POLISH JOURNAL OF ECOLOGY (Pol. J. Ecol.)	55	4	691–704	2007

Regular research paper

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EFFECTS OF FORESTED STRIPS ON SPIDER ASSEMBLAGES IN ADJACENT CEREAL FIELDS: DISPERSAL ACTIVITY OF SPIDERS

ABSTRACT: Spiders are important components of agricultural ecosystems as far as they affect markedly the abundance of crop pests. The objective of the study was to determine whether the planting of forested strips (shelterbelts) in agricultural area enhances the biomass of spiders active on soil surface of cereal fields and if the exchange of individuals between these habitats depends on the age of trees. The investigations were carried on in 2000 and repeated in 2003/2004 along transects across young shelterbelts (2–11 years old) – ecotones – fields. In the second period the 150 years old forest strip was included into the study. So altogether in both periods the study was performed in the strip-managed area in forested strips 2, 6, 7, 11, and 150 years old, adjacent cereal fields and in the control field located in a deforested area. The intensity of patrolling (number of individuals captured per trap per day) the soil surface by spiders was investigated using pitfall traps forming lines parallel to the shelterbelt. The results of both investigation periods show, that forested strips increased the biomass of patrolling spiders (BP – biomass of spiders per trap per day) in the fields. It was higher in the fields located in the strip-managed area than in the deforested area by ca 70%. The BP decreased gradually with the increasing distance from the strips. Differences between the strip and the field at a distance of 50m were significant (two-way ANOVA, post hoc Tukey test). The reason for the higher BP in the fields adjacent to forested strips was mainly the dispersal of larger spiders from strips to adjacent fields. Dispersal is high between the very young strip and the field and low between the oldest strip and the field. The group of forest-inhabiting species accounted for 0.3–0.5% of the total number of spiders in the field located in deforested area. In the fields adjacent to young shelterbelts this proportion increases with the strips age from 1 to 6%. But in the field bordering the oldest forest strip it is low again and accounted for 1.4%. In this field the proportion of agrobionts is almost as high (94%) as in the field located in deforested area (98%). Similarly the species diversity was very low there. The mean individual body mass of spiders from all the fields located in the strip-managed area was 2.7 times higher than in the control field (P <0.001).

It can be concluded, that in the old forest strips the number of specific species, which don't disperse to surroundings, increases. This conclusion may be important for landscape management.

KEY WORDS: spiders, biomass, intensity of patrolling, body mass, agrobionts, forest species, species diversity

1. INTRODUCTION

Many papers have analysed the importance of the planting of strips of perennial habitats (shelterbelts) into an agricultural landscape. Such strips can reduce wind erosion, modify climatic conditions, reduce eutrophication of ground waters and increase an organic matter content in the soil of adjacent arable fields (Ryszkowski and Kędziora 1987, Życzyńska-Bałoniak *et al.* 1996, Bartoszewicz and Ryszkowski 1996, Prusinkiewicz *et al.* 1996, Kostro-Chomać 2003). These changes are reflected also in the composition and abundance of the fauna (Kajak *et al.* 2000).

The objective of this paper is to estimate the effects of forested strips on spider assemblages in adjacent cereal fields and to analyse trends of spider dispersal associated with the succession of the strips. The investigations were performed in 2000 and repeated in 2003/2004 basing on larger number of strips. The results obtained in the first period were published in Kajak and Oleszczuk (2004).

Spiders are mobile animals that can run on the soil surface or disperse by air over considerable distances. It may therefore be expected that they are able to colonize new areas rapidly, and that an exchange of individuals between adjacent ecosystems will occur. It has been found that spider assemblages, being present all over the year, can respond quickly to changes in prey populations and markedly affect the abundance of crop pests (Nyffeler 1982, Sunderland *et al.* 1986, Riechert and Bishop 1990, Marc *et al.* 1999). They can also influence the content of organic matter in soil by modifying the composition of saprophages (Kajak *et al.* 2000).

I assumed that if forested strips affect arable fields, it can be expected, that the biomass of spiders active on soil surface will be higher near the strips and decrease with increasing distance from them, as well as it will be higher in crop fields located in the strip-managed area than in fields in the deforested area. The presence of strips should also influence the diversity of spider communities.

Based on the habitat preferences of dominant species in spider assemblages, I analysed changes in the contribution of agrobionts and inhabitants of seminatural habitats in the shelterbelts of different age. The spiders were grouped into 4 categories: agrobionts, forest dwellers, grassland dwellers, and eurytopic species. The species were assigned to respective groups based on literature data concerning their abundance in various habitat types (Breymeyer 1966, Toft 1976, Biström and Väisänen 1988, Hänggi *et al.* 1995, Łęgowski 1995, Platen 1996, Samu and Szinetar 2002, Kupryjanowicz 2005). A difficult point was that many species are numerous and even dominant in habitats that differ greatly in abiotic conditions and in the composition of plant communities (Duffey 1978, Hänggi *et al.* 1995, Marc *et al.* 1999).

Many spider species are not habitat specialists. In this situation species were classified into distinct habitat groups according to the maximal abundance in given habitat.

2. MATERIALS AND METHODS

2.1. Study sites

The study was carried out in the experimental area of the Research Center for Agricultural and Forest Environment of the Polish Academy of Sciences situated near the village of Turew, the Wielkopolska region, west Poland (16°45' to 16°50' E and 52°00' to 52°06' N). In the study region, prevail Glossoboric Hapludalf soils on loamy sand over light loam and Arenic Hapludalf soils on slightly loamy sand over light loam (Marcinek 1996). They are slightly acid, poor in organic matter, with low water holding capacity (Table 1).

In the strip-managed area investigations were carried on along three transects across shelterbelts, ecotones and cereal fields. The shelterbelts formed longitudinal forest plantations of different ages, 12–18 m wide (7–11 rows of trees), 350–800 m long. In adjoining (east side) cereal fields samples were taken at the distance 0.5, 15, 50 m from the trees. The field located in the deforested area was treated as a control. All the strips were planted on arable land and were meridian oriented to form a barrier against wind erosion (shelterbelts). In research done in 2000 strips 2 and 7 years old were analysed (Kajak and Oleszczuk 2004). In 2003/2004 trapping was repeated in the same transects, the shelterbelts being

Table 1. Chemical properties of soils in forested strips, adjacent cereal fields and in control field located in deforested area (after Kostro-Chomać 2004, Bernacki unpublished) F15, F50 – fields at distances 15m and 50 m respectively from trees.

Organic carbon %

Age of strip (yrs)	Forested strip	Edge of strip	F15	F50
Control field	–	–	–	1.05
2	0.50	0.49	–	0.44
6	1.1	1.03	0.85	0.87
7	0.55	0.64	–	0.48
11	1.30	1.0	0.85	0.90
150	4.51	1.80	1.35	1.03

Total nitrogen %

Age of strip (yrs)	Forested strip	Edge of strip	F15	F50
Control field	–	–	–	0.07
2	0.05	0.05	0.05	0.04
6	0.07	0.06	0.04	0.05
7	0.06	0.09	–	0.05
11	0.08	0.06	0.05	0.05
150	0.22	0.10	0.09	0.07

pH (KCl)

Age of strip (yrs)	Forested strip	Edge of strip	F15	F50
Control field				6.0
2	5.4	5.3	–	5.1
6	5.0	5.8	4.8	5.6
7	4.3	4.3	–	4.4
11	5.0	6.5	6.2	5.6
150	3.6	4.4	5.6	6.2

Data: from transects across forest strips (2) and (7) yrs old – after Kostro-Chomać 2004, others – after Bernacki (unpublished).

already 6 and 11 years old and the 150 years old strip was included into the study.

The composition of trees in young shelterbelts (2–11 years old) was diverse, the basic species being oak (*Quercus robur* L.), accompanied by marple (*Acer pseudoplatanus* L. and *A. negundo* L.), birch (*Betula verrucosa* Ehrh.), beech (*Fagus sylvatica* L.), elm (*Ulmus minor* Mill.), linden (*Tilia cordata* Mill.), whitebeam (*Sorbus intermedia* Pers.), larch (*Larix deciduas* Mill.), pine (*Pinus sylvestris* L.), and spruce (*Picea abies* Karst.) Trees formed patches of several species (10–15 trees) replicated along the strip.

The old strip (150 years after planting) consisted mainly of black locust (*Robinia pseudoacaccia* L.) with elder (*Sambucus nigra* L.) and hawthorn (*Crategus* sp.) in the shrub layer, and couch grass (*Agropyron repens* L.) in the herb layer (Ryszkowski *et al*. 2003, Karg 2004). Soil organic matter increased within the forested strips and in the adjacent fields with the age after tree planting. However, a relatively high carbon content was found also in the control field (Table 1). Low precipitation and low water holding capacity of the soils were also important factors. An extremely low amount of precipitation was noted in the year 2003, just before the beginning of the second period of the study (338 mm in 2003 against 590 mm – a long-term mean).

Cereals were the main crop in the fields under study. In 2003/2004, it was wheat in the strip-managed areas and barley in the control field, while in 2000 wheat and oat respectively.

2.2. Methods

The patrolling intensity of the soil surface by spiders (number of individuals captured per trap per day – called by many authors "activity density") was recorded by using pitfall traps (7 cm in diameter, 10 cm deep) placed 2 m apart, containing ethylene glycol and detergent. Samples were taken from strip-managed sites and from a control field (C) located in a deforested area. In every transect traps formed five parallel lines, each consisting of 10 traps: (1) in the centre of the strip (S), (2) at the edge of the strip (Es), (3) at the field edge (Ef), and (4) within the adjacent cereal field at distances of 15 m (F 15) and 50 m (F 50) from the strip edge. The distance between two rows of pitfalls situated in the marginal zone (Es and Ef) was only 10 to 20 centimeters. The distribution of traps and data from the first investigation period were presented in Kajak and Oleszczuk (2004).

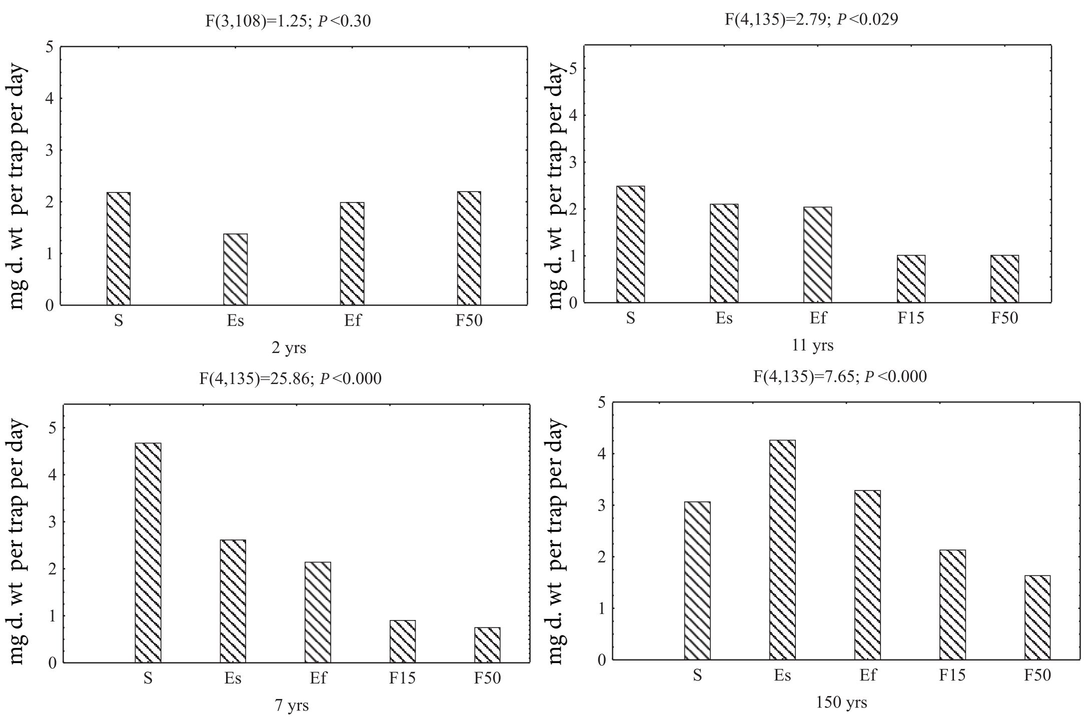

Fig. 1. Mean (all sampling dates) biomass (mg d. wt per trap per day) of spiders patrolling soil surface in four shelterbelts differentiated by age and in adjacent cereal fields (significance of differences between shelterbelts and fields in Table 2).
Plots: S – forested strip, Es – strip edge, Ef – field edge, F15 and F50– cereal field at the distance15 m and 50 m from the tree line. Shelterbelts 2 and 7 yrs old and adjacent fields sampled in 2000, 6, 11 and 150 years old and adjacent fields in 2003/04.

Traps were exposed for one week three times a year (May, June, September in 2000 and October, May, July in 2003/2004). In total, 2859 individuals were trapped in 2000, and 4489 in 2003/2004.

The differences in the number and biomass of patrolling spiders and in the mean individual body mass were tested using the two way (site, date) analysis of variance (ANOVA). Subsequent Tukey's separation procedure was used for pair wise comparisons between plots. Kendall rank correlation coefficient was applied to estimate the similarity between assemblages from various plots (Siegel 1956, Huhta 1979). Statistical analyses were performed using software Statistica 5.5 PL. Species diversity was tested by the Shannon-Wiener diversity index ($H`$), and significance of differences between indices – by the t test.

$$H` = -\sum_{i=1}^{s} p_i \log_2 p_i$$

where: p_i – proportion of individuals of species i in the total number of individuals,

s – number of species

The full list of spider species of the area was given in Kajak and Oleszczuk (2004).

3. RESULTS

3.1. Biomass and number of patrolling spiders

The biomass (BP) of patrolling spiders (dry weight of captured individuals per trap per day) as a rule was the highest in forested strips and gradually declined in the fields with increasing distance from the strip edge (Fig. 1). These results were found in both investigation periods (2000 and 2003/2004). The mean biomass of surface active spiders in the fields was by 77% lower than the mean value recorded in the forested strips. Differences between the strip and the field at a distance of 50 m from the edge were significant (Tuckey post hoc test) (Table 2). Exceptional was the youngest, two-year-old strip, where the biomass (BP) was similar in both habitats (Fig. 1, Table 2).

The lowest biomass value occurred in the control field, situated in the area without any wood in the vicinity (Fig. 2). Differences between BP in this field and in the fields adjacent to strips were significant (Table 3). The mean BP in the control field was reduced by ca 70% as compared with the analogous value from the fields located in the strip-managed area. Moreover in the fields adjacent to forested strips the BP values increased with the age of the planted trees (Fig. 2). The highest biomass was recorded in the field adjacent to the 150-year-old strip.

The intensity of patrolling (number of spiders captured per trap per day) in particular plots was very variable, often even higher in the field habitats than in semi-natural ones (Table 4). Moreover the mean intensity of patrolling was similar in the fields located in strip-managed area and in the deforested area (difference not significant, P = 0.72). Only in the field bordering the oldest, 150 years old forested strip the intensity of patrolling was significantly higher than in the control field (Table 5).

The main reason of the higher BP values in the strips was the mean body mass of individuals, significantly higher in the forested strips than in the adjacent cereal fields, decreasing gradually with the distance from the strip edge (Fig. 3). Again this was not true in the youngest habitat. In all other sites, differences in the body mass between the field and the strip were significant (Table 2, Tukey test).

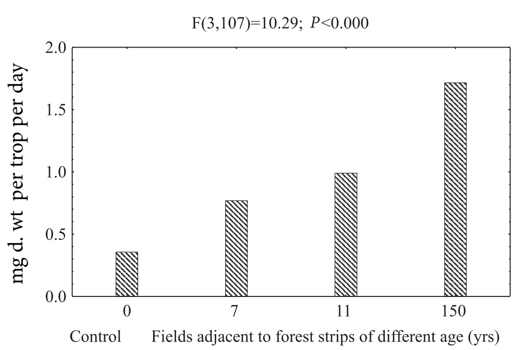

Fig. 2. Mean biomass (mg d. wt per trap per day) of spiders patrolling soil surface in cereal fields: control field (located in area with no wood in the vicinity) and fields located in forested-strip managed area, at the distance 50 m from the tree line. (Significance of differences between control field and fields adjacent to shelterbelts in Table 3). Explanations as in Fig. 1.

Table 2. Significance of differences (*P*) between total biomass of patrolling individuals (BP) and mean body mass of spiders in forested strips and in adjacent cereal fields (Tukey post hoc test).

Age of forested strip (years)	S – Es	S – Ef	S – F15	S – F50
	Biomass of patrolling individuals			
2	n.s.	n.s.	n.s.	n.s.
6	****	****	****	****
11	n.s.	n.s.	*	*
150	n.s.	n.s.	n.s.	*
	Mean body mass			
2	n.s.	n.s.	n.s.	n.s.
6	n.s.	n.s.	***	***
11	*	n.s.	**	**
150	n.s.	****	****	***

S – forested strip, Es – strip edge, Ef – field edge, F15, F 50 – field at a distance 15 or 50 m from edge of strip * $P<0.05$, ** $P<0.01$, *** $P<0.001$, **** $P<0.0001$.

Table 3. Significance of differences between biomass of patrolling individuals (BP) and mean body mass in control field (located in deforested area) and fields adjacent to forested strips (Tukey test).

Parameter	Field adjacent to forested strip of age (yrs):				
	2	6	7	11	150
BP	***	*	**	****	***
Mean body mass	n.s.	n.s.	***	*	n.s.

n.s. – not significant
* $P<0.05$, ** $P<0.01$, *** $P<0.001$, **** $P<0.0001$.

Table 4. Intensity of area patrolling (ind. trap^{-1}day^{-1}) by spiders in forested strips and adjacent cereal fields.

Age of forested strip (Yrs)	S	Es	Ef	F 15	F 50
2	1.45a	1.78a	1.14a	–	**2.12b**
6	1.01a	0.91a	0.70a	**1.41b**	0.65a
11	0.48a	0.74a	0.43a	0.64a	**0.75a**
150	0.94a	1.71b	2.22b	**3.46c**	2.37b

Bold – maximal value within transect
S – forested strip, Es –strip edge, Ef – field edge, F15, F50 – field at distance to tree line in m
Values followed by the same letter in the row are not significantly different $P > 0.05$.

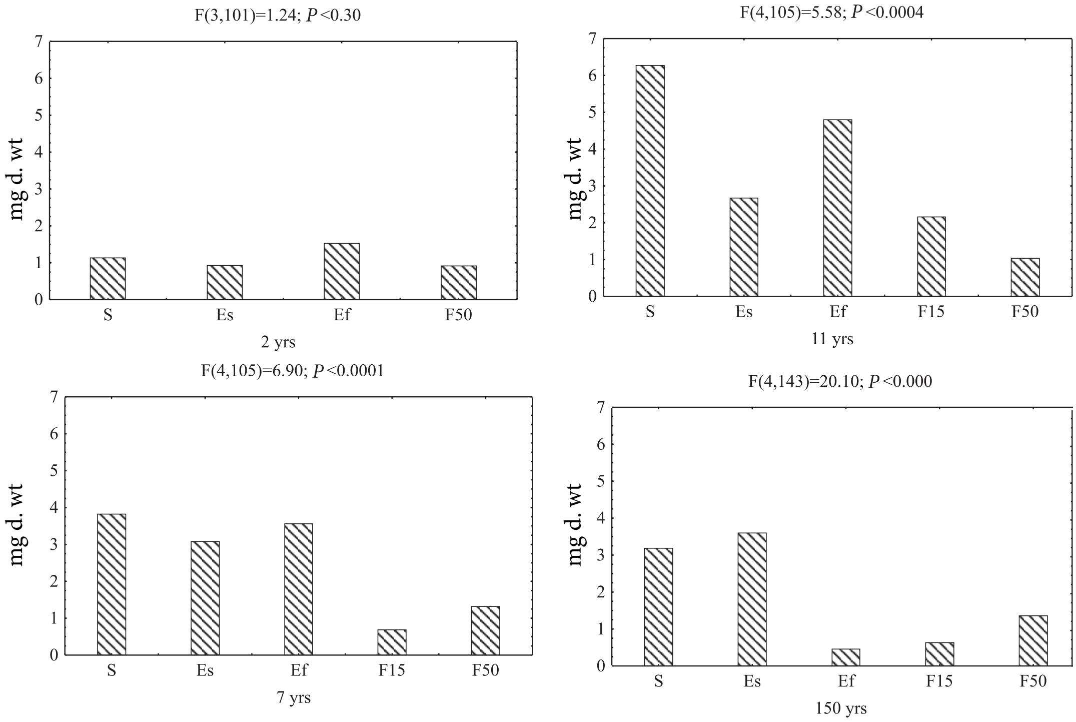

Fig. 3. Mean body mass (mg d. wt) of spiders in forested strips differentiated by age and in adjacent cereal fields. (Significance of differences between strips and fields in Table 3). Explanations as in Fig. 1.

The mean individual body mass of spiders for all the fields located in the strip-managed area was 2.7 times higher than in the control field ($P < 0.001$) (Fig. 4). However differences between the control field and the fields adjacent to very young and very old shelterbelts were not significant (Table 3).

It can be concluded, that the main differences in BP values between semi-natural and agricultural habitats resulted mainly from the dispersal of larger spiders from strips towards the fields.

3.2. Community structure

Four categories of dominant species were distinguished based on the literature data concerning habitat preferences: 1. agrobionts, 2. forest species, 3. grassland species, 4. eurytopic species.

Agrobionts consisted of *Oedothorax apicatus* (Blackwall), *Erigone atra* (Blackwall), *Erigone dentipalpis* (Wider), *Araeoncus humilis* (Blackwall), *Meionetha rurestris* (C.L. Koch). These are small spiders, adapted to cyclic disturbances, able to colonize new habitats and to escape in periods when conditions deteriorate, with a high reproductive potential and short life cycle (Duffey 1978, Łuczak 1979, Platen 1996, Ratschker and Roth 2000, Samu and Szinetar 2002, Thorbek *et al.* 2004).

The second category – forest spiders – comprised *Trochosa terricola* (Thorell), *Pardosa lugubris* (Walkenaer) and *Tapinocyba pallens* (O.P. Cambridge). These species are abundant in various types of forests, especially in coniferous ones; they were recorded from ancient forests as well as from plantations (Breymeyer 1966, Bisröm and Väisänen 1988, Hänggi *et al.* 1995, Łęgowski 1995, Pajunen *et al.* 1993, Kupryjanowicz 2005).

The third category, considered as grassland spiders (Breymeyer 1966, Hänggi *et al.* 1995, Kupryjanowicz 2005), consisted of *Drassyllus pusillus* (C.L. Koch), *Alopecosa pulverulenta* (Clerck), *Pardosa pullata* (Clerck), and *Pardosa amentata* (Clerck). The last category – eurytopic species, included *Pachygnatha degeeri* (Sundevall), *Pardosa palustris* (L.), *Xysticus kochi* (Thorell) – spiders captured in natural and arable habitats as well (Kajak and Łukasiewicz 1994,

Table 5. Mean patrolling intensity (ind. trap $^{-1}$ day $^{-1}$) in control field located in deforested area and in fields adjacent to forest strips (means for all sampling dates). Significance of differences between control field and fields in strip-managed area tested by Tukey test.

Study period	Control field	Fields adjacent to forested strips of age:				
		2	6	7	11	150
2000	1.44	2.12ns		0.97ns		
2003/04	0.45		0.65ns		0.75ns	2.37***

*** P <0.001, ns – not significant.

Table 6. Proportion (% of total numbers) of agrobionts in spider assemblages of fields located in deforested area (control) and in fields adjacent to forested strips.

Study period	Strip age (yrs)	S	Es	Ef	F15	F50
2000	2	62	75	60	–	71
2003/04	6	9	22	41	89	79
2000	7	2	3	9	39	35
2003/04	11	2	3	25	65	66
2003/04	150	4	16	70	92	94
2000	Control					80
2003/04	Control					98

S – forested strip, Es – strip edge, Ef – field edge, F15, F50 – fields at distance to15 and 50 m respectively to tree line.

Table 7. Proportion (% of total numbers) of forest, grassland and eurytopic category of species in spider assemblages of cereal fields (A) and forested strips (B).

A. Fields

	Field in deforested area		Fields adjacent to forested strips Age of strips (yrs):				
Species category	Control 2000	Control 2003/04	2	6	7	11	150
Forest	<1	<1	1	2	6	6	1
Grassland	<1	<1	<1	1	4	<1	<1
Eurytopic	17	<1	22	5	34	10	<1

B. Forested strips

Species category	Age of strips (yrs)				
	2	6	7	11	150
Forest	1	15	16	40	46
Grassland	3	18	30	11	6
Eurytopic	17	14	15	0	1

Forested strips 2 and 7 years old and adjacent fields sampled in 2000, others in 2003/04.

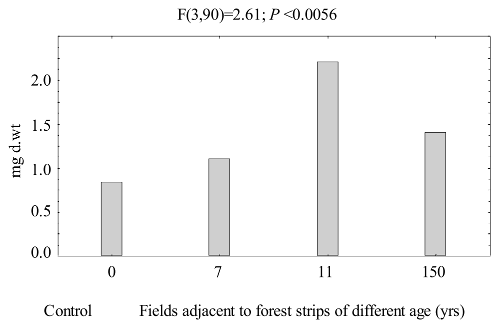

Fig. 4. Mean body mass (mg d. wt) of spiders in control field and in fields located in forested strip – managed area. (Significance of differences between control field and fields adjacent to strips in Table 3). Explanations as in Fig. 1.

Hänggi *et al*. 1995, Kajak and Oleszczuk 2004).

Agrobionts constituted a very high proportion of spiders in all the fields, especially in those located in the deforested area (78 and 98% respectively in the years compared), but also in the field bordering the oldest shelterbelt (94%) (Table 6). In the three fields revisited after 4 years, an increase in the proportion of agrobionts (by 7 to 26%) was noted (Table 6).

The group of forest species in the deforested landscape accounted only for 0.3–0.5% of the total number of spiders. In the fields adjacent to the young forest strips (2–11years old) this proportion increases with age of trees from <1% (field adjacent to the 2 years old strip) to 6% (field adjacent to the 11 years old strip). It is low again in the field bordering the oldest strip (150 years old) where it accounted for 1.4%. Proportion of eurytopic species also increases with the age of trees but the two study periods should be analysed separately. Low precipitation in the 2003 decreased markedly the number of individuals in this species category (Table 7A). The contribution of grassland species in the field habitats was very variable.

Within all forested strips, the proportion of forest species in the assemblage increased with the age of trees , while eurytopic species regularly decreased (Table 7B). In two-years-old strip forest species constituted less than 1% of the community, but 46% in the oldest strip. In the youngest forest strip agrobionts accounted for almost as much as in some fields (62% of the total numbers of spiders).

Indices of similarity also varied with the age of the strips. The similarity indices between the forest strips and the adjacent fields were higher in the young strips (aged 2 and 6 years) than in the older ones (aged 11 and 150 years) (Table 8). The field adjacent to the youngest strip was also most similar to the control field, whereas the lowest similarity was found between the field adjacent to the oldest forest strip (Table 9).

3.3. Diversity

The young strips, characterized by diverse tree composition enhanced significantly species diversity of spiders in the adjacent fields. The indices are higher in the fields in the strip-managed area than in the control field located in deforested area (Table 10). However the lowest values of the diversity index were recorded in the field adjacent to the 150-year-old forest strip, consisted mainly of black locust at both the distances, 15 and 50 m, from the strip edge. The difference between the values for this field and those recorded for the control field were not significant.

4. DISCUSSION

According to many field studies the numbers of spiders in crop fields depend mainly on the intensity of agriculture and the frequency and kind of agricultural practices (Samu *et al*. 1999, Büchs 2003, Jeanneret *et al*. 2003, Wardle *et al*. 1999, Marshall *et al*. 2006). But heterogeneity of the landscape also influences the abundance and composition of spider communities.

The introduction of semi-natural habitats into arable fields can enhance the abundance of predatory arthropods in these fields (Nentwig 1988, Lys and Nentwig 1992, Ryszkowski and Karg 1991, Thomas *et al*. 1991, 1992, Dennis and Fry 1992, Harwood and Wratten 1992, Ryszkowski *et al.* 1993, Frank and Nentwig 1995, Imhasly and Nentwig 1995, Marshall and Mooney 2002, Asteraki *et al.* 2002, Schmidt and Tscharntke 2005, Marshall *et al*. 2006). This is mainly due to the

Table 8. Similarity indices (τ) (Kendall`s rank correlation) between spider communities in forested strips (S) and adjoining cereal fields at the distance 50 and 15 m from the tree line (N – number of samples, z – association between two variables).

S age years	Forested strip → Field 50m				Forested strip → Field 15m			
	N	Corr. coeff. τ	z	*P*	N	Corr. coeff. τ	z	*P*
2	32	0.49	3.93	***	28	0.44	3.28	***
6	42	0.33	3.08	**	34	0.32	2.65	**
7	29	0.18	1.40	n.s.	32	0.35	2.82	**
11	25	0.24	1.70	n.s.	28	0.14	1.08	n.s.
150	22	0.28	1.80	n.s.	31	0.24	1.87	n.s.

** $P < 0.01$, *** $P < 0.001$.

Table 9. Similarity indices (τ) (Kendall`s rank correlation) between spider communities in control field (located in area without wood in vicinity) and fields located in differently aged strip-managed area (N – number of samples, z –association between two variables).

Field adjoining strips of age (years)	N	τ	z	*P*
Control →2	20	0.70	4.29	****
Control →6	20	0.47	2.88	**
Control →7	18	0.29	1.66	n.s.
Control →11	13	0.58	2.74	**
Control →150	14	0.29	1.46	n.s.

** $P<0.01$, **** $P < 0.0001$.

Table 10. Diversity indices (Shannon-Wiener index) of spider assemblages in control fields located in deforested area and in fields in strip managed area at distances 15 and 50 m from trees.

Study period	Control field	Fields adjacent to forested strips of age (years):							
		2	6	6	7	11	11	150	150
		50m	15m	50m	50m	15m	50m	15m	50m
2000	2.46	3.02			3.46				
2003/04	0.93*		2.55	2.84		2.85	3.25	0.69*	0.73*

(* $P < 0.05$ in both study periods)

fact that perennial habitats provide shelters for overwintering and for periods of various agronomic treatments in crop fields (Dennis and Fry 1992, Samu *et al.* 1999, Marc *et al.* 1999, Pfiffner and Luka 2000, Bell *et al.* 2002, Lemke and Poehling 2002, Pywell *et al.* 2005, Schmidt and Tscharntke 2005). Some authors show, however, that the stimulating effect of the introduced semi-natural habitats is limited to their closest surroundings. Spiders that can find suitable habitat conditions at the margins of arable fields do not tend to abandon such places (Weyman and Jepson 1994, Thomas and Jepson 1999, Samu *et al.* 1999).

The present paper confirms that the total biomass of spiders patrolling the soil surface is significantly higher within the strips or at their edges than in the fields and gradually declines towards the field center. The only exception was the youngest, two-year-old strip where no sufficient time elapsed for the development of this pattern. Four years later in this field, the biomass of patrolling individuals also declined with the distance from the strip. Spider biomass in the fields increased also with the age of the planted strip. It was the highest in the field adjacent to the oldest strip, aged 150 years.

It is important for landscape planning, that the total biomass of patrolling spiders is higher in the fields located in the strip-managed area than in the deforested area. This is confirmed by the present and the previous studies (Kajak and Oleszczuk 2004). But the number of individuals captured, was significantly higher in the strip – managed area only in the case of the field bordering the oldest forest strip. In most cases the main component of higher biomass is the size, not number of individuals. The proportion of forest and eurytopic species in the fields adjacent to the young shelterbelts (2–11 years old), increases with the age of trees and is low again in the field bordering on the oldest strip (150 years old). Probably the number of stenotopic forest species that do not tend to move outside its border increases in the old forest. This is likely to be the reason why the field adjacent to the oldest forest strip was inhabited by a relatively high proportion (over 90%) of agrobionts, and by only few species of other categories, emigrating from the forest strips.

In the period 2003/2004, the proportion of agrobionts increased at all revisited sites, as compared with 2000. As an opposite the proportion of eurytopic species decreased in this period. The likeliest reason would seem to be the drought in the period preceding investigations. Agrobionts are more resistant to such conditions than other species (Łuczak 1980, Büchs 2003).

Many authors report that habitat heterogeneity with hedges or strips of perennial vegetation increases the diversity of spider communities occurring in arable fields (Marshall and Moonen 2002, Büchs 2003, Asteraki *et al.* 2002 Schweiger *et al.* 2005). But the present study does not fully support this view. The communities in the fields adjacent to young, multispecies strips are significantly more diverse, but the lowest diversity was found in the field adjacent to the oldest forest strip. The spider community in the last field was even poorer than in the field located in the deforested landscape. The reason was probably the high proportion of forest specific species within the strip, which do not migrate beyond the forest border.

The midfield strips were rather quickly colonised by forest spiders, proportion of this category increases with succession. In the strip only two years old, they contributed to only 1% of the community, but in the 11-year-old strip for almost 40%, and in the oldest one for over 45%.

Analysis of the succession of the fauna in pine woods planted in former fields as compared with the succession in forests regrown after clear cutting shows that the succession of predatory macrofauna takes several tens of years, though it proceeds at a higher rate than the succession of saprophages (Szujecki 1983, Szyszko 1983, Szujecki 1990, Łęgowski 1995). The forest species *Trochosa terricola* Thorell, which is dominant also in the forested strips described in this paper, appeared abundantly in these large forested areas only after more than ten years. In stands 18–23 years old, it accounted for 30% of the community. It seems that the succession in the midfield forest strips observed in the present study proceeded at a higher rate. The same species accounted for 24% of the community already in the strips 7 years old, and for

30% in the strip 11 years old. It can be suggested that the species richness of the introduced tree stands may be important, as well as the shape of the afforested area. Strips with long bordering lines seem to be more readily accessible to the colonizing fauna.

5. CONCLUSIONS

1. The introduction of forested strips into arable fields markedly increases the biomass of spiders patrolling the fields. This is mainly because larger individuals disperse to the fields, whereas the intensity of patrolling does not change.

2. In fields adjacent to the young forest strips the proportion of forest species of spiders increases with the age of strips. But the field bordering on the oldest strip was inhabited almost exclusively by agrobionts. The likeliest reason is the high contribution in the old forest of stenotopic species that do not tend to move outside the forest border.

3. Young midfield forest strips enhance the species diversity of spider assemblages occurring in cereal fields. Diversity of spiders in the field adjacent to the old shelterbelt was as low as in the field located in the deforested area.

ACKNOWLEDGEMENTS: The author is grateful to Teresa Glazer and Ernest Barton for checking the English and to prof. Jerzy Karg for his kind assistance and organizational support during field works and valuable comments to the manuscript. The study was supported by the grant of the Polish State Committee for Scientific Research (3 PO4F 012 24).

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Received after revising May 2007