

The Impact of Shelterbelts on Mulch Decomposition and Colonization by Fauna in Adjacent Fields

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1. Introduction

There is an increasing need of planting the strips of perennial habitats (shelterbelts, grass margins and others) into an agricultural landscape. Such strips play invaluable role in ecosystem functioning by reducing wind erosion, modifying climatic conditions, reducing eutrophication of ground waters and enhancing an organic matter content in the soil of adjacent arable fields etc. (Harper et al., 2005, Karg et al., 2003, Kostro-Chomać, 2003, Laurance et al., 2002, Prusinkiewicz et al., 1996). These changes are reflected also in the composition and abundance of the fauna (Bowen et al., 2007, Olechowicz, 2007, Szanser, 2003). The significance of relations between faunal and plant diversity, landscape structure and soil carbon dynamics is described in many studies (Dauber et al., 2003, Marshall et al., 2006).

The objective of this paper is to evaluate, in the field experiments, the effect of mid-field woody shelterbelts on litter decomposition rate and the numbers and biomass of litter and soil inhabiting macrofauna. Data concerning litter and soil fauna of the studied habitats are compared. The question was how far into the fields an effect of shelterbelts could reach.

2. Materials and methods

2.1 Study site and experimental design

The study was carried out in village of Turew, west Poland (16°45' to 16° 50' E and 52° 00' to 52° 06' N). In the study region, prevail Glosoboric 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.

The experiments were performed along the transect of the forest strip planted in 1993 (S), in the ecotone (E) and in the field 10 (F 10 - 15) and 50 (F 50) meters far from the tree line in 1999-2000 (I experiment) and 2003-2004 (II experiment). In the second experiment additional studies were performed in the control field (CF 50) located in deforested area. During the study time barley and wheat were cropped on field adjacent to strip and wheat and barley on field in deforested area(control field). Mulch was obtained from

grass cocksfoot (*Dactylis glomerata*) cut in autumn in every year of the study time which had to simulate the input of decaying plants to soil. Grass litter was laid out on a uniform, poor in organic matter substrate (sand mixed with clay) (I experiment) or on soil (II experiment) in each study site. Grass was placed in modified litterbags (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, 2000, 2003).

2.2 Sample collecting and processing

Samples of litter (I and II experiment) and soil underlying it (II experiment) from the middle of a wood strip (S) and along the ecotone and field transect were taken on 26 September and 21 October 2004 after 11 months of litter exposure in I and II experiments, respectively (Table 1). Analyses from earlier studies revealed that macrofauna colonized litter intensively in later stages of its decomposition so only data for 11th months since litter exposure are compared (Szanser, 2003, unpubl.).

	I Experiment	II Experiment
Soil	Introduced sandy substrate	Local soil
Time of sampling since litter exposure	11 months	11 months
Sites along transect	Shelterbelt - S	Shelterbelt - S
	Ecotone at shelterbelt edge - Es ¹	Ecotone - E
	Ecotone at field edge - Ef ¹	Field 15m since ecotone - F 15 ²
	Field 10m since ecotone - F 10 ²	Field 50m since ecotone - F 50
Field in deforested area	-	CF 50
	Parameters analysed	
Litter decomposition		
Faunal composition and biomass	+	+
Mass of invertebrate remnants	+	+

1 - values obtained from Es and Ef sites were recalculated as a mean for comparing to data from E in II experiment.

2 - values obtained from F 10 and F 15 sites compared between I and II experiment.

Table 1. Experimental design and parameters analysed. Treatments applied: S - forest strip, E - ecotone, F 10 - field 10 m from the strip, F 15 - field 15 m from the strip, F 50 - field 50 m from the strip, CF 50 - Control field 50 m not surrounded by the forest strip.

8 - 14 litter and soil samples were taken from every treatment on each sampling occasions. Soil samples for assessments of invertebrate organic matter input and macrofauna biomass were taken to the depth of 0-1 and 0-10 cm, respectively with a soil corer 100 cm² in area.

2.3 Plant and invertebrate materials

2.3.1 Litter mass loss

Litter mass was dried at 65°C before the weight loss was determined using the gravimetric method.

2.3.2 Macro- and microarthropod collection

Temperature gradient Thompson, Kempson, Lloyd and Gheraldi's apparatus was used for extraction of macro- and microarthropod fauna (Górny & Grüm, 1993).

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).

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

2.3.3 Input of invertebrate remnants into litter and underlying substrate.

The input of the remnants of invertebrate origin (exuviae, cocoons, other remnants) was assessed in the litter and soil samples underneath the litter by hand-sorting and using the stereoscope microscopy.

2.4 Statistical analysis

Statistical analyses of results (one-way ANOVA and regression) were performed using Statistica 8.0. software (StatSoft, Inc. (2007). Differences in the biomass of animals and their remnants were analysed using multivariate ANOVA, the Tukey's test at $P < 0.05$. Relationships between the biomass of fauna and the distance from the shelterbelt and between predators and prey were tested by the correlation significance with ANOVA.

3. Results

3.1 litter decomposition

The amounts of litter decomposed during the study periods varied. In average 48.2 and 63.1% of the exposed litter decomposed during 11 months in I and II experiments, respectively along the study transect. Litter decomposition rate along the transect forest-ecotone-centre of the field proceeded differently in both experiments. Remaining mass of the litter was similar in the ecotone (E) after 11 months in both experiments while it was significantly lower in the strip (S) and field (F 10-15 and F 50) at the end of II comparing to I experiment (Table 2). Interestingly grass litter decomposed differently in the fields comparing to strip and ecotone sites in every experiment. Significantly greater by 23.4% amounts of decomposing litter were left in the field comparing to strip and ecotone during the I experiment. On the other side significantly smaller by 19.8% mass of remaining litter was left in the field comparing to strip and ecotone during the II experiment. The mass of remaining litter in the centre of the control field located in deforested area was similar as in

the field adjacent to forest strip in the II experiment (Table 2). Obtained data show that the litter decomposition does not depend on the location in the transect.

	S	E	F 10-15	F 50	F C
I experiment ¹	465.8 ^a (22.19)	458.1 ^a (24.79)	540.3 ^b (23.75)	599.7 ^b (16.88)	n.a. ²
II experiment	387.61 ^a (23.36)	428.78 ^a (14.79)	339.02 ^b (32.14)	310.19 ^b (23.45)	308.76 ^b (18.52)
Ratio II/I	0.83 n = 20, F = 4.648 P < 0.045	0.94 n = 20, F = 1.121 P < 0.286	0.63 n = 18, F = 21.225 P < 0.0003	0.52 n = 19, F = 87.151 P < 0.0000000	-

1 - modified after Szanser 2003

2 - not analysed

Table 2. Mass of remaining litter (g dry weight m⁻²) after 11 months of its exposure in I and II experiment and relation between both experiments. Sites as in Table 1. Different letters denote significant differences between experimental treatments at $P < 0.05$ (Tukey's test) for $n = 8-10$. SE - standard error in parentheses.

3.2 Macrofauna biomass

Significant decrease of the macrofauna biomass in the litter along the transect from strip to the field was observed during the I experiment while this trend was not significant in the II experiment. The ratio of macrofaunal biomass in strip and ecotone to the field was 3.98 and 1.63 respectively in I and II experiments (Table 3). Lower was the biomass of litter dwelling macrofauna in the middle of field located in deforested area comparing to the field adjacent to forest strip being respectively 0.564 and 0.733 g dry weight m⁻² but the difference was not significant (Table 4).

Macrofauna group	Mass ratio: S, E / F 10-15, F 50 and significance of differences
	I experiment ¹
Total biomass	3.98 P < 0.00000, F = 53.49
Nonpredatory biomass	6.19 P < 0.04, F = 4.616
Predatory biomass	1.41 P < 0.001, F = 17.15
	II experiment
Total biomass	1.63 P < 0.327, F = 0.986
Nonpredatory biomass	3.76 P < 0.199, F = 1.709
Predatory biomass	1.01 P < 0.987, F = 0.00

1 - modified after Szanser 2003

Table 3. Biomass ratio of macrofaunal groups (S, E/F 10-15, F 50) after 11 months of the I and II experiments ($n = 40$) assessed by ANOVA. Sites as in Table 1.

There were no differences in predatory biomass between strip - ecotone and field being similar for both group of sites: 0.538 and 0.542 g dry weight m⁻² during the II experiment contrary to the findings in I experiment (Table 4, Szanser 2003).

There was significantly lower by 9.6 time ($P < 0.04$) predatory biomass in the litter on the field in deforested area comparing to the centre of field adjacent to strip during the II experiment (Table 4).

	S	E	F 10	F 50	F C
I experiment ¹					
Total biomass	3.596 ^a (0.50)	2.637 ^a (0.30)	0.785 ^b (0.13)	0.782 ^b (0.14)	n.a.
Nonpredatory biomass	1.221 ^a (0.34)	1.014 ^a (0.31)	0.100 ^b (0.03)	0.262 ^b (0.07)	n.a.
Predatory biomass	2.375 ^a (0.35)	1.623 ^a (0.13)	0.686 ^b (0.13)	0.520 ^b (0.14)	n.a.
II experiment					
Total biomass	2.058 ^a (0.79)	0.582 ^b (0.21)	0.930 ^b (0.40)	0.733 ^b (0.20)	0.564 ^b (0.31)
Nonpredatory biomass	1.214 ^a (0.75)	0.161 ^b (0.08)	0.113 ^b (0.07)	0.258 ^b (0.08)	0.514 ^b (0.32)
Predatory biomass	0.824 ^a (0.20)	0.259 ^b (0.12)	0.601 ^b (0.34)	0.475 ^b (0.18)	0.05 ^c (0.03)
Ratio 2004/2000 total biomass	0.57	0.22	1.19	0.94	-
Nonpredatory biomass	0.99	0.16	1.13	0.98	-
Predatory biomass	0.35	0.16	0.88	0.91	-

1 - modified after Szanser 2003

Table 4. Macrofauna biomass (g dry weight m⁻²) in litter after 11 months of I and II experiments. Sites as in Table 1. Different letters denote significant differences between experimental treatments at $P < 0.05$ (Tukey's test) for $n = 8-10$. SE - standard error in parentheses.

The nonpredatory biomass was by 3.8 times lower on field comparing to strip and ecotone but the difference was not significant. Similarly there was no difference in nonpredatory biomass between fields in deforested area and adjacent to strip belt.

The negative correlation between the biomass of predators and non-predators dwelling the litter along the transect from strip to the centre of the field was observed in both experiments. It was only significant for carabids and their prey; collembolans and dipteran larvae during the I experiment (Szanser 2003) while between the total predatory and nonpredatory biomass ($r = -0.843$, $P < 0.01$) for all treatments including field in deforested area during the II experiment.

Differences between treatments in faunal biomass were greater in the soil underlying exposed litter than in the litter itself. Significantly by 4.3 and 5.7 times higher was the fauna

biomass in strip comparing to ecotone (and adjacent field (Table 5). There were no significant differences in faunal biomass either between ecotone and field and between F 10 and F 50 sites. Interestingly, significantly lower by 5.0 times was the fauna biomass in soil of the field located in deforested area comparing to the field adjacent to forest strip (Table 5).

	S	E	F 10-15	F 50	F C
II experiment	2.063 ^a (0.51)	0.475 ^b (0.25)	0.367 ^b (0.11)	0.360 ^b (0.12)	0.072 ^c (0.04)

Table 5. Macrofauna biomass (g dry weight m⁻²) in soil layer 0-10cm under the litter after 11 months of II experiment. Sites as in Table 1. Different letters denote significant differences between experimental treatments at $P < 0.05$ (Tukey's test) for $n = 8-10$. SE - standard error in parentheses.

The experiment revealed significant predator-prey relationships within the transect. It may be concluded that the presence of shelterbelts adjacent to field leads to the increase of macrofaunal biomass comparing to the field not surrounded by strip. The stimulating effect of mulching on faunal biomass was clearly seen mainly in the litter along the transect with strip comparing to the field without strip area. Soil under the litter in ecotone and fields was colonized to much lesser extent comparing to litter.

3.3 Input of invertebrate remnants

Input of dead invertebrate mass to the litter and soil under litter decreased significantly from the shelterbelt towards the field center in both experiments. The correlations between dead invertebrate mass and distance from the centre of the strip to field were found to be $r = -0.425$, $P < 0.0021$ (Szanser 2003) and $r = -0.907$, $P < 0.05$, respectively in I and II experiment. There were no differences in remaining mass of invertebrate remnants in forest strips and ecotones between two experiments. On the opposite there was considerably smaller amount of invertebrate remnants on fields during the II experiment comparing to I (Table 6). Input of invertebrate remnants into the litter and soil under litter was lower in deforested area comparing to the field adjacent to forest strip, but the differences between treatments were not significant (Table 6).

Input of animals remains into the soil can be quite high and reflects the fauna ability to penetrate the fields.

	S	E	F 10-15	F 50	F C
I experiment ¹	0.859 ^a (0.39)	0.462 ^a (0.33)	0.302 ^a (0.26)	0.183 ^a (0.13)	-
II experiment	1.04 ^a (0.55)	0.893 ^a (0.42)	0.234 ^a (0.2)	0.049 ^a (0.02)	0.037 ^a (0.01)
Ratio II/I	1.21	1.93	0.73	0.27	-

1 - modified after Szanser 2003

Table 6. Invertebrate matter mass (g dry weight m⁻²) in litter after 11 months of I and II experiments. Sites as in Table 1. Differences between experimental treatments tested at $P < 0.05$ (Tukey's test) for $n = 11-14$. SE - standard error in parentheses.

4. Discussion

The grass litter decomposition was different in the fields during two experiments while it proceeded similarly in the ecotone area though considerably greater in average litter mass loss was observed during II comparing to I experiment. Decomposition of forest litter placed along the studied transect proceeded faster on field comparing to forest and ecotone sites but the litter was exposed only for a few weeks (Bernacki unpubl.) comparing to the long-term grass decomposition in presented study. On the other side slower decomposition processes in field comparing to forest and ecotone transect were found for buried litter samples (Bernacki 1994). Differences in litter decomposition in fields could not be attributed to temperature and soil water content changes (Bernacki unpubl.). Mean precipitation did not differ between study periods being 607 and 616 mm for I and II experiment, respectively (after Bernacki, unpubl.). The differences between both experiments could arise from different substrata underlying the exposed litter as sandy-clay poor in organic matter substrate and natural soil were used in I and II experiment, respectively. Litter placed on poor uniform sandy-clay substrate decompose slower comparing to litter on natural soil (Szanser and Bogdanowicz 1997). It also seems that the differences in crop chemical composition being different during consecutive seasons might influence the process of mulch litter decomposition. Barley and wheat were cultivated during the I and II experiments, respectively. Chemical composition of crop biomass impacts its decomposition and carbon sequestration (Johnson et al., 2007, Wang et al., 2004). Use of fertilizers and herbicides might determine the way of litter disappearance processes in studied fields (Szanser 2003). It may be concluded from these statements that the presence of forest strip did not influence the litter decomposition in fields.

Mean mass of macroarthropods in exposed litter was higher than that found in soil and turf in the same site (Olechowicz 2004a,b, 2007). The differences between biomass of aboveground dwelling fauna along the studied transect and in the experimental mulch in my experiments were of 8 and 2 times respectively during the I experiment and 127 and 3.5 times during the II experiment. Lower predatory biomass data for control field than in site adjacent to forest belt are corroborated by lower average body mass, mean patrolling intensity and diversity index of spiders in the same studied field in deforested area comparing to fields adjacent to forest belts (Kajak 2007). It is known that introduction of semi-natural habitats into arable fields enhances the development of predatory arthropods' assemblages in these fields (Asteraki *et al.*, 2002, Marshall & Mooney 2002, Marshall *et al.*, 2006, Ryszkowski *et al.*, 1993, Schmidt & Tschardt 2005).

It seems that the applied litter stimulated the number of animals. Dwelling the exposed litter seemed to reflect not only the numbers of animals in the environments but was the indicator of fauna ability to disperse from forest to the field. The lack of correlation between the mass of remaining litter and either fauna biomass and mass of invertebrate remnants was found in both experiments. This finding implies that the main reason for colonizing the exposed mulch by fauna was not searching for food resources but rather for shelters.

It must be pointed out that longtime field experiments show the effects of processes which confirm that colonization of area without strips was not so intensive as in the case of field with adjacent strip. Thus then introduced habitats of permanent vegetation are the reservoirs of fauna enabling it to colonize adjacent fields to far distances. The experimental

studies indicated that establishment of strips margins in arable fields may enhance ecosystem services.

5. Conclusions

In general the results suggest that (1) the decomposition rate of grass litter proceeded similarly in the forest strip and its ecotone zone as in the fields, so the presence of forest strip did not influence mulch decomposition in the fields. It can be concluded basing on the comparison of the data of two experiments and on the comparison of the field located in deforested area and the field adjacent to the forest strip; (2) the biomass of macrofauna in the soil under the introduced litter was lower in deforested area than in the field adjacent to forest strip; (3) also the biomass of predators colonizing the introduced litter was clearly lower in the field in deforested area comparing to the field adjacent to the strip; (4) input of invertebrate remnants into the litter and soil under litter was lower in deforested area comparing to the field adjacent to forest strip but differences were not significant.

6. Acknowledgments

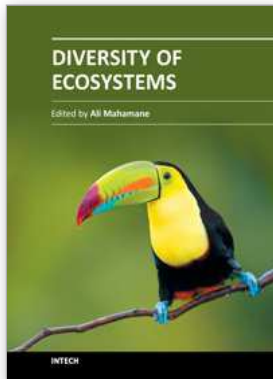
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Diversity of Ecosystems

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The ecosystems present a great diversity worldwide and use various functionalities according to ecologic regions. In this new context of variability and climatic changes, these ecosystems undergo notable modifications amplified by domestic uses of which it was subjected to. Indeed the ecosystems render diverse services to humanity from their composition and structure but the tolerable levels are unknown. The preservation of these ecosystemic services needs a clear understanding of their complexity. The role of research is not only to characterise the ecosystems but also to clearly define the tolerable usage levels. Their characterisation proves to be important not only for the local populations that use it but also for the conservation of biodiversity. Hence, the measurement, management and protection of ecosystems need innovative and diverse methods. For all these reasons, the aim of this book is to bring out a general view on the function of ecosystems, modelling, sampling strategies, invading species, the response of organisms to modifications, the carbon dynamics, the mathematical models and theories that can be applied in diverse conditions.

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