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SOIL MESOFAUNA (ACARINA AND COLLEMBOLA) ALONG TRANSECTS CROSSED SHELTERBELTS OF DIFFERENT AGE AND ADJACENT FIELDS

ABSTRACT: The communities of soil mesofauna were studied in the year 2004 along three transects crossed shelterbelts of different age (6, 11 and 170 years old) and adjacent wheat fields at a distance of 0.5, 15 and 50 m. Studies were carried out in the Gen. D. Chłapowski Landscape Park near Turew, Western Poland ($16^0$45'E, $52^0$01'W). The age of shelterbelts vegetation affected soil mesofauna of adjacent fields in a diverse way. The mean density of mites amounts 7.4×10^3ind. m^{-2} and 2.6×10^3 ind. m^{-2} respectively for the shelterbelts and fields. Densities of Acarina communities were affected not only by the presence of a shelterbelt (P = 0.000) but also its age (P = 0.02) and the distance from it (P = 0.000), and these effects were similar in spring and autumn (P = 0.08). The mean density of springtail noted in shelterbelts of different age was 2.0×10^3 ind. m^{-2} and in the field sites 2.2×10^3 ind. m^{-2}. Although the effect of the shelterbelts' age on the density of Collembola was not found (P = 0.3), the densities were different in shelterbelts and in adjacent fields (P = 0.006) but statistical significance was found only between spring and autumn (P = 0.000). The distance from the shelterbelt influenced (though less intensely) the density of Collembola on adjacent field (P = 0.01). Eighteen species of Collembola were found in studied shelterbelts and fields.

Isotoma notabilis Schäff. usually dominated in shelterbelts. Its contribution to abundance of communities varied depending on the age of shelterbelts (in 6 years old shelterbelt it constituted as many as 71% of the whole community). In 11 years old shelterbelt *Schoetella ununguiculata* (Tullb.), was more common than *Isotoma notabilis* Schäff. and in the 170 years old shelterbelt the dominant species was *Onychiurus armatus* (Tullb.). *Friesea mirabilis* (Tullb.), *Proisotoma minuta* (Tullb.), *Isotoma notabilis* or *Onychiurus armatus* dominated in adjacent fields though their contribution was depended on shelterbelt's age and on the distance from it.

KEY WORDS: Collembola, Acarina, shelterbelts of different age, species diversity

1. INTRODUCTION

The role and functioning of midfield shelterbelts in agricultural landscape have been the object of studies for the last several dozen years. Midfield woodlots affect water balance and wind shields, decrease soil erosion and increase biodiversity in agricultural landscapes (Altieri 1999, Banaszak 2000, Karg *et al.* 2003, Riksen *et al.* 2003). Already 3–4 years old woodlots have been shown to restrict soil erosion and to improve water cycling (Karg *et al.* 2003). Midfield shelterbelts are the refuges for many organisms and enable them to colonise or intensively penetrate cultivated croplands (Marshal and

Arnold 1995, Altieri 1999, Alvarez *et al.* 2000). The importance of midfield shelterbelts for soil organisms, particularly for soil mesofauna including the communities of Collembola, is still poorly understood (Alvarez *et al.* 2000), in spite of the role these organisms play in mineralization and humification of organic matter (Coleman 1985, Huhta *et al.* 1988, Czarnecki 1989, Striganowa 1992). Moreover, they are considered as the indicator organisms in studies of soil quality (Heisler 1995, Kopeszki 1997). Presented results are part of the long term multidisciplinary studies carried out in agricultural landscape crossed by wood belts (Ryszkowski 1998). Previous studies (Olej niczak 2004) proved the influence of shelterbelts on densities and species composition of mesofauna communities: Collembola and Acarina in adjacent fields. Although the results suggested that mesofauna, especially Collembola could disperse from shelterbelts to the adjacent fields, the knowledge of the influence of the shelterbelt age on mesofauna is still scarce.

The aim of presented study was the estimating whether and how the age of a shelterbelt might affect densities of soil mesofauna and species composition of Collembola in adjacent fields and to what degree the age of the shelterbelt vegetation might affect the biodiversity of agricultural landscapes.

2. STUDY AREA AND METHODS

Studies were carried out in the Gen. D. Chłapowski Landscape Park near Turew in Western Poland (16^{0}45'E, 52^{0}01'W) (Ryszkowski 1998). Forests in the area are very fragmented. Their functions had to be taken over by midfield shelterbelts (Ryszkowski 1998). In the agricultural landscape near Turew belts of woods were planted already 200 years ago (Bałazy *et al.* 1998). Existing network of shelterbelts is protected and successively supplemented (since 1993 1–4 new belts have been planted every year) (Karg 1998, Ryszkowski 1998, Ryszkowski *et al.* 2003). Oak is the basic tree species in new plantings; in the past oak forests dominated in the area (Ryszkowski *et al.* 2003). It was accompanied by birch, elm, beech, larch, linden, spruce and pine. Shrubs like rose, currant, spindle tree and hawthorn were planted together with trees (Ryszkowski *et al.* 2003). Changes in species composition of plants, particularly in the undergrowth, were observed with time (Ryszkowski *et al.* 2003).

Studies were carried out in three shelterbelts of different age: 6 (S6), 11 (S11) and 170 (S170) years old and in easterly adjacent fields. The first two, 18 m wide belts – length 2000 m and 400 m respectively, were planted in 1998 and 1993 (Ryszkowski *et al.* 2003). In these two shelterbelts trees were planted in 11 rows. Oak, larch, poplar and pine dominated tree stands in both shelterbelts. Species composition of the undergrowth underwent rapid changes in subsequent years (Ryszkowski *et al.* 2003). The oldest, about 20 m wide and over 2000 m lenght, 170 years old shelterbelt (S170) was built mainly of locust accompanied by elder and hawthorn. Undergrowth was dominated by grasses, mainly by couch grass (Ryszkowski *et al.* 2003). Easterly adjacent fields were sown with wheat.

Both shelterbelts and fields were situated on light loamy soils (Ryszkowski *et al.* 2003) of pH_{KCl} varying from 3.6 to 6.5. Most acidic (pH in KCl = 3.64) was the soil in the oldest shelterbelt (Bernacki unpublished data). The content of organic matter in soil decreased with the distance from the shelterbelt (data of the Department of Agricultural and Forest Environment Polish Academy of Sciences in Turew) (Fig. 1A).

During the study period (April-October 2004) the most intensive rainfalls were noted in May and August (Fig. 1B). The highest air temperatures 0.5 m above ground, at the ground and 10 cm beneath were noted in August i.e. in the period of most intense atmospheric precipitation (Fig. 1C).

Samples were collected in the year 2004 twice: in April and October i.e. in the beginning of the crop growth and after harvest. Soil samples were collected in the central part of shelterbelts and in adjacent fields 0.5 m, 15 m and 50 m from the shelterbelt's edge. On every sampling occasion 10 soil samples of an area of 10 cm^2 and a depth of 10 cm were taken every 2 m. In total 240 samples were collected.

Collembola were chased out from soil samples in the Tullgren's apparatus (Kacz-

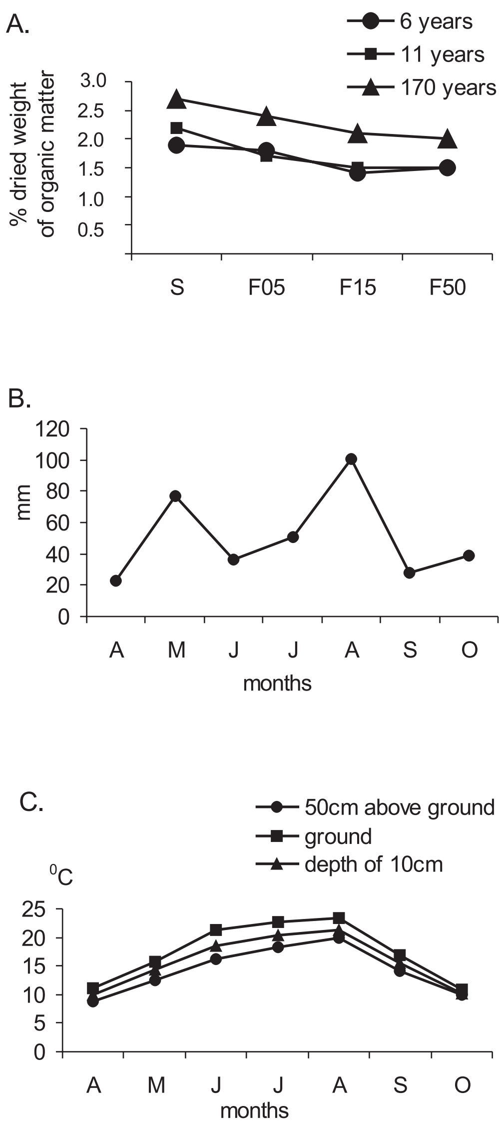

Fig. 1. A – Content of organic matter (% of dried mass of organic matter) in arable soils of investigation plots B – Monthly rainfall during season of investigation, C – Mean monthly temperatures: 50 cm above ground, a the ground and at a depth of 10cm, during season of investigation (all data of Department of Agricultural and Forest Environment Polish Academy of Sciences).

marek 1981) and determined to species using the keys by Stach (1955), Gisin (1960) and Rusek (1982). Non-parametric Wilcoxon's test of rank for pairs and Kruskall-Wallis non-parametric analysis of variance were used in statistical data processing since the data were not normally distributed even after log transformation.

Species diversity of Collembola communities was calculated with the Shannon-Wiener index (H') using logarithms at a base of 2 (Shannon and Wiener 1963). Total numbers of Collembola caught in spring and autumn were used in calculation. Hutcheson's (1970) test was used to check statistical significance of differences in the H' index. Species similarity (s) of the Collembola communities was calculated with the formula of Marczewski and Steinhaus (1959),

$$s = \frac{w}{a+b-w} \qquad (1)$$

where a – is the number of individuals of a given species in the community A, b – is the number of individuals of given species in the community B, and w – is the number of individuals of common species for the communities A and B.

Three groups of insects were distinguished in the communities of Collembola due to their preference to particular soil layer using Christiansen's (1964) division into epigeon – species occurring on the surface of soil and plants, hemiedaphon – species dwelling the litter and upper soil layer and euedaphon – species inhabiting the deeper layer of soil.

3. RESULTS

The age of shelterbelts affected soil mesofauna from adjacent fields in a different way. The density of Acarina depended on the presence of a shelterbelt (Kruskall-Wallis test, $P = 0.000$) but also on the distance from it ($P = 0.000$). Impact of shelterbelts on mites communities was independent from the period of investigations ($P = 0.08$).

The density of Acarina was usually higher in the autumn than in the spring, only in 170 years old shelterbelt (S170) and in adjacent field no significant seasonal difference was found. The density of Acarina usually decreased with the distance from shelterbelt which was particularly visible in 11 years old shelterbelt (S11) and its adjacent field (Fig. 2). In both spring and autumn periods markedly higher densities were found there in the shelterbelt than in the field (Wilcoxon's test for spring: $P = 0.005$, 0.005 and 0.01 and for autumn: $P = 0.015$, 0.01 and 0.015 for distances

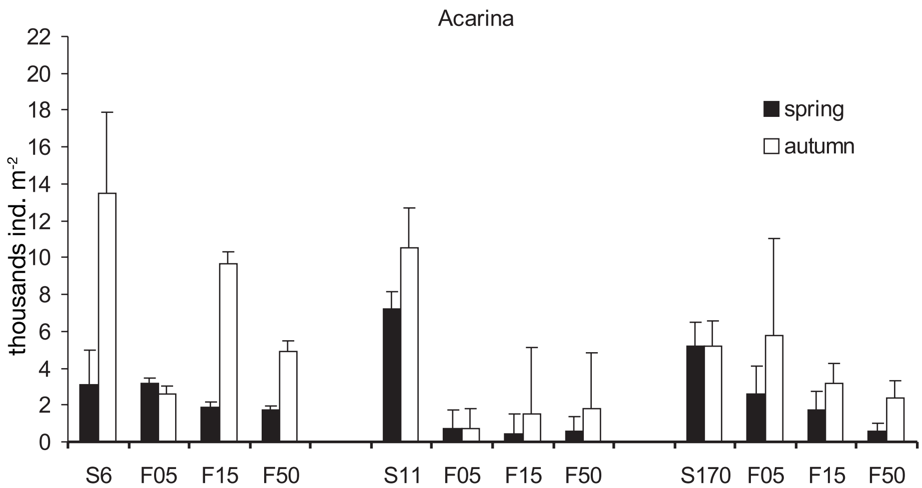

Fig. 2. Densities of mite communities in shelterbelts of different ages (S6 – 6 years shelterbelt, S11 – 11 years shelterbelt, S170 – 170 years shelterbelt) and adjacent fields (F05 – 0.5 m from the shelterbelt, F15 – 15 m from the shelterbelt, F50 – 50 m from the shelterbelt) in spring and autumn. Vertical bars represents S.E.

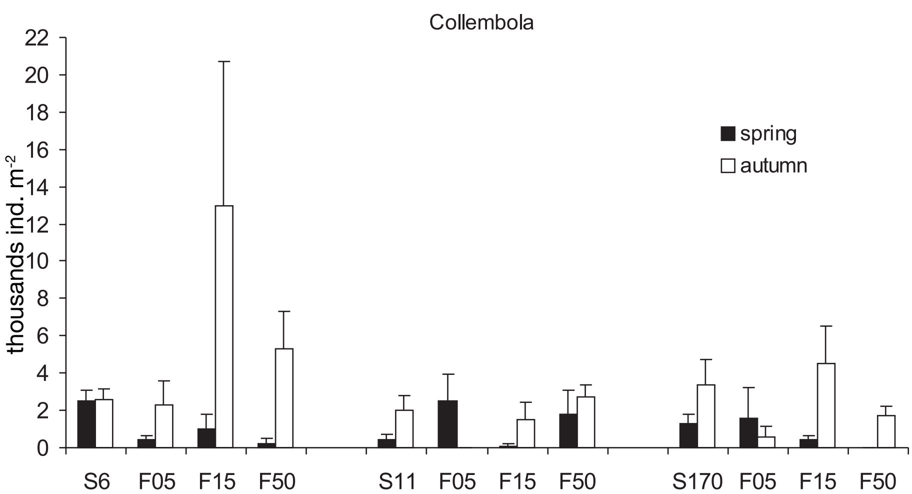

Fig. 3. Densities of collembolan communities in shelterbelts of different ages (S6, S11, S170) and adjacent fields (F05, F15 , F50) in spring and autumn. See Fig 2. for explanation.

of 0.5 m, 15 m and 50 m, respectively). These differences were not so distinct in 6 (S6) and 170 (S170) years old shelterbelts and their adjacent fields (Fig. 2) though in the autumn the density of mites was smaller in the field 50 m (F50) apart from the shelterbelt than in the shelterbelt itself (P = 0.005 and 0.01 for 6 (S6) and 170 (S170) years old shelterbelt, respectively). In spring, similar relationship was found only in 170 years old shelterbelt (S170) (P = 0.01) (Fig. 2).

The effect of shelterbelts' age on the density of Collembola was not confirmed (Kruskall-Wallis test, P = 0.3), different densities of these insects were, however, noted in shelterbelts and in adjacent fields (Kruskall-Wallis test, P = 0.006). Season was extremely important for densities of Collembola (spring – summer, P = 0.000). The density was also affected by the distance from shelterbelts though the impact was less significant (P = 0.006).

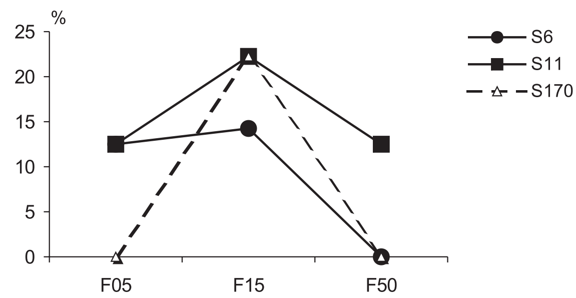

Fig. 4. Species similarity (% value of Marczewski and Steinhaus 1959 index for total individuals) of Collembola between communities in shelterbelts of different ages (S6 , S11, S170) and adjacent fields (F05, F15, F50). See Fig 2. for explanation.

Some tendencies were found for insect densities in shelterbelts and in adjacent fields. In spring the densities of Collembola were significantly higher (Wilcoxon's test, P= 0.05) in 6 and 170 years old shelterbelts than in adjacent fields 50 m apart while in 11 years old shelterbelt they were lower (Wilcoxon's test, P = 0.05) (Fig. 3). In autumn the densities of Collembola were lower in 6 and 170 years old shelterbelt (S170) than in adjacent fields 15 m (F15) and 50 m (F50) apart (P = 0.05) (Fig. 3) and the greatest differences were found between 6 years old shelterbelt and the field 15 m (F15) apart (Fig. 3).

Eighteen species of Collembola were recorded in collected samples, most of them (9) were found in 170 years old shelterbelt (Table 1).

Species similarity of springtail communities in studied shelterbelts decreased with increasing age difference being the lowest between the communities of 6 (S6) and 170 (S170) years old shelterbelts (8%) and the highest between the communities of 6 (S6) and 11 (S11) years old shelterbelts (37%). While the species similarity of collembolan communities of 11 (S11) and 170 (S170) years old shelterbelts was 23%.

Irrespective of shelterbelt's age, the species similarity of communities of Collembola was smaller than for adjacent fields. The communities from sites situated 15 m (F15) from the shelterbelt appeared the most similar (Fig. 4).

Isotoma notabilis was usually the dominating species in shelterbelts though its contribution varied depending on age (in 6 years old shelterbelt it constituted as many as 71% of the whole community – Table 1). *Schoetella ununguiculata* was more numerous than *Isotoma notabilis* in 11 years old shelterbelt (S11) and *Onychiurus armatus* dominated 170 years old shelterbelt (S170) (Table 1). *Friesea mirabilis*, *Proisotoma minuta, Isotoma notabilis* or *Onychiurus armatus* usually dominated in adjacent fields but it depended on shelterbelt's age and on the distance from the belt (Table 1)

Species diversity of collembolan communities measured with the H' index showed an interesting pattern in both shelterbelts of different age and in adjacent fields. In 6 years old shelterbelt springtail communities showed similar or smaller species diversity than those in adjacent fields (Fig. 5). Older shelterbelts demonstrated higher species diversity of springtail communities than the neighbouring fields (Fig. 5).

The species of Collembola belonged to very common ones. Hemiedaphic species were prevailing (Fig. 6 A, B and C). The contribution of other groups, especially among field springtail communities, was rather accidental (Fig. 6 A, B and C). Nevertheless, euedaphic species dominated in field sites 15 m (F15) from the oldest shelterbelt while the same sites adjacent to 6 (S6) and 11 (S11) years old shelterbelts were inhabited exclusively by the species belonging to hemiedaphon. The presence of euedaphic and epigeic species in the field 50 m (F50) from shelterbelts was noted only near 6 (S6) and

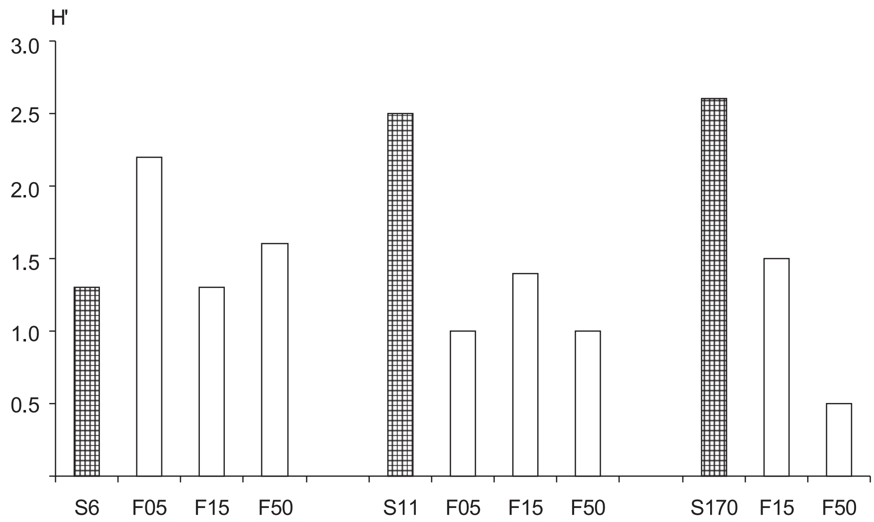

Fig. 5. Diversity of collembolan communities expressed as the Shannon-Wiener H' index values in shelterbelts of different ages (S6, S11, S170) and adjacent field (F05, F15, F50). See Fig 2. for explanation.

Table 1. Domination structure (% of the total numbers of individuals) among Collembola in shelterbelts of different ages (S6 – 6 years old shelterbelt, S11 – 11 years old shelterbelt, S170 – 170 years old shelterbelt) and adjacent fields (F05 – 0.5 m from the shelterbelt, F15 – 15 m from the shelterbelt, F50 – 50 m from the shelterbelt).

Species	S6	F05	F15	F50	S11	F05	F15	F50	S170	F15	F50
Cryptopygus bipunctatus Axels.									2		
Entomobrya corticalis (Nic.)				14							
Entomobrya quinquelineata Börn.									6		
Entomobryidae	7										
Friesea mirabilis (Tullb.)	15	27	64		16		65	57		19	13
Isotoma notabilis Schäff.	71			40	19				21		
Isotoma viridis Bourl.					3						
Isotomiella minor (Schäff.)									4		
Isotomina thermophila (Axels.)		28	3				14		18	13	
Mesaphorura macrochaeta Rusek		18		3	27				2		
Neanura muscorum (Templ.)					3						
Onychiurus armatus (Tullb.)								43	30	62	
Orchesella cincta (L.)									2		
Proisotoma minuta (Tullb.)		9	25	43		40	17				87
Pseudosinella asigillata (Börn.)		18								6	
Schetella ununguiculata (Tullb.)			8		22	60	4				
Sinella curviseta Brook.									15		
Sminthurus viridis (L.)	7										
Stenophorura quadrispina Börn.					10						

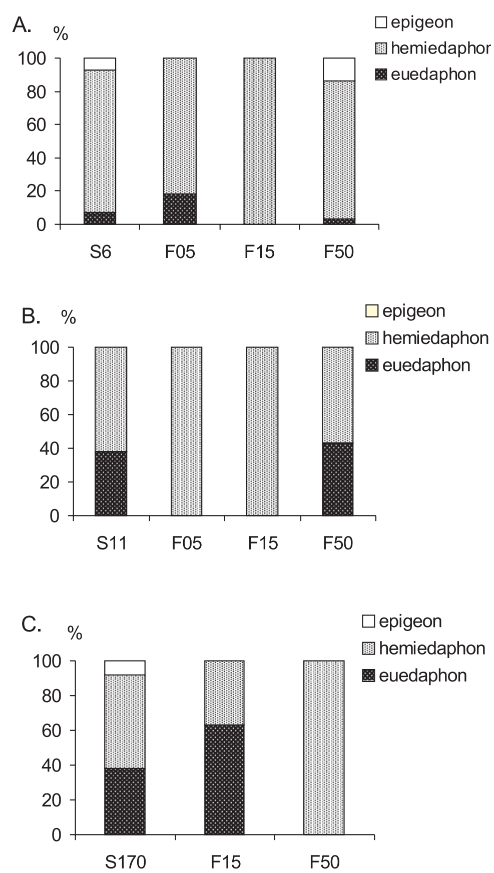

Fig. 6. Proportion (% of total numbers of individuals) of ecological groups of Collembola in shelterbelts of different ages (S6, S11, S170) and adjacent field (F05 , F15, F50). See Fig 2. for explanation.

11 (S11) years old shelterbelts. In the latter case euedaphic species constituted 43% of the whole community (Fig. 6 B).

4. DISCUSSION

Densities of soil mesofauna in studied shelterbelts and in neighbouring fields did not differ from those noted by other authors. During earlier studies in the same area Wasylik (1975) estimated mean density of Acarina at 10×10^3 ind. m^{-2} and Czarnecki (1989) who compared various crops found the mean densities close to 26×10^3 ind. m^{-2}. Olejniczak (2004) in the same area recorded the densities of invertebrates varying from 2800 to 4400 individuals per m^2 thus similar to those obtained in the present study (mean density of Acarina in field sites was 2.6×10^3 ind. m^{-2}). Densities of Acarina found in shelterbelts of different age were 7.4×10^3 ind. m^{-2} on average being lower than those found in 7 years old (now 11 years old) shelterbelt where the mean density was 13.1×10^3 ind. m^{-2} (Olejniczak 2004).

During the studies carried out in 7 years old (now 11 years old) shelterbelt Olejniczak (2004) recorded mean density of springtails equal 18.4×10^3 ind. m^{-2}. Czarnecki (1989) in the same area in a 5 years old pine forest found mean density of Collembola varying from 11×10^3 ind. m^{-2} to 30×10^3 ind. m^{-2}. However, springtail density noted in shelterbelts of different age was 2×10^3 ind. m^{-2} so markedly lower than those found earlier by cited authors. It seems that differences could result from habitat conditions, mainly from differences in moisture, to which Collembola are particularly sensitive (Christiansen 1964, Czarnecki 1989, Olejniczak 2000). There are usually two peaks of the density of springtails – in spring and autumn, the periods of high humidity and relatively low temperatures (e.g. Takeda 1979, Huhta and Mikkonen 1982). In earlier studies in the same area Olejniczak (2004) also found such two peaks in the density of Collembola distinctly associated with moisture and temperature. During present studies in the spring – the period of one such peak – only small atmospheric precipitation was noted (Fig. 1). Therefore, small rainfall and consequently small soil and litter moisture were probably the reason for small densities of springtails (Fig. 3).

Though the densities of Collembola in agrocoenoses might be similar or only slightly lower than in the natural ecosystems on the same type of soil (Czarnecki 1989), due to intensive agrotechnical measures and monocultural crops they are usually much lower (Edwards and Lofty 1975, Rusek 1998). The density of Collembola found in various crops by Czarnecki (1989) varied from 5×10^3 ind. m^{-2} to 41×10^3 ind. m^{-2}. Olejniczak (2004) found mean densities of springtails between 5.6×10^3 ind. m^{-2} and 7.1×10^3 ind. m^{-2} for the same area as in present study. Mean density of springtails (4.4×10^3 ind. m^{-2}) noted in this study was close to minimum densities reported by cited authors.

Decreasing density with increasing distance from shelterbelts was noted for Acarina. Similar relationship was found by Reddersen (1997) and Olejniczak (2004). This was not true for Collembola in the present study. It was found that their density in the field 15 m from the shelterbelt was close to or even higher than in the shelterbelt as was in the case of the field adjoining 6 years old woodlot. The phenomenon might be explained by moisture conditions within the shelterbelt and in the field and by the range of falling leaves i.e. by the availability of organic matter (Bernacki unpublished.). The factors like moisture, temperature, soil pH and food resources are known to affect the density of springtails (Altieri 1999, Chagnon *et al.* 2000, Olejniczak 2000, Hasegawa 2001).

Several reasons might explain a lack of a distinct effect of shelterbelt's age on the density of Collembola found in the presented results. One of them is the cluster distribution of springtails (Hasegawa 2001). The importance of succession should also not be neglected. Young shelterbelts were planted on post-arable soils relatively late, in the years 1993–1998 (Ryszkowski *et al.* 2003). Species composition of herb vegetation still undergoes dynamic changes (Ryszkowski *et al.* 2003) accompanied by gradual increase of organic matter content in these soils (Karg *et al.* 2003), which may also affect the communities of Collembola. Herb layer in various types of forests is important for springtail densities as demonstrated by Materna (2004).

The effect of shelterbelt's age on Collembola was more visible for species composition and diversity of communities. From 2 to 9 species of Collembola were found during present studies in soils of shelterbelts of different age and from 2 to 4 in soils of adjacent fields, it was slightly less than previously found by Olejniczak (2004) (12 species in shelterbelts and 8–10 in fields) or Czarnecki (1989) (10–14 species in the field).

Species diversity in springtail communities varied from 1.3 in the youngest to 2.6 in the oldest shelterbelt and from 0.5 to 2.2 in adjacent fields. Olejniczak (2004) in her earlier studies found the indices for field sites varying from 2.3 to 2.6. Diversity of the communities of Collembola in shelterbelts of different age was similar to that obtained earlier (2.6 – Olejniczak, 2004) with the exception of the youngest 6 years old shelterbelt (S6). Markedly lower (except for the ecotone site of 6 years old shelterbelt) species diversity of Collembola in the field than in the shelterbelt proves the importance of shelterbelts for maintaining biodiversity in agricultural landscape.

As in the earlier studies (Olejniczak 2004) the species found in shelterbelts were pioneers and rapid colonisers. *Proisotoma minuta* (Dunger 2001, Olejniczak 2004) was such a coloniser in the field. It seems that some species of springtails inhabiting shelterbelts could penetrate adjacent fields. The presence of eurytopic forest-associated species like *Isotoma notabilis*, *Friesea mirabilis* or *Onychiurus armatus* in the field 50 m (F50) far from the shelterbelt might evidence such penetration. The last species is of special importance since it is a euedaphic species, of relatively small mobility and indicative for soil degradation. Its presence would confirm a positive impact of shelterbelts on the soil structure in adjacent fields and a role of shelterbelts age because it was found in the oldest shelterbelt and in the neighbouring field.

Similarity of springtail species in shelterbelts and in adjacent fields, greatest in the site 15 m (F15) from the former, may also indicate migration from the shelterbelt to neighbouring field. The importance of organic matter remained in the field, suggested by Olejniczak (2004) may be confirmed by presented results from the field near 11 (S11) years old shelterbelt. Only there, 50 m (F50) from the shelterbelt, the species of Collembola were similar to those in the shelterbelt since this field was enriched with displaced litter.

It seems thus that age of shelterbelt vegetation may affect soil mesofauna but rather the species composition than density. That would confirm the assumption that any shelterbelt, even the young one, may influence the biodiversity of agricultural landscapes.

The following conclusions can be formulated:

– The density of soil mesofauna in an agricultural landscape is affected by the presence of midfield shelterbelts.

– The densities of Acarina are depended on the age of trees component of the shel-

terbelt. In the case of Collembola the age of shelterbelt plays a role in determining species composition rather than density.

– Shelterbelts, irrespective of the age of their vegetation, may affect the biodiversity of agricultural landscapes.

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