Improving natural pest suppression in arable farming: field margins and the importance of ground dwelling predators

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Abstract:
Overwintering of soil dwelling arthropods and especially carabid beetles was much higher in unmown perennial field margins than in mown grass strips or barren crop fields. Over 200 generalist predators per m2 were trapped in field margin enclosures after hibernation. Predator exclusion experiments showed that high-density aphid colonies in May were reduced by 49% compared to predator-free conditions, both in field margins and in summer wheat crops. Over a 4 years period, aphid infestation levels in summer wheat and potatoes were 15%-65% lower in a farming system with a network of perennial field margins, compared to a system without field margins. However, Diamond back moth and slug damage in Brussels sprouts were higher in the system with field margins compared to the control system without margins.

Key words: Farming systems, functional biodiversity, predation, overwintering.

Introduction

Habitat management for the conservation of natural enemies of insect pests is recognized as a valuable strategy in sustainable agriculture (Landis et al., 2000; Gurr et al., 2003). Accumulating evidence shows that generalist predators from field margins can contribute significantly to the suppression of insect pests (Sunderland, 2002; Symondson et al., 2002). Here we report on an ongoing study to quantify such effects at the scale of a farming system.

Materials and methods

Experimental system

All experiments and sampling were carried out at the experimental farm in Nagele (NL) in the ‘BIOdivers’ and ‘BIOintensief’ systems as described in Van Alebeek et al. (2003). We compare two organic farming systems of six crops and 10 ha each; one system with a network of perennial field margins (21% of total surface) and one system with few margins (5%). Since 2001, pitfall traps, yellow water pans and crop inspections are being used to monitor natural enemies and key insect pests in crops and surrounding field margins (Van Alebeek et al., 2003). Because of the scale of the two systems, replication was not possible, and a full crop-rotation period of six years is required for a statistical analysis. Results from different locations in the two systems within one year, as presented here, are pseudo-replicates and no statistical tests are applicable.

Hibernation in field margins

To quantify the role of field margins for the survival of overwintering, soil-surface dwelling arthropods, we used pitfall traps within small scale enclosures in field margins and in bare soil in crop fields. A wooden frame 1 x 1 meter and 30 cm high was buried 5 cm into the soil, and covered by an insect net (mesh width 1.4 x 1.4 mm). In two corners inside the frame, a pitfall trap (9.5 cm diameter, filled with a 4% formaldehyde solution) was placed, to catch arthropods becoming active after hibernation. Pitfall samples were collected between March 15 and May 1, 2004. Sampling was finished in the field plots when farming activities for the cropping season had to start. Pitfall samples in the unmown, biodivers field margins were continued for another three weeks (end of May). Samples were stored in 70% ethanol at 5ºC and sorted and counted into functional groups. Three enclosures were placed in unmown, species-rich perennial field margins, three enclosures in short-mown grass strips, and six enclosures in bare soil plots in the field.

Predator impact on aphid infestations

Early season aphid mortality in summer wheat is difficult to assess due to low densities of the founding colonies. Predation pressure was therefore measured by an exclusion technique and an aphid banker plant system. Polyvinylchloride rings (47 cm diameter, 30 cm high) were buried 5 cm into the soil and left open on top. Inside, one pitfall trap (9.5 cm diameter, filled with a 4% formaldehyde solution) was placed to remove any soil-surface dwelling predators. Flying insects and parasitoids and most spiders had free access. Commercially available summer wheat seedlings infested with cherry-oat aphids (*Rhopalosiphum padi*) (Aphibank, Koppert Biological Systems, NL, www.koppert.nl) were used to measure predator impact. After 14 days of predator trapping, a small plastic pot (5 cm diameter) with wheat seedlings and aphids was buried inside the ring, and a similar pot with seedlings and aphids was buried at 20 cm distance outside the ring. A sample of wheat pots was taken to the laboratory to assess the number of aphids in each pot at the start of the experiment. After one week exposure, all pots were taken to the lab and remaining aphid numbers were counted. Six rings were placed in field margins with approximately 25 species of grasses and perennials, and 14 rings were placed in an adjacent summer wheat field. Summer wheat was sown on March 12, predator trapping started on May 13, the introduction of aphids was on May 27, and assessment of the number of aphids remaining was done on June 3, 2004.

Pest suppression in different crops

During 2002 – 2005, crops were inspected two or three times per season, at periods of key pest population peaks. Small plots at 5, 15 of 50 m from the field edge were sampled. Plants were inspected for all pest stages and natural enemies that could be observed on the plants. We compared pest counts in fields of different sizes surrounded by field margins (see Van Alebeek et al., 2003 for details) with control fields in the BIOintensief system of 1 ha with only one side bordered by a grass strip.

Results and discussion

Hibernation in field margins

Unmown field margins are attractive overwintering sites for a range of organisms, especially Carabid beetles. Twice as many carabids survived in field margins compared to field plots without vegetation (Table 1). Generalist predators (carabids, spiders, some rove beetles) hibernate in field margins in densities of at least 150 predators per square meter. But bare field plots also yielded considerable numbers of surviving predators, approx. 100 per m^2. Prolonged trapping in the unmown field margins indicated that, after 10 weeks (by the end of May), more than 540 arthropods (of which over 200 predators) per square meter survived wintertime (data not shown). It is assumed that after May still many more arthropods may become active out of hibernation. Overall arthropod and predator densities are well within the ranges reported by others, e.g. Pfiffner & Luka (2000) and Frank & Reichart (2004).

Table 1. Average numbers of soil-surface dwelling invertebrates caught in pitfall traps within 1 m^2 enclosures in different farm habitats during 7 weeks in early spring (March-May), 2004.

	Unmown, biodivers field margins (n=3)	**Short mown grass strips (n=3)**	**Bare soil plots (n=6)**
Carabid beetles	101	33	48
Spiders (all families)	35	59	33
Rove beetles (*Staphylinidae*)	66	32	71
Other beetles	112	45	36
Remaining groups	47	32	13
Total catch per m^2	361	200	201

Predator impact on aphid infestations

Predators appear to be responsible for almost 50% mortality after one week exposure (Table 2). This indicates the potential impact of predators on the colonising phase of aphid infestations in spring. The effect of ground dwelling predators on aphid mortality is higher than found in other studies (21% in Holland & Thomas, 1997; 35% in Collins et al., 2002 and 15% in Schmidt et al., 2003). This may be due to the high aphid densities on the banker plants, which normally do not occur under field conditions by the end of May.

Table 2. Average numbers of aphids surviving after one week exposure in enclosures from which predators were removed and with free predator access (end of May, 2004).

	n	**# aphids surviving[1]**	**% mortality due to predation**	**# predators removed per ring[1]**
Before the experiment	8	230 ± 78		
In field margin, predators removed	6	172 ± 130		46 ± 22
In field margin, predators free access	6	88 ± 31	49%	
In wheat, predators removed	14	134 ± 57		39 ± 22
In wheat, predators free access	14	68 ± 61	49%	

1: mean ± standard deviation

Pest suppression in different crops

Monitoring key pests at peak densities (summer wheat and potatoes in July, Brussels sprouts in August or September) revealed that aphid densities in summer wheat were 30% - 50% lower in the BIOdivers system with field margins as compared to the BIOintensief system without margins (Table 3). For aphids in potatoes, densities were 15% - 65% lower in the presence of field margins than without margins. Sunderland (2002) reviewed studies on predation impact and reported 28%-86% aphid reduction in wheat and 80%-88% aphid reduction in potato. We hypothesize that early season predation as shown in the exclusion experiment is an important factor in reducing aphid population pressure. However, in some other key pests, such as Diamond back moth (*Plutella xylostella*) and slugs in Brussels sprouts, the effect of field margins on pest control appears to be negative. Slugs (data not shown) may be stimulated by a better survival and a favourable microclimate in the margins, whereas Diamond back moth may react to increased crop edge length of the smaller plots, divided by field margins, in the BIOdivers system.

Table 3. Key pest densities in three crops in 2002 – 2005 in the BIOdivers system with field margins compared to the BIOintensief system without margins.

	2002	**2003**	**2004**	**2005**
	Aphids in summer wheat (% shoots infested)			
With field margins	13,0 ± 4,4	16,1 ± 10	30,9 ± 8,1	35,3 ± 12,6
Without field margins	24,1 ± 4,3	26,7 ± 5,8	43,5 ± 11,3	57,3 ± 10,9
% aphid reduction	*46%*	*40%*	*29%*	*38%*
	Aphids in potato (% shoots infested)			
With field margins	5,4 ± 2,6	24,8 ± 13,2	58,3 ± 14,2	17,3 ± 12,8
Without field margins	15,2 ± 6,9	43,3 ± 12,3	68,3 ± 9,6	37,3 ± 11,6
% aphid reduction	*65%*	*43%*	*15%*	*54%*
	Diamond back moth in Brussels sprouts (# caterpillars / plant)			
With field margins	---	4,3 ± 2,3	1,8 ± 1,7	0,8 ± 0,5
Without field margins	0,5 ± 0,3	1,9 ± 1,0	1,3 ± 0,6	0,7 ± 0,4
% caterpillar increase	---	*130%*	*32%*	*18%*

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References

Alebeek, F.A.N van, Kamstra, J.H., Venhorst, B. & Visser, A.J., 2003. Manipulating biodiversity in arable farming for better pest suppression: which species and what scale? IOBC / WPRS Bull. 26(4): 185-190.

Collins, K.L., Boatman, N.D., Wilcox, A., Holland, J.M. & Chaney, 2002. Influence of beetle banks on cereal aphid predation in winter wheat. Agric. Ecosyst. Environ. 93: 337-350.

Frank, T. & Reichhart, B., 2004. Staphylinidae and Carabidae overwintering in wheat and sown wildflower areas of different age. Bull. Entomol. Res. 94: 209-217.

Gurr, G.M, Wratten, S.D. & Luna, J.M., 2003. Multi-functional agricultural biodiversity: pest management and other benefits. Basic Appl. Ecol. 4: 107-116.

Holland, J.M. & Thomas, S.R., 1997. Quantifying the impact of polyphagous invertebrate predators in controlling cereal aphids and in preventing wheat yield and quality reductions. Ann. Appl. Biol. 131: 375-397.

Landis, D.A., Wratten, S.D. & Gur, G.M., 2000. Habitat management to conserve natural enemies of arthropod pests in agriculture. Ann. Rev. Entomol. 45: 175-201.

Pfiffner, L. & Luka, H., 2000. Overwintering arthropods in soils of arable fields and adjacent semi-natural habitats. Agric. Ecosyst. Environ. 78: 215-222.

Schmidt, M.H., Lauer, A., Purtauf, T., Thies, C., Schaefer, M. & Tscharntke, T., 2003. Relative importance of predators and parasitoids for cereal aphid control. Proc. R. Soc. Lond. B 270: 1905-1909.

Sunderland, K.D., 2002. Invertebrate pest control by carabids. In: The Agroecology of Carabid Beetles, ed. J.M. Holland: 165-214

Symondson, W.O.C., Sunderland, K.D. & Greenstone, M.H., 2002. Can generalist predators be effective biocontrol agents? Ann. Rev. Entomol. 47: 561-594.