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The decomposition of maple (*Acer* sp.), poplar (*Populus* sp.), and plane (*Platanus* sp.) leaf litter as affected in different cropping systems — A preliminary study

Juhar (*Acer* sp.), nyár (*Populus* sp.) és platán (*Platanus* sp.) avar bomlásának vizsgálata különböző termesztési rendszerekben – Előzetes tanulmány

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ABSTRACT

To understand the nutrient cycle in natural systems, it is essential to study the decomposition of terrestrial leaf litter, a key element in these processes. Studies on litter decomposition can also provide fundamental information for forestry and agricultural management. The decomposition rates of three leaf litter types (maple, poplar, and plane) were evaluated under three different field treatments: a Hügelkultur plot, a plot with soil amended with compost, and a conventional field plot. The decomposition rates were assessed using the litter bag method based on the weight of the litter bags collected every three weeks. At the end of the 107-day study, treatment had a significant effect on litter decomposition, whereas no significant differences were observed among litter types. This pattern was also reflected in the analysis of the decomposition rate coefficient.

Keywords: leaf litter decomposition, exponential decay coefficient, field experiment, maple, poplar, plane

ÖSSZEFOGLALÁS

Fontos a természetben történő tápanyag-ciklusok megértése, melynek szerves részét képezi a szárazföldön történő avarlebontás is. Az avarlebontáshoz kapcsolódó kutatások fontos információkat nyújthatnak az erdőgazdálkodással, valamint mezőgazdasággal foglalkozó szakemberek számára. Kutatásunkban célul tűztük ki egy szántóföldi parcellán, egy szervestrágyázott parcellán és egy Hügel-plotban történő avarlebontás sebességének meghatározását. A kísérletbe három, a vizsgálati helyszín környékén jellemzően előforduló avartípust vontunk be: juhart (*Acer* sp.), nyárt (*Populus* sp.), valamint platán (*Platanus* sp.) avart helyeztünk ki a beállított kezelések területére. A vizsgálat során avarzsákos módszerrel állapítottuk meg az avarlebontás ütemét. A vizsgálati időszak végén megállapítottuk, hogy a kezelések hatása szignifikáns volt az avarlebontásra, míg az avartípusok között nem találtunk szignifikáns különbséget. Ezt a tendenciát figyelhettük meg a bomlási együtthatók vizsgálatakor is.

Kulcsszavak: avarlebontás, exponenciális bomlási együttható, szabadföldi kísérlet, juhar, nyár, platán

INTRODUCTION

The decomposition of leaf litter links aboveground and belowground biogeochemical processes, playing a vital role in regulating the nutrient cycle, soil fertility, and ecosystem carbon dynamics (Hunt et al., 1988; Berg and McClaugherty, 2008; Staelens et al., 2011). Leaf litter deposited on the soil surface serves as the primary source of energy, carbon, nitrogen, and phosphorus in the soil, providing readily available nutrients that can be reabsorbed during plant growth (Jenny et al., 1949; Wardle et al., 2004). Without this process, these elements would accumulate in the litter layer, progressively reducing ecosystem productivity.

Litter decomposition is primarily governed by the chemical quality of the litter (e.g., initial nitrogen and lignin content), the soil biota (e.g., mesofauna), and the physicochemical characteristics of the environment (e.g., temperature, soil type) (Swift et al., 1979; Lu and Liu, 2012; Wang et al., 2013). The number of studies focusing on organic matter decomposition has increased rapidly since the 2000s (Rawlik et al., 2021). Studies comparing the decomposition rates of different litter types under field conditions have also been published (Hobbie et al., 2006; Rawlik et al., 2021).

According to the literature, litter quality and environmental factors account for approximately 60–70% of the variation in decomposition rates (Parton et al., 2007). This highlights the importance of the fact that about 90% of terrestrial ecosystem biomass returns to the soil in the form of decomposing litter (Wardle et al., 2004). Litter decomposition is predominantly driven by microbial activity, while the dynamics of soil fauna largely depend on soil chemical and physical properties (Coleman and Crossley, 1996).

The presence, abundance, species richness, and activity of decomposers are fundamentally determined by local microclimatic conditions, soil properties, and applied agricultural practices (Swift et al., 1979; Tate, 2020; Khmelevtsova, 2022). Climate change is also expected to impact microbial communities and, consequently, the process of leaf litter decomposition; however, notable differences may arise due to local specificities (Boyero et al., 2011; Su et al., 2023). The results of numerous studies indicate that leaf litter decomposition is generally faster in warmer and wetter environments due to enhanced microbial activity (García-Palacios et al., 2013; Portillo-Estrada et al., 2015). On the contrary, anthropogenic disturbances (such as deforestation, land-use change, changes in cultivation practices, intensive farming, and pollution) can slow down leaf litter decomposition, depending on the severity of the disturbance (Röder et al., 2024).

The experiment aimed to investigate litter decomposition dynamics of three temperate tree species under three different field treatments using the widely applied litter bag method. This method also enabled the determination of the decomposition constant (k).

MATERIALS AND METHODS

The experiment was conducted on the Georgikon Campus of the Hungarian University of Agriculture and Life Sciences (MATE) between May and September 2024. The 2 × 4 m plots were established in April 2024, and buckwheat (*Fagopyrum esculentum* cv. 'Eskalar') was sown in them on May 6, 2024. The experiment consisted of three plot treatments:

Treatment A: a Hügelkultur plot, the base of which was made of logs that had been rotting for several years. These were covered with a layer of fresh and older branches, and then soil typical of the test site was added, followed by thinner branches of fruit trees and grape cuttings, which were also covered with soil. The bed was then covered with an approx. 25 cm thick layer of mosses, approx. 15 cm of litter and soil mixture, and finally with a layer of compost that was about 20 cm thick. The final height of the Hügelkultur was about 90 cm.

Treatment B: a plot with soil amended with compost, where the top 20 cm of arable soil from conventional farming was mixed with the compost used in treatment A in a 50-50% ratio. The composition of the compost was 50% organic manure, 35% litter, and 15% herbaceous plant residues.

Treatment C: conventional field plot, where the original arable soil from conventional farming was in its original state, cultivated to a depth of 20 cm (Ramann-type brown forest soil, sandy loam, 21% clay, and 1.7% organic matter content, pH(KCl) = 7.1; pH(H_2O) = 8.1).

In the experiment, neither fertilizers nor pesticides were applied to the plots.

The study aimed to investigate the effect of different treatments on litter decomposition dynamics using the litter bag method (Bärlocher, 2010). This widely used, internationally recognized method involves placing plant material in plastic mesh bags (~20 × 20 cm, with a mesh size of ~2 mm). A litter of three tree species – maple, poplar, and plane – was collected separately from areas near the test site 5 months before the start of the experiment. The samples were air-dried (24 °C) to a constant weight. Subsequently, 10 g of litter per tree species was put in the bags, which were randomly placed on the soil surface of the plots (A, B, and C), with three replicates per treatment and litter type, on May 27, 2024. After placement, three samples per litter type and plot were collected on days 24, 44, 65, 86, and 106 of the experiment.

The plant material retrieved from the field was transported to the laboratory, washed with water, and air-dried for approximately 10 days until constant mass was achieved. Mass loss was determined by weighing the remaining dry litter ± standard deviation, free of debris.

The decomposition rate constant (k) was calculated using the following exponential decay equation (Bärlocher, 2010):

$$W_t = W_0 \times e^{-kt}$$

where t represents time (days), W_t is the remaining dry mass of the litter at time t (g), W_0 is the initial dry mass of the litter at time zero (g), e is the base of the natural logarithm, and k is the exponential decomposition coefficient.

The half-life time, indicating the time required for the litter mass to decrease by half, was calculated using the relationship described by Greca et al. (2005) and Bärlocher (2010).

Differences in the residual dry mass of the litter, calculated k-values, and decomposition rates across treatments and plant species were analyzed using Student's t-test (Microsoft Office Excel 2016) and Analysis of Variance (ANOVA; IBM SPSS Statistics).

RESULTS

In the case of maple litter (Figure 1a), the most significant litter mass loss was observed in Treatment A (Hügelkultur plot), with a remaining litter mass of 8.8 ± 0.13 g. In Treatment B, the remaining mass was 9.0 ± 0.23 g, whereas in Treatment C, it was 8.9 ± 0.24 g. No significant differences were detected between treatments A and B (P = 0.2233), B and C (P = 0.4674), or A and C (P = 0.2295) regarding decomposition dynamics. Except for the first sampling event, this pattern was similar throughout the entire study.

The remaining litter masses for poplar at the end of the experiment ranged from 8.9 ± 0.16 g (treatment B) to 9.1 ± 0.12 g (treatment C). The weight of the remaining litter mass in treatment A is 9.0 ± 0.08 g for poplar. Examination of the decomposition process (Figure 1b) showed that the highest initial decomposition rate occurred in treatment B during the first two sampling times. During the subsequent two sampling events, treatment C exhibited the lowest remaining litter mass, with the final sampling values reverting to the initial pattern observed. These minor variations were not statistically significant between treatments A and B (P = 0.3465), B and C (P = 0.4468), or A and C (P = 0.3929).

For the plane litter decomposition dynamics (Figure 1c), results were similar to those obtained for maple litter. The most significant litter mass loss was also recorded in treatment A, with 9.2 ± 0.23 g remaining by day 106 of the experiment. Minimal differences in litter mass were found between treatments B and C (9.5 ± 0.05 g and 9.5 ± 0.16 g, respectively), with no significant difference proven (P = 0.2418). Likewise, no statistically significant differences were detected between treatments A and B (P = 0.2566) or between treatments A and C (P = 0.1460).

In the ANOVA, the effects of treatment and litter type were evaluated independently rather than by comparing individual treatment–species combinations. When analyzing the effects of treatments (A, B, and C) and litter types (maple, poplar, and plane) collectively, treatment significantly influenced the remaining litter mass (P = 0.0176), while litter type did not produce significant differences (Table 1). The interaction between treatment and litter type also did not show statistical significance regarding residual litter mass (P = 0.203).

From the litter masses remaining in the experiments, the exponential decay coefficient (k) can be calculated, facilitating the comparison of litter decomposition studies conducted under different treatments and litter types. Additionally, the calculated k values allow the categorization of decomposition dynamics into rapid, moderate, or slow. Figure 2 illustrates these exponential decay coefficients. According to the methodology described in the Materials and Methods section, the decomposition dynamics for all three litter types and all treatments in this experiment fall into the "slow" category (k < 0.005).

During the experiment, the treatments (A, B, and C) had a significant effect on the decomposition coefficient (k) (P = 0.0190). In contrast, no significant differences were observed among the litter types (Table 2).

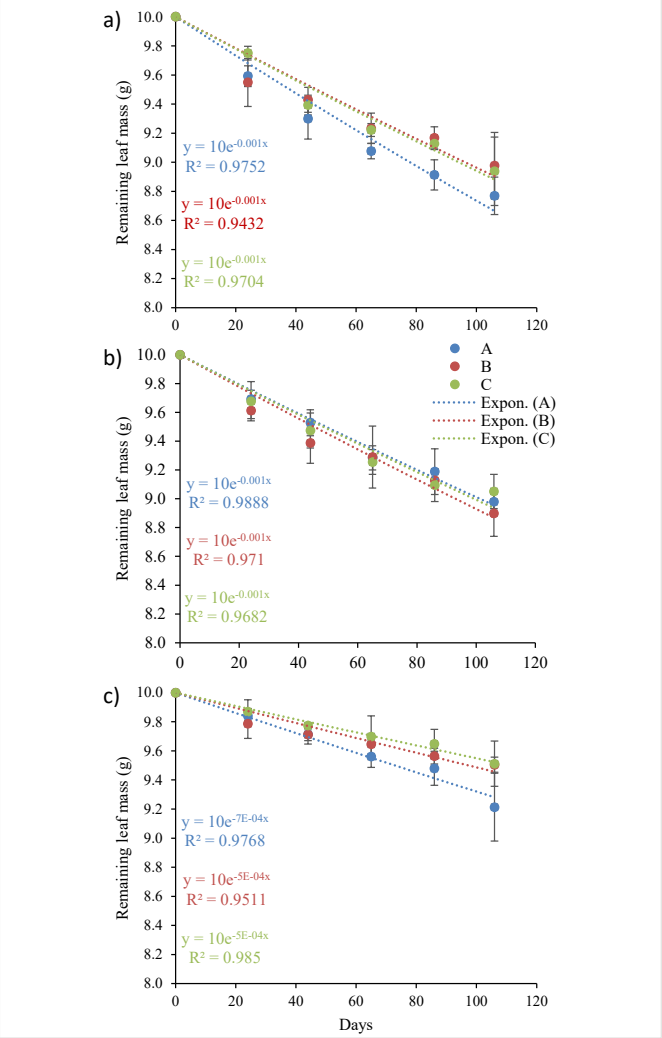


Figure 1. Remaining litter mass (a – maple; b – poplar; c – plane) under different treatments (A – Hügelkultur plot; B – plot with soil amended with compost; C – conventional field plot) measured 24, 44, 65, 86, and 106 days after placement

Table 1. Analysis of variance (ANOVA) of remaining litter mass for different treatments and litter type (df – degrees of freedom; F – F statistic; Sig. – significance level; R^2 – coefficient of determination)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.882[a]	8	0.235	8.4	0.000
Intercept	2223.9	1	2223.9	79580.4	0.000
Treatment	1.589	2	0.795	28.4	0.000
Litter type	0.107	2	0.054	1.9	0.176
Treatment × Litter type	0.186	4	0.046	1.6	0.203
Error	0.503	18	0.028		
Total	2226.368	27			
Corrected Total	2.385	26			

[a] R^2 = 0.789 (Adjusted R^2 = 0.695)

Table 2. Analysis of variance (ANOVA) of exponential decay coefficient for different treatments and litter types (df – degrees of freedom; F – F statistic; Sig. – significance level; R^2 – coefficient of determination)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.004E-6[b]	8	2.505E-7	8.2	0.000
Intercept	2.285E-5	1	2.285E-5	745.9	0.000
Treatment	1.692E-6	2	8.461E-7	27.6	0.000
Litter type	1.117E-7	2	5.583E-8	1.8	0.190
Treatment ×Litter type	2.000E-7	4	4.999E-8	1.6	0.210
Error	5.513E-7	18	3.063E-8		
Total	2.540E-5	27			
Corrected Total	2.555E-6	26			

[b] R^2 = 0.784 (Adjusted R^2 = 0.688).

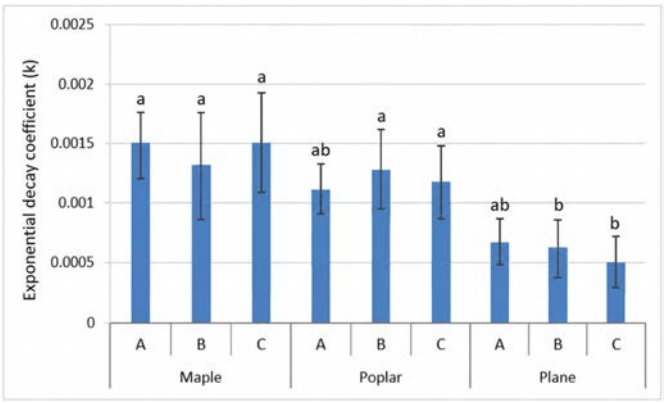


Figure 2. Values of the exponential decomposition coefficient (*k*) for three litter types (maple, poplar, plane) under three treatments (A – Hügelkultur plot; B – plot with soil amended with compost; C – conventional field plot)

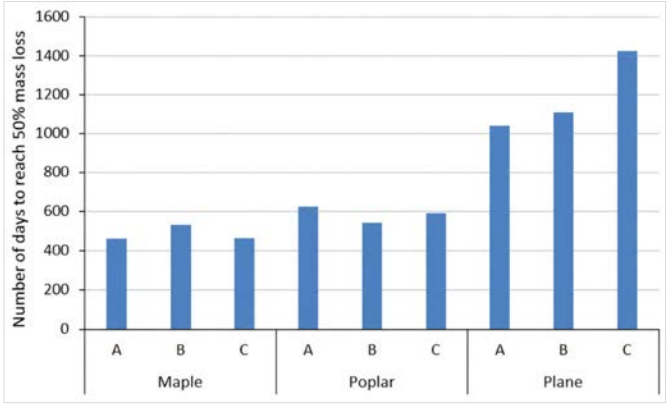


Figure 3. Half-life times for three litter types (maple, poplar, plane) under three different treatments (A – Hügelkultur plot; B – plot with soil amended with compost; C – conventional field plot)

The interaction effect between treatments and litter types also did not significantly influence the calculated k values (P = 0.210).

Based on the calculated decomposition coefficient (*k*), the half-life times were also determined (Figure 3). These half-life times indicate the time required for the litter mass within the litter bags to decrease by half. Figure 3 illustrates these values. As shown, the half-life times for maple (461–531 days) and poplar litter (543–624 days) were similar, whereas substantially longer half-life times were recorded for plane litter (1042–1425 days).

DISCUSSION

In the Hügelkultur plot (treatment A), the decomposition of maple litter was the fastest, followed by poplar and plane litter. Treatment C showed a similar pattern; however, in treatment B, poplar litter decomposed the fastest, followed by maple and then plane litter. Significant differences were observed in decomposition dynamics: in treatment A, significant differences were detected between poplar and plane litter (P = 0.0219). In treatment B, significant differences emerged between maple and plane litter (P = 0.0053) and between poplar and plane litter (P = 0.0098).

Similarly, treatment C also showed significant differences between maple and plane litter (P = 0.0122) and between poplar and plane litter (P = 0.0093).

Yang et al. (2020) assessed litter mass loss and nutrient content in microcosm incubations over a three-month period, using soil layers treated with various isopods, including those from plane tree litter. Their results demonstrated that the presence of isopods (*Porcellionidae* and *Armadillidiidae*) significantly increased litter decomposition rates compared to the control (P < 0.05). The average litter mass loss (2.56 g) and mass-loss ratio (85.47%) in the isopod-treated group were substantially greater than those of the control group (0.43 g and 14.31%, respectively).

In a field-based study conducted in Poland, Rawlik et al. (2022) investigated the decomposition of platan litter, observing a 95% mass loss within the first two months. In contrast, the present study showed approximately 10% mass loss for plane litter over a similar time period. This discrepancy likely results from differences in treatment conditions; forest ecosystems, such as those studied by Rawlik et al. (2022), typically feature high biological activity in soils, whereas arable field conditions in the present experiment supported significantly lower soil biological activity.

Nikula et al. (2010) investigated the decomposition of poplar litter in urban and rural environments in Finland. Their study indicated significantly greater litter mass loss in urban-collected litter decomposed in urban areas (13%) compared to rural-collected litter decomposed in rural areas. In the present study, a similar mass loss of nearly 10% was observed, despite the differences in meteorological conditions and soil biological activity between the two study sites.

In a recent study in China by Yang et al. (2022), which compared four litter types, poplar litter decomposed faster than oak, larch, and walnut litter, which is consistent with the findings of the present study. They also observed increased decomposition rates when oak, larch, or walnut litter was mixed with poplar litter. In another study by Yang et al. (2020), the decomposition of sycamore (*Platanus acerifolia*), cherry (*Catalpa bungei*), and Chinese horse chestnut (*Aesculus chinensis*) litter was evaluated, with sycamore litter classified as having a slow decomposition rate. Furthermore, no significant differences were observed between treatments, which may be attributed to the robust structural properties and slow decomposition characteristics of sycamore leaves.

In an experiment by Hobbie et al. (2006) evaluating 14 litter types, maple litter was placed within the slow-decomposing category. However, it was noted to decompose relatively faster compared to other slow-decomposing litter.

The variation in decomposition characteristics among different litter types can be attributed to both environmental factors and intrinsic plant traits. Several earlier studies demonstrated strong positive correlations between decomposition rate and leaf nitrogen concentration, while negative correlations have been observed between decomposition rate and leaf lifespan (Bakker et al., 2011; Cornwell et al., 2008; Wright et al., 2005).

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