Green field margins as a strategy to promote the diversity of pest natural enemies on rice cropping.

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Abstract

The increasing demand of environmentally-friendly produced food by society is motivating a change in the agricultural paradigm. The use of herbicides, although traditionally important for the control of weeds, may entail the loss of habitat for insect species that are potential allies of farmers such as natural enemies of pests. To improve the diversity of natural enemies of pests, an alternative practice could be to avoid the use of herbicides in those areas where weeds do not compete directly with the crop, such as the field margins. To investigate this question, we evaluated how the presence of natural vegetation on rice field margins in the Ebro Delta affects the diversity (morphospecies richness) and abundance of arthropods that can potentially act as enemies of rice pests. We performed several arthropod samplings on rice margins with natural vegetation and rice margins with naked soil (herbicide treatments). Our results indicate that both the diversity and the abundance of arthropods was practically double in margins with natural vegetation (morphospecies richness: 35.3 ± 2.1; abundance: 124 ± 62) than in margins that had been treated with herbicides (21.0 ± 9.6; 65 ± 35). It is important to highlight that the chironomids group represents 84% of all the sampled arthropods when accounted for both types of margins. The rest of the arthropods detected do not pose a threat to rice cropping. On the contrary, most species can act as potential enemies of pests (e.g., syrphids, spiders, beetles or wasps among others). These results suggest that promoting green margins on rice fields can be a promising strategy for mitigating the loss of biodiversity while promoting biological control by natural enemies of pests.

Keywords: Biodiversity, arthropods, insects, agriculture, pest control, sustainability, ecological intensification.

Introduction

The growing global demand for food has entailed that around 40% of free-ice Earth surface is currently occupied by agricultural activities. These productive lands are mostly managed under the paradigm of agricultural intensification (Foley et al. 2011). This strategy is based on the use of agricultural inputs (eg fertilizers, herbicides or pesticides) that largely replace ecosystem services provided by soil microorganisms (cycling of nutrients), pollinating insects (pollination) or natural enemies of pests (biological control). Yet new agricultural paradigms, such as ecological intensification, have been considered during the last decade as response to the increasingly demand of sustainable-produced food. Ecological intensification contemplates a more efficient use of inputs (although it does not imply zero use) while promoting biodiversity in agroecosystems (e.g. natural enemies of pests) as pivotal actors in different processes of crop production (Garibaldi et al. 2019).

The use of herbicides has been important to minimize the impact of weeds that compete for resources with crops, thus allowing a substantial improvement in agricultural yield. However, the excessive use of these inputs, especially in non-productive areas (e. g. crop margins), entail several problems such as herbicide resistance or the loss of food and habitat resources for a myriad of organisms that can act as potential farmer allies (e.g. natural enemies of pests). For example, syrphid larvae (Order Diptera, family Syrphidae) are efficient aphid controllers (White et al. 1995; Meyer et al. 2009). Yet the lack of vegetation in agricultural areas can limit its presence as adults feed mainly on pollen and flower nectar (Rotheray and Gilbert 2011). Avoiding the use of herbicides in favor of mechanical clearings, especially on non-productive areas (e.g. field margins), could be a potential strategy to mitigate these negative effects. This strategy could have three fundamental advantages: *i*) reduce or slow down weed resistance to herbicides, *ii*) reduce the impact on biodiversity as it would provide feed and nesting resources and *iii*) increase biological pest control offered by natural enemies. Despite the potential benefits of this agricultural practice, there is not much evidence to support these issues.

Rice (*Oryza sativa*, L) is the food base for a third of the world's population and occupies 12% of global cultivated land. Spain produces around 900,000 tons of rice every year, of which 20% is produced in the Ebro Delta (Tarragona, Spain) (MAPAMA 2019). A common practice in rice fields is the use of land margins to individualize and connect the different plots allowing the management of water on each plot independently. Traditionally, these non-productive areas are treated with herbicides for preventing the establishment of weeds and to facilitating the passage of farmers. This practice is common not only in Spain but in a high proportion of rice farms in other world regions, such as in South America (e. g. Argentina, Brazil or Uruguay). In order to improve the diversity of natural enemies of rice pests, an alternative practice could be the use of mechanical clearing to control weeds, in order to preserve natural habitat that would offer food and nesting habitat for many arthropod species throughout the year. However, there is not much evidence on the effectiveness of this strategy to promote the presence of potential natural enemies of pests such as spiders, flies, wasps or coleopterans in the rice-growing areas. The objective of this study is to evaluate the influence of the presence of natural vegetation in the margins of rice fields on the diversity (richness of morphospecies) and abundance of arthropods that can potentially act as natural enemies of rice pests in the Ebro Delta.

MATERIAL AND METHODS

Study area

The study was carried out in the Ebro Delta Natural Park (Tarragona, Spain) (40° 43' 04.3" N; 0° 41' 24.7" E), which is considered one of the best preserved and most biodiverse wetlands in Europe. Average annual temperature is about 18 ºC and an annual accumulated rainfall averages 500 mm. Approximately 65% of the delta surface is occupied for rice growing (approx. 21,000 Ha). Rice cycle begins approximately the first week of May (sowing) and, depending on the variety, usually ends in the last weeks of September (harvest).

Experimental design and data analysis

To carry out the experiment, we selected 3 rice farms (average surface = 2.24 Ha) distributed along the Ebro Delta and cultivated with the same rice variety (Bomba). Given the accumulated precipitation in the area and the fact that rice fields remain flooded most of the year, humidity is not usually limiting for the establishment of natural vegetation on rice field margins. Yet margins are conventionally treated with different herbicides (eg bentazone, MCPA or penoxsulan) to keep the soil bare for most of the year. We selected 2 margins in each farm with a minimum length of 300 m and with a separation of at least 100 m between them: a bare margin that had been traditionally treated with herbicide ("without vegetation" hereafter) and a margin treated mechanically that enable the presence of vegetation ("with vegetation" hereafter) (Figure 1). All sampled farms hosted a very similar plant community in terms of diversity and surface coverage. Nitrophilous species of the *Sonchus* genus (Fam. Asteraceae) and several species of grasses (Fam. Poaceae) were the most dominant species, except in one of the farms (Locality 1) where *Iris pseudacorus* (Fam. Iridaceae) dominated the community. To characterize the diversity of arthropods in both types of margins, during the summer of 2019 (June 21 to July 2), a series of samplings were carried out. We installed on each margin three *pitfalls* separated by 50 m and interspersed with three sets of colored traps (*pantraps*; yellow, blue and white) which were also separated by 50 m (Figure 1). All traps were filled with a solution composed of water, salt and soap to break the water surface tension thus preventing the escape of trapped. Pitfalls allows to sample the arthropofauna associated with the soil surface, while pantraps allows to characterize the community of flying arthropods, which are attracted by the different colors of traps. Ptifalls were kept open for five days while pantraps were installed during 24 h. All captured arthropods were preserved in 70% ethanol for later identification. The individuals were separated by morphospecies and assigned to one of the following taxonomic categories: Diptera, Coleoptera, Himenoptera, Dermaptera, Ortoptera, Arachnida and a pooled group represented by the rest of minority groups (*others*) inclunding Lepidoptera, Odonata, Neuroptera, Isopoda and Hemiptera. We worked at the morphospecies level for two fundamental reasons *i*) the aim of the study is focused on comparing the patterns of diversity (richness) between both types of margins beyond the taxonomic identity of species, and *ii*) the identification at the species level it is complicated for some groups, thus it seems more appropriate to use "recognizable taxonomic units" or "morphospecies" as a proxy for the diversity of species (Oliver and Beattie 1996).

We applied two GLMM (Generalized Linear Mixed Model) models for evaluating the differences in richness and abundance of arthropods between margins with vegetation and margins without vegetation. Richness of morphospecies (Model 1) and abundance of arthropods (Model 2) were used as response variables, the presence or absence of vegetation as a fixed factor and the farm as a random factor. A negative binomial distribution was used, which takes into account the over-dispersion of the data, a very typical statistical phenomenon in this type of data with counts. In the same way, the same models were applied for each taxonomic group separately.

Results and Discussion

Rice lands are often characterized by a high abundance and diversity of arthropods (Jarvis et al. 2007). In our study we sampled a total of 3,520 individuals, of which 84% belonged to the Chironomidae family (Diptera order), a group of nematocerous dipterans that represent an important pest during the establishment phase of rice cropping (Català et al. 2013). Of the 568 remaining individuals, 51% belonged to different families of flies, 15% arachnids, 12% coleopterans, 8% hymenopterans (bees and wasps) and the rest (14%) to different families of other minority groups (e. g. Orthoptera, Hemiptera, Dermaptera, etc) (Figure 2A). Arthropod diversity (richness of morphospecies) showed a similar pattern with the Diptera order presenting the highest number of morphospecies (n = 40), followed by arachnids (n = 18) and coleopterans (n = 13) and hymenopterans (n = 13) (Figure 2B). The high abundance and richness found for Diptera suggests that this group tolerates better the agricultural matrix than other groups of arthropods. These results coincide with previous studies that show that certain families of flies such as hoverflies (Syrphidae), whose larvae feed on soft-bodied insects (eg aphids), may be favored in agricultural environments (Scheweiger et al. 2007; Meyer et al. al. 2008; Winfree et al. 2011).

Given that vegetation offers feeding and nesting resources to most arthropod species, our hypothesis was to find a higher diversity and abundance in margins that had been mechanically cleared than in those treated with herbicide (Winfree et al. 2011). Our results were consistent with this hypothesis as margins with vegetation hosted richer arthropod communities than naked margins ($p < 0.05$). Arthropod abundance follows the same pattern ($p < 0.05$), except in locality 1, where the abundance in margins without vegetation was higher (Figure 3). This could be explained because plant community in this locality is almost completely dominated by a single plant species (*Iris pseudacorus*). This could limit the amount of resources available entailing a reduction of the carrying capacity of the margins (White 2008).

The observed patterns are consistent when we observe the trends for each taxonomic group (Table 1), although statistically significant differences were only observed for Hymenopterans and for the group of “others”. These trends seem to support the results found in previous studies showing that the Hymenoptera group (especially bees and wasps) is highly vulnerable to habitat loss and land use changes (Winfree et al. 2011).

It is interesting to note that chironomids, a pest that has a very marked impact on rice production, accounts for 84% of all individuals sampled. This result demonstrates the need to generate new strategies for controlling their populations through the implementation of green margins that promote the presence of pest natural enemies. None of the other arthropod morphospecies sampled in the margins poses a priori threat to rice cultivation. Contrarily, many of these arthropods have been identified as effective natural enemies of pests, such as various families of flies (e. g. Syrphidae), spiders, coleopterans (e. g. Coccinellidae, Carabidae or Cantaridae families) or wasps predators and parasites among others (Hajek and Eilenberg 2018).

It remains to be seen how diversity and abundance of pest natural enemies are related to abundance of rice pests and the impact on different components of crop yield on fields with both green and naked margins. This would allow to better understand the relationships among management practices (herbicide use vs. mechanical clearing), biodiversity conservation and crop production. For the moment, this study shows the positive effect of maintaining vegetation margins in rice fields for promoting diversity of pest natural enemies. These results could be extrapolated to other agricultural areas where extensive agriculture predominates, for example, in large areas of soybean or rice monoculture in South America (e. g. Argentina or Brazil). Margins could provide not only habitat for multiple species but also increasing landscape heterogeneity (Garibaldi et al. 2017). Therefore, promoting green margins at field margins can be a promising strategy that allows buffering the loss of biodiversity associated with agroecosystems, while promoting biological control by natural enemies of pests.

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Table 1. Differences (mean ± standard deviation) in morphospecies richness and abundance (number of individuals per margin) for each taxonomic group (Chironomidae family not included) when comparing margins with and without vegetation. Asterisks (*) indicate statistically significant differences ($p < 0.05$) between the two types of margins.

Taxonomic Group	***Morphospecies richness (num. morphospecies · margin^{-1})***		***Abundance (Individuals · margin^{-1})***	
	With vegetation	*Without vegetation*	*With vegetation*	*Without vegetation*
Diptera	14.0 ± 5.3	9.3 ± 7.0	58.3 ± 47.1	38.0 ± 27.1
Aracnida	6.0 ± 4.4	3.0 ± 2.6	16.7 ± 7.5	11.7 ± 12.6
Coleoptera	3.3 ± 2.1	4.0 ± 1.0	16.0 ± 11.8	6.7 ± 2.3
Himenoptera	**4.3 ± 0.6**	**1.7 ± 1.5** *	12.0 ± 7.0	2.7 ± 3.0
Dermaptera	1.0 ± 1.0	0.7 ± 0.6	6.3 ± 6.5	3.7 ± 3.2
Ortoptera	3.0 ± 1.7	1.0 ± 0.0	7.3 ± 1.5	1.0 ± 0.0
Otros	3.7 ± 1.5	1.3 ± 1.1	**7.3 ± 2.5**	**1.7 ± 1.5** *

Figure 1. A) Spatial distribution of the experimental locations. Orange circles represent the location of the study farms. B) Experimental design and distribution of both pantraps (squares) and pitfalls (circles) within each farm for trapping flying and ground arthropods, respectively. Margins with vegetation are represented in light grey and margins without vegetation in dark grey. Rice fields are represented by the unfilled large rectangles located between the margins.

Figure 2. Morphospecies richness and relative abundance of the main functional groups of sampled arthropods

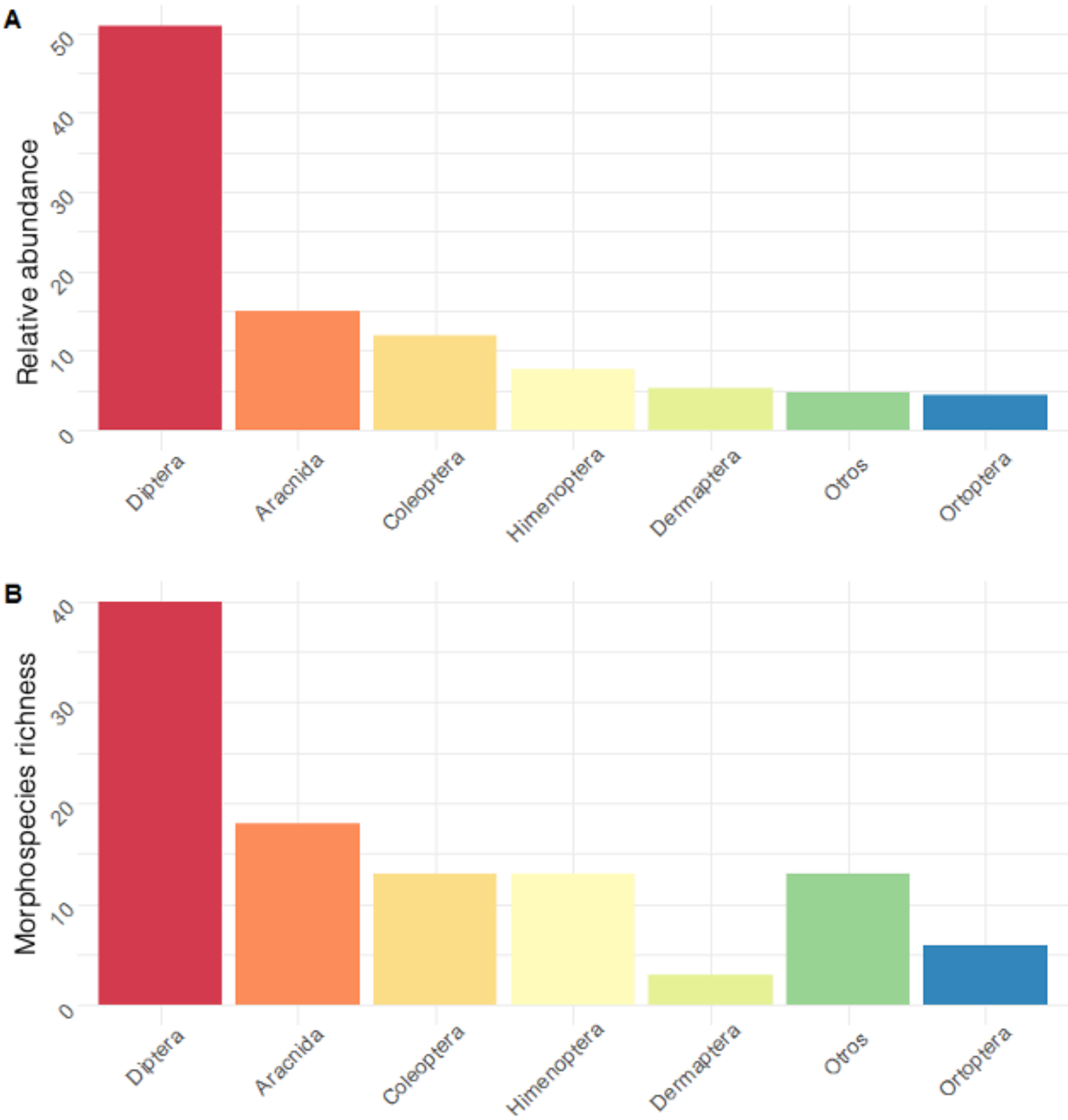

Figure 3. Relative abundance (Chironomidae family is not included) and richness of arthropods morphospecies in margins with and without vegetation across the three different sampled localities.