Effects of potassium/sodium fertilization and water availability on wood properties of *Eucalyptus grandis* trees

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INTRODUCTION

In Brazil, most Eucalyptus plantations are located in regions experiencing periods of water shortage where fertilizers such as potassium (K) are intensively used to achieve high productivity. Recently, sodium (Na) has also been considered a potential nutrient in K deficient soils. K and Na supply can increase water stress in *Eucalyptus grandis* trees, which could impact negatively on forest productivity over prolonged droughts. Wood properties are also an important factor to consider in order to measure the impacts of silvicultural practices and water deficit on forest productivity, since they are determinants for quality and yield of pulp and paper. Wood formation in trees is a dynamic process that is strongly affected by environmental conditions, including nutrient availability. Thus, the application of silvicultural traits in changing environmental conditions has to consider the potential impacts on wood quality.

The aim was to evaluate the effects of K and Na fertilization under water reduction and non-water reduction conditions, on stem volume, heartwood proportion, basic density, fiber and vessel attributes, on *Eucalyptus grandis* trees at four and six years after planting.

We intend to answer:

How do additions of K and Na to tree fertilization affect tree wood properties?

How do the effects of K and Na supply on wood properties change under water deficit?

MATERIALS AND METHODS

The experiment was conducted at the Itatinga Experimental Station of the University of São Paulo, São Paulo, Brazil (Figure 1). Seedlings of a highly productive clone of *Eucalyptus grandis* were planted on June 20, 2010, spaced to 2 m × 3 m. At the time of planting, all plants were fertilized N, P, and micronutrients.

Three months after planting, two levels of water regime and three levels of fertilization were applied on the plantation in a split-plot design, producing six treatments (Figure 1):

- +K+W: Potassium (K) addition and no throughfall reduction
- +Na+W: Sodium (Na) addition and no throughfall reduction
- Nf+W: Without additional fertilizer supply and no throughfall reduction
- +K-37W: Potassium addition and 37% throughfall reduction
- +Na-37W: Sodium (Na) addition and 37% throughfall reduction
- Nf-37W: Without additional fertilizer supply and 37% throughfall reduction

Sampling was carried out at four and six years after planting. At each age, 48 trees were sampled (8 trees per treatment) distributed in eight diametric classes. From each tree, a log of 50 cm length was cut at breast height and then divided into several cross-sectional discs (variable thickness) for analysis of wood properties.

The stem volume inside bark was calculated by Smalian method. Wood basic density and heartwood/sapwood ratio was determinate in the whole transversal section. Fibers and vessels features were measured on the last growth ring representing the wood formed in the last year.

Mixed-effect models were used to test the effects of water regime, fertilization regime, stand age, and interaction water regime × fertilization, water supply × stand age, fertilization × stand age, water regime × fertilization × stand age (as fixed effects) on stem volume, heartwood proportion, wood basic density, and fiber and vessel properties. Blocks and water regime × blocks were considered as random effects.

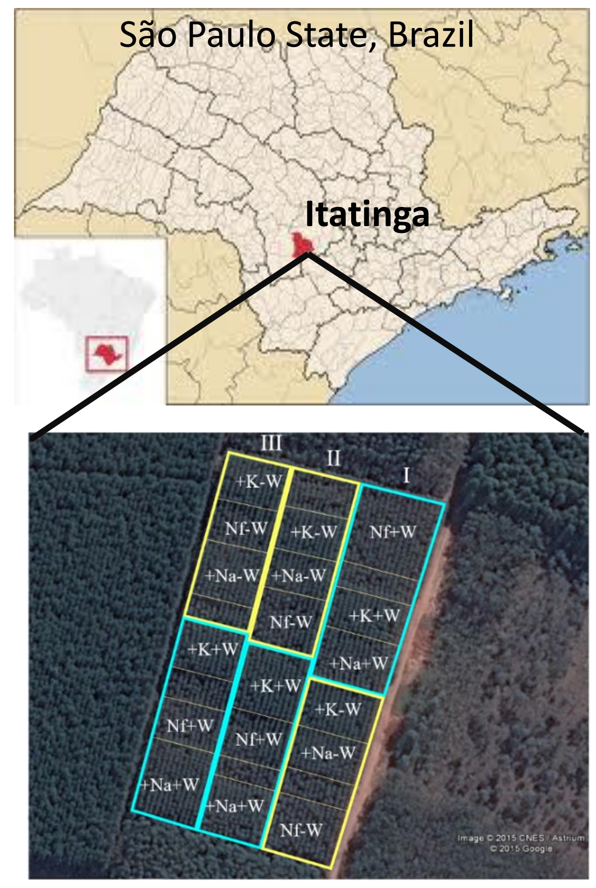

Figure 1. Localization of study area and experimental design, in Itatinga, São Paulo- Brazil

RESULTS

Non-significant interaction between water supply, fertilization regime, and stand age showed that the effects of treatments on stem volume and wood properties did not change over tree growth. In addition, the non-significant interaction between water supply and fertilization regime indicate that effects of K and Na supply on wood properties did not change significantly under lower water availability (Table 1).

K and Na increased significantly stem volume by three and two-fold respectively, however, it generally decreased sapwood proportion. Wood basic density was affected detrimentally only by Na. Effects of fertilizers on stem volume were stronger at older ages (Figure 2).

The reduction on wood density was significantly higher under Na fertilization than under K fertilization, mainly under normal water availability.

Respect to fibers features, fertilization regimes affected significantly only fiber length, which increased significantly under K and Na fertilization at each annual growth ring, regardless of water availability (Figure 3). In all treatments, the length and diameter of fibers decreased slightly in the sixth year of growth. In contrast, a trend of increase in wall thickness over 6 years was observed (Figure 3).

In contrast, vessels were more responsive to K and Na supply. The effects of K and Na on diameter and density of vessels was clear and consistent throughout tree growth. K fertilization considerably increased vessel diameter and decreased vessel density, and Na fertilization had an intermediate effect. On the other hand, K did not significantly affect vessel area, while Na decreased it (Figure 4).

Regardless of the treatments, diameter, density, and area of vessels decreased from four to six year old. Thus, the xylem of the sixth growth ring, showed the smallest vessels with the lowest density, resulting in the lowest vessel area (Figure 4).

Table 1. Effects (p-value) of Water regime, Fertilization regime, Stand age, and its interactions, on wood properties. p-value>0.05 indicate non-significant effect.

Factors	Stem volume	Basic density	Sapwood : Heartwood ratio	Fiber length	Fiber diameter	Wall thickness	Vessel diameter	Vessel density	Vessel area
Water	0.021	<0.001	0.086	0.132	0.447	0.895	0.271	0.965	0.399
Fertilization	<0.001	<0.001	<0.001	0.023	0.738	0.493	<0.001	<0.001	0.000
Stand age	<0.001	<0.001	0.001	0.004	<0.001	<0.001	<0.001	0.055	<0.001
Water × Fertilization	0.272	0.099	0.699	0.214	0.121	0.352	0.503	0.933	0.464
Water × Stand age	0.703	0.942	0.368	0.377	0.690	0.392	0.207	0.353	0.930
Fertilization × Stand age	0.000	0.007	0.190	0.084	0.012	0.113	0.623	0.779	0.307
Water × Fertilization × Stand age	0.963	0.932	0.377	0.537	0.113	0.795	0.662	0.457	0.717

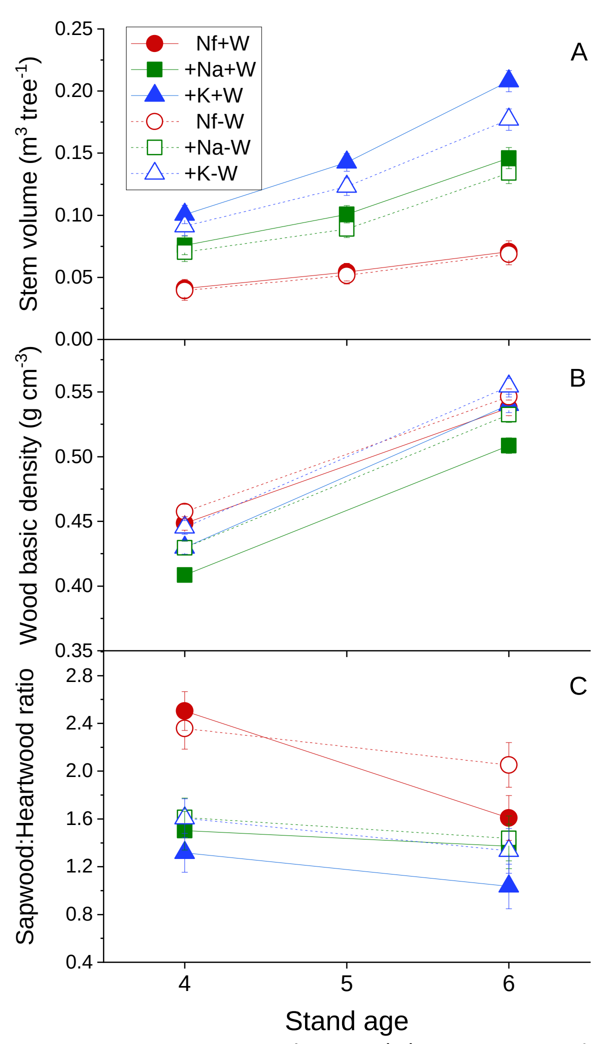

Figure 2. Stem volume (A), Heartwood proportion (B), and wood basic density (C), by treatment of fertilization and water regime, in *Eucalyptus grandis* trees. Error bars show the standard error.

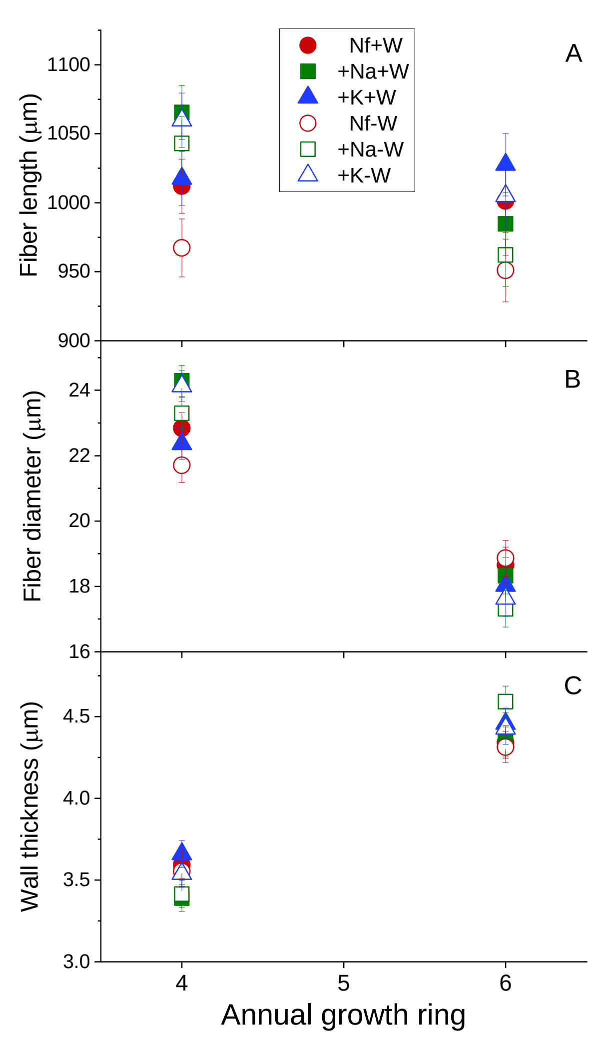

Figure 3. Fiber length (A), fiber diameter (B), and fiber wall thickness (C), by radial position and treatment of fertilization and water regime, in *Eucalyptus grandis* trees. Error bars show the standard error.

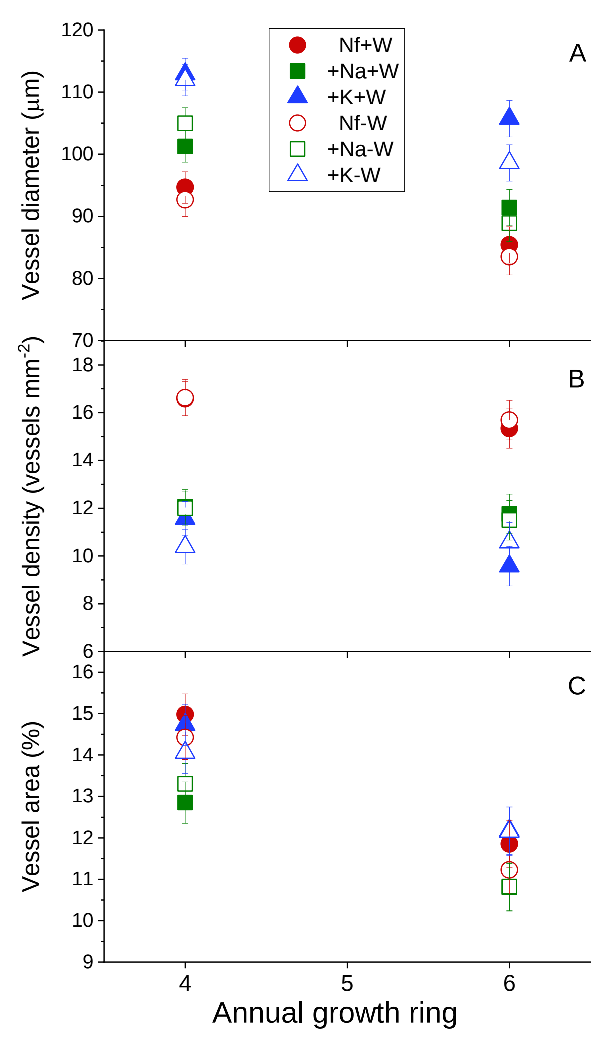

Figure 4. Vessel diameter (A), vessel frequency (B), and occupied area by vessels (C), by radial position and treatment of fertilization and water regime, in *Eucalyptus grandis* trees. Error bars show the standard error.

CONCLUSIONS

Effects of Na fertilization on wood properties were more pronounced that K fertilization. Na detrimentally affected sapwood:heartwood ratio and wood basic density. However, both the K and Na supply increased stem volume by three and two-fold respectively. The beneficial effects of K and Na on stem volume, even under a water availability reduction, largely compensate for the loss in wood quality for pulp and paper production. Vessels features were responsive to fertilization.

These findings predict that under water deficit, wood density and fiber features will not decline in commercial *Eucalyptus grandis* plantations fertilized with potassium. The use of sodium, as a substitute for potassium, should consider their negative impacts on wood density.

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