

The Impact of Fertilization and Throughfall Exclusion on Loblolly Pine Growth and Water Use

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Methods

This study utilized a randomized complete block design containing two levels of fertilization and throughfall exclusion in a 2x2 factorial arrangement. Treatments include: fertilization with 224N, 28P, 56K (kg/ha) and micronutrient blend as to eliminate any nutrient deficiencies, and an exclusion of 30% of incoming throughfall. The factorial design results in four individual treatment types. Each individual treatment type was replicated four times for a total of 16 plots. Treatment types include: Control (C), Fertilization (F), Throughfall Exclusion (D), and Fertilization and Throughfall Exclusion (FD).

Transpiration was measured on five trees per plot in Taylor county, Florida using heat dissipation sap flow probes as described by Granier in 1987. Measurement trees were selected using the "quantiles of total" technique (Cermák and Michálek 1991). Canopy transpiration was calculated using the proportion of measurement tree sapwood area to total plot sapwood area. In order to account for radial variation in sap flow, eight trees (2 per treatment) were outfitted with additional probes to measure sap flow at the 2-4 cm and 4-6 cm depths. Measurements were taken every minute throughout 2013 and half hour averages were stored on data loggers.

A weather station was installed at the site to measure photosynthetically active radiation (PAR), temperature, vapor pressure deficit (VPD) and precipitation. All sensors were measured every minute and half hour averages were collected on data loggers. All analyses were conducted using SAS version 9.3.

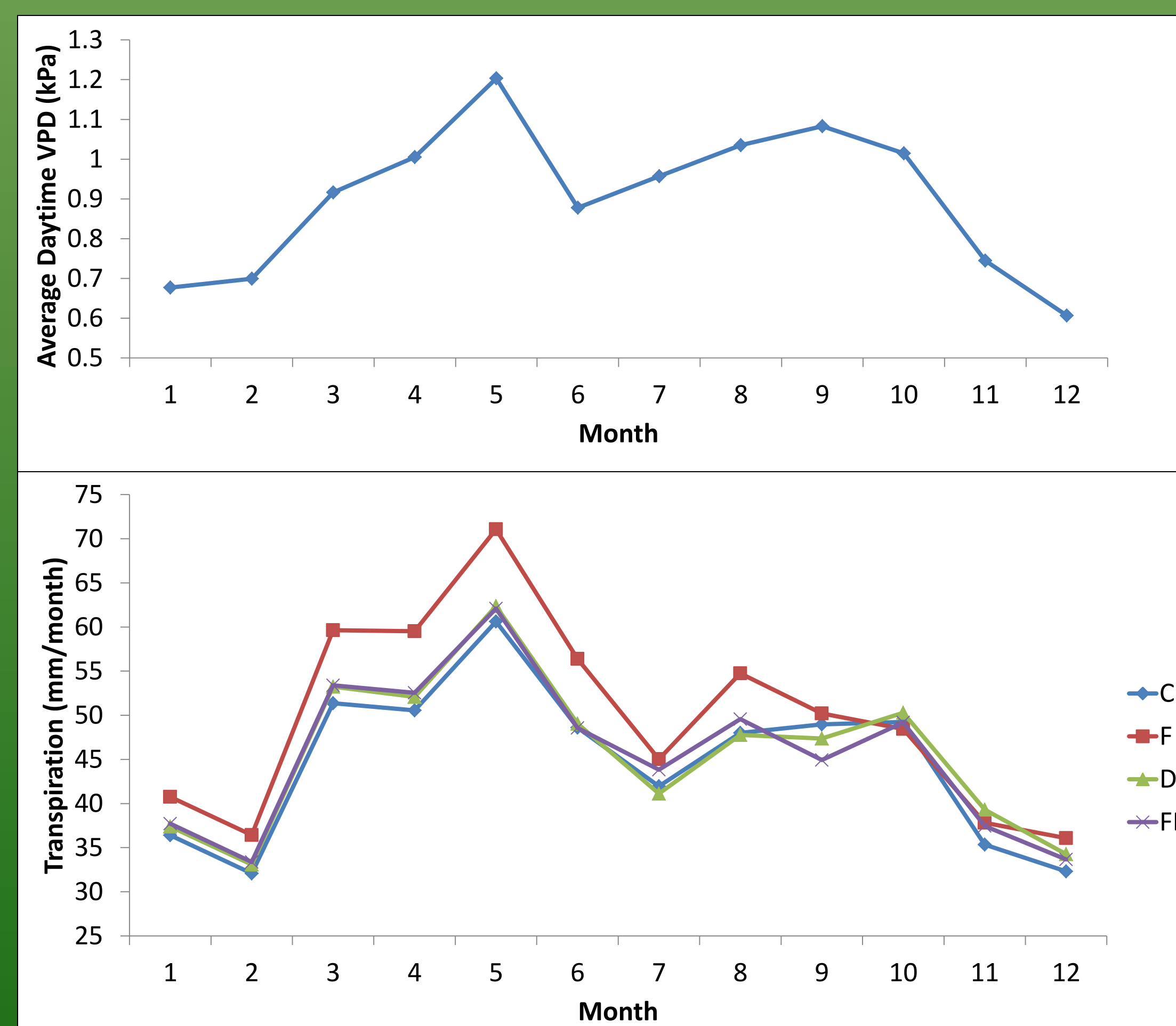


Figure 2. Mean Monthly Transpiration and VPD

Results

Monthly transpiration rates were found to vary significantly over time with higher transpiration rates being realized during the spring and summer months when leaf area index (LAI) and VPD were high (Figure 2). There tended to be greater monthly transpiration in the F treatment, but this difference was only significant during the month of May when VPD was at a maximum. There was no significant impact of treatment on annual transpiration rate.

The response of stomatal conductance (G_s) to VPD was not significantly affected by treatment (Table 1). The sensitivity of G_s to changes in VPD ($dG_s/d\ln D$) and G_s at VPD = 1 kPa (G_{Sref}) were found to be $78.1 \text{ mmol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}\cdot\ln(\text{kPa})^{-1}$ and $135.5 \text{ mmol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, respectively.

Sap flux density (J_s) varied significantly with depth (Figure 3). The J_s of the 2-4 cm depth was on average 87% of the 0-2 cm J_s in all treatments. The J_s of the 4-6 cm depth was 58% of the 0-2 cm J_s for the C, D and FD treatments but 76% for the F treatment (Figure 4).

The main effect of fertilization significantly impacted both basal area growth and leaf area index (LAI) (Table 1). The throughfall exclusion treatment did not significantly impact growth, however, there was a trend of decreased basal area growth in the FD treatment when compared to the F treatment.

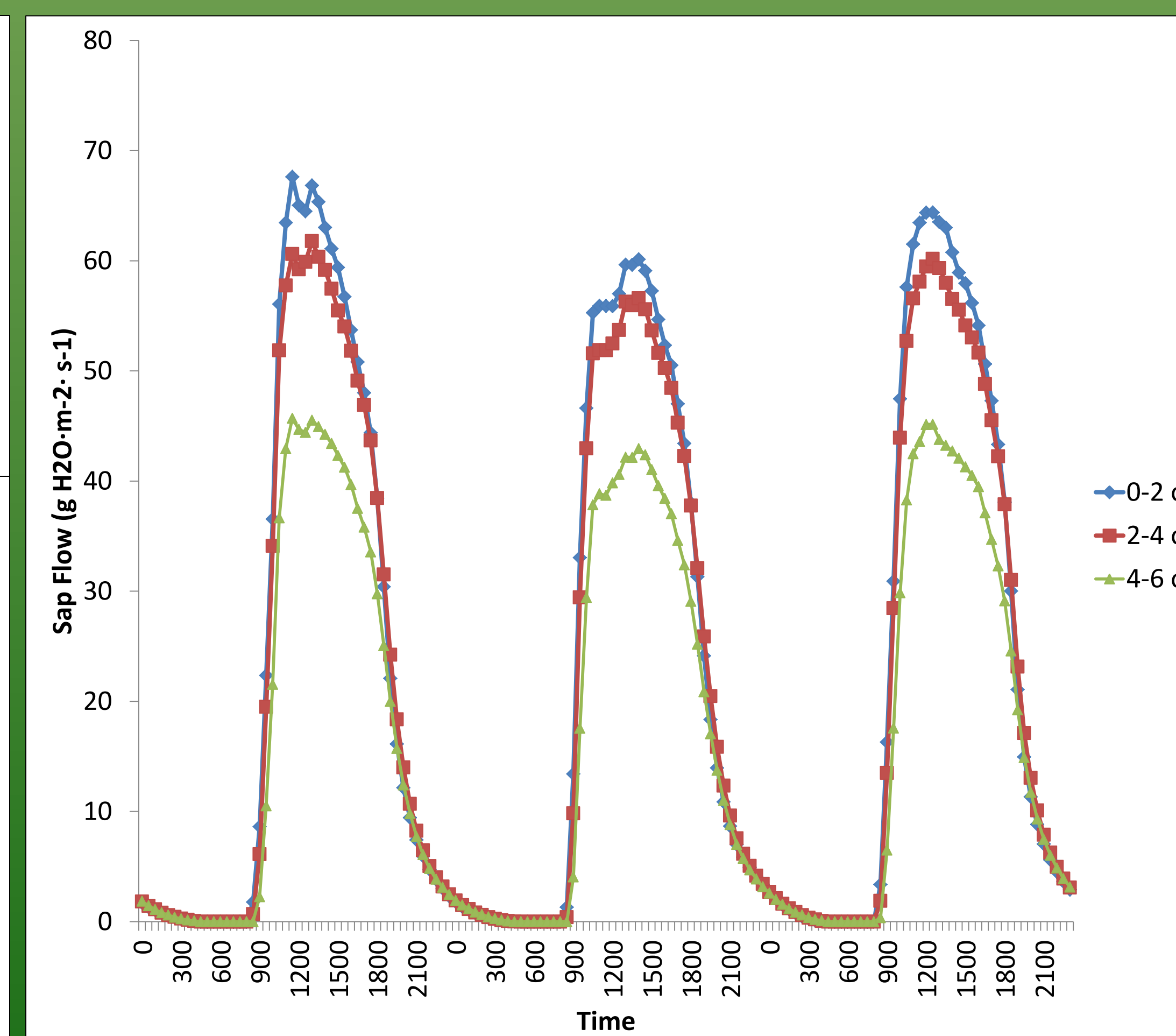


Figure 3. Example of Radial Variation in Sap Flow

Table 1. Impact of Treatments on Water Relations and Growth. The main effect F was significant for the LAI and basal area growth analyses ($p = 0.05$).

Trt	G_{Sref} ($\text{mmol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$)	$-dG_s/d\ln D$ ($\text{mmol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}\cdot\ln\text{kPa}^{-1}$)	Transpiration ($\text{mm}\cdot\text{year}^{-1}$)	LAI	Basal Area Growth ($\text{m}^2\cdot\text{ha}^{-1}\cdot\text{yr}^{-1}$)
C	138.14	81.05	535	3.0	3.35
F	136.67	77.08	547	3.4	4.31
D	139.28	79.32	596	3.0	3.48
FD	127.67	75.07	546	3.5	3.86

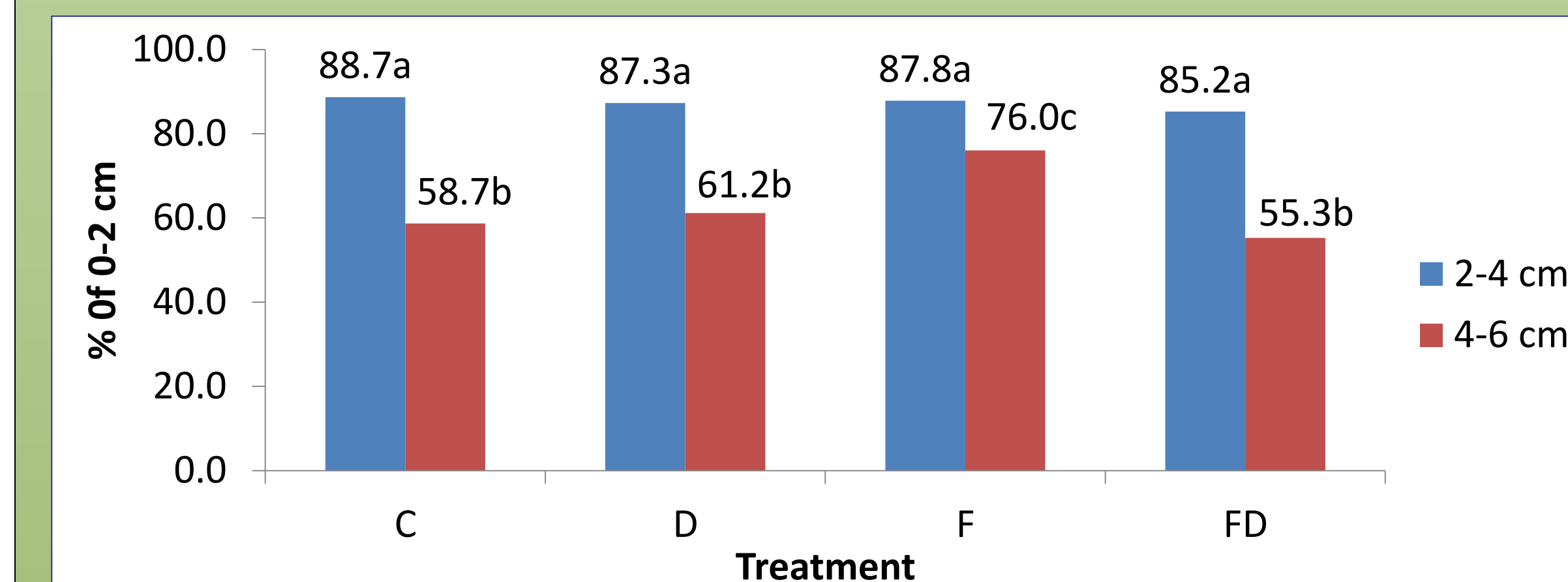


Figure 4. Sap flow rates at 2-4 cm and 4-6 cm depths expressed as a percentage of sap flow at 0-2 cm depth. Percentage values shown above each bar; values followed by the same letter are not significantly different ($p = 0.05$).

Introduction

Over the last 60 years the productivity and extent of pine plantations in the Southeast United States has dramatically increased. From 1952 to 2000, the area of pine plantations in the Southeast increased from 0.7 million hectares to 13 million hectares (Wear and Greis 2002). During this period the mean annual increment of southern pine plantations has more than doubled while rotation lengths have decreased by more than 50% (Fox *et al.* 2007). This increase in productivity is largely due to the implementation of site preparation, fertilization, herbaceous weed control, density management, and genetically improved planting stock.

Loblolly pine (*Pinus taeda*) is often intensively managed in the Southeastern United States and is the nation's leading timber species (Schultz 1997). The influence of climate change on temperature and precipitation patterns in the Southeast U.S. will likely have an important impact on the productivity of loblolly pine plantations. The Southeast is predicted to experience an increase in average temperature of 2.5 to 5°C by the 2080s (Karl *et al.* 2009). Predictions for changes in precipitation, although less certain, generally indicate a 10% to 30% reduction in summertime precipitation (Karl *et al.* 2009, Christensen *et al.* 2007). Increased average temperature and decreased precipitation will increase vapor pressure deficits (VPD). Potential increases in VPD will likely impact forest tree water use. The objective of this study was to quantify the impact of fertilization and throughfall exclusion on loblolly pine water relations and productivity.

Discussion

In this study throughfall exclusion and fertilization treatments were found to have little effect on loblolly pine plantation water use in northern Florida. In May of 2013, when monthly VPD was at a maximum, the F treatment had significantly higher transpiration rates than all other treatments. This suggests that the predicted increases in VPD associated with climate change have the potential to alter loblolly pine plantation water use, especially in fertilized stands.

The response of stomatal conductance to vapor pressure deficit was not impacted by treatment suggesting that this relationship is consistent for loblolly pine plantations in northern Florida. The Physiological Principles in Predicting Growth (3-PG) model has been shown to accurately estimate loblolly pine plantation growth using physiological process data, statistical growth and yield models, and easily obtained weather and site conditions (Bryars *et al.* 2013). This model incorporates a single function to describe the relationship between stomatal conductance and VPD. The results of this study support this assumption.

The sap flux density of the interior sapwood was significantly less than the outer 0-2 cm region typically measured by heat dissipation sap flow probes. These results reiterate the need to account for radial variation in sap flux density when generating stand level transpiration estimates. Although the F treatment changed the radial sap flow profile, the mechanism behind this is unclear. It is possible that the higher levels of LAI in these plots are driving this difference.