The Effects of Crop Type and Production Systems on the Activity of Beneficial Invertebrates

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Key words: Beneficial invertebrates, natural enemies, crop production, fertiliser, crop protection

Abstract

Beneficial invertebrate activity (13 groups) was assessed in five crop types on a split-plot experimental system in northern England using pitfall trapping and suction sampling in May-October 2005. Very significant differences were detected in activity between crop type, and in the preference of groups for individual crops. Within crop types, differences in fertiliser and crop protection approaches appeared to significantly affect activity, with preferences for either organic or conventional management differing between groups. In general, inorganic fertiliser application had more effect on activity than pesticide, herbicide and fungicide use.

Introduction

Changes in agricultural land management and in crop production systems away from intensive, chemically-enhanced, methods towards low-input or organic systems requires an understanding of the consequent changes in the farming landscape. This includes assessments of the effects of crop management systems on the activity and efficacy of beneficial invertebrates given the reduction, and probable cessation, of pesticide applications in the lower input systems.

The change from conventional to organic management is generally thought to increase the activity of predator invertebrates, but the evidence is not conclusive and, in some cases, contradictory (Hole et al. 2005). Crop type has been shown to affect activity more than management system (Weibull & Ostman 2003) whilst the influence of non-crop and other landscape factors has also been stressed (Fuller et al. 2005). The Nafferton Factorial Systems Comparison Experiments (Leifert et al. 2007) provides an opportunity to assess beneficial invertebrate activity at the plot scale in a system where the effects of major components of conventional farming, the use of inorganic fertilisers and crop protection chemicals, are separated from each other, within a number of crop types.

Materials and methods

The Nafferton Factorial Systems Comparison Experiments provided 128 plots (24 x 12 m) in an area converted to organic management between 2001 and 2003. In 2005 the plots contained wheat, barley, beans, vegetables (potatoes, cabbage, onions, lettuce, carrots) and grass/clover. Each plot was sampled for invertebrates using five pitfall traps (8.5 cm diameter, 10 cm deep), 0.5 m apart, part-filled with saturated salt (NaCl) solution containing a small amount of strong detergent as a preservative. The traps were set in the first week of May 2005 and five monthly samples were generated. In

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addition, three one-minute suction samples were taken from the crop vegetation using a modified leaf-blower on sunny days in the first week of July, August and September.

The total numbers of Carabidae (ground beetles), Staphylinidae (rove beetles), Coccinellidae (ladybirds), predatory beetle larvae (Carabidae and Staphylinidae), Linyphiidae (money spiders) and Lycosidae (wolf spiders) were counted from the five pitfall samples. The numbers of Syrphidae (hoverflies), Neuroptera (lacewings), predatory bugs (Hemiptera) and parasitic wasps (Hymenoptera: Ichneumonidae, Proctotrupidae, Braconidae, Pteromalidae) were a product of both sampling methods. The number of individuals of each group recorded was considered to reflect activity and analyses were carried out the number recorded, transformed by $\log_{10}n+1$, using linear mixed-effects models in the R statistical environment (R Development Core Team 2005). Analysis of variance was generated using models with fertility, health and crop as fixed factors and the blocks of the trial as a random factor. Data from all plots were used to assess the effect of crop type whilst the effects of differing fertility and crop protection management (conventional and organic) were assessed within each crop type.

Results

Of the 13 invertebrate groups, the activity of 12 was highly significantly related to crop (Tab. 1) with only Neuroptera appearing to be unaffected. Considerable differences were observed in the activity of different groups in the five crops. Whilst the cereal crops had the most of some groups (e.g. Carabidae, Staphylinidae, Syrphidae), they had the fewest of others (e.g. Coccinellidae, Hemiptera) whilst the activity of the four hymenopterous groups was greatest in grass/clover for two, as with both spider groups, and in beans and wheat for the other two. Within individual crops (Tab. 2), all significant responses in wheat and most in barley were fertility related whilst significant responses to crop protection were greatest in the beans and vegetables. With the three beetle groups, two had a preference for conventional fertility management (Staphylinidae, larvae) but Carabidae were most active in organic fertilised plots. Similar differences were also seen for the two spider groups, with Linyphiidae most active on conventional plots and Lycosidae on organic.

Tab. 1: The significant relationships between invertebrate group activity and crop type, derived from linear mixed effects models, together with the trend of activity recorded in the five crops (most>least).

Group	Significance	Trend
Carabidae	***	wheat>barley>beans>vegetables>grass/clover
Staphylinidae	***	barley>beans>wheat> grass/clover>vegetables
Beetle larvae	***	barley> grass/clover>beans>wheat>vegetables
Coccinellidae	***	vegetables>wheat>beans> grass/clover>barley
Syrphidae	***	wheat>beans>vegetables>barley>grass/clover
Hemiptera	***	beans>vegetables>barley> grass/clover>wheat
Ichneumonidae	***	beans>vegetables>grass/clover>wheat>barley
Proctotrupidae	***	wheat>barley>vegetables>beans>grass/clover
Braconidae	***	grass/clover>vegetables>beans>wheat>barley
Pteromalidae	***	grass/clover>beans>vegetables>wheat>barley
Linyphiidae	***	grass/clover>wheat>barley>beans>vegetables
Lycosidae	***	grass/clover>beans>barley>wheat>vegetables

*** significant for $P<0.001$

Tab. 2: The significant effects of conventional (C) and organic (O) fertility and crop protection management on the activity of invertebrate groups within crop types derived from linear mixed effects models and the trend of activity recorded in the two management systems (most>least).

Crop and group	Factor/interaction	Significance	Trend
Grass/clover			
Staphylinidae	Fertility	**	C>O
Ichneumonidae	Crop protection	*	C>O
Braconidae	Fertility	**	C>O
Lycosidae	Fertility	*	O>C
Beans			
Staphylinidae	Fertility	**	C>O
Staphylinidae	Crop protection	**	C>O
Hemiptera	Crop protection	**	O>C
Linyphiidae	Fertility	*	C>O
Lycosidae	Crop protection	*	O>C
Wheat			
Carabidae	Fertility	**	O>C
Staphylinidae	Fertility	***	C>O
Beetle larvae	Fertility	*	C>O
Coccinellidae	Fertility	**	O>C
Pteromalidae	Fertility	**	O>C
Linyphiidae	Fertility	**	C>O
Barley			
Carabidae	Fertility	*	O>C
Staphylinidae	Fertility	***	C>O
Staphylinidae	Crop protection	**	C>O
Staphylinidae	Fertility:crop protection	**	CC>CO>OC>OO
Beetle larvae	Fertility	***	C>O
Beetle larvae	Crop protection	*	C>O
Linyphiidae	Fertility	***	C>O
Lycosidae	Fertility	***	O>C
Vegetables			
Carabidae	Crop protection	**	O>C
Hemiptera	Crop protection	**	O>C
Linyphiidae	Fertility	**	C>O

* significant for $P<0.05$
** significant for $P<0.01$
*** significant for $P<0.001$

Whilst Staphylinidae and beetle larvae were more active with conventional crop protection in beans and barley, organic management appeared to favour Hemiptera, Lycosidae and Carabidae in beans and vegetables. Only one significant interaction response was observed, in barley with Staphylinidae, with most activity in the plots with both conventional management approaches and the least with both organic. In general, fertility management had more significant effects than crop protection, with some groups more active on conventional plots and others on organic plots.

Discussion

Too much credence cannot be put on the results from the crop production plots because of their small size and of other factors such as the lack of adjacent non-crop habitat but they provided interesting insights into factors influencing beneficial invertebrate activity. The results agree with the conclusions of Bengtsson et al. (2005) that crop type significantly affects the activity of different groups but the more interesting observation was that the use of inorganic fertiliser appeared to have more impact on activity than the application of chemical crop protection sprays. This observation will need to be tested at the farm-scale but it does not appear to have been obvious from studies which have tended to concentrate on one crop on a number of farms (e.g. Fuller et al. 2005). The effects of the cessation of the use of both inorganic fertiliser and chemical pesticides, and of the time since conversion to organic management, will have to be taken into account because the efficacy of the pest natural enemy assemblage will need to be maximised. These management factors will need to be assessed in conjunction with enhancement methods such as the provision of beetle banks and conservation headlands (Landis et al. 2000). Another aspect to be researched thoroughly is the effect of production-linked activity increases on biodiversity because the evidence on species richness in different management systems is not consistent (Hole et al. 2005).

Acknowledgements

The authors gratefully acknowledge funding from the European Community financial participation under the Sixth Framework Programme for Research, Technological Development and Demonstration Activities for the Integrated Project QUALITYLOWINPUTFOOD, FP6-FOOD-CT-2003- 506358.

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