EFFECT OF *PHRAGMITES AUSTRALIS* ON SOIL PROCESSES IN HORIZONTAL SUBSURFACE FLOW CONSTRUCTED WETLAND

T. Ozimek, P. Maszczyk

Department of Hydrobiology, University of Warsaw, Banacha 2, 02-097 Warszawa, Poland

ABSTRACT

The constructed wetlands with subsurface flow consist of shallow basins with a seepage barrier. Their beds were filled with gravel and sand, and vegetation was planted in the media.

The material of the bed was mineral at the beginning of operations, while the main sources of the particulate organic matter accumulated in the beds have been plants, and suspended solids from sewage.

The aim of the investigations was to determine the importance of reeds as regards the budget for particulate organic matter in the media beds. The level of accumulation of reed material is taken to depend on its biomass production, plus the mortality and rate of decomposition of dead shoots. Deadreed material can be divided into stalks that remain standing and fallen litter.

The seasonal effects of biomass of biomass production were investigated in the constructed wetland in Nowa Słupia (Central Poland), between March 2005 and June 2006. Decomposition rate was determined by reference to litter-bag experiments in the field and the laboratory.

Despite 10 years with high levels of production of reeds, the level of accumulation of matter in beds has been low, due on account of the rate of decomposition being high. Indeed, the stems and leaves of *Phragmites australis* decomposer faster in CW than in natural ones.

KEYWORDS

Constructed wetlands; decomposition; organic matter; *Phragmites australis*.

INTRODUCTION

Plants have long been recognized as key regulators of soil formation (Jenny, 1941). Species produce soil through the build up of organic matter and plant species influence soil structure, weight, density and thickness of soil horizons. Plant species can have large effects on the physical structure and chemical properties of soil (Gliński and Lipiec, 1990). *Phragmites australis* is a highly productive semi-aquatic plant. Common reed is widely distributed in natural wetlands and it is one of the most often using species in subsurface flow constructed wetlands. At the beginning of operation such CW the substrate of beds is mineral (gravel and sand). Reed biomass is the main source of particular organic matter. Reed litter is an important source of humic substances and creation soil in wetlands (Balogh et.al., 2006).

The aim of the investigations was to determine the importance of reeds as regards the budget for particulate organic matter in media beds. The level of accumulation of reed material is taken to depend on its biomass production, mortality and rate of decomposition of dead shoots, standing dead shoots and fallen litter.

According to model of Wetzel (2001) reed biomass increases with increasing of habitat fertility. Accumulation of organic matter and an anaerobic substrate is typical for wetlands dominated by *P. australis* (Asaeda *et al.*, 2002). Most of reed biomass remains ungrazed and enters to detritus system (Westlake et. al., 1998). In natural wetlands dominates by *P. australis* more than 50% of deposition is organic due to the decomposition rate of reed litter is very low (Gessner, 2000). In constructed wetlands supplied by westewater biomass of common reed is higher than natural stands (Ozimek, 1999, Motel, 2003). Assuming that in constructed wetlands during 10 years subsequently accumulating matter deposition should be very high.

Our working hypothesis was – despite 10 years with high levels of biomass production, the level of accumulation of matter in reed beds has been low, due on account that the rate of decomposition being high. Our work describes the growth of *P. australis*, the collapse of standing dead shoot and decomposition of leaves and stems in subsurface flow CW in Nowa Słupia (Central Poland). In Poland the greatest number of CW are subsurface flow with *P. australis* and they are mainly applied as the second biological stages in sewage treatment (Ozimek and Czupryński, 2003). Results of our investigations being a part of project on "Long-term changes in *P. australis* population and substrate of CW" can help to improvement CW ecotechnology.

AREA DESCRIPTION

The sub-surface flow constructed wetland in Nowa Słupia is an example of the most common type of constructed wetland in Poland. The wetland was constructed in 1995 in order to treat municipal wastewater. The wetland consists of three parallel gravel beds (78m x 24m x 1.2m each) overgrown with common reed (*P. australis*). A sedimentation pond and aeration thank provide preliminary treatment. The first time above ground biomass of reed was harvested and removed from all beds in February 2004, and this operation was repeated only on bed III in February 2005.

The beds were inundated twice per month and wastewater of deep 1-10 cm stagnant on surface about week. Litter was altering wetting and drying.

METHODS

W March 2004 nine frames of 0.25 m^2 were established on each bed for density investigation. One a month from March 2005 to June 2006, the density of shoots (standing dead and live) was measured in frames and 100 shoots were randomly collected on each bed. Shoots were separated into leaves and stems and weight after drying for 24 h at 105°C in laboratory.

The decomposition of leaf and stems litter of reed (*P. australis*) was measured in the field by a litter bag method and in laboratory. Standing dead leaf and stem were collected in autumn placed into (5 mm) coarses mesh bag so that air, water, and decomposing organisms can be exchanged. Each bag contained 10g dead material. 35 bags with dead leaves and 35 with dead stems were staked to the ground at various locations (chosen at random) within the beds at April 2005. Litter were sampled after 1, 3, 4,6 8, 12 and 14 months and analysed litter mass loss (5 replicates). In laboratory the decomposition rate of litter leaves and stems was conducted in thermostat with changing temperature according data from autumn 2005 in the field. The decomposition rate coefficient , k, is calculated from the exponential decay formula: $k = \ln(x/x_0)/t$, where x is the dry weight of litter initially present and x is the dry weight of litter remaining at the end of the measurement's period, t is the duration time of the experiment.

Temperature in substrate on 2 cm deep and temperature of air was measured daily from March 2005 to June 2006 and frequency of inundation.

RESULTS

Phragmites australis in CW had the basic growth pattern. On all beds the aerial shoots emerged in May in both year (2005 and 2006) and grow rapidly. Their maximal rate of growth in weight (of 0.07g/g/d) was noted between the May and June. Shoots weight was achieved maximum in August on beds I and II and in September on the bed III. (Fig.1a). The differences of maximal dry weight of individual shoots were not statistically significant between beds. The data were examined statistically using ANOVA followed by Tukey's t-test. The level of significance was set to $P<0.05$.

The leaf weight ratio was the highest in August – September. Losses of leaves lead to a decline in weight shoots, at over 30% between September and November. In autumn shoots started to die rapidly. The mean dry weight of individual shoot developed in 2005 was relatively constant until to summer next 2006 year. "Shoots 2004" decreased ca. 70 % in weight during 15 months from March 2005 to June 2006 (Fig.1a). The first flush of shoots had emerged during May and achieved maximal density in June. The density in summer was quite stable. The highest density of shoots were noted on bed III. On this bed the reed biomass was removed twice in 2004 and 2005. The proportion of standing live and dead plants varies seasonally. From spring to autumn live and dead standing shoots existed together, from autumn to late spring only standing dead shoot were noted. The biomass of dead "plants 2004" in the next years decreased successively per m^2 (Fig.1b). At the same time the litter of different age supply the bed substrate.

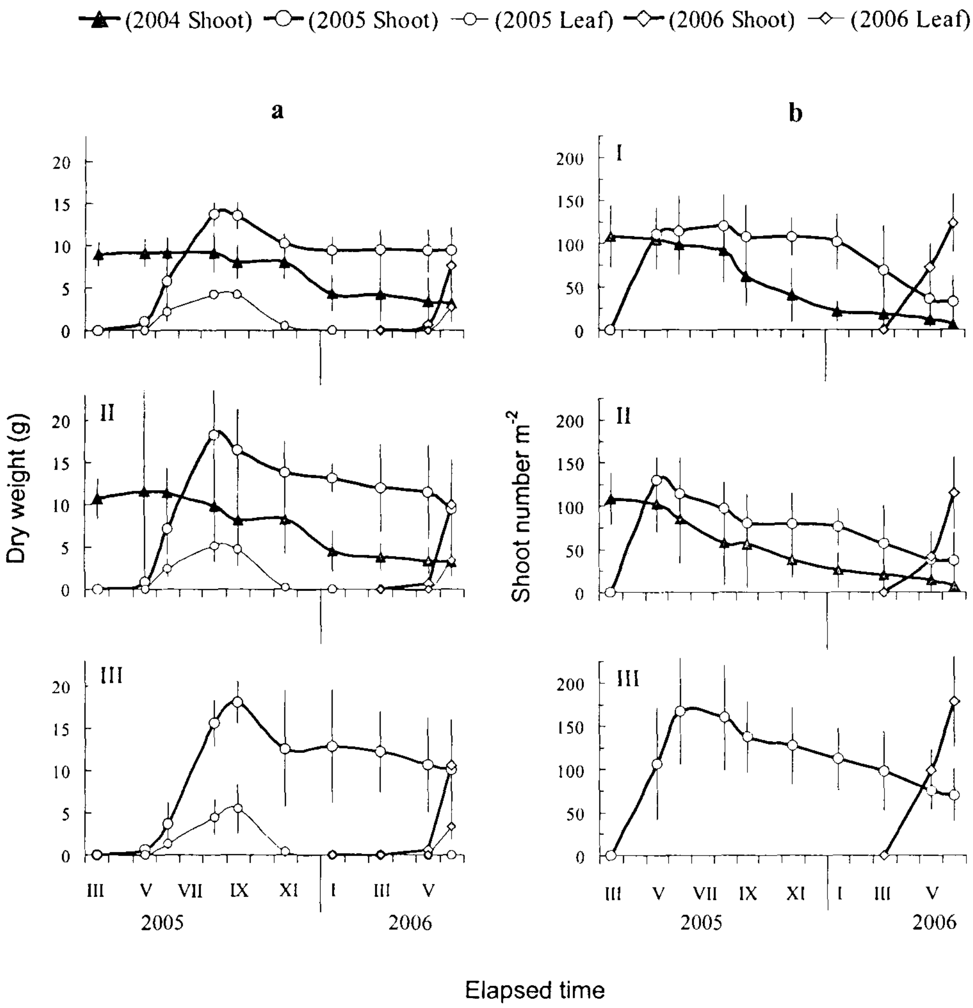

Figure 1. Seasonal changes of stem and leaf dry weight of individual shoots (mean ± SD, n=100) and density of shoots (mean ± SD, n=9) in CW in Nowa Słupia (Poland

The highest standing crop was noted on bed III, but it was no statistically significant in comparison with beds I and II (Fig. 2).

In the field the initial weight loss of decomposing litter was very fast. Decomposition coefficient was the highest in spring (Table 1) and it caused mostly by leaching of soluble components. The mean annual decomposition coefficient was ranged from 1.44 for stem to 1.9 for leaf.

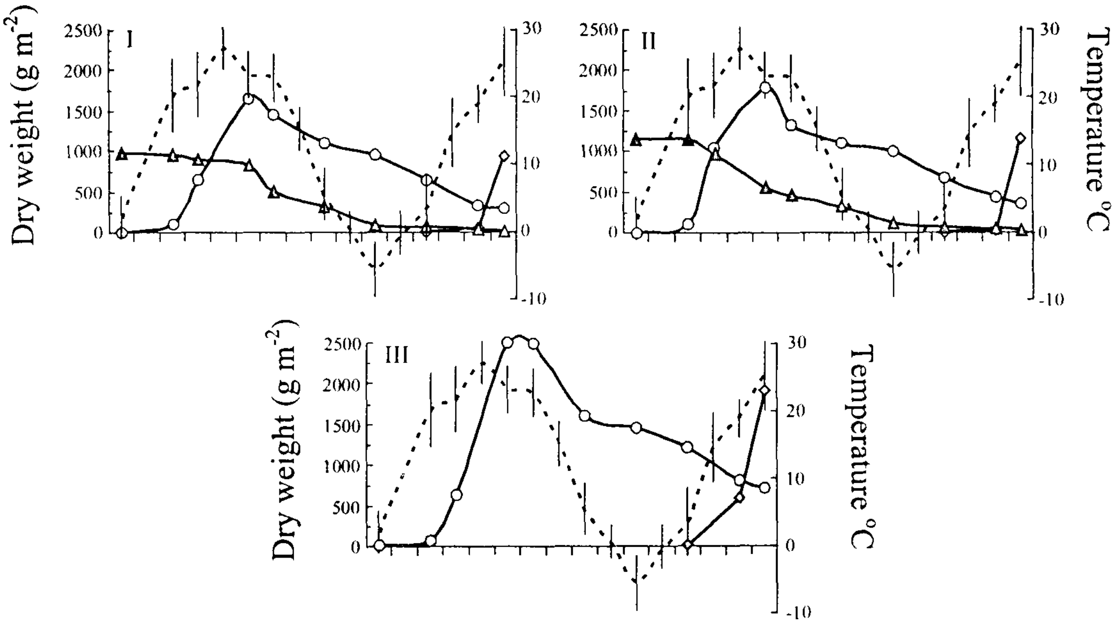

Figure 2. Seasonal changes of mean biomass of *P. australis* on reed beds (I, II,III) in constructed wetland in Nowa Słupia (Poland). (explanation of curves - see Fig. 1)

Table 1. The annual changes in daily decomposition coefficient of reed stem and leaf in litter bags field experiment (Nowa Słupia, Poland, May 2005 – June 2006)

Period	Daily decomposition coefficient	
	stem	leaf
May - June 2005	0.0190	0.0260
June – August 2005	0.0070	0.0130
August – September 2005	0.0005	0.0030
September – November	0.0005	0.0030
November 2005 – April 2006	0.0005	0.0004
April 2006 – June 2006	0.0080	0.0100

During spring and summer the litter bags were occupied by detritivorus macroinvertebrates - *Eristalis sp.* (*Symulidae*), *Ochthera mantis* (*Ephydridae*), *Lumbricidae*, and macroinvertebrate predator *Hybomitra sp.* (*Tabanidae*).

The stem litter lost 76 %, and leaves 86% of the initial dry weight during 14 months of field experiment (Fig. 3A). In laboratory litter decomposition was conducted in temperature which was noted in field in period from October 2005 to June 2006.

The weight loss of decomposing litter was very low. After 6 months leaves lost only 20%, and stems 10% of initial weight due to low temperature. In this time content of organic matter in decomposing litter was the stable (Fig.3B and C).

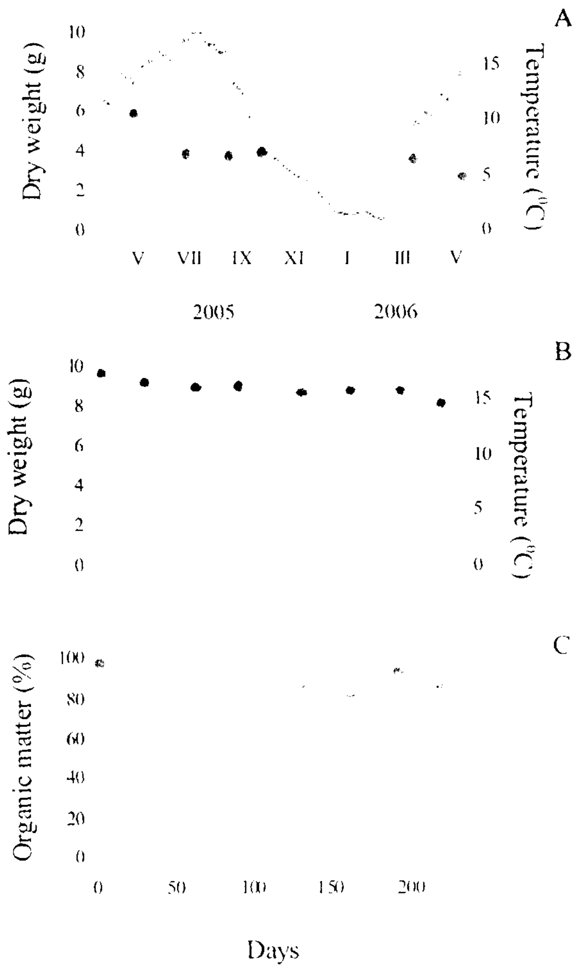

Figure 3. Changes in dry weight of stem and leaf litter of *P. australis* during decomposition (A –litter bags field experiment, B and C – laboratory experiment)

DISCUSSION

The maximal biomass achieved on the reed beds in Nowa Słupia was higher than in many natural stands and over double the values noted for the littoral of eutrophic lakes (Björk, 1967) and similar to biomass noted in others CW with reed in Poland (Ozimek, 1999). In successive years 2001 – 2005 the growth pattern and the maximal biomass were very similar on reed beds in Nowa Słupia (Motel, 2003; Zakrzewska, 2004). The reed was the main source of autochthonous organic matter. In course of year the main of organic matter support to substrate of bed had place in autumn when plants lost the leaves. The stems litter fall down in small portion during two years.

During 10 years 20 kg dry weight litter was fall down on m^2, theoretically this biomass should create ca. 50 cm layer. After 9 years of operation of CW in Nowa Słupia the layer of litter ranged only from 0.5 to 2 cm in reed beds (Zakrzewska, 2004) due to high decomposition rate. Flooding, its duration may influence decomposition in wetlands. Alternating wetting and drying results in higher respiration, mineralisation and litter disappearance. Most rapid decomposition rates occur with aerobic conditions under some optimum of wetting and drying regime (Asaeda *et al.*, 2002). In Nowa Słupia litter was alternating wetting and drying due to periodically inundation the beds.

During flooding of beds in upper layer of litter concentration of oxygen in wastewater increased from 2 to 4 mgO_2/l from spring to summer (Wachniew *et al.*, 2003).

Because decomposition increases with increasing oxygen and temperature (Asaeda et. al., 2002) decomposition rate of litter increased from spring to summer.

Alternations between aerobic and anaerobic conditions result in somewhat lower rates of decomposition and continuously anaerobic conditions in the lowest one (Asaeda *et al.*, 2002). Such conditions occurred in autumn and winter on beds of CW in Nowa Słupia). Bayo et. al (2005) concluded that in hypertrophic lagoon decomposition rate is significantly higher than in eutrophic one. Our results confirmed this conclusion.

CONCLUSIONS

1. Temperature is the chief controlling factor of decomposition rates in habitats well supplied with moisture and oxygen.
2. Periodically flooding of reed bed results higher litter disappearance.
3. Detritivorous macroinvertebrates accelerate litter decomposition in CW.

4. Decomposition of reed litter is higher in CW than in natural wetlands.
5. Due to high decomposition rate of reed litter fulfil of beds in CW is slower than it can be predict on the basis of data reed biomass production.

ACKNOWLEDGEMENTS

This study was supported financially by Ministry of Education and Science(project 2P04G 08428).

Special thanks to Anna Hankiewicz for her help in laboratory and Jarek Słoń for his help in field.

REFERENCES

Asaeda T., Nam L.H., Hietz P., Tanaka N. and Karunarante S. (2002). Seasonal fluctuations in live and dead biomass of *Phragmites australis* as describes by a growth and decomposition model: implications of duration of aerobic conditions for litter mineralization and sedimentation. Aquat. Bot. 73: 223-239.

Balogh K. V., Présing M., Vörös L and Tóth N. (2006). A study of the decomposition of reed (*Phragmites australis*) as a possible source of aquatic humic substances by measuring the natural abundance of stable carbon isotopes, Internat. Rev. Hydrobiol., 91: 15-28

Bayo M.M., Casas J.J. & Cruz-Pizarro L. (2005). Decomposition of submerged *Phragmites australis* leaf litter in two highly eutrophic Mediterranean coastal lagoons: relative contribution of microbial respiration and macroinverterate feeding, Arch. Hydrobiol., 163: (3) 349-367

Björk S. (1967). Ecologic investigations of *Phragmites communis*. Studies in theoretic and applied limnology. Folia Limnol. Scand., 14: 3-248.

Gessner M.O. (2000). Breakdown and nutrient dynamics of submerged *Phragmites* shoots in the littoral zone of a temperate hardwater lake. Aquat. Bot. 66: 9-20.

Gliński J., Lipiec J. (1990). Soil physical conditions and plants growth. Bocca Raton, FL: CRC. 250 pp.

Jenny H. (1941). Factors of soil formation. McGraw –Hill, New York 360 pp.

Motel P. (2003). Charakterystyka i rola trzciny *(Phragmites australis)* w oczyszczalni hydrofitowej w Nowej Słupii. Master Thesis. Uniwersytet Warszawski, 30 pp.

Ozimek T. (1999). Characteristic of *Phragmites australis* population after 4 years of operation hydrophyte wastewater plant in Darżlubie. Procc. International workshop.

Ozimek T., Czupryński P. (2003). Ten years's experience of constructed wetlands in Poland. Publi. Inst.Geogr. Univ. Tartuensis, 94: 201-204.

Wachniew P., Czupryński P., Chmura W., Małoszewski P., Nęcki J.M.. Ozimek T. and Zimnoch M. (2003). An assessment of the hydraulic properties and performance of a subsurface flow constructed wetland, Nowa Słupia, Poland. Publ.Inst.Geogr.Univ. Tartuensis 94: 205-208.

Westlake D.F., Kvet J. & Szczepański A. (1998). The production ecology of wetlands. The IBP synthesis. 1st edn.,Cambrdge University Press. 568 pp.

Wetzel R. G. 2001. Limnology. Lake and river ecosystems.3rd edn., New York, 006 pp.

Zakrzewska K. (2005). Rola *Phragmites australis* w tworzeniu osadów na poletkach trzcinowych oczysczalni hydrofitowej w Nowej Słupi. Master thesis, Uniwersytet Warszawski, 31 pp.