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Implementing Integrated Pest Management in commercial crops of radish (*Raphanus sativus*)

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ABSTRACT

The aim was to determine, for commercial radish production, a method of reducing damage by larvae of *Delia radicum,* to replace the application of an organophosphorus insecticide. It was anticipated that this change in practice would have implications for other pests and pathogens affecting the crop. Use of net covers appeared to be the most effective approach and plot experiments confirmed that covers reduce damage by *D. radicum* considerably. The covers had less impact on feeding damage to foliage by *Phyllotreta* spp. and no impact on the prevalence of lesions believed to be caused by *Peronospora parasitica*. Despite the apparent effectiveness of the covers there were still incidents of high levels of damage by *D. radicum* in commercial crops. Possible reasons were investigated and, in particular, it appeared that the production system, where several crops were sown sequentially in the same piece of land, allowed infestations to develop from eggs laid on waste radish which remained after the crop was harvested and from where larvae moved onto the new crop. The study has shown clearly that a good understanding of pest biology is fundamental to developing an effective integrated approach to crop protection and that changing management approaches for one pest species may have implications for the management of others.

1. Introduction

Integrated Pest Management (IPM) has been defined as 'A decision-based process involving coordinated use of multiple tactics for optimizing the control of all classes of pests (insects, pathogens, weeds, vertebrates) in an ecologically and economically sound manner' (Prokopy, 2003). Whilst the development of commercially-viable Integrated Pest Management (IPM) approaches is well-advanced in many protected crops such as tomato (van Lenteren, 2000), it can be more challenging in outdoor crops and particularly where crop quality is paramount. In addition, the costs of implementing IPM can be high and some approaches may not be viable for relatively low value crops. However, a number of factors are influencing farmers and growers to consider IPM as an option. This may be because of a lack of suitable pesticides to control certain pests or pathogens (Hillocks, 2012) or to pressures from their customers to reduce pesticide use (Garcia Martinez and Poole, 2004). This paper describes research undertaken through collaboration between growers and entomologists to develop an IPM strategy for the control of the cabbage root fly (*Delia radicum* (L.)) on radish.

Delia radicum is a pest of Brassicaceous crops in the holarctic region, particularly northern Europe and North America (Coaker and Finch, 1971). The female flies usually lay their eggs close to the soil surface around the base of host plants and the larvae feed on the plant roots, causing damage that can lead to reduced growth and, in some cases, plant death. Where part of the root system is marketed (e.g. swede (*Brassica napus* var. *napobrassica*), turnip (*Brassica rapa*), radish (*Raphanus sativus*)), feeding damage reduces plant quality, rendering the roots unmarketable.

On leafy brassica crops that are sown in modules and subsequently transplanted into the field, the most common method of controlling *D. radicum* in the UK in recent times has been through the use of pre-planting module drenches of the organophosphorus insecticide chlorpyrifos (Kennedy and Collier, 2000). More recently there has been the opportunity to apply a similar treatment using spinosad and a new treatment using cyantraniliprole was approved in 2016. Control of *D. radicum* on directly-sown root crops has been more problematical and for control of *D. radicum* on swede crops many UK growers have moved

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to the use of fine mesh net covers to exclude adult flies (Kennedy and Collier, 2000). For radish, a single insecticide treatment, involving a post-sowing field spray of chlorpyrifos, has been available until recently, but this has not always been completely effective and use of chlorpyrifos in this way is no longer approved.

This paper describes research undertaken to develop an alternative approach to control *D. radicum* on radish and to examine the impact of this new approach on other factors that may affect crop yield and quality. These include damage to the foliage by species of flea beetle (*Phyllotreta* spp.) and through lesions believed to be due to downy mildew (*Peronospora parasitica*), which can affect the marketable quality of radish and, in particular, whole radish plants sold in bunches. All potential approaches to manage *D. radicum* in radish were considered including the use of net covers to exclude adult flies, which have been used previously in a number of situations to manage this pest (Folster, 1989; Antill et al., 1990; Steene et al., 1992; Finch, 1993; Kennedy and Collier, 2000). The radish crops which are the focus of this study were grown within a relatively small area near Feltwell, Norfolk, UK (52.4864° N, 0.5194° E, 10 m) in soil with high organic matter content. Prior to implementation of the new approach, radish crops were sown sequentially in the same location two to four times in a season and then in the following year radish crops were grown in other fields in the locality. Other brassicaceous crops grown in the locality include oil seed rape (*Brassica napus*) and Chinese cabbage (*Brassica rapa*).

2. Materials and methods

2.1. Distribution and phenology of D. radicum populations in the locality

Information was collected on the distribution and phenology of *D. radicum* populations in the radish production area to inform the future approach to control.

2.1.1. Proportion of early-emerging flies in the field population

A sample of several hundred overwintering pupae was collected on 1 December 2011 from a crop of radish infested with *D. radicum*. The pupae were washed, mixed with damp vermiculite and placed in a jar in a refrigerator at 4 ± 2 °C until 1 May 2012 to complete diapause development, when the jar containing the pupae was placed in a cage held at a temperature of 20 ± 2 °C to record emergence of flies. This was to determine whether a significant proportion of the population consisted of 'late-emerging' flies (Finch and Collier, 1983).

2.1.2. Monitoring with water traps

Field monitoring was undertaken to investigate the temporal and spatial distribution of *D. radicum* in the radish production area. White water traps (Finch, 1991) (17 cm diameter) were used to monitor adult flies in both host and non-host crops in the area. Traps (1–3 per field) were placed from May–October 2011 (22 locations) and May–August 2012 (15 locations) in the field margins to avoid them interfering with, or being damaged by, cultural operations. Traps were part-filled with water to which was added a small amount of detergent to lower the surface tension and some sodium metabisulphite tablets to keep the water 'pure'. They were emptied once or twice a week by scooping out the dead insects into small plastic containers with a 4 cm sieve. The contents were examined in the laboratory to identify male and female *D. radicum*. It is relatively easy for an expert to separate this species from other Diptera captured in the locality and to separate the sexes based on body shape.

2.1.3. Infestations in Chinese cabbage crops

In addition to the use of traps, crops of Chinese cabbage grown in the locality were sampled close to harvest to determine whether they were infested by *D. radicum* despite having been treated with a pre-planting drench of chlorpyrifos. Ten randomly-selected plants were taken from commercial crops of Chinese cabbage and examined for the presence of *D. radicum* on 4 July 2012 and on 5 occasions in 2013 (30 June, 2 August, 18 September, 4 and 16 October). The roots and surrounding soil were sorted in a tray to find and count any larvae and pupae.

2.2. Using net covers to manage D. radicum on radish

Experiments were undertaken at Warwick Crop Centre, University of Warwick, Wellesbourne (52.20988,-1.60053, 49 m) to determine the effects of the net covers on damage by *D. radicum*. For all of the experiments, the plots were 1 bed wide (1.5 m) x 1 m long and contained 8 rows of radish plants (0.2 m between rows and 35 seeds/m). Nitrogen was applied at a rate of 100 kg/ha. Weed control was with Dacthal W75® applied as a spray after sowing. Irrigation was applied on two occasions to each of the first and second experiments in 2013.

Each year the pattern of oviposition by female *D. radicum* was monitored in a nearby plot of cauliflower using the method described by Coaker and Finch (1971). The eggs laid around 15 plants were sampled on each occasion from one of three sequentially-planted plots.

2.2.1. Effect of net covers on crop damage

The aim of the first set of experiments was to determine the effects of the net covers on damage by *D. radicum* and of uncovering the crops briefly during the growth period to ventilate them (to reduce the risk of the development of mildew (*P. parasitica*)) or to allow the crops to 'stand up' before harvest. Newly-purchased net with the mesh size of 1.33 mm recommended for control of *D. radicum* was used (Wondermesh®). Two replicate plots were sown and harvested on 3 occasions in each of 2 years (Sowing and harvest dates were: In 2012: 26 Jun-30 Jul; 23 Jul-7 Sep; 14 Aug-18 Sep; In 2013: 12 Jun-26 Jul; 18 Jul- 20 Aug; 10 Sep-16 Oct). Treatments were as follows: Covered until harvest; Uncovered all the time: Uncovered 5 days before harvest; Uncovered for 1 day 10 days before harvest; Uncovered for 1 day 20 days before harvest. Samples of 60 radish plants per plot were harvested, washed and assessed for damage to the bulbs by *D. radicum* larvae. The foliage was assessed for damage by *Phyllotreta* spp. (feeding holes in the foliage) and the plants were also assessed for any other damage to the bulbs and foliage. The data were summarised and analysed using Analysis of Variance on transformed data. An angular transformation was used because this is an accepted procedure for data that are expressed as a percentage of plants damaged.

2.2.2. Effect of mesh size of crop covers on crop damage

Nets with mesh sizes < 1.33 mm are available to exclude smaller pests such as aphids. The aim of further field experiments at Warwick Crop Centre was to determine the efficacy of covers of various mesh sizes for exclusion of *D. radicum*. The plots were also assessed to determine the effect of the net covers on damage by *Phyllotreta* spp. and other damage to the foliage and bulbs. The plot size was as above. In 2012, mesh sizes of 1.33, 0.8 and 0.6 mm (Wondermesh®) were evaluated (new netting) together with an uncovered control treatment and one treatment where the 1.33 mm mesh was supported above the crop on plastic pipe hoops so that the net did not touch the foliage. In 2013, the same mesh sizes were used plus an additional mesh size of 0.3 × 0.7 mm (Wondermesh®). There was no treatment using hoops. Two replicate plots were sown and harvested on 3 occasions in each year (Sowing and harvest dates were: In 2012: 26 Jun-7 Aug; 23 Jul-11 Sep; 14 Aug-20 Sep; In 2013: 12 Jun-18 Jul; 18 Jul- 20 Aug; 10 Sep-16 Oct). Nitrogen was applied at a rate of 100 kg/ha. Weed control was with Dacthal W75 applied as a spray after sowing. Irrigation was applied on two occasions to the first and second experiments in 2013. Samples of 60 radish plants per plot were harvested, washed and the bulbs were assessed for damage by *D. radicum* larvae. The plants were assessed for damage to the foliage by *Phyllotreta* spp. (feeding holes in the foliage) and any other damage to the foliage and bulbs. The data