

# Use of analytical chemistry to examine controls over decomposition

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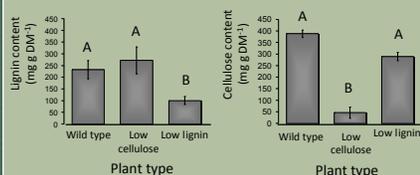
## BACKGROUND

- **Decomposition releases CO<sub>2</sub> to the atmosphere** at a rate that is 10 times the current rate due to anthropogenic emissions.
- We must understand the mechanisms of litter decomposition in order to improve predictions of carbon sequestration under global change.
- **Plant chemistry should influence rates of litter decomposition** by controlling the activity of decomposer microbes.
- Lignin is a recalcitrant aromatic compound that surrounds more labile cellulose and protein in plant cell walls.
- The amount and chemical structure of lignin is hypothesized to influence the decay rate of litter by controlling microbial access to labile litter components.

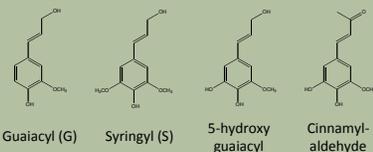
*Objective: To determine the mechanism of initial litter chemistry effects on decomposition rate by mapping the structure and chemical composition of plant cell walls in decomposing litter.*

## STUDY SYSTEM

- We used *Arabidopsis thaliana* mutants that vary in lignin, cellulose, or N content or in lignin chemical composition.



- Mutants have either low lignin content, low cellulose content, or different lignin chemical composition: a low ratio of syringyl to guaiacyl (S:G) units, a high S:G ratio, 5-hydroxyguaiacyl units, or a high proportion of cinnamyl-aldehydes compared to wild type.



- Wild type (Columbia) *Arabidopsis* were grown with low-N fertilizer (3 mM KNO<sub>3</sub>-N) or high-N fertilizer (15 mM KNO<sub>3</sub>-N) to produce stem tissue with either high or low N content.

## METHODS

- Over 4000 *Arabidopsis* plants were grown from January-June 2008.
- Stem tissue from each plant type was harvested and placed in 10 cm x 10 cm litterbags made of 1-mm mesh.
- Three to six litterbags were made of each plant type for a total of 30 litterbags.
- Stems were decomposed from July 2008 - July 2009 in the boreal forest of interior Alaska.
- Decomposition rate of each plant type was calculated as total mass loss.



Fig 1. *Arabidopsis* growing in the UCI greenhouse April - July 2008.

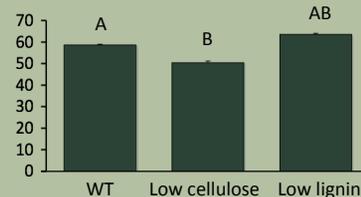
Fig 2. Wild type *Arabidopsis* grown under high-N or low-N fertilizer.



Fig 3. Litterbags decomposing in the field site in Alaska in July 2008.

## HYPOTHESES

1. Low cellulose litter will decompose slower than wild type litter due to less labile C substrate available for decomposer microbes.
2. Low lignin litter will decompose faster than wild type litter due to less protection of cellulose and protein.
3. Litter will decompose in the order low S:G < wild type < high S:G < 5-hydroxyguaiacyl units < cinnamyl-aldehyde lignin content due to less condensed lignin structure.
4. Litter with high N content will decompose faster than litter with low N content by alleviating the N limitation of decomposer microbes.



### Hypothesis 1: Supported.

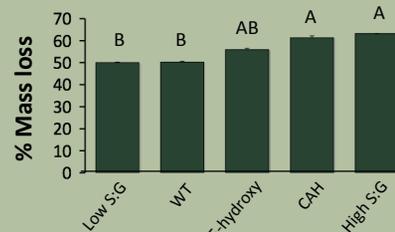
The low cellulose mutant decomposed slower than the wild type *Arabidopsis* ( $P = 0.008$ ).

### Hypothesis 2: Not supported.

The low lignin mutant decomposed at a rate similar to the wild type.

### Hypothesis 3: Partially supported.

There was a significant effect of lignin chemistry on decomposition ( $P = 0.007$ ). Stems decomposed in the order: low S:G ratio > wild type > 5-hydroxyguaiacyl > high cinnamyl-aldehydes > high S:G ratio.



### Hypothesis 4:

**Supported.** Plants with high N content decomposed faster than plants with low N content ( $P = 0.002$ ).

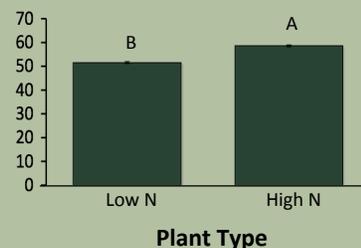


Fig 4. Mass loss of stem tissue decomposed in an Alaskan boreal forest from July 2008-2009. Bars represent standard errors,  $n = 1-6$ . Letters represent Tukey groupings ( $P < 0.05$ ).

## DISCUSSION

- Cellulose and nitrogen content of plant tissue appear to control rates of decomposition in the boreal zone by acting as a substrate for decomposers.
- Lignin chemical composition is a stronger control over litter decay rates than lignin content alone.
- In terms of lignin chemistry, the amount of syringyl units and cinnamyl-aldehyde units in lignin are the best predictors of litter decay rates.
- Analysis of cell wall structure in decomposed litter is required to determine the mechanisms driving these patterns.

## FUTURE WORK

- We will test the mechanisms underlying hypotheses 1-4 by analyzing the structure and composition of whole cell walls of decomposed tissue for each plant type.
- Whole cell walls will be dissolved using the ionic solvent is DMSO-*d*<sub>6</sub>/1-methylimidazole-*d*<sub>5</sub>.
- 1-methylimidazole-*d*<sub>5</sub> will be synthesized by methylating imidazole-*d*<sub>4</sub> with iodomethane-*d*<sub>3</sub>.
- We will quantify the cell wall structure and the loss of litter chemical components during decomposition of each plant type using 1D and 2D NMR spectroscopy.

## ANTICIPATED PRODUCT

- Quantitative analysis of changes in the chemical composition of litter material during decomposition.
- Development of a procedure to quantify the degradation of chemical structures in litter using quantitative 2D NMR.
- Ability to identify the mechanistic link between initial litter chemistry traits and decomposition rate.
- One chapter in a dissertation and an associated publication in a peer-reviewed journal.