Leaching losses with special references on nutrient dynamics from five leaf litter species in a side arm of the Danube at Gemenc floodplain, Hungary

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1 Introduction

Large river floodplains are characterised by a high diversity of biogeochemical processes (Junk et al. 1989) and are among the most endangered and diverse ecosystems in the world (Malmqvist & Rundle 2002). An important ecological function of these ecosystems is the exchange of nutrients between the water and its adjacent floodplain. The floodplain vegetation has a remarkable role in this exchange and it was also mentioned as an important element in the flood pulse concept (Junk et al. 1989).

Leaf litter originating from the vegetation of transitional areas constitutes a major part of the total allochthonous organic matter input to rivers (Chauvet 1997). Leaves can immediately enter the aquatic environment by falling straight into it (vertical contribution), or are blown in later by the wind or washed in by floods (lateral contribution) (Chergui & Pattee 1990). Once in the water they loose soluble substances, labile C, N and antimicrobial compounds trough leaching (Gessner & Dobson 1993). Nutrients released from leaves represent a notable energy source for aquatic food webs and play an important role in the metabolism and nutrient cycle of floodplain ecosystems (Gessner & Schwoerbel 1989). The release of nutrients occurs in two main steps: leaching of soluble chemical compounds and microbial mineralization of the structural components (Swift et al. 1979).

The litter breakdown rate is influenced by the intrinsic leaf characteristics (texture, chemical composition) and by the extrinsic factors such as the physico-chemical characteristics of the environment (especially the inorganic nutrients available from the water) (Taylor & Parkinson 1988).

The objective of this study was to quantify and compare the rates of mass loss and the amount of C, N, P, S released during the initial decomposition phase of five different single leaf species: oak (*Quercus robur*), elm (*Ulmus laevis*), willow (*Salix alba*), ash (*Fraxinus excelsior*), poplar (*Populus* hybrids). These trees are characteristic to Gemenc part of the Danube-Drava National Park (46º15'N 018º51'E), which is the largest (178 km^2) forested floodplain of the Danube, unique in Europe, characterised by a variety of hard and soft-wooded tree species and various floodplain habitats (Guti 2001). The hypothesis of this work was that the leaching process varies between the different leaf species and these differences may be related to the quality of leaf litter.

2 Materials and Methods

2.1 Study area and sampling design

The floodplain area of the Danube at Gemenc includes different water body types with different hydrological regime depending on their connectivity with the main arm (Guti 2001). Our study site was located at Rezéti-Holt-Duna (RDU) parapotamal type side arm (Fig. 1) with primarily running water (at 300 cm water level in the main arm, at 1478 rkm) and a current speed of 0.4-0.5 m s^{-1} at MQ. The side arm is 15 km long, 25-40 m wide, 140-400 cm deep (at mean water level) with the junction at 1488 rkm and the mouth at 1485 rkm of the

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main arm. It was originally a bend of the main arm, which was cut off in 1893-1894 in the course of river regulation; as a consequence, due to the deposition of fine suspended matter, it is gradually filling up.

Leaves were collected for decomposition studies in October 2007, immediately after abscission, and transported to the laboratory. 10 g air dried leaves were put in litter bags of 1 mm^2 mesh size and exposed in the water of the Rezéti-Holt-Duna side arm in March 2008 (Fig. 1).

The willow and poplar leaves were exposed at site 1 situated in the depositional part, and the oak, ash and elm leaves at site 2 situated in the erosional part of the side arm; because the depositional bank of the side arm is characterised by softwood (willow, poplar) and the erosional bank mainly by hardwood vegetation (i.e. ash, elm).

2.2 Chemical and statistical analyses

Three bags from each type of leaf litter were retrieved after 48 h exposition for laboratory analyses. Subsamples of decomposing leaf material were dried at 105 ºC to determine the dry mass, then combusted (550^o C, 4 h) for determination of ash content.

Organic matter (OM) content was calculated as ash free dry mass. The C, N, S concentrations were determined by elemental NCS analyser (NA-1500, Fisons Instruments), the P concentrations by spectrophotometric molybdenum blue method, after digestion with concentrated sulphuric acid.

Temperatures, oxygen saturation, electrical conductivity, pH of the water were measured in situ with Hydrolog 2100 field equipment (Grabner). The total (TOC) and dissolved organic carbon (DOC) concentrations were determined in the laboratory by TOC analyser (Elementar-liqui TOC), the NO_3^--N concentrations with DX-120 ionchromatograph (Dionex), the PO_4^{3-}-P, dissolved (DTP) and total phosphorus (TP), NH_4^+-N, suspended matter and chlorophyll-a concentrations by standard chemical methods (Golterman et al. 1978).

Analyses of variance and Pearson product moment correlation analysis of the data was performed according to Hammer et al (2001).

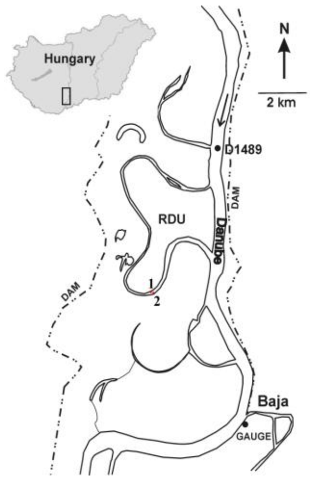

Figure 1: *Sampling sites (1 and 2) at Rezéti-Holt-Duna (RDU) side arm (Gemenc/Hungary)*

3 Results and Discussion

3.1 Environmental background conditions

The water chemistry results are presented in Table 1. During the sampling the water level of the main arm was 332-290 cm. The chemical parameters of the sampling site 1 and 2 were similar. However the NO_3^--N, PO_4-P, DTP and TP concentrations were lower in the side arm than in the main arm; also lower chlorophyll-a and suspended matter (SPM) concentrations were recorded in the side arm as compared to the main arm.

Table 1. *The main physico-chemical parameters of the water in the Rezéti-Holt-Duna side arm (site 1 and 2) and in the main arm (Danube) in March 2008*

Site	T C°	Cond. µScm^{-1}	pH	O_2 %	SPM mgl^{-1}	Chl-a µgl^{-1}	NH_4^+-N µgl^{-1}	NO_3^--N mgl^{-1}	PO_4- µgl^{-1}	DTP µgl^{-1}	TP µgl^{-1}	DOC mgl^{-1}	TOC mgl^{-1}
Danub	**9.**	**334.0**	**7.5**	**89.**	**21.6**	**21.3**	**18.7**	**2.88**	**38.2**	**49.1**	**119.4**	**5.1**	**5.6**
Site 1	**9.**	**323.0**	**7.4**	**87.**	**10.0**	**11.5**	**71.2**	**2.41**	**22.5**	**45.4**	**79.5**	**4.9**	**5.9**
Site 2	**9.**	**328.0**	**7.4**	**87.**	**10.0**	**9.8**	**81.0**	**2.37**	**18.9**	**34.1**	**86.6**	**5.2**	**5.8**

3.2 Mass losses

The mass loss of decomposing leaf litter was rapid: 4-26% of the initial mass was lost during the first 48 h of decomposition (Fig. 2). The loss showed a strong positive correlation with the amount of organic matter leached out (Table 3). Ash leaf litter lost the highest amount of dry mass and oak leaf litter the lowest. The poplar, willow, elm and ash leaf litter decomposed with similar rate during the leaching period: 25%, 21%, 24% and 26% of the initial dry mass was lost, respectively. These losses exceeded significantly ($p<0.05$), i. e. 6-7 times the mass loss of oak leaf litter.

The relative fast loss of dry mass and nutrients in the initial decomposition phase of the different leaf species can be explained by the rapid loss of the soluble organic and inorganic compounds. Berg & Ekbohm (1991) reported a positive relationship between the amount of substances leached out and the overall breakdown rate; this means that the litter types which release higher amounts of soluble compounds decompose faster.

According to our results leaching may account for less than 26% loss of the initial mass (except for oak: 4%), which is similar to the results of Bärlocher (2005) and Nykvist (1963) who reported a loss of about 30-33% or less.

The strong correlation between the amount of dry mass and organic matter lost (Table 3) suggest that the major part of the substances washed out were soluble organic compounds, which also support the results of Nykvist (1963) who found that about 90% of the leached compounds are of organic nature.

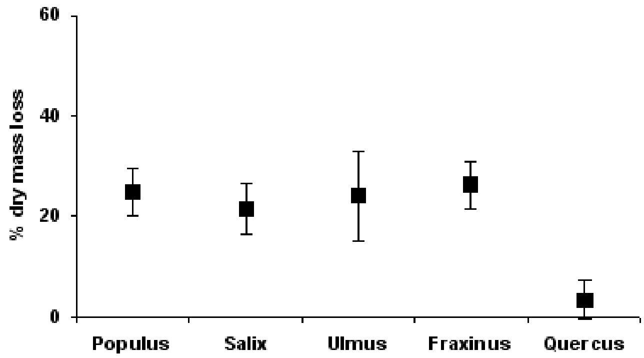

Figure 2. *The amount of mass leached out from decomposing leaf litter within 48 h. Means ± 1SE, n=3.*

3.3 Nutrients leached

The loss of C, N, P and S varied among species and the C loss of different leaf litter types followed patterns similar to the N, dry mass and organic matter losses (Fig. 3).

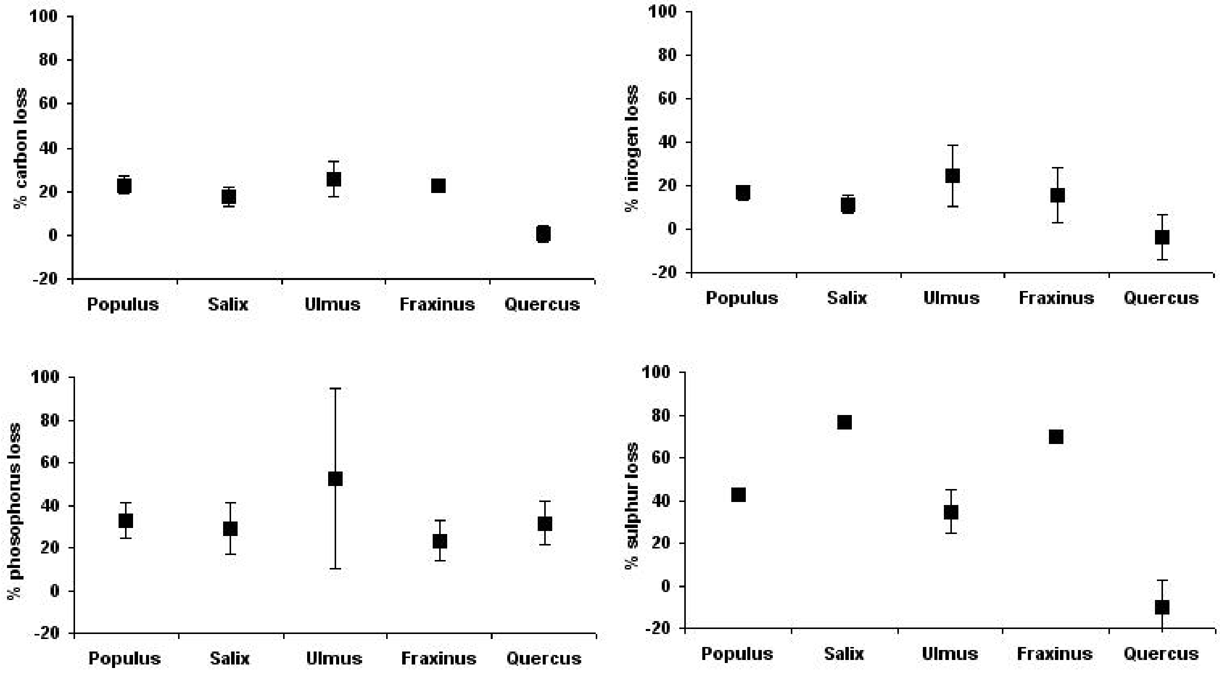

Figure 3. *The amount of C, N, P, S leached out from different leaf litter types within 48 h. Means ± 1SE, n=3.*

Substantial quantities of C, N, P and S were lost from the different leaf litter species during the leaching period (C: 18-26%, N: 11-24%, P: 23-52% and S: 34-77%) (Fig. 3), except of the oak leaf litter, where the C loss (0.8%) was significantly ($p<0.05$) lower as compared to the other leaf species, and on which N and S immobilization occurred. The decreasing order in the amount of nutrient released was: elm>poplar>oak>willow>ash for P and elm>poplar>ash>willow for N.

Accoring to Xiong & Nilsson (1997) the leaching period lasts from one day to a few weeks (regardless of leaf litter type), however several authors suggested that the leaching of soluble substances occurs within the first 24-48 hours of decomposition (Gessner & Schwoerbel 1989, Poppe et al. 1999, Bärlocher 2005); our leaching rates for 48 h are comparable with the results of other studies e.g. the percentage of N released from *Populus* leaf litter (17%) was similar to the results of Andersen & Nelson (2006), who found that *Populus* leaves lost 20% of their N content through leaching (within the first 24 h) and have an important role in the floodplain nitrogen dynamics. The nutrients derived from leaves have the potential to influence the ecosystem processes (Friberg & Winterbourn 1996).

3.4 Influence of the initial litter quality on the leaching

The initial C:N, C:P, N:P ratios of the different leaf litter types varied significantly ($p<0.05$) Table 2. The amount of dry mass lost was interrelated with the initial C:P, N:P ratio and with the amount of organic matter of the initial leaf litter, while the C:N ratio which varied from 22 in *Fraxinus* to 65 in *Populus* did not show any correlation with the amount of dry mass and organic matter washed out (Table 3). The ranges of C:N ratio (22-65) obtained in this study were similar with the ranges (20-60) reported by Chauvet (1997) for deciduous forest tree species.

Table 2. *Chemical characteristics (C, N, S, P concentrations) and quality indices (C:N, C:P, N:P molar ratio) of the initial litter. Means ± 1SE, n=3.*

	***Populus* hybrids**		***Salix alba***		***Ulmus laevis***		***Fraxinus excelsior***		***Quercus robur***	
	mean	*SE*	**mean**	*SE*	**mean**	*SE*	**mean**	*SE*	**mean**	*SE*
C [%]	**47.27**	*0.32*	**47.57**	*1.15*	**46.31**	*0.19*	**49.11**	*2.43*	**47.88**	*0.50*
N [%]	**0.85**	*0.02*	**1.97**	*0.11*	**1.21**	*0.02*	**2.66**	*0.53*	**1.40**	*0.03*
S [%]	**0.17**	*0.10*	**0.54**	*0.08*	**0.12**	*0.00*	**0.56**	*0.01*	**0.09**	*0.02*
P [%]	**0.06**	*0.01*	**0.12**	*0.01*	**0.07**	*0.01*	**0.12**	*0.01*	**0.16**	*0.03*
C:N	**64.77**	*1.09*	**28.13**	*0.85*	**44.56**	*0.51*	**21.95**	*2.99*	**39.97**	*0.56*
C:P	**2168.54**	*303.65*	**997.88**	*111.36*	**1729.00**	*375.83*	**1095.43**	*66.19*	**777.25**	*123.45*
N:P	**33.48**	*4.68*	**35.54**	*4.73*	**38.75**	*7.96*	**50.82**	*10.07*	**19.45**	*3.16*

Table 3. *Pearsons's correlations between the amounts of organic matter (OM), dry mass (DM) leached out and the initial leaf litter quality indices (C:N, C:P, N:P molar ratio) (p<0.05)*

	N:P	**C:N**	**C:P**	**DM**	**OM**
N:P	**1.00**				
C:N	**-0.39**	**1.00**			
C:P	**0.28**	**0.75**	**1.00**		
DM	**0.51**	**0.03**	**0.41**	**1.00**	
OM	**0.39**	**0.18**	**0.50**	**0.96**	**1.00**

Some studies define leaching mainly as an abiotic process (Bärlocher 2005), however biotic processes may also play a role in this initial phase of decomposition. The correlation of dry mass and organic matter with the initial C:P and N:P ratio suggests that the initial leaf litter quality influences the leaching phase of the decomposition and the biological processes in addition to physico-chemical processes. Microbial conditioning of leaf litter could be the reason for N and S immobilization in the oak leaf litter. Another explanation of the accumulation of these elements in the decomposing oak leaves may be that they are bound in complex insoluble molecules such as lignin.

4 Conclusions

In their initial decomposition phase the examined leaf litter species (*Populus, Salix, Ulmus, Fraxinus, Quercus*) contributed in different degree to the allochthonous nutrient input of the Danube side arm. Leaf species affects ecosystem functions such as nutrient cycling through their chemical composition. The differences in the amount of dry mass and nutrients released may be accounted for the differences in the initial leaf litter structure and quality. Our results may contribute to understand the interaction between the river and its floodplain, especially the contribution of the forested floodplain vegetation to the nutrient dynamics of the river and provide data for the management to optimize the maintenance of the river and its floodplains.

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