Impacts of Cover Crop Decomposition and Nutrient Release on Agronomic Systems in Southern Illinois

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Background

Midwestern farmers face the challenge of increasing crop production while reducing environmental impacts of nutrient losses, particularly nitrogen. To decrease nutrient and soil loss, many growers have returned to cover cropping practices, but are uncertain about cover crop nutrient release and subsequent cash crop uptake. Both the quantity and rate of nutrient release can vary, making it challenging to coordinate cover crop nitrogen release during decomposition with peak cash crop uptake needs. Cover crop residue decomposition and nutrient release can be affected by substrate quality, soil temperature, moisture, or aeration, and microbial and faunal heterotrophs (e.g., Robertson and Paul, 2000). Plant substrate quality can differ greatly among closely related species (e.g. Cobo et al., 2002), among plant parts (leaves, stems, roots; e.g., Hackney and De La Cruz, 1980) or even within species based on age or height (Harre et al, 2014).

Objective

To determine aboveground and belowground biomass production, decomposition rate, and nitrogen release rate of cereal rye (*Secale cereale* L.) and hairy vetch (*Vicia villosa* Roth) in a corn-soybean system.

Materials and Methods

Field samples of cereal rye and hairy vetch aboveground biomass were harvested, air-dried for one week, and placed in 20 x 20 cm litterbags. Belowground root biomass was collected as intact root cores (Dornbush et al., 2002). Samples were placed into respective hairy vetch and cereal rye plots in the cover crop study location (part of a larger cover crop study) at the Agronomy Research Center (ARC) in Carbondale, Illinois. Litterbags and intact root cores were collected at Week 0, 2, 4, 6, 8, 12, and 16. Plant Root Simulator™ (Western Ag, Saskatoon, Canada) probes were inserted into the soil to measure plant available ammonium and nitrate from decomposition *in situ* cover crops in each plot and collected at the above sampling times. To account for differences in decomposition due to plot location within the field, a modified Tea Bag Index decomposition study (Keuskamp et al., 2013) was conducted using green and black tea within each cover crop plot. Week 0 samples were dried, ground, and analyzed for initial nitrogen content, acid detergent fiber, neutral detergent fiber, lignin content, and ash content, and all subsequent samples were analyzed for nitrogen content and ash content. The following equations were used for calculations and statistical analysis:

Equation 1. $\% MR \text{ or } NR = 100\, X_t / X_0$

where percent mass remaining (% MR) or nitrogen remaining (% NR) at any given time or week (t) is calculated using the mass of the cover crop at each week (X_t) divided by the initial mass at Week 0 (X_0). Decomposition rates of cover crops over a 16-week period were derived from the 3-parameter single negative exponential model with an asymptote (Harmon et al., 2009), using the nonlinear regression function:

Equation 2. $\% MR \text{ or } \% NR = ae^{-kt} + Y_0$

where % MR or % NR is a result of the estimated asymptote (Y_0), the y-intercept (a), and the decomposition constant (k). Decomposition constants were subjected to an equivalence test to determine if decomposition rates of each cover crop were significantly different from each other. Soil moisture readings and PRS probe nitrogen capture in each cover crop plot were compared at each week using a t-test to compare means of cereal rye and hairy vetch plots each week. All statistical analyses were performed using the JMP statistical analysis package (JMP Pro, Version 12, SAS Institute Inc., Cary, NC, 1989-2007).



Picture 1 (left): Intact root cores with mesh wrapped ends prior to installment in the field. **Picture 2 (middle):** Litterbag and root core placement in the field. Colored flags represent different collection intervals. **Picture 3 (right):** Remnants of cover crop residue from a litterbag after being taken from the field into the lab.

Results

Table 1. Parameter estimates for the asymptotic exponential model used to describe the dry mass loss and nitrogen loss of cereal rye, hairy vetch, black tea, and green tea in each cover crop plot over 16 weeks of residue decomposition.

		Parameter Estimates*				
Crop	**Part**	***k***	**a**	**Y_0**	**RMSE****	**R^2**
		% Mass Remaining				
Cereal rye	Above	0.1368	85.63	10.80	4.88	0.9787
Hairy vetch	Above	0.4505	87.96	11.31	2.74	0.9952
Cereal rye	Below	0.1866	94.00	3.32	13.55	0.8928
Hairy vetch	Below	0.6821	90.68	8.35	8.79	0.9557
Black tea	Rye	0.5047	51.50	47.99	2.22	0.9908
Black tea	Vetch	0.5866	53.52	46.11	2.39	0.9902
Green tea	Rye	0.7061	70.66	29.07	2.79	0.9924
Green tea	Vetch	0.8333	70.02	29.74	4.26	0.9823
		% Nitrogen Remaining				
Cereal rye	Above	0.0703	110.28	-15.16	8.40	0.9364
Hairy vetch	Above	0.6148	93.10	6.49	2.94	0.9951
Cereal rye	Below	0.1928	83.78	15.05	12.54	0.8866
Hairy vetch	Below	0.6052	87.25	11.57	8.97	0.9504

*Asymptotic exponential model is $XRM = Y_0 + ae^{-kt}$, where XRM is the percent mass or percent nutrient remaining at time (t), Y_0 is the estimated asymptote, a is the y-intercept, and k is the decomposition constant.
**RMSE = root mean square error

Table 2. Estimated nitrogen release from aboveground (shoots) and belowground (roots) parts of cover crops.

		Cereal rye		Hairy vetch		Roots + Shoots		C:N Ratio	
		Shoots	**Roots**	**Shoots**	**Roots**	**Cereal rye**	**Hairy vetch**	**Cereal rye**	**Hairy vetch**
Date	**Week**	------------------*Nitrogen Release (kg ha⁻¹)*------------------							
5 May	0	0.00	0.00	0.00	0.00	0.00	0.00	35.8	9.7
19 May	2	3.59	11.35	58.16	14.00	14.94	72.16	34.4	12.4
2 June	4	1.59	-3.55	11.39	-0.97	-1.96	10.42	34.5	14.2
16 June	6	-0.15	12.18	5.40	4.56	12.03	9.96	28.8	15.7
30 June	8	0.92	2.27	2.57	-0.06	3.19	2.51	20.7	14.5
28 July	12	4.31	0.25	3.49	0.03	4.56	3.52	21.1	15.5
25 August	16	0.29	1.22	-0.27	0.91	1.51	0.64	18.7	16.3

Results

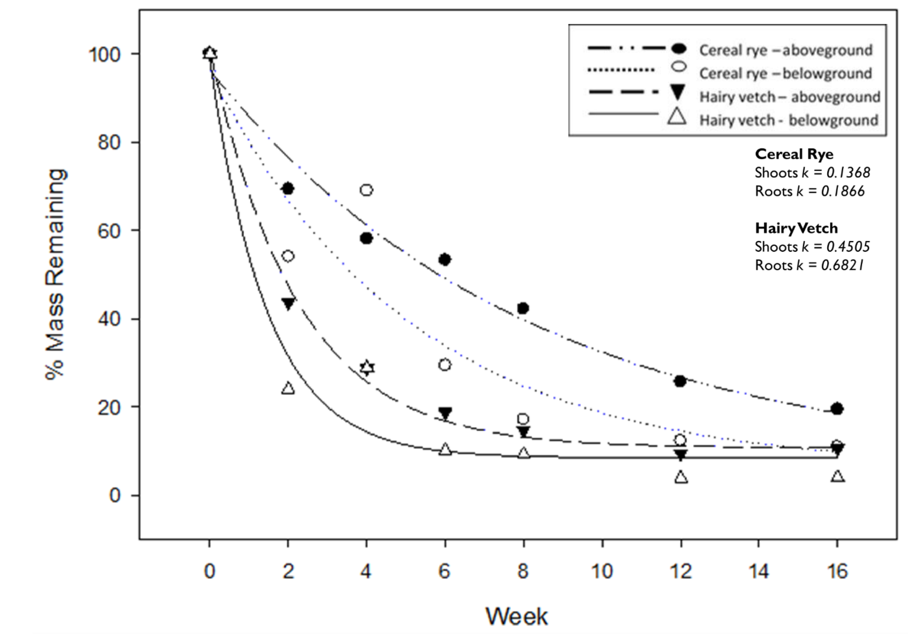

Figure 1. Percent mass remaining for aboveground and belowground plant material for cereal rye and hairy vetch over 16 weeks of decomposition.

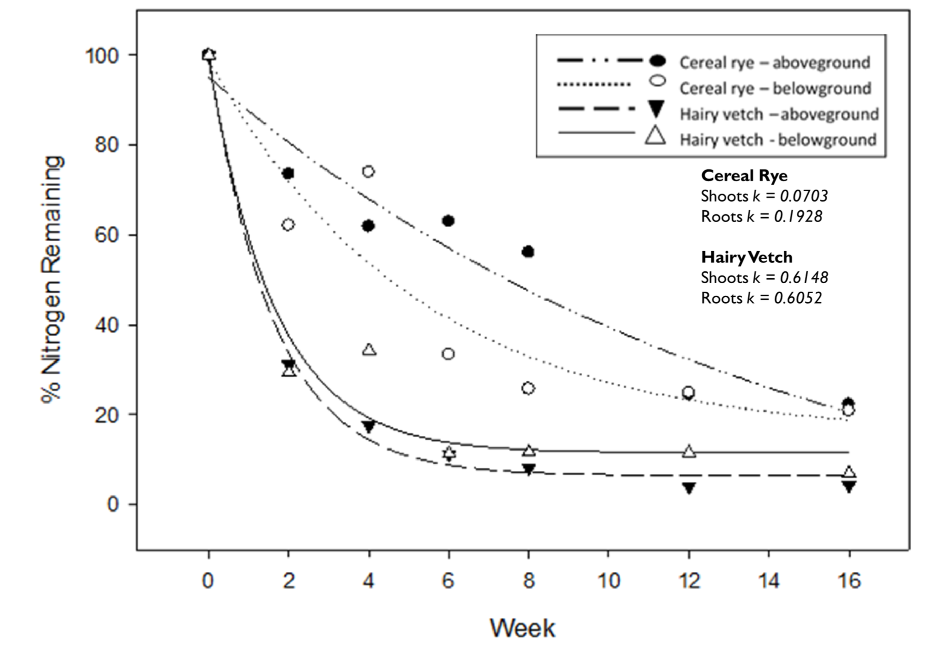

Figure 2. Percent nitrogen remaining in aboveground and belowground cereal rye and hairy vetch cover crops throughout 16 weeks of residue decomposition. Percent nitrogen remaining is based on nitrogen content in kg ha^{-1}.

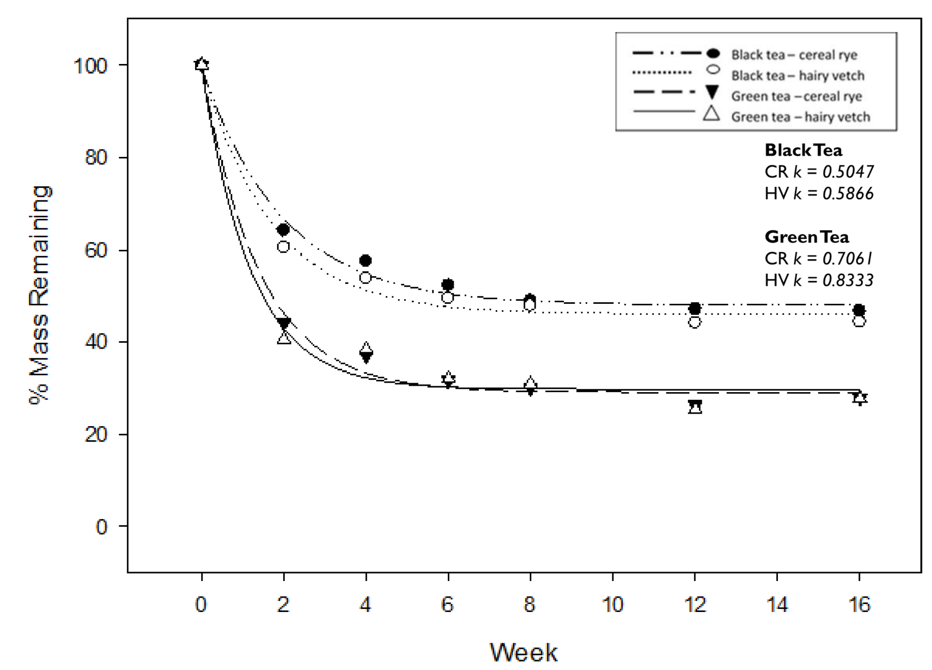

Figure 3. Black tea and green tea percent mass remaining over 16 weeks of decomposition in either cereal rye or hairy vetch decomposition plots.

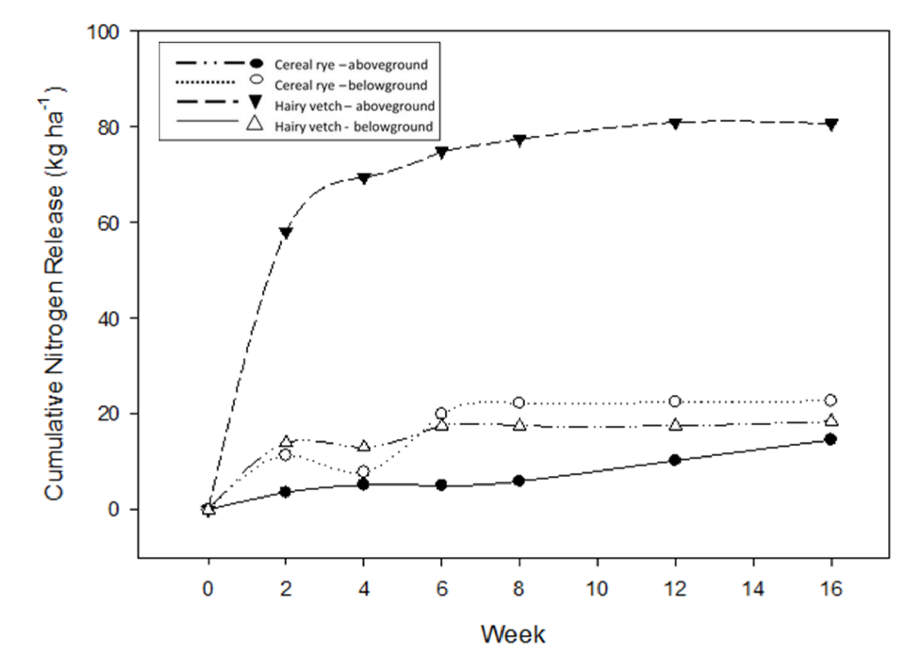

Figure 4. Estimated cumulative nitrogen release of cereal rye and hairy vetch residue over 16 weeks of decomposition.

Results and Discussion

- **Cereal rye aboveground (*k* = 0.14) and belowground (*k* = 0.19) biomass decomposed more gradually compared to hairy vetch aboveground (*k* = 0.45) and belowground (*k* = 0.68) biomass (Table 1; Figure 1).**
- **Cereal rye aboveground (*k* = 0.07) and belowground (*k* = 0.19) biomass released nitrogen slower and more gradually compared to hairy vetch aboveground (*k* = 0.61) and belowground (*k* = 0.61) biomass (Table 1; Figure 2).**
- **Black tea and green tea in each cover crop plot had similar decomposition curves, therefore plot location did not appear to affect decomposition rates (Figure 3).**
- **Hairy vetch rapidly decomposed and released N within the first two weeks, but began to slow after Week 4 (early June; Figure 4; Table 2).**
- **It is likely that initial crop C:N ratios and initial N content influenced decomposition rates. Cereal rye had a higher C:N ratio and lower initial N content compared to hairy vetch (Table 2).**
- **Total nitrogen (nitrate + ammonium) capture by the PRS Probes was significantly higher for Weeks 2, 4, 6, 8, and 12 in the hairy vetch cover crop treatments versus the cereal rye treatments.**
- **Only at Week 12 was there a significant difference in soil moisture between cover crop treatments.**

Future Directions

- **Greater understanding of cover crop decomposition will allow growers to better synchronize cash crop uptake with cover crop nitrogen release.**
- **Future research could investigate multiple cover crops, varying plant growth stages, or even simulation of different termination timings and methods to better synchronize cover crop nutrient release with cash crop uptake.**
- **Results from this research can help inform Midwestern farmers utilizing cover crops in corn (*Zea mays* L.) and soybean (*Glycine max* L. Merr.) production systems to understand likely nutrient release from preceding cover crops.**

References

Cobo, J.G., E. Barrios, D.C.L. Kass, and R.J. Thomas. 2002. Decomposition and nutrient release by green manures in a tropical hillside agroecosystem. *Plant and Soil*. 240: 331-342.
Dornbush, M.E. T.M. Isenhart, and J.W. Raich. 2002. Quantifying Fine-Root Decomposition: An Alternative to Buried Litter Bags. *Ecology*. 83:2985-2990.
Hackney, C.T. and A.A. De La Cruz. 1980. In Situ Decomposition of Roots and Rhizomes of Two Tidal Marsh Plants. *Ecology*. 61:226-231.
Harmon, M.E., W.L. Silver, B. Fasth, H. Chen, I.C. Burke, W.J. Parton, S.C. Hart, W.S. Currie, and LIDET. 2009. Long-term patterns of mass loss during the decomposition of leaf and fine root litter: an intersite comparison. Global Change Biology. 15:1320-1338.
Harre, N.T., J.E. Schoonover, and B.G. Young. 2014. Decay and Nutrient Release Patterns of Weeds Following Post-Emergent Glyphosate Control. *Weed Science*. 62:588-596.
Keuskamp, J.A., B.J.J. Dingemans, T. Lehtinen, J.M. Sarneel, M.M. Hefting. 2013. Tea Bag Index: a novel approach to collect uniform decomposition data across ecosystems. Methods in Ecology and Evolution. 4:1070-1075.
Robertson, G.P., and E.A. Paul. 2000. Decomposition and soil organic matter dynamics. Pages 104-116 in E.S. Osvaldo, R.B. Jackson, H.A. Mooney, and R. Howarth, eds. Methods in Ecosystem Science. Springer Verlag, New York, New York, USA.

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