Diamondback Moth (Lepidoptera: Plutellidae) in Cabbage: Influence of Initial Immigration Sites on Population Distribution, Density and Larval Parasitism[1]

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ABSTRACT Examinations of cabbage plants in five fields near Bunnell, Flagler Co., FL, in spring 1995 showed that larvae of the diamondback moth, *Plutella xylostella* (L.), were more abundant on the field ends (perpendicular to cabbage rows) adjacent to weed-filled drainage ditches than the fields ends abutting wooded swamp areas. There were no significant differences in the numbers of diamondback moth larvae on cabbage plants on the ends next to other cabbage fields or at sites located within the interior of the fields. Cabbage heads rated for damage due to diamondback moth larvae at harvest showed a distributional pattern similar to that observed for diamondback moth larvae. Parasitism of diamondback moth larvae was not significantly different between field ends and interior fields. Cabbage damage ratings on field sides (parallel to cabbage rows) showed that no edge effect was detected on the sides abutting other cabbage fields, that edge effect only occurred on the first one or few rows on the sides adjacent to other cabbage fields but separated by irrigation ditches, and that edge effect occurred continuously and decreased from the first to the 12th row on sides adjacent to earlier planted cabbage or an open weed-filled ditch area. These results suggest that diamondback moth first invaded cabbage fields from outside areas, and that more diamondback moth spread to the interior of the fields from adjacent open, weed-filled ditches than from bordering wooded and bushy areas.

Key Words *Plutella xylostella, Diadegma insulare, Conura side*, cabbage, diamondback moth

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 US $1 billion (Talekar and Shelton 1993). This pest typically has been controlled using pesticides (Shelton et al. 1993b). The diamondback moth, however, has become resistant to synthetic insecticides used in many countries (Shelton et al. 1993b, Talekar and Shelton 1993). In the U.S.,

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control failures have occurred in several states including Florida, Georgia, North Carolina, Texas, Wisconsin, and New York (Shelton et al. 1993a). Therefore, a biological control-integrated pest management system (Biever et al. 1994) has been developed for the diamondback moth. Field population studies of diamondback moth larvae are essential for maximizing the use of biological control agents and adopting other control tactics such as the use of trap crops (Srinivasan and Krishna Moorthy 1992, Mitchell et al. 1996) and pheromones for mating disruption (McLaughlin et al. 1994).

Plants in vegetational-diverse habitats usually have lower insect herbivore populations compared with plants in simple-vegetation habitats (Andow 1992). Studies have shown that various types of intercropped vegetation decrease population densities of diamondback moth larvae in cabbage (Bach and Tabashnik 1990, Buranday and Raros 1973, Srinivasan and Krishna Moorthy 1992) and in collard (Horn 1987). Edge effects on diamondback moth damage to cabbage heads have been reported (Biever et al. 1994, McLaughlin et al. 1994). The objective of this study was to determine if any significant differences exist on densities of diamondback moth larvae on cabbage plants, larval parasitism, and the pest-caused damage to cabbage between field margins (including ends and sides) and interior fields.

Materials and Methods

Study location. Five cabbage fields in Bunnell, Flagler Co., FL were used in the study. Field locations, crop row directions, surrounding backgrounds, and diamondback moth larval sampling sites and cabbage rating sites are shown in Fig. 1. Field ends indicate the edges vertical to cabbage rows, and field sides indicate the edges parallel to cabbage rows. West ends of field A-C were adjacent to a weed-filled ditch area. Fields A, B, C and D were adjacent to one another. The east end of field A was adjacent to a woody area (pine, palm, and various deciduous shrubs and hardwoods); that of field B to a marshy bush area; and that of field C to a cabbage field. The north end of field D was adjacent to a weed-filled area, and its south end was adjacent to a weed- and shrub-filled ditch area. Fields A and B were separated by a drive road and two irrigation ditches; field B and C by two rows of collard plants (Mitchell et al. 1996a); and field C and D by a weed- and shrub-filled ditch area. The south side of field A and the east side of field D were abutting to other cabbage fields, and the west side of field D was adjacent to the weed-filled ditch area extending from the west ends of fields A-C. Field E was 2 km southwest of field A. The south end was adjacent to a cabbage field; the north end to a weed-filled ditch area; the east side to potato crops and early planted cabbage plants; and west side to an area of weed-filled ditch, paved road and open field with housing.

Weeds along fields edges, especially the weed-filled ditch areas (7 to 10 m wide), included dog fennel [*Eupatorium capillifolium* (Lam.)], wild radish [*Raphanus raphanistrum* L.], wild mustard [*Brassica kaber* (DC) Wheeler], field pennycress (*Thlaspi arvense* L.), shepherds purse [*Capsella bursa-pastoris* (L.) MediK], spreading dayflower [*Commelia diffusa* Burm.] cutleaf groundcherry [*Physalis angulata* L.], Johnsongrass [*Sorghum halepense* (L.) Pers.], and various other unidentified weeds, grasses, and trees. Cabbage

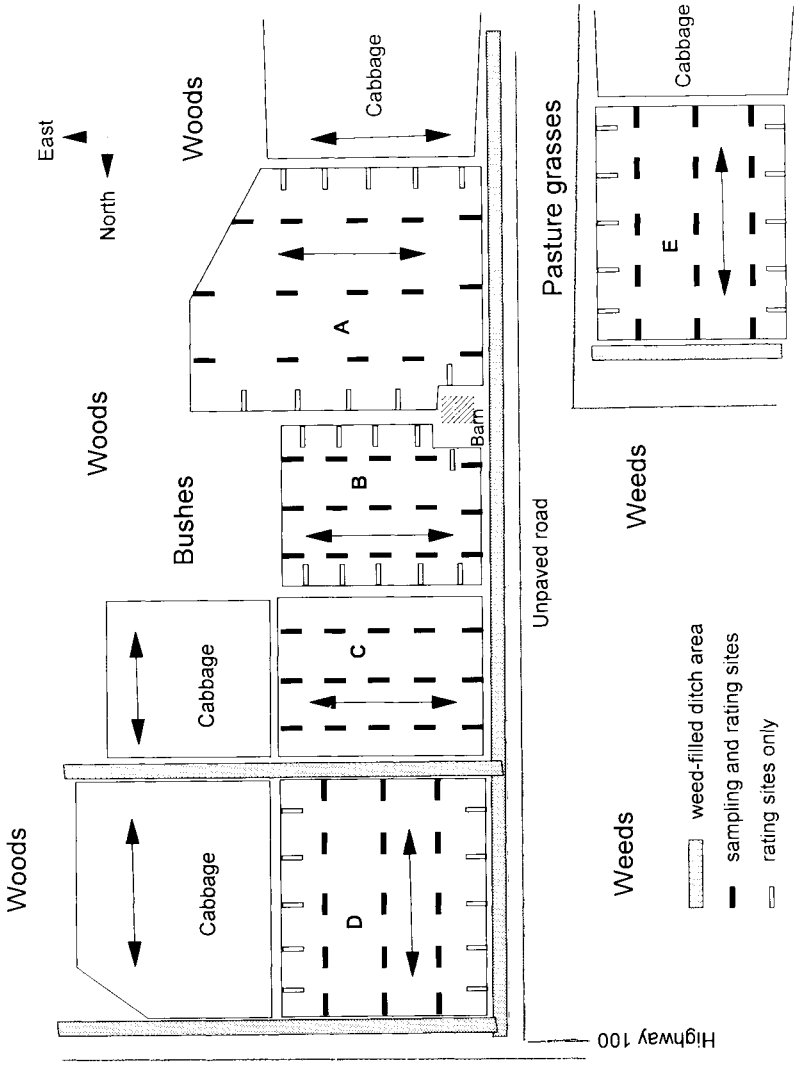

Fig. 1. Distribution, row directions (arrows), sampling and cabbage rating sites, and surrounding areas of the experimental fields in Flagler Co., FL. (Field E including the surrounding areas was about 1.5 km SW of field A). Areas (acres) for the fields: A = 31, B = 12.5, C = 13.0, D = 30, and E = 30.

(*Brassica oleracea* var. *capitata* L.) seedlings were planted in rows 0.76 m apart with 0.23-m plant spacing. Cabbage crops were planted in field A and B on 20 January, field C and D on 4 January, and field E on 27 January 1995.

Fields A and B were sprayed with Monitor (methamidophos; Valent USA Corp., Walnut Creek, CA) on 3 February, and XenTari (*Bacillus thuringiensis* var. *aizawai*; Abbott Laboratory, Chemical & Agricultural Products Div., North Chicago, IL) and Larvin (thiodicarb; Rhone-Poulenc Ag Co., Research Triangle Park, NC) on 3 April. Field C was sprayed with Monitor on 22 March, Agree (transconjugated strain of *B. thuringiensis* var. *aizawai*; Ciba-Geigy Corp., Greensboro, NC) and Phosdrin (mevinphos; Amvac Chemical Corp., Los Angeles, CA) on 28 March, and Agree and Phosdrin on 3 April. Field D was sprayed with Phosdrin on 20 March and Phosdrin plus Agree on 26 March. Field E was sprayed almost weekly from late February to the end of the growing season alternately with XenTari, Monitor, Thiodan (endosulfan; FMC Corp. AG Chemicals Group, Philadelphia, PA), Phosdrin, Asana (fenvalerate; DuPont Agricultural Products, Wilmington, DE), and Larvin.

Insect sampling. Cabbage plants were sampled weekly for diamondback moth larvae. The numbers of plants sampled on each site decreased as their sizes increased, from 65 (15 m row-length) in the first week to 13 (3.5 m row-length) in the week of harvest. All surfaces of the plants at different ages were searched in the same way for larvae and cocoons of diamondback moth. Five sampling zones across each field were arranged as follows: along each end, in the middle, and halfway between the middle and each end (50 to 70 m from ends). Each of the three rows across the interior fields contained three sampling sites 50 to 80 m apart, none closer than 35 m to the field edge (Fig. 1).

Collected diamondback moth larvae were transported to the laboratory in a cool box, dissected under a dissecting microscope and examined for the presence of parasitoids (Day 1994).

Cabbage damage rating. At harvest, 13 mature consecutive cabbage heads (3 m row length) larger than 15.2 cm diam were rated on the sites of ends and interior fields. Also, on each side of the fields, the first 12 rows of cabbage heads were rated on 5 sites each containing 5 cabbage heads (Fig. 1). The rating scales used were developed by Greene et al. (1969) and modified by Leibee et al. (1995). The ratings were: (1) no damage on head or four 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.

Statistical analysis. The variation of weekly diamondback moth larval counts, cabbage ratings at harvest, and average percent parasitism among the sampling zones were analyzed using analysis of variance (ANOVA). The means were separated with Duncan's multiple range test (DMRT; SAS Institute 1990). Original larval counts and parasitism were transformed by log (n + 1) to meet the assumptions of ANOVA before the analysis (Marks 1990). Nontransformed data (mean ± SE) are presented.

Results

Field A. Mean numbers of diamondback moth larvae per plant were consistently low in the interior of the field and peaked 31 March and 18 April (Fig. 2). The abundance of larvae on cabbage plants at both ends of the field had the same pattern as did the interior of the field, but the peaks were much higher, especially at the west end adjacent to a weed-filled ditch area. Mean larval counts among the five sampling rows were significantly different on 28 March ($F = 5.48$; df = 4, 10; $P < 0.01$) and 18 April ($F = 7.51$; df = 4, 10; $P < 0.01$). The mean number of larvae was the highest on the west end ($P < 0.05$, DMRT), followed by the east end, and the lowest in the middle of the field for both dates. The mean larval densities for the two dates above showed the same distribution pattern ($F = 12.2$; df = 4, 25; $P < 0.01$) as did the separate dates. Diamondback moth larva-induced damage to the cabbage heads at harvest was the greatest at the west end, followed by the east end, and the least for the interior of the field ($F = 13.37$; df = 4, 190; $P < 0.01$).

Total average cabbage ratings (combined from 5 sites) among the first 12 rows showed no significant differences for the south side ($F = 1.518$; df = 11, 48; $P > 0.05$). On the north side, cabbage on the first row suffered the greatest damage, decreased to the fifth row ($Y = 2.72 - 0.272X$, $R^2 = 0.957$), and then no significant differences were detected among the remaining rows ($F = 1.643$; df = 7, 32; $P > 0.01$; Fig. 3).

Parasitism of diamondback moth larvae fluctuated throughout the growing season and showed an increase for both field ends and the interior in the late season (Fig. 2). The average percentage parasitism from 9 March to 18 April 1995 was not significantly different between the ends and interior ($F = 0.581$; df = 2, 12; $P > 0.05$).

Field B. Mean numbers of diamondback moth larvae per plant were consistently low on interior sampling sites and peaked 31 March (Fig. 2). Mean larval counts per plant differed among the five sampling zones for collections on 31 March ($F = 11.92$; df = 4, 10; $P < 0.01$), with the highest for the west end, followed by the east end, and the lowest for the interior. At harvest, damage to the cabbage heads caused by diamondback moth larvae showed a similar pattern to that of diamondback moth larval infestation, with the greatest on the west end, followed by the east end, and the least in the interior of the field ($F = 16.74$; df = 4, 190; $P < 0.01$).

Total average cabbage ratings (combined from 5 sites) for the first 12 rows showed that the 1st row had significantly greater damage than the remaining rows for the south side ($F = 2.338$; df = 11, 48; $P < 0.05$), but no significant differences were shown among the 12 rows on the north side ($F = 0.94$; df = 11, 48; $P > 0.01$; Fig. 3).

Parasitism of collected diamondback moth larvae in field B was lower than field A, and did not exhibit significant differences in average parasitism between both the field ends and the interior ($F = 0.027$; df = 2, 15; $P > 0.05$; Fig. 2).

Field C. Diamondback moth larval infestation on cabbage plants in this field was far less than fields A and B for the ends and interior (Fig. 2). The larval counts on cabbage plants at the west end of the field (adjacent to a weed-filled ditch area) were greater than the east end (adjacent to another cabbage

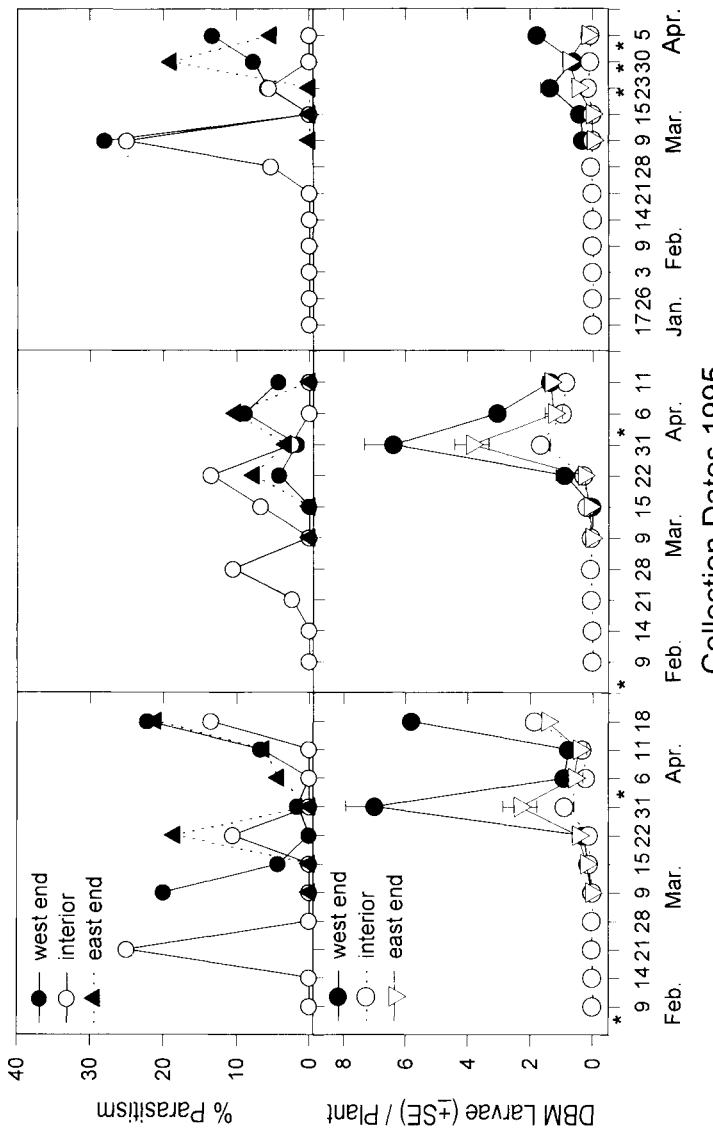

Fig. 2. Mean (± SE) numbers of diamondback moth larvae per plant and larval percent parasitism throughout the growing season in fields A, B, and C. Interior included midwest, middle, and mideast sampling rows. * shows dates of insecticide spray. Legends on the left are for all the three fields.

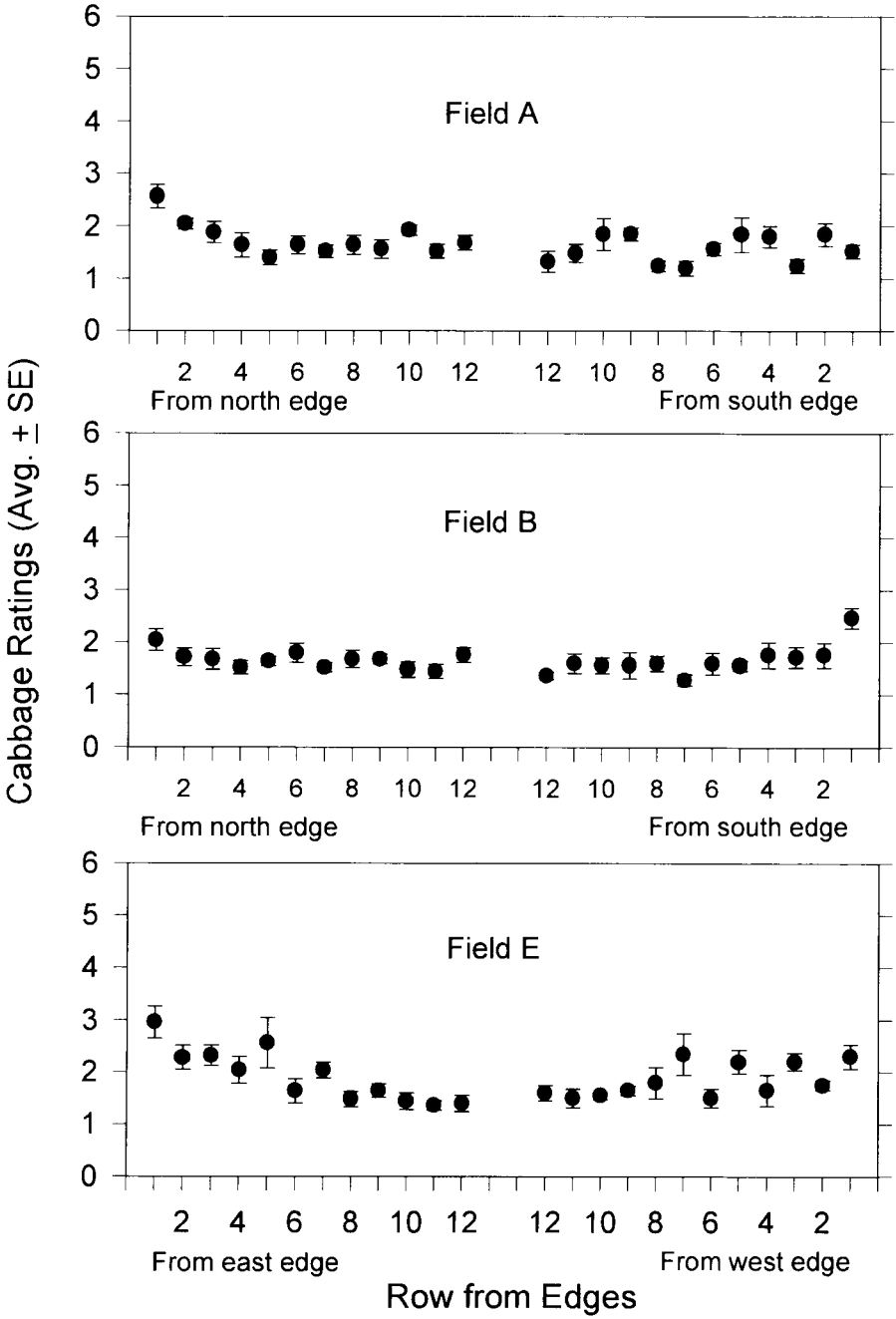

Fig. 3. Cabbage ratings (mean ± SE) for damage induced by diamondback moth larvae on the first 12 rows from each side of fields A, B, and E.

field) and the interior for 23 March ($F = 5.33$; df = 4, 10; $P < 0.05$) and 5 April ($F = 39.63$; df = 4, 10; $P < 0.01$). However, there were no significant differences between the east end and the interior for both dates. Combined data from 23 March and 5 April showed the same distribution pattern of larval densities ($F = 12.55$; df = 4, 25; $P < 0.01$) as did the separate dates. Diamondback moth larva-induced damage to the cabbage heads at harvest was greater on the west end than the east end and interior field ($F = 5.91$; df = 4, 190; $P < 0.01$), but no significant difference was detected between the east end and the interior. Unfortunately, rating cabbage for damage on the first 12 rows on each side of this field was not done. However, before harvesting we observed obvious damage to the cabbage heads on the first 2 rows of north side, but no obviously damage on the south side.

No parasitism of diamondback moth larvae collected from field C was detected until late February, and the average parasitism for the remaining weeks was not significantly different between the field ends and interior ($F = 0.635$; df = 2, 12; $P > 0.05$; Fig. 2).

The west ends of field A, B and C were all adjacent to the same weed-filled ditch (Fig. 1) and the cabbage plants had the greatest larval infestation (combined data from these three fields), followed by east end, the least for the interior fields ($F = 11.83$; df = 4, 60; $P < 0.01$; Fig. 4). Diamondback moth larvae-caused damage to cabbage heads was the most severe at the west end, followed by the east end, then the midwest, and the least was in the middle of the field ($F = 30.53$; df = 4, 515; $P < 0.01$; Fig. 4).

Field D. Diamondback moth larval density was low during the entire growing season for the interior sampling sites, but one peak occurred on 23 March (Fig. 5). Larval counts per plant on this date were significantly greater for both ends than the interior ($F = 5.38$; df = 4, 10; $P < 0.01$), but the differences were not significantly different between the two ends (both adjacent to a weed-filled area) and among the three sampling zones across the interior (Fig. 6). The cabbage growing on field ends suffered more damage than the cabbage growing in field interior, but no significant differences were detected between the two ends and among the interior sampling zones ($F = 8.70$; df = 4, 190; $P < 0.01$; Fig. 6). Unfortunately, rating cabbage for damage on the first 12 rows on each side of field D was not done. However, before harvest, we observed significantly greater damage to the cabbage on the first 2 to 3 rows on the west side, but no obvious damage on the east side.

Accumulated parasitism in this field reached 30% at the time of cabbage harvest on the end and interior cabbage. However, there was no significant difference in mean parasitism between the field ends and interior throughout the growing season ($F = 0.174$; df = 2, 12; $P > 0.05$; Fig. 5).

Field E. Diamondback moth larval densities were low for the interior and south end (adjacent to another cabbage field), but increased steadily on the north end during the late season (Fig. 5). The larval counts were significantly greater on the north end than the south end and interior on 23 March ($F = 4.26$; df = 4, 10; $P < 0.05$), 31 March ($F = 37.87$; df = 4, 10; $P < 0.01$), 3 April ($F = 29.47$; df = 4, 10; $P < 0.01$), and 13 April ($F = 4.93$;df = 4, 10; $P < 0.05$; Fig. 5). However, the differences among the south end and the three interior sampling zones were not significant. The mean larval counts from the four dates above showed the same pattern as did individual dates ($F = 20.08$; df = 4, 55; $P < 0.01$; Fig. 7).

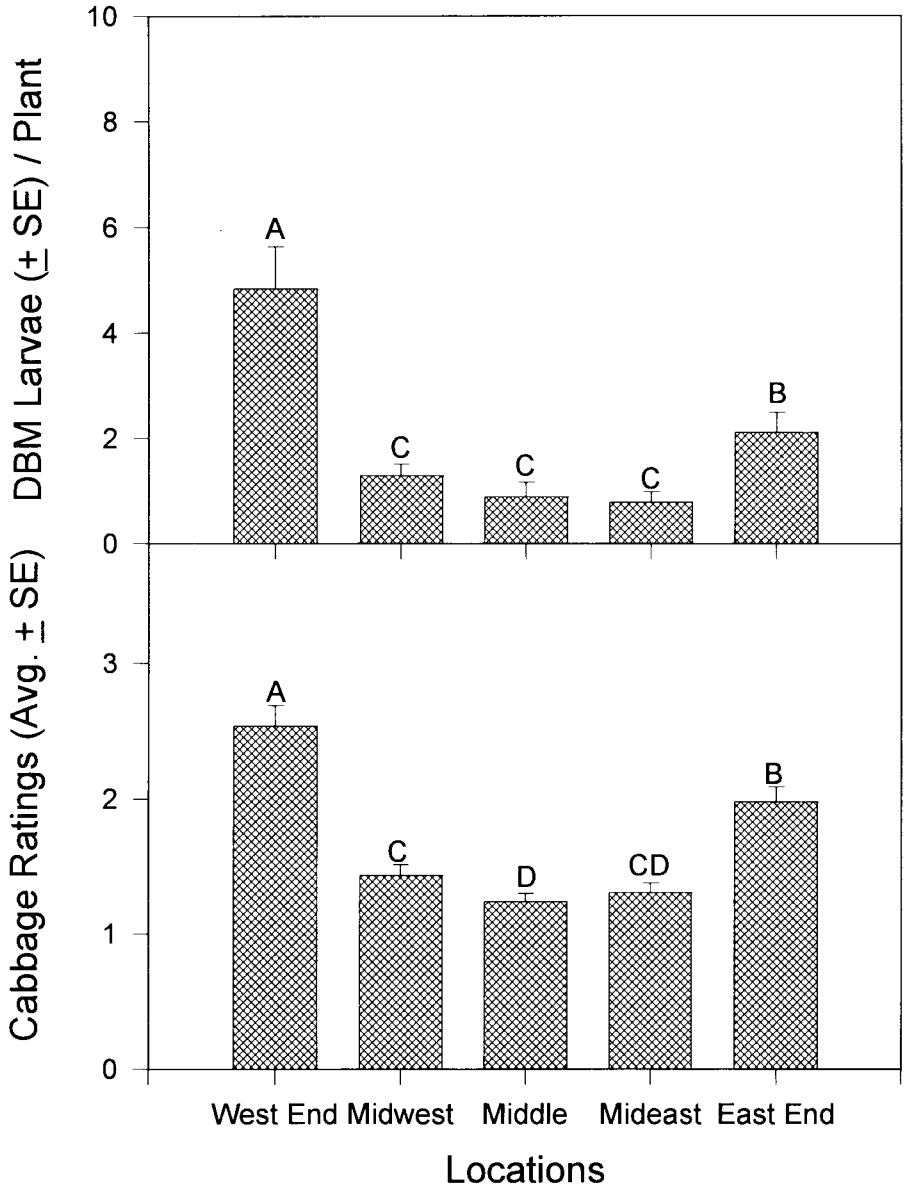

Fig. 4. Mean (± SE) numbers of diamondback moth larvae and mean (± SE) cabbage ratings at harvest from fields A, B, and C. (Larval counts were transformed by log (N + 1) for ANOVA, but nontransformed means are presented. Means topped by different letters are significantly different ($P < 0.05$; DMRT).

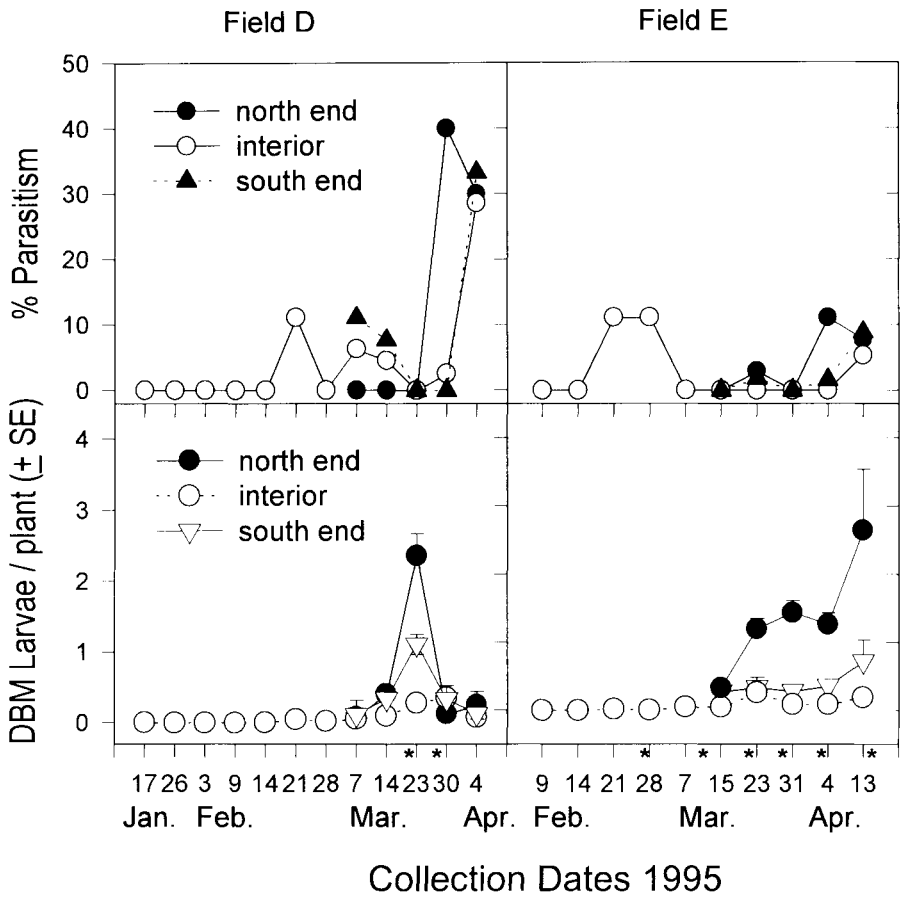

Fig. 5. Mean (± SE) numbers of diamondback moth larvae and larval percent parasitism throughout the growing season in fields D and E. (Interior included midnorth, middle, and midsouth sampling rows. * indicates spray dates).

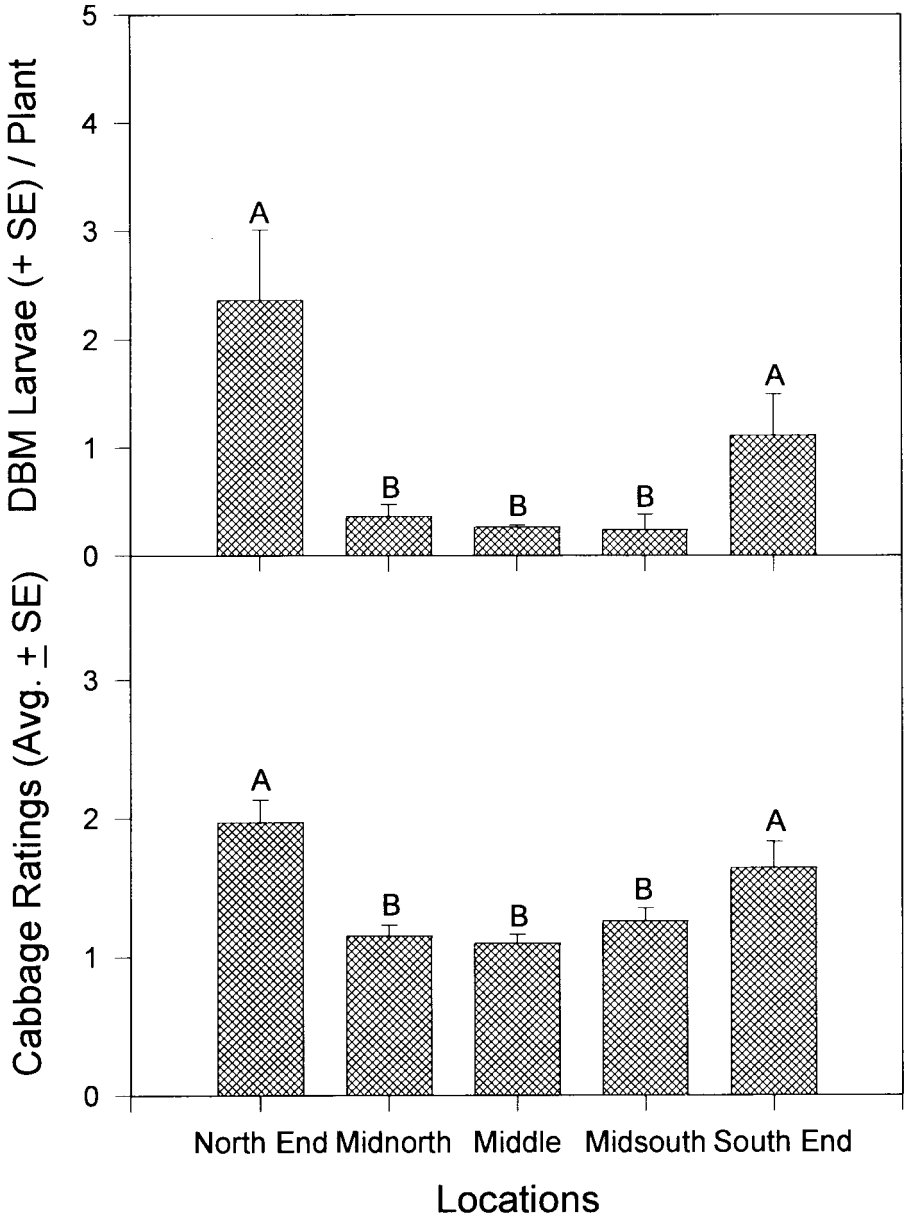

Fig. 6. Mean (± SE) numbers of diamondback moth larvae per plants on 31 March and average cabbage ratings at harvest at five collection zones across field D. (Means topped by different letters are significantly different [$P < 0.05$; DMRT]).

Cabbage damage ratings had the same distribution patterns as the larval counts, i.e., the north end was higher than the other sampling zones across the field ($F = 32.86$; df = 4, 190; $P < 0.01$), but no significant differences were found among the remaining sampling zones (Fig. 7). Average cabbage ratings for the first 12 rows decreased from the 1st to the 12th row on the east side ($Y = 2.758 - 0.127X$, $R^2 = 0.781$) and west side ($Y = 2.175 - 0.051X$, $R^2 = 0.325$), but the damage on the west side was less than the east side (Fig. 3).

Larval parasitism for this field was low throughout the growing season. There were no significant differences for the mean parasitism between the field ends and interior ($F = 0.934$; df = 2, 12; $P > 0.05$; Fig. 5).

Parasitoids dissected from diamondback moth larvae included *Diadegma insulare* (Cresson), Conura (*Spilochalcis*) side (Walker), and an unidentified hymenopteran species. More than 90% of the parasitoids found were *D. insulare*.

Discussion

In general, more diamondback moth larvae were found on cabbage plants at the ends of rows than on plants in the interior of fields. Although the differences varied among sampled fields, diamondback moth larval density was higher on cabbage plants at row ends adjacent to weed-filled ditches than on cabbage plants at row ends adjacent to woods and bushes. Cabbage heads along the field ends suffered more larval damage than did the cabbage heads in the interior fields. Furthermore, damage to the cabbage on the margins next to the weed-filled ditch area was greater than that next to woods and bushes. There were no significant differences in larval densities and damage to cabbage between the ends abutting other cabbage fields (fields C and E) and the interior of the fields. No significant differences were shown in percentage parasitism of diamondback moth larvae between ends and the interior of fields for any of the five fields inspected.

Among the interior sampling zones across the field, the zone halfway between the middle and west end (i.e., next to the weed-filled ditch area) had greater plant damage than the middle zone of fields A-C though the difference of the larval densities was not significant. This suggests that diamondback moth populations spread from the end next to the weed-filled ditch inwards up to 50 to 70 m of the cabbage field and caused corresponding damage to cabbage plants.

The damage to cabbage growing on the first row was not greater than interior rows on the south side of field A, the north side of field B and the east side of field D, all of which abutted other cabbage fields. More damage on the first one or few rows than the inside rows on the north side of field A and the south side of field B, both adjacent to irrigation ditches. More rows had greater damage to cabbage heads than the interior rows on the west side of fields D and E, which were both adjacent to drainage ditches. The spread of diamondback moth into the east side of field E might be from the earlier planted cabbage. After these cabbage heads were harvested, diamondback moths migrated to the cabbage in adjacent fields.

Reasons for invasion of the diamondback moth are not known, but the weeds along the field margins may serve as nonhost plants or shelters for

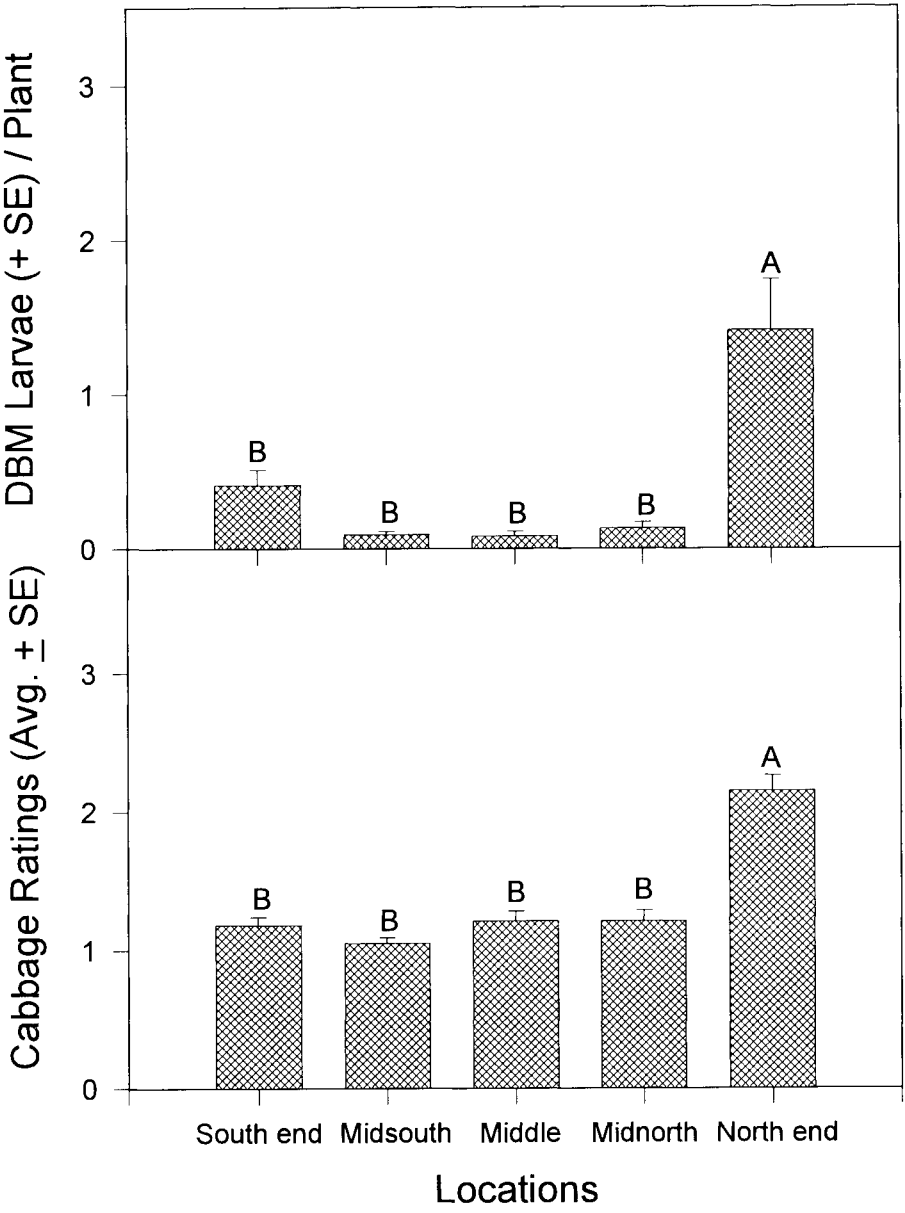

Fig. 7. Mean (± SE) numbers of diamondback moth larvae per plants from 23 March to 13 April and average cabbage ratings at harvest at five collection zones across field E. (Means topped by different letters are significantly different [$P < 0.05$; DMRT]).

diamondback moth. A few weeds occurring along these field edges, including wild radish, wild mustard, field pennycress, and shepherds purse, have been shown to be alternate hosts of diamondback moth larvae (Idris and Grafius 1996). We have observed that the larvae also feed on spreading dayflower leaves under laboratory conditions (unpublished data). These wild plants may be important as reservoir hosts for the diamondback moth before cabbage seedings are planted in the fields. More weeds occurred along the banks of drainage ditches than along irrigation ditches and other edges of the fields, resulting in a greater infestation of diamondback moth on the cabbage adjacent to these areas.

Previous studies have shown that diverse vegetation reduces diamondback moth density on cabbage plants (Bach and Tabashnik 1990, Buranday and Raros 1973, Srinivasan and Krishna Moorthy 1992) or collards (Horn 1987). During preparing the land for planting cabbage, cultivation of the crop during the growing season, and spraying the cabbage with pesticides, diamondback moth populations would be greatly reduced or destroyed. However, diamondback moth populations in the untilled and unsprayed areas around the periphery of the fields would normally be unaffected. Thus, as diamondback moth populations increase in these areas gravid females apparently move into the edges of fields and deposit their eggs on cabbage plants.

Because of the propensity of diamondback moth populations to build up along field edges and subsequently move into the field interior, sampling strategies to estimate the pest numbers and to time spray applications should include interior and edge areas. Sampling only along the edge will overestimate diamondback moth larval populations. However, avoiding the edge area will also underestimate the population.

It is generally accepted that the use of chemical pesticides is essential for protection of the cabbage crop from damage caused by the diamondback moth. Growers often assess the need to apply pesticides for control of diamondback moth by examining the edge of cabbage fields for evidence of diamondback moth infestation and crop damage. This may result in an overuse of chemical insecticides in cabbage. DeBach and Rosen (1991) have estimated that at least 50% of insecticides currently used in agriculture are not necessary.

To overcome the edge effect, control measures should be strengthened along the edge of cabbage fields. Spraying the cabbage along the edge of the fields may be helpful in reducing diamondback moth numbers in these areas, resulting in the need for fewer pesticide applications that blanket the entire field. Moreover, the release of larval parasitoids such as *Cotesia plutellae* Kurdjumova (E. R. Mitchell, unmpublished) along field margins may enable the parasitoid to find diamondback moth larvae more easily, build up their numbers, and spread into the cabbage field. This strategy could be used in combination with pesticides, e.g., *B. thuringiensis*-based materials, known to be less harmful to the environment, and to *Cotesia* parasitoids (Kao and Tzeng 1992).

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References Cited

Andow, D. A. 1992. Population density of *Empoasca fabae* (Homoptera: Cicadellidae) in weedy beans. J. Econ. Entomol. 85: 379-383.

Bach, C. E. and B. E. Tabashnik. 1990. Effects of nonhost plant neighbors on population densities and parasitism rates of the diamondback moth (Lepidoptera: Plutellidae). Environ. Entomol. 19: 987-994.

Biever, K. D., D. L. Hostetter and J. R. Kern. 1994. Evolution and implementation of a biological control-IPM system for crucifers: 24-year case history. Am. Entomol. 40: 103-108.

Buranday, R. P. and R. S. Raros. 1973. Effects of cabbage tomato intercropping on the incidence and oviposition of the diamondback moth, *Plutella xylostella* (L.). Philip. Entomol. 2: 369-374.

DeBach, P. and D. Rosen. 1991. Biological control by natural enemies. 2nd ed. Cambridge Univ. Press, New York.

Day, W. H. 1994. Estimating mortality caused by parasites and diseases of insects: comparison of the dissection and rearing methods. Environ. Entomol. 23: 543-550.

Greene, G. L., W. G. Genung, R. B. Workman and E. G. Kelsheimer. 1969. Cabbage looper control in Florida: a cooperative program. J. Econ. Entomol. 62: 798-800.

Horn, D. J. 1987. Vegetational background and parasitism of larval diamondback moth on collards. Entomol. Exp. Appl. 43: 300-303.

Idris, A. B. and E. Grafius. 1996. Effect of wild and cultivated host plants on oviposition, survival, and development of diamondback moth (Lepidoptera: Plulellidae) and its parasitoid *Diadegma insulare* (Hymenoptera: Ichneuminidae). Environ. Entomol. 25: 825-833.

Kao, S., and C. Tzeng. 1992. Toxicity of insecticides to *Cotesia plutellae*, a parasitoid of diamondback moth, Pp. 287-296. *In* Talekar, N. S. [ed.], Diamondback moth and other cruciferous pests: proceedings of the second international workshop. Shunhua, Taiwan. Asian Vegetable Research Development Center.

Leibee, G. L. R. K. Jansson, G. Nuessly and J. L. Taylor. 1995. Efficacy of emamectin benzoate and *Bacillus thuringiensis* at controlling diamondback moth (Lepidoptera: Plutellidae) populations on cabbage in Florida. Florida Entomol. 78: 82-96.

Marks, R. G. 1990. Analyzing research data. Robert E. Krieger Publ. Co., Malabar, FL.

McLaughlin, J. R., E. R. Mitchell and R. Kirsch. 1994. Mating disruption of diamondback moth (Lepidoptera: Plutellidae) in cabbage: reduction of mating and suppression of larval populations. J. Econ. Entomol. 87: 1198-1204.

Mitchell, E. R., G. Y. Hu and J. S. Okine. 1996a. Diamondback moth (Lepidoptera: Plutellidae) infestation and parasitism by *Diadegma insulare* (Hymenoptera: Ichneumonidae) in collards and adjacent cabbages. Florida Entomol. 80 (1): in press.

SAS Institute. 1990. User's Guide: Statistics. Ver. 6, 4th ed. SAS Institute, Cary, NC.

Shelton, A. M., J. L. Robertson, J. D. Tang, C. Perez; S. D. Eigenbrode, H. K. Preisler, W. T. Wilsey and R. J. Cooley. 1993a. Resistance of diamondback moth (Lepidoptera: Plutellidae) to *Bacillus thuringiensis* in the field. J. Econ. Entomol. 86: 697-705.

Shelton, A. M., J. A. Wyman, N. L. Cushing, K. Apfelbeck, T. J. Dennehy, S. E. R. Mahr and S. D. Eigenbrode. 1993b. Insecticide resistance of diamondback moth (Lepidoptera: Plutellae) in North America. J. Econ. Entomol. 86: 11-19.

Srinivasan, K. and P. N. Krishna Moorthy. 1992. The development and adoption of integrated pest management for major pests of cabbage using Indian Mustard as a trap crop, Pp. 10-14. *In* Talekar, N. S. [ed.], Diamondback moth and other cruciferous pests: proceedings of the second international workshop. Shunhua, Taiwan. Asian Vegetable Research and Development Center.

Talekar, N. S. and A. M. Shelton. 1993. Biology, ecology, and management of the diamondback moth. Annu. Rev. Entomol. 38: 275-301.