

Impact of flowering buckwheat on Lepidopteran cabbage pests and their parasitoids at two spatial scales

Jana C. Lee ^{a,*}, George E. Heimpel ^b

^a University of California Davis, Entomology Department, Davis, CA, USA

^b University of Minnesota, Entomology Department, St. Paul, MN, USA

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Abstract

We assessed the potential of annual buckwheat, *Fagopyrum esculentum* Moench, to lead to improved parasitism of lepidopteran cabbage pests over four years. Pest, parasitism, and hyperparasitism rates were monitored in replicated cabbage plots (12 × 20 m) with or without 3 m wide buckwheat borders from 2000 to 2003. Floral borders did not significantly increase egg, larval, or pupal densities of cabbage looper, *Trichoplusia ni* (Hübner), imported cabbageworm, *Pieris rapae* (L.), or diamondback moth, *Plutella xylostella* (L.). Buckwheat increased parasitism rates by *Voria ruralis* (Fallen) on *T. ni* larvae and *Cotesia rubecula* (Marshall) on *P. rapae* larvae over four years. Parasitism by *Diadegma insulare* (Cresson) on *P. xylostella* larvae was higher in buckwheat than control plots in the first year, and parasitism by *Euplectrus plathypenae* (Howard) on *T. ni* larvae was lower in buckwheat than control plots in the second year. The hyperparasitoid *Conura side* (Walker) attacked *D. insulare* all four years, but buckwheat did not affect hyperparasitism rates. The effect of spatial scale on pest densities and parasitism in 2001 was evaluated by comparing plots separated at least 67 m (nearby) versus 800 m apart (isolated). *T. ni* pupae and *P. rapae* eggs and pupae were more abundant in plots in closer proximity, whereas *P. xylostella* densities did not vary by the spatial separation of plots. Tachinids and *Pteromalus puparum* (L.) attacked more *P. rapae* in nearby plots. *E. plathypenae* responded to the treatment × scale interaction, parasitizing more in control than buckwheat when plots were isolated but not when plots were nearby.

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1. Introduction

Herbivores are often less abundant in diversified than simplified agricultural habitats (Risch et al., 1983). The ‘resource concentration’ hypothesis suggests that herbivores are more likely to find and remain on densely concentrated host plants than host plants in diversified settings (Root, 1973). Habitat diversity may also increase the abundance of predators and parasitoids, leading to a reduction in herbivore populations accord-

ing to the ‘enemies’ hypothesis (Root, 1973). A review by Andow (1991) provided support for the enemies hypothesis—75% of parasitoid species and 42.7% of predator species had higher densities in polycultures compared to monocultures.

Habitat diversification benefits natural enemies by providing alternative prey, suitable microclimate, and resource subsidies of nectar and pollen (Landis et al., 2000). Numerous laboratory and field cage studies have demonstrated that parasitoids given flowers have greater longevity (Johanowicz and Mitchell, 2005; Orr and Pleasants, 1996) and fecundity than starved parasitoids (Foster and Ruesink, 1984; Idris and Grafius, 1995; Tylianakis et al., 2004). Sugar sources enable adult

* Corresponding author. Fax: +1 530 297 1098.
E-mail address: jtleee@ucdavis.edu (J.C. Lee).

parasitoids to build glycogen reserves (Fadamiro and Heimpel, 2001; Giron and Casas, 2003) and slow the decline of lipid reserves (Ellers, 1996; Lee et al., 2004). Not surprisingly, a number of studies have shown that fields with flowering vegetation have higher parasitism rates than fields without flowers (English-Loeb et al., 2003; Irvin et al., 1999; Lavandero et al., 2005; Leius, 1967; Manojlovic et al., 2000; Stephens et al., 1998) and parasitism rates have been shown to decline as distance from floral resources increases (Baggen and Gurr, 1998; Tylanakis et al., 2004). However, other studies have found no differences in parasitism rates between fields with and without floral nectar (Berndt et al., 2002; Cappuccino et al., 1999; Irvin et al., 2000; Nicholls et al., 2000).

These widely varied research outcomes may occur due to several factors. In order for floral habitats to improve parasitism rates, parasitoids should: (1) be limited by sugar, (2) feed on floral nectar in the field, and (3) have increased fecundity in the presence of nectar (the parasitoid nectar provision hypothesis, Heimpel and Jervis, 2005). These criteria may not be met in experiments with negative outcomes. Some parasitoids do not readily feed from available nectar in the field (Heimpel and Jervis, 2005). Other insects such as bees and syrphid flies may diminish the nectar supply to parasitoids (Lee and Heimpel, 2003). An increase in fecundity that a parasitoid obtains from feeding may be negligible if predators or unsuitable field conditions reduce life expectancy to values similar to starvation (Heimpel et al., 1997, 1998). Negative outcomes may also occur if nectar sources increase oviposition by pests (Baggen and Gurr, 1998), or benefit the fourth trophic level (Stephens et al., 1998) and reduce pest suppression. Finally, treatment effects may have been masked in past studies if host patches (experimental plots) were within the parasitoid's dispersal ability, allowing movement between different treatment plots (Keller and Baker, 2003).

Our objectives in this study were to determine: (1) whether floral borders have an undesired effect of increasing pest densities or hyperparasitism rates in cabbage, (2) whether floral borders increase parasitism rates, and (3) how pests and parasitoids respond to floral borders when host patches are in close proximity versus distant. Cultivated cabbage plants, *Brassica oleracea* var. *capitata* L., are attacked by cabbage looper, *Trichoplusia ni* (Hübner) (Lep., Noctuidae), imported cabbageworm, *Pieris rapae* (L.) (Lep., Pieridae), and diamondback moth, *Plutella xylostella* (L.) (Lep., Plutellidae), in Minnesota (Wold-Burkness, in press). These pests are often managed with action thresholds and insecticides (Hines and Hutchison, 2001), but a variety of parasitoids in cabbage fields attack these lepidopteran pests (Godin and Boivin, 1998). The pest–parasitoid complex in cabbage is an ideal system for studying the parasitoid nectar provision hypothesis since the parasitoids differ in life-history

strategies, attacking host egg, larval, or pupal stages (Wold-Burkness et al., in press).

2. Methods

A four-year experiment was conducted at the University of Minnesota Field Experiment Station, Rosemount, Minnesota from 2000 to 2003. To test for effects of floral habitat on pest and parasitism rates, we monitored four cabbage plots (12 m by 20 m) with and without buckwheat (*Fagopyrum esculentum* Moench) borders. An ideal floral species should bloom while parasitoids are active (Landis et al., 2000), and have accessible nectar (Patt et al., 1997). Buckwheat meets these criteria, and has been commonly used in manipulation programs (Heimpel and Jervis, 2005). In 2000 and 2001, eight cabbage plots were embedded in a large soybean field (>5.5 ha), each plot was spaced at least 67 m apart to minimize dispersal of parasitoids between treatments (Fig. 1). However, a greater separation appeared necessary as the study continued. Therefore, in 2001–2003, eight cabbage plots were separated at least 800 m apart and embedded in separate soybean fields of at least 3 ha (Fig. 1). These two spatial scales are referred to as 'nearby' and 'isolated,' and the study was conducted at both spatial scales in 2001. We embedded cabbage plots in soybean fields since soybean is common in Midwest US landscapes and soybean flowers cannot be fed upon by parasitoids of cabbage pests (Lee, 2004).

Cabbage (cv. 'Gourmet') seedlings were transplanted on 22 June 2000, 8 June 2001, 6 June 2002, and 5 June 2003. Plots consisted of 10 cabbage rows in 2000–2001 and 12 rows in 2002–2003. Rows were 20 m long with ~55 cabbage plants per row with 100 cm row spacing. Cabbage plots were planted in new sites every year and left untreated. Weeds between rows were removed by hand. Buckwheat strips (3 m wide) were planted along the 20 m borders on 7 June 2000, 25 June 2001 (nearby sites), 28 June 2001 (isolated sites), 11 June 2001, and 9 June 2003. Buckwheat strips were also planted along the shorter 12 m borders to maximize nectar availability at the end of summer on 3 July 2002 and 14 July 2003.

We removed all eggs, larvae, and pupae of *T. ni*, *P. rapae*, and *P. xylostella* from 5 to 10 randomly selected cabbage plants in each plot weekly twice in 2000 and weekly once in 2001–2003. We sampled 10 cabbage plants per plot early in the season when plants were small, and sampled fewer plants, not less than 5 per plot as plants grew. *P. xylostella* eggs were not collected since they were not easily seen in the field. In the laboratory, eggs, larvae, and pupae were kept individually in 1 oz plastic cups at 27 °C and 24 h light, larvae were fed fresh cabbage leaves every two days. Pests were monitored until adult or parasitoid emergence. Parasitoids were identified and deposited at the Entomology museum of

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