The role of weeds in field margins in supporting wild pollinators in Mediterranean cereal agroecosystems

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Summary: Concerns about a global decline in pollinators have called for more knowledge about the drivers of wild pollinator abundance and diversity. In this study we observed pollinator foraging activity in 27 field margins, from 2014-2016, in order to investigate the role of native weeds in supporting wild pollinators in Mediterranean cereal agroecosystems. In total, 175 different plant species were identified and 1,959 wild pollinators were observed foraging on margin flora. The most visited floral species were *Papaver rhoeas* L. (251 pollinator visits), *Torilis arvensis* (Huds.) (229 visits) and *Malva sylvestris* L. (141 visits). Pollinator abundance increased with flower abundance, vegetation height and floral diversity. Pollinator visits increased initially with open flower richness, but began to decrease when high richness likely resulted in lower densities of individual species.

Keywords: biodiversity, field margin flora, habitat quality, pollinator declines.

1. INTRODUCTION

During the last century, a growing proportion of worldwide natural ecosystems have been transformed into agroecosystems. With these land use changes came increased monoculture and usage of pesticides and fertilizers, causing dramatic reductions in plant diversity (Andreasen et al., 1996) and changes in weed flora composition at the field scale (Romero et al., 2008). Reduced weed diversity and richness have been reported in Spain in the last decade, as well as throughout Europe (Chamorro et al., 2007).

Concerns have also been emerging about a global decline of wild pollinators. Not only is pollination essential for agricultural production, but also for the conservation of biodiversity as it ensures the reproduction of wild plants (Nielsen et al., 2011). With increasing proportions of agricultural land use, pollinators face numerous threats including: habitat loss, reduced food source diversity and abundance, fragmentation, pesticide use, introduced species and climate change (Hopwood, 2008; Marini et al., 2012). These concerns have sparked new interest in research aimed at protecting pollinator communities. Further knowledge is required about the drivers of wild pollinator diversity and abundance in agroecosystems.

Biodiversity conservation is a key factor in sustainable agricultural planning. Agricultural field margins present an excellent opportunity for an effective and minimally invasive way of supporting weed diversity and pollinators in agricultural zones. Margins and other semi-natural habitats in the landscape surrounding crops have been found to offer pollinators refuge by providing permanent, although often impoverished, floral and nesting resources (Kwaiser and Hendrix, 2008), and to support pollinator diversity and pollinator services in general (Marini et al., 2012). Studies have suggested that weed diversity is a good indicator of overall biodiversity because of their close relationship with other living organisms in the ecosystem (Gerowitt et al., 2003).

Rarely studies attempt to establish the beneficial relationship between weed diversity and pollination. Consequently, there is a need to know the role of native weeds in agroecosystems, and how they can support pollinators.

In this study we observed pollinator foraging activity in agricultural field margins with naturally diverse flora, not treated with herbicides nor sown with supplementary flowers, in order to investigate the role of native weeds in supporting wild pollinators in Mediterranean cereal agroecosystems. The objectives were to 1) determine which native floral species were most attractive to which pollinators, and 2) observe trends in the abundance of pollinator visits with overall margin floral characteristics.

2. MATERIALS AND METHODS

The experiment was carried out during three years, from 2014 to 2016, at 27 cereal field margins in Catalonia, Spain (Fig. 1). The climate throughout Catalonia is predominantly Mediterranean with moderate temperatures (Bassa et al., 2012). The mean monthly temperature in Catalonia from 2014 to 2016 was 18°C and mean yearly rainfall was 671 mm (World Weather Online).

Figure 1. Location of the 27 sample margins (black dots) in Catalonia, Spain.

We elected only field margins greater than 1 m wide, separating two crops, or a crop from a low traffic country road. For consistency, adjacent fields were restricted to cereal crops or fallow land. Each year, different margins were sampled and the minimum distance between margins was maintained at 2 km in order to ensure that the bee community sampled at each site was unique, taking into account that the typical foraging range of most native bee species collected in pan traps is less than 1 km (Greenleaf et al., 2007; Ricketts et al., 2008).

Each year, the study comprised four days of sampling per margin, dispersed evenly throughout the highest period of pollinator activity, May through July. Sampling consisted of observations of foraging activity and plant inventory. Each round of sampling occurred within the same week for

all margins. Sampling only took place in ideal weather conditions: temperatures of at least 13°C in 60% clear sky or 17°C in any sky, low wind velocity and no rain (Pywell et al., 2005).

Observations of pollinator foraging activity took place between 10h and 17h. The order and time of day that each margin was observed varied systematically. In each margin, five observation plots of 2x5 m were set approximately 10 m apart. During a five minute period for each observation plot (25 minutes/margin), each insect making contact with the sexual organs of a flower was recorded, as well as the species of the flower.

Before observations began, in 1x1 m quadrats within each observation plot, all living plant species were recorded and the coverage of each species was estimated visually as a percentage. Tree or shrub species were recorded if the canopy was present vertically over the quadrat. On each day of observations in each quadrat, flower abundance (the number of open floral units) was counted, the mean height of vegetation was measured and the plant species inventory was updated if necessary. One floral unit was defined as a single flower or collection of flowers that an average-sized insect could traverse by walking, without needing to fly (Grass et al., 2016). Plants were identified according to Flora Europaea (Tutin, 1964-1993).

At the end of the sampling season, mean vegetation height and total flower abundance were established for each margin. Total floral diversity was calculated with the Shannon index using the coverages all plant species present in each margin, omitting species belonging to the family Gramineae (Pielou, 1975).Total open flower richness was calculated as the total number of species with open flowers in the quadrats of each margin during sampling days. The data from all margins were compiled in order to determine which plant species were most attractive to which type of pollinator. Box plots were derived using R version 3.2.2 (R Development Core Team, 2015) in order to observe trends in the abundance of observed pollinators with total flower abundance, mean vegetation height, total floral diversity and total open flower richness.

3. RESULTS AND DISCUSSION

The mean height of vegetation ranged from 45.0 to 99.3 cm (mean=63.3 cm) and total flower abundance ranged from 2 to 1305 floral units/m^2 (mean=330 floral units/m^2). Floral diversity ranged from 0.27 to 2.57 nats (mean = 1.63 nats) and open flower richness ranged from 1 to 18 (mean = 6). In all three years, a total of 175 different plant species were identified, from 50 different families. Of the species identified, 149 were flowering (non-Gramineae) species. The flowering species found most frequently were: *Papaver rhoeas* L. (found in 59% of the margins), *Galium aparine* L. (52%), *Fumaria officinalis* L. (48%), *Convolvulus arvensis* L. (44%) and *Lactuca serriola* L. (41%).

A total of 1959 wild pollinators were observed foraging on margin flora. The most visited floral species were *P. rhoeas* (251 unique pollinator visits), *Torilis arvensis* (Huds.)(229 visits), *Malva sylvestris* L. (141 visits), *Quercus ilex* L. (110 visits) and *Euphorbia serrata* L. (108 visits) (Fig. 2).The most visited species for bees were *M. sylvestris* (70 visits), *Ligustrum vulgare* L. (56 visits), *Vicia villosa* (Roth.) (54 visits), *Rubus* sp. L. (38 visits), *P. rhoeas* (30 visits) and *T. arvensis* (30 visits).The most visited species for beetles and true bugs were *P. rhoeas* (201 visits), *Q. ilex* (109 visits), *T. arvensis* (73 visits), *M. sylvestris* (55 visits) and *Erucastrum nasturtiifolium* (Poiret) (51 visits). The most visited species for hoverflies were *T. arvensis* (45 visits), *Diplotaxis erucoides* L. (28 visits), *E. nasturtiifolium* (21 visits), *P. rhoeas* (16 visits) and *Anacyclus clavatus* (Desf.) (9 visits).

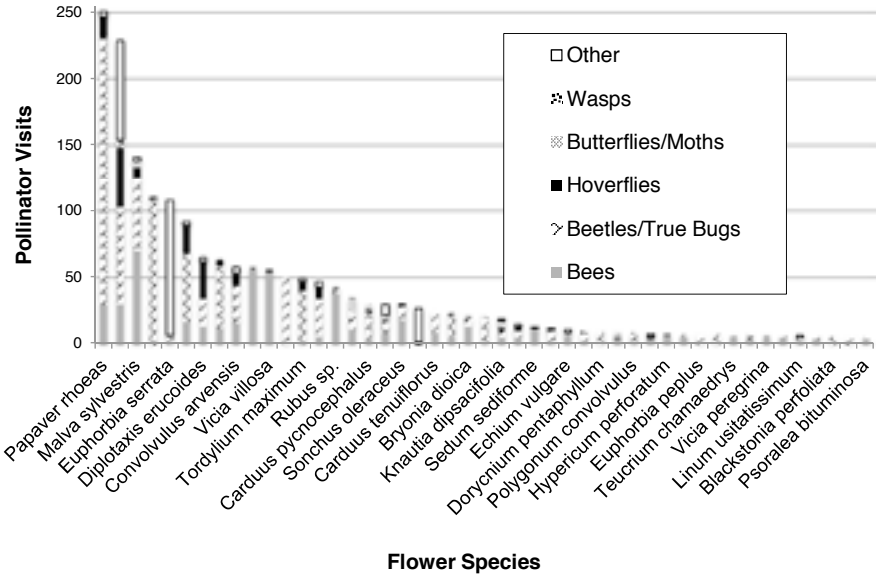

Figure 2. Total number of foraging pollinator visits per flower species (for species with more than five visits).

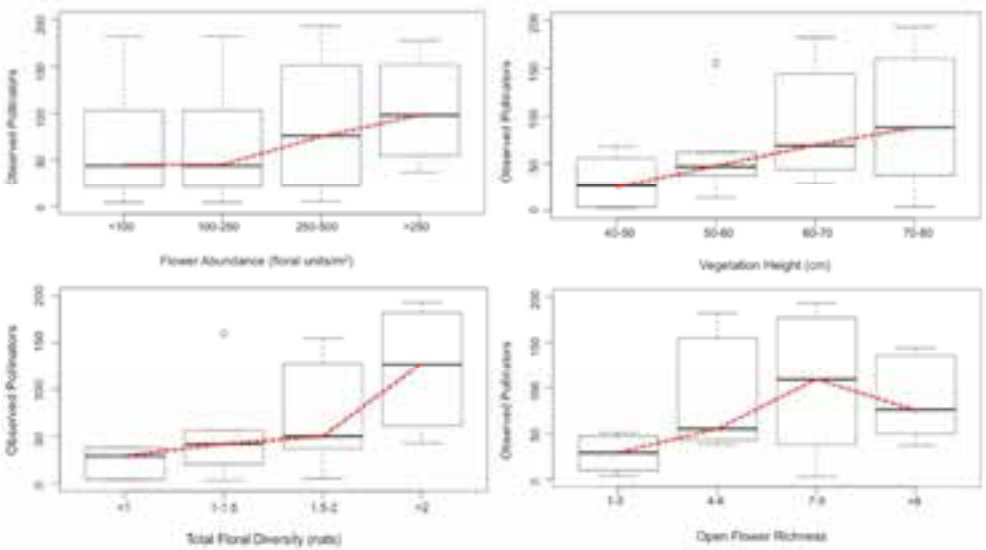

Figure 3. Box plots of number of total observed pollinators vs. total flower abundance, mean vegetation height, total floral diversity and total open flower richness.

According to the box plot analysis, the total number of observed pollinators appears to be increasing with increasing total flower abundance, mean vegetation height and total floral diversity (Fig. 3) although these differences were not found to be statistically significant. The total

number of observed pollinators increased initially with total open flower richness, then decreased for >9 open flower species.

Numerous other studies using visual observations and netting also reported positive influences of floral resources and vegetation height on pollinator abundance (Nicholls and Altieri, 2013; Rosa García and Miñarro, 2014). It is unsurprising that observed pollinator visits increased with floral richness as different pollinator species favour different plant species. Furthermore, as floral richness increases, so does variety in bloom periods and thus the overall temporal availability of pollen and nectar resources in the margin. The decrease in observed pollinator abundance as open flower richness increased past nine may be due to the fact that as richness increased, density of each individual species decreased.

Future analysis will examine functional relationships between the floral traits present in the margin (e.g., organ sizes, shape, colour, nectar availability, etc.) and the morpho-physiological features of wild bees to function as pollinators (e.g., body characteristics, behaviours, etc.) in order to attempt to understand the complex interdependences. A separate analysis will model relationships between biotic and abiotic margin characteristics, surrounding landscape structure and wild bee populations using generalized linear models. Using a variety of approaches, we aim to determine which factors have a statistically significant impact on wild pollinator abundance and diversity and how we may use this information to conserve pollinator biodiversity in agroecosystems.

This research is especially relevant under the reformed Common Agricultural Policy (CAP) to be implemented in Europe from 2014 to 2020 which aims to preserve the natural resources that agricultural productivity depends upon (European Commission, 2013). Hopefully this work will help lead the way for the development of appropriate management strategies for efficient and environmentally sustainable farming, shifting agricultural paradigms to create more robust agroecosystems.

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