5. Decomposition of birch foliar litter and model cellulose at sites with the synanthropic biological soil crusts

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INTRODUCTION

As a part of the biological soil crusts investigation, a decomposition study in Chvaletice and Ralsko stands was performed. Decomposition of organic matter is a fundamental process in ecosystem carbon flux and nutrient cycling. The investigation of decomposition is therefore an important aspect of the analysis of ecosystem function.

Decomposition is one of the main factors influencing plant succession through soil formation and there is evidence that decay rates co-vary with productivity of sites (Swift et al. 1979). Hence in human-affected stands – as the both studied stands are – decomposition of plant litter is a process of crucial importance with respect to their reclamation. However, decomposition has been studied mostly in forest ecosystems (e.g., Witkamp 1963; McClaugherty et al. 1985; Bååth 1989; Albers et al. 2004; Osono & Takeda 2005) and there is still little information about it from such anthropogenic stands.

Both Chvaletice and Ralsko stands are of an early state of succession and provide harsh microclimatic conditions, which may become the main factor controlling the decay rate (Kurka et al. 2001; Sjögersten & Wookey 2004). Apart of this, the "soil" substrate of the abandoned sedimentation basin Chvaletice is characterised by low pH, high salinity and high heavy metals content, which all are factors known individually to have negative effect on microbial communities and microbially mediated processes (Rühling & Tyler 1973; Freedman & Hutchinson 1980; Nordgren et al. 1984; Cotrufo et al. 1995; Ramsey et al. 2005; Rejmánková & Houdková 2006). However, high manganese soil pollution – characteristic for the Chvaletice stand – is rare and there is no information about its effect on the decomposition process.

The present study aimed to reveal the decomposition rate of such stands in comparison with other ecosystems, and whether there is any difference in decomposition rate between the toxic environment of the Chvaletice stand and the more natural stand of Ralsko.

MATERIALS AND METHODS

As study localities, the abandoned ore-washery basin at Chvaletice and an unforested area near the former military airport Ralsko were chosen. The decomposition rate was studied both for *Betula pendula* leaf litter, as a natural organic substrate of both sites, and for filter paper which, as model cellulose, is widely used to compare decomposition activity among stands.

For both substrates studied the litterbag method was used. In November 2005 freshly fallen birch foliar litter was collected in both stands. Litterbags (12 × 12 cm) of 1.5 mm and 0.042 mm mesh size were prepared and filled with 1.3 g of oven-dried (85 °C) birch litter. Additionally, 1.5 mm mesh bags (12 × 12 cm) filled with 0.6 g oven-dried (85 °C) filter papers (80 $g \cdot m^{-2}$) were prepared.

In each stand a plot of about 10 × 10 m was chosen with 12 subplots (50 × 50 cm) covered by the biological soil crust. The experiment started in May 2006 when six sets of 8 litterbags – 4 of coarse and 4 of fine mesh size – and one set of 4 cellulose bags were placed ca 3 cm under the biological soil crust, each set in one subplot. Bags were attached to the ground with metal pins to prevent movement. Every two months over a year sampling took place. On each sampling occasion a set of 8 litterbags from one subplot and a set of 4 cellulose bags were removed and another set of cellulose bags was placed for the next two-month interval.

Cellulose and litter samples were cleaned of soil particles and foreign plant remains and oven-dried at 85 °C to constant weight. Mass loss of each sample was determined as the difference in dry weight before and after exposition. K-value (the annual decomposition rate constant) of birch litter was determined to make the results comparable with that of other studies. The calculation used the Olson's single exponential decay model (Olson 1963): $x_t = x_0 \cdot e^{-kt}$, where x_t is mass of litter in time t, x_0 is original mass and t is time in years. For studies where only mass loss values were given k-values were assigned according this equation.

For statistical analysis of cellulose and litter mass loss values two-sample t-test, one-way ANOVA and Tukey-Kramer multiple comparison test were used. For all analyses, differences were considered to be significant when $P \leq 0.05$.

RESULTS

Birch litter decomposition

The course of litter decomposition throughout the one year study was similar in both stands and under both treatments. It was relatively rapid in the first four months of the

litter exposition (mean mass loss values reached 8–14% for the two-month interval) thereafter, it considerably decelerated (mean mass loss values were 0–8%).

Using coarse mesh litterbags, no significant difference in decomposition rate between stands was detected. Mean mass loss values after twelve months of experiment were 28.9% and 31.7% for Chvaletice and Ralsko stands, respectively. K-values reached 0.34 and 0.38 for Chvaletice and Ralsko stands, respectively (Fig. 5.1a).

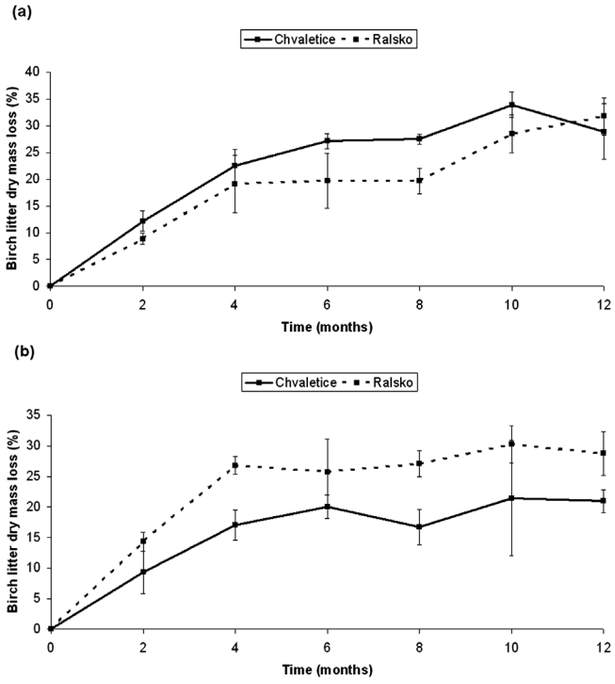

Fig. 5.1 (a–b) Accumulated dry mass losses (% ± SD) of birch litter exposed in (**a**) coarse mesh litterbags and (**b**) fine mesh litterbags in Chvaletice and Ralsko.

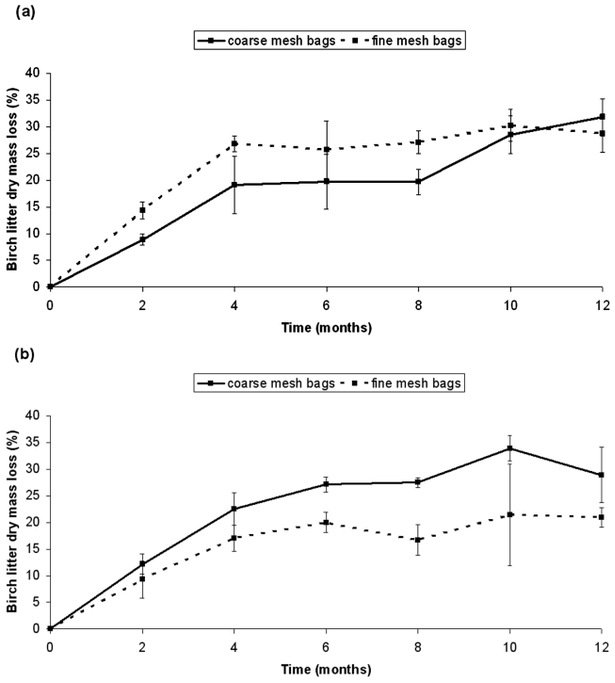

Fig. 5.2 (a–b) Accumulated dry mass losses (% ± SD) of birch litter exposed in two types of litterbags in (**a**) Ralsko and (**b**) Chvaletice.

Using fine mesh litterbags, there was significantly higher mass loss in Ralsko (28.8%) than in Chvaletice (20.9%) at the end of the experiment. K-value reached 0.34 and 0.23 for Ralsko and Chvaletice, respectively (Fig. 5.1b).

No significant difference was found in decomposition rate between litter deposed in coarse and fine mesh bags in Ralsko. However, after the first four months mass loss was significantly higher in fine mesh bags (Fig. 5.2a).

In Chvaletice the litter deposed in coarse mesh litterbags was significantly more decomposed at the end of experiment (Fig. 5.2b).

Cellulose decomposition

In the first study period (May–July) there was no significant difference in mass loss between stands. In the second and third study period (July–September, September–November) mass loss was significantly higher in Ralsko (56.9% and 30.2%) than in Chvaletice (9.8% and 5.7%). In the fourth study period (November–January) mass loss was higher for cellulose exposed in Chvaletice (Fig. 5.3). In the two last study periods there was no significant mass loss on either of the stands and these values are not given in the graph. Except the January–March period in Chvaletice, the mean weight of cellulose after exposition was even higher than before it.

In Ralsko, mean mass loss values differed significantly among individual periods of the experiment. Only between the two last periods was no difference found. The only significant difference in cellulose decay rate in Chvaletice was found between the fourth and fifth period.

DISCUSSION

Birch litter decomposition

The course of decomposition throughout the one year experiment followed the same pattern described in many other litter decomposition studies (e.g., Parsons et al. 2004; Johnson & Hale 2004; Fioretto et al. 2005; Jirout et al. 2005; Quideau et al. 2005) although they were performed in different ecosystems and for different litter types. Changes in the decay rate observed during the experiment period reflect both direct chemical changes in the substrate itself and the succession in microorganisms able to compete for substrate with a given chemical composition. Mass loss is relatively rapid in the early phase due to decomposition of soluble compounds such as polyphenols and soluble carbohydrates and non-lignified holocellulose. Later, it is slowed down due to the exhaustion of these compounds and the slow decomposition of lignified holocellulose and lignin (Berg et al. 1984; Aber et al. 1990).

The birch litter decay rate was rather slow in both stands. A *Betula pendula* leaf litter decomposition study performed in central Finland over three vegetation seasons resulted in k-values of 0.43, 0.56 and 0.45 year^{-1} (Kasurinen et al. 2006). Parsons et al. (2004) revealed the k-value of 0.89 year^{-1}

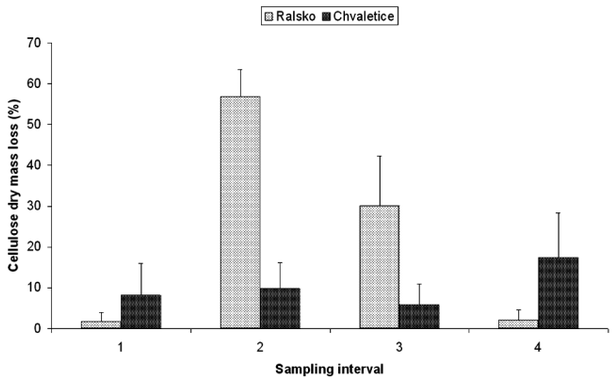

Fig. 5.3 Dry mass losses (% + SD) of model cellulose in individual periods of the experiment (**1** – May–July, **2** – July–Sep, **3** – Sep–Nov, **4** – Nov–Jan).

for *Betula papyrifera* leaf litter in forest site of northern Wisconsin, USA. There were gained k-values of 0.63 and 0.97 for the same litter type under laboratory conditions at temperature of 10 °C and 25 °C, respectively (Daubenmire & Prusso 1963). *Betula pubescens* leaf litter decomposed in birch forest in Scottish Highlands with k = 0.94 year^{-1} (King et al. 2002). A three-year decomposition experiment in subalpine coniferous forest in Japan resulted in k = 0.43 year^{-1} for *Betula* sp. litter (Tian et al. 2000). K-values revealed in the present study were very similar to that found by Johnson & Hale (2004) for white birch foliar litter at seriously heavy metal contaminated forest sites near Sudbury, Ontario and Rouyn-Noranda, Quebec. These were 0.24 and 0.36 year^{-1}, respectively in comparison with 0.56 and 0.51 year^{-1} at control sites.

The result of the intersite decomposition rate comparison was different depending on the type of litterbag used. Using fine mesh bags decomposition rate was slower in the toxic environment of Chvaletice stand as expected but there was no significant difference when coarse mesh bags were used. This corresponds with Hopkins et al. (1990), Koide & Shumway (2000) or Jirout et al. (2005) who also found litter decay rate to be affected by litterbag mesh size used. With the coarser mesh size there is a lower probability that decomposition rate will be affected either through modification of microclimatic conditions of the enclosed litter or through exclusion colonization by invertebrates. Too coarse mesh, on the other hand, can cause overestimation of the decomposition rate because particles of decomposing litter fall through the mesh or are removed by soil fauna. Litterbags of 1–2 mm mesh size are an acceptable compromise and therefore they are most frequently used in decomposition studies. The decomposition rate of litter confined in such litterbags is supposed to be rather similar to that of unconfined litter. That is why for assessment of the litter decomposition rate of the study sites, and for the intersite comparison, higher importance should be attached to the result gained using coarse mesh bags. Thus, one can say that no difference was found in litter decomposition rate between study sites.

The decay rate comparison between litter confined in two types of litterbags in one stand is commonly used for evaluation of the role of different decomposer groups in the process. In addition it can also indicate the main factors influencing decay rate in a stand. Lower mass loss of litter confined in fine mesh bags observed in Chvaletice is a quite common phenomenon mainly explained as a direct result of soil mesofauna exclusion. The trend of more rapid decomposition in fine mesh litterbags in Ralsko can be explained as a microclimatic artefact. Where soil moisture content is limiting the more convenient moisture conditions in fine mesh bags (Jirout et al. 2005) can accelerate the decomposition process even when some groups of decomposers are excluded. It is likely that even under comparable climatic conditions in both stands there is a higher probability of soil moisture deficit in the sandy soil substrate of the Ralsko stand than in sediments of the Chvaletice stand which are of rather fine texture.

Cellulose decomposition

The cellulose decomposition rate was extremely slow in both stands. According to Školek's scale for cellulose decay rate evaluation (Školek 1980) the mass loss in Chvaletice should be classified as very poor decomposition, and in Ralsko as very poor to poor decomposition (July–September).

Except the November–January study period, the decay rate in Ralsko was always higher or the same as in Chvaletice and the total mass loss after the experiment was more than two times higher in Ralsko than in Chvaletice (90.3% and 41.2%, respectively). Thus, one can say that cellulose decomposition proceeded more rapidly in Ralsko.

Significant differences in mass loss among specific periods of the experiment in Ralsko reflect a determining effect of climatic conditions upon the decay rate. The highest cellulolytic activity was found in July–November period which corresponds with Šimonovičová (1986) who also found the highest cellulolytic activity at the end of the vegetation season. The unusually stable decomposition rate throughout the season together with extremely low mass loss values in Chvaletice suggest that cellulolytic activity in this stand is limited more by the "soil" substrate quality.

Negative mass loss values found in the January–May period is the result of a not-overcome lag-phase. In this phase, preceeding the phase of exponential decay, substrate is beeing colonised and its mass is often observed to increase. The length of the lag-phase can differ, and is mainly moisture limited. Low cellulolytic activity in spring is usual (Suchara 1987) but when the lag-phase is not overcome even after two months it provides evidence of the very extreme conditions of the study sites in regard to decomposition.

It is interesting that results of the intersite decomposition rate comparison were different for litter and for model cellulose (using the same litterbag type). It suggests that results of studies based on model cellulose decomposition experiments commonly used for different sites comparison may not reflect real differences in decomposition rate of natural litter, and that any extrapolation of such model cellulose based decomposition information to ecosystem functioning is questionable.

CONCLUSIONS

Throughout one year, the decomposition of birch foliar litter and model cellulose was studied using the litterbag method in two anthropogenic stands with occurrence of biological soil crust. Birch litter decomposition in both stands followed the common pattern but was rather slow when compared to data known from another ecosystems for this litter type. Cellulolytic activity expressed as dry mass loss of filter paper was very slow in both stands as well.

Different results were gained when the decay rate of cellulose and litter in the two stands were compared. Although cellulose decomposition proceeded more slowly in the toxic environment of the Chvaletice stand, as expected, there was no significant difference in the litter decomposition rate between stands.

Site specific litterbag effect and seasonal variability in cellulolytic activity suggest that the decay rate in Chvaletice was limited by toxic parametres of the soil substrate while in Ralsko it was limited by soil moisture content.