**EFFECTS OF PULP AND PAPER MILL WASTE WATER ON HYBRID *Eucalyptus* CLONE GROWTH**

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## SUMMARY

The direct use of sewage from pulp and paper mills as irrigation water is appealing as a disposal system, but information is lacking on the nutritional and biological impacts on plant growth and soil fertility. A field trial was carried out at VCP Forest Research Unit to evaluate the effects of pulp and paper mill sewage water on *Eucalyptus* clone growth and some soil characteristics. The experiment used a completely randomized design with 5 replications of 4 levels of sewage mixed into irrigation water (from 100% water to 100% effluent). Each plot was represented by one seedling of *Eucalyptus* planted in a 5L pot filled with sandy clay soil. Two liters of each treatment solution were applied every two days. Plant growth and the soil characteristics were evaluated three months after the transplanting. There were no statistical difference between treatments for stem diameter, plant height, and mass dry weight. The application of waste water in irrigation water reduced the nitrogen, potassium, magnesium and manganese partitioning to leaves, and sodium concentration increased. The waste water solution increased soil pH, $Ca^{2+}$, $Mg^{2+}$, sum of base, BS% and organic matter content; and decreased $Al^{3+}$ and $Al^{3+}$+H concentration in the soil. No effects were evident on soil physical properties.

## INTRODUCTION

A high volume of water is required in the pulp and paper mills, generating large amounts of sewage rich in nutrients (particularly potassium and calcium). The direct use of this sewage as irrigation water would be a useful disposal system RESENDE et al (2000), but a lack of balanced nutrients in the solution could affect plant growth and soil fertility. Fertilization is promising, but more studies are needed on the fate of irrigated water, salt, nitrogen and other nutrients across a range of conditions of soils, climates, and crops (SNOW et al, 1999). High sodium concentrations in pulp and paper mill sewage could affect soils high in clay content, reducing water infiltration capacity (RESENDE et al, 2000). Special care is needed to design programs for the use of sewage in agriculture and forestry. Key issues include the sewage characteristics (chemical, physical and biological), impacts on soil and groundwater; optimal application regimes (amount, frequency, and homogeneity of application) and how applications relate to site characteristics (including distance from the mill), laws and social issues, and economics. Answers to these issues would lead to a next step with operational sewage application systems, including monitoring of soil and groundwater (GLORIA, 1992). The objective of this trial is to evaluate the effects of pulp and paper mill sewage water on *Eucalyptus* clone growth and some soil characteristics.

## MATERIALS AND METHODS

This field trial was carried out at VCP Forest Research Unit. The completely randomized experimental design used 5 replications and 4 treatments constitued by different proportions of sewage in the irrigation water (0%, 25%, 50% and 100%), Table 1. The sewage chemicals characteristics was analyzed at VCP Forest Chemical Lab for about one year, with one sample collected each week at the exit of the treatment section. Each plot was represented by one seedling of *Eucalyptus* which was planted in a 5L pot filled with sandy clay soil (25-35% of clay), and fertilized with 40g.pot$^{-1}$ 4-28-6+0,3%Cu+0,7%Zn. Two liters of each treatment solution were applied every two days.

Plant growth was assessed three months after planting by measuring stem length and diameter. Dry mass and chemical concentrations were determined for leaves, braches and roots. Soil chemical parameters were also evaluated: pH, P, $K^{+}$, $Ca^{2+}$, $Mg^{2+}$, sum of base cations, $Al^{3+}$, $Al^{3+}H^{+}$, cation exchange capacity (CEC, sum of base cations), base saturation and organic matter. Finally physical features of the soil were evaluated.

Table 1 – Experimental treatments description.

| **Treatment** | **Sewage** | **Water** |
|---|---|---|
| | (%) | |
| 1 | 0 | 100 |
| 2 | 50 | 50 |
| 3 | 75 | 75 |
| 4 | 100 | 0 |

## RESULTS AND DISCUSSION

### SEWAGE WATER CHEMICAL CHARACTERISTICS

The average of nutrients concentration on sewage were 3.45, 0.41, 11.30, 49.17, 2.54, 31.33, 0.45 and 240.92 ppm to N, P, K, Ca, Mg, S, B and Na, respectively. However, these nutrients changed sharply during the year (Table 2), with coefficients of variation of 20% for sodium and 96% for phosphorus. This variation results from changes of pulp and processing during the year. Nitrogen and sodium are of greatest concern, as they may impair groundwater quality (N) and soil water infiltration capacity (Na) and it could be a difficult its application on soil. HOWE

AND WAGNER (1996a) and HOWE AND WAGNER (1996b), found much higher values for Ca, Mg and Na in pulp mill wastewater when compared to present study, about 108, 22.7 and 422 ppm, respectively. It could indicate efficiency of VCP pulp and paper mill process and wastewater treatment.

Table 2 – Sewage nutrient concentration. Samples collected and analyzed every week during a year.

| | nutrient concentration (mg . $L^{-1}$) | | | |
|---|---|---|---|---|
| | Average | minimum | maximum | CV (%) |
| N | 3,45 | 1,35 | 6,70 | 31 |
| P | 0,41 | 0,08 | 1,77 | 96 |
| K | 11,30 | 1,20 | 27,00 | 38 |
| Ca | 49,17 | 28,60 | 77,40 | 23 |
| Mg | 2,54 | 1,00 | 4,10 | 25 |
| S | 31,33 | 7,33 | 54,38 | 45 |
| B | 0,45 | 0,26 | 0,70 | 27 |
| Na | 240,92 | 127,00 | 360,00 | 20 |

**EUCALYPTUS GROWTH**

There were no statistical difference between treatments for stem diameter, plant height, and leaves, branches, roots and total biomass dry weight (Table 3). However, there was slight tendency for treatments to increase values, and these increases might have been significant if the experiment lasted longer. Similar results were obtained by HOWE AND WAGNER (1996) where no negative effects were observed when waste water from a pulp mill was applied as irrigation to Populus for six months. Sewage water nutrients, such as N, P, K, Ca, S and B, may benefit *Eucalyptus* growth (MALAVOLTA et al, 1997) reducing any negative effect of high Na. According to SILVEIRA et al (2001), the total nutrient accumulation in Eucalyptus aerial part follow this way N>Ca>K>S>Mg>P, showing the need of these elements to growth.

Table 3 – Eucalyptus growth and dry mass under different proportions of sewage in the irrigation water after three months of planting.

| Treatment | Height | | diameter | | leaves | | branches | | roots | | total biomass | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (cm) | | | | (g.$plant^{-1}$) | | | | | | | |
| 1 | 35.60 | a | 2.18 | a | 4.74 | a | 3.88 | a | 9.00 | a | 17.62 | a |
| 2 | 36.20 | a | 2.31 | a | 7.40 | a | 4.92 | a | 9.22 | a | 21.54 | a |
| 3 | 35.40 | a | 2.37 | a | 6.34 | a | 4.54 | a | 9.32 | a | 20.20 | a |
| 4 | 37.60 | a | 2.36 | a | 6.74 | a | 4.48 | a | 9.32 | a | 20.54 | a |
| $F_{treatment}$ | $0.20_{ns}$ | | $0.60_{ns}$ | | $1.98_{ns}$ | | $0.97_{ns}$ | | $0.21_{ns}$ | | $1.84_{ns}$ | |
| CV (%) | 12 | | 12 | | 34 | | 26 | | 8 | | 17.00 | |

Different letters within a column represent a significant difference among treatments at P<0,05; ns – non significant differences (P>0,05).

**EUCALYPTUS CHEMICAL CHARACTERISTICS**

The aplication of waste water on irrigation water reduced the N, K, Mg, S, Mn, Zn and Fe partitioning to leaves; also reduced N, P, K, Fe partitioning to branches and similary reduced

Mg, Cu, Mn partitioning, however increased B to roots (Table 4-9). Concentrations of sodium increased with increasing rates of sewage water addition, with the highest amount in the leaves (2400-7000 $mg.kg^{-1}$), followed by roots (800-4000 $mg.kg^{-1}$) and by branches (1300-2000 $mg.kg^{-1}$). Strong Na accumulation was not observed by HOWE AND WAGNER (1996), where organic amendments did not affect the concentration of Na in stem material.

The effect of high sodium may result from an imbalance with other nutrients (MALAVOLTA, 1997). The N partitioning on the leaves are in high levels, about twice, when compared to SILVEIRA et al (2001). However, the other nutrientes followed adequate levels according to same researcher. Visually there was no effects of Na or excessive N on the Eucalyptus plants.

Table 4 – Macronutrients concentration of Eucalyptus leaves under different proportions of sewage in the irrigation water after three months of planting.

| Treatment | N | P | K | Ca | Mg | S |
|---|---|---|---|---|---|---|
| | ($g.kg^{-1}$) | | | | | |
| 1 | 40.6a | 1.65a | 16.60a | 7.88a | 3.14a | 2.872a |
| 2 | 37.3b | 1.65a | 14.14b | 6.45a | 2.62ab | 2.152a |
| 3 | 37.2b | 1.69a | 13.34b | 6.84a | 2.78ab | 2.912a |
| 4 | 37.2b | 1.70a | 11.64b | 6.54a | 2.34b | 2.586a |
| $F_{treatment}$ | 7.62** | $0.22_{ns}$ | 11.57** | $2.87_{ns}$ | 8.23** | $0.61_{ns}$ |
| CV (%) | 6 | 7 | 15 | 15 | 15 | 43 |

Different letters within a column represent a significant difference among treatments at P<0,05; ns – non significant differences (P>0,05); ** highly significant differences (P<0,01).

Table 5 – Micronutrients concentration of Eucalyptus leaves under different proportions of sewage in the irrigation water after three months of planting.

| Treatment | B | Cu | Mn | Zn | Fe | Na |
|---|---|---|---|---|---|---|
| | ($mg.kg^{-1}$) | | | | | |
| 1 | 44.2a | 5.6a | 882.6a | 39.0a | 331.6a | 2367b |
| 2 | 39.6a | 6.4a | 690.0b | 30.6a | 226.8a | 6158a |
| 3 | 41.4a | 8.0a | 791.4ab | 32.0a | 246.4a | 6940a |
| 4 | 38.4a | 5.6a | 678.4b | 30.6a | 235.0a | 6778a |
| $F_{treatment}$ | $1.43_{ns}$ | $0.91_{ns}$ | 10.40** | $3.36_{ns}$ | $1.82_{ns}$ | 8.97** |
| CV (%) | 14 | 51 | 13 | 17 | 33 | 44 |

Different letters within a column represent a significant difference among treatments at P<0,05; ns – non significant differences (P>0,05); ** highly significant differences (P<0,01);* significant differences (P<0,05).

Table 6 – Macronutrients concentration of Eucalyptus branches under different proportions of sewage in the irrigation water after three months of planting.

| Treatment | N | P | K | Ca | Mg | S |
|---|---|---|---|---|---|---|
| | | | $(g.kg^{-1})$ | | | |
| 1 | 16.47a | 1.82a | 13.93a | 4.11a | 1.50a | 1.634a |
| 2 | 15.23a | 1.56a | 12.79ab | 4.17a | 1.48a | 1.298a |
| 3 | 16.18a | 1.68a | 13.19ab | 4.32a | 1.62a | 2.010a |
| 4 | 14.62a | 1.51a | 10.97b | 4.64a | 1.50a | 1.606a |
| $F_{treatment}$ | $1.45_{ns}$ | $0.94_{ns}$ | 5.11** | $0.90_{ns}$ | $1.02_{ns}$ | $0.75_{ns}$ |
| CV (%) | 11 | 21 | 13 | 15 | 9 | 43 |

Different letters within a column represent a significant difference among treatments at P<0,05; ns – non significant differences (P>0,05); ** highly significant differences (P<0,01).

Table 7 – Micronutrients concentration of Eucalyptus branches under different proportions of sewage in the irrigation water after three months of planting.

| Treatment | B | Cu | Mn | Zn | Fe | Na |
|---|---|---|---|---|---|---|
| | | | $(mg.kg^{-1})$ | | | |
| 1 | 16.8a | 8.4a | 307.6a | 47.6a | 127.6a | 934b |
| 2 | 17.2a | 9.4a | 294.8a | 43.6a | 86.4a | 1667b |
| 3 | 14.8a | 14.0a | 325.8a | 42.6a | 92.0a | 2228b |
| 4 | 17.0a | 8.4a | 314.2a | 41.2a | 110.0a | 4226a |
| $F_{treatment}$ | $0.51_{ns}$ | $0.99_{ns}$ | $0.35_{ns}$ | $1.37_{ns}$ | $1.47_{ns}$ | 11.87** |
| CV (%) | 20 | 65 | 14 | 11 | 33 | 67 |

Different letters within a column represent a significant difference among treatments at P<0,05; ns – non significant differences (P>0,05); ** highly significant differences (P<0,01).

Table 8 – Macronutrients concentration of Eucalyptus roots under different proportions of sewage in the irrigation water after three months of planting.

| Treatment | N | P | K | Ca | Mg | S |
|---|---|---|---|---|---|---|
| | | | $(g.kg^{-1})$ | | | |
| 1 | 16.73a | 1.18a | 8.70a | 3.09a | 1.20a | 1.99a |
| 2 | 14.74a | 1.10a | 9.93a | 2.70a | 0.93a | 2.56a |
| 3 | 17.40a | 1.24a | 9.80a | 2.79a | 0.96a | 1.60a |
| 4 | 15.61a | 1.12a | 9.51a | 3.16a | 1.00a | 1.63a |
| $F_{treatment}$ | $3.46_{ns}$ | $0.75_{ns}$ | $1.02_{ns}$ | $2.71_{ns}$ | $1.00_{ns}$ | $1.23_{ns}$ |
| CV (%) | 13 | 2 | 44 | 14 | 25 | 46 |

Different letters within a column represent a significant difference among treatments at P<0,05; ns – non significant differences (P>0,05).

Table 9 – Micronutrients concentration of Eucalyptus roots under different proportions of sewage in the irrigation water after three months of planting.

| Treatment | B | Cu | Mn | Mn | Fe | Na |
|---|---|---|---|---|---|---|
| | ($mg.kg^{-1}$) | | | | | |
| 1 | 29.4b | 22.4a | 91.6a | 51.8a | 3566.0a | 845b |
| 2 | 33.2b | 20.6a | 84.8a | 51.2a | 2998.4a | 1634ab |
| 3 | 35.4ab | 19.4a | 85.4a | 46.6a | 2423.8a | 2160ab |
| 4 | 47.8a | 18.0a | 81.4a | 53.6a | 2845.0a | 3394a |
| $F_{treatment}$ | 6.25** | $1.29_{ns}$ | $1.18_{ns}$ | $0.55_{ns}$ | $0.74_{ns}$ | 7.61** |
| CV (%) | 30 | 20 | 11 | 16 | 38 | 61 |

Different letters within a column represent a significant difference among treatments at P<0,05; ns – non significant differences (P>0,05); ** highly significant differences (P<0,01).

## SOIL CHEMICAL CHARACTERISTICS

The waste water solution increased soil pH, $Ca^{2+}$, $Mg^{2+}$, cation exchange capacity (sum of base cations), base saturationand organic matter content; and decreased $Al^{3+}$ and $Al^{3+}$+H concentration in the soil (Table 10).

No effects were observed on soil physical features such as texture (Table 11), perhaps as a result of the short period of the experiment. .

Table 10 – Soil chemical characteristics under different proportions of sewage in the irrigation water after three months of sewage aplication.

| Treatment | pH | P | $Ca^{2+}$ | $Mg^{2+}$ | $K^{+}$ | SB | $Al^{3+}$ | $Al^{+3}+H^{+}$ | CEC | BS% | OM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ($Ca Cl_2$) | ($mg.dm^{-3}$) | ($mmolc.dm^{-3}$) | | | | | | | | (g.kg-1) |
| | 4.18 | 65 | 4.34 | 2.48 | 4.56 | 11.38 | 3.76 | 42.62 | 54.00 | 21.0 | 18.06 |
| 1 | a | a | a | A | a | a | a | a | a | a | A |
| | 4.24 | 67 | 5.98 | 2.50 | 4.86 | 13.34 | 3.32 | 41.22 | 54.56 | 24.2 | 18.06 |
| 2 | ab | a | ab | A | a | ab | ab | ab | a | a | A |
| | 4.42 | 94 | 6.18 | 3.00 | 5.56 | 14.74 | 2.54 | 39.18 | 53.92 | 27.2 | 17.52 |
| 3 | bc | a | ab | A | a | ab | ab | bc | a | ab | A |
| | 4.46 | 69 | 9.34 | 3.16 | 5.22 | 17.72 | 2.16 | 36.94 | 54.66 | 32.2 | 17.82 |
| 4 | c | a | b | A | a | b | c | c | a | b | A |
| $F_{treatment}$ | 8.22 ** | 0.33 ns | 6.45 ** | 1.15 Ns | 0.54 ns | 4.01 ** | 7.23 ** | 12.61** | 0.07 ns | 6.67** | 0.37 Ns |
| CV (%) | 3.59 | 73.99 | 38.73 | 24.30 | 23.87 | 24.68 | 28.65 | 6.91 | 5.84 | 21.2 | 5.05 |

Different letters within a column represent a significant difference among treatments at P<0,05; ns – non significant differences (P>0,05); ** highly significant differences (P<0,01).

Table 11 – Soil physical characteristics under different proportions of sewage in the irrigation water after three months of sewage application.

| Treatment | Coarse sand | fine sand | total sand | Clay | silt |
|---|---|---|---|---|---|
| | | | (%) | | |
| 1 | 22.04a | 54.90a | 76.90a | 17.44a | 5.62a |
| 2 | 19.92a | 56.92a | 76.86a | 17.04a | 6.12a |
| 3 | 25.92a | 55.20a | 81.14a | 17.16a | 7.30a |
| 4 | 22.80a | 56.16a | 78.96a | 17.82a | 4.66a |
| $F_{treatment}$ | 1.16ns | 1.32ns | 0.78ns | 0.85ns | 1.19ns |
| CV (%) | 23.33 | 4.02 | 6.13 | 4.93 | 38.76 |

Different letters within a column represent a significant difference among treatments at P<0,05; ns – non significant differences (P>0,05).

## CONCLUSIONS AND RECOMMENDATIONS

- Using pulp and paper mil sewage water as Eucalyptus irrigation is adviced.
- More studies about Na effects on soil is needed.

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