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Non-crop habitats in the landscape enhance spider diversity in wheat fields of a desert agroecosystem

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ABSTRACT

Spiders (Araneae) are an important group of generalist predators in arable land. In temperate climates, spiders recolonise cropland annually from the surrounding landscape. In arid climates however, irrigated crops and the surrounding landscape matrix offer sharply different habitat conditions and this might negatively affect spider migration into crops. We studied whether the spider fauna in desert crops is influenced by the surrounding landscape in a similar way to that found in temperate climates. Spiders were sampled with pitfall traps in 13 wheat fields (*Triticum aestivum* L.) in the Negev Desert (Israel). The fields were situated along a gradient from crop- to non-crop-dominated landscapes (1–72% non-crop habitats). Species richness of spiders in wheat fields increased with the percentage of non-crop habitats in the landscape. In addition, activity-densities of crab spiders (Thomisidae) and cobweb spiders (Theridiidae) were enhanced by high percentages of non-crop habitats in the surrounding landscape. Activity-densities of the dominant sheetweb spiders (Linyphiidae) showed no significant response to landscape composition. As the immigrant spider families employ different foraging strategies than the dominant sheetweb spiders, they functionally enriched the spider fauna in crops and potentially increase the range of prey types consumed by spiders. Thus, non-crop habitats can be expected to increase the potential for biological control by spiders in nearby crops.

1. Introduction

While the increase in global human population creates a demand for an increase in food production, there is growing consensus that more sustainable agriculture is needed to ensure long-term productivity and stability of ecosystems (Tilman et al., 2002). Many countries in arid or semi-arid regions of the world are challenged with feeding a growing population while environmental conditions are worsening due to human impacts (J. F. Reynolds et al., 2007). Intensification of agriculture in such regions carries the danger of desertification and therefore requires more sustainable production techniques (Tilman et al., 2002; Thomas, 2008). One way to increase sustainability is to make use of naturally occurring ecosystem services, such as the control of agricultural pest species by means of natural enemies rather than by use of chemical pesticides (Riechert, 1999; Loreau et al., 2001; Tilman et al., 2002; Tscharntke et al., 2005a; Farwig et al., 2009).

Generalist predators such as spiders (Araneae) provide an ecosystem service important for sustainable agriculture by feeding on pest insects (Riechert and Lockley, 1984; Symondson et al., 2002). Spiders display a wide range of foraging methods and as such may reduce herbivore densities (Marc et al., 1999; Schmitz, 2008). Nevertheless, for efficient pest suppression, a large regional species pool is needed (Symondson et al., 2002), so that spiders may quickly colonise cropland after tillage, sowing or harvest. Research on spiders in agroecosystems therefore aims to find ways to preserve and enhance spider activity-density and species richness in arable fields by maintaining a diverse fauna in the agricultural landscape.

Mobile organisms experience their surroundings at a variety of temporal and spatial scales (Tscharntke et al., 2005a). The composition of the landscape around crop fields can influence predator abundance and species richness in crop fields (Prasifka et al., 2004; Schmidt et al., 2005, 2008; Drapela et al., 2008). Conservation of biodiversity in agroecosystems therefore requires a landscape approach (Tilman et al., 2002; Bengtsson et al., 2003; Loreau et al., 2003; Bianchi et al., 2006; Billeter et al., 2008). While landscape effects on arthropod communities in arable fields have been documented for temperate areas (Prasifka et al., 2004; Dauber et al., 2005; Tscharntke et al., 2007; Clough et al., 2007; Drapela et al., 2008; Schmidt-Entling and Döbeli, 2009), we are not aware of similar studies carried out in arid climate zones.

In semi-arid and arid climates such as the Negev desert in Israel, differences between irrigated and fertilised cropland and the arid surroundings are greatly accentuated, and are likely to affect the

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Table 1
Geographic location, water supply (in mm) and the percentage of cropland in a 1000 m radius around the 13 studied fields of winter wheat (*Triticum aestivum* L.) in the northwest Negev Desert, Israel.

Location	*y*-North	*x*-East	Rainfall	Irrigation	Total water	% Crop
Sede Teiman A	31°18′N	34°42′E	174	200	374	35.5
Sede Teiman B	31°18′N	34°39′E	159	200	359	98.6
Sede Teiman C	31°18′N	34°40′E	165	200	365	71.7
Eshel-Hanasi	31°20′N	34°41′E	186	200	386	50.6
Moshavei HaNegev - Administration	31°15′N	34°33′E	205	180	385	94.0
Urim	31°17′N	34°31′E	205	80	285	83.9
Wadi Besor	31°18′N	34°28′E	194	120	314	55.3
Tal-Or	31°21′N	34°30′E	284	0	284	97.6
Re'im	31°22′N	34°29′E	243	100	343	83.4
Be'eri A	31°24′N	34°30′E	272	60	332	87.8
Be'eri B	31°23′N	34°30′E	209	40	249	96.0
Be'eri C	31°26′N	34°30′E	299	70	369	74.5
Be'eri D	31°26′N	34°29′E	288	0	288	28.6

population dynamics of spiders. Compared with temperate climates, winters are mild and winter rains initiate a period of growth of herbaceous vegetation followed by high herbivore prey abundance in uncultivated land. Hence, in semi-arid climates with winter rainfall, spider activity is reduced during the dry summer months (Cardoso et al., 2007). Spider populations in arable land however are reduced due to the sowing of the winter crop early in November and thus immigration of spiders from the less disturbed surroundings could be important for pest suppression purposes. Gavish-Regev et al. (2008) found that immigrants from non-crop habitats contribute considerably to the spider fauna of wheat fields in the northwest Negev. This suggests that the composition of the landscape around wheat fields can influence within-field densities of spiders also in this climate zone. The present study aims at supplying this knowledge. Given the high mobility of spiders, we expect that the composition of the surrounding landscape would affect local spider communities in wheat fields as follows: Species richness and activity-density of spiders in wheat fields in the northwest Negev are lower than in non-crop habitats during the winter cropping season (Pluess et al., 2008). Thus we predicted that a high percentage of non-crop habitats in the surrounding landscape should increase both species richness and activity-densities of spiders in wheat fields. In contrast to the majority of the other spider families, the crop-dominating Linyphiidae show a strong preference for cropland in the northwest Negev (Gavish-Regev et al., 2008; Pluess et al., 2008), and we therefore expected a lower activity-density of Linyphiidae in landscapes with high percentages of non-crop habitats. Further, arthropods respond to the surrounding landscape at different spatial scales depending on their dispersal abilities (Steffan-Dewenter et al., 2002; Schmidt et al., 2008). Based on this, we analysed activity-densities of abundant spider families at different spatial scales to gain insight into migration distances of these families in the Negev Desert. We tested the following hypotheses:

1. Overall spider species richness and activity-density in wheat fields increase with increasing percentages of non-crop habitats in the surrounding landscape.
2. The different families reach higher activity-densities in landscapes dominated by their preferred habitat, thus reflecting family specific habitat preferences.
3. Cursorial spiders respond to the surrounding landscape at smaller spatial scales than aerial migrants.

2. Materials and methods

2.1. Study sites

Spiders were sampled in 13 fields of winter wheat (*Triticum aestivum* L.) in the northwest Negev Desert in Israel. The sampling sites were situated in a region with intensive agriculture northwest of the city of Beer Sheva (31°14′N, 34°45′E) and were scattered over an area of 30 km × 30 km. This area is dominated by large fields of mostly irrigated annual crops. Two crops are grown within a year. The summer crops typically consist of cotton, sunflowers, melons or peanuts. In the winter months, potatoes and winter wheat are grown. Depending on rainfall and the availability of water, some fields are not irrigated or irrigated only occasionally. The winter wheat of the studied sites was sown in early November, germination and growth were induced by rain or irrigation in late November. Management of the sampled wheat fields varied but no insecticide spraying was applied during the entire sampling season. All but two fields were irrigated. The soils of the fields consisted of loess with varying proportions of sand. The semi-desert habitats were composed of loess and sandy soils and were sparsely vegetated with perennial shrubs and geophytes. In some areas, eucalyptus and acacia trees were planted in recent decades. Annual grass and herb species appeared after winter rains. At the first sampling in mid-December, the semi-desert was devoid of green vegetation, while wheat growth had been triggered by local rainfall and/or irrigation. The studied wheat fields were a subset of the 16 fields used in Pluess et al. (2008). Three fields were discarded from the original dataset to achieve better standardisation of local site conditions and wheat growth. The characteristics of the wheat fields included in the current study are listed in Table 1.

2.2. Spider sampling

In each wheat field, spiders were sampled with 20 pitfall traps in winter 2006/2007. Pitfall traps were used assuming that numbers of individuals captured per field reflected between-field differences in activity-densities for each species (Topping and Sunderland, 1992; Schmidt-Entling and Döbeli, 2009). The traps were 10 cm deep with an opening diameter of 9 cm and were situated 50 m from the border of a winter wheat field. A 50% dilution of ethylene glycol in water was used as preservative (150 ml/trap) and a drop of detergent was added to break the solution superficial tension. The traps were opened three times (mid-December, end of January and the second half of February) for 1 week during the growing season of the winter wheat. Captures over the entire trapping period were pooled for the analyses. Upon retrieval, spiders were transferred to 70% ethanol. All individuals were identified to family and adult individuals to species or morphospecies. Families totalling at least twenty individuals over the entire sampling period were considered frequent enough for separate spatial scale analyses.