Evolution of decomposition coefficients for different leaf litters

A bomlási együtthatók alakulása különböző avarfélék esetében

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Abstract: Temperature is one of the main abiotic drivers of decomposition processes in water. In the international literature, the values measured under different environmental conditions can be compared with the value of the traditional exponential decay coefficient (k, day-1). However, this indicator does not take temperature into account, it only calculates the remaining mass and the elapsed time. The water temperature-based daily mean breakdown rate is suitable for taking water temperature into account (ktemp, day-1). During the research, 3 types of litter (willow, Salix sp.; poplar, Populus sp.; reed, Phragmites australis) and their mixture were examined using the litterbag method. The experiment was set up between June 10 and September 2, 2022. Based on our results, it can be said that ktemp values are higher than k values. The differences between the varieties and their mixtures became more visible in the case of ktemp than in the case of k. With the exception of reed, the litter mixtures showed a higher deviation than the litter samples containing only one type of leaf litter when comparing the values of k and ktemp.

Keywords: *willow, poplar, reed, litter mixture, decomposition coefficient*

Összefoglalás: A vízben történő avarlebontási folyamatok egyik fő abiotikus mozgatórugója a hőmérséklet. A nemzetközi szakirodalomban a hagyományos exponenciális bomlási együttható (k, nap-1) értékével tehetjük összehasonlíthatóvá a különböző környezeti feltételek közt mért értékeket. Ezen mutató azonban nem veszi figyelembe a hőmérsékletet, csupán a visszamaradt tömeggel és az eltelt idővel számol. A vízhőmérséklet figyelembevételére a vízhőmérséklettel kompenzált bomlási együttható alkalmas (ktemp, nap-1). A kutatás során egy mikrokozmosz kísérletben (hagyományos A kádban) 3 avar-típus (fűz avar, Salix sp.; nyár avar, Populus sp.; nád, Phragmites australis), valamint ezek keverékét vizsgáltuk avarzsákos módszerrel 2022. június 10 és szeptember 2. között. Eredményeink alapján elmondható, hogy ktemp értékei magasabbak a k értékeknél, valamint az avarféleségek és keverékeik közti különbségek is a ktemp esetében jobban láthatóvá váltak. A nádat leszámítva az avarkeverékek magasabb eltérést mutattak, mint az egyféle avart tartalmazó avarmintáknál k és ktemp értékeit összehasonlítva.

Kulcsszavak: *5 fűz, nyár, nád, avarkeverék, bomlási együttható*

1. Introduction

Leaf fall means approximately 1000 to 7000 kg/ha dry matter annually (Mátyás, 1997: 45-65). Allochtonous input from riparian vegetation provides a significant amount of organic matter to the energy cycle of water bodies (Nakajima et al., 2006). After entering the water, CPOM (coarse particulate organic matter) turns into FPOM (fine particulate organic matter) and DOM (dissolved organic matter) due to dissolution, physical fragmentation and the decomposing activity of micro- and macroorganisms (Wallace et al., 1995; Dobson & Frid, 1998; Abelho, 2001).

Leaf litter decomposition is limited by a number of factors. Meentemeyer (1978) mentions temperature as the main influencing factor of leaf litter decomposition. It affects both the speed of chemical and biological reactions (Brown et al., 2004). The rise of temperature accelerates the mass loss of leaf litter, directly by leaching, and indirectly by increasing the energy consumption of invertebrate detrivores and microbial organisms (Chergui, 1990; Ferreira & Chauvet, 2011). In general, it can be stated, that an increase in water temperature stimulates the metabolic rate, but only up to a certain limit (Sokolova & Lanning, 2008). It is expected that leaf litter decomposition processes will also respond sensitively to global climate change (Boyero et al., 2011).

To examine the speed of decomposition, the negative exponential decay model is most commonly used, where exponential decay coefficient (k) expresses the rate of decomposition (Petersen & Cummins, 1974; Webster & Benfield, 1986). In knowledge of the „k" value, decomposition rates of the given samples can be categorized into slow ($k < 0.005$), medium ($k = 0.005$-0.01) and fast ($k > 0.01$) categories (Bärlocher et al. 2005, Petersen and Cummins, 1974), furthermore, using the formula of Bärlocher et al. (2005) the halving times can also be expressed. The model, on the other hand, is not wholly accurate, as it omits the temperature factor, which is – as previously described - a key factor in decomposition processes. It assumes that the litter mass loss at any given point in time is proportional to the litter mass present, regardless of temperature (Bärlocher et al., 2020). The exponential decay model can be expanded, assuming a linear temperature dependency of the overall decay rate (Bärlocher et al. 2020). This is called temperature-normalized decay rate coefficient (k_{temp}). The expanded model is more accurate, because it takes the temperature factor also into account. Determination and comparison of the different leaf litter decomposition rates can help to better understand the importance of temperature factor by the examination of cycle processes of aquatic ecosystems.

The aim of the research was to compare the extent to which the decomposition rates calculated with the two different methods differed. The two equations used differ in that one of them also takes water temperature into account, because temperature plays a prominent role in the decomposition processes.

2. Materials and Methods

The experiment was set up at the university's Agrometeorological Research Station (latitude: 46°440' N, longitude: 17°140' E, elevation: 124 m a.s.l.) in a class A evaporation pan. This class A pan filled with water was 1.21 m in diameter and 0.25 m in height located on an elevated (~0.15 m) wooden grid. The class A pan was covered on the bottom with sediment to a thickness of 0.003 m. Water temperature was collected with a Delta Ohm HD-226-1 data logger. In this class A pan, we examined the rate of decomposition of the following 3 type leaf litter and their mixture using the litterbag technique (Bärlocher et al., 2005), under water conditions: willow (*Salix* sp.), poplar (*Populus* sp.), reed (*Phragmites australis*).

The litter was collected in the fall of 2021 and dried to a constant mass. After reaching a constant mass, the litters were filled into litterbags, which are made of plastic material. We put 10 grams of each type of litter into the litterbags (with 3 repetitions), in the case of bags containing mixed litter, we measured 5 grams from one litter and 5 grams from the other litter.

In the case of a mixture of the 3 types of litter, the litterbag contained equal leaf litter of willow, aspen and reed. Based on these, we set up the following treatments:

- willow
- poplar
- reed
- willow – poplar
- willow – reed
- poplar – reed
- willow – poplar – reed

The experiment was set up between June 10, 2022 and September 2, 2022. A total of 6 sampling happened on the 14th, 28th, 42nd, 56th, 70th and 84th days after the placement. After the sampling, the litters were cleaned and then dried again until the weight was constant. After that, we remeasured their weight, so the weight loss can be determined.

In the literature, decomposition coefficients are used for better comparability of changes during litter decomposition. One way to do this is to use the most used exponential model (Bärlocher et al., 2005):

$$\frac{dm}{dt} = -k \times m$$

where m (g) is the mass loss as a proportion of initial mass, t the time in days after the initial exposure, and k (day^{-1}) is the decomposition constant.

Using another formula, the temperature can also be considered when calculating the decomposition rate:

$$\frac{dm}{dt} = -k_{temp} \times \frac{T_w}{T_R} \times m$$

where T_w is the water temperature, k_{temp} (day^{-1}) is the temperature-normalized decomposition rate coefficient. Set TR=10 °C as Bärlocher et al. (2020) suggested, for ease of comparison with other temperaturebased models (Anda et al., 2023).

3. Results and Discussion

Figure 1 shows the values of the exponential decay coefficient (k). Similar k values can be observed in the case of willow and reed (k= 0.0047 and 0.0041), in the case of poplar the k value is higher (k=0.0068). The litter mixtures show similar values (k=0.0046 – 0.0059). Based on the results of the t-test (at a significance level of 0.05) a significant difference can be observed between the k values of willow and poplar, poplar and reed, poplar and reed-poplar, poplar and reed-willow, poplar and willow-poplar-reed, reed and willow-poplar, willow-poplar and reed-willow litters ($p<0.05$ – $p=0.03$). Comparing the results of our experiment with data of other similar researches, even significantly different k values can be observed in the case of the examined plant parts. The main reason for the differences may be the timing and the location of the experiment (Asaeda & Nam, 2002), furthermore, decomposition rates are also influenced by biotic (saprotrophic organisms present, leaf litter quality) and abiotic factors (water parameters, like chemical compound, temperature and movement) (Chen et al., 2019).

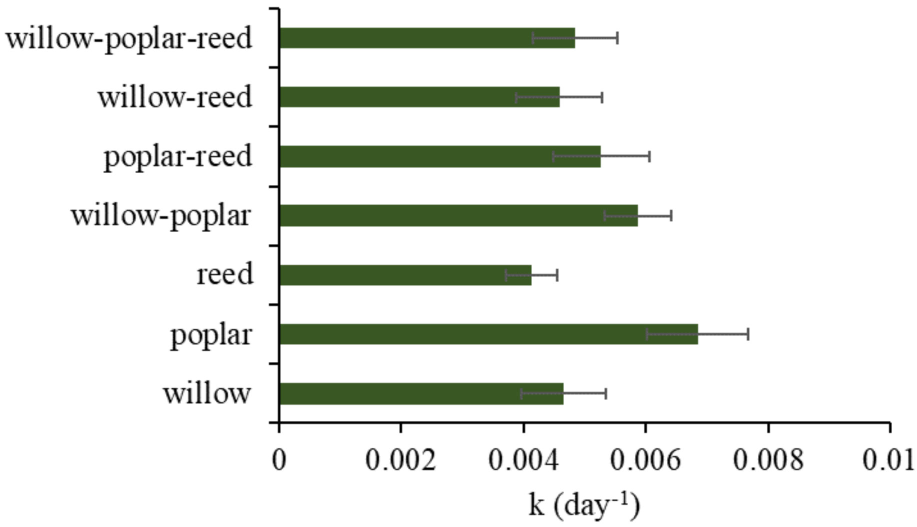

Figure 1. *Exponential decomposition rates, k (day^{-1}) of three plant species (willow, Salix sp.; poplar, Populus sp.; reed, Phragmites australis) and their mixtures*

The Water temperature-based decay coefficient (k_{temp}) values are shown in Figure 2. Compared to the k values, in the case of k_{temp}, we can already see several differences in the values of the decomposition coefficients. All this is due to the fact that the method used also takes the effect of temperature into account. In the case of k_{temp}, reed (k= 0.0445) shows the highest value compared to poplar and willow (k=0.0078 and 0.0085). In the case of k_{temp}, the litter mixtures did not develop similarly: willow-reed and poplar-reed show higher values (k= 0.0258 and 0.0254), while willow-poplar (k=0.0078) and willow-poplar-reed (k= 0.0131) show lower values.

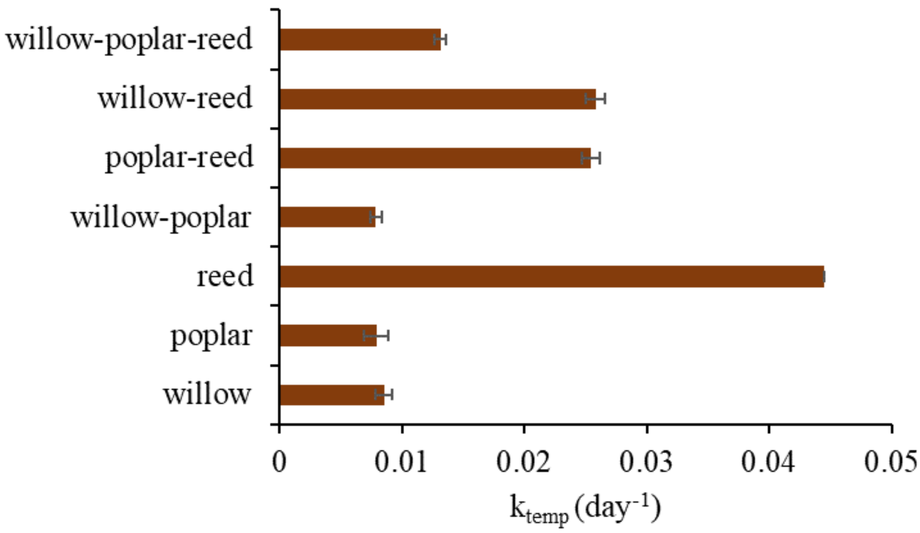

Figure 2. *Water temperature-based daily mean breakdown rates, k_{temp} (day^{-1}) of three plant species (willow, Salix sp.; poplar, Populus sp.; reed, Phragmites australis) and their mixtures*

Comparing k and k_{temp} values, 13.3-79.3% higher values were observed for ktemp compared to k values. These differences between k and k_{temp} values were significant ($p<0.05$ – p= 0.0021). Based on this, it seems that k_{temp} better shows the difference between different litters and their mixtures for decomposition processes under water surface. Furthermore, it seems that, with the exception of reed, the mixture treatments are more sensitive to the value of the decomposition coefficient, which also takes into the temperature into account, compared to the traditional k coefficient.

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