FIELD PRODUCTION OF TWO SPECIES OF PARASITOIDS OF THE DIAMONDBACK MOTH (LEPIDOPTERA: PLUTELLIDAE)[1]

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ABSTRACT

Two species of parasitoids, *Cotesia plutellae* (Hymenoptera: Braconidae) and *Diadegma insulare* (Hymenoptera: Ichneumonidae), of diamondback moth, *Plutella xylostella*, (Lepidoptera: Plutellidae), were colonized in cages in cabbage fields west of Bunnell, Florida, from November 1996 to February 1997. Two kinds of cages were used: large-screened cages and screened laundry hampers. Both parasitoids attacked their host during the winter, completed development within the host, and increased in numbers within field cages. Parasitism of diamondback moth larvae by *C. plutellae* was 36-42% in laundry hampers, and 35-65% in large screened cages. The sex ratio of

emerging *C. plutellae* was 1:1-1.2 (♀:♂) in laundry hampers and 1:0.8-1.3 in large screened cages. Parasitism of diamondback moth larvae by *D. insulare* was 55-90%, parasitoid adults emerged from 89% of the cocoons, and the sex ratio was 1:1.4-2.1 (♀:♂) in large screened cages. The results showed that it is possible to rear these parasitoids in field nursery cages to provide parasitoid sources for release to control diamondback moth in cabbage in Florida.

Key Words: *Plutella xylostella*, *Cotesia plutellae*, *Diadegma insulare*, biological control, parasitism, cabbage

RESUMEN

Dos especies de parasitoides, *Cotesia plutellae* (Hymenoptera: Braconidae) y *Diadegma insulare* (Hymenoptera: Ichneumonidae), de la palomilla dorso de diamante, *Plutella xylostella* (Lepidoptera: Plutellidae), fueron colonizadas dentro de jaulas en campos de col al oeste de Bunnell, Florida, de noviembre de 1996 a febrero de 1997. Dos tipos de jaulas fueron usadas: jaulas grandes con tela de malla y canastas para la ropa con tela de malla. Los dos parasitoides atacaron a sus hospederos durante el invierno, completaron su desarrollo dentro de sus hospederos, y aumentaron en sus números dentro de las jaulas en el campo. El nivel de parasitismo de larvas de la palomilla por *C. plutellae* fue de 36-42% en las canastas de ropa y de 35-65% en las jaulas grandes. El coeficiente sexual de los *C. plutellae* que emergieron fue de 1:1-1.2 (♀:♂) en los canastos de ropa y de 1:0.8-1.3 en las jaulas grandes. El nivel de parasitismo de larvas de la palomilla por *D. insulare* fue de 55-90%, el 89% de los parasitoides adultos emergieron de los capullos, y el coeficiente sexual fue de 1:1.4-2.1 (♀:♂) en las jaulas grandes con malla. Los resultados demostraron que es posible criar estos parasitoides dentro de jaulas el en campo para proveer a los parasitoides con recursos para su liberación para controlar la palomilla dorso de diamante en la col en Florida.

The diamondback moth, *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). In Florida, the annual average production of cabbage is 4,555 hectares with an average total value of $34.4 million, and diamondback moth is one of the major pests of this crop (Leibee 1996). The diamondback moth typically has been controlled using pesticides (Shelton et al. 1993). To prevent damage to cabbage by diamondback moth, Florida growers typically have relied on one or two applications of insecticide per week; however, this has led to problems from insecticide resistance (Leibee 1996).

Integrated pest management (IPM) programs provide the most viable alternative to reliance on pesticides. An IPM approach to control lepidopterous pests in cabbage using multiple tactics is described by Biever et al. (1994). In Florida, an IPM program has been under trial for control of diamondback moth in cabbage fields. This pilot program contains a combination of strategies such as biological control (releases of parasitoids; Mitchell et al. 1997a, 1998), trap crops (Mitchell et al. 1997b), pheromone for disrupting mating (McLaughlin et al. 1994, Mitchell et al. 1997c) and *Bt* pesticides.

Of the parasitoids attacking diamondback moth, *Cotesia plutellae* Kurdjumov and *Diadegma insulare* (Cresson) show the most promise (Ooi & Lim 1989, Ooi 1990, Tabashnik et al. 1990). *Diadegma insulare* is the most important parasitoid of dia-

mondback moth in North America (Latheef & Irwin 1983, Pimentel 1961, Oatman & Platner 1969, Harcourt 1960, 1963, 1986, Losata & Kok 1986, Horn 1987), and has resulted in greater than 90% parasitism in untreated fields (Muckenfuss et al. 1990). It is the most abundant parasitoid of diamondback moth in Florida (Mitchell et al. 1997b). The female wasps primarily attack 2nd and 3rd instars of diamondback moth (Hu, et. al.: unpublished data). After completing larval development, this parasitoid makes its cocoon within the host cocoon. In cabbage fields in northeast Florida, however, *Diadegma insulare* populations typically do not increase until late March (Hu et al. 1997).

An imported diamondback moth parasitoid, *C. plutellae*, has been released in cabbage in Florida. This parasitoid primarily attacks early instars of diamondback moth (Hu et al.: unpublished data). After completing development, the parasitoid larva migrates outside the host larva to form its own cocoon. The results from field releases have shown that *C. plutellae* competes with *D. insulare* for increasing parasitism following inundative releases. Unfortunately, *C. plutellae* has not yet been found to establish in cabbage production areas in Florida (Mitchell et al. 1997a). Moreover, purchasing this parasitoid for release is costly (Mitchell et al. 1998). The objective of this study was to determine the feasibility of colonizing these two parasitoids in field cages to provide local sources for releases in cabbage for control of diamondback moth.

Materials and Methods

Experimental Location

This study was conducted in an area of commercial cabbage production, west of Bunnell, Flagler County, Florida. Approximately 800 hectares of cabbage grow in the winter-spring and fall-winter crop in this area. The fall-winter crop lasts from October to February and the winter-spring season lasts from January to April. Temperature and humidity were recorded in that area while the study was carried out (November 1996 - February 1997). Average daily high temperature was 24°C, ranging from 9.4 to 32.2°C. Average daily low temperature was 9.6°C, ranging from -4.4 to 21.1°C. Relative humidity was 22-100%, with an average of 61.8%.

Cages

Two types of cages were used in this study: screened Sterilite® laundry hampers (Sterilite Corporation, Townsend, MA) and large screened cages. Laundry hampers (Fig. 1, left) were trapezoidal and 61 cm high: the bottom was 38-cm long x 27-cm wide and the top (opening) was 46.4-cm long x 33.7-cm wide. Air vents on the sides were covered using a fine Saran® screen of eight meshes per cm. The large screened cages (Fig. 1, right) were constructed of a wire frame covered with two layers of Saran® screens: the outer layer was fine with 16 meshes per cm and the inner layer was coarse with six meshes per cm. The cage was semicircular in section, 2.5-m long, 2.2-m wide (bottom), and 1.0-m high. Edges of the screens were buried into soil to prevent the insects within the cage from escaping and the insects outside from invading the cage. A fire ant bait, Amdro® (American Cyanamid, Wayne, NJ), was applied onto the ground inside and around the cages once a week to help control *Solenopsis invicta* Buren (Hymenoptera: Formicidae), which attacked immature diamondback moth and its parasitoids in the cages.

Parasitoid Source

Cotesia plutellae used in this study were purchased from Biofac, Inc., Mathis, Texas. Cocoons established on paper towels (about 1,000 each) were placed in plastic

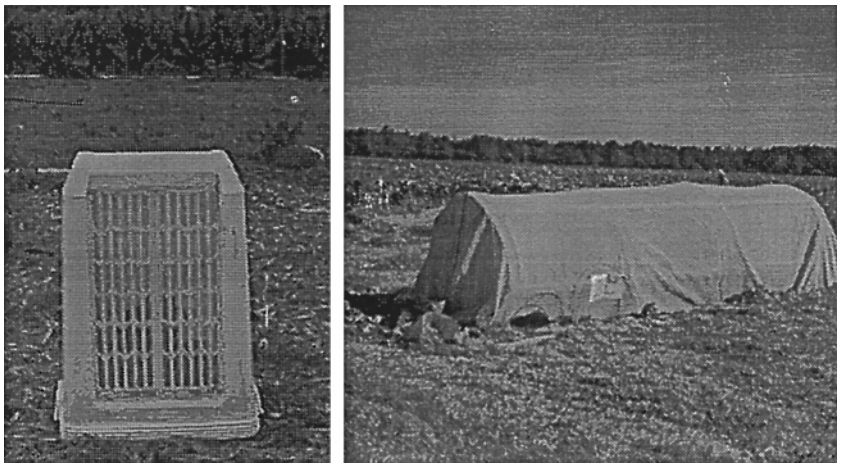

Fig. 1. Screened laundry hampers (left) used for rearing *Cotesia plutellae* and large screened cages (right) used for rearing *C. plutellae* and *Diadegma insulare* in cabbage fields.

bags, wrapped with old newsprint, inserted into styrofoam containers, and shipped to Gainesville, Florida. *Diadegma insulare* (collected from Bunnell, Florida, May 1996) were reared on diamondback moth larvae reared on wheat germ-based artificial diet (Shelton et al. 1991). Both species of parasitoids were fed honey and water, and maintained under a 12:12 h L:D cycle at 25°C and 50% RH.

Parasitoid Rearing in Large-Screened Cages

To initiate rearing, 10 to 20 individually potted collard plants, infested with 100-200 diamondback moth larvae (mixed instars) each, were introduced into each of the two cages. A cumulative total of 75 pairs of *D. insulare* was introduced into one cage from 25 November to 10 December, 1996. On 28 November, 1996, 200 pairs of *C. plutellae* were introduced into the other large cage. No more parasitoids were added to the cages.

Follow-up visits to the cages were made once a week. Each visit included watering the collard plants, removing dead plants and adding new infested plants when needed. Every 2-3 weeks, samples of diamondback moth larvae and parasitoid cocoons were collected from the plants in the cages and brought to our Gainesville laboratory, where the larvae were dissected to determine parasitism. Parasitoid cocoons were allowed to emerge as adults to obtain sex ratio data.

Parasitoid Rearing in Laundry-Hampers

Because *C. plutellae* is an exotic species, no data were available on the possibility for survival in our experimental location. To start tests, two fully-grown potted collard plants were infested with mixed instars of 100-200 diamondback moth larvae, and were covered by an upside down screened laundry hamper. Next, 50 pairs of 3-d old *C. plutellae* were introduced into the hamper. Four pieces of metal wire were used to

anchor each corner of the cage edges to the soil. This test was replicated three times and each replicate included three cages. After the third wk, the collard plants along with the laundry hampers were brought to the Gainesville lab. The diamondback moth larvae collected from the plants were dissected for parasitism, and the cocoons collected from the plants and the laundry hampers were reared to adults to obtain sex ratio data.

Results and Discussion

Cotesia plutellae

A total of 225 diamondback moth larvae (mixed instars) collected from the laundry hampers was dissected to determine parasitism by *C. plutellae*. Parasitism caused by this parasitoid was 36-42% from November 1996 to February 1997. A total of 310 cocoons of *C. plutellae* was collected, from which 256 adults emerged. Emergence success ranged from 80.8 to 85.3%, with an average of 82.8% per trial. Sex ratios of the emerging adults were 1: 1.0-1.2 (♀:♂), with an average of 1: 1.13 (Table 1).

Eighty diamondback moth larvae collected over the four sampling dates from the large screened cage also were dissected for eggs or larvae of *C. plutellae* (Table 1). Parasitism caused by this parasitoid ranged from 35 to 65%, with an average of 55%. Sex ratios of emerging adults were 1: 0.8-1.3, with an average of 1: 1.1 (♀:♂). Adults *C. plutellae* were observed to fly around within the large screened cage during the entire rearing period, but remained on plants when ambient temperature dropped below 5°C.

Diadegma insulare

In the large screened cage, 75 diamondback moth larvae collected from the four sampling dates were dissected to determine parasitism by *D. insulare* (Table 2). Parasitism caused by *D. insulare* ranged from 55 to 90%, with an average of 75%. Sex ratios of emerging adults were 1:1.4-2.1, with an average of 1:1.8 (♀:♂), which is similar to that reported to occur in field populations (Idris & Grafius 1993, Mitchell et al. 1997b) and in our rearing facility. Adult *D. insulare* were observed to fly around within the large screened cage. They were seen to hover a few cm to 20 cm above collard plants or weeds. When ambient temperature dropped below 5°C, however, they stayed on the plants.

The results showed that *C. plutellae* and *D. insulare* attacked diamondback moth larvae, completed their development within the host larvae, and reproduced continuously within the nursery cages during the winter months in east-central Florida. An estimate of three generations completed in cages. At the end of the rearing period (late-February of 1997), the numbers of *D. insulare* and *C. plutellae* increased greatly but we did not attempt to quantify populations of the caged parasitoids.

The unparasitized larvae of diamondback moth used for the rearing developed into cocoons, and adults emerged from the cocoons continuously throughout the rearing period within the cages where *C. plutellae* and *D. insulare* were maintained. The adult parasitoids were observed to stay on collard plants or in weeds, occasionally flying between plants. However, even though diamondback moth adults were continuously present, larvae had to be introduced continuously into the cages with collard plants because larval numbers were very low during the winter and the plant quality decreased over time.

Following lifting the fine (outer layer) screen from the large cage, *C. plutellae* colonized in the large-screened cage were observed to fly out through meshes of the

TABLE 1. SURVIVAL AND HOST-ATTACKING RATES OF *COTESIA PLUTELLAE* UNDER LAUNDRY HAMPERS IN A CABBAGE FIELD DURING WINTER 1996-1997. BUNNELL, FLORIDA. REPLICATES = 3 FOR EACH DATE.

Dates		*Cotesia* Released	Diamondback Moth		Parasitoid Emergence		
Start	End	(Pairs per Cage)	Larvae Checked per Cage	Parasitism (%)	Total No. Cocoons Collected	% Emergence	Sex Ratio (♀:♂)
07/11/96	29/11/96	50	25	41.3 ± 5.0	130	80.8	1:1.2
25/11/96	31/12/96	50	25	42.0 ± 4.9	85	82.4	1:1.2
21/01/97	12/02/97	50	25	36.7 ± 6.7	95	85.3	1:1.0

TABLE 2. PARASITISM OF DIAMONDBACK MOTH LARVAE AND SEX RATIOS OF *DIADEGMA INSULARE* AND *COTESIA PLUTELLAE* REARED IN LARGE NURSERY CAGES IN CABBAGE FIELDS DURING WINTER 1996-1997. BUNNELL, FLORIDA.

Dates	No. Larvae Dissected	% Parasitism	Adults Emerging	Sex Ratio (♀:♂)
D. insulare				
Jan.7	20	55	39	1:1.8
Jan. 19	20	90	48	1:1.8
Feb. 4	15	80	34	1:2.1
Feb. 16	20	75	22	1:1.4
Total	75	75	143	1:1.8
C. plutellae				
Jan. 16	20	35	52	1:1.3
Jan. 28	20	65	34	1:0.8
Feb. 14	20	55	27	1:1.1
Feb. 26	20	65	36	1:1.3
Total	80L	55	149	1:1.1

coarse (inner layer) screen and spread into the cabbage in nearby fields. The adults of diamondback moth, however, could not escape through the screen due to their larger size, eliminating the spread of this pest from the nursery cages.

Unfortunately, *Diadegma insulare* could not be released in this way because its size is nearly the size of diamondback moth adults and they could not migrate through the coarse layer screen. Therefore, cocoons of this parasitoid were collected from the cage and placed into adjacent cabbage fields. Unfortunately, released parasitoids could not be evaluated for establishment due to heavy chemical pesticide applications by growers in the fields near the rearing cages.

Diamondback moth larvae sterilized by gamma radiation are just as suitable hosts for the parasitoid (*C. plutellae*) as are unsterilized larvae (Okine et al. 1998) and may be used in the future as the host for rearing *D. insulare* in field cages. The adults of *D. insulare* and those of sterile diamondback moth can then be released simultaneously from the cages into the fields by lifting the cover screens without infesting the field with diamondback moth.

Augmentation of parasitoids to increase their effectiveness involves their direct manipulation, either by mass production and periodic colonization, or by some type of planned genetic improvement, or by employing chemical cues that affect their behavior (Debach & Rosen 1991). Our results showed that *D. insulare* and *C. plutellae* were successfully colonized in field cages. Both parasitoids survived, completed their development within the host, and increased in numbers. Therefore, colonizing these two species of parasitoids in field cages may provide a good source of large numbers of *C. plutellae* and *D. insulare* for control of diamondback moth in cabbage. The parasitoids were ready for release into the cabbage fields either as adults or cocoons. This procedure can be easily adopted by growers of commercial cabbage. Moreover, the rearing facility was not costly and required minimal labor, both important considerations for implementation of biological control.

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ENDNOTES

1. This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement or the recommendation for its use by USDA.

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