Effects of cultural intensity, planting density, physiographic region and canopy level on leaf $\delta^{13}C$ and nitrogen in mature loblolly pine stands

Miles W. Ingwers, Dehai Zhao, Michael Kane, Daniel Markewitz, Mary Anne McGuire, & Robert O. Teskey
Daniel B. Warnell School of Forestry and Natural Resources, University of Georgia 30602, USA

Objectives

Determine how cultural intensity, planting density, physiographic region and needle placement in canopy affect $\delta^{13}C$ (a surrogate for water use efficiency) and needle nitrogen content.

Introduction

-A better understanding of water relations and crown attributes is needed to maintain sustainable production of Loblolly pine (*Pinus taeda* L.) plantations.

-Carbon isotope discrimination ($\delta^{13}C$) can be used as a time-integrative surrogate for water use efficiency (WUE).

-Cultural intensity (fertilization and vegetation control) and planting density (number or trees per hectare) have both been shown to effect biomass accumulation and allocation (Akers et al. 2013, Zhao et al. 2011, Zhao et al. 2012), but very little is known about how these factors effect water use efficiency.

-Variation in moisture availability in different physiographic regions may also affect water use efficiency.

-Needle placement in canopy, meaning its vertical orientation in the top, middle, or bottom of the canopy, is known to affect $\delta^{13}C$ and considered to be largely influenced by light (Francey et al. 1985). Still, it is unclear how this relationship is affected by cultural intensity, planting density and other regional factors.

-We hypothesized that $\delta^{13}C$ and needle nitrogen content (N) would be affected by cultural intensity, planting density, physiographic region and needle placement in canopy with significant interactions among factors.

Methods

-In 1997-1998 the Plantation Management Cooperative of the University of Georgia established six research sites, three each, in the Upper Coastal Plain (Florida) and Piedmont (Georgia and Alabama) physiographic regions.

-Two different silvicultural intensities were established: an operational treatment, which included initial vegetation control and fertilization as well as an additional fertilization during 12th growing season and a managed treatment, which consisted of repeated fertilization and vegetation control (figure 1).

-Within each cultural intensity, subplots from five different planting densities (1,483, 2,224, 2,965, 3,706, and 4,448 trees per hectare) were studied.

-Sampling occurred in 2012 (Upper coastal plain) and 2013 (Piedmont). Four trees were sampled in each of the cultural density combinations. Two trees had an average diameter at breast height (DBH), while one tree had a below average DBH and one tree had an above average DBH.

-Needle samples were separately taken from the bottom, middle and top of each tree to determine canopy level.

-Pooled samples were taken at each canopy level and cultural density combination. Samples were dried at 65°C for >72 hours prior to milling.

- Carbon isotope discrimination ($\delta^{13}C$) was conducted at the Stable Isotope and Soil Biology Laboratory, Odum School of Ecology, University of Georgia, Athens,GA, USA.

-All statistical analyses were conducted with a mixed model (PROC MIXED) using SAS 9.3.

Figure 1. Images of a "managed" cultural intensity plot (A.) and an "operational" cultural intensity plot (B) which has considerably more understory vegetation.

Results

Table 1. P-values coinciding to different treatments and treatment interactions for both $\delta^{13}C$ and N. P-values for planting density were 0.063 ($\delta^{13}C$) and 0.067 (N) indicating marginal significance.

	$\delta^{13}C$	N
Canopy level	**<0.001**	**<0.001**
Cultural intensity	0.221	**0.007**
Planting density	**0.063**	**0.067**
Physiographic region	0.617	0.759
Canopy level x cultural intensity	0.715	0.772
Canopy level x planting density	0.968	0.757
Canopy level x physiographic region	0.501	0.090
Cultural intensity x planting density	0.435	0.334
Cultural intensity x physiographic region	0.140	0.888
Planting density x physiographic region	0.465	0.298
Canopy level x cultural intensity x planting density	0.758	0.393
Canopy level x cultural intensity x physiographic region	0.499	0.585
Canopy level x planting density x physiographic region	0.533	0.968
Cultural intensity x planting density x physiographic region	0.162	0.756
Canopy level x cultural intensity x planting density x physiographic region	0.712	0.891

Results: Canopy position

The vertical position in the canopy had a strong effect on both $\delta^{13}C$ and N. Specifically, $\delta^{13}C$ and N were highest in the top portion of the canopy, lowest, in the lower portion of the canopy, suggesting that photosynthesis coincides with, and may drive $\delta^{13}C$ and N accumulation.

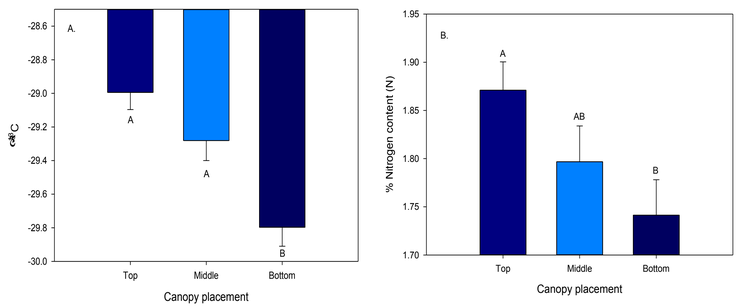


Figure 2. Mean effects of vertical position in the canopy on (A.) $\delta^{13}C$ and (B.) N. Thin bars represent standard error. Different letters denote statistical significance at α=0.05.

Results: Cultural intensity

The repeated fertilization in the managed treatment resulted in a higher tissue nitrogen content (N). Cultural intensity did not, however, affect $\delta^{13}C$.

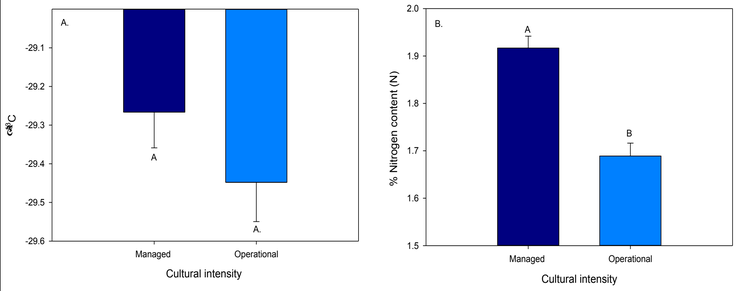
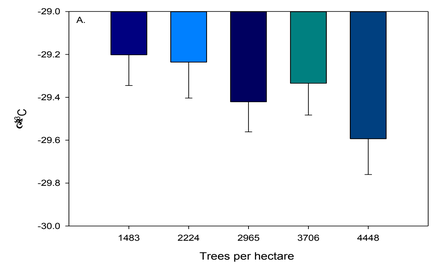


Figure 3. Mean effects of cultural intensity on (A.) $\delta^{13}C$ and (B.) N. Thin bars represent standard error. Different letters denote statistical significance at α=0.05.

Results: Planting density

Although only marginally significant, plating density did have an effect $\delta^{13}C$ and N; with $\delta^{13}C$ possibly increasing with planting density, and N following a more normal distribution with the highest concentration at 2,965 tree per hectare. A possible explanation for the unusual relationship with N and planting density might be because that the stands were mature, and significant die-off had already occurred in at the higher planting densities, resulting in greatest competition (and least growth) at the 2,965 tree hectare.



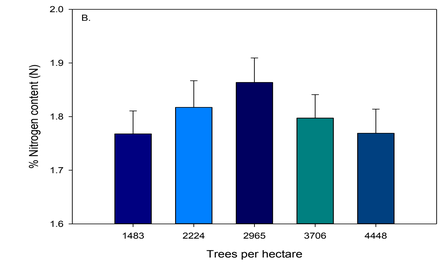


Figure 4. Mean effects of planting density on (A.) $\delta^{13}C$ and (B.) N. Thin bars represent standard error.

Conclusions

-Both $\delta^{13}C$ and N were strongly affected by canopy level suggesting a strong relationship with light and photosynthesis.

-Cultural intensity affected N but not $\delta^{13}C$.

-Planting density had marginally significant response for both N but not $\delta^{13}C$, possibly due to variation in stand dynamic and growth.

-Physiographic region did not affect N or $\delta^{13}C$.

-No significant interactions were found among canopy level, cultural intensity, planting density or physiographic region.

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Contact

Miles William Ingwers,Warnell School of Forestry, Teskey Lab
University of Georgia, Email: milesingwers@gmail.com, Phone: (530) 902-2350