

IMPACT OF CONSERVATION BIOLOGICAL CONTROL PRACTICES ON NATURAL ENEMIES: A CASE STUDY OF DIAMONDBACK MOTH AND ITS PARASITOIDS

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INTRODUCTION

The performance of natural enemies in agricultural systems is often limited by the absence or scarcity of essential resources (van den Bosch and Telford, 1964). For example, many parasitic wasps need a source of sugar to realize their maximum longevity and fecundity (Jervis *et al.*, 1996). Habitat management presents an opportunity to enhance the suppression of pests by natural enemies, thereby increasing the role of biological control in pest management systems (Landis *et al.*, 2000).

The diamondback moth, *Plutella xylostella* (L.), is a key pest of brassicaceous crops worldwide (Talekar and Shelton, 1993). The development of resistance by the diamondback moth to a wide range of insecticides has hastened the search for effective alternatives to insecticides. Parasitoids and predators have not delivered consistently effective control of the diamondback moth (Talekar and Shelton, 1993), but their effectiveness may be limited, in part, by the absence or reduced availability of flowering plants in agricultural systems. Some of the parasitoids of the diamondback moth are known to have greater longevity and fecundity if they feed on nectar (Idris and Grafius, 1995, 1997; Johanowicz and Mitchell, 2000). Johanowicz and Mitchell (2000) suggested that planting selected flowers into brassicaceous crops could enhance control of the diamondback moth by parasitic wasps.

Investigations were undertaken to determine the feasibility of enhancing biological control of diamondback moth by growing flowering plants within broccoli crops, *Brassica oleracea* L. cv. Marathon. These studies were intended to provide a foundation for ongoing research on improving biological control in commercial crops of *Brassica* vegetables. Therefore, identification of impediments to success was a key aim.

Brassica vegetable crops in southern Australia often have unplanted alleys to provide access for tractors during spraying and at harvest, or for irrigation pipes. These alleys often harbor weeds, so farmers would welcome an alternative management practice for them if it is neither too expensive nor too time consuming to manage. Alleys provide space that could be used to grow insectary plants to promote selectively the activities of parasitoids and predators. Ideally, insectary plants should provide nectar, pollen, or nonpest prey for natural enemies that attack the full spectrum of pests that occur within a managed crop. The plants should be neither weedy competitors for crops nor impede access to the crop.

MATERIALS AND METHODS

Two flowering plants were chosen to provide nectar to parasitoids. Alyssum (*Lobularia maritima* [L.] Desv., Brassicaceae) has been shown to prolong the lifespan of *Cotesia marginiventris* (Cresson) (Hymenoptera: Braconidae) and *Diadegma insulare* (Cresson) (Johanowicz and Mitchell, 2000). Pak choi (*Brassica campestris* L., Brassicaceae) has been shown to have accessible floral nectaries and nectar that prolongs the life of *Cotesia rubecula* (Marshall) (Hymenoptera: Braconidae) (Siekmann, 2002).

It is also an excellent source of food for *Diadegma semiclausum* Hellén, which is the most abundant parasitoid of *P. xylostella* in southern Australia (Goodwin, 1979). Pak choi can be induced to flower quickly after transplanting by growing seedlings under a long-day photoperiod. Both species flower continuously over long periods.

We conducted two experiments to investigate how planting selected flowers would influence the densities of diamondback moth, levels of parasitism, and the incidence of other pests in broccoli.

Small Plot Experiment

A crop of broccoli was transplanted on the Waite Campus of the University of Adelaide, Urrbrae, South Australia, on 26 January 2001. The crop was divided into two plots and each plot had eight rows of broccoli. The plants were 50 cm apart along rows, and the distance between rows alternated between 50 cm and 80 cm. A 2 m wide alley divided each plot in half. In one of the plots, flowering plants were transplanted down the middle of this alley. The flowers were pak choi (1/m) and alyssum (3/m). A row of sweet corn was sown in the middle of a 4 m wide fallow strip that separated the two plots. Plants that failed to establish or that were damaged by ducks were replaced. There was virtually no population of diamondback moth after establishment of the crop, so 600 adults were released into the crop between 1 and 9 March. Also 30 female and 15 male *D. semiclausum* were released between 6 and 21 March.

The crop was sampled weekly to assess plant growth, and the density and level of parasitism of larvae of the diamondback moth and other insects. Once the crop was established, each plant along a row was assigned a number. These were randomized, and on each sampling date four plants per row were sampled. The height of the plant was measured and its developmental stage was recorded. Then the entire plant was inspected. The numbers of larval and pupal diamondback moth were recorded and all larvae and pupae were collected. The presence of other insects, most notably aphids, was also recorded, but densities were not determined. In the laboratory, larval diamondback moth were dissected to determine the frequency of parasitism. Pupae were held in vials closed with a cotton wool plug to determine viability and the frequency of parasitism. Sampling commenced on 7 March and ended on 18 April, when the first heads were ready for harvest.

Experiment in a Commercial Crop

A second investigation of insectary plants grown within the crop alleys was undertaken in a commercial broccoli crop at Virginia, South Australia. Broccoli was transplanted weekly in 21 row strips (10.4 m wide), and each strip was separated by a 2.8 m alley. Flowering plants were transplanted for a distance of 30 m from one boundary along the centers of two alleys flanking a broccoli strip that was transplanted 28 March 2001. One pak choi, six alyssum, and one dill (*Anethum graveolens* L., Apiaceae) were transplanted per metre on 12 April. The alyssum was flowering at the time of transplanting, pak choi began flowering approximately one week later, and the dill never flowered. A gap of 30 m separated the flowers from a second plot within the crop that was sampled but had no insectary flowers.

All larval and pupal diamondback moth were collected from 25 randomly selected plants from each plot on each sampling date between 19 April and 15 June, when plants were nearly ready to harvest. Larvae were dissected to determine the level of parasitism, and pupae were held in vials closed with a cotton wool plug to determine viability and the level of parasitism. The species of parasitoids that were attacking larval *P. xylostella* was determined by rearing additional larvae collected on two dates (10 and 24 May). The height and developmental stage of each plant were also recorded. The farmer applied one spray of *Bacillus thuringiensis* (Berliner) (Dipelâ) on 23 April and one spray of trace elements on 4 June.

RESULTS

In the Small Plot Experiment, fewer fourth instar diamondback moth were found on broccoli plants associated with alleys of flowers than on plants adjacent to open alleys (Fig. 1). The difference was not substantial and virtually the same numbers of pupae of the diamondback moth were found in both treatments, so flowers did not reduce populations of diamondback moth in this experiment. There were no consistent differences in rates of parasitism between the treatments (Fig. 2). Although the species of parasitoids was not determined in dissections, visual censuses indicated that *D. semiclausum* was the dominant parasitoid and *Apanteles ippeus* Nixon (Hymenoptera: Braconidae) was also abundant. An outbreak of cabbage aphids on flowers of pak choi spread to the broccoli.

No suppression of diamondback moth was observed in the experiment in the commercial broccoli crop (Fig. 3). The population of diamondback moth declined at the end of the experiment

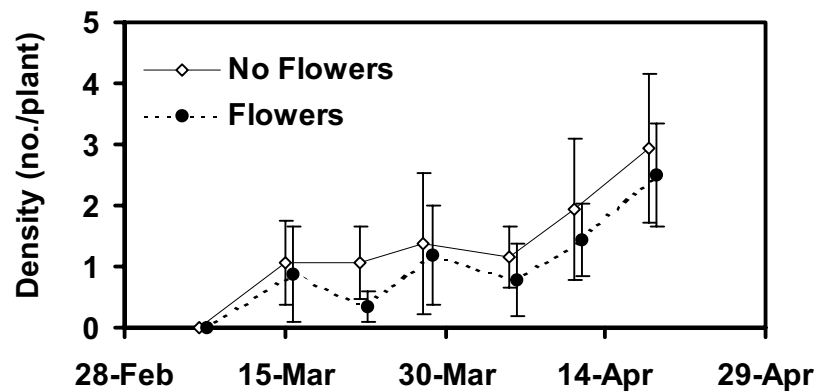


Figure 1. Densities of fourth instar diamondback moth on broccoli in the Small Plot Experiment at Urrbrae, South Australia (values are mean \pm 95% confidence interval).

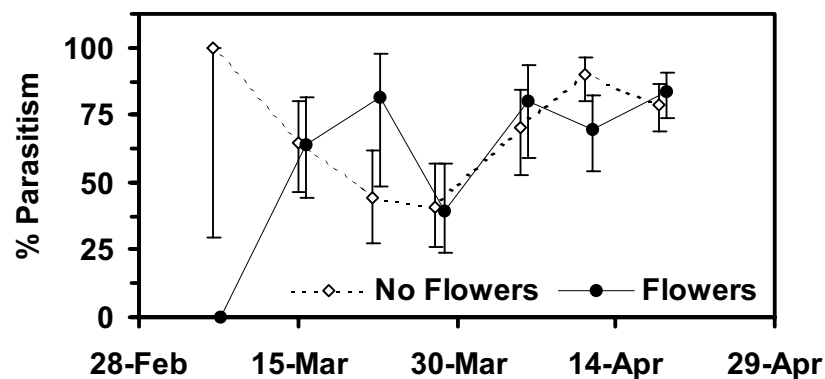


Figure 2. Parasitism of fourth instar diamondback moth on broccoli in the Small Plot Experiment at Urrbrae, South Australia (values are mean \pm 95% confidence interval).

due to an epizootic of *Zoophthora radicans* (Brefeld) Batko (Zygomycetes: Entomophthorales). There were no consistent differences in rates of parasitism between the treatments (Fig. 4). Larval parasitism ($n = 47$) was predominantly caused by *D. semiclausum* (72%) and to a lesser extent by *A. ippeus* (28%).

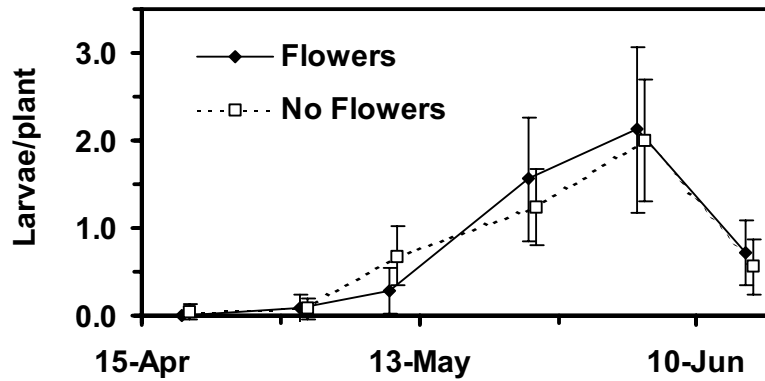


Figure 3. Densities of fourth-instar diamondback moth on broccoli in the Commercial Broccoli Crop Exp. at Virginia, South Australia (values are mean \pm 95% confidence interval).

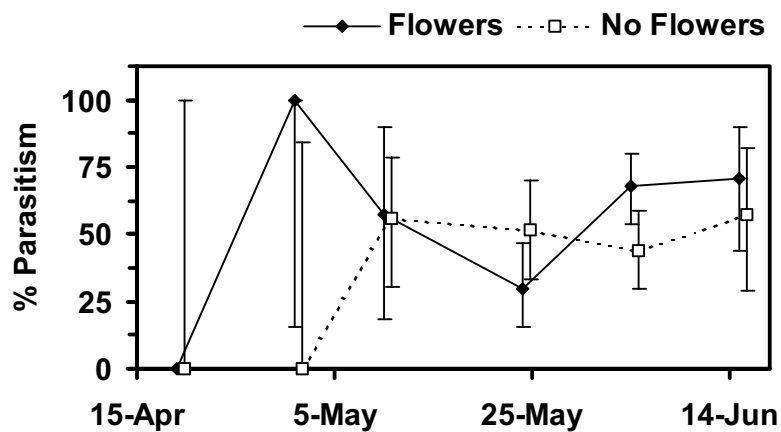


Figure 4. Parasitism of fourth instar diamondback moth on broccoli in the Commercial Broccoli Crop Exp. at Virginia, South Australia (values are mean \pm 95% confidence interval).

Diadegma semiclausum and *A. ippeus* were observed feeding from flowers of Chinese cabbage and alyssum. Both species flowered throughout the experiments.

DISCUSSION

In spite of high levels of parasitism, populations of diamondback moth increased over the experimental period and exceeded the action thresholds used by most South Australian farmers. Flowers failed to improve biological control of diamondback moth in either experiment. This could be due to the wrong choice of flowers, the wrong density or spatial arrangement of flowers, or movements of parasitic wasps between the experimental treatments. It is also possible that wasps had sufficient other sugar sources in the vicinity of the experimental areas that flowers had no effect. Honeydew from aphids may have delivered sufficient sugar to meet the needs of wasps.

Although *D. semiclausum* and *A. ippeus* were observed feeding from flowers of Chinese cabbage and alyssum, it is not known whether they received sufficient nectar to increase their longevity and fecundity. Alyssum and Chinese cabbage are known from laboratory experiments to provide excellent food for wasps (Johanowicz and Mitchell, 2000; G. Siekmann, 2002). Thus the nutritional value of the nectar of the chosen flowers was undoubtedly very high. Native bees and introduced honey bees were abundant and active in removing nectar throughout the experiment. They may have

left insufficient nectar to supplement the food of parasitoids significantly. Adult diamondback moths were also observed feeding on alyssum and pak choi. It is possible that the beneficial impact of the flowers on the activities of natural enemies was negated by providing food for the target pest. Ideally, flowers could be chosen that provide food for natural enemies, but not for pests. However, this goal may not be achievable in many instances.

In order to demonstrate the role of flowers in biological control and to design effective cropping systems, consideration must be given to the movement of natural enemies (Corbett and Plant, 1993). Movements of wasps between the experimental treatments may have prevented them from showing localized improvements in the level of biological control in either experimental broccoli crop. In the future, experiments that aim to demonstrate the beneficial impact of habitat management on biological control should be designed with a knowledge of the dispersal ranges of natural enemies. Such experiments could be conducted either on isolated experiment plots that are replicated in space or on plots of sufficiently large size that movements by natural enemies don't lead to substantial mixing of their populations between treatments.

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