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Host plant genotype of the herbivore *Plutella xylostella* (Lepidoptera: Plutellidae) affects the performance of its parasitoid *Diadegma insulare* (Hymenoptera: Ichneumonidae)

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Abstract

Understanding interactions among brassicaceous host plants, their oligophagous herbivore *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), and the parasitoid *Diadegma insulare* (Cresson) (Hymenoptera: Ichneumonidae) are important for developing optimal integrated crop management strategies, but empirical studies investigating such tritrophic interactions are uncommon. We evaluated the bottom–up effects of some cultivated Brassicaceae on several fitness correlates of *D. insulare* and the potential top–down effects on *P. xylostella*. Survival and parasitism of *D. insulare* varied considerably among the tested plant genotypes on which host larvae were reared with most on *Sinapis alba* L. and least on *Brassica napus* L. cv. Q2. Egg to pre-pupal development was fastest on *B. juncea* (L.) Czern. and slowest on *B. oleracea* L., whereas pupae developed most rapidly on *B. napus* cv. Liberty. *Plutella xylostella* larvae parasitized with female *D. insulare* consumed the largest and smallest leaf areas when reared on *B. napus* cv. Liberty and *B. carinata* L., respectively. Parasitized *P. xylostella* larvae that consumed more food subsequently produced heavier *D. insulare* pupae with heavier silk cocoons than larvae on hosts that consumed less foliage. Heaviest *D. insulare* males were produced on *B. rapa* L. whereas females were heaviest on *B. carinata*. Female and male specimens reared on *B. napus* cv. Q2 lived for the shortest time in the absence of food. Female wasps reared on *B. carinata* and *B. rapa* had the largest forewings whereas wasps reared on *B. napus* cv. Q2 had the smallest forewings. Females reared on *B. napus* cv. Liberty and *B. rapa* developed the largest hindwings whereas male wasps reared on *B. napus* cv. Q2 had the smallest hindwings. *Plutella xylostella* larvae parasitized by *D. insulare* consumed significantly less foliage than their non-parasitized counterparts, suggesting that this parasitoid could provide a direct benefit to the plants. Strategies for obtaining additive benefits of the biological control agent and host plant resistance for the integrated management of *P. xylostella* are discussed.

Keywords: Brassicaceae; Diamondback moth; Biological control; Tritrophic interactions

1. Introduction

The diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is one of the most destructive insect pests of brassicaceous crops worldwide (Talekar and Shelton, 1993; Sarfraz et al., 2006). It is a "leader" among difficult to control field crop insect pests owing to its rapid development of high levels of resistance to various insecticides (Mota-Sanchez et al., 2002; Sarfraz and Keddie, 2005). Consequently, increased efforts worldwide have been undertaken to develop integrated management strategies for its control, based principally on manipulation of its parasitoids. Although over 135 parasitoid species are known to attack various life stages of *P. xylostella*, most control worldwide is achieved by relatively few species belonging to the hymenopteran ichneumonid genera *Diadegma* and *Diadromus*, the braconid genera *Microplitis* and *Cotesia*, and the eulophid genus *Oomyzus* (see Sarfraz et al., 2005).

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Diadegma insulare (Cresson) (Hymenoptera: Ichneumonidae) is a solitary koinobiont, host-specific larval endoparasitoid of *P. xylostella* and is one of its most important biological control agents with a range extending from the Nearctic to northern Neotropical regions (Harcourt, 1960; Fitton and Walker, 1992; Idris and Grafius, 1996, 2001; Braun et al., 2004; Sarfraz et al., 2005). In 1992, *D. insulare* accounted for ca. 30 and 45% of the total parasitism in canola fields in Alberta and Saskatchewan, respectively (Braun et al., 2004). In New York, *D. insulare* resulted in 46.5% of the total *P. xylostella* parasitism from 1979 to 1994 (Shelton et al., 2002). In Florida, its contribution was 55–90% to the total *P. xylostella* parasitism recorded in cabbage crops during 1996 and 1997 (Hu et al., 1998). From 1994 to 2003, *P. xylostella* parasitism by *D. insulare* was 62–82% in Minnesota cabbage fields (Wold-Burkness et al., 2005).

Compared with other parasitoids, *D. insulare* is an efficient host searcher (Xu et al., 2001; Wang and Keller, 2002). It parasitizes all four larval instars of *P. xylostella*; it kills and emerges from the pre-pupal stage of its host and spins its own cocoon inside the loosely woven cocoon of its host (Harcourt, 1960; Putnam, 1968). The number of generations per year of *D. insulare* corresponds to the number of generations of *P. xylostella* as one host larva supports only one parasitoid larva (Putnam, 1968; Sourakov and Mitchell, 2000). However, despite its importance as a biological control agent, extensive research on factors affecting its life history traits is uncommon. Few previous studies have investigated the impacts of the host plant genotype utilized by its *P. xylostella* hosts on the fitness and developmental biology of *D. insulare*. For instance, Idris and Grafius (1996) reared *P. xylostella* on excised leaves of various cultivated and wild Brassicaceae, exposed them to *D. insulare* and measured parasitism rates, development times, and sex ratios.

The present study was designed to build upon previous studies and provide detailed insights on some key life history traits of both male and female *D. insulare* when its *P. xylostella* host larvae were reared on various host plant species and cultivars. This study focused on determining effects on *D. insulare* of eight Brassicaceae commonly grown in various crucifer-growing areas worldwide, and which serve as hosts for *P. xylostella*. It is usually assumed that proteins conferring herbicide tolerance should not affect insect herbivores or their natural enemies, but recent research published by Sarfraz et al. (2007) demonstrated that *P. xylostella* performance varied considerably on conventional and herbicide-tolerant canola (*Brassica napus* L.) along with other tested Brassicaceae. We therefore used the same plant genotypes to investigate their potential bottom–up effects, if any, on the third trophic level. Several key life history parameters directly related to parasitoid population dynamics (e.g., parasitism, survival, pre-imaginal developmental time, larval herbivory, pupal weight, adult body weight, longevity without food, forewing area, and hindwing area) were investigated on all eight Brassicaceae. A further objective of this study was to provide detailed comparison between parasitized and unparasitized *P. xylostella* for defoliation when specimens were reared on tested plant genotypes.

2. Materials and methods

2.1. Insects and plants

The laboratory colonies of *P. xylostella* and *D. insulare* were maintained on potted *B. napus* cv. Q2 plants at 22 ± 0.5 °C with 16 h L:8 h D. Moths and wasps collected from different fields in Alberta, Canada were added to the culture every summer to maintain genetic diversity.

Eight Brassicaceae, namely *B. napus* cv. Q2 (susceptible to both glufosinate ammonium and glyphosate herbicides), *B. napus* cv. Liberty (resistant to glufosinate ammonium), *B. napus* cv. Conquest (resistant to glyphosate), *B. rapa* L. cv. Reward, *B. juncea* (L.) Czern. cv. Cutlass, *B. carinata* L. (Accession No. BCA-003), *B. oleracea* L. cv. Red Acre, and *Sinapis alba* L. (Accession No. SAL-004) were grown under greenhouse conditions. Plants were grown individually in 15.2-cm-diameter pots using Metromix-220 (W.R. Grace & Co., Ajax, Ontario, Canada) as a potting medium and fertilized with 20:20:20 (N:P:K) at 0.5 g per pot when plants were two to three weeks old. Four-week-old plants were used for all experiments.

2.2. Intact plant study: survival and parasitism

Survival of *D. insulare* from egg to pupa was assessed in screened cages ($40 \times 40 \times 80$ cm), arranged on a greenhouse bench in a completely randomized design with each cage considered one replicate. Each cage contained a single plant; the entire experiment used 80 cages with 10 plants from each species/cultivar. All plants were infested with first-instar *P. xylostella* larvae at 10 larvae per plant by holding neonates carefully from their silk to avoid handling damage; neonates had no prior feeding experience. Larvae were observed daily until they molted to second instars. Five plants of each genotype received two female and two male wasps ($\leqslant$3 days old) whereas the remaining five plants served as controls; wasps were allowed to parasitize *P. xylostella* larvae for 24 h and were then removed from the cages. Plants were observed every 48 h and the numbers of surviving individuals were recorded, but daily observations were made when pupation began. *Diadegma insulare* pupae were harvested, weighed within 24 h of pupation and kept individually in labeled transparent plastic cups until adult emergence.

We assumed that mortality of *P. xylostella* larvae other than control mortality was caused by parasitoids and the percent parasitism was calculated using the following equation:

$$\text{Parasitism}(\%) = [(P_{\text{di}} \div L_{\text{t}}) \times 100] + M_{\text{c}}$$