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The effectiveness of field margin enhancement for cereal aphid control by different natural enemy guilds

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ABSTRACT

Studies demonstrating the empirical impact of natural enemies on pests and the effect of habitat manipulation are required if farmers are to be persuaded to adopt conservation biocontrol. The relative abundance of different natural enemy guilds were manipulated to investigate their impact on grain aphids (*Sitobion avenae*) and whether the establishment of wider field margins increased levels of control. The impact of epigeal and flying aphid predators, in isolation and together, on cereal aphids was tested in five fields with standard field margins (*ca.* 2 m wide) and in five fields with wide margins (*ca.* 6 m wide). Flying predators alone were as effective as all predators in controlling the grain aphid and reduced aphids by 90% and 93%, whereas epigeal predators alone achieved a reduction of only 40% and 18% in fields with standard and wide margins respectively. Levels of parasitism measured by counts of aphid mummies were relatively low ($\leqslant 12\%$) on all sampling occasions. There was no evidence that the wide field margins increased natural enemies within the adjacent field as measured using pitfall traps, suction sampling and sticky traps. The wide field margins were considered to have no benefit for biocontrol because flying predators capable of moving between fields were primarily responsible or the amount of uncropped land suitable for natural enemies was not a limiting factor in the landscape.

1. Introduction

Achieving a fully integrated pest management (IPM) system is the goal for any sustainable crop production process, however, in the most widely grown crops in Europe this has yet to be achieved. Some components of IPM are implemented, but the focus has been on pest monitoring and use of selective products to reduce insecticide usage, rather then the encouragement of natural enemies through the adoption of conservation biocontrol. This is in part due to the uncertainty of control by natural enemies and the perceived risk of alternative approaches, farmers on the whole being strongly risk averse (Cowen and Gunby, 1996). There is good evidence that natural enemies may be encouraged through the establishment of non-crop habitats that provide shelter or alternative food resources (Landis et al., 2000; Griffiths, 2008). Flower-rich habitats were shown to attract and support a wide range of natural enemies (Hickman and Wratten, 1996; Holland and Thomas, 1996; Nentwig, 1998) and tussocky grasses established along 'Beetle banks' supported high densities of overwintering beetles and spiders (Thomas et al., 1991). However, there is only limited evidence that populations of natural enemies were encouraged sufficiently to enhance biological control in the adjacent crop (Gurr et al., 2000; Griffiths et al., 2008). Agri-environment schemes offer the funding to establish habitats that may enhance biological control (Holland, 2007), yet with agri-environment schemes in England there was little uptake of options to establish flower-rich habitat or Beetle banks. Instead, buffer zones were the most popular of the agri-environment options that necessitate the establishment of new habitats (Boatman, 2007). These are typically 2–6 m wide, grass margins established by natural regeneration or by sowing with a simple grass mix. The reasons behind the reluctance of farmers to adopt conservation biocontrol were considered by Gurr et al., 2000 and they concluded that studies demonstrating their impact on crop yield and quality along with full economic costings are needed if the approach was to move from technical credibility to "real world" success.

Crop pests may be controlled by natural enemies from different guilds and theoretically the most effective control may be achieved by having a diversity of natural enemy guilds, each consisting of species or groups with varying phenologies, to ensure that the pest is attacked throughout its lifecycle. Even so, synergism between different guilds is not always a certainty and instead intraguild predation may occur (Rosenheim et al., 1995; Snyder and Ives, 2001). In cereal crops, summer infestations of aphids have the potential to reduce yield (Larsson, 2005). Although economically damaging aphid infestations are now relatively rare in the UK, aphids and their enemies are useful as a model system because artificial aphid infestations can be created and the subsequent natural enemy response observed. Natural aphid enemies include epigeal species that are typically generalist predators, of which

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ground beetles (Coleoptera: Carabidae), rove beetles (Coleoptera: Staphylinidae) and spiders (Araneae) are the most abundant in arable fields. Many of these taxa are also capable of flight or passive aerial dispersal (e.g. Linyphiidae: Araneae), but it is not known whether they use flight when searching for prey within a field, as exhibited by parasitoids (Hymenoptera: mainly Aphidiidae), aphidophagous species, e.g. hoverflies (Diptera: Syrphidae), ladybirds (Coleoptera: Coccinelidae) and lacewings (Neuroptera: Chrysopidae) and generalists such as predatory flies (Diptera: Empididae and Dolichopodidae) and cantharids (Coleoptera: Cantharidae). There is scant knowledge about the effectiveness of these flying generalists or whether there is complementarity between them (Schmidt et al., 2003). The relative abundance of different natural enemy guilds, along with the species composition are likely to vary within a field according to the time of year, the field's biotic composition (Holland et al., in press), its current and historic management and the proportion and type of non-crop habitats (Thies and Tscharntke, 1999). Consequently the level of biocontrol and guilds/species through which this is achieved are likely to vary substantially.

In 2005, an interdisciplinary project was started to investigate the impediments to the adoption of biological control in UK arable crops (http://www3.imperial.ac.uk/rebug). The objectives of the biological component of the project are to examine: (a) the relative importance of natural enemy diversity and abundance (temporal and spatial) in pest control in cereal-based systems; (b) the roles of semiochemicals in crop–pest–natural enemy interactions and new opportunities for practical exploitation; (c) how to integrate habitat manipulation and semiochemical technologies. In this paper we report on the first of these objectives. Exclusion cages were used to identify the impact of ground and flying natural enemies, in isolation and together, on cereal aphids. Furthermore, whether the provision of alternative resources improved levels of biocontrol was tested by comparing the contribution of the different predatory guilds in fields with standard and wide grass field margins and at different distances from the crop edge. Previous studies indicated that the spatial influence of floral resources (Nentwig, 1998) and overwintering habitat (Collins et al., 2002) was relatively restricted and we wished to test this further.

2. Materials and methods

Ten fields of winter wheat (size range of 5–50 ha), under the same management, were selected in south Wiltshire, UK in 2005. Five of the fields selected had standard field margins comprised grasses and herbaceous plants, approximately <1-m wide, whereas the other five fields had in addition to the standard margin, a sown 2-year-old, 5–6 m-wide grass margin around all or most of the field edges. The wide margins were established using seed collected from a local hay meadow and were expected to be floristically rich. Within each of the 10 fields, two transects were established at 20 and 80 m from the crop edge avoiding edges in close proximity to woodland. Each transect consisted of two replicates of four natural enemy treatments that compared the impact of epigeal and flying natural enemies on cereal aphids, alone and in combination. Each treatment plot was 1-m^2 and treatments were randomly allocated along each transect, 5 m apart. The four treatments were: (E) epigeal predators only, through exclusion of flying natural enemies; (F) flying natural enemies only, through exclusion and removal of epigeal predators; (N) no natural enemies, through exclusion and removal of epigeal and flying natural enemies; (A) all natural enemies, an open control. Epigeal predators were excluded using a plastic ring that was buried 10 cm deep into the ground and extended 30 cm above the soil surface (treatments F and N). Within each of these plots, two pitfall traps (6-cm diameter, half-filled with a 50% solution of ethylene glycol and detergent) were installed near the plastic ring to remove any arthropods that existed or emerged within the enclosure. Pitfall traps were emptied fortnightly and operated for the duration of the aphid monitoring period. To remove spiders that are less likely to be captured by pitfall trapping within treatments F and N, the base of the plots was sprayed with an insecticide of short persistence (tetramethrin 0.15% and permethrin 0.03%) one day prior to the aphid inoculation. For treatment E, flying natural enemies were excluded using insect proof netting. The netting was attached at its base to the plastic ring which was raised approximately 1–2 cm above the ground to allow access by ground predators. The netting extended above the crop and was sealed to a central support. Flying natural enemies in treatment N were excluded using this method with the netting attached to the plastic ring and the ring dug into the ground to exclude epigeal predators. Treatments A and F included a roof of insect netting above the crop covering 1 m^2 to reduce aphid fall-off as a consequence of rainfall. Netting was installed a few days prior to aphid inoculation on 10 June. Each of the plots was inoculated with 500 *Sitobion avenae* reared on winter wheat within a parasitoid-free environment. Introduced aphid colonies were distributed throughout the cage and provided an initial infestation of approximately one per tiller. The abundance and location were recorded of all cereal aphids and parasitized aphids (aphid mummies) on the ear and flag leaf of 25 tillers on 6 June prior to inoculation and on three post-inoculation occasions (20 June, 30 June and 11 July).

A range of trapping methods were used to provide an assessment of predators in the locality of the transects. Epigeal predators were collected using six pitfall traps containing ethylene–glycol. These were located along the transects between the treatment plots, operated continuously from the start of the aphid inoculation and emptied fortnightly between 2 June and 14 July 2005. All Coleoptera were identified to species and Araneae to family. As part of an intensive study investigating the movement of flying predators (Oaten et al., 2007), suction and sticky trap sampling was conducted at 20 and 80 m in eight of the same fields, four in fields with standard margins and four with wide margins. Sticky trap and suction sampling sites were located within 30 m of the transects. A Dvac suction sampler was used to collect aphid predators from an area of 1 m^2 on 10 June and 25 June. Flying predators were collected using double-sided clear acrylic sticky traps (A4 size, coated with Tanglefoot, The Tanglefoot Co., Grand Rapids, Michigan, USA). These were mounted 1.0 m above the crop facing towards the boundary and operated for a 5-day period starting on 16 June and 29 June. Owing to the scale of the study, assessments were staggered over two days, however, on no occasion did the weather vary to any great extent between consecutive days. Known aphid predators were identified on each sticky trap and within each suction sample to species for Carabidae, Coccinelidae, Staphylinidae and Neuroptera. All other predators were identified to family.

The aphid data (transformed using $\log_{10}(x+1)$) for aphids on the ear and aphids on the flag leaf within each cage was analysed for each sampling occasion using a general ANOVA with position along transect nested within transect nested within field as blocking factors and cage type, margin width and distance from margin as treatment factors. Contrasts were used to compare between: (1) E, F, N and A; (2) E and F; (3) E and A; (4) F and A. The same ANOVA model was used to analyse the proportion of parasitized aphids (aphid mummies/total aphids transformed using arcsine-square root) in treatments F and A and the total number of predatory arthropods, Carabidae, Staphylinidae and Lycosidae (transformed using $\log_{10}(x+1)$) within each cage captured in the pitfall traps within treatments F and N.