

# Partitioning root and heterotrophic respiration from soil CO<sub>2</sub> efflux in clonal loblolly pine plantations that differ in growth efficiency and carbon allocation

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## Introduction

Belowground carbon allocation (BCA) supports root production and maintenance, rhizosphere food webs, mycorrhizal fungi, and provides the majority of soil detrital C. These complex and interrelated processes make BCA the most unpredictable component of the forest C cycle. However, BCA may vary in predictable ways with changes in growth phenology and ontogeny and with changes in resource availability (water, nutrients, atmospheric CO<sub>2</sub>).

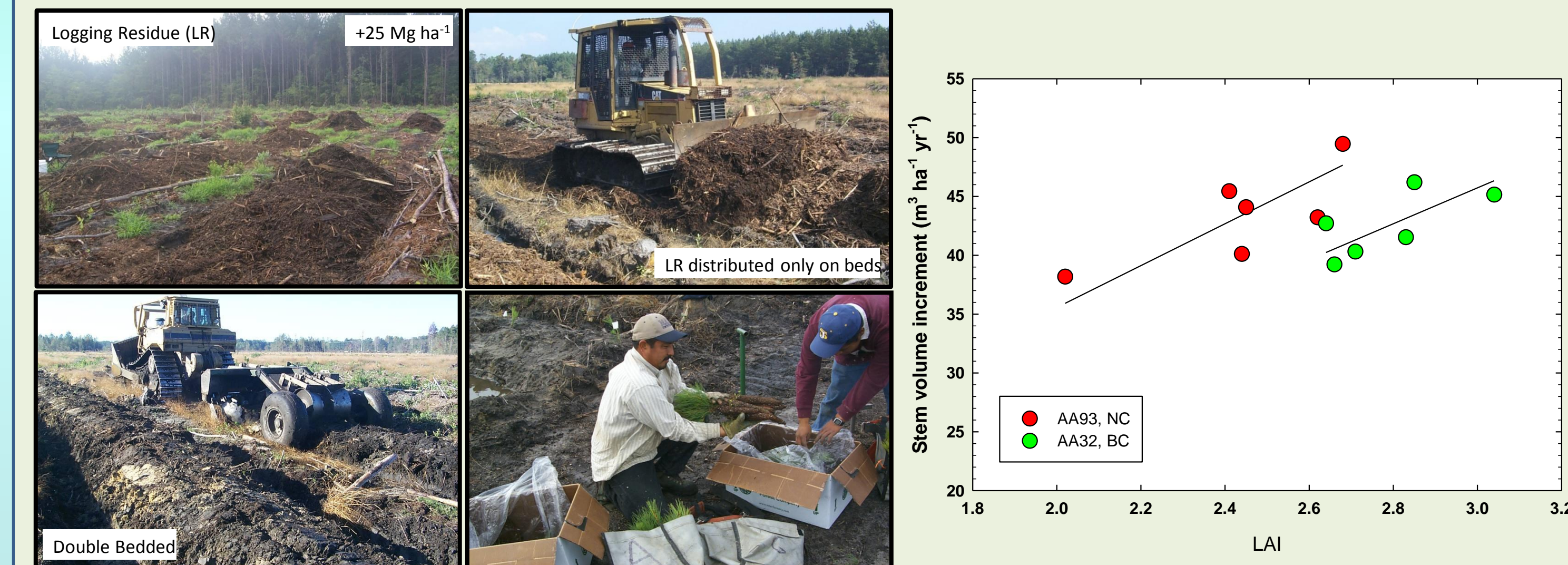
Partitioning soil CO<sub>2</sub> efflux ( $S_f$ ) into root ( $R_a$ ; root and rhizosphere) and heterotrophic ( $R_h$ ) respiration is an important step in understanding how climate and management influence BCA.

We measured  $S_f$  in an eight-year-old loblolly pine clone by silviculture study to determine how genotype and soil organic matter influence  $R_a$  and  $R_h$ . Estimates of  $S_f$ ,  $R_a$ ,  $R_h$  and carbon in the soil, root biomass and litter were used to calculate BCA.

## Methods

Study site: The Cross Carbon Study is a long-term collaborative research project designed to quantify the relationship between resource availability, stand productivity, and carbon sequestration in clonal loblolly pine plantations. For this study we focused on genetic by environmental interactions on  $S_f$ ,  $R_a$ ,  $R_h$ , and BCA.

- The study design is RCB replicated three times with whole-plot treatments in a 2 x 2 factorial combination with two logging residue treatments and two clones (Arborgen: AA-93 and AA-32) (12 plots). Soil organic matter treatments consisted of no addition (-LR) and soil incorporation at planting of 25 Mg ha<sup>-1</sup> comminuted logging debris (+LR, C:N=700).



- Clones represent a narrow crown (NC: AA93) and broad crown (BC: AA32) ideotype. Both clones have similar stem growth rates; however, the NC ideotype had less leaf area (15-20%) and greater growth efficiency than the BC ideotype. During the second year of growth, the BC clone had greater fine root length and turnover (Pritchard et al. 2010).

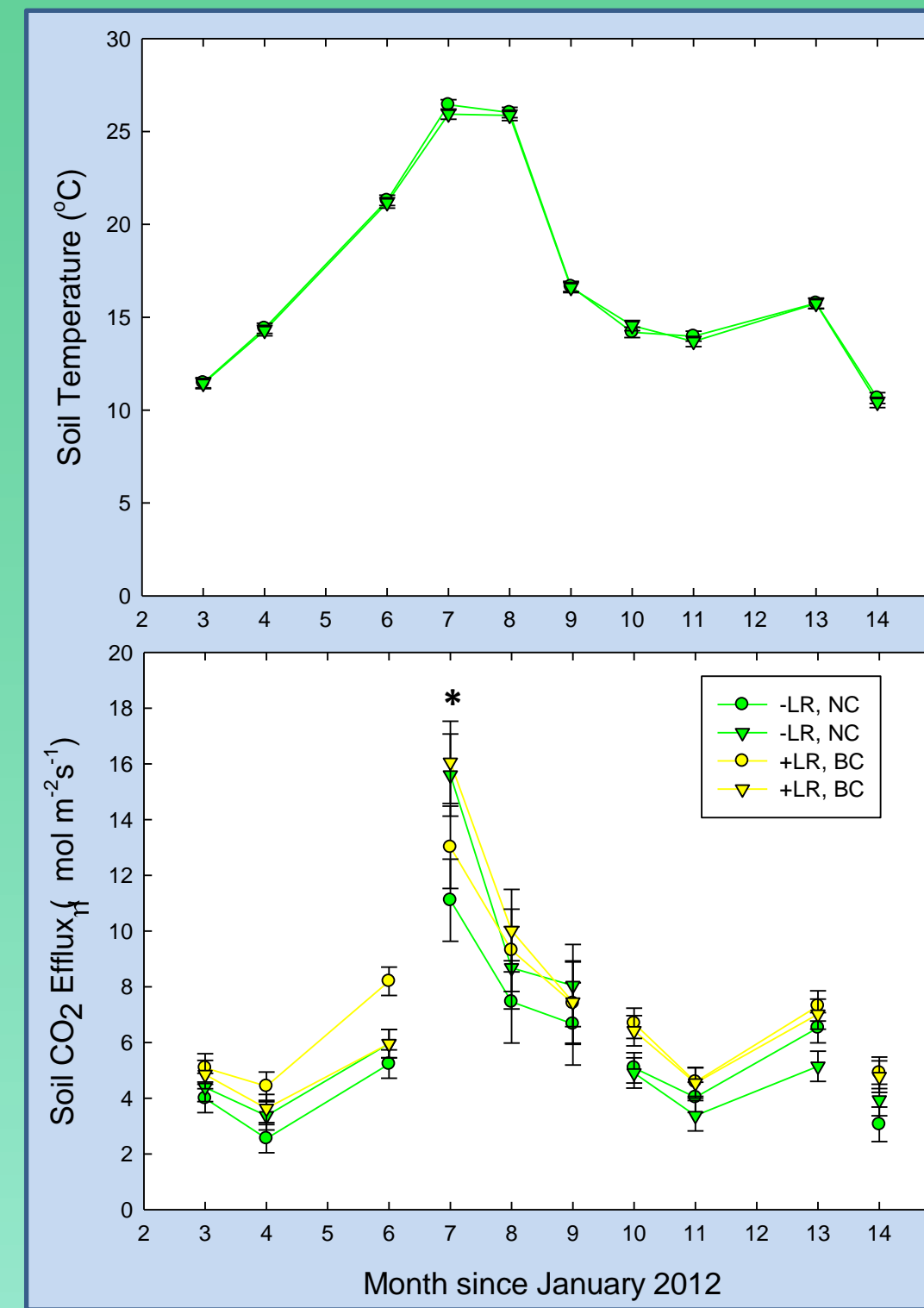
- We hypothesized that 1) because of greater leaf and fine root length, the BC clone would have greater  $S_f$ ,  $R_a$ ,  $R_h$ , and BCA than the NC clone, and 2) +LR would have increased  $R_h$  and microbial biomass carbon eight years after treatment.

- The root exclusion pipe method was used to partition  $S_f$  into  $R_a$  and  $R_h$ . In March, July, and October, three randomly selected locations on the bedded rows were selected in each plot. At each location,  $S_f$  was measured with a Licor 6400 in two positions 15 cm apart. After the initial  $S_f$  measurement, a 10.7cm diameter by 20cm pipe was installed in one of the two positions.  $S_f$  was measured periodically in the pipe and no-pipe positions over the next 80-95 days.

- $R_a$  was estimated by calculating the relative difference in  $S_f$  between the pipe and no-pipe positions ( $dS_f = (S_{f,pipe} - S_{f,no-pipe}) / S_{f,no-pipe}$ ). The  $dS_f$  value was then corrected for the initial differences between positions, that is, the difference in  $S_f$  between the pipe and no-pipe position before pipe installation.

- After the final measurement, soil cores in the pipe and no-pipe positions were collected and analyzed for microbial biomass carbon (MBC, chloroform fumigation method), root biomass, coarse organic matter, and mineral soil carbon.

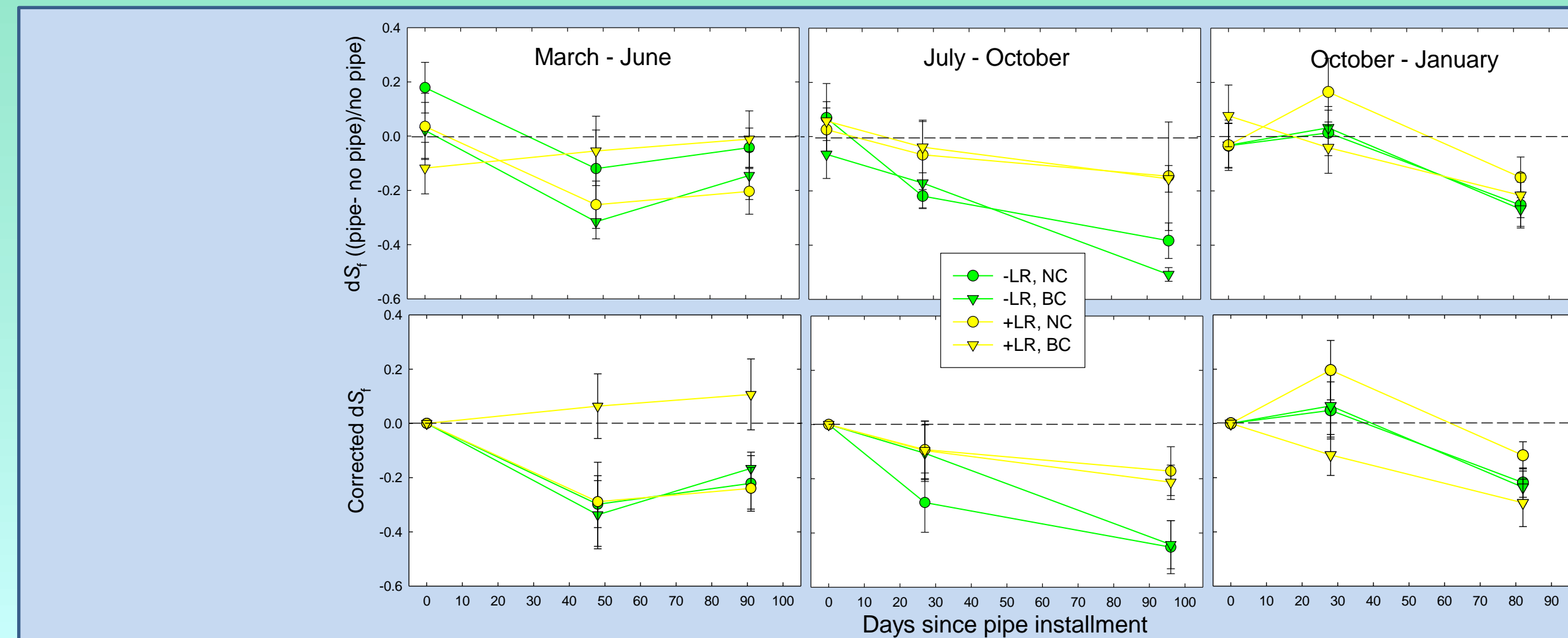
- $S_f$ ,  $dS_f$ ,  $R_a$ ,  $R_h$ , COM, and live root biomass were analyzed using repeated measures ANOVA. All data are reported as LSMEANS (n=3) and standard errors.



## Results

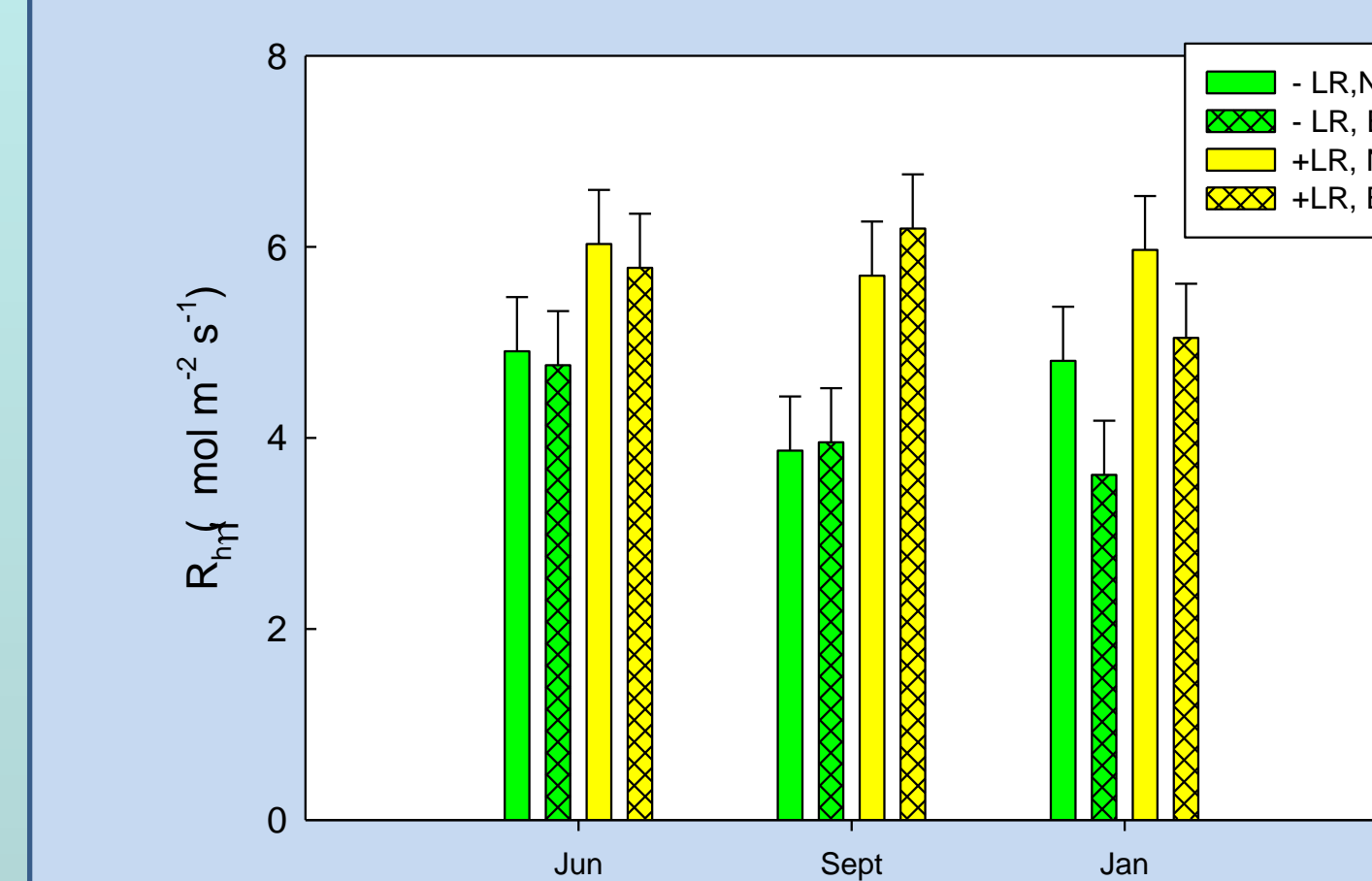
**Figure 1.** Seasonal pattern of soil temperature (10 cm depth) and soil CO<sub>2</sub> efflux ( $S_f$ ) as influenced by clone and LR treatments.

- There were no treatment effects on soil temperature
- Mean  $S_f$  in the +LR treatment ( $7.07 \pm 0.32$ ) was 15% greater than in the -LR treatment ( $5.96 \pm 0.32$ ) ( $p=0.04$ ).
- There were no clone or clone x LR effects on  $S_f$ ; however, there was a clone x season effect ( $p=0.008$ ), where  $S_f$  was 17% greater in BC clone in July (\*).



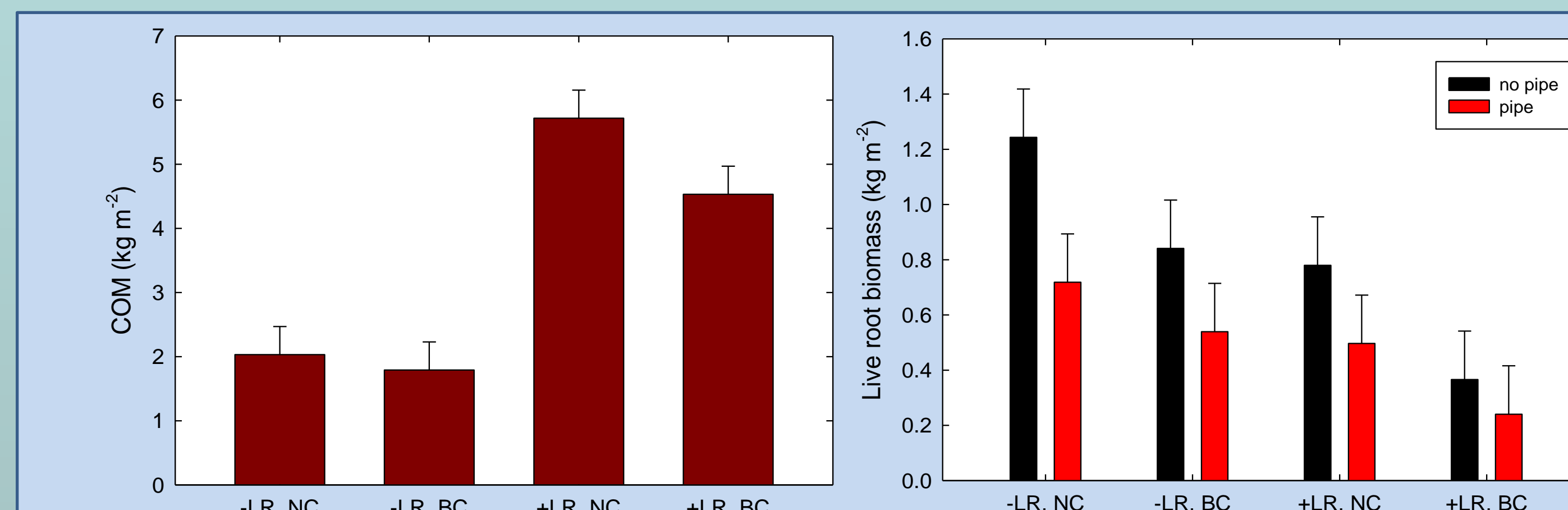
**Figure 2.** Soil CO<sub>2</sub> efflux ( $S_f$ ) measured before and after root exclusion pipe installation in March, July, and October. In panels a, b, and c,  $S_f$  is expressed as the relative difference between pipe and no-pipe positions ( $dS_f$ ). In panels d, e, and f,  $dS_f$  has been corrected for the initial difference between positions before pipe installation (i.e. Day 0).

- In most treatments, pipes had significantly less  $S_f$  relative to no-pipe positions after 80-95 days.
- The proportion of  $S_f$  attributed to  $R_a$  (i.e.  $dS_f$ ) ranged from 0.10 - 0.42 and varied with time of year.  $R_a$  was a larger component of  $S_f$  during the summer (0.32) than in the spring (0.13) or fall (0.22).
- For pipes installed in July,  $dS_f$  was significantly less in -LR (0.42) than in +LR (0.19) treatments ( $p=0.002$ ) indicating that  $R_a$  was a larger proportion of  $S_f$  in -LR treatments at this time of year.



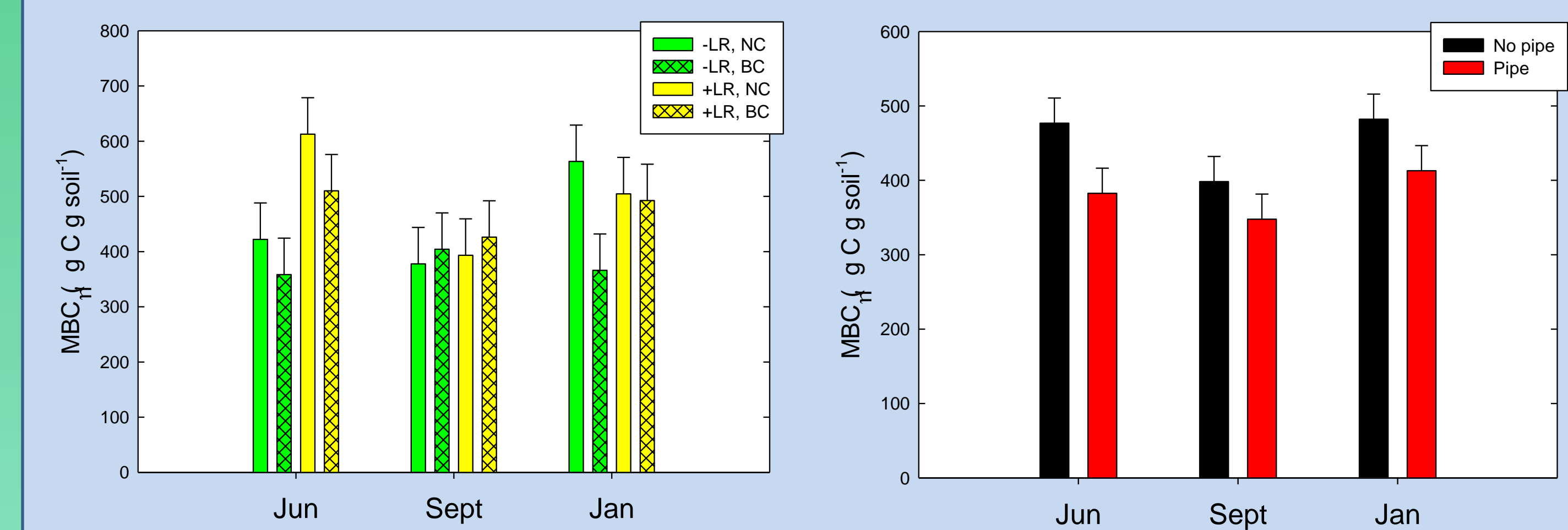
**Figure 3.** Heterotrophic respiration ( $R_h$ ) measured 80-95 days after pipe installation.

The addition of organic matter (+LR) increased  $R_h$ . Mean  $R_h$  was 25% greater in the +LR ( $5.78 \pm 0.31$ ) than in the -LR ( $4.32 \pm 0.31$ ) treatment ( $p=0.0001$ ). There were no significant clone or clone x LR effects.



**Figure 4.** Coarse organic matter (COM, > 2 mm) and live root biomass. Data are LSMEANS and standard error across all sampling dates.

- COM and mineral soil C concentration (data not shown) was greater in the +LR treatments.
- Pipe installation resulted in a decrease in live root biomass ( $p=0.002$ ).



**Figure 5.** Microbial biomass carbon (MBC,  $\mu\text{g C g soil}^{-1}$ ).

- Addition of organic matter (+LR) increased MBC. Mean MBC was 18% greater in the +LR ( $489.9 \pm 27.4$ ) than in the -LR ( $415.32 \pm 27.4$ ) treatment ( $p=0.07$ ).
- Pipe installation decreased MBC. Mean MBC was reduced 16% in the pipes compared to no-pipe (pipe:  $381.0 \pm 22.4$ , no-pipe:  $452.5 \pm 22.4$ ;  $p=0.008$ ).

## Belowground Carbon Allocation (BCA)

BCA ( $\text{kg C m}^{-2} \text{ yr}^{-1}$ ) was estimated using a modified mass balance approach (Giardina and Ryan 2002):

$$\text{BCA} = F_s - L + \Delta(C_R + C_L),$$

where,  $F_s$  is carbon loss in  $S_f$ ,  $L$  is aboveground litterfall, and  $\Delta(C_R + C_L)$  is the change in root biomass C and forest floor litter C, respectively.

	kg C m <sup>-2</sup> yr <sup>-1</sup>	NC	BC	SE	p-value
BCA		2.214	2.426	0.165	0.0606
$F_s$		2.028	2.252	0.152	0.0496
$L$		0.166	0.186	0.001	0.0003
$\Delta(C_R + C_L)$		0.352	0.362	0.023	0.0543

- The large annual  $F_s$  reflects the high productivity of these plantations (> 27 Mg ha<sup>-1</sup> yr<sup>-1</sup>)
- $F_s$ ,  $L$ ,  $\Delta(C_R + C_L)$  was higher in the BC plots leading to 10% greater BCA.
- BCA does not include change in mineral soil C, which may be large for these sites (-0.5 to -1.0 kg C m<sup>-2</sup> yr<sup>-1</sup>).

## Summary

- The proportion of  $S_f$  attributed to  $R_a$  ranged between 0.10 - 0.42 and varied with time of year.  $R_a$  was a larger component of  $S_f$  during the summer.
- Effects of organic matter treatments (+LR) applied at planting were evident in year eight. The +LR treatment increased  $S_f$ ,  $R_h$ , and MBC by 15, 25, and 18%, respectively.
- There was a clone x season effect on  $S_f$ , where  $S_f$  was 17% greater in the BC clone in July. This clone x season effect was also observed by Tyree (2008) during the third growing season. These results suggest that the BC clone has greater root growth and BCA than the NC clone during the growing season.
- The BC clone had about 10% greater annual BCA than the NC clone which is consistent with greater leaf area and potentially greater canopy C uptake.
- These early results suggest that genotype and management can alter  $S_f$ ,  $R_h$ , and  $R_a$ . Establishing the seasonal variation in the relationship between  $S_f$ ,  $R_h$ , and  $R_a$  will help quantify belowground carbon partitioning.

## References

- Giardina, C.P. and M.G. Ryan. 2002. Total belowground carbon allocation in a fast-growing Eucalyptus plantation estimated using a carbon balance approach. *Ecosystems* 5, 487-499.
- Pritchard, S.G., C.A. Maier, K.H. Johnsen et al. 2010. Soil incorporation of logging residue affects fine-root and mycorrhizal root-tip dynamics of young loblolly pine clones. *Tree Physiology* 30, 1299-1310.
- Tyree, M.C. 2008. Genetics by nutrient availability interactions on short-term carbon pools and fluxes in young *Pinus taeda* plantations. Ph.D. Dissertation, Forestry, Virginia Tech, Blacksburg, p. 272.