New Pulping Technology and *Eucalyptus* Wood: The Role of Soil Fertility, Plant Nutrition and Wood Ion Content

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Introduction

Wood is the main source of raw material to the pulp and paper industry. Today, due to the environmental concerns, this industry is switching to cleaner and closed water cycle technologies. New chemicals such as hydrogen peroxide and ozone are being used in pulp bleaching. These chemicals are very sensitive to the presence of metal ion in the process. Iron and manganese have the ability to decompose peroxide and to influence the degradation of carbohydrates. Another move is to close water cycle. Effluent-free mill will soon be a reality. In this condition, most of the ions present in the wood are going to accumulate in mill process flows. Calcium, magnesium, potassium, aluminum may become problems to the manufacturing process because of scaling, fouling and final product contamination. These ions, except for aluminum, are essential to plant functions. Different *Eucalyptus* species and clones, growing in different sites, have different ion contents. The study of ion concentration in plant tissues has gained increased importance due to the fact of nutrient exports from the forest site. In order to guarantee the sustainability of site productivity, it is fundamental to know the amounts of nutrients which remain in the site and how much is exported in the wood and other forest products removed from the area. The most frequently evaluated nutrients both in tree tissues and in the soil are nitrogen, phophorus, potassium, calcium and magnesium.

Distribution of main nutrients in tree tissues

Nowadays, forestry management shall not discard nutrient balances which are important to help fertilizer recommendations and to estimate the amounts of nutrients removed from the site. Therefore, most of forestry-based companies are associated to, or have laboratories to evaluate soil fertility and plant nutrient composition.

In general, in this process, tree above-ground portion may be separated in individual parts as wood, bark, branches and leaves. Bark, branches and leaves are nutrient exporting components when they are used for purposes such as fuel. The use of biomass as source of energy is a common practice in Brazil. Forests are also planted with this purpose by most of pulp mills. There are exceptions, like Riocell, that obtains the required energy from other available fuel sources in the surroundings, leaving these tree components in the site, removing only the wood. Thus, a substantial amount of nutrients is not exported from the forest.

In Riocell, a partial nutrient balance sheet is estimated by evaluating:

- wood weight/ha;
- bark weight/ha;
- branches, leaves weight/ha;
- nutrient concentration in the different tissues;
- total amount of nutrients, stored in each of these tree compartments (example: total nitrogen in wood in kg N/ha; total potassium in leaves in kg K/ha, etc);
- available nutrient concentrations in the soil;
- total available nutrients in the soil in kg/ha.

Based on these data, it is possible to calculate the amount of each nutrient removed from the area and the nutritional efficiency for each nutrient. Different species and clones, growing in different sites have different performances. How many kg of wood is produced by each kg of nitrogen found in the same wood? Or in the above-ground portion? The same type of information may be searched for P, K, Ca, Mg, etc.

Therefore, it is possible to match species or clones to site according to soil fertility and plant nutritional requirement.

The knowledge of such features allows the forest manager to adopt techniques to maintain or to improve site productivity and justifies investments in this area.

Riocell is a pulp and paper mill located in South Brazil. Its main raw material is *Eucalyptus* wood to be converted by the kraft/antraquinone process. The main planted species are *Eucalyptus saligna*, *E. grandis*, *E. tereticornis*, *E. dunnii* and *E. globulus*. Clones are obtained from selected superior trees of pure species or by hybrids. The most important species till now are *E. saligna* and *E. grandis*. However, because of higher frost tolerance, higher wood density, lower lignin content and higher pulp yield, the company is increasing the area planted with *E. globulus* and *E. dunnii*.

Our purpose in this paper is to present some results obtained from *E. saligna*, and to discuss the impacts and relationships between plant nutritional behaviour and pulping/bleaching technologies.

Ranges of 7 year-old *Eucalyptus saligna* features in Riocell's clonal plantations.

• Mean tree stem volume:	0.20 - 0.35m³	**Mean tree dry weight**	
• Percent of bark in volume:	5.5 - 7.0%	Wood	80 - 180 kg
• Percent of bark in weight:	2.7 - 4.5%	Bark	3 - 10 kg
• Wood basic density:	0.45 - 0.55 g/cm³	Branches	7 - 30 kg
• Bark basic density:	0.23 - 0.28 g/cm³	Leaves	1.5 - 7 kg

Nitrogen concentration and content on tree components (based on dry weight).

	%	kg/t of dry matter	kg/ha
Wood	0.08 - 0.13	0.8 - 1.3	150 -300
Bark	0.30 - 0.45	3.0 - 4.5	20 - 40
Branches	0.25 - 0.35	2.5 - 3.5	40 - 80
Leaves	1.70 - 2.25	17.0 - 22.5	100 - 200

Phosphorus concentration and content on tree components (based on dry weight).

	%	kg/t of dry matter	kg/ha
Wood	0.008 - 0.012	0.08 - 0.12	15 - 80
Bark	0.05 - 0.15	0.5 - 1.5	2 - 10
Branches	0.03 - 0.05	0.3 - 0.5	2 - 10
Leaves	0.08 - 0.20	0.8 - 2.0	4 - 8

Potassium concentration and content on tree components (based on dry weight).

	%	kg/t of dry matter	kg/ha
Wood	0.08 - 0.20	0.8 - 2.0	150 - 450
Bark	0.25 - 0.85	2.5 - 8.5	15 - 80
Branches	0.35 - 0.80	3.5 - 8.0	20 - 100
Leaves	0.40 - 1.00	4.0 - 10.0	20 - 80

Calcium concentration and content on tree components (based on dry weight).

	%	kg/t of dry matter	kg/ha
Wood	0.015 - 0.120	0.15 - 1.20	30 - 200
Bark	2.5 - 4.5	25 - 45	50 - 200
Branches	0.4 - 0.9	4 - 9	40 - 150
Leaves	0.3 - 0.8	3 - 8	20 - 100

Magnesium concentration and content on tree components (based on dry weight).

	%	kg/t of dry matter	kg/ha
Wood	0.015 - 0.050	0.15 - 0.50	20 - 140
Bark	0.20 - 0.45	2.0 - 4.5	10 - 50
Branches	0.10 - 0.20	1.0 - 2.0	8 - 40
Leaves	0.25 - 0.35	2.5 - 3.5	5 - 30

Dry matter/ha (t/ha).

Wood	100 - 240
Total above-ground matter	130 - 300

Range of nutritional efficiency (kg wood/kg of nutrient in the wood)

Nitrogen	750 - 1500
Phosphorus	3000 - 20000
Potassium	500 - 1300
Calcium	1000 - 10000
Magnesium	2000 - 5000

Range of nutritional efficiency (kg above-ground dry matter / kg of nutrient in the above-ground portion).

Nitrogen	400 - 800
Phosphorus	2000 - 10000
Potassium	500 - 1000
Calcium	150 - 900
Magnesium	1500 - 2200

It is really amazing the amount and the range of variation of nutrients in the trees. Trees are living beings which have demands varying from one to another. Depending on the demands and on soil nutrient availability, tree bodies may be richer or poorer in the studied nutrient elements. Some trees become more efficient than others by manufacturing more dry matter per weight unit of nutrients. Such characteristics must be considered in breeding programs or in clonal propagation. Nutritional efficiency has to be regarded as a tree improvement parameter for upgrading the future forests.

Considering all projections for the new technologies in pulp manufacture, it is reasonable to state that water demands will be sharply reduced by closing the water cycle as much as possible.

Considering also that the mineral nutrients present in wood will necessarily be in the process, there is an enormous fear of ion accumulation and scaling up in the mill systems. These elements are soluble in the mill flow conditions and they will have increased concentrations in these flows. Non-process elements, like K^+, Ca^{++}, Mg^{++}, Cl^-, must be removed somewhere from the process. A possible alternative is to purge fly ashes from the electrostatic precipitators and to develop uses for them. Another possibility is to wash these ashes in a selective way, separating process elements (Na^+, $SO4^{--}$, etc), from the non-process ones. Also, filtration of liquors to remove precipitated salts are viable and growing technologies.

Just for illustration, in a modern 1000 t/d chemical pulp mill, a wood demand of about 2000 t will bring daily to the process the following amounts of nutrients:

- Nitrogen: 1600 - 2600 kg/day
- Phosphorus: 160 - 240 kg/day
- Potassium: 1600 - 4000 kg/day
- Calcium: 300 - 2400 kg/day
- Magnesium: 300 - 1000 kg/day

Other elements not considered in this study, but also fundamental to deserve further evaluation are chloride ion (Cl^-), silica and aluminum.

Micronutrients (Fe, Mn, Zn, Cu)

In general, micronutrients like iron, manganese, zinc and copper are available in the soil in small concentrations. However, in some special conditions they may become more available due to redox potential or due to soil parent-material composition. Manganese and iron easily go to the soil solution in anaerobic conditions, in other words, in flooded soils or in poor drained soils.

All these elements are essential to plants, although they are taken up in small quantities. When the concentration goes up in tree tissues, they are toxic and may cause damage, specially to the leaves.

Today, due to the development of new bleaching technologies in pulp manufacturing, these elements are becoming very important. They are "poisons" to hydrogen peroxide and ozone, bleaching chemicals used in total chlorine-free pulp bleaching sequences.

On the other hand, these elements are very tricky to evaluate. They require special training and equipment in laboratory conditions. Iron and copper are very often used in lab equipment and all care must be taken in the study. Contamination in wood sampling is also very common. Thus, attention in these operations is essential.

A wide evaluation on these elements was performed by Riocell, under different soil and climate conditions, using Merlich as extractor for soil and nitro-perchloric analysis for wood. The purpose was to analyse the range of variation and the possible correlation between content in the wood and extracted soil solution concentrations.

Samples were taken and after analysis, the results were in the following range:

	Wood (ppm)	Soil (ppm)
Iron	7 - 25	1 - 160
Manganese	2 - 100	0.1 - 150
Zinc	0.6 - 5	0.6 - 20
Copper	0.4 - 1.4	0.1 - 5.0

There were no significant correlations between soil availability of these four elements and their concentration in the wood. This is an indication that trees are very clever to remove them from the soil. Since they know they may be hurt in case of high concentrations in the tissue, they have developed mechanisms to control nutrient uptake to the required amounts. However, under extreme conditions these mechanisms may not work and plant toxicity and reduction in growth may be observed. Some trees remove more than others, and we may suspect they need more than others. In all cases, although the wide span, concentrations were far from toxic levels (at least in the wood).

Hints to the forester are to study heritability of these characteristics and to avoid planting eucalyptus in poor drained soils. First, because eucalyptus do not grow well on them. Second, because surface contamination of logs by mud containing iron and manganese is unavoidable. Another suggestion to the pulp maker using hydrogen peroxide and ozone is to improve as much as possible the washing of logs prior to chipping. Anyhow, this is a new world to be explored.

Fig 1. Iron in soil and iron in wood

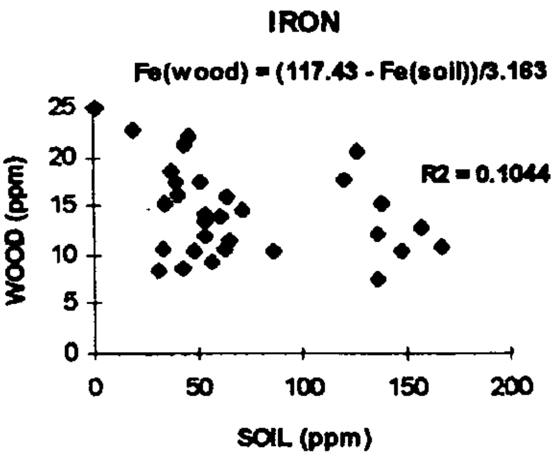

Fig 2. Manganese in soil and manganese in wood

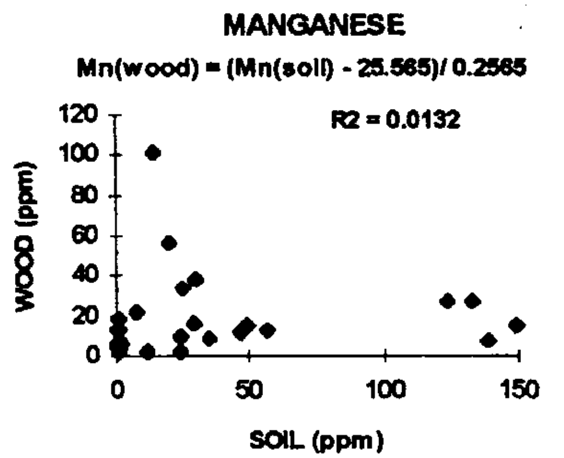

Fig 3. Zinc in soil and zinc in wood

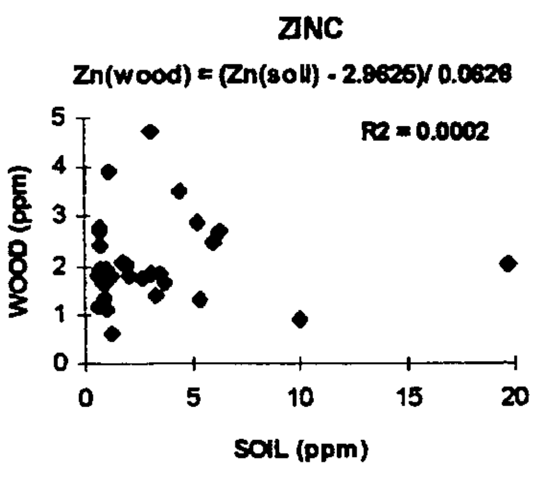

Fig 4. Copper in soil and copper in wood