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Insect pollinated plants benefit from organic farming

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Abstract

Organic farming is predicted to enhance diversity in agroecosystems. This study addresses the question of whether the often observed positive effect of organic farming on arable weed and pollinator diversity results in a significant shift in arable weed community structure towards a higher proportion of insect pollinated species in organic crop fields. To examine whether plant community patterns were consistent with this hypothesis, arable weed communities were compared with respect to the type of pollination (i.e. insect pollination versus non-insect pollination) in the edges and centres of 20 organic and 20 conventional wheat fields. Plant species numbers of both pollination types were much higher in organic than in conventional fields and higher in the field edge than in the field centre. A comparison of the proportions of both pollination types to all plant species revealed that the relative number of insect pollinated species was higher in organic than in conventional fields and higher at the field edge than in the field centre, whereas the relative number of non-insect pollinated species was higher in conventional fields and in the field centre. Our results show that insect pollinated plants benefit disproportionately from organic farming, which appeared to be related to higher pollinator densities in organic fields, whereas in the centres of conventional fields non-insect pollinated plants dominate presumably due to a limitation of pollinators. Hence, disruption of plant-pollinator interactions due to agricultural intensification may cause important shifts in plant community structure.

Keywords: Arable weeds; Conventional farming; Feed-back; Plant fitness; Pollination

1. Introduction

Pollination plays an important role in flowering plant reproduction and fruit set for wild plant communities (Corbet et al., 1991; Buchmann and Nabhan, 1996). In natural and semi-natural habitats up to 90% of all flowering plant species rely on pollination by animals mainly insects such as bees (Richards, 1986; Buchmann and Nabhan, 1996). However, in highly disturbed systems such as arable fields, plants are well adapted to changing conditions created by annual soil cultivation, harvest of crops, and crop rotation. The majority of arable weeds are annuals and prevalently self pollinated. They produce large amounts of seeds without dependence on other plants as pollen donors and insect pollinators, which themselves depend on weather condition, nesting habitats etc. (Baker, 1974; Hess, 1983). Therefore, plant community structure of disturbed habitats is characterised by higher proportions of self-pollinated plants compared to natural and semi-natural systems (Regal, 1982; Hess, 1983). Out of 108 rare arable weed species in Germany, about 45% are mainly self pollinated of which 8% are obligatory autogamous, 47% are pollinated by animals and 9% by wind (Schneider et al., 1994). The most important pollinators for arable weeds are wild bees, honeybees and bumblebees, and sometimes flies and butterflies (Schneider et al., 1994).

In the last decades both plant and animal diversity have decreased in agroecosystems due to an increasing intensification in agricultural practices (Vandermeer et al., 1998; Robinson and Sutherland, 2002) including large declines and changes in species richness and abundance of arable weeds (Albrecht, 1995; Sutcliffe and Kay, 2000) and the main pollinators of insect pollinated arable weeds (Buchmann and Nabhan, 1996; Allen-Wardell et al., 1998).

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Organic farming is generally found to enhance biodiversity in agroecosystems because of the lack of use of pesticides and mineral fertilizer, and the greater variability in crop rotation (van Elsen, 2000; Bengtsson et al., 2005; Hole et al., 2005). Beneficial effects of organic farming on the abundance and species richness of arable weeds and pollinators have been reported (Menalled et al., 2001; Hyvönen et al., 2003; Morandin and Winston, 2005; Roschewitz et al., 2005; Gabriel et al., in press; A. Holzschuh, personal communication; but see Weibull et al., 2000). Hence, an increased diversity on both sides of the plant-pollinator interactions might lead to a significant shift in plant community structure towards more insect pollinated species in organic crop fields.

To address this question, arable weed communities were analysed with respect to the type of pollination (insect versus non-insect pollination) in the edges and centres of 20 organic and 20 conventional wheat fields in Germany. The hypothesis was (1) that arable weed species richness and percentage cover would be higher in organic than in conventional fields and higher in the field edges than in the field centres and (2) that insect pollinated plant species benefit disproportionately from organic farming due to higher densities of pollinators in organic fields.

2. Methods

The study was conducted in three agricultural regions in Germany: Soester Boerde (51°35′00″N, 008°07′00″E, North-Rhine Westphalia), Leine Bergland (51°32′00″N, 009°56′00″E, Lower-Saxony), and Lahn-Dill Bergland (50°49′00″N, 008°46′00″E, Hesse). Seven field pairs of one organic and one conventional winter wheat field (*Triticum aestivum* L.) were selected in the regions Soester Boerde and Lahn-Dill Bergland and six field pairs in the region Leine Bergland. The matched fields were in close proximity to ensure similar abiotic conditions. Organic fields were managed according to European Union Regulation 2092/91/EEC, which prohibits the use of synthetic fertilisers and pesticides. The average amount of organic fertilizer applied in organic fields was 40 ± 56.4 kg N ha^{-1} per year (min: 0 kg N ha^{-1}, max: 180 kg N ha^{-1}). The average time since conversion to organic farming was 11.6 ± 5.9 years, varied between 2 and 24 years and was not related to species richness and percentage cover of insect and non-insect pollinated species (all $P > 0.1$, $N = 40$). In conventional fields, herbicides were applied on average 1.7 ± 0.8 times per year (min: 1, max: 3) and fertilisers at a rate of with 174 ± 32.8 kg N ha^{-1} per year (min: 125 kg N ha^{-1}, max: 260 kg N ha^{-1}). Nine conventional fields were treated once with insecticides.

At the end of May 2003, all herbaceous plant species were recorded and the percentage cover of each species was estimated visually along two 95 m transects in each field. Each transect consisted of 10 plots (5 m × 1 m) at intervals of 5 m. One transect followed the field edge adjacent to a field margin and one transect was at least 30 m away from the edge transect, running parallel to it in the field centre. For this study we only focus on herbaceous dicots as grasses are all wind pollinated. Species richness is the total number of plant species within a transect. The percentage cover is the average cover within a transect. The classification of herbaceous species into pollination types (i.e. self and wind pollination = non-insect versus insect pollination) was done by selecting the most frequent pollen vector according to the BIOLFLOR-data base (Durka, 2002; Klotz et al., 2002).

2.1. Statistics

The variability of the response variables were analysed using linear mixed effect models (Pinheiro and Bates, 2000), which account for non-independent errors that may occur due to the hierarchically nested sampling design. The effect of farming system (organic/conventional), position in the field (edge/centre), region (Soester Boerde/Leine Bergland/Lahn-Dill Bergland) and first-order interactions on the response variables were tested as fixed effects and field pairs as random effect. The following error structure (number of levels indicated in parenthesis): "field pairs" (20)/"farming system" (2)/"position in the field" (2) was included in the models to account for the variance that may be explained by the study design. Poisson errors and logit link function were specified for models analysing species numbers and normal errors for the percentage cover. Binomial and quasibinomial errors and logit link function were specified for the models analysing the relative species numbers and relative cover of insect pollinated plants (i.e. proportion of insect pollinated species to all species found in a site, i.e. transect). Additionally the species number and percentage cover of all species were used in binomial and quasibinomial models as weights to prevent that the proportions that were estimated from small samples (e.g. small species number) from having undue influence (Crawley, 2002). Models were simplified by removing first non-significant interactions ($P > 0.05$) and then non-significant factors. Non-significant factors which figured in significant interactions were not removed (Crawley, 2002). The appropriateness of statistical models was checked by plotting standardized residuals against fitted values. Mantel tests (Legendre and Legendre, 1998) were performed to test for spatial autocorrelation by relating residuals from statistical models with *xy*-coordinates of study fields. No spatial autocorellation was found (all $P > 0.1$ and $R < 0.05$). Percentage cover values were logarithmic transformed. Statistical analysis was carried out using *R* (R Development Core Team, 2004).

3. Results

A total of 87 herbaceous species was identified, of which 85 species occurred in organic fields and 56 species in conventional fields (Appendix A). The species pool of the