Manipulating biodiversity in arable farming for better pest suppression: which species and what scale? [1]

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Abstract: Field margins can attract and conserve predators and parasitoids, and thus contribute to pest suppression. On 20 hectares of organic farming, a network of field margins has been laid down to investigate two main questions: how far can field margins be apart and what vegetation diversity is required in order to achieve pest populations suppression? Pitfall traps and yellow water pans in field margins and crops are used to assess antagonists' densities. Samples of key pests and damage assessments in different crops are related to the distance from the nearest margins. The first results out of these massive data sets are presented.

Key words: Field margins, functional biodiversity, biological control, predators, spatial variation

Introduction

During the last decades, biodiversity in agricultural landscapes in Western Europe has declined considerably. Road verges, watercourses and field margins have become the dominant refugia for biodiversity in agricultural landscapes. Consequently, the role of field margins in the conservation of plants, birds, mammals, butterflies and other groups has received a lot of attention (e.g. Boatman, 1994; Boatman et al., 1999; Tamis et al., 2001). Among many functions (Marshall & Moonen, 2002), field margins may play an important role in conserving pollinators, generalist predators and parasitoids, and may contribute to substantial degrees of natural control of agricultural pests in adjacent field crops (e.g. Thomas et al., 1992; Meek et al., 2002; Collins et al., 2002).

In the open landscape of the Dutch Noordoostpolder, with very few natural landscape elements, we started a large-scale field experiment to investigate whether field margins can attract and conserve predators and parasitoids, and thus contribute to pest suppression. A network of permanent field margins sown with grass and perennials has been laid down on an organic farm to investigate two main questions: how far can field margins be apart and what vegetation diversity is required in order to achieve pest populations suppression?

Materials and Methods

At an experimental farm in Nagele, an organic farming system with a six year crop rotation of potato, summer wheat, iceberg lettuce, carrots, white cabbage and grass-clover is being studied. On a 10 hectare subsystem, hence called "BIOdivers", a network of permanent field margins sown with different grass and wild flower mixtures has been laid down in spring 2001 (Figure 1). Field margins were laid down in such a way that 6 plots were created (one

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for each crop) as follows (also see Fig. 1): two large parcels of 110 x 130 m, another two large parcels which are subdivided each by field margins into four smaller plots of 50 x 60m, and the last two parcels that are divided each by field margins into eight smaller plots of 36 x 50 m. Field margin width was varied in such a way that the surface ratio of plot versus surrounding margin remains constant. The East-West axis represents the network intensity gradient, and should clarify the maximum distance over which arthropod predators and parasitoids significantly reduce pest population densities. Field margins were sown and managed in such a way that a vegetation diversity gradient was created along the North-South axis. This gradient is used to clarify how diverse field margins should be in order to host sufficient antagonists to reduce pest population densities.

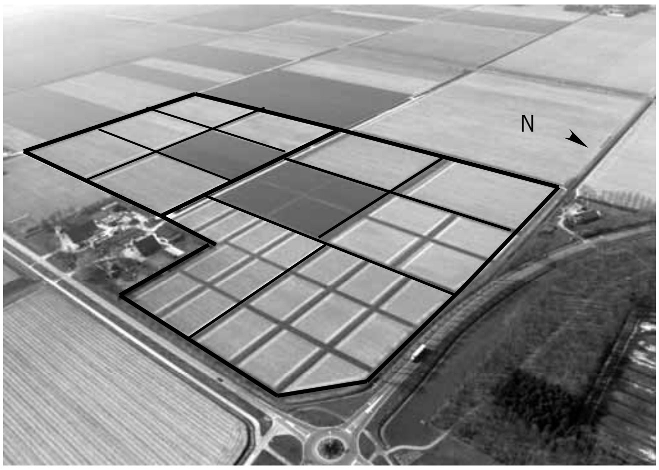

Figure 1. Aerial view of the experimental systems at Nagele. The lower right half shows the BIOdivers subsystem with the network of field margins. The upper left half is the reference system without a margins network. Each subsystem is 10 ha in surface.

A second subsystem of 10 hectares (called "BIOintensief") has six large parcels (one for each crop) and has 3 narrow field margins along the top, middle and bottom of the subsystem, in East-West direction. This system serves as a reference ("control") system, in order to correct for background infestation levels of mobile (airborne) pest densities in spring. This setup (20 hectares in total) has no replicates, and thus statistics can only be applied to a very limited extend (if at all). In subsequent years, crops rotate through the system and are positioned in one subplot-size only in anyone year, and a such we will be able to compare two crops in the smallest plots (the finest margin network) with large plots in the reference system without margins.

Pitfall traps and yellow water pans, in use from mid-May until mid-October, were used to collect samples of the natural enemies in the systems. Pitfall sampling took place by sampling 80 locations distributed over both systems (3 pitfalls per location, 5 m apart). A total of 30 yellow water pans were distributed over both systems. Pitfalls were filled with a 5% formaldehyde solution and emptied every 14 days. Catches were stored in 70% ethyl-alcohol at 5 °C and were sorted and counted in the laboratory into functional groups (mostly at the order or family level).

Key pests (aphids, caterpillars, root flies, thrips, leaf beetles and slugs) were selected for each crop, and optimal sampling periods and methods were chosen for each pest. In 2002, pest densities (numbers), incidence (presence/absence per plant or shoot) or damage levels were assessed at 2, 15 and 50 m into the crop from the nearest field margin or crop edge.

Results

To this date (March 2003), about 40% of the pitfall samples of the 2001 season have been sorted and counted (approx. 400 hrs work, 62800 arthropods sorted). Spiders (Araneae; predominantly dwarf spiders, Erigonidae) were the dominant group with 30400 specimens (48% of total catch). Carabid beetles (Col.; Carabidae) were presented by 15900 individuals (25%) and rove beetles (Col.; Staphylinidae) constituted 7900 (13%) of the catches. The pitfall samples of the 2002 season will be sorted and counted in January 2003, and could therefor not be included in this article. Data of the pitfall traps presented here fall into two groups. The first group presents results from 3 sampling locations (in a cabbage plot, in a field margin, and in a grass-clover plot) in the BIOdivers subsystem, that have been sorted for the whole 2001 sampling season (time series from mid-May until mid-October 2001). The second group represents two sampling periods (week no. 20 – 22, i.e. second half of May, and week no. 30 – 32, i.e. late July and early August 2001) in which all traps in the system were sorted (spatial overviews). Yellow water pans yielded rather poor catches both in 2001 and 2002, compared to traps operated in other (nearby) experiments and locations and are therefor left out of the data presentations.

To illustrate the first finding in this experiment, we present here the trapping results for carabid beetles (Figure 2A) and spiders (Figure 2B) as a time series throughout the 2001 sampling season (May – October) from 3 locations in the BIOdivers subsystem. Carabid beetles (Fig. 2A) seemed to prefer the open plots of white cabbage above the densely grown grass-clover plots and grassy field margins. In contrast, spiders (Fig. 2B) clearly preferred the field margins and grass-clover plots above cabbage fields.

An example of the spatial variation in the systems is given in Figure 3, for carabid beetles caught in August 2001. Highest carabid densities were found in the plot of white cabbage of the BIOdivers system (Fig. 3A, lower left corner).

Sampling of key pests revealed lower levels of leaf-feeding beetle (*Lema sp.*; Col., Chrysomelidae) damage along the margins of summer wheat, compared to the centre of large plots (results not shown here). In contrast, in white cabbage and Brussels sprouts, the density of Diamond-back moth (*Plutella xylostella*; Lep., Plutellidae) appeared highest along field edges (results not shown).

In summer wheat, aphid incidence in June 2002 appeared unrelated to the distance to the nearest crop edge. However, aphid densities were much lower in the BIOdivers subsystem than in the BIOintensief system (Fig. 4A). A similar pattern was also observed for (other) aphids in potato in July (Fig. 4B) and for carrot fly (*Psila rosae*; Dipt.; Psilidae) damage in carrots in October 2002 (data not shown).

Discussion

The data presented here provide only the first glimpses of what is going on in this complex system. More time and effort, more seasons and further processing and analyses of data are required to answer our research questions. The 2001 season yielded approx. 150,000 arthropods in the pitfall traps alone, about 50% of them belonging to the spiders, 25% to the carabid beetles and 13% to the rove beetles. Sofar, only 40% of the 2001 samples have been

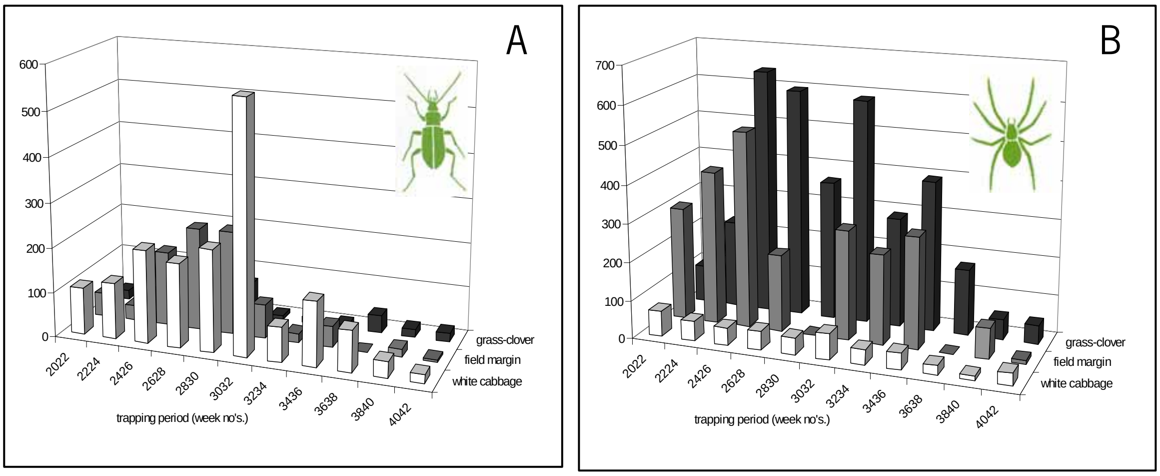

Figure 2. Results from 3 pitfall traps in the BIOdivers subsystem (+ margins) during the 2001 trapping season (11 biweekly samples from week 20, early May, until week 43, end October). A: Carabid beetles. B: Spiders.

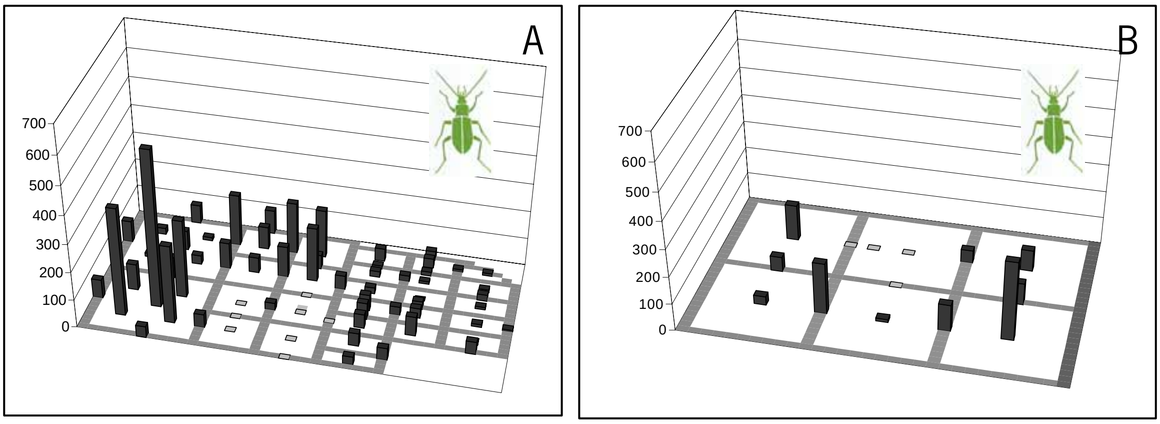

Figure 3. The numbers of carabid beetles caught in each pitfall trap in week no. 30-32, August 2001. A: in the BIOdivers subsystem (+ margins) and B: in the BIOintensief subsystem (no margins).

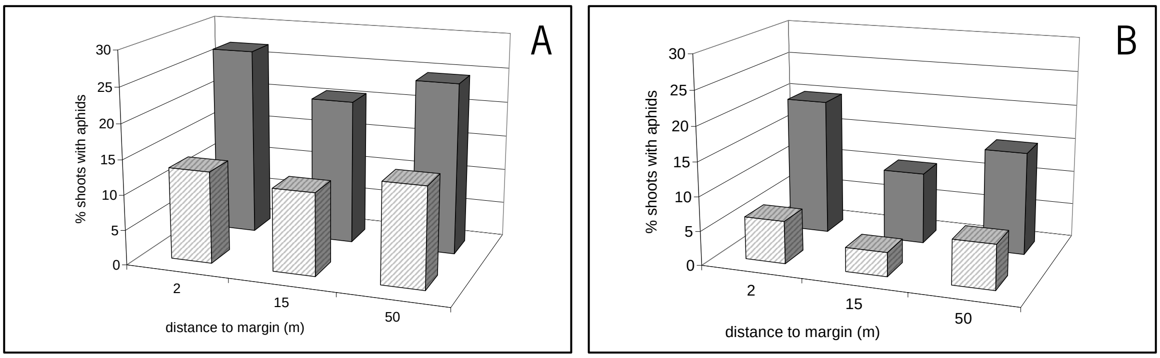

Figure 4. Percentages of shoots infested by aphids at different locations within plots in relation to the distance to the nearest crop edge. Hatched columns: in the BIOdivers subsystem (+ margins); filled grey columns: in the BIOintensief subsystem (no margins). A: in summer wheat, June 2002 and B: in potatoes, July 2002.

sorted due to limited budgets and manpower. Numbers (as an indication of activity) of these generalist predators vary widely in time and space, representing seasonal phenology but also distinct habitat preferences (Figs. 2A and B, 3A). Habitat preference may be influenced by vegetation structure, microclimate, prey abundance, agricultural activities, and other factors. The pitfall samples of the 2002 season are currently being analyzed and will improve our insight in the spatial and temporal dynamics of the functional groups in our experimental system.

In 2002 key pest populations were sampled for the first time in every crop. For only a few pests, density gradients in relation to the field margins were observed. Damage of leaf-feeding beetles (*Lema sp.*; Col., Chrysomelidae) was lower along the margins of summer wheat, compared to the centre of large plots (data not shown). This suggests pest suppression by predators (with a limited mobility) from the field margins. In contrast, in white cabbage and Brussels sprouts, the density of Diamond back moth (*Plutella xylostella*; Lep., Plutellidae) appeared highest along field edges (results not shown).

An interesting pattern of aphid densities (for the total species complex) was found in summer wheat and potato. In both crops, aphid incidence appeared unrelated to the distance from the nearest crop edge. However, aphid densities were much lower in the BIOdivers subsystem compared to the BIOintensief system (Fig. 4A and B). A similar pattern was observed for carrot fly (*Psila rosae*; Dipt.; Psilidae) damage in carrots. This reoccurring pattern suggests that in the field margin network of the BIOdivers system, the total assemblage of (generalists and specialists) predators and parasitoids exert a degree of pest suppression in several crops, over distances of at least 50 m.

Since most key pests were sampled only once or twice in the 2002 season and data of the antagonists monitoring are not yet available, causal relationships and underlying mechanisms cannot be analysed. In the 2003 season, pest sampling will be focussed on two or three key pests and crops only, and carried out with a (bi)weekly frequency, in order to get a better insight in population dynamics and rates of predation and parasitism. Possibly, exclusion experiments with barriers and cages to exclude antagonists at different distances from field margins, can be carried out to analyse the effects of pest suppression and the contributions of antagonists from the field margins. Marking and release experiments could demonstrate the dispersal distances of predators, and whether field margins act as sources or sinks for antagonists in crops. The BIOdivers field margin system thus offers great opportunities to study different hypotheses with regard to functional biodiversity in agricultural systems.

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