POLISH JOURNAL OF ECOLOGY (Pol. J. Ecol.)	51	3	309–321	2003

Regular research paper

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THE EFFECT OF SHELTERBELTS ON LITTER DECOMPOSITION AND FAUNA OF ADJACENT FIELDS: *IN SITU* EXPERIMENT

ABSTRACT: The effect of mid-field shelterbelts on litter decomposition and the numbers and biomass of litter inhabiting invertebrate macrofauna was evaluated. The question was how far into the fields such an effect could reach. To answer this question an experiment was set up, in which a uniform substratum (sand and loam) was laid out inside the metal frames dug in the earth. Litter of cocksfoot (*Dactylis glomerata*) was laid out on these substrates. Samples were taken from the middle of a seven years old wood strip (S) and along the transect i.e. in the ecotone from its wooded side (E_S), from its field side (E_F) and in the field 10 (F_{10}) and 50 (F_{50}) meters far from the shelterbelt. Decomposition rate of litter was retarded with increasing distance from the shelterbelt. Biomass of the litter dwelling macrofauna was lower in the field as compared to the shelterbelt and ecotones. Input of dead invertebrate mass to the soil under litter decreased also from the shelterbelt towards the field center. At the end of the experiment dead invertebrate biomass contributed to 24% of the total (dead and alive) of animal biomass in the transect. Average contribution of predators to the total animal biomass was the highest in the field ecotone (E_F – 79%) and the lowest in the field site F_{50} (56%). A significant negative relationship was found between the density and biomass of predators (Carabidae) and the density and biomass of their potential prey (larvae of Diptera and Collembola) along the whole transect.

KEY WORDS: shelterbelt, ecotone, field, litter, invertebrate remains, biomass, density, fauna

1. INTRODUCTION

Islands of permanent vegetation among crop fields significantly affect climatic conditions, their role as barriers filtering water is also well documented (Pokojska 1988, Ryszkowski and Bartoszewicz 1989, Ryszkowski *et al.*1990, Bartoszewicz and Ryszkowski 1996, Kędziora and Olejnik 1996, Prusinkiewicz *et al.* 1996, Kędziora and Palusiński 1998). There are also data sets on the effect of forest and meadow ecosystems on animals of the above-ground layer of agrocoenoses, including crop pests (Banaszak 1983, Kemp and Barrett 1989, Nentwig 1989, Gałecka 1991, Ryszkowski and Karg 1991, Kajak and Łukasiewicz 1994, Lys and Nentwig 1992, Lys 1994, Dąbrowska-Prot 1999, Cierzniak 2000, Kajak 2000). Few papers described this effect on fauna living in or on the surface of soil (Górny 1968a, b, Kajak *et al.* 2002). It is assumed that islands of permanent vegetation among fields provide a basis for maintaining a high numbers and species diversity of epigeic and soil fauna on intensively managed croplands (Altieri 1999, Paoletti 1999, Kajak *et al.* 2002, Karg in press). Refuges provided by the islands enable the occurrence in the field habitat the species of longer life-cycles than a given crop. Thus then the contribution of animals, which do not belong to pioneer species, is higher.

Litter dwelling invertebrates were analysed more frequently in meso- than macrofauna (Seastedt *et al.* 1983, Kaczmarek and Kajak 1997, Szanser 2000a). Here data, concerning litter and soil fauna of the studied habitats is compared. An important aspect of this paper is that such a comparison was done under the same trophic conditions.

The aim of this study was to analyze if and how shelterbelts affect the litter decomposition and the numbers and biomass of the litter dwelling fauna and what is the range of such an effect of shelterbelt. Since one of the important factors in studying ranges of the impact of fauna is their ability to move in space, the course of litter colonization by fauna was also studied. Macrofauna, i.e. animals of a length of 0.2 to 2 cm were the main objects. Litter dwelling by mesofauna – springtails (Collembola), the animals of a size of 0.01–0.2 cm (van der Drift 1951) was also estimated.

2. STUDY SITE AND METHODS

Studies were carried out on the Kościan Plain near a field station of the Department of Agricultural and Forest Environment, PAS in Turew (west Poland, region of Wielkopolska). Parent rock is light loam there and the upper layer is composed mainly of Hapludalfs and Udipsamments of a humus content of ca. 1.6%, slightly acidic (pH between 5 and 6), which dominate there (Marcinek 1996, Karg 1998).

Planted wood strips have diversified flat landscape of croplands in the region. They were formed in various periods during the last 200 years (Ryszkowski *et al.* 2003). Studies were carried out in the years 1999 and 2000 within the 7-years-old, 18 m wide shelterbelt in "Wyskoć" and in the nearby field (details in Ryszkowski *et al.* 2003). The field was sown by maize (in 1999) and wheat (in 2000). Fertilizers were applied in amounts of N – 85 kg ha^{-1}, P – 70 kg ha^{-1}, K – 150 kg ha^{-1} (in 1999) and N – 115 kg ha^{-1}, P – 82 kg ha^{-1}, K – 100 kg ha^{-1} (in 2000). Herbicides were the only biocides used. "Laso" and "Mazina" were applied in doses of 3 l ha^{-1} and 1.5 l ha^{-1} respectively (in 1999) and "Lentipur" in amount of 1.5 l ha^{-1} (in 2000) (Karg pers. inform.).

To follow changes in the litter decomposition and the numbers, and biomass of invertebrate macro- and mesofauna dwelling the soil surface a field experiment was set up along the transect from shelterbelt through ecotone to field. One-species grass litter composed of cocksfoot (*Dactylis glomerata*) was laid out on a uniform, poor in organic matter substratum. The litter consisted of grasses collected near studied site just before earring. It was placed in containers (PVC rings with drilled holes and with top and bottom covered with a nylon gauze of a mesh size of 1 mm) per 10 g in each (Szanser 2000a, b).

The experiment for estimating decomposition rate of litter was set up on the eastern (leeward) side of the shelterbelt along five lines parallel to the shelterbelt: within the shelterbelt (S), in the ecotone strip at the wood side (E_S), several dozen (50 cm on average) centimeters further in the ecotone at the field side (E_F) and in the field 10 m (F_{10}) and 50 m (F_{50}) from the shelterbelt. The litter was placed in the metal frames (0.5×0.5×0.2 m) filled with a poor substratum were dug in the soil along these lines. They were filled with sand and loam to a depth of 0–3 cm and with sand at the depth 3–20. The substratum was similar to the surrounding soil. In total, 90 metal frames were installed, 18 in each site. The frames had to prevent from overgrowing the substratum with roots and from penetrating the area by strictly soil animals. Eight litter containers were placed on surface of every frame. Small amount of sand and loam mixture was scattered all over the litter placed in the field. This procedure simulated the plowing up plant remains into the field soil. Litter remained there for 11 months, since November 1999 till September 2000. Samples of litter and sand layer of 0–1 cm underlying it were taken three times in 2000.

The litter samples, were dried for three days at 65 °C, before decomposition rate analyses were determined.

Animals were extracted with the use of Kempson's funnels (Kempson *et al.* 1963). Dead remains and spider cocoons-were hand sorted from the same litter samples and from 0–1 cm substratum layer.

Macrofauna was divided into two trophic groups:

1 – predatory macrofauna: spiders, chilopods, beetles (Carabidae and Staphylinidae).

2 – other macrofauna mostly saprophagous mainly dipteran larvae, Symphyla, non-predatory beetles (Coleoptera).

Mesofaunal springtails (Collembola), mostly saprophagous, were extracted from the same litter samples.

Collected data were processed with the Statgraphics 6.0 computer software. Differences in the biomass of animals and their remains were analysed using multivariate *ANOVA*, the Tukey's test at $P < 0.05$, and Mann-Whitney's non-parametric U test. Relationships between the biomass of fauna and the distance from the shelterbelt and between predators and prey were tested by Kendall's rank correlation test and the correlation significance with ANOVA.

3. RESULTS

Decomposition rate of the litter composed of *Dactylis glomerata* was retarded with increasing distance from the shelterbelt. The significant positive correlation was found between the remaining mass of it and the distance from the shelterbelt (Fig. 1).

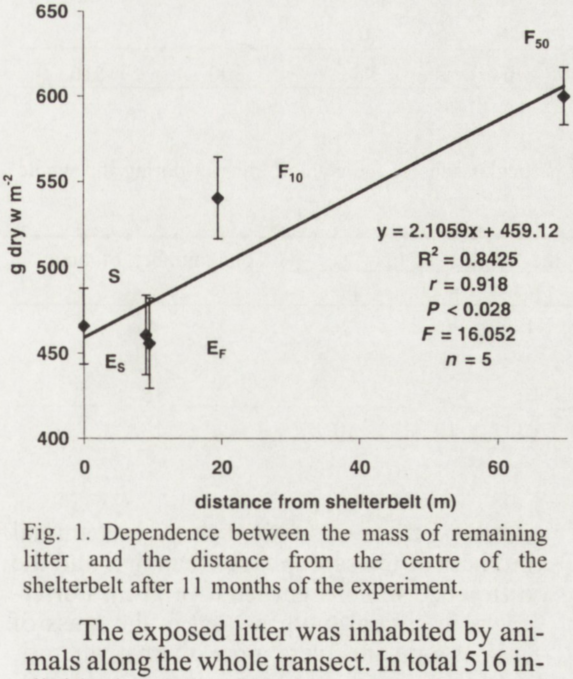

Fig. 1. Dependence between the mass of remaining litter and the distance from the centre of the shelterbelt after 11 months of the experiment.

The exposed litter was inhabited by animals along the whole transect. In total 516 individuals were found in the litter and underlying sand, of 0–1cm layer, during the study period (Table 1).

The number of litter dwelling taxa increased with time. Between the 6th and 7.5th month there were only 6 taxa while after 11 months the number increased to 16 (Table 2). The highest number of taxa (14 and 13) was found in litter laid out within the shelterbelt (S, E_S), in the field there were only 10 taxa per each site (Table 2).

Biomass of litter dwelling animals increased progressively during the experiment. In spring i.e. 6 months after laying the litter, the biomass was very low ranging from 0.0 to 0.09 g dry wt. m^{-2} (Fig. 2). One and a half month later it increased 8.6 times on average ranging from 0.161 to 0.629 g dry wt. m^{-2}. In the autumn, after 11 months of the experiment, the biomass increased 3.2 times compared with the summer values, between 0.617 and 2.829 g dry wt. m^{-2} (Fig. 2). Thus, the maximum biomass of macrofauna was recorded in the autumn, 11 months since the litter exposure.

Average contribution of predatory taxa to the total animal biomass was high – from 56 to 79% (Table 3). Dominating taxa were spiders (12–58%), Chilopods (4–34%) and carabid beetles (0.4–27%). Among the non predatory animals, dipteran larvae (0.3–23%) and adult beetles (other than Carabidae and Staphylinidae) (11–24%) were dominating (Table 3).

The mass of dead organic matter of invertebrate origin (corpses, invertebrate remnants, spider cocoons) also increased with time. It was over 2.1 times higher in the autumn than in June (Table 4). After 11 months, non-living matter of invertebrate origin comprised 24% of the total animal mass (dead and alive) within the transect and ranged from 0.183 to 0.895 g dry wt. m^{-2} (Table 4). Thus, litter dwelling fauna may supply the soil with different amounts of matter.

Density and biomass of animals and organic matter originating from invertebrates differed within the transect. Significant differences between sites could be noted not earlier than in the 11th month of the experiment.

Density of particular macroarthropod taxa in exposed litter responded differently to the distance from the shelterbelt. Density of Araneae was significantly higher in S and E_S sites than in the field and density of Carabidae was significantly higher in E_F than in the wood center (Table 5). The numbers of other adult Coleoptera were significantly higher in the wooded ecotone (E_S) than in the field sites (Table 5). Dipteran larvae were more numerous in the field (F_{50}) than in other sites by 6.4 times in average (Table 5).

Table 1.The number of individuals of different macrofauna taxa found in litter and sand (0–1 cm) beneath (per 100cm^2) on particular sites of the transect for the whole study period (April – September 2000). S – shelterbelt, E_S – ecotone from the wood side, E_F – ecotone from the field side, F_{10} – field 10 m from the wood strip, F_{50} – field 50 m from the wood strip.

Taxon	Sites					
	S	E_S	E_F	F_{10}	F_{50}	Sum S–F_{50}
Enchytraeidae	22	0	0	0	0	22
Aphididae	3	0	0	0	1	4
Thysanoptera	2	0	0	0	0	2
Homoptera larvae	0	1	0	0	0	1
Lepidoptera larvae	0	1	0	0	0	1
Heteroptera	3	3	1	0	0	7
Hymenoptera	3	0	0	3	2	8
Diptera adult	8	3	3	2	3	19
Diptera larvae	19	4	1	15	64	103
Carabidae	2	17	20	17	7	61
Staphylinidae	24	15	10	7	0	56
other Coleoptera adult	6	12	3	4	3	28
Coleoptera larvae	4	16	3	34	4	63
Araneae	28	39	13	5	13	98
Chilopoda	7	2	4	5	2	20
Symphyla	8	1	6	6	1	22
Formicidae	0	1	0	0	0	1
Sum per site	139	115	64	98	100	516

Table 2. The number of taxa of macrofauna found in particular sites of the studied transect during the whole study period. Sites as in Table 1.

Time of litter exposure in months	Sites and the number of taxa					Total number of taxa
	S	E_S	E_F	F_{10}	F_{50}	
6	0	1	1	0	2	4
7.5	2	4	3	4	3	6
11	14	12	10	8	8	16
Total number of taxa in site	14	13	10	10	10	17

Average seasonal biomass of macrofauna was 3.5 times smaller in the field (F_{50}) than in the wood strip (S) and that of dead animals and spider cocoons was 4.3 times smaller (Table 6). After 11 months of experiment biomass of predators was over 3.5 times and 3.8 times smaller in F_{50} than in S and E_S, respectively and the difference was significant (Fig. 2). As for other animals, their biomass in the field was only in F_{10} significantly (11.8 times) smaller than in S. Far in the field (site F_{50}) there was only 4 times less animal biomass of the saprophages than in S and the difference was insignificant (Fig. 2). Differences in animal biomass and in the mass of animal remnants were more distinct when final data from the combined sites – wooded (S + E_S) were compared with the field sites (E_F, F_{10}, F_{50}) (Table 7). The biomass of some animal taxa was correlated with the distance from the wood strip. For example, Carabidae and Chilopoda, as opposed to Araneae and

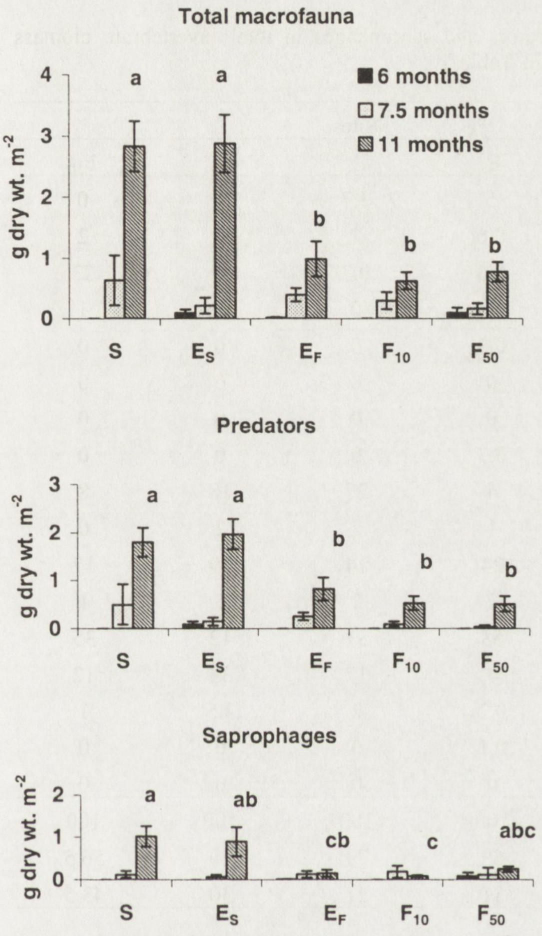

Fig. 2. Biomass (g dry wt. m^{-2}) of total macrofauna and predatory and saprophagous groups in the study period along the transect. Sites as in Table 1. Different letters denote significant differences between experimental treatments, after 11 months of experiment, at $P < 0.05$ (Tukey's test) for n = 10. In other sampling times differences between sites were insignificant. Bars denote standard error.

Staphylinidae, inhabited the litter with similar intensity regardless of the distance from the shelterbelt (Table 7). For Carabidae and Chilopoda, the ratio of biomass in the field to that in the shelterbelt and the ecotone was 1.4 and 1.2, respectively. Biomass of Araneae and Staphylinidae was significantly smaller in the field than in the shelterbelt and the ecotone – 6.5 and 4.7 times, respectively. Similarly the total mass of macrofauna and animal remnants decreased with the increasing distance from the shelterbelt (Table 7).

Significant negative relationships were found between the density or biomass of predators (carabids) and the density or biomass of their potential prey (dipteran larvae and springtails) within the transect (Figs. 3, 4 and 5). Dipteran larvae were the most numerous macroarthropods of all potential prey in F_{50} as compared to other sites after 11 months of the experiment (Table 1).

The data show that the increase in the number of taxa and the number of animals dwelling the litter was distinct not earlier than between the 7th and the 11th month of the experiment. The experiment revealed significant predator-prey relationships variable within the transect.

4. DISCUSSION

The slowing down of litter decomposition from shelterbelt toward the field center of the field, found in my investigations, is not always the case. Opposing to present studies it is claimed, by several authors, that decomposition processes go faster in intensively managed or being in early stages of succession ecosystems comparing to permanent or extensively used ones (Tesařova 1990, Hassink 1992, Bogdanowicz and Szanser 1997). Tesařova (1990) and Hassink (1992) obtained results from studies in soils taken from different sites. Bogdanowicz and Szanser (1997) received results from the experimental studies in which identical poor soil substratum and litter of *Dactylis glomerata*, similarly as in this experiment, on different aged meadows was used. It may be supposed that the differences between other authors' findings and mine are not the result of methodological differences between these studies. It is supposed that using the herbicides in studied field in consequence retarded the mineralization processes. In some cases the decrease of microbial biomass and activity was reported for soils treated with herbicides (Prado and Airoldi 2001, Perucci *et al.* 2000, Harden *et al.* 1993, Duah-Yentumi and Johnson 1986). The decreasing decomposition rate of litter along the shelterbelt – field transect was described by Bernacki (1994) in the same region, in the case of the litter buried to 10 cm depth-in the field-adjacent to 100 year old shelterbelt.

Mean mass of litter dwelling macroarthropods was found to be higher than that found in soil and turf in the same site (Olechowicz in press). Along the studied transect, average biomass of arthropods in turf and soil (0–15 cm) amounted to 1.431 g

Table 3. Percentage share (%) of particular taxa, predators and saprophages in total invertebrate biomass along the transect for the whole study period. Sites as in Table 1.

Taxa		Sites				
		S	E_S	E_F	F_{10}	F_{50}
Heteroptera		4	5	3.7	0	0
Diptera	Adults	1	0.6	1	1	2
Diptera	Larvae	13	0.5	0.3	4	23
Hymenoptera		0.3	0	0	1.5	1
Homoptera	Larvae	0	0.3	0	0	0
Thysanoptera		0.3	0	0	0	0
Aphididae		1	0	0	0	0
Lepidoptera	Larvae	0	0.3	0	0	0
Carabidae		0.4	4	27	18	8
Staphylinidae		2	1	2	2	0
Coleoptera others	Adults	11	24	14	19	17
Coleoptera	Larvae	1	2	2	5	1
Araneae		52	58	31	12	35
Chilopoda		12	4	17	34	12
Symphyla		1	0.2	2	3.5	1
Formicidae		0	0.1	0	0	0
Enchytraeidae		1	0	0	0	0
Total		100	100	100	100	100
Predators share in		67	69	79	70	56.5
Saprophages share in		33	31	21	30	43.5

Table 4. Dead organic matter of invertebrate origin (corpses, macroarthropod remains, sloughs, spider cocoons) (g dry wt. m^{-2}) and its percentage share (%) in total dead and alive mass of invertebrates along the transect. Sites as in Table 1. Different letters denote significant differences between experimental treatments at $P < 0.05$ (Tukey's test) for n = 10. SE – standard error in parentheses

Time of litter exposure	Mass	Sites					*ANOVA*
		S	E_S	E_F	F_{10}	F_{50}	
7.5 months	Dead invertebrate matter	0.126^a (0.06)	0.350^a (0.14)	0.538^a (0.263)	0.008^a (0.01)	0.052^a (0.03)	$P < 0.055$ $F = 2.518$
	Sum of dead and alive invertebrate matter	0.755^a (0.40)	0.564^a (0.21)	0.928^a (0.28)	0.299^a (0.14)	0.214^a (0.10)	$P < 0.247$ $F = 1.408$
	Share of dead invertebrate matter %	**17**	**62**	**58**	**3**	**24**	
11 months	Dead invertebrate matter	0.895^a (0.39)	0.469^a (0.11)	0.455^a (0.22)	0.302^a (0.26)	0.183^a (0.13)	$P < 0.310$ $F = 1.234$
	Sum of dead and alive invertebrate matter	3.724^a (0.37)	3.343^a (0.50)	1.438^b (0.35)	0.919^b (0.34)	0.951^b (0.24)	$P < 0.00001$ $F = 13.390$
	Share of dead invertebrate matter (%)	**24**	**14**	**32**	**33**	**19**	

Table 5. Density of dominating macroarthropods (ind. m^{-2} ± SE) along the transect 11 months after laying out the litter. Sites as in Table 1. Different letters denote significant differences between experimental treatments at P <0.05 (Tukey's test) for n = 10. SE – standard error in parentheses.

Taxa	Sites				
	S	E_S	E_F	F_{10}	F_{50}
Chilopoda	70.0^{a}	20.0^{a}	40.0^{a}	50.0^{a}	20.0^{a}
	(26.1)	(13.3)	(22.1)	(22.4)	(13.3)
Symphyla	80.0^{a}	10.0^{a}	60.0^{a}	60.0^{a}	10.0^{a}
	(29.1)	(10.0)	(26.7)	(16.3)	(10.0)
Araneae	220.0^{ab}	310.0^{b}	60.0^{cd}	30.0^{cd}	110.0^{ad}
	(44.2)	(52.6)	(26.7)	(15.3)	(34.8)
Carabidae	20.0^{a}	170.0^{ab}	200.0^{b}	160.0^{ab}	70.0^{ab}
	(13.3)	(53.8)	(39.4)	(60.0)	(33.5)
Staphylinidae	240.0^{a}	150.0^{a}	100.0^{a}	70.0^{a}	0.0^{a}
	(102.4)	(68.7)	(69.9)	(36.7)	(0.0)
Other Coleoptera adults	40.0^{ab}	110.0^{b}	10.0^{a}	0.0^{a}	0.0^{a}
	(16.3)	(45.8)	(10.0)	(0.0)	(0.0)
Coleoptera larvae	40.0^{a}	$140.\ ^{a}$	30.0^{a}	100.0^{a}	30.0^{a}
	(22.1)	(87.2)	(15.3)	(44.7)	(15.3)
Diptera adults	80.0^{a}	30.0^{a}	10.0^{a}	0.0^{a}	30.0^{a}
	(69.6)	(21.3)	(10.0)	(0.0)	(15.3)
Diptera larvae	190.0^{a}	40.0^{a}	10.0^{a}	150.0^{a}	630.0^{b}
	(98.3)	(22.1)	(10.0)	(68.7)	(192.1)
Heteroptera	22.22^{a}	33.3^{a}	11.1^{a}	33.3^{a}	11.1^{a}
	(14.7)	(23.6)	(11.1)	(16.7)	(11.1)

Table 6. Mean dead* and alive invertebrate mass (g dry wt. m^{-2}) along the transect for the whole study period. n = 125. Sites as in Table 1. The same letters denote a lack of significant (P <0.05) differences between experimental treatments (Tukey's test). SE – standard error in parentheses

Group	Sites					ANOVA
	S	E_S	E_F	F_{10}	F_{50}	
Alive invertebrate mass	1.383^{a}	1.253^{a}	0.552^{a}	0.366^{a}	0.391^{a}	P <0. 015.
	(0.33)	(0.33)	(0.14)	(0.10)	(0.10)	F = 3.223
Dead invertebrate mass	0.511^{a}	0.410^{a}	0.496^{a}	0.155^{a}	0.118^{a}	P <0.131.
	(0.21)	(0.09)	(0.17)	(0.13)	(0.07)	F = 1.824

*corpses. remains of macroarthropods. sloughs. spider cocoons.

dry wt. m^{-2} in the shelterbelt , 0.593 g dry wt. m^{-2} in the ecotone and was much smaller in the field – 0.053 and 0.097 g dry wt. m^{-2} at a distance of 10 and 50 m, respectively, from the shelterbelt (Kajak *et al.* 2002, Olechowicz in press). Animal biomass was smaller in the soil surrounding the experiment than recorded in the litter laid out in these sites, by 39, 34, 85 and 75%, respectively in the shelterbelt, ecotone and in the field 10 and 50 m from the tree line. Differences in fauna biomass between surroundings of the experiment and exposed litter were always higher in the field than in the wooded area. Laid out litter was probably a good food source and shelter for animals, much better than the soil or stubble and thus the higher animal biomass was reached there. Enhanced retention of litter under extensive agriculture enables to keep lower temperature and higher moisture of the soil surface as compared with the soil under conventional agriculture (Coleman 1985, Stinner and House 1990).

Table 7. Correlation coefficients between the distance from the shelterbelt and mass of macroarthropods, dead invertebrate matter and mass ratio of dominating taxa and dead invertebrate matter (S, E_S, E_F/F_{10}, F_{50}) after 11 months of the experiment ($n = 50$). Sites as in Table 1.

Taxa	Correlation between the distance and biomass and its significance	Mass ratio: S, E_S, E_F/F_{10}, F_{50} and significance of differences
Araneae	$r = -0.358^A$ $P < 0.011$, $F = 7.052$	6.46 $P < 0.0002$, $F = 16.297^A$
Staphylinidae	$r = -0.325^A$ $P < 0.021$, $F = 5.674$	4.67 $P < 0.04$, $F = 4.616^A$
Carabidae	$r = -0.076^A$ $P < 0.599$, $F = 0.281$	1.41 $P < 0.528$, $F = 0.404^A$
Chilopoda	$r = -0.176^A$ $P < 0.221$, $F = 1.535$	1.24 $P < 0.656$, $F = 0.201^A$
Total biomass of macroarthropods	$r = -0.436^A$ $P < 0.0015$, $F = 11.268$	3.22 $P < 0.000006$, $F = 19.288^A$
Dead invertebrate mass	$r = -0.425^A$ $P < 0.0021$, $F = 10.581$	2.50 $P < 0.0007$, $Z = 3.404^U$

^{A} – *ANOVA*, ^{U} – U Mann-Whitney's test.

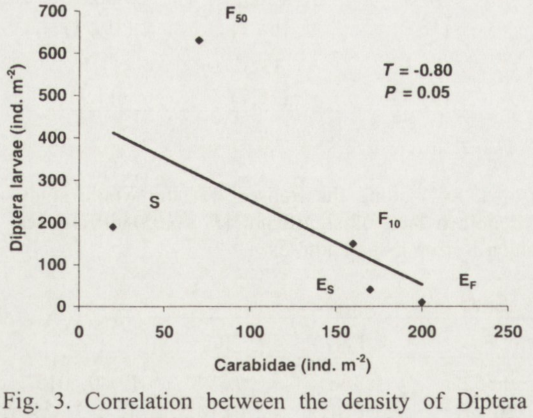

Fig. 3. Correlation between the density of Diptera larvae and Carabidae in the transect after 11 months of the experiment. Sites as in Table 1. n = 5. Kendall's rank test.

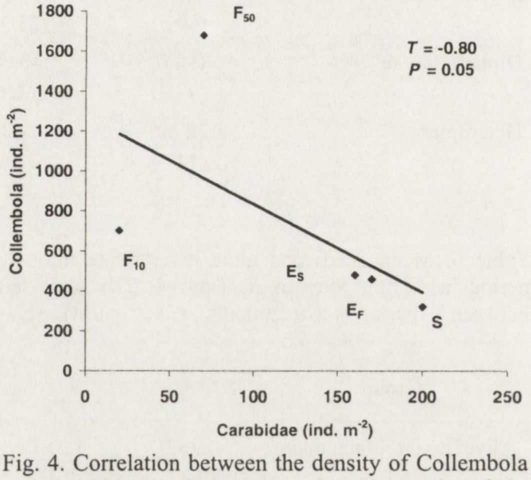

Fig. 4. Correlation between the density of Collembola and Carabidae in the transect after 11 months of the experiment. Sites as in Table 1. n = 5. Kendall's rank test.

Methodically similar field experiment was set up on a permanent meadow of the order Arhenatheretalia (Szanser 2000a, b, c). In both experiments the litter was laid out in autumn (on meadow at the end of September and at the break of October and November on the field). After a similar time, since litter laying out, in the field (after 7.5 months) densities of fauna in litter were smaller comparing to meadow site (after 8 months) (Szanser and Olechowicz unpubl.). Certain groups such as Araneae, larval Diptera and Coleoptera colonized the litter much faster on the meadow, already after the first month of the experiment density of these animals was similar to that found in the present study at the end of the experiment. Slower colonization of litter in the field was the consequence of smaller overall density of macrofauna recorded in field comparing to meadow.

In spite of similar trophic conditions in all compared sites (the same amounts of the litter laid out on the same substratum) a significant decrease of animal mass was observed from the shelterbelt to the field center. But the decrease was smaller than in the biomass of soil dwelling invertebrates. While in the present experiment a mean seasonal de-

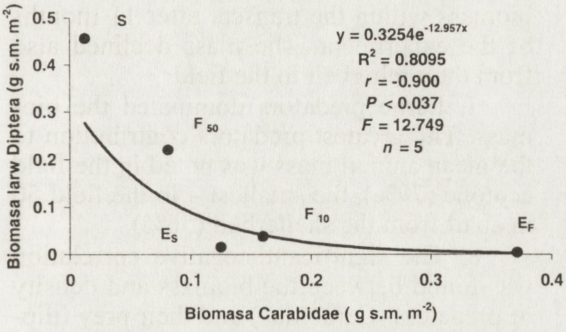

Fig. 5. Correlation between the biomass of Diptera larvae and Carabidae in the transect after 11 months of the experiment. Sites as in Table 1. n = 5.

crease of invertebrate biomass along the transect was 3.5-fold, the biomass of animals living on the surface and in the surrounding soil decreased over 14 times (Olechowicz in press). However, differences concerning typical epigeic fauna (insect imagines, spiders and myriapods) between the shelterbelt and the field becomes close to these found in the litter (Olechowicz in press). Biomass of the epigeic animals decreased in F_{50} 8 times in relation to the shelterbelt, while in the case of experimental litter the decrease was 4-fold. The difference in biomass decline for this group of animals between the surrounding soil and experimental litter was smaller than for the whole fauna. Similar observation was shown for springtails (Olejniczak in press). Epigeic species, dwelling in experimental litter were more numerous in the field than in the shelterbelt, while numbers of soil dwelling Collembola were significantly lower in the field.

In the fauna of exposed litter relatively high proportion was found of invertebrates that are able to migrate. Therefore, the litter colonization reflected not only the actual number of animals in particular sites but also their abilities of penetrating the surrounding area. For example, proportion of predators was higher in the litter than in the upper soil layer, it ranged in the litter from 63 up to 86 per cent of the total invertebrate biomass while 36 up to 62 per cent in the soil. Biomass of very mobile animals (Carabidae and Chilopoda) did not differ between the field and the shelterbelt but the others – (Araneae, Staphylinidae and non-predatory adult Coleoptera) was significantly higher in the shelterbelt than in the field. Thus then differences in colonization occur between the spiders and carabids despite the fact that both groups can inhabit the area not only by patrolling the soil surface but also via air (Van Huizen 1980, Kromp 1999, Kajak *et al.* 2002, Kajak and Oleszczuk in press). The litter of my experiment was dominated by small carabid beetles of a mean weight of 3 mg, which penetrate the area more often by air than other, larger species. This finding suggests that exposure of the litter significantly affects the density of some mobile species.

It was found that not only biomass of fauna, but also soil sorption potential, organic matter content, microbial activity and nitrogen mineralization potential in soil and in experimental substratum decreased from the wood strip to the field along the transect (Popławska 2001, Kajak *et al.* 2002, Wojewoda and Russel 2003, Kusińska and Szanser unpubl.). Noteworthy, using the litter could partially moderate unfavourable effect of ploughing on the number and biomass of fauna.

Decrease of the total animal biomass in litter proceeding from the shelterbelt towards the field center was closely correlated with higher amount of remaining litter mass and with the decrease of organic matter content in substratum under the litter (Kusińska and Szanser unpubl.). Similar observation was made for fauna in the surrounding of the experiment, in other shelterbelts of various ages and in adjacent fields. An interesting problem is the relationship between organic matter content in the environment and the intensity of penetration by predators. Far in the field, the intensity of area penetration by predators was smaller than in the shelterbelt and ecotones (Kajak and Oleszczuk in press). Significant positive relationship was found between the mass of non-living matter of invertebrate origin in litter along the studied transect and the biomass of predators while relationships between the former and the biomass of non-predatory or total fauna were insignificant (Szanser in prep.). These data suggest that the biomass of non-living invertebrate matter depended on predators' activity. Thus then predatory taxa significantly changed the potential prey number and biomass (dipteran larvae and springtails) and in consequence dead animal matter input into the system. The relationship shown here is interesting because the predator-prey relations in croplands are usually described only for predatory arthropods and crop pests (Kromp 1999, Marc *et al.* 1999, Lang *et al.* 1999).

Presented results demonstrate that introduction of the litter in arable fields is followed by an increase in the numbers and biomass of animals. After a year, differences between shelterbelt and the field were lower in the litter than in the soil, although they are still observed. Moreover increase of organic matter content in the soil covered by the litter was found (Kusińska and Szanser unpubl.). It is difficult to estimate from obtained results if the litter exposed in the field, could be colonized abundantly in the farming system without shelterbelts. Lowering with the distance biomass of fauna in litter suggest that midfield islands, shelterbelts in this case, arranged among agricultural landscape can be the reservoir of invertebrate fauna, which may penetrate and inhabit adjacent fields to a relatively far distance.

5. CONCLUSIONS

1. Decomposition of litter proceeded slower in the field area than in the shelterbelt. It is accompanied by the decrease of fauna biomass in exposed litter and microbial activity of substratum-underlying the decomposing material.

2. Litter dwelling by invertebrate fauna was slow during 6 months since litter exposure. The numbers and biomass of litter dwelling macrofauna increased intensively between the 6th and 11th month of the experiment.

3. The number of taxa of litter dwelling fauna after 11 months of the experiment was smaller in the field and in the field ecotone than in the shelterbelt and the wooded ecotone. There were 1.75 times more taxa in litter laid out in the shelterbelt than in the field.

4. Biomass of litter dwelling animals decreased significantly from the shelterbelt towards the field. The differences between sites appeared not earlier than after 11 months since the litter exposure. After that period biomass of fauna in the shelterbelt was 3.7 times larger than in the field.

5. Differences between sites in the numbers of animals found in litter are much smaller than in the numbers of soil fauna. Litter laying out significantly increases animal biomass compared with the soil and may intensify dwelling of the area by animals.

6. Mass of non-living invertebrate matter comprised 24% of the total dead and alive biomass within the transect after 11 months of the experiment. The mass declined also from the shelterbelt to the field.

7. Large predators dominated the biomass. The greatest predators contribution to the mean animal mass was noted in the field ecotone (79%), the smallest – in the field 50 m apart from the shelterbelt (56%).

8. The significant negative correlation was found between the biomass and density of predators (Carabidae) and their prey (dipteran larvae, Collembola) within the transect.

ACKNOWLEDGMENTS: The study was financially supported by the Polish Committee for Scientific Research within the grant 6 P04F 028 16

6. SUMMARY

The study was aimed at estimating the effect of a 7-years old midfield shelterbelt on one-species (cocksfoot – *Dactylis glomerata*) grass litter decomposition processes and fauna dwelling the decomposing material. Litter was laid out along the transect from the shelterbelt (S) to ecotone from the wood side (E_S) to ecotone from the field side (E_F) to the field 10 m (F_{10}) and 50 m (F_{50}) far from the strip. In the field experiment, litter was laid out in metal frames dug in the soil. Frames were filled with a poor substratum of sand and loam to a depth of 0–3 cm. At the depth 3–20 cm substratum consisted of sand. In total 90 frames were dug in, 18 in every site. The experiment was carried out between November 1999 and September 2000. One hundred and twenty five samples of litter and 1 cm substratum layer from beneath were collected during the year 2000. Animals from the litter were agitated with the Kempson's funnels (Kempson *et al*. 1963). Then, from the same samples animal remains and spider cocoons were collected.

After 11 months of the experiment loss of litter was retarded with increasing distance from the shelterbelt (Fig. 1).

In total 516 induividuals of macrofauna were agitated from the litter (Table 1). After 11 months of the experiment there were 1.75 times more taxa found in litter laid out in the shelterbelt than in the field (Table 2).

Litter dwelling by invertebrate fauna was slow during the first 6 months. Biomass and the numbers of epigeic taxa increased quickly between the 6th and the 11th month of the experiment (Table 2 and Fig. 2). Average share of predators in the total biomass was high and ranged from 56% in F50 to 79% in E_F (Table 3). Spiders (12–58%), chilopods (4–34%) and carabids (0.4–27%) dominated there. From among other animals, dipteran larvae (0.3–23.0%) and adult beetles

other than Carabidae and Staphylinidae (11–24%) were the dominating taxa (Table 3).

Mass of non-living invertebrate matter comprised on average 24% of the total dead and alive matter within the transect after 11 months of the experiment (Table 4).

Differences between sites in animal biomass and density increased with time to become significant after 11 months of the experiment. Biomass of particular litter dwelling animal groups decreased significantly from the shelterbelt towards the field (Fig. 2). Dipteran larvae were the most numerous taxa recorded and their numbers were higher in the field (F_{50}) than in other sites by 6.4 times in average (Table 5).

Mean seasonal biomass of macrofauna and that of dead animals and spider cocoons in litter were respectively 3.5 and 4.3 times smaller far in the field (F_{50}) than in the wood strip (S) (Table 6).

The distance from the middle of the shelterbelt to the field was another measure, apart from differences in faunal biomass between sites, confirming the impact of shelterbelts on litter dwelling fauna. A great differentiation was found in spatial distribution of predatory animal biomass (Table 7). For example Carabidae and Chilopoda, in contrary to Araneae and Staphylinidae, inhabited litter with similar intensity regardless of the distance from the shelterbelt. Total mass of macrofauna and dead matter of invertebrate origin declined with the distance from the shelterbelt (Table 7).

A negative significant relationship was found between biomass and density of predators (Carabidae) and their prey (dipteran larvae, Collembola) within the transect (Figs 3, 4 and 5).

Laying litter out on the field significantly increased animal biomass in comparison with the surrounding soil and may enhance density of fauna in the habitat.

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Received after revising April 2003