Host Plant Preference of Harlequin Bug (Hemiptera: Pentatomidae), and Evaluation of a Trap Cropping Strategy for Its Control in Collard

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ABSTRACT  Harlequin bug, Murgantia histrionica (Hahn) (Hemiptera: Pentatomidae), is a piercing-sucking pest of cole crops, causing cosmetic damage in low populations, while heavy pest pressure can kill plants or entire fields. Field studies were conducted to evaluate a trap crop for control of harlequin bug in collard. Field-cage choice tests found that potential trap crop plant species, mustard (Brassica juncea 'Southern Giant Curled'), rapeseed (B. napus 'Athena'), rapini (B. rapa), and arugula (Eruca sativa) attracted more harlequin bugs than collard (B. oleracea 'Champion') and a nonbrassica control, bean (Phaseolus vulgaris 'Bronec'). Mustard was the most consistently selected by harlequin bug over collard in choice tests, and was found to be an effective trap crop for reducing feeding injury on collard at two experimental sites. Augmentation of the mustard trap crop with a systemic, neonicotinoid insecticide provided no added control of harlequin bug for the 10 wk duration in the spring season.

KEY WORDS  harlequin bug, Murgantia histrionica, cole crop, trap crop, choice test

Harlequin bug, Murgantia histrionica (Hahn) (Hemiptera: Pentatomidae), is an important pest of cole crops in the United States, and is considered a Brassicaceae specialist, feeding on unrelated species only in the absence of Brassicas (McPherson and McPherson 2000). The piercing-sucking feeding of adults and nymphs creates white blottches on leaves, making vegetables sold as greens unmarketable, and heavy pest pressure can kill plants or entire fields of untreated cole crops (Paddock 1915, Ludwig and Kok 2001). Harlequin bug adults survive the winter under shelter in field litter and debris, and typically complete two to four generations per year, depending on climate (White and Brannon 1933). Aggregations of adults and nymphs are often observed on cole crops as well as wild host plants (McClain 1981).

Although there are several broad-spectrum insecticides that are effective at controlling harlequin bug (Rogers and Howell 1972, McLeod 2005, Walgenbach and Schoof 2005, Kuhar and Doughty 2009), these classes of insecticides cannot be used in organic systems and are also detrimental to important natural enemies in the crucifer crop agroecosystem (Xu et al. 2001, 2004; Hill and Foster 2003; Cordero et al. 2007). Many growers are opting for newer insecticides that specifically target lepidopteran pests, and are safer for conservation of natural enemies, but do not control hemipteran pests such as harlequin bug (Edelson and Mackey 2006a; Walgenbach and Schoof 2005, 2009).

We foresee a need for an alternative management strategy for harlequin bug that does not rely solely on the use of broad-spectrum insecticides and can be integrated into current management strategies.

A trap crop is a highly attractive plant stand grown to draw pest pressure from a protected crop, which also concentrates pests in a certain part of the field where they can be managed (Hokkanen 1991). Before the widespread use of synthetic chemical controls, trap cropping was recommended control of harlequin bug, using radish (Raphanus sativus L.), turnips (Brassica rapa L.), mustard (B. juncea L.), rapeseed (B. napus L.), or kale (B. oleracea L. Acephala group) to draw pressure away from cabbage (B. oleracea L. Capiptata group; Thomas 1915, Chittenden 1920, Fulton 1930). Trap cropping has shown some success in reducing injury of several species of pests attacking cole crop including harlequin bug in broccoli (Ludwig and Kok 1998, Shelton and Badenes-Perez 2006).

A dead-end trap crop is one which is highly attractive for feeding or oviposition but does not allow development of offspring because of lack of nutrition or through chemical defense (Shelton and Nault 2004). Trap crops can be rendered “dead-end” by using conventional pesticides to knock down pest populations. Additionally, neonicotinoid insecticides are known for their low mammalian toxicity, reduced effects on nontarget insects, and low potential for environmental hazards (Thomson 2000). Several neonicotinoid products have been found to be effective in...
controlling harlequin bug when used as a foliar spray (Edelson 2004a, b; Edelson and Mackey 2005a, b; Edelson and Mackey 2006b; Walgenbach and Scoof 2011). Neonicotinoids are water soluble and can be taken up by plants through the roots and translocated through the xylem vessels to plant tissues (Tomizawa and Casida 2005). Application to the root zone, compared with a foliar treatment, allows for better reduction in nontarget effects, and is a more attractive method for many growers because of a longer residual efficacy in controlling harlequin bug (Kuhr and Doughty 2009; Wallingford 2012).

Harlequin bug displays many characteristics of a pest that can be successfully managed by trap cropping in that it displays host preference, is highly mobile, and aggregates on field margins. Aggregation is aided by the production of a male-synthesized pheromone that attracts both male and female harlequin bug (Zahn et al. 2008, 2012). There is also potential for a complex of cole crop pests to be controlled by the same strategy (Shelton and Badenes–Perez 2006). It is important that a trap crop can be deployed in a manner that fits into current practices of commercial cole crop managers and does not create an unexpected pest problem. Information on host plant preference will aid in the selection of a proper trap crop species. Augmenting a trap crop with a systemic insecticide could contribute to better control of harlequin bug without applying additional insecticide to the protected crop. Our objective is to 1) identify an attractive host plant for feeding, habitation, and oviposition of harlequin bug and 2) evaluate a method of trap cropping to control harlequin bug that is augmented by the use of a systemic insecticide.

Materials and Methods

Host Preference. Host Plants. Potential trap crop species, mustard (B. juncea ‘Southern Giant Curled’), rapeseed (B. napus ‘Athena’), arugula (E. sativa ‘Roquette’), and rapini (B. rapa), were compared with collard (B. oleracea ‘Champion’) and bean (Phaseolus vulgaris ‘Bronco’), a typical cash crop and a nonbrassica control, respectively. Plants were grown from seed in the greenhouse in a mix of sphagnum peat moss, perlite, and vermiculite (2:1:1), irrigated daily and fertilized weekly with Scott’s Water Soluble Plant Food (18–18–21 N–P–K with micronutrients; Scotts–Sierra Horticultural Product Company, Marysville, OH). Plants used in all experiments were 8–10 wk old, with no reproductive structures, and at least four true leaves on plants that remained in pots, while plants in field-cages had a minimum of eight true leaves.

Insects. Adult harlequin bugs were field-collected from collards grown at the Virginia Tech Eastern Shore Agricultural Research and Extension Center (AREC) in Painter, VA. In 2009, participants were collected from the field in June and were likely a mix of overwintered and first generation adults. In 2010, participants were collected in September and were likely a mix of second and third generation adults. Lab-reared insects were originally collected from mustard and collards grown at the Virginia Tech Kentland Research Farm near Blacksburg, VA. Insects were reared in mesh cages (30 × 30 × 30 cm; Bioquip Products, Rancho Dominguez, CA) on a mix of cabbage leaves and cauliflower florets, and maintained at 24 + 5°C, −10% relative humidity (RH), and a photoperiod of 16:8 (L:D) h.

Field-Cage Choice Tests. Host plant preference for harlequin bug feeding, habitation, and oviposition was evaluated at the Eastern Shore AREC in Painter, VA, June 2009 and September 2010. A row of five plants of each species were randomly planted in each of four cages (2 × 2 × 1 m; Bioquip Products, Rancho Dominguez, CA) at 6–8 wk and experiments were started at 8–10 wk. Adults (30–50) were introduced in the center of each cage and plants were observed for insects and egg masses at 24, 48, and 72 h after introduction. Weather conditions for the duration of both experiments were generally partly cloudy, and daytime temperatures ranged from 24 to 30°C.

Oviposition Choice Test. Oviposition rates were low in both field-cage experiments, so an additional choice test was conducted in the greenhouse at Virginia Tech in Blacksburg, VA in May 2011. One potted plant of each species was placed in each of six wooden framed cages with wire mesh sides (45 × 45 × 60 cm). Three mating pairs were taken from the colony and introduced to cages in the evening and plants were observed daily for egg masses over the following 72 h. This procedure was repeated twice for a total of 12 replications. Weather conditions were generally overcast and greenhouse temperatures ranged from 26 to 32°C.

Trap Crop Experiments. Experiments were conducted in summer 2011 at Virginia Tech’s Kentland Research Farm near Blacksburg, VA, and the Virginia Tech Hampton Boads AREC in Virginia Beach, VA. In mid-May at both locations, collards (B. oleracea ‘Champion’) and mustard (B. juncea Southern Curled Giant) were direct seeded at 2–4 kg/ha, and managed with minimal inputs other than weed management, which were applied according to conventional management practices (Wilson et al. 2010). Collard plots consisted of eight 5 m rows spaced 0.3 m apart, each plot being a minimum of 10 m from any other. Experiments were arranged in a randomized complete block design and replicated four times at each site. Treatments included: 1) no trap crop, collard plot as described; 2) mustard border rows, collard plot as described with the addition of a 5 m row of mustard seeded on both sides; and 3) insecticide-treated mustard border rows, collard plot as described with the addition of a 5 m row of mustard seeded on both sides to which a drench application of thiamethoxam + chlorantraniliprole (0.16 liters [active ingredient] a.i./hectare Durivo; Syngenta, Greensboro, NC) was applied at first observation of harlequin bug in plots. Plots were scouted weekly for arrival of local populations and, when adults were first observed, insect densities were recorded twice weekly until collard greens reached harvest maturity (10 wk). On each observation date, 10 collard plants and 10 mustard
Table 1. Harlequin bug adults and egg masses (EM) observed on plants in choice tests in June 2009, Sept. 2010, and May 2011; mean no. of adults observed on all five plants, per cage for each plant type 24, 48, and 72 h after introduction to field cages, and mean no. egg masses observed on plants over 72 h in field cages (n = 4), and in greenhouse oviposition choice test (n = 12)

<table>
<thead>
<tr>
<th>Plant</th>
<th>2009 Adults</th>
<th>2010 Adults</th>
<th>2011 Greenhouse</th>
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<tbody>
<tr>
<td></td>
<td>24 h</td>
<td>48 h</td>
<td>72 h</td>
</tr>
<tr>
<td>Arugula</td>
<td>1.0b</td>
<td>0.3b</td>
<td>0.0c</td>
</tr>
<tr>
<td>Bean</td>
<td>0.0c</td>
<td>0.3b</td>
<td>0.0c</td>
</tr>
<tr>
<td>Collard</td>
<td>1.5b</td>
<td>1.0b</td>
<td>0.0c</td>
</tr>
<tr>
<td>Mustard</td>
<td>10.0a</td>
<td>11.3a</td>
<td>7.3a</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>1.0b</td>
<td>0.5b</td>
<td>0.5b</td>
</tr>
<tr>
<td>Rapini</td>
<td>1.5b</td>
<td>0.3b</td>
<td>1.3b</td>
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</tbody>
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Values in the same column followed by the same letter are not significantly different according to Kruskal-Wallis (P < 0.05) and means separation was determined by nonparametric multiple comparisons based on rank sums.

Results

Host Preference and Performance. In 2009 and 2010, significantly more harlequin bug adults were observed on mustard than on any other plant species with the exception of arugula at the 24 h observation in 2010 (Table 1). More adults were observed on rapeseed and rapini than on collard, arugula, or bean by the end of the experiment in 2009, while arugula was also preferred over collard and bean in 2010 (Table 1).

In 2009, more harlequin bug egg masses were observed on arugula, collard, mustard, and rapeseed than on rapini or bean, while in 2010, more egg masses were found on rapeseed and collard than any other species, and mustard was not different from bean (Table 1). In the greenhouse cage tests, more egg masses were observed on rapeseed than any other species, while mustard was not different from bean (Table 1).

Trap Crop Experiments. Harlequin bugs appeared on plants well before harvest in all experiments and the insecticide applications to treatment three plots occurred at week 5 and 3 for Virginia Beach, and Blacksburg, respectively. Peak numbers of adults occurred after week 8, and the subsequent generation of nymphs reached a peak after week 10.

More harlequin bug adults and nymphs were observed in mustard border rows than in accompanying collard plots on several observation dates for trap crop treatments, while there was no difference in egg masses between mustard and collards (α = 0.05; Fig. 1). This difference was seen earlier in untreated mustard plots, while differences were not seen in insecticide-treated plots until 60–70 d after treatment (Wallingford 2012).

More damaged collard leaves were observed in plots with no trap crop than in plots with mustard border rows at Virginia Beach and Blacksburg (F = 37.56; df = 2, 9; P < 0.0001 and F = 6.45; df = 2, 9; P = 0.0183, respectively), while there was no difference between plots protected by either untreated or insecticide-treated trap crops (Fig. 2).

Discussion

Harlequin bug demonstrated a strong preference for mustard over collard for feeding and habitation, confirming historical recommendations and previous reports of host preference (Paddock 1915, Ludwig and Kok 1998). A trap crop of mustard decreased the number of damaged leaves seen in collard for up to 10 wk, a time frame comparable to that of a cabbage or broccoli crop started from transplants, although some cole crops started from seed would require a longer period of protection.

There was no difference in control between plots with untreated versus thiamethoxam-treated mustard trap crops (Fig. 2) and this was likely because of the peak colonization of harlequin bug occurring after the period of residual efficacy of the insecticide. The rate of harlequin bug colonization was slow, generally 3–4 wk between the first observation and peak populations of harlequin bug adults in plots, which resulted in the highest insect pressure occurring when residual efficacy of one drench application of thiamethoxam was sinking (Wallingford 2012). Without a proper action threshold, the use of a systemic insecticide may be viewed as unnecessary for the 10 wk time period.
evaluated, although control of the pest population is highly recommended. Control of congregated harlequin bug could also be accomplished with a foliar insecticide treatment, vacuuming, burning, or tilling under that trap crop, which will destroy eggs and nymphs.

Oviposition choice data differed between years, and this may be because of the variability in the time of year during which experiments were conducted (Table 1). Ovipositing females in the September 2010 experiment may have been more selective than those used in June 2009, because shorter days indicate that the season is ending. Variation in tactile cues from the plant surface may have played a role in oviposition choice. Although the effect of tactile cues on harlequin bug is unknown, the presence of pubescence on the leaf surface and increased waxy bloom have been reported to affect the behavior of other phytophagous insects and their natural enemies (Lamb 1980, White and Eigenbrode 2000).

Harlequin bug females did not show a preference for laying eggs on mustard in the field as there were no differences between the number of egg masses observed in mustard border rows versus accompanying collard plots; however, nymphs did show a preference for mustard (Fig. 1). Oviposition choice and the subsequent nymphal densities probably did not contribute to the overall damage observed on collard leaves during the time frame of the field experiments, as nymphs were not observed until late in the experiment. Nymphs are highly mobile and capable of finding host plants, although nymphal host preference is unknown. The movement of ovipositing females and their nymphs between trap crop and protected plants should be investigated for longer infestation periods.

Although mustard was found to be the most consistently preferred plant species for feeding and habitation, rapeseed, and rapini were also preferred over collard in choice tests (Table 1). There is potential for several plant species or varieties to be used as a trap crop and a mix of more than one plant species is potentially the most effective trap crop. Furthermore, using one or more of these plant species may control a complex of pests. B. juncea, also known as Indian mustard, has been previously cited as an effective trap crop for harlequin bug (Ludwig and Kok 1998), as well as flea beetle and several lepidopteran pests of cole crops (Luther et al. 1996, Smyth et al. 2003).

Trap cropping is a viable option in several farming systems and is currently used regularly on organic
farms. Often a preferred host plant will slow movement of pest species to a great enough extent that no further management is necessary. If management is required, insects can be hand-picked or vacuumed off these plants, and there are several organically certified insecticides whose active ingredients include spinosad and azadirachtin (Edelson and Mackey 2006b, Overall et al. 2008) that provide some efficacy on harlequin bug. Trap cropping can also be augmented with natural enemies, such as entomopathogens, parasitoids, and predators, and can improve overall arthropod diversity that can maintain pest populations below economic thresholds (Correa-Ferreira and Moscardi 1996, Aguilar-Fenollosa et al. 2011). In summary, knowledge of a predictable behavior in harlequin bug can be used to devise management strategies for its control in cole crops. A border row of mustard reduced harlequin bug injury in collard by roughly 50%, without the use of insecticides. Although there was no difference in control between untreated and insecticide treated plots, the use of insecticides may be required for management of harlequin bug aggregations on trap crops, to reduce on-farm pest populations that may infest subsequent plantings of cole crops.

Acknowledgments

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