Available at www.sciencedirect.com

ScienceDirect

http://www.elsevier.com/locate/biombioe

# Wastewater and sewage sludge application to willows and poplars grown in lysimeters–Plant response and treatment efficiency

*I. Dimitriou**, *P. Aronsson*

*Department of Crop Production Ecology, Swedish University of Agricultural Sciences (SLU), Ecology building, P.O. Box 7043, SE 750 07 Uppsala, Sweden*

ARTICLE INFO

*Article history:*
Received 20 May 2009
Received in revised form
28 July 2010
Accepted 4 August 2010

*Keywords:*
Short-rotation coppice
Willow
Poplar
Wastewater
Sewage sludge
Sweden

ABSTRACT

Adding nutrient-rich residues such as municipal wastewater and sludge to willow and poplar short-rotation coppice gives more cost-effective and sustainable cultivation, but leaching to groundwater and disturbance to plant growth must be avoided. The effects of adding municipal wastewater irrigation to willows and poplars and sewage sludge to willows were compared in a two-year experiment. Wastewater irrigation enhanced plant growth. Near-zero nitrate-N concentrations occurred in drainage water when the root system of both species was well-established. The ability to retain N and P was satisfactory when poplars and willows were irrigated with wastewater. Thus relatively high additions of N and P with wastewater will probably not contaminate groundwater, but potential P leaching should not be underestimated. The same applies for sewage sludge applications to willow.



## 1. Introduction

Short-rotation coppice (SRC) of willow (*Salix* sp.) is a commercial crop currently cultivated on approx. 14 000 ha of agricultural land in Sweden to produce biomass for energy. Crop management is similar to that of an ordinary agricultural crop, with mechanised operations (weeding, planting, fertilisation, harvest), and the biomass harvested is used undried in the form of chips for heating and/or power generation plants for combined heat and electricity generation. After harvest the plants coppice vigorously and replanting is therefore not necessary.

For more cost-efficient and sustainable cultivation of SRC, it is necessary to fertilise and recycle minerals exported from the field at harvest. Therefore, the use of nutrient-rich residues as an alternative, cost-efficient fertilisation method was proposed from the early stages of willow SRC development and has been successfully practised in Sweden [1,2]. The main residues used for such practices in Sweden are municipal wastewater and mixtures of sewage sludge and wood-ash. A number of SRC fields are receiving wastewater [3] and approx. 80–90% of all SRC fields in Sweden have been fertilised with sludge (and wood-ash when available) (Lantmännen Agroenergi, personal communication). The benefits of such practices are both environmental and economic. The residues, which are considered more as resources than as wastes in this instance, are dealt with more cost-efficiently than in conventional treatments [4], and the nutrients contained in the residues are used as fertilisers to increase plant

* *Corresponding author*. Tel.: +46 18 672553 (Office)/+46 702474583 (Mobile); fax: +46 18 672890.
E-mail address: ioannis.dimitriou@vpe.slu.se (I. Dimitriou).
0961-9534/$ – see front matter 
doi:10.1016/j.biombioe.2010.08.019

production. The basic idea is to reduce the content of pollutants, nutrients or both in waste liquids and solids by plant uptake and by soil filtration and microbial transformation. The relatively high evapotranspiration rate of SRC willows [5] and the tolerance of their root systems to anaerobic conditions [6] make it possible to use high irrigation rates. Willows have been reported to take up substantial amounts of heavy metals (e.g. cadmium) in their shoots [7], and can therefore be beneficial for reducing the input of heavy metals in the system after stem harvest.

All the above-mentioned advantages of utilisation and treatment of wastewater and sewage sludge in SRC are valid only if sustainability is ensured and therefore i) high biomass production should be achieved (and consequently no plant growth disturbances due to the application), and ii) treatment efficiency should be high (in terms of minimal nutrient leaching to the groundwater). At the same time, the highest possible amounts of residue should be applied to SRC to reduce the usually large volumes available. In the present study, willows and poplars – the two species most commonly used for SRC – were grown in lysimeters in order to evaluate growth disturbances and leaching losses when the plants were irrigated with wastewater and supplied with sewage sludge. Lysimeter experiments allow easy calculation of water balance and are rather similar to field conditions. To evaluate the effect of plants on treatment efficiency, control lysimeters were left unplanted, while to 'stress' the SRC system comparatively high irrigation rates and sewage sludge doses were applied.

## 2. Materials and methods

### 2.1. *Lysimeter station*

The lysimeter station used for the experiments was established in 1988 at Ultuna, Uppsala, Sweden (59°49′N, 17°39′E). The mean annual temperature at the site is 5.5 °C and mean precipitation is 527 mm/yr. The lysimeters consist of cylindrical fibreglass containers with a cross-sectional area of 1.0 $m^2$ filled with soil. Each lysimeter is fitted with a polyethylene pipe at the base for collection of leachate (Fig. 1), which is diverted to an underground collection point. During spring 1989, half the containers were filled with Nåntuna sand (postglacial, alluvial sediment), which is a practically structureless soil, while the remainder were filled with Kungsängen gyttja clay (postglacial, alluvial sediment), which has a well-developed structure, with stable aggregates and permanent cracks down to at least 1 m depth. These soils were taken from nearby arable fields and their initial properties are shown in Table 1.

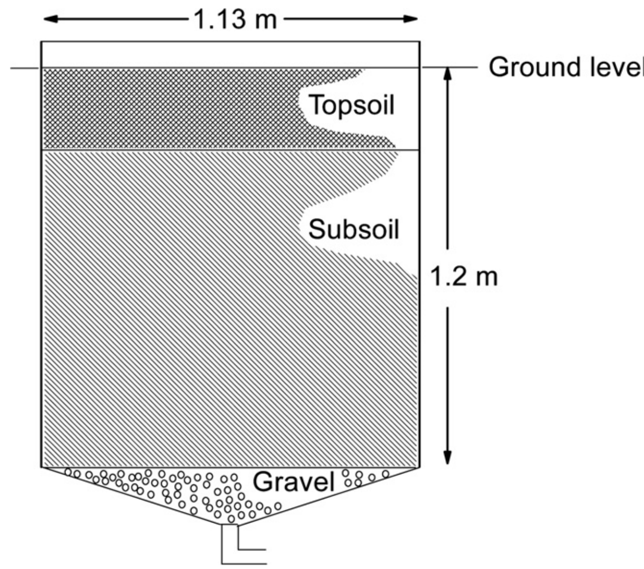


**Fig. 1 – Schematic diagram of a lysimeter installed in the belowground bunker at the lysimeter station.**

When the lysimeters were being filled, a layer of gravel was first placed in the funnel at the base. Subsoil and topsoil from the relevant field site were then added to re-establish soil profiles in the lysimeters. Soil layers approx. 0.2 m thick were carefully compressed to give a bulk density which resembled that at the site of the original soils as closely as possible. After installation, the soil profiles were allowed to settle for eight years, and no experiments were carried out until May 1997. Despite the disturbance during installation, the soil conditions were assumed to resemble those of undisturbed soils, although the major structural features of the clay soil probably still differed somewhat from those of the natural soil. On 23 May 1997, the weeds in the lysimeters were treated with glyphosate. After 1997, the lysimeters were used for several experiments [8,9]. A more detailed description of the lysimeter station can be found in these articles.

### 2.2. *Treatments and climate data*

Sixteen lysimeters (half filled with Nåntuna sand and half with Kungsängen clay) were used for this experiment. Each treatment was applied in two lysimeters of the same soil type ($n = 2$). In total, four lysimeters (2 clay + 2 sand) with willow

**Table 1 – Properties of the original arable soils used in the lysimeter experiments.**

| | | Clay content | Organic matter content | C/N Ratio | Water content (vol.-%) at tensions (cm) | | |
|---|---|---|---|---|---|---|---|
| | | (%) | (%) | | 5 | 100 | 15000 |
| Nåntuna | Topsoil | 8 | 1.3 | 11 | 43 | 18 | 3 |
| | Subsoil | 1 | 0.4 | 9 | 38 | 6 | 2 |
| Kungsängen | Topsoil | 45 | 3.5 | 11 | 54 | 48 | 21 |
| | Subsoil | 49 | 3.4 | 16 | 60 | 52 | 24 |