk to 13 the last wk of sampling and from 47 collard plants the first wk to 5 the last wk of sampling.

DBM larvae were brought into the laboratory and held for emergence of parasitoids and diamondback moths. If nothing emerged, the hosts were dissected (Day 1994) to examine parasitoids. The larvae were reared in 0.26-liter food cups (10 cm high × 5 cm diam) under laboratory conditions of 21°C, 50 -60% RH, and 12:12 [L:D] photoperiod. A 5 cm diam hole was cut through the center of the cup's lid, and the hole was coated with Porex™ porous plastics (Porex Technologies, Fairburn, Georgia) for ventilation. Fresh collard leaves were supplied for food daily.

Cabbage Damage Rating

At harvest, 13 consecutive mature cabbage heads >15.2 cm diam at each site were individually rated using the rating scale developed by Greene et al. (1969) and modi-

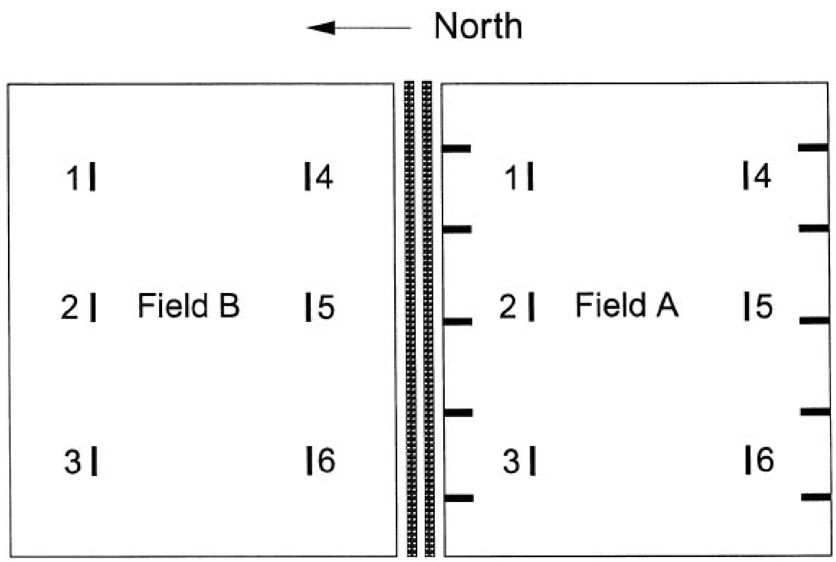

Fig. 1. Schematic of collard plantings and adjacent cabbage fields. Two vertical dotted lines between field A and B are the collard planting. Vertical bars in the cabbage fields indicate sampling sites for DBM immatures and cabbage head damage ratings. Horizontal bars in field A indicate cross-ratings of the first 12 rows of cabbage heads from edges of the field.

fied by Leibee et al. (1995). The ratings were: 1) no damage on head or 4 wrapper leaves; 2) no head damage but minor feeding damage on wrapper leaves; 3) no damage on head but obvious feeding damage on wrapper leaves; 4) very minor feeding damage on head, but no feeding through outer head leaves; 5) feeding damage through outer head leaves; and 6) severe damage to head and wrapper leaves. Leibee et al. (1995) categorized cabbage heads rated ≤ 3 marketable under normal market conditions. However, the growers with whom we were working considered only cabbage heads rated in categories 1 and 2 as acceptable to the market in spring 1995.

Besides rating cabbage at the permanent sample sites in each field, damage ratings also were made on cabbage at selected sites along the field edges. Five sampling sites, 50 m apart, were chosen along each edge of field A (Fig. 1); five cabbage heads were rated in each of the first 12 rows from the edge at each site. Unfortunately, this was not done for field B because the cabbage heads were harvested before we could collect data.

Statistical Analysis

The variation of DBM larval counts, the percentage of parasitism and cabbage ratings at the permanent sites between collard and cabbage plants in both fields were analyzed using general linear models procedure (GLM), and differences between the means were tested with least significant difference multiple range test (LSD; SAS Institute, 1990). The raw numbers were transformed by log (n + 1) to meet the assumptions of GLM (Marks 1990) before performance of the analysis. Average damage ratings of cabbage along edges of field A were analyzed with an independent student *t*-test for each of the 12 rows.

RESULTS

DBM Larval Abundance

Numbers of DBM larvae per collard plant were inconsequential until mid-March and then increased rapidly to a peak in late April (Fig. 2). Numbers of DBM cocoons per collard plant showed a trend similar to that observed for DBM larvae (Fig. 2).

Densities of DBM larvae on collard plants on each collection date were greater than densities on cabbage plants in fields A and B (Fig. 3). Mean numbers of DBM larvae per plant from 13 March to 10 April were significantly higher on collard plants than on cabbage plants in fields A and B (13 March, $F = 4.12$; df = 2,19; $P < 0.05$; 20 March, $F = 7.98$; df = 2,19; $P < 0.01$; 28 March, $F = 13.75$; df = 2,19; $P < 0.01$; April 3, $F = 38.43$; df = 2,19; $P < 0.01$; 10 April, $F = 16.68$; df = 2,19; $P < 0.01$), but no significant differences were shown between the two cabbage fields ($P > 0.05$). These results suggest that the collards were more attractive than cabbage to gravid DBM females.

Parasitism

The parasitism rates of DBM larvae from collard showed an increase from 3.2% on 13 March to 72% on 1 May (Fig. 2). By contrast, parasitism rates of DBM larvae on cabbage remained very low throughout the season, even at harvest (Fig. 4). The per-

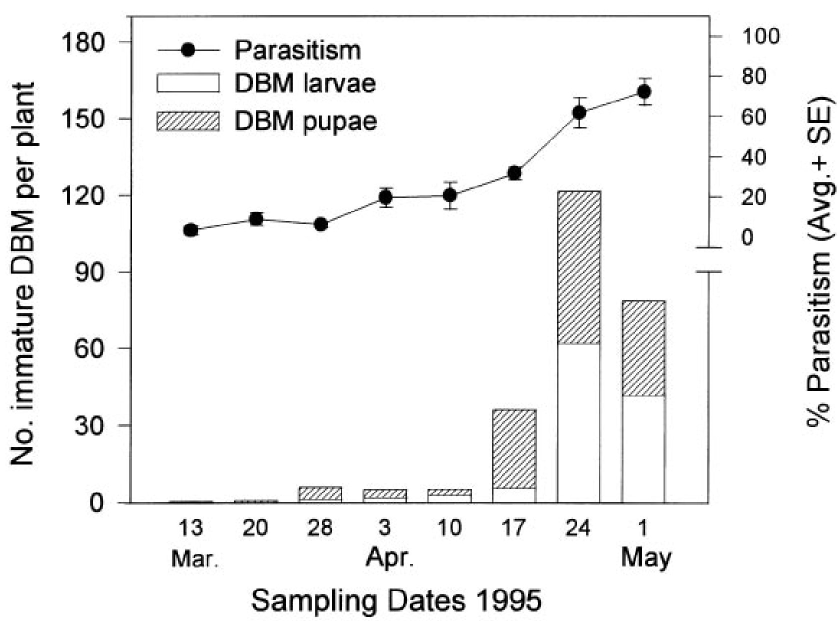

Fig. 2. Average numbers of diamondback moth larvae and pupae per collard plant and the larval parasitism (% ± SD) per site by *D. insulare*.

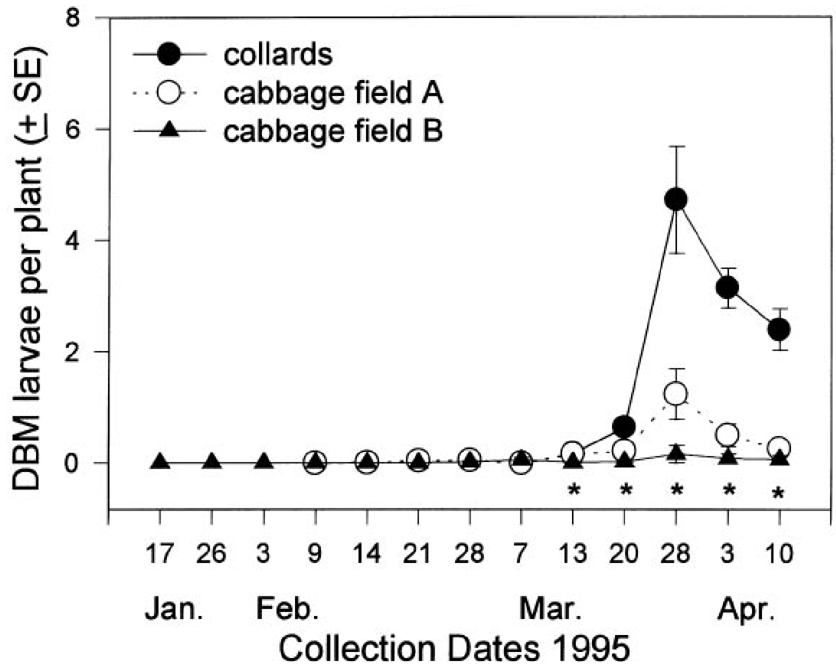

Fig. 3. Average numbers of diamondback moth larvae per collard plant and per cabbage plant from adjacent fields; * shows that means are significantly different on the same sampling dates.

cent parasitism of DBM larvae on the collards from 4 and 10 April was significantly higher than on cabbage ($F = 13.35$ and 7.54, respectively; df = 2,19; $P < 0.01$). The difference in DBM larval parasitism in fields A and B was not significant ($P > 0.05$).

Of 1,812 parasitoids found, 1,683 were reared to adults and 129 were dissected at the larval, pupal or pharate adult stage. *D. insulare* was the most abundant parasitoid (99.5%), and the sex ratio was 1:1.1 ♀:♂. No obviously biased sex ratio was found from each collection throughout the season. Eight *Conura (Spilochalcis) side* (Walker) (Hymenoptera: Chalcididae) (0.5%) were reared from DBM cocoons collected in April.

The numbers of parasitoids collected and the densities of DBM larvae were not correlated ($r = 0.3403$, df = 14, $P > 0.05$), but percent parasitism and the DBM larval densities were correlated ($r = 0.7183$, df = 14, $P < 0.05$). There were significant correlations ($r = 0.8876$ and 0.9723, respectively; df = 14; $P < 0.01$) between the numbers of the DBM larvae collected at any particular week and the percent parasitism and the numbers of parasites collected 2 weeks later (i.e., 2-week-lag, Fig. 5).

After the field collections were finished, the collard plants (heavily damaged by feeding of DBM larvae) were brought into the laboratory, and the cocoons of DBM and *D. insulare* were collected and checked for parasitoids. From 607 cocoons collected, 284 parasitoids emerged (46.8%). The parasitoids included 225 *D. insulare* (79.3%), 39 *C. side* (13.7%) and 20 unidentified hymenopterous parasitoids (7%). The sex ratio of *D. insulare* was 1:1.5 (♀:♂).

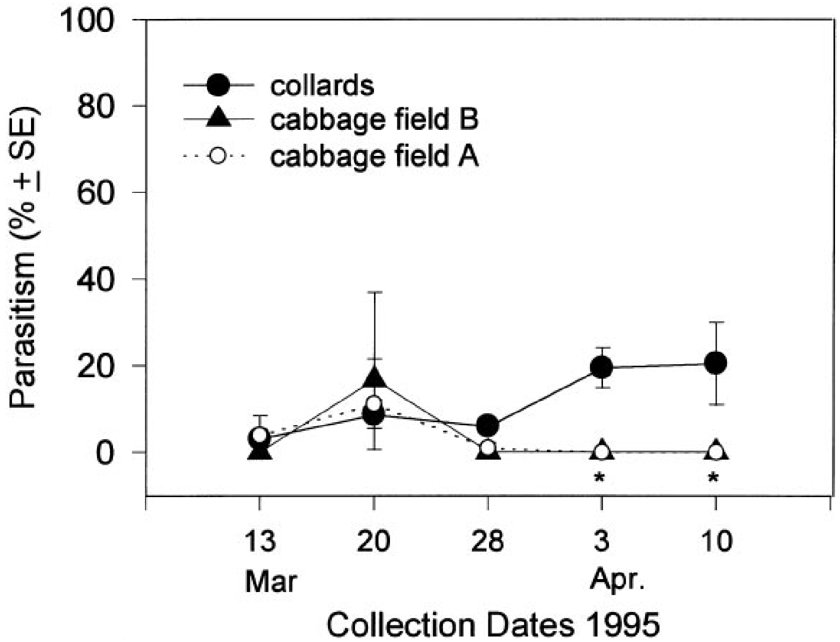

Fig. 4. Percent parasitism of diamondback moth larvae by *D. insulare* per site on collard and cabbage plants in adjacent fields; * shows that means are significantly different on the same sampling dates.

Cabbage Damage Rating

Percentage of marketable cabbage heads in rows 1-12 did not show significant differences between the north and south sides ($P > 0.05$). The cabbage damage ratings for the plots from inner 1/3 of fields A (1.36 ± 0.55) and B (1.31 ± 0.60) were not significantly different ($F = 0.3088$; df = 3, 152; $P > 0.05$) from the outer 1/3 of these fields (farthest away from the collards, Fig. 1) of field A (1.41 ± 0.62) and B (1.26 ± 0.40). There also was no significant difference in the percentage of marketable cabbage heads among those sampling locations ($F = 1.2381$; df = 3, 8; $P > 0.05$). This suggests that DBM populations did not spread from the collards to the adjacent cabbage fields even though the DBM population reached very high levels in the collards. Leaves of the collard plants were observed to have much heavier damage by DBM larvae than cabbages throughout the season.

Discussion

Compared with the cabbage plants in the adjacent fields, collard plants had greater DBM larval infestation and suffered greater damage. Therefore, collard may be evaluated as a trap crop in cabbage fields for control of DBM. Detailed interplanting plans may be needed for large area trial as the use of Indian mustard in cabbage fields (Srinivasan & Krishna Moorthy 1992). Planting collards earlier than cabbage may help to attract early arrivals of DBM. Planting collards over a larger area in and

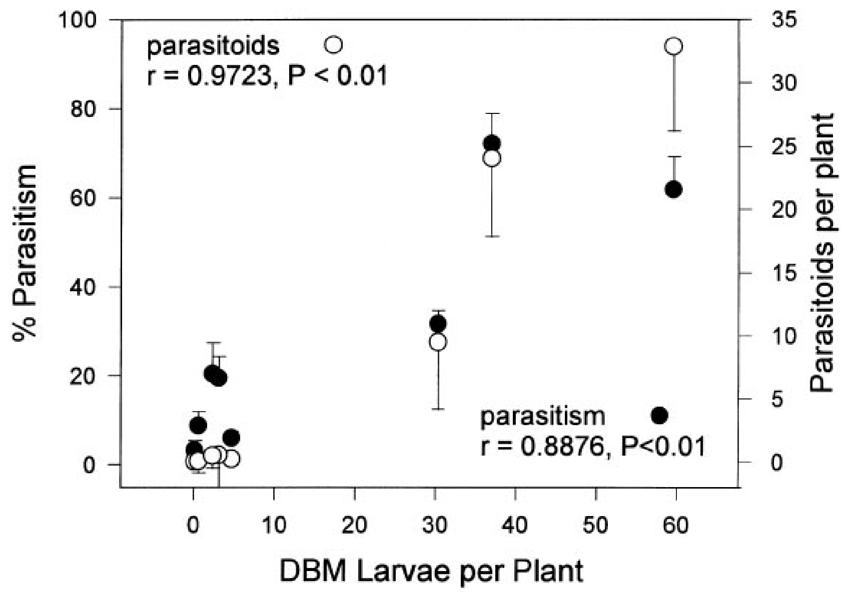

Fig. 5. Correlation showing the relationship between % parasitism and the numbers of parasitoids per collard plant and the numbers of DBM larvae per plant. The parasites were collected 2 weeks later than were the DBM larvae (i.e., 2-week-lag).

around cabbage fields may offer growers a significant level of protection of their cabbage crop from attack by DBM.

In the study of Harcourt (1957), collards were shown to have greater numbers of DBM larvae than six other cultivated crucifers (including cabbage), which agrees with our results.

It is not clear why DBM is more attracted to collards than cabbage. It is reported that DBM is attracted to crucifers that contain chemical stimulants (Talekar & Shelton 1993) for feeding (e.g. glucosides) and oviposition (e.g., sulfur-containing glucosinolates). Collards may contain higher levels of those volatile chemicals than does cabbage.

D. insulare has been recorded from Southern Canada to Venezuela and west to Hawaii (Fitton & Walker 1992) and is a major parasitoid of DBM in north America (Harcourt 1960, Idris & Grafius 1993, Lasota & Kok 1986). High parasitism in collards and the significant correlations shown in our study between the 2-week-lagged DBM larval abundance and parasitism by *D. insulare* suggest that this species was responsible for regulating DBM populations in the collards. When the parasitism reached a certain level (64%, April 24), the population of DBM in collards started to decrease (Fig. 2). However, *D. insulare* did not show the same relationship with DBM in the cabbage fields, possibly because of the low densities of the host.

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