POPLAR VEGETATION FILTERS FOR THE BEER INDUSTRY: WASTEWATER TREATMENT COMBINED WITH BIOMASS PRODUCTION – Preliminary results

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ABSTRACT

The use of land application as a means for wastewater treatment dates back to the ancient Greek, and reached its peak during the 19th century, before being replaced for currently conventional treatment plants. A vegetation filter is a type of land application system in which a forestry plantation is irrigated with pre-treated or treated wastewater for its treatment. The main aim of this project is to assess the viability of a poplar short rotation coppice in terms of wastewater treatment, using wastewaters from a local brewery for irrigation. To test the adequacy of different poplar genotypes for this specific scenario, a hydroponic experiment was carried out. We evaluated several plant development parameters and analysed the quality of wastewater before and after its use on the system. Here we present the detailed methodology and some preliminary results, as well as the currently and ongoing research on this project.

Keywords: Vegetation Filter, Brewery Wastewater, Poplar, Phytoremediation, Nature-Based-Solutions

INTRODUCTION

The use of land application as a means for wastewater treatment dates back to the ancient Greek (Metcalf & Eddy, 2003). There are also examples of its use during the 16th and 17th centuries in Germany or Scotland (Hartman, 1972), but it reached its peak during the 19th century, when its application became an alternative to direct discharge to the rivers for health reasons (Jewell & Seabrock, 1979; Crites *et al*., 2006). Nevertheless, during the 20th century these systems were progressively abandoned and replaced by currently conventional systems, as a response to the massive city growth and the changes in magnitude of industrial activities (Metcalf & Eddy, 2003; Jewell & Seabrock, 1979), which would need enormous surfaces for water application. Nowadays, environmental concerns are on the rise, so the use of Land Application Systems (LAS) can be revaluated as an environmentally friendly purification system.

A vegetation filter (VF) is a type of LAS in which pre-treated or treated wastewater is used to irrigate a vegetated soil, usually a forestry plantation (De Miguel *et al*., 2014). The combined action of soil, vegetation and microorganisms treats water contaminants. Poplar plantation growing in a short rotation coppice (SRC) is a realistic alternative to obtain biomass in many countries in a bioeconomy context (Tallis *et al*., 2013). In Mediterranean conditions, watering is a necessary practice in cultivation, due to the marked summer drought (Sixto *et al.*, 2013).

The main aim of this project is to assess the viability and efficiency of a field-scale poplar SRC irrigated with wastewaters from the beer industry in terms of wastewater treatment. Specifically, this SRC will be installed in a local brewery, located in the northern part of the Community of Madrid (Fig. 1).

For irrigation, secondary wastewater coming from the brewery industry will be applied to the SRC, derived rightly after the anaerobic treatment in the factory's treatment plant. Hence, the VF would be a partial alternative to the aerobic treatment that is currently applied before the discharge to the Jarama River.

The first secondary aim of the project is to test the adequacy of different poplar genotypes to be grown with the wastewater coming from the brewery. To this end, a hydroponic experiment was carried out using the effluents from its secondary anaerobic treatment as our study wastewater.

Fig. 1. Aerial photo of the factory and their wastewater treatment plant. Green: Future Vegetation Filter emplacement. Source: Modified from PNOA.

MATERIALS AND METHOD

PLANT MATERIALS

Twenty genotypes belonging to different species and hybrids of the *Populus* genus and one of the *Salix* genus were tested. These were the following: *P. x euramericana* Dode (Gunier) ('I-214';'2000verde'; 'AF2'; 'AF8'; 'AF34'; Viriato'; 'Luisa Avanzo'; 'MC';' I-454/40'; 'Guardi'; 'Triplo'; 'Baldo; 'Branagesi' and 'Monviso'); *P. alba* L. ('GU 1 F21-29'; 'PO 9-F16-25'; 'PO 10-10-

20'; 'J 1-3-18' and 'S 18-F5-22') and *Salix x matsudana x ?* ('Levante'). Some of them are autochthonous, such as those belonging to *P. alba*. Among the hybrids, some were selected for biomass production and some for wood production.

For the study, unrooted cuttings of 30 cm long were selected from lignified one-year-old stems (Fig. 2).

EXPERIMENTAL DESIGN

The experiment was carried out in a greenhouse under controlled conditions (maxT: 25 ± 3ºC and minT: 10 ± 3ºC, humidity 65% and lighting 1000 µE m^{-2} s^{-1}).

Ten buckets with a capacity of 55 L were used. Five of them were filled up with the control solution (tap water with Naturamin (2.51 ml/l) and Naturmix (2 ml/l) to cover the nutrient needs of the plants) and the other five with the study wastewater (Fig. 3). In order to avoid biodegradation problems due to stagnation, 4.8 W pumps were incorporated to the buckets and water was renewed every two weeks.

Five replicates per treatment and genotype were randomly installed in the corresponding container, inserting the cuttings in a foam slab floating over the water level in order to fix the cuttings and to prevent them from rubbing the bucket's bottom or walls (Fig. 4).

Once the cuttings were established and the majority of them had developed roots, a single dominant shoot was selected per cutting for ease of comparison.

We evaluated different parameters, such as i) root emission, ii) sprouting capacity, iii) biweekly evolution of height, iv) biweekly evolution in the number of leaves, v) stem diameter evolution, vi) stomatic conductance and vii) photosynthesis rates.

Additionally, we also evaluated the assimilation and attenuation of nutrients (Total nitrogen, TN, and total phosphorous, TP) and other parameters in the wastewater, such as Chemical Oxygen Demand (COD), Biological Oxygen Demand (DBO_5) and Total Suspended Solids (TSS).

DATA ANALYSIS

Repeated Measures ANOVA one-way will be performed in order to assess the effect of the treatments on each of the growth, production and physiological variables. A post hoc Duncan test will be performed when statistical differences appear. For this, the statistical package Statgraphichs Centurium will be used.

VISUAL MEMORY AND PRELIMINARY RESULTS

Fig. 2. 30 cm long cutting being prepared from a lignified 1-year-old stem. Each cutting will be placed in a different bucket and will develop as a single tree.

PLANT DEVELOPMENT

As explained above, we considered several plant development parameters (root emission, sprouting capacity, biweekly evolution of height and biweekly evolution in the number of leaves). Nevertheless, the majority of this parameters is currently being measured and evaluated, with no solid results yet. Thus, here we only present the visual evaluation for root development.

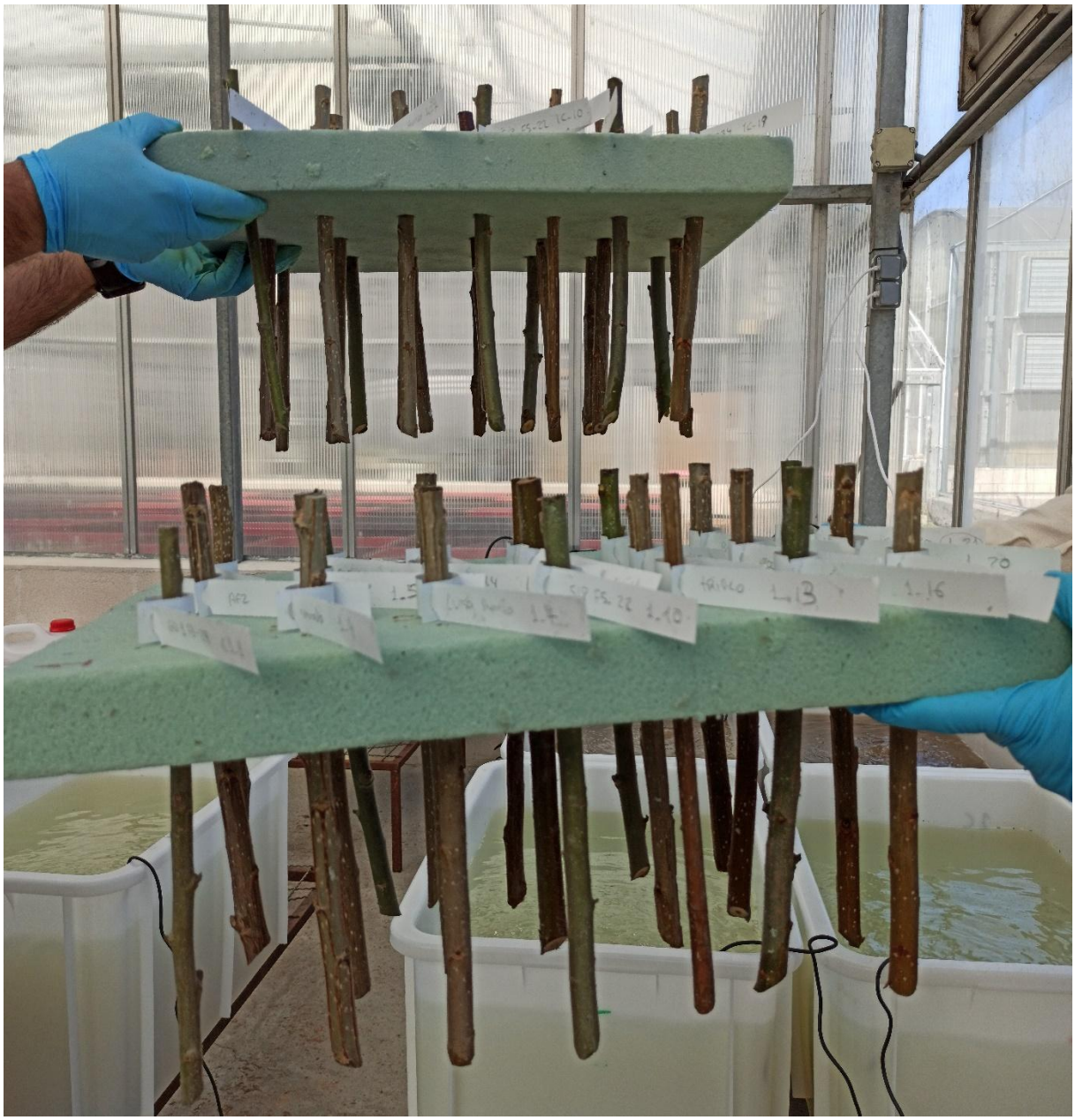
Fig. 3. Buckets being filled with wastewater. The foam slab with one cutting per genotype will be placed floating over the water level.

ROOT DEVELOPMENT

Roots are the most important factor in plant development, as they are the responsible for the nutrient uptake.

In our experiment, root development is being evaluated, grading from no presence of roots, through callus presence and opening callus presence to proper developed roots. Only in this final stage of development we consider the cuttings to be fully established.

Fig. 4. Cuttings placed in the foam slabs. Each cutting corresponds to one different genotype.



During the first weeks of the test, the genotypes belonging to the *Populus alba* species showed the first callus development. These cuttings showed a high proportion of callus, while the genotypes showed fewer callus per cutting during their growth.

The genotypes that, overall, showed the fastest developments were the willow genotype 'Levante', the *euramericana* hybrids '2000verde' and 'MC' and the white poplars 'J 1-3-18' and 'PO 9-F16-25'.

A month and a week after the experiment began, 81% of the total cuttings submerged in control water and 79% of those placed in wastewater had fully developed roots. Thus, there was no quantitative difference between the study group and the control group. Nevertheless, qualitative differences were found, as the roots systems in the control group showed better developments (Figs. 5 & 6).

Zero time (T_0) was then established in our experiment and the subaerial development started to be measured.

Fig. 5. Comparison in root development between the genotypes in wastewater (up) and in control (down) previous to the T_0. Developments showed in the control buckets showed qualitative better developments, although quantitative differences were not found.

WASTEWATER TREATMENT

Water analysis results are summarized in table 1. Samples are paired by date, the first one corresponds to the wastewater analysis right after being sampled from the factory and the second one the analysis after two weeks being used for the hydroponic tests. The results show fewer values for every main parameter after two weeks of residence time in the test, although they present different removal rates.

In terms of reduction percentages, SS show the best values (mean: 64.8%), followed by BOD (57.8%), COD (46.9%), TN (21.4% and TP (13.5%).

Fig. 6. Comparison in root development between the genotypes in wastewater (up) and in control (down) at T_{15}. Qualitative differences in roots development increased with time.

Nevertheless, further research is needed, as control tests using buckets in the same conditions that those in the study but with no cuttings are currently ongoing. This will clarify whether the reduction rates for the different parameters are related to the presence of the cuttings and their nutrients uptake or whether it responds to different mechanisms (volatilization, microbial activity, etc.).

Table 1. Water analysis values and reduction percentages between the influent and the effluent. Each sample is named after the date in which the water was sampled from the brewery. Samples are paired by date, being the first one (ARHE) the analysis right after sampling and the second (ARHS) after two weeks in the buckets.

Sample	TN (mg/L)	Reduct. (%)	TP (mg/L)	Reduct. (%)	COD (mg/L)	Reduct. (%)	SS (mg/L)	Reduct. (%)	BOD (mg/L)	Reduct. (%)
200311 ARHS	60		12.6		642		132.9		137.5	
200324 ARHE	91	24.2	17.4	17.2	1074	54.0	951.4	88.3	345	68.1
200324 ARHS	69		14.4		494		111.3		110	
200407 ARHE	83	10.8	17.4	5.7	846	36.2	362.1	55.4	260	48.1
200407 ARHS	74		16.4		540		161.6		135	
200421 ARHE	73	16.4	12.4	8.1	898	40.1	488.7	42.5	330	50.0
200421 ARHS	61		11.4		538		281		165	
200505 ARHE	102	34.3	18.2	23.1	1424	57.4	931	73.0	427	64.9
200505 ARHE	67		14		606		251		150	
200519 ARHE	80		20.6		1598		1251		760	

CURRENT AND ONGOING RESEARCH

Further research is currently ongoing. Differences in wastewater quality with and without the presence of plant genotypes are being tested, while water residence time in the buckets have been reduced, changing the water input once a week, in order to get more analysis and to establish better conditions for plant survival and growth.

Other plant parameters are currently being measured (stem diameter evolution, stomatic conductance, photosynthesis rates…) or will be measured by the end of the trial, such as the final basal diameter, the different biomass fractions (root, foliar and woody) or gas exchange parameters.

Future research on this project will consist in the study of the relationships between the wastewater and the soil, as it represents another key parameter in a Vegetation Filter. To this end, we are currently designing column tests, in which we will sample the soil from the VF future emplacement. Hydraulic dynamics will be tested and then we will evaluate the nutrients removal rates in different scenarios, testing different residence times and C/N ratios in the soil, by adding different amount of carbon-rich amendments. Additionally, we will also test the effect, in terms of nitrogen removal, of porous materials with high specific surface that enhance microbial activity, as a potential amendment to apply in the field.

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