THE EFFECTS OF DECREASED WATER AVAILABILITY ON LOBLOLLY PINE (PINUS TAEDA L.) PRODUCTIVITY AND THE INTERACTION BETWEEN FERTILIZER AND DROUGHT

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Abstract—As part of the regional PINEMAP (Pine Integrated Network: Education, Mitigation, and Adaptation project) funded by the NIFA – USDA, we established a factorial study in McCurtain County, OK near Broken Bow. This study examined the effects of fertilization and ~30 percent reduction in throughfall on a seven-year-old loblolly pine (Pinus taeda L.) plantation. The objective of this study was to determine effects of decreased water availability and fertilization on tree growth. We measured tree and stand development as well as a suite of ecophysiological variables. Tree growth was reduced in throughfall exclusion treatments and increased in fertilizer treatments. At various times during the measurement period, throughfall exclusion reduced net photosynthesis, stomatal conductance, and mid-day leaf water potential. These results indicate that lower availability of soil moisture reduces leaf gas exchange and slows growth.

INTRODUCTION

Over the last half century, increases in pine plantation productivity and management in the southeastern United States has enabled these forests to produce more wood than any other region in the country (Fox and others 2007, Cubbage and others 2007). Loblolly pine have a greater growth rate than other commercially important southern pines and consist of over 50 percent of pine plantations across the Southeast are loblolly pine (Pinus taeda L.), thus making it the most commercially important tree species and a large driver of commercial timber production and habitat for numerous wildlife species (Baker and Langdon 1990, Dipesh and others 2015). Across the Southeast it is predicted that a shift towards a warmer and drier climate will likely occur. Increasing temperatures and decreasing or more variable precipitation is expected to impact forests productivity in the Southeast (IPCC 2007). More specifically, larger precipitation events with longer drying periods are predicted to lead to an increased intensity and duration of drought (Easterling and others 2000, Walsh and others 2014).

As part of the regional PINEMAP (Pine Integrated Network: Education, Mitigation, and Adaptation project) funded by the NIFA – USDA, this study examined the effects of fertilization and ~30 percent reduction in throughfall on a loblolly pine plantation over 2012, 2013, and 2014 growing seasons. The objective of this study was to determine effects of decreased water availability and fertilization on tree growth. We hypothesized that fertilizer added to a water stressed loblolly pine plantation will lead to tree growth similar to that of an unfertilized, non-water stressed loblolly pine plantation.

SITE

This study was conducted on a privately owned loblolly pine plantation near Broken Bow in southeastern OK planted in January 2008. Planting density for the site was 2 by 3 m (~1650 trees ha⁻¹). Elevation for the site was 150 m. Soil consisted of Ruston fine sandy loam with 3 to 8 percent slopes, very deep, and well drained (U.S Department of Agriculture 2015). Depth to the water table is greater than 2000 mm. Precipitation over the three years was 1026 mm in 2012, 1312 mm in 2013, and 1289 mm in 2014. Average temperature was 15.4 °C with average maximum and minimum temperatures of 22.6 and 8.8 °C (Mesonet Weather 2015).

PROCEDURES

Experimental Design

The study consisted of four blocks (16 plots). Each block consisted of four treatment plots designed as a two by two factorial combination of fertilization and throughfall reduction. Plots had a 0.03 ha measurement plot for tree growth and yield within a 0.10 ha treatment plot. For leaf gas exchange, each plot had five measurement trees (80 total). Treatments include fertilization (optimum nutrition), ~30 percent reduction in throughfall, fertilization plus ~30 percent reduction in throughfall, and no fertilization. The elemental fertilization treatment

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RESULTS AND DISCUSSION

Soil Moisture

Throughfall reduction reduced VWC. Ambient precipitation plus fertilizer treatments maintained greater VWC than control treatments. Across all plots, VWC at 0 to 12 cm was reduced from 10.8 to 8.5 percent by throughfall excluders.

Growth

Fertilizer increased tree growth and throughfall reduction decreased tree growth. Throughfall reduction decreased total height growth over 2012, 2013, and 2014 growing seasons (p < 0.0001) compared with ambient precipitation treatments (fig. 1A). Throughfall reduction decreased total diameter growth over 2012, 2013, and 2014 growing seasons (p = 0.0009) and fertilizer increased total diameter growth (p = 0.0003), compared with ambient precipitation and non-fertilized treatments, respectively (fig. 1B). Fertilization compensated for drier conditions in diameter growth, where throughfall reduction plus fertilization had similar growth as control treatments (fig. 1B).

Leaf Gas Exchange

Throughfall reduction decreased net photosynthesis and stomatal conductance (p < 0.0001). Fertilization decreased stomatal conductance (p = 0.006) and had no effect on net photosynthesis. Throughfall reduction caused increasingly negative mid-day leaf water potentials (p < 0.0001) and fertilization caused less negative mid-day leaf water potentials (p = 0.02).

Effects of Fertilization and Reduced Precipitation

These results indicate that lower availability of soil moisture reduces leaf gas exchange and slows growth. However, it was shown that fertilization can compensate for throughfall reduction. Tree growth was increased by fertilization and decreased by throughfall reduction. Additive effects of throughfall reduction and fertilization indicate that positive effects of fertilization are not eliminated when growth is reduced by throughfall reduction. Differences between the two responses determined whether volume growth decreased or increased when responses were combined, thus determining the net effect on growth. Throughfall reduction decreased net photosynthesis and stomatal conductance. These changes are related to increasingly negative mid-day leaf water potential and higher degree of tree water stress. Fertilizer decreased stomatal conductance and led to less negative mid-day leaf water potential, indicating how fertilization can be beneficial in loblolly pine plantations experiencing reduced water availability.

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**LITERATURE CITED**


Figure 1—Total height growth (A) and diameter growth (B) by treatment over three growing seasons. DF = 30 percent throughfall reduction plus fertilization, DNF = 30 percent throughfall precipitation reduction with no fertilization, WF = ambient precipitation plus fertilization, and WNF = ambient precipitation with no fertilization.