Pathways and Patterns of Plant Litter Chemistry during Decomposition

Miranda Vega[1], Katelyn Berry[3], Stephen Peters-Collaer[2], Patrick Susman[2], Lynn Christenson[2], Kyle Wickings[3], Becky Ball[1]
[1]School of Mathematical & Natural Sciences, Arizona State University at the West Campus
[2]Biology, Vassar College, [3]Entomology, Cornell University

Introduction

- Decomposition is the breakdown of dead organic material into smaller particles releasing nutrients for plant and microbial production. This is a key process in carbon regulation and nutrient cycling, soil formation, and fundamental to energy flow in food webs.
- Plant litter chemistry can alter decomposition yet few studies have been conducted to examine the chemical composition of plant litter throughout decay. The majority of studies measure the initial plant litter chemistry, focusing primarily on carbon and nitrogen, and presume that the initial measures will explain how litter will behave throughout decomposition.
- The main goal of this project is to test the assumption that initial chemistry predicts the route taken by plant litter during decomposition and examine the chemical pattern change in systems with different biotic and abiotic environments.
- Figure 1 illustrates the three possible outcomes of the assumption.

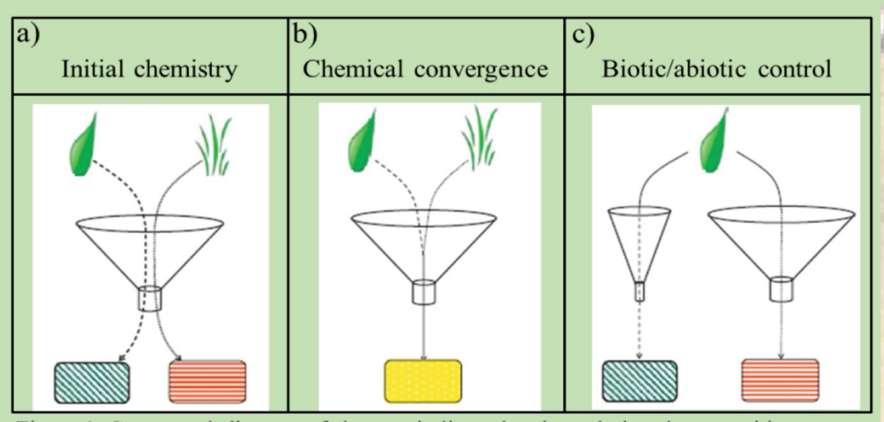


Figure 1. Conceptual diagram of changes in litter chemistry during decomposition (Wickings et al. 2012). The shape of litter represents different initial chemistry. The shape of funnel denotes different decomposer communities. Squares represent the chemistry of the decomposing litter.

Methods

- The litter samples were collected from archived Long-Term Ecological Research (LTER) study sites.
- The archived litter samples were single species, untreated, and from their native environment.
- The four analyses conducted were:
  1) Carbon to Nitrogen ratio measured using an elemental analyzer (this method combusts the litter sample, then reports CO_2 and N_2 percentages).
  2) Pyrolysis Gas Chromatography Mass Spectrometry (Py-GCMS): samples run to measure major compounds detectable through mass spectrometry (lipids, lignin, proteins, phenols, etc.).
  3) Fiber analysis by conducting a sequential acid digestion (this method measures hemicellulose, cellulose, lignin, and solubles).
  4) Phosphorus and micronutrients were measured by doing an elemental analysis on an inductively coupled plasma optical emission spectrometer (ICP-OES).

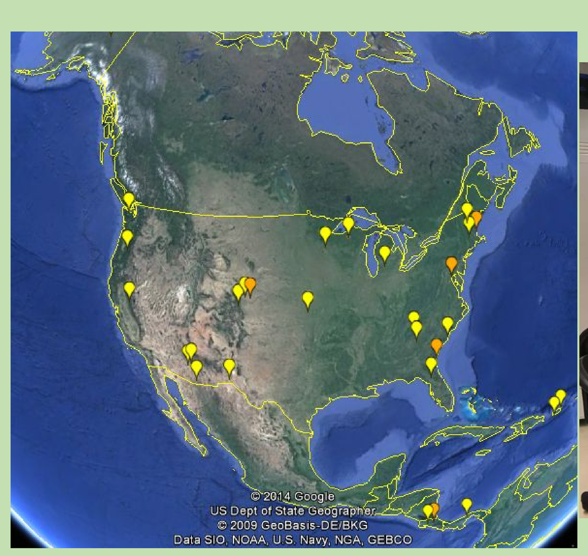


Image of the distribution of the origins of litter samples and data to be analyzed. Yellow placemarkers represent the locations of samples to be analyzed in this research. Orange placemarkers represent additional sites from which archived data have been collected.

Photo credit: Miranda Vega

Results

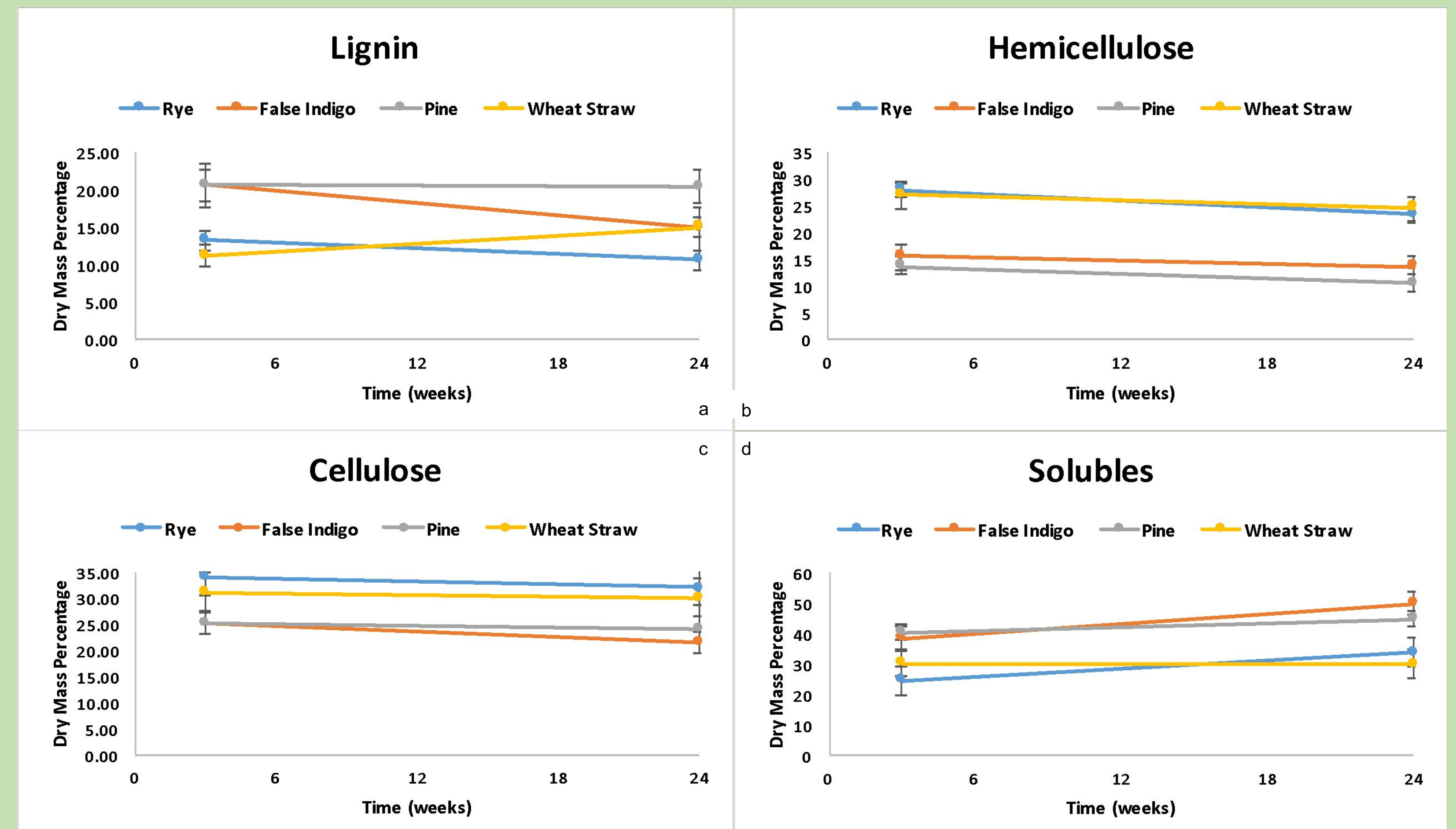


Figure 2. Fiber analysis of four farm plants in fields in Georgia, US. a. represents lignin compounds in rye, wheat straw, false indigo and pine species that were collected at four points over a two year period, shown as time in weeks. Compound concentrations were gathered as percentage of litter mass. b and c are hemicellulose and cellulose concentrations and d represents various soluble compounds. The many parallel lines, i.e. false indigo and pine hemicellulose should be noted as they may support initial chemistry (option A figure 1). However, also note the diverging lines like in false indigo and pine lignin (a).

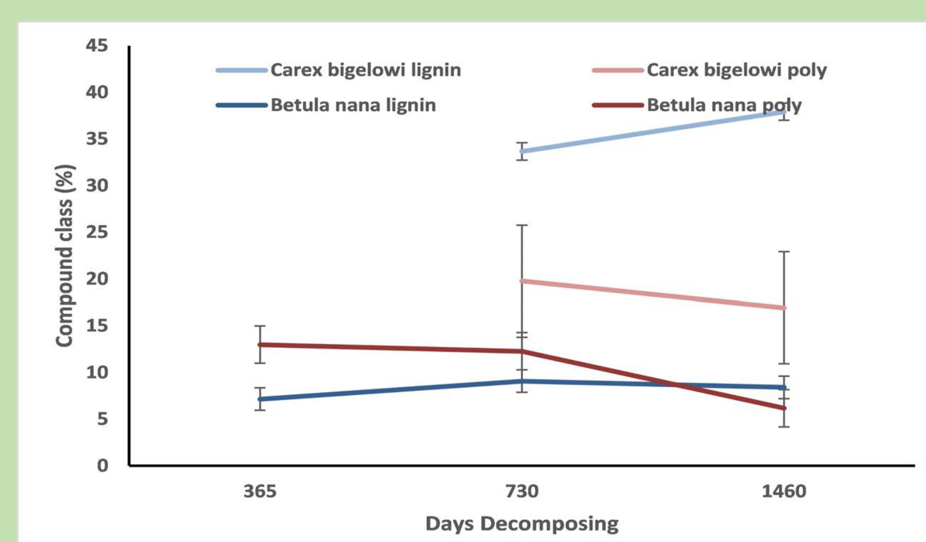


Figure 3. Py-GCMS compound class data for two arctic species. Lignin and polysaccharide percentages are represented in one arctic grass species and one arctic shrub species. Samples were collected after a certain number of days in litter bags. Polysaccharides in the grass and shrub follow a similar decreasing trend starting, appearing to converge on similar values in the 50% mass remaining decay stage. The relative amount of lignin in the grass was significantly higher than in the shrub, both following an increasing trend as decay occurs.

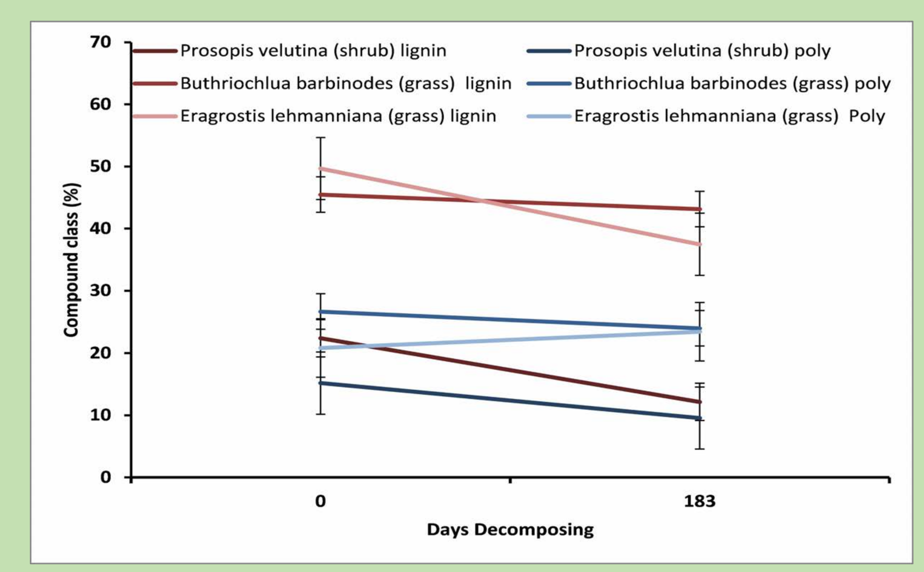


Figure 4. Py-GCMS compound class data for three desert species. We used litter bag decomposition samples from the Desert at initial stage prior to decay, 0 days, and at 183 days when 50% mass remaining in litter bag occurred. Three species were examined focusing on two compound classes, lignin, in red and polysaccharides, in blue. Lignin in the grass species follow a similar decreasing trend, polysaccharides do not follow a similar trend and instead converge to the nearly the same value. Lignin and polysaccharides for the shrub appear to follow a similar decreasing trend as well as converge to a similar value, they also have lower initial and final compound class % than the grasses.

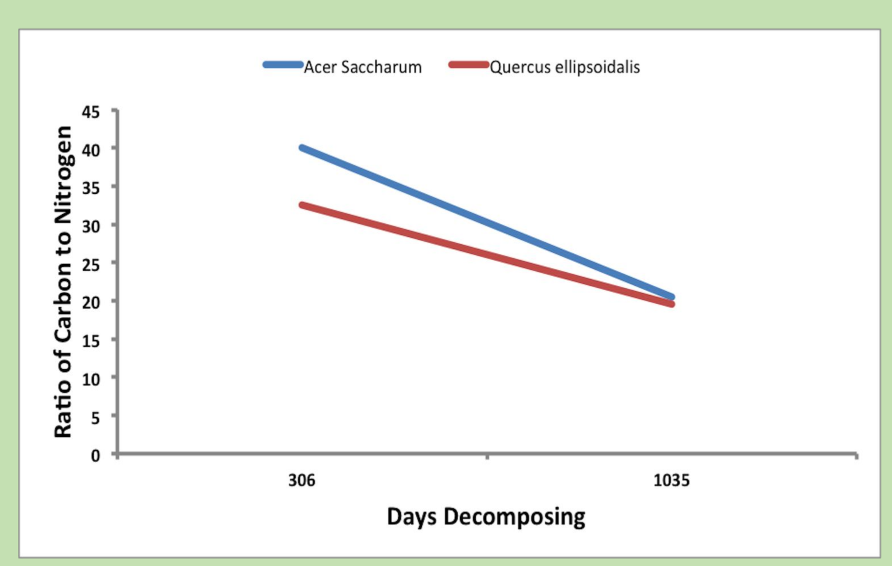


Figure 5. Carbon to nitrogen ratio for *Acer saccharum* (sugar maple) and *Quercus ellipsoidalis* (northern pin oak) at Cedar Creek LTER, MN. Days decomposing represent number of days after litterbag deployment. Ratios were measured using an elemental autoanalyzer, and raw data were used. Initial C:N values for maple and oak were significantly different ($p<0.0001$, ANOVA), but final values were not, indicating convergence of leaf litter chemistry throughout decomposition (figure 1., option b).

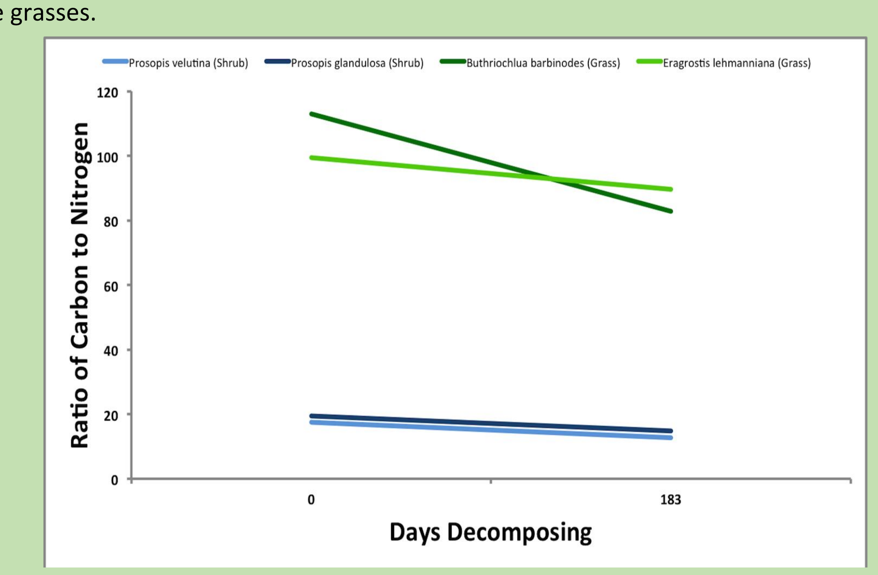


Figure 6. Carbon to nitrogen ratios throughout decomposition for four desert plant species. Two desert grass species and two desert shrub species in the Southwestern US. Days decomposing are days after litterbags were put in the field. Carbon and nitrogen percentages were gathered by an elemental autoanalyzer and ratios raw data were used. Initial and final C:N values were not significantly different for the two shrubs. Initial C:N values were significantly different for the two grasses ($p=0.0271$, ANOVA), but final C:N values were not, indicating convergence of leaf litter chemistry throughout decomposition (figure 1., option b).

Images from left to right: *Prosopis velutina*-a desert shrub, *Buthriochlua barbinodes*-a desert grass, ground litter from desert and tropical litter samples, *Betula nana*-an arctic shrub and *Carex Bigelowii*-an arctic grass

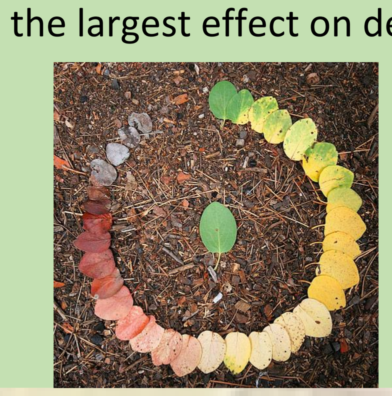
Discussion

Our results support all three hypotheses portrayed in figure 1.

- Much of our data follow the pattern where initial chemistry explains decomposition best.
  - This is supported by the parallel lines illustrated in figures 2-6, indicating that differences in initial chemistry remain throughout decomposition.
- However, there is evidence for convergence of litter chemistry.
  - Figures 5 and 6 show chemistry of some samples becoming more similar during decomposition.
- We also see evidence for divergence of litter chemistry.
  - Pine and False Indigo in Figure 2 have similar initial chemistries that diverge during decomposition.
- In summary, our data demonstrate that litter chemistry varies throughout decomposition, not strictly following one pattern. More samples need to be analyzed to understand what drives these differing fates.
  - The py-GCMS data provide interesting results that will help fill in the gaps left by the relatively simple C:N analysis.

Future (continuing) Research:

- We will continue to collect litter samples from completed decomposition studies across the LTER network and analyze the complete set of litter chemistry parameters.
- With more data we hope to understand how climatic factors as well as species specific factors influence decomposition.
- We will examine the role of specific compounds in the decomposition of litter and attempt to isolate which compounds have the largest effect on decay rates.



Acknowledgements: We would like to sincerely thank everyone involved in this project, the National Science Foundation Division of Environmental Biology (NSF DEB-1537920), the Long Term Ecological Research Network, Dr. Stuart Grandy, Scott Greenwood, Dr. Chelsea Prather, Paul Cattelino, Dr. Jennie DeMarco, Dr. Grizelle Gonzalez, Dr. D. Jean Lodge, Dr. Marshall McDaniel, and Gary Lovett.