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Contrasting genotypes, soil amendments, and their interactive effects on short-term total soil CO_2 efflux in a 3-year-old *Pinus taeda* L. plantation

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ABSTRACT

Intensively managed pine forests in the southeastern United States are considered an important C sink and may play a critical role in offsetting increased global CO_2 emissions. The combination of improved silvicultural methods and the use of superior genotypes are estimated to result in future volume gains of up to 60 percent. However to date, no work has looked at whether selection of elite genotypes could influence soil C dynamics, which could decrease the time necessary for the stand to function as a C sink. We evaluated the effects of contrasting loblolly pine genotypes on total soil surface CO_2 efflux (F_S) and heterotrophic respiration (R_H) under two soil amendment treatments: 1.) fertilization and 2.) logging residue (LR) incorporation. We found an immediate and sustained difference in F_S ($p = 0.05$) and R_H ($p < 0.01$) among our two genotypes throughout the first two years of stand development. Our soil amendment treatments did not significantly change F_S, but did influence R_H. LR increased ($p = 0.05$) R_H while N and P fertilization induced a slight ($p = 0.06$) decrease throughout the study. Our genotypes differed ($p = 0.05$) in their temperature response of F_S, which resulted in an 11% difference in total cumulative C loss from the soil over the duration of the study. We hypothesize that observed treatment effects in F_S and R_H are largely due to differences in belowground C allocation among genotypes, which is supported by others that have looked at fine-root standing crop and turnover on these same genotypes. This work underscores the importance of accounting for differences among genotypes when developing stand-level C estimates.

1. Introduction

Forests are considered an important global C sink (Raich and Schlesinger, 1992). Recent estimates by Pan et al. (2011) show that from 1990 to 2007 the world's forests captured the equivalent of 60% of cumulative fossil fuel emissions during that same period (73 Pg C and 126 Pg C, respectively). It has been suggested that forests, and more specifically managed southern pine forests, may play an important role in offsetting increases in global CO_2 emissions (Johnsen et al., 2001). Currently, southern pine plantations occupy more than 13 million ha and are forecast to increase to 22 million hectares by the year 2040 (Fox et al., 2007; Wear and Greis, 2002). The combination of improved silvicultural methods and the use of superior planting stock has more than tripled volume production of intensively managed southern pine plantations over the last 50 years (Fox et al., 2004; Schultz, 1997), and is estimated to result in future volume gains of up to 60% (Allen et al., 2005; Martin et al., 2005; McKeand et al., 2006). While increased primary productivity would increase the stands ability to function as a C sink, to fully evaluate the total ecosystem C exchange, a measure of C loss through ecosystem respiration is necessary.

Total soil surface CO_2 efflux (F_S) is the sum of autotrophic respiration resulting from maintenance and growth of plant roots, and heterotrophic respiration resulting from the decomposition of soil organic matter by soil microbes (Bond-Lamberty et al., 2004). F_S is the dominant loss of C from terrestrial systems contributing 60–90% of total ecosystem respiration (Bolstad et al., 2004; Law et al., 1999) and the second largest flux of C globally (Raich and Schlesinger, 1992). Consequently, even minor changes in F_S brought about by forest management decisions could have a profound impact on stand level C balance (Maier and Kress, 2000). This has led to an extensive body of research focused on the effects of

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forest management on F_S in southern pine forests. These experiments have advanced our understanding of how management treatments such as: fertilization (Butnor et al., 2003; Gough and Seiler, 2004), forest thinning (Selig et al., 2008; Tang et al., 2005), and site preparation (Tyree et al., 2006) impact F_S rates, however, no studies that we are aware of have compared the effects of planting elite genotypes on F_S in managed southern pine stands.

This research is part of a collaborative effort designed to evaluate the genetic by environmental interaction between two contrasting loblolly pine (*Pinus taeda* L.) genotypes and soil amendments (Maier et al., 2012). These amendments were high C:N (about 700:1) logging residue (LR) incorporated into the mineral soil and fertilization (N and P). Previous work found that the incorporation of LR into the mineral soil led to N immobilization (Tisdale, 2008), which negatively affected growth in one of the *P. taeda* genotypes, but not the other (Tyree et al., 2009). Additionally, differences in fine-root standing crop and turnover were observed between the two genotypes (Pritchard et al., 2010). Our primary objective with this work was to evaluate the effects of contrasting *P. taeda* genotypes on total soil surface CO_2 efflux (F_S) across varying degrees of nutrient availability, as manipulated by soil amendments. Specifically, we hypothesized that:

(H1) F_S will be different among our planted genotypes due to differences in belowground fine-root mortality and overall fine-root standing crop, observed using mini-rhizotrons (Pritchard et al., 2010), which will also have an influence on heterotrophic respiration (i.e., microbial activity);
(H2) the addition of LR would increase F_S rates as a result of increased microbial activity and the addition of N and P fertilizer would result in decreased microbial activity.

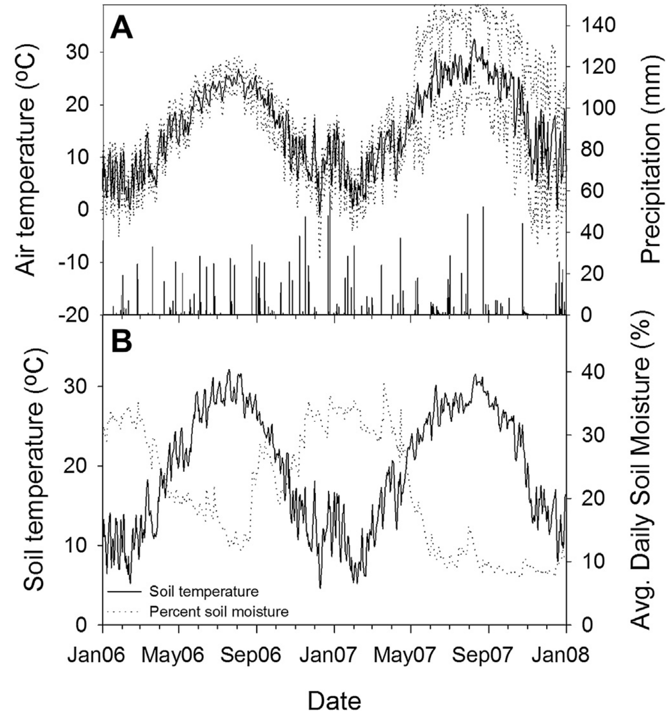

Fig. 1. (A) Average, minimum, and maximum (solid, upper, and lower dotted lines, respectively) daily air temperature (°C), total daily precipitation (bars) measured continuously using an onsite weather station. (B) average daily soil temperature (15 cm depth), and percent soil moisture measured using four dataloggers (CR10x; Campbell Scientific Inc.) located throughout the site between January 2006 and January 2008 for the Cross study site located in Berkeley Co., SC.

2. Materials and methods

2.1. Site location, climate, and stand history

The study site is located in Berkeley County, SC (33° 16′ 50″ N, 80° 10′ 9″ W) at an elevation of 24 m above mean sea level. Average annual temperature was 14.6 °C and 17.4 °C with an average daily maximum of 17.3 °C and 25.2 °C and an average daily minimum of 11.7 °C and 11.2 °C for the 2006 and 2007 year, respectively. Highest daily average temperature was 26.8 °C and 32.5 °C occurring in August 2006 and August 2007, respectively, and a low of −0.9 °C and 0.4 °C occurring in December 2006 and February 2007, respectively (Fig. 1A). Total precipitation was 902 mm in 2006 and 749 mm in 2007 spread evenly throughout the year, which was well below the average of 1200 mm recorded between 1949 and 1973 (Long, 1980). The dominant soil series was a Seagate series (sandy over loamy, siliceous, active, thermic Typic Haplohumods). Harvest of the previous 21-year-old *P. taeda* stand took place in May 2004 and the site was sheared of residual material in July 2004. Logging residue treatments were applied in October 2004, and site preparation (bedding) took place in early November 2004. *P. taeda* genotypes were planted in January 2005 and data for this study were collected between January 2006 and January 2008.

2.2. Study design and treatments

The study was a split-plot, randomized complete block design replicated three times with the whole-plot treatments arranged as a full two by two factorial. Each 0.18 ha plot (48 × 38 m) contained approximately 243 container grown, clonal *P. taeda* seedlings planted in nine rows at a 1.8 m spacing within rows and a 4.3 m spacing between row centers. Two levels of logging residue (LR) and two genotypes ("broad crown" and "narrow crown") served as the whole-plot treatments. The two levels of LR were no LR incorporated (NoLR) and LR incorporated into the mineral soil (LR) at a rate of 25 Mg ha^{-1} (residue weights are presented as oven-dried at 70 °C), which was concentrated onto the beds (equivalent to 75 Mg ha^{-1}) (Maier et al., 2012). Both LR treatments also incorporated the residual forest floor of approximately 25 Mg ha^{-1}. The two *P. taeda* genotypes chosen both exhibit increased aboveground productivity but have different growth efficiencies (i.e., stem growth per unit leaf area). The "narrow crown" genotype (NC) has been shown to allocate more of its resources to stem growth while the "broad crown" genotype (BC) carries more leaf area and thus would require more N (assuming similar foliar N concentrations; Tyree et al., 2009).

Each whole-plot was split into two 13 m^2 split-plots located at opposite ends of the whole-plot, which served as the experimental unit (*EU* = 24). Each split-plot consisted of six seedlings (four measurement trees with one buffer tree on each side), and received one of two fertilizer treatments. No nutrient additions (NF) or N and P fertilization (F) in the form of diammonium phosphate (DAP) and ammonium nitrate (applied in the spring at a rate totaling 209 kg N and 116 kg P ha^{-1} in 2006 and 200 kg N ha^{-1} applied in 2007. Complete competition control was maintained within the measurement plots throughout the study using chemical (2.5% glyphosate) and mechanical control.

2.3. Total soil surface CO_2 efflux (F_S)

Manual point-in-time sampling of total soil surface CO_2 efflux (F_S) was performed using a Li-Cor 6200 portable infrared gas analyzer (Li-Cor Inc., Lincoln, Nebraska) with a dynamic closed soil