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A first approach to pest management strategies using trap crops in organic carrot fields

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ABSTRACT

Cultural control methods in integrated pest management (IPM) refer to practices that modify the agricultural environment in ways that favour crop protection to the detriment of pest performance. Trap cropping is one of these practices and involves luring insect pests away from the main crop to a more attractive host plant growing beside or around the crop. The trap crop can then be destroyed, and the pest killed. The carrot psyllid, *Trioza apicalis* Förster (Homoptera: Triozidae), is one of the most important carrot pests in Scandinavia, and cultural control of this pest could be achieved through the introduction of more attractive cultivars of carrots in the trap crop at different sowing times than used for the main crop. In a multichoice bioassay and a field experiment, *T. apicalis* females oviposited the highest numbers of eggs on the most developed carrot plants in the trap crop, while different carrot cultivars did not play any role in females' choice. In the field experiment, probability of damage was highly correlated with number of eggs counted on the plants, which was highest on the most developed plants. The cultivar Bolero was used as trap crop in subsequent trials in three commercial carrot fields in different regions of Sweden. The trap crop concentrated the egg laying to the field edges and it decreased with increasing distance within the main crop from the first row of carrots, while this pattern could not be observed in control plots. These first results are promising, but further trials to better quantify efficacy and to evaluate the spatial design of the trap crop in field, at different sites and population pressure, are needed before trap cropping can be a reliable strategy for carrot psyllid control.

1. Introduction

Cultural control methods in integrated pest management (IPM) refer to practices that modify the agricultural environment in ways that favour crop protection to the detriment of pest performance (Brunner, 2014). To date, these practices have been based on known life history features of the target pest (Altieri, 1993). Trap cropping aimed at attracting a pest away from the main crop is one of these cultural practices.

In trap cropping, the insect pest is lured away from the main crop to a more attractive host plant growing beside or around the crop (Shelton and Badenes-Perez, 2006). For successful pest control, it is important to find a trap crop that is more attractive for feeding or oviposition than the main crop being protected. Differences in attractiveness could be based on either a more attractive plant species or cultivar and/or a more preferred development stage of the same plant species (Hokkanen, 1991). Trap cropping has great potential in the design of pest control strategies compared with other control schemes based on intercropping. Herbivore densities in trap crop systems are primarily determined by trap crop coverage and attractiveness, factors that more easily can be manipulated in field, whilst herbivore colonization rates mainly governed herbivore densities in row-intercropping (Banks and Ekbom, 1999). An additional benefit is that the trap crop can be destroyed before the pest insect has developed a new generation. Many insects colonize crops from outside the field and exhibit preferences among their host plants which can be exploited to arrest pest migration on a trap crop that completely encircles the main crop (Boucher and Durgy, 2004). For example, perimeter trap cropping is a form of trap crop deployment in which more attractive crops are planted around the entire outer edge of the main crop (Shelton and Badenes-Perez, 2006).

The carrot psyllid [*Trioza apicalis* Förster (Homoptera: Triozidae)] and the carrot rust fly [*Psila rosae* F. (Diptera: Psilidae)] are the most important insect pests on carrot plants (*Daucus carota*) in Sweden, Norway and Finland. The carrot psyllid overwinters as adults on conifer trees (Láska, 1974; Rygg, 1977). The migration period to winter host trees starts in August and may continue until late October, with only one generation a year. The migration to summer host plants usually starts at the end of May and early June in the Nordic countries (Rygg,

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1977; Nissinen, 2008). When feeding on the leaves of carrot plants, the carrot psyllid introduces a toxic substance into the plant. This substance causes physical disorders such as curled leaves and stunted growth and roots. Young seedlings are more vulnerable to these physical disorders than older plants and therefore as carrot plants grow, they can better withstand carrot psyllid feeding (Nissinen et al., 2007, 2008). Overwintered females cause more damage to the plant than males, nymphs or the new generation of adults emerging in late summer (Markkula et al., 1976).

Swedish conventional farmers currently rely on chemical pesticides for control of the carrot psyllid (Ragnarsson et al., 2016), while organic farmers primarily cover carrot fields with different types of insect nets, but with negative effects on the crop due to weed proliferation (Ellgardt, 2008). There is therefore an urgent need for research into more sustainable pest control practices. The spatial pattern of damage is not that well studied, however scientists and farmers, have noted a concentration at field edges (Nissinen et al., 2000; Kristoffersen and Anderbrant., 2007). This field edge concentration could further be strengthened in field by planting an attractive trap crop luring the pest away from the main crop. However, finding a more attractive trap crop species than carrots seems to be the greatest challenge in trap cropping for control of carrot psyllid. Láska (1974) and Valterová et al. (1997) investigated the host range of the carrot psyllid and found that cultivated and wild carrots were more preferred hosts compared with other members of the family Apiaceae, e.g. parsley (*Petroselinum crispum*), parsnip (*Pastinaca sativa*), fennel (*Foeniculum vulgare*) and coriander (*Coriandrum sativum*), on which carrot psyllid can complete its life cycle. Targeting early attacks by carrot psyllid to effectively protect the most susceptible plant stage is another challenge, and identification of the optimal timing is therefore crucial for success in a trapping crop strategy. The trap crop should be in its most attractive stage at the time when carrot seedlings are emerging in the main crop.

In this study, we examined issues that are important in advancing research on trap cropping for carrot psyllid and that are also applicable for growers. Therefore, field experiments were designed in close collaboration with growers to facilitate implementation in existing farming systems. The experimental assessment consisted of (i) an initial phase in which different carrot cultivars in different developmental stages were tested in multichoice bioassays in cages and (ii) a second phase where the most attractive cultivars were tested in trap cropping systems in two-year field experiments. The aim of these was to identify the best carrot cultivars for use as trap crops to effectively attract overwintered carrot psyllids compared with the cultivated carrot species in the main crop and the optimal timing of their emergence relative to that of the main crop.

2. Material and methods

2.1. Cage experiments

2.1.1. Plant material

Plant material was grown in a greenhouse chamber with a photoperiod of 20:4 (L:D) h and 18 °C during the day and 13 °C at night. Individual seeds were sown in 0.33 L plastic pots either one, two, three or four weeks before the start of the experiment. A commercial peat and sand mixture was used as substrate (Hasselfors Garden Special, Hasselfors Garden AB, Örebro, Sweden) and the seedlings were watered regularly with a 1‰ plant fertiliser (Wallco växtnäring, NPK 4.6-0.9-3.8).

The cultivar Bolero was used in tests seeking to identify the preferred developmental stage as it is the preferred carrot cultivar of organic carrot growers in Sweden, while a total of six different carrot cultivars (Bolero, Calibra, Caravejo, Mignon, Namdal and Newhall) were used for cultivar choice tests. These cultivars are recommended for organic carrot production in Sweden due to their relative rapid development from seed to seedling, and thereby having better competitiveness against weeds.

2.1.2. Insect material

Wild collected *T. apicalis* individuals were used in all experiments. The insects were captured weekly on young carrot seedlings using an insect aspirator and magnifying glass, starting in the last week of May until third week of June, in an organically managed carrot field in Dalarna, central Sweden. Males and females were placed in a cage with potted carrot plants, cv. Caravejo (Seminis) and acclimatised in a greenhouse environment (climate as described for plant material) for five days before being used in experiments. Gravid females, recognised by their swollen abdomen, were collected 3 h before experiment start-up and released individually into plastic tubes.

2.1.3. Egg-laying preference for development stage and for cultivar

A series of different choice experiments were performed outdoors in plastic insect cages (32.5 × 32.5 × 77.0 cm, Bugdorm- 43074, Megaview Taiwan) in June 2015. A temperature logger was placed in one cage for every trial for monitoring the difference in temperature between replicates. In the experiment for preference for development stage, four carrot plants (cv. Bolero) of different ages (1 week old = cotyledon, 2 weeks old = first true leaf, 3 weeks old = 2 true leaves, 4 weeks old = 3 true leaves) were placed at one end of the cages in two rows. Plant position in terms of age was randomised for each cage. In the experiment for preference for cultivar, six different cultivars, as described above, were randomised within each cage, with three rows of two cultivars per row. Each plant was separated from the next by at least 10 cm (Supplementary Fig. 1). One gravid *T. apicalis* female was released 30 cm from the first row of plants and was allowed to lay eggs for 72 h. Each cage was placed 0.5 m away from the next to avoid shading. At the end of the experiment, eggs were counted on each plant. A total of 28 replicates were conducted on three different occasions in June and July 2015 for the experiment of development stage and a total of 18 replicates were conducted during the two first weeks of July for the experiment of cultivars. The frequency with which females oviposited on a certain type of plant (hereafter, referred to as "frequency of visits") and number of eggs laid were recorded.

2.2. Field experiments

Field experiments were conducted in organically managed vegetable farms in Valbo (N 60°632′ E 16°993′), Borlänge (N 60°437′ E 15°480′) and Dala-Floda (N 60°491′ E 14°845′), all located in central Sweden, in 2013 (only Valbo) and 2015. The experimental fields were treated according to the standards of KRAV, a Swedish certification organisation for organic production and a member of the International Federation of Organic Agriculture Movements (IFOAM).

2.2.1. Field design in 2013

In 2013, the experimental field consisted of a main carrot crop (130 m × 75 m) with randomised treatment plots placed in 10 different blocks parallel to the long sides of the field. The distance between carrot rows was 75 cm, and the field consisted of 100 carrot rows. Each block was spaced 3 m away from the neighbouring block and contained six different treatments plots (3 m × 3 m), each with 4 rows of carrots. Treatment plots were separated from each other by 75 cm within the block (Supplementary Fig. 2). The carrot cultivars Calibra and Bolero were selected as trap crops due to their rapid emergence and development during the early development stages, as shown in an earlier greenhouse experiment (Rämert and Nilsson, 2014). In addition, cv. Namdal was included as a trap crop, as it was the main crop grown in the field experiment. All three cultivars used as trap crops were sown on two dates, 10 and 20 May, hereafter referred to as 'early' and 'late' trap crops (Table 1). The main crop was sown on 31 May. The seed rate was 100 seeds per m for trap crops and 75 seeds per m for the main crop, following the experimental setup by Ellgardt (2008).