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‘Attract and reward’: Combining a herbivore-induced plant volatile with floral resource supplementation – Multi-trophic level effects

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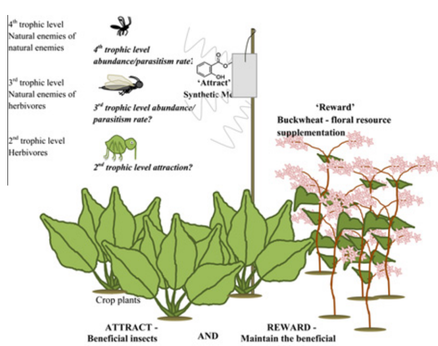
HIGHLIGHTS

- Arthropods from two trophic levels were affected by elements of ‘attract and reward’.
- MeSA increased aphid parasitism rate.
- Different natural enemy species were attracted to either buckwheat (*Fagopyrum esculentum*) or methyl salicylate (MeSA).
- Fourth trophic level arthropod species may be attracted to buckwheat.
- Both MeSA and buckwheat may repel certain species from the third and fourth trophic level.

GRAPHICAL ABSTRACT



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ABSTRACT

Two field experiments were conducted to assess whether a concept termed ‘attract and reward’ (A&R) could enhance conservation biological control (CBC). In A&R, a synthetically-produced herbivore-induced plant volatile (HIPV) (‘attract’) is combined with a floral resource (‘reward’). It is anticipated that the two will work synergistically, attracting natural enemies into the crop (‘attract’) and maintaining them within it (‘reward’).

The study was conducted in Canterbury, New Zealand and the system consisted of brassica crop, commonly occurring brassica herbivores, their natural enemies and higher order natural enemies. The HIPV deployed was methyl salicylate (MeSA) and the floral resource was buckwheat *Fagopyrum esculentum*.

The first experiment assessed the abundance of arthropods from three trophic levels and the second evaluated herbivore abundance, parasitism and hyper-parasitism rates. No synergistic effect of ‘attract’ and ‘reward’ was observed in either experiment. Populations of three parasitoids, one hoverfly and one lacewing from the third trophic level and a fourth trophic level lacewing parasitoid increased significantly in treatments with buckwheat. One hoverfly species was significantly more abundant in treatments with MeSA, but less abundant in treatments with buckwheat. The effect of MeSA on

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Diadegma semiclausum abundance depended on sex, with fewer males and more females being caught. Treatments with MeSA had significantly higher aphid parasitism rate.

Combining MeSA and buckwheat could be beneficial because the two techniques increase the abundance of different natural enemies. Thus, these results indicate that A&R has potential as a CBC technique, as long as any unwanted side effects can be managed.

1. Introduction

The frequent disturbances linked with high-intensity agricultural practices and the modification of the habitat to an environment low in physical and biological resources required by natural enemies of pests often result in a decline in biological control (Chaplin-Kramer et al., 2011). Conservation biological control (CBC) can be used to mitigate those effects by modification of the environment and of existing pesticide practices (Eilenberg et al., 2001; Landis et al., 2000). Habitat manipulation techniques are used within CBC to enhance trophic cascades. These occur when changes in a predatory species' abundance alters the distribution and abundance of a plant species (Schmitz et al., 2000). One type of habitat manipulation is the provision of floral resources by non-crop plants grown within or around the crop. These provide omnivorous natural enemies with alternative food sources, such as nectar and/or pollen which may enable them to remain in an area with temporarily low prey/host densities (Landis et al., 2000; Olson et al., 2005). Dietary floral supplementation can also increase components of the natural enemies' 'ecological fitness' such as longevity and fecundity (Berndt and Wratten, 2005; Landis et al., 2000; Lavandero et al., 2005). However, the results from field trials with floral resource subsidies have been mixed. For example, Jonsson et al. (2010) found that of the 11 studies that were published between 1998 and 2007, on the effect of floral subsidies on natural enemies of invasive pests in different agricultural systems, seven demonstrated an increase in predation/parasitism rates and only one showed a decrease in pest populations and crop damage.

One way to potentially increase the pest-reducing efficiency of natural enemies is by combining provision of floral resources with deployment of substances that attract more enemies into the crop, a new concept termed 'attract and reward' (A&R) (Jonsson et al., 2008; Khan et al., 2008; Simpson et al., 2011a). The 'attract' concept is based on the use of synthetically produced herbivore-induced plant volatiles (HIPVs). These are a form of induced plant defense that may function both through 'top-down', by attracting natural enemies (Dicke and Bruin, 2001) and 'bottom-up' mechanisms, repelling the herbivore (Dicke et al., 1990). Production of HIPVs is induced by herbivore feeding damage (Geervliet et al., 1997) or by egg deposition on the plant (Hilker and Meiners, 2002). HIPVs can function as attractants of natural enemies to herbivore-affected plants and as a signal to other plants to produce their own herbivore defenses (inter-plant communication) (Dicke and Bruin, 2001). They can also function as a 'primer', signaling to surrounding undamaged plants of an impending herbivore attack without initiating the undamaged plants to produce a full defense response (Engelberth et al., 2004). HIPVs can be synthetically produced and the deployment of some of these substances within agricultural systems has been shown to increase natural enemy numbers near the crop (James and Grasswitz, 2005; Orre et al., 2010; Thaler, 1999).

Both HIPVs and floral resources can affect arthropods from second (Dicke and Minkenberg, 1991; Lavandero et al., 2006) and fourth trophic levels (Araj et al., 2008; Jonsson et al., 2009; Orre et al., 2010). Attraction of arthropods from the fourth trophic level may cause an un-wanted trophic cascade, which results in lower abundance of the lower level natural enemy (third trophic level) and a higher abundance of the mid-level consumers (herbivorous pest) causing a reduction in the abundance of basal producers (crop plants) (Carpenter and Kitchell, 1993).

As both 'attract' and 'reward' may affect arthropods from the untargeted second and fourth trophic levels, the change in abundance of arthropods from these, as well as from the targeted third trophic level needs to be evaluated. Any consequences these changes may have on population and community structure need to be assessed before the A&R-concept can be considered as a potential habitat manipulation strategy within crop pest management.

The aim of this work was to examine the extent to which 'attract and reward' improves biological control in a brassica crop. The 'attract' component was the HIPV methyl salicylate (MeSA) and the 'reward' was buckwheat *Fagopyrum esculentum* (BW). An initial experiment evaluated the effect of 'attract and reward' on the abundance of a range of arthropods from three trophic levels, focusing on brassica pests, predators and parasitoids of these pests as well as parasitoids attacking the pests' predators and parasitoids. A second experiment evaluated any effects these changes may have had on biological control efficacy.

2. Methods

2.1.1. Study system

The study system was kale *Brassica oleracea* L. (Brassicaceae) cv. Sovereign in the first experiment and a mixture of kale and swedes *Brassica napus* L. (Brassicaceae) in the second as well as the most common herbivores and their associated natural enemies within the crop. Methyl salicylate (MeSA) was used for the 'attract' part of this work. MeSA is naturally produced by brassicas in response to herbivore damage (Geervliet et al., 1997; van Poecke et al., 2001) and MeSA produced by herbivore-damaged Brussels sprouts is perceived by parasitoids with hosts on brassicas (Steinberg et al., 1992). Previous experiments in turnip *Brassica rapa* L. (Brassicaceae) have shown that synthetically produced MeSA can increase the abundance of *Diadegma semiclausum* Hellén (Hymenoptera: Ichneumonidae) (Orre et al., 2010) a parasitoid of the diamondback moth (DBM) *Plutella xylostella* L. (Lepidoptera: Plutellidae) one of the most common herbivores reaching pest status in brassicas (Cameron and Walker, 2000; Kok, 2004). Synthetically produced MeSA also increases the abundance of predators in soybean *Glycine max* L. Merr. (Fabaceae) (Mallanger et al., 2011; Zhu and Park, 2005), cotton *Gossypium* spp. (Malvaceae) (Yu et al., 2008), apples *Malus domestica* Borkh. (Rosaceae) (Jones et al., 2011), cherries *Prunus* spp. (Rosaceae) (Tóth et al., 2009), cranberries *Vaccinium* spp. (Ericaceae) (Rodriguez-Saona et al., 2011) and strawberries *Fragaria* spp. (Rosaceae) (Lee, 2010), and predators and parasitoids in hops *Humulus* spp. (Cannabaceae) and grapes *Vitis* spp. (Vitaceae) (James and Price, 2004).

The flowering plant used for the 'reward' part was buckwheat (BW) *Fagopyrum esculentum* Moench (Polygonaceae) cv. Katowase. Supplementation with BW in the field can contribute to the pest management of DBM (Lavandero et al., 2005; Lee and Heimpel, 2005).