

The Effect of Throughfall Reduction and Fertilization on Water Use in Loblolly Pine Over Two-Years at the Georgia Tier III Installation

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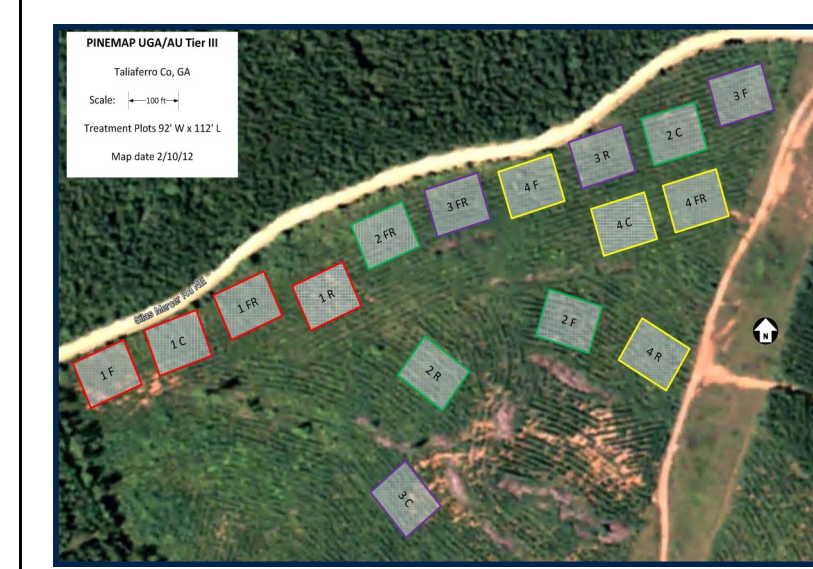
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INTRODUCTION

The southeastern United States (U.S.) has experienced a 1-2°C increase in average annual temperature over the last 30 years, a trend that is expected to continue over the next century. Climate projections for the southeastern U.S. indicate that the frequency of extreme precipitation events may increase with the water-holding capacity of a warming atmosphere, and that the intensity of summertime droughts may also increase in proportion to the rate of warming. Reduced soil water availability has been shown to decrease stand productivity and associated physiological mechanisms including canopy stomatal conductance and transpiration whereas fertilization has been shown to increase stand

productivity and transpiration, which may be attributed to leaf area production. Increased leaf area with fertilization may result in greater soil water depletion and plant water stress. As part of PINEMAP, the objective of this research was to examine the main and interactive effects of reduced throughfall and fertilization on loblolly pine water use over multiple years. We hypothesized that an increase in leaf area index (LAI) and the leaf-to-sapwood area ratio ($A_L:A_S$) with fertilization combined with throughfall reduction treatment may increase water stress and result in reduced transpiration per unit leaf area (E_L), to limit water loss, and increased water use efficiency (WUE).

MATERIALS AND METHODS



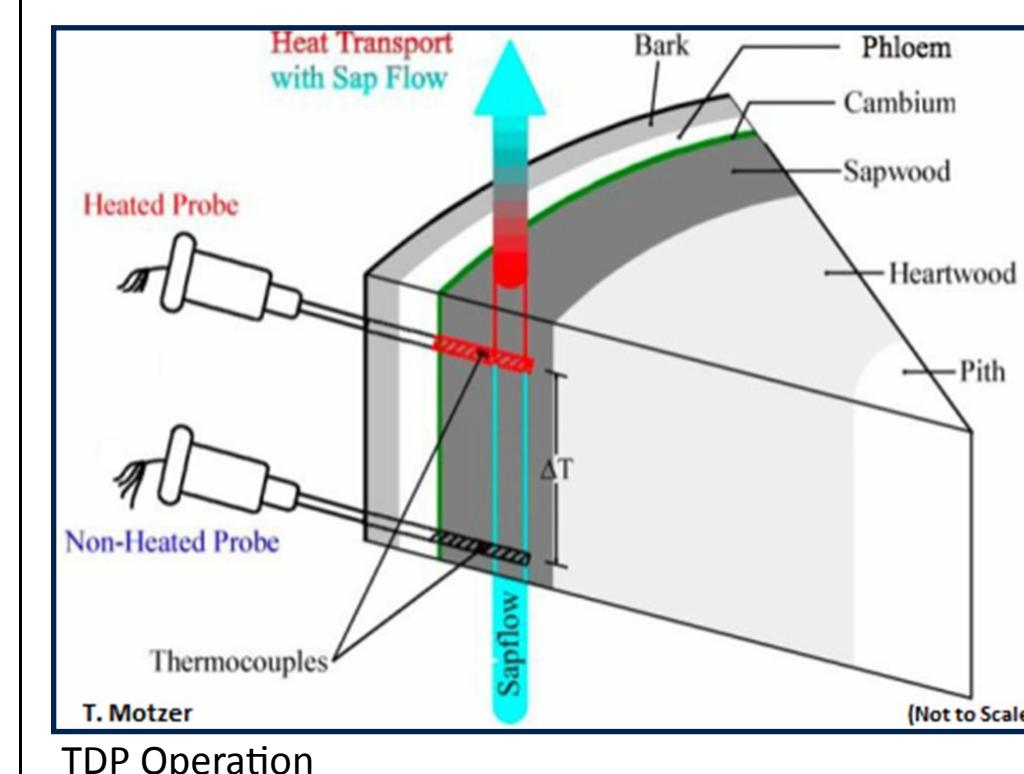
- The PINEMAP Tier III Experimental Site is located in Taliaferro Co., Georgia and was planted with a second generation open-pollinated family of loblolly pine in 2006.
- The experimental design is a 2x2 factorial combination of throughfall reduction and fertilization treatments replicated in four blocks.

Throughfall Treatments

- Ambient Throughfall (TR_0)
- Throughfall Reduction (TR_r) (installed under tree canopy to divert ~30% of throughfall from the treatment plots)

Fertilization Treatments

- No Fertilization ($Fert_0$)
- Fertilization ($Fert_r$) (224 kg N ha⁻¹, 28 kg P ha⁻¹, 56 kg K ha⁻¹, 1.1 Kg B ha⁻¹ applied March, 2012)



- Five trees in each measurement plot (80 trees total) were randomly selected based upon basal diameter distribution.
- Sap flow was determined using 20 mm thermal dissipation probes (TDP), modified after Granier (1985).
- A cellular networked weather station is collecting continuous environmental data (precipitation, photosynthetic active radiation (PAR), temperature, and relative humidity).

- Whole tree transpiration on a projected leaf area (E_L) and ground area (E_G) bases were calculated following Samuelson et al. (2008) and summed annually.
- Stand-level water use efficiency (WUE) was calculated in both study years (2013-2014) by dividing the amount of carbon produced in the stem wood, estimated from annual stem increment (g C ha⁻¹), by the amount of water transpired (kg H₂O ha⁻¹).



RESULTS

- The 30-year average annual precipitation is 1113 mm.
- In 2013, annual precipitation was 1413 mm (22% more than the 30-year normal) and the 24 hour minimum and maximum temperature ranged from 0.2°C to 32.0°C (Figure 1).
- In 2014, annual precipitation was 1070 mm (4% less than the 30-year normal) and the 24 hour minimum and maximum temperature ranged from -4.5°C to 34.4°C (Figure 1).
- The PDSI indicated no drought conditions in 2013, whereas 2014 was abnormally dry (Figure 1).
- Fertilization treatment increased LAI both years and LAI was

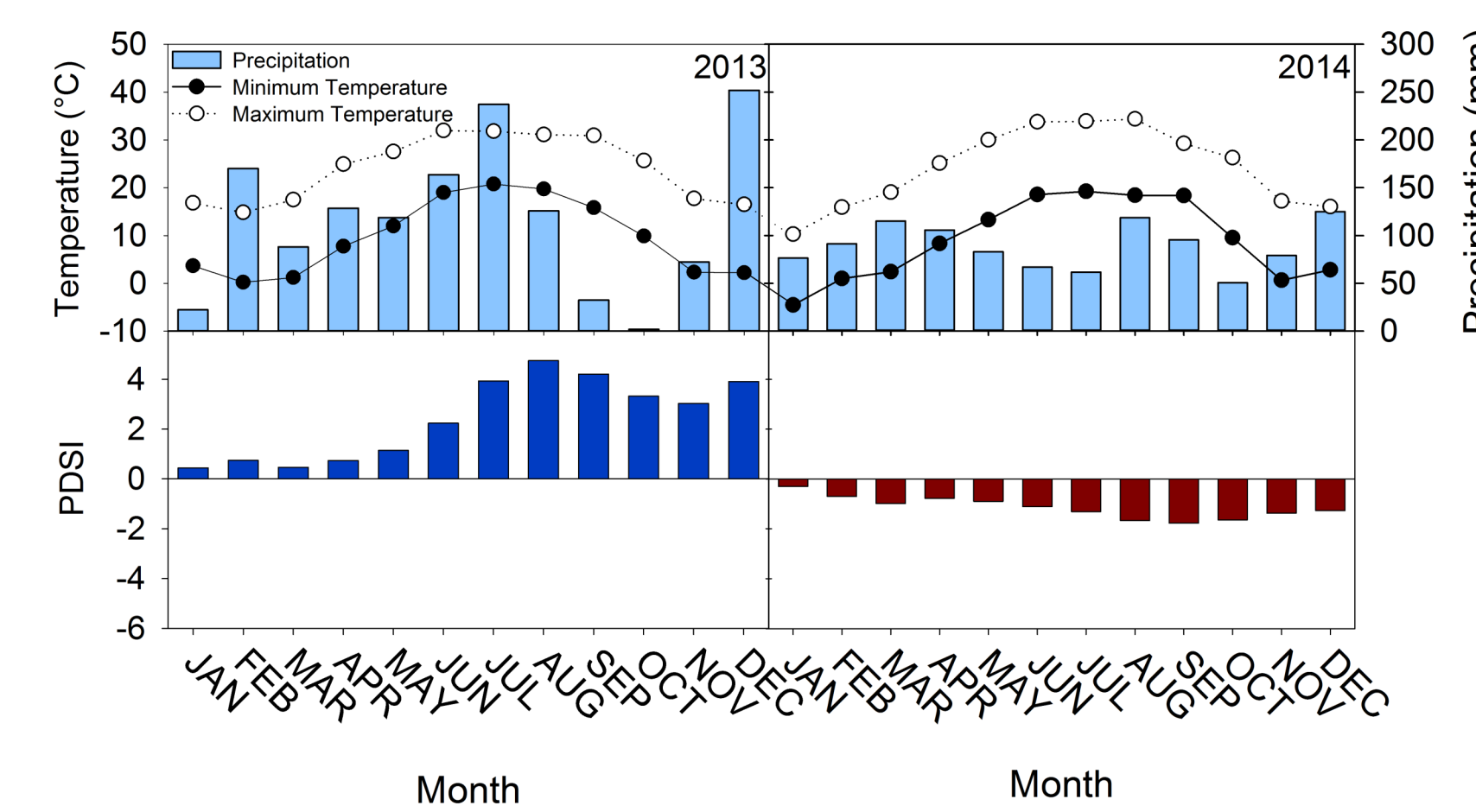


Figure 1. Monthly summed precipitation, average monthly 24-hour minimum and maximum temperature, and the Palmer Drought Severity Index (PDSI).

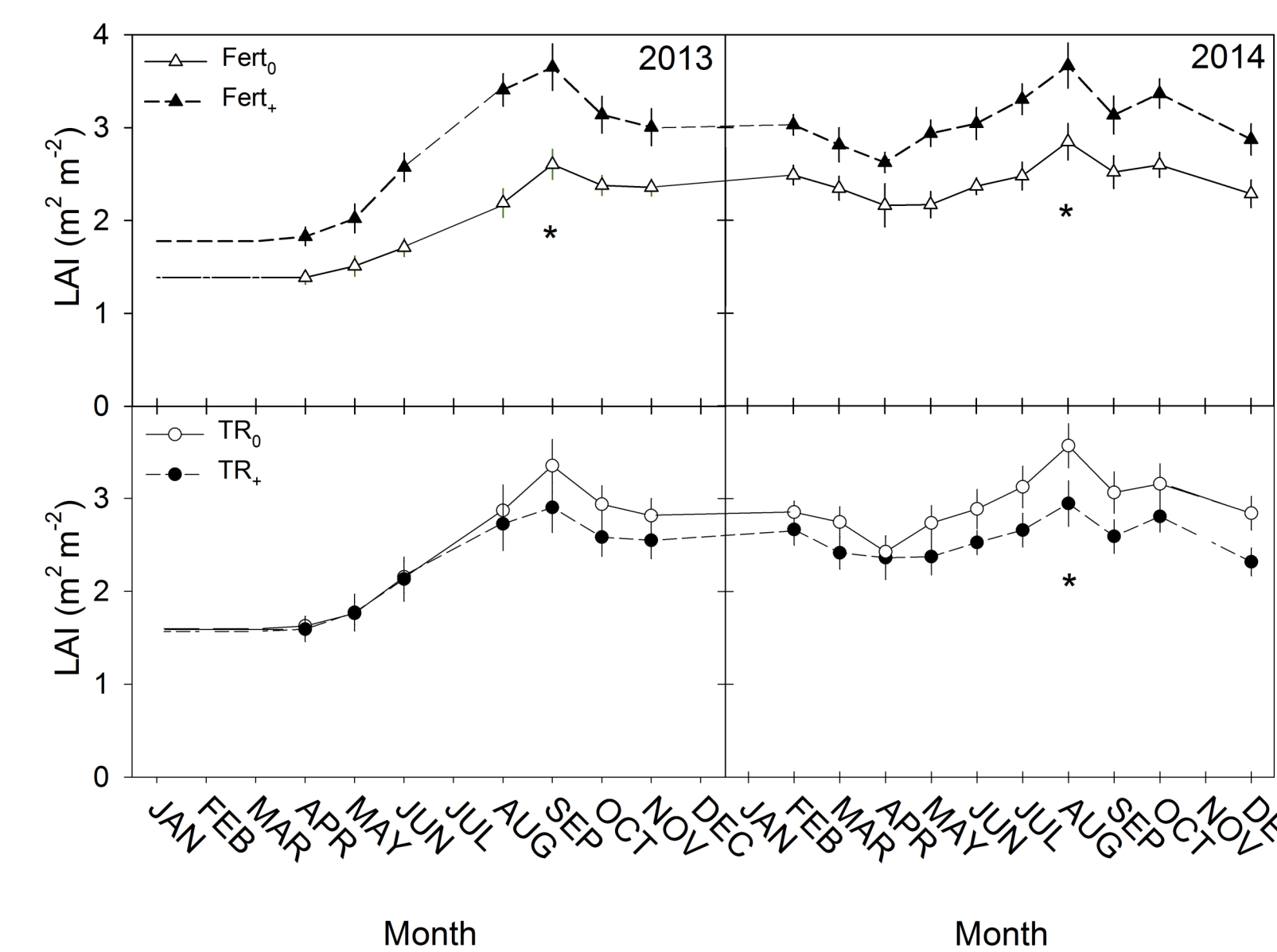


Figure 2. Response of leaf area index (LAI) to throughfall and fertilization treatments. Asterisks indicate a significant fertilization treatment or throughfall treatment effect on peak LAI.

- reduced in response to throughfall reduction treatment in 2014 (Figure 2). The peak $A_L:A_S$ ratio was increased with fertilization and decreased with throughfall reduction (Table 1). No interactive effects on peak $A_L:A_S$ were detected (Table 1).
- Daytime averaged q demonstrated typical seasonal patterns, ranging from 1.7 to 75.9 g m⁻² s⁻¹ and from 0.9 to 81.2 g m⁻² s⁻¹ in 2013 and 2014, respectively (Figure 3).
- Preliminary analysis of the 2014 data, a drier year than 2013, indicated that fertilization treatment reduced monthly E_G and E_L by 23% and 40%, respectively (Figure 4). Whole-tree water use

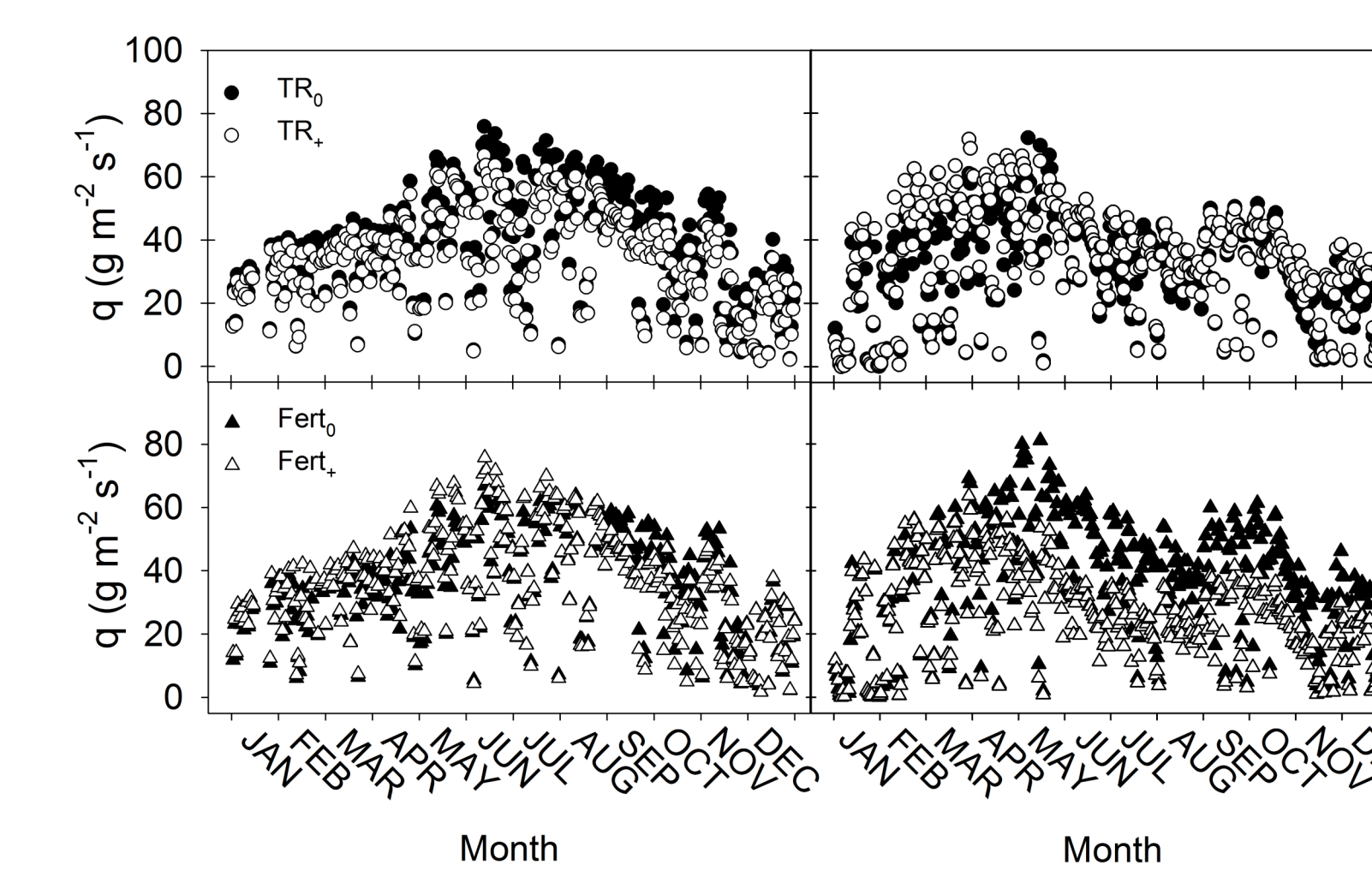


Figure 3. Daytime averaged sap flux density (q) in response to throughfall and fertilization treatments.

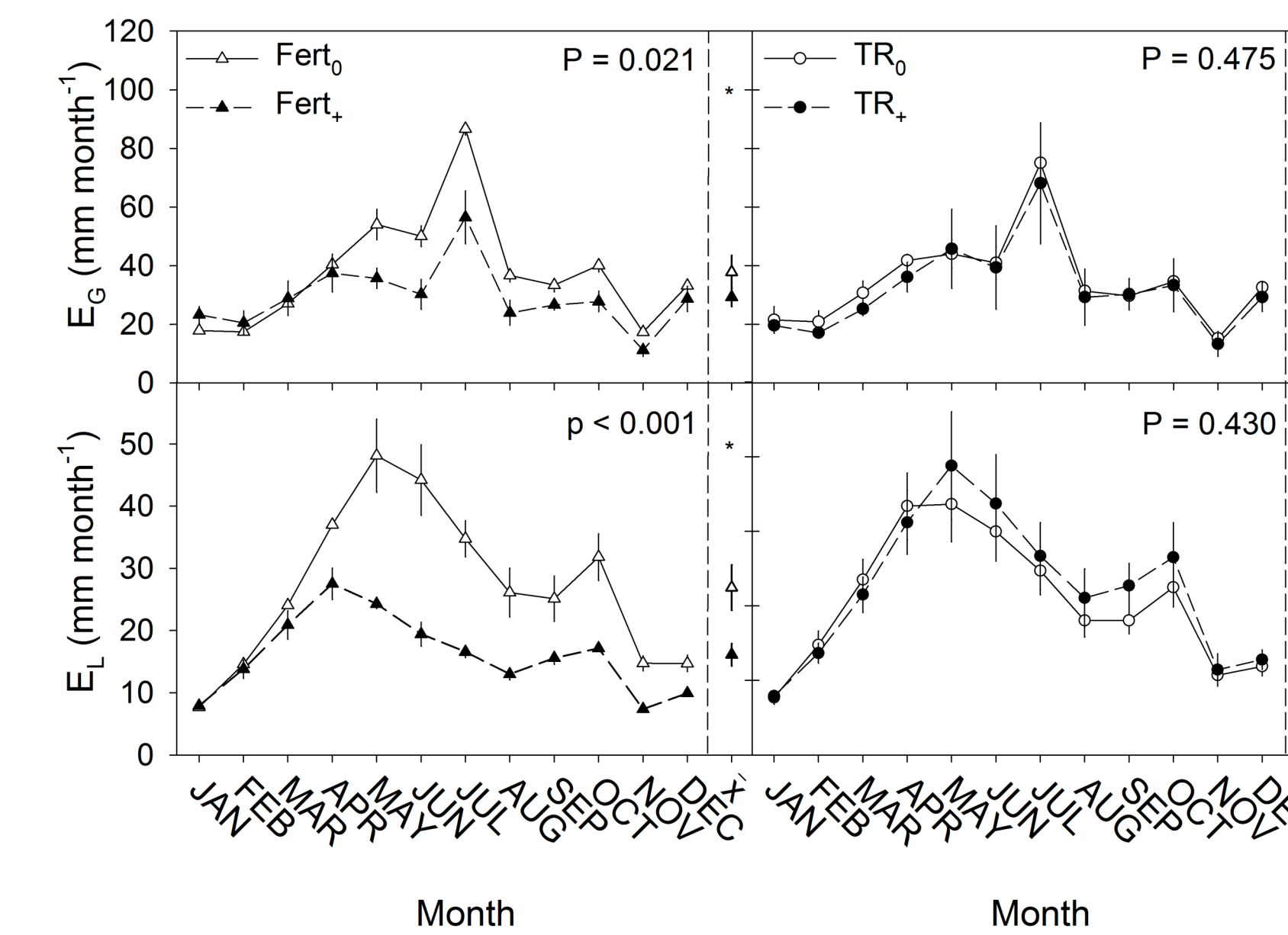


Figure 4. Monthly sums of transpiration on a ground (E_G) and leaf (E_L) area bases in response to fertilization and throughfall treatments in 2014.

- was not effected by throughfall reduction in 2014 (Figure 4).
- A year x fert effect indicated that fertilization significantly reduced annual E_G by 26% in 2014 but fertilization had no effect on annual E_G in 2013 (Table 1).
- An interactive effect of throughfall reduction and fertilization treatments was detected for annual E_L and WUE both study years (Table 1). Fertilization reduced E_L from 345 to 207 mm year⁻¹ and increased WUE from 0.67 to 1.26 g C kg⁻¹ H₂O in the throughfall reduction treatment but not in the ambient throughfall treatment (Figure 5).

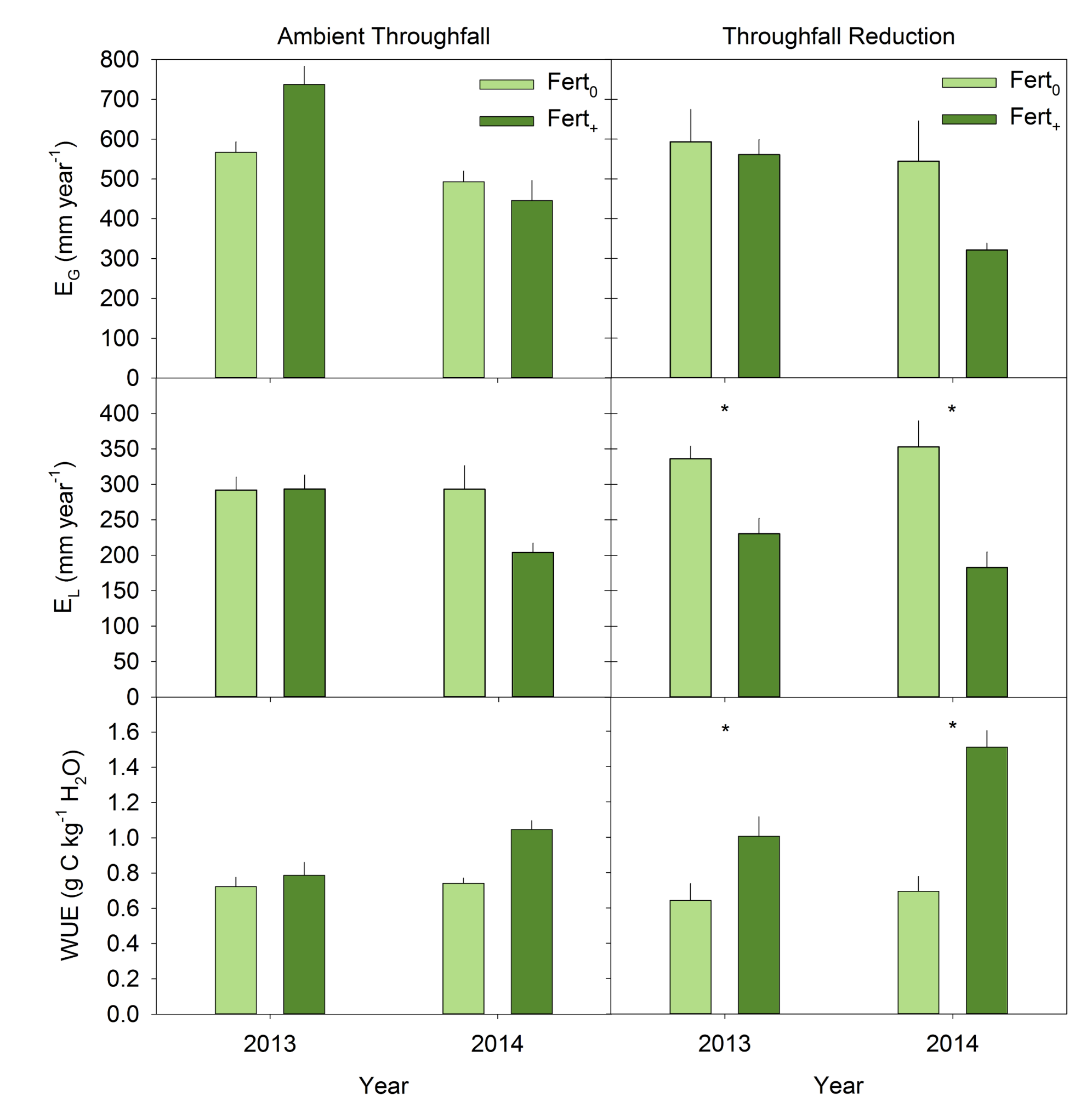


Figure 5. Annual transpiration on a ground (E_G) and leaf (E_L) area bases and annual water use efficiency (WUE) in response to fertilization in the throughfall treatments in 2013 and 2014.

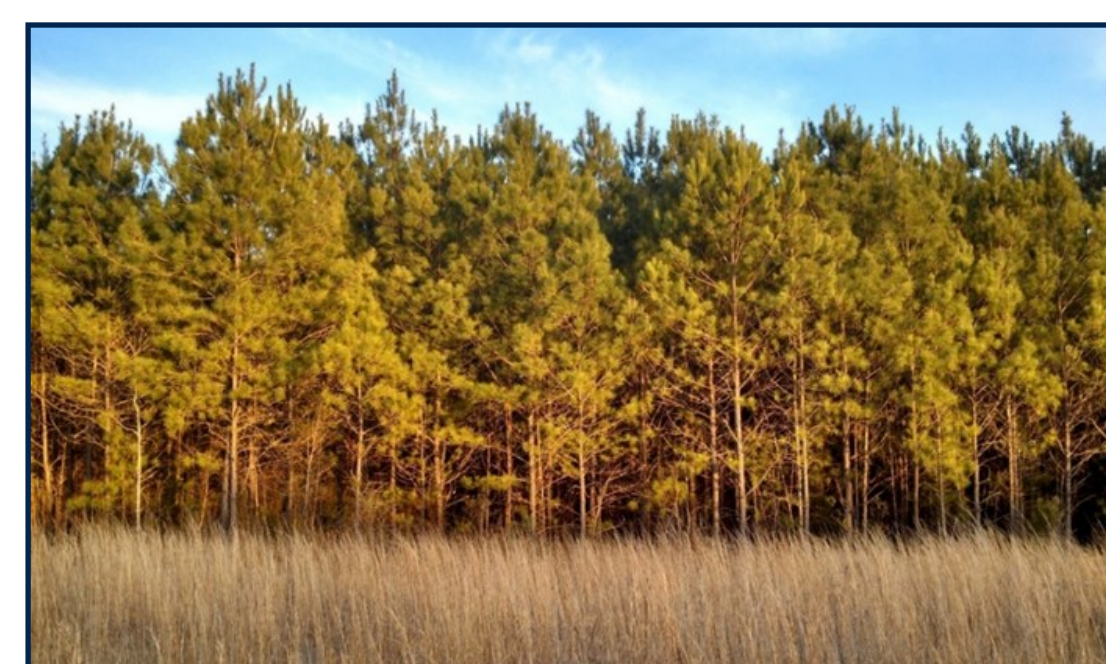
Table 1. Observed probability values for the main and interactive effect of year, and throughfall (TR) and Fertilization (Fert) treatments on annual transpiration on a ground (E_G) and leaf (E_L) area bases, water use efficiency (WUE), and peak leaf-to-sapwood area ratio ($A_L:A_S$) over 2013 and 2014.

	Year	TR	Fert	TR x Fert	Year x TR	Year x Fert	Year x TR x Fert
E_G	<0.001	0.361	0.583	0.134	0.255	<0.001	0.685
E_L	0.017	0.822	0.001	0.047	0.212	0.004	0.562
WUE	<0.001	0.079	<0.001	0.015	0.037	<0.001	0.098
$A_L:A_S$	0.001	0.030	0.041	0.870	0.829	0.206	0.934

CONCLUSIONS

- The increase in LAI and $A_L:A_S$ with fertilization resulted in a greater sensitivity to water availability defined by a reduction in annual E_L and increased WUE only in the combined fertilization and throughfall reduction treatment.
- Annual E_G was reduced by fertilization only in the drier year (2014).
- No interactive effect of throughfall reduction and fertilization treatments has

been detected on leaf-level gas exchange or stand growth (ie. DBH, basal area, height, etc.) in 2013 or 2014 (see poster by Charles Pell et al.). The lack of an interactive effect on growth may be due to the increase in WUE with fertilization, particularly in the throughfall reduction treatment, over the study period.



ACKNOWLEDGEMENTS

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