Agriculture, Ecosystems and Environment 173 (2013) 66–71

Contents lists available at SciVerse ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Road verges and winter wheat fields as resources for wild bees in agricultural landscapes

Casper Ingerslev Henriksen*, Vibeke Langer

Department of Plant and Environmental Sciences, Faculty of Science, Copenhagen University, Højbakkegård Allé 9, 2630 Taastrup, Denmark

ARTICLE INFO

Article history:
Received 30 November 2012
Received in revised form 15 April 2013
Accepted 17 April 2013
Available online 20 May 2013

Keywords:
Organic farming
Winter wheat
Road verge
Wild plants
Bumblebees
Solitary bees

ABSTRACT

The effects of farming system on plant density and flowering of dicotyledonous herbs of high value for bees were investigated in 14 organic and 14 conventional winter wheat fields and adjacent road verges. The organic and conventional winter wheat fields/road verges were paired based on the percentage of semi-natural habitats in the surrounding landscape at 1-km scale. Mean density of high value bee plants per Raunkiaer circle was significantly higher in organic winter wheat fields and their adjacent road verges than in their conventionally farmed counterparts. The effect of organic farming was even more pronounced on the flowering stage of high value bee plants, with 10-fold higher mean density of flowering plants in organic fields than in conventional fields and 1.9-fold higher in road verges bordering organic fields than in those bordering conventional fields. In summary, organic farming had a strong positive effect in both road verges and wheat fields on the density of high value bee plants. This was due to the absence of herbicides and to practices inherent to organic farming systems, such as the use of clover (a high value bee plant) as a green manure and fodder crop.

1. Introduction

Wild and cultivated dicotyledonous plants in agricultural landscapes play an important ecological role as providers of pollen and nectar resources for bumblebees and solitary bees. The decline in bee abundance and diversity documented in many Western countries (Biesmeijer et al., 2006; Potts et al., 2010) is a threat to both crop production and wild plant communities (Fontaine et al., 2006; Klein et al., 2007). Denmark is the most intensively cultivated country in Europe, with 62% of the land area used for agriculture and 58% of all land in rotation (Meltofte, 2012). In such intensive agricultural landscapes, where undisturbed areas with low nutrient levels are scarce, the presence of diverse plant communities even in highly disturbed and nutrient-rich habitats such as arable fields and field borders becomes essential to maintain populations of wild bees (Holzschuh et al., 2007).

During recent decades, a decline in the richness and density of wild plants in Danish agricultural fields has been observed. The overall frequency of the 67 most common wild plants in rotational fields declined by around 60% from the late 1960s to late 1980s and, although a follow-up study found that the frequency increased again from 1987/89 to 2001/04, it did not reach the levels found in 1967–70 (Andreasen and Stryhn, 2008). The intensified use of herbicides in conventional Danish arable fields between 1967 and 1987 was the driving factor behind these changes. Herbicide use also led to a 48% decrease in the amount of viable plant seeds in rotational fields between 1964 and 1989 (Jensen and Kjellsson, 1995). Similar findings have been made in other countries (Fried et al., 2009).

Winter wheat is the most widely cultivated cereal in Denmark and occupied approximately 27% of all agricultural land in 2011 (Anonymous, 2012). Winter cereals harbour fewer species of wild plants than spring cereals and have lower plant density and species density (Hald, 1999a).

Wild plants in uncropped habitats bordering arable fields are affected by farming practices in the adjacent field and thus by crop type and farming system. If fertilisers are misplaced and cause high N and P levels in uncropped areas, this has large impacts on plant diversity (Kleijn and Verbeek, 2000). Herbicide drift into field borders, resulting in low but regular exposure, has also been shown to affect plant diversity, flower abundance (Bruus et al., 2008), number of flowers per plant (Christensen, 2008) and seed production (Strandberg et al., 2012). The subtle effects of herbicides could be critical for pollinators, and may also affect the quantity and quality of pollen and nectar in wild plants (Strandberg et al., 2011).

In Denmark, road verges differ from other types of field borders in that they are typically mown a minimum of once a year. Furthermore, they are not only affected by field practices but also by nitrogen deposits from traffic (Truscott et al., 2005). The mowing is assumed to be the main reason for the greater plant species

* Corresponding author. Tel.: +45 61338282.
E-mail addresses: ccingerslev@hotmail.com, cih@life.ku.dk (C.I. Henriksen).

0167-8809/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.agee.2013.04.008

richness in road verges than in other field border types observed in comparative studies (Aavik and Liira, 2010; Hovd and Skogen, 2005). In addition, road verges are typically characterised by well-drained and fairly dry soils and, for example in Sweden, they have been shown to harbour a considerable number of grassland specialist species (Cousins, 2006). However, reflecting the decline in plant species in arable fields, mean plant species richness in Danish road verges declined by 21% per site from 1969 to 2000 (Lange and Jelnes, 2002). Truscott et al. (2005) found that high nitrogen deposits in road verges next to heavily trafficked roads was a factor in reducing plant species richness.

A study of 12 Danish landscapes (4 km^2) dominated by agriculture found that there were 27 m/ha of roads and paths, 20 m/ha of semi-natural field borders and 15 m/ha of hedges (Levin and Brandt, 2006). It is well-documented that organic farming increases the abundance and diversity of wild plants in arable fields (Jonason et al., 2011; Winqvist et al., 2011) and semi-natural field borders (Aavik and Liira, 2010; Petersen et al., 2006). For instance, Hald (1999b) found that plant species associated with many herbivores, as well as plant species with flowers located high in the crop and thus available to flying insects, grew in consistently greater densities in organic cereal fields than in conventional fields. Similarly, although increased plant abundance and diversity does not necessarily increase food resources for wild bees, positive effects of organic farming on diversity of wild bees have been documented (Holzschuh et al., 2007; Rundlof et al., 2008). Plant species, timing and intensity of flowering also seem to be of importance, with Holzschuh et al. (2007) attributing the benefit of organic farming to wild bees as an effect of enhanced flower availability. Some studies on farming-mediated effects on plant diversity and density in arable fields and semi-natural habitats report on plant species richness (Holzschuh et al., 2007), but do not distinguish between plants of varying quality as food resources for wild bees. Others focus on species known to function as forage plants for specific groups, e.g. bumblebees (Rundlof et al., 2008). Ulber et al. (2009) showed that herbicide treatment reduced the species richness of weeds of high quality for seed-eating birds and herbivores more than mechanical weeding. Similarly, Armengot et al. (2011) found that harrowing, which reduced cover, biomass and density of weeds, could be done efficiently without compromising crop yield.

The following hypotheses were tested in the study:

- The density of high value bee plants, and the density of all other plants, is greater in organic winter wheat fields and adjacent road verges than in conventional winter wheat fields and their adjacent road verges.
- Species density of all plants will be greater in organic winter wheat fields and bordering road verges than in conventional winter wheat fields and their adjacent road verges.
- The plant density of flowering high value bee plants and other flowering plants is greater in organic winter wheat fields and adjacent road verges than in conventional winter wheat fields and their adjacent road verges.

Organic and conventional winter wheat fields/road verges were paired based on the percentage of semi-natural habitats in the surrounding landscape. It was assumed that landscape composition did not create a bias in the results due to this pair-wise selection.

2. Materials and methods

The study was carried out on loamy soils in Denmark (located in a coastal temperate climate zone in southern Scandinavia) in spring and summer 2011. Fourteen organic and 14 conventional winter wheat fields, together with an adjacent road verge for each field, were selected in landscapes dominated by agricultural land (Table 1). Road verges were next to a small- to intermediate-sized paved or gravel road, without trees and dominated by grassy/herbaceous vegetation. Each organic field was matched with a conventional field, creating an organic/conventional field pair located in a similar landscape, based on the percentage of semi-natural habitats at 1-km scale. Estimated percentage area of semi-natural habitats in landscapes surrounding road verges next to organic wheat fields and conventional wheat fields did not differ significantly (Table 1). GIS analysis was performed in ArcInfo 10. Data were obtained from several databases, which were merged to create a single database that contained the following land-use classes identified as semi-natural habitats: Permanent grass-land (wet and dry), fallow areas on agricultural land, forest edges, field borders and road verges, bogs, heaths, gardens and ruderal areas. The length of linear habitats (field borders and road verges) bordering agricultural fields was calculated in ArcInfo using Markkort (GLR-The Danish General Farming Register, from Ministry of Food, Agriculture and Fisheries), which is an almost 100% complete annually updated register containing spatially explicit data on location of field and crop type. This is an indirect method for estimating length of linear permanent field borders because it assumes that permanent field borders are present between all adjacent field parcels registered in the Markkort. It does not give values comparable with other studies on length of permanent field borders but it is useful for comparisons within the same study.

For all locations, farming practice was the same on both sides of the road. Mean distance within a pair was 6.3 km (min. 2.8 km, max. 11.1 km). Mean width of road verges was not statistically different between organic (1.8 m) and conventional sites (1.9 m) ($p = 0.62$, two-sample *t*-test). Road verges were kept similar and in preceding years had been cut at least once a year, but time of cutting and number of cuts could not be determined. However, for all road verges, cutting did not involve removal of biomass. All road verges except one were left unmown during the entire period of the inventory, at our request to local authorities or private owners. All organic fields were managed organically for a minimum of three years before the plant inventory.

2.1. Vegetation analysis

An extended version of the Raunkiaer method (Böcher and Bentzon, 1958) was used for the vegetation inventories. Four nested circles (0.001, 0.01, 0.1 and 1 m^2) were used for the plant inventories in fields and in road verges. In fields, each nested circle was placed randomly 10 times at a distance of approximately 9 m from the field border. In road verges, the nested circle was placed in the middle a total of 10 times. All dicotyledonous herbs (wild, undersown and cultivated species) rooted within one of the four nested circles were identified to species or genus. Seedlings were only considered if two or more permanent leaves were present. All species were divided into two classes: vegetative or generative stage. The generative stage was defined as plants with visible petals or seed capsule. The vegetation inventories were carried out twice during the growing season in both fields and road verges (9–20 May 2011 and 25 July to 10 August 2011). An organic and conventional field/road verge pair was sampled on the same day. Due to an exceptionally warm April in Denmark in 2011 and high summer precipitation, winter wheat fields were harvested earlier than usual. Plant inventory data from two organic fields and one conventional field were not available on the second inventory occasion due to early harvest. Identification of plants followed Madsen and Jakobsen (2004) and Mossberg and Stenberg (2007).