Decomposition of Rye Cover Crops in Long-Term Cropping Systems

Sarah Kelley and Stephen J. Herbert
Dept. of Plant and Soil Sciences

Winter cover crops are an essential part of fertility management on many northeastern farms, and cereal rye (*Secale cereale*) is the most widely used cover crop in this region. Rye has many advantages, including its rapid establishment, hardiness, and ability to reduce nutrient leaching losses, but it may cause a period of "nitrate immobilization," when microbes decomposing the rye outcompete plants for soil N and cause crop N deficiency.

To maximize the benefits and minimize the disadvantages of rye cover crops, it is essential to understand the way rye decomposes. Decomposition will affect the release or immobilization of nutrients, the growth of main crops, and long-term soil health. Age at incorporation has a major influence on residue decomposition, and timing of cover crop incorporation is a critical aspect of cover crop management. More information is needed about the decomposition patterns of rye incorporated at different life stages under northeastern conditions. Our objectives were to:

1. Investigate decomposition of rye cover crops incorporated at three life stages.
2. Determine effects of combinations of rye incorporation date and N fertilizer rates on sweet corn yield.
3. Examine effects of initial rye tissue composition on decomposition and attempt to develop equations based on tissue components that could help predict decomposition patterns.

Preexisting rye cover crop plots at the University of Massachusetts Agronomy Farm in South Deerfield were divided into three subplots. In the previous growing season plots had received NH_4NO_3 at 0, 60, 120, and 180 lb N/ac. Rye was incorporated by rototilling at three stages: vegetative (May 4, 2001), initiation of bloom (May 18, 2001), and fully headed (June 2, 2001). Just after rototilling, cover crop samples were placed in fine-mesh nylon bags and buried in the subplots. Sweet corn ('Sweet Sal') was planted June 7 and sidedressed July 11 with NH_4NO_3 at 0, 60, 120, and 180 lb N/ac. Mesh bags containing rye samples were recovered at 1, 2, 3, 5, 8, 12, and 16 weeks after burial; samples were analyzed for total N, cellulose and lignin. Soil nitrate, soil temperature, corn leaf N, and number of marketable and non-marketable ears were also measured.

Dry matter losses from rye samples in mesh bags showed trends consistent with the characteristics of the rye at the time of incorporation (Table 1). 50% of original dry matter had been lost after 3 weeks for incorporation 1, after 5 weeks for incorporation 2, and after slightly more than 5 weeks for incorporation 3 (Figure 1). Decay stabilized at about 20, 25-30, and 35% of initial dry matter for incorporations 1, 2, and 3, respectively. Figure 1 suggests that incorporation date was the most important factor determining patterns of rye tissue decomposition. Residual N rate and applications of sidedressed N at the same rates as previously used (0, 60, 120, and 180 lb N/ac) did not cause discernable changes in decomposition.

Table 1: Composition of rye tissue at time of incorporation

Treatment		Tissue Component			
Inc (date)	N Rate (kg/ha)	Total N % of tissue	Lignin % of tissue	Cellulose % of tissue	C:N
1 (5/5/01)	1 (0 lb N/ac)	1.9	2.5	18.4	29.4
	2 (60 lb N/ac)	1.9	2.3	18.7	29.0
	3 (120 lb N/ac)	2.1	2.8	20.2	26.2
	4 (180 lb N/ac)	2.3	2.8	20.8	24.1
2 (5/18/01)	1 (0 lb N/ac)	1.3	2.5	25.3	43.9
	2 (60 lb N/ac)	1.3	3.1	25.9	44.7
	3 (120 lb N/ac)	1.3	3.7	27.8	42.6
	4 (180 lb N/ac)	1.6	4.5	28.2	34.6
3 (6/2/01)	1 (0 lb N/ac)	1.2	4.4	33.4	49.5
	2 (60 lb N/ac)	1.4	4.1	34.2	42.7
	3 (120 lb N/ac)	1.2	4.5	34.5	48.9
	4 (180 lb N/ac)	1.4	5.0	33.4	40.9
significance, Inc		***	**	***	***
significance, N Rate		**	*	*	**

*, **, and *** = significant at 0.05, 0.01, and 0.001 probability levels

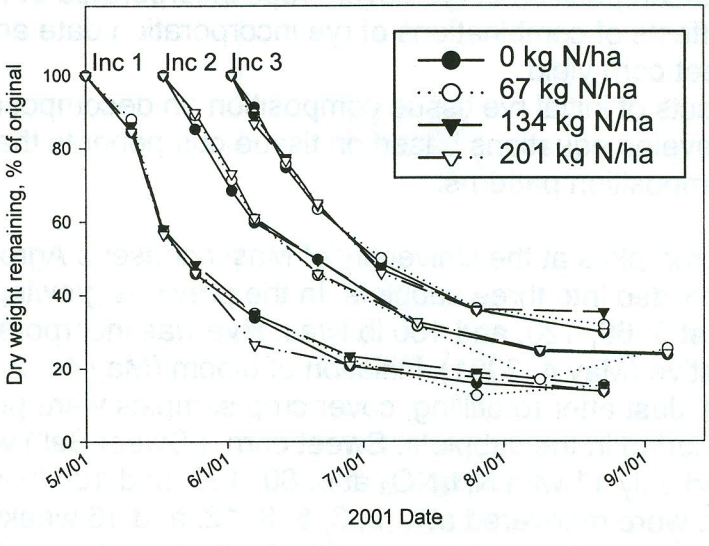

Figure 1. Dry matter loss from decomposing rye

Changes in N concentration and absolute N amount of the recovered rye tissues were examined to determine whether and to what extent nitrogen immobilization was occurring. During the decomposition period, N concentration (%) of the rye tissue rose in all three incorporations. Conversion of N concentration to C/N ratio indicated that incorporation 1 C:N dropped from ~25:1 to ~16:1-18:1, Incorporation 2 C:N from ~ 35:1-45:1 to ~20:1-22:1, and Incorporation 3 C:N from ~40:1-50:1 to ~ 25:1. Since nitrogen immobilization is known to begin at C:N of ~25:1 or higher, immobilization was expected in this experiment, especially after incorporations 2 and 3.

However, no definitive evidence for N immobilization was found in this experiment. Increases in N concentration are normally seen during decomposition, since C is lost as CO_2 more quickly than N is lost as NH_4^+ from decomposing tissue. N amount in the decomposing rye also dropped over the decomposition period, suggesting that N was not being immobilized in the tissue. In addition, Figure 2 shows that soil NO_3^- levels in all three incorporations began to rise at approximately the same time: around June 10, 2001. This pattern definitely suggests a lack of N immobilization, since tissue of differing maturity at incorporation should have begun allowing net N mineralization at different dates. Figure 2 also shows that soil temperature began to rise at around the same time as soil NO_3^- levels, suggesting that soil NO_3^- levels were primarily determined by soil temperature rather than by NO_3^- immobilization.

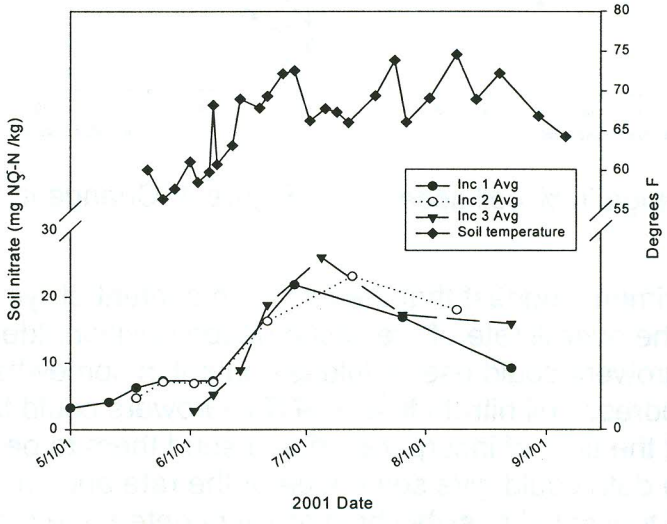

Figure 2. Changes in soil nitrate and soil temperature.

The lack of evidence for soil NO_3^- immobilization in this experiment was surprising, especially given the high C:N of the rye at the time of incorporations 2 and 3. A likely explanation may lie in the history of the experimental plots. After 10 years of continuous cover cropping, incorporation of sweet corn stover after harvest, and N fertilizer applications, high soil organic matter (SOM) levels (3 to 4%) and residual NO_3^- levels are present in these plots. Since Figure 2 shows that soil NO_3^- levels were not very high at the beginning of the decomposition period, most of this residual N was probably present in rye shoots or roots. These factors may have combined to provide enough N for microbial digestion of rye without the need for immobilization of soil NO_3^-. Eventually, available NO_3^- levels would have risen above the levels needed by microbes, resulting in the sharp rises in soil NO_3^- seen in Figure 2. Sidedressing of N did not occur until after these rises, and so did not likely contribute to the lack of N immobilization during the early part of the decomposition period.

Figure 3 indicates that cellulose concentration in the rye tissue initially rose, then began to drop (incorporation 1) or stayed level for about a month before starting to drop (incorporations 2 and 3). Since the amount of rye biomass was also dropping during this period (Figure 1), metabolism of cellulose by soil microbes apparently began at

approximately the 2nd week after incorporation in all three incorporations. Lignin concentrations in tissue from all three incorporations rose sharply over the decomposition period (Figure 4), indicating that loss of dry matter was not matched by loss of lignin as decay proceeded and illustrating the resistance of lignin to decay.

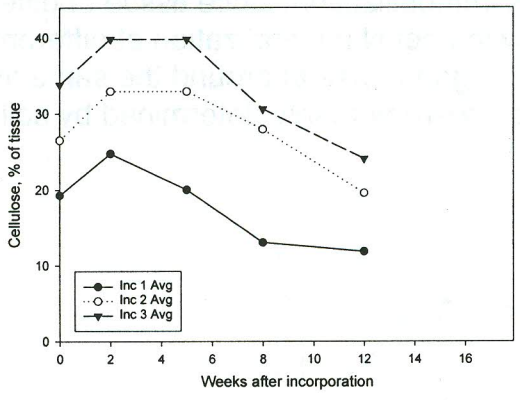

Figure 3: Change in % cellulose

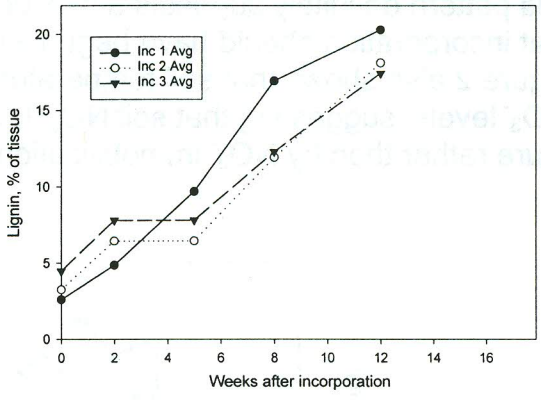

Figure 4: Change in % lignin

Results from this experiment suggest that the cellulose content of rye tissue is a very important predictor of the overall rate of rye tissue decomposition. Ideally, after further research and testing, growers could use cellulose content in somewhat the same manner as the pre-sidedress soil nitrate test (PSNT). Growers could take samples of their rye cover crops at the time of incorporation and send them to be analyzed for cellulose, and cellulose data could give some idea of the rate and timing of rye decomposition. Such a tool could possibly help growers determine the timing of main crop planting with respect to rye incorporation date. If future research can better establish the relationship between timing of rye incorporation and degree of soil NO_3^- immobilization, this information might help avoid yield reductions due to NO_3^- immobilization.

Despite significant effects on rye decomposition and soil NO_3^- levels, incorporation date had no significant effect on sweet corn yield in this experiment. Figure 5 indicates that sweet corn showed no yield response to N fertilizer rates above 60 lb N/ac. This effect may be related to the high SOM and residual NO_3^- levels on the test plots mentioned above, meaning that additional N fertilizer did not provide added nutritional benefits to the corn, or to dry weather at the time of sidedressing, meaning that N fertilizer was poorly dissolved or distributed. Figure 5 also shows that total sweet corn ear #/plant was in an acceptable range of 0.9 to 1 ear/plant for the three higher N fertilizer levels (60, 120, and 180 lb N/ac), but also shows that marketable ear #/plant was very low in this experiment, 0.25 to 0.45 ear/plant. The remaining ears had kernel development but were small and immature, suggesting that ear formation was successful during this growing season but that many ears did not mature.

The most likely explanation for this phenomenon is provided by rainfall data for the 2001 growing season (Figure 6). Although rainfall was adequate at the beginning of the corn

growth period (planting date June 7), these levels dropped later in the growing season, and no rain was recorded between August 15 and September 1 by a weather monitor next to the test plots. Sweet corn was at milk stage on September 1, so silking and ear filling occurred during a period of almost no rainfall on the plots. Corn pollen could have become nonviable due to very hot or dry conditions and/or these conditions might have prevented kernel filling. Corn leaf samples taken at silking were within a sufficiency range of 2.7 to 3.5% N for this growth stage, so moisture deficiency rather than N deficiency appears to have been the main reason for the poor yields this season.

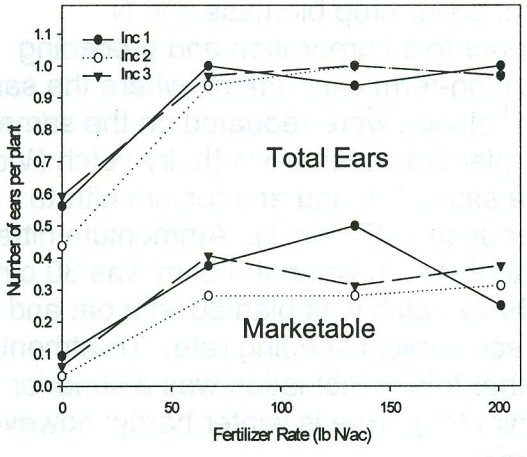

Figure 5: 2001 sweet corn yields

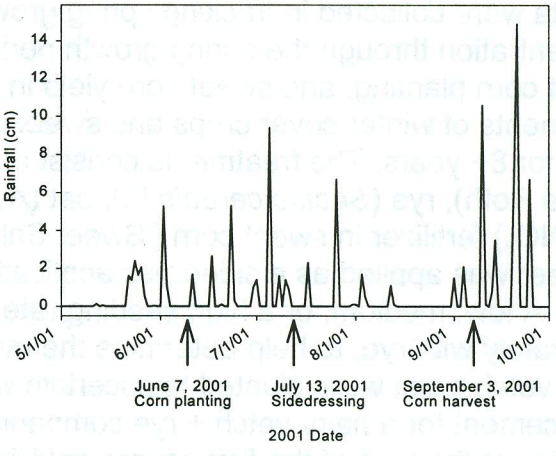

Figure 6: 2001 growing season rainfall

Conclusions

1. Rye will decompose more quickly if incorporated at an earlier life stage, but there is a greater difference between vegetative and reproductive stages than among reproductive stages.
2. While incorporation at a vegetative stage is still the best strategy to reduce soil N immobilization, in fertile soils incorporation at later dates may not pose as much of a risk of N immobilization as previously thought. More research is needed to confirm this.
3. Although rye does not contribute substantial N to a cropping system during the growing season, it can prevent losses of N, recycle residual N, and increase SOM levels, all of which make positive contributions to the nutrient status of a cropping system. With better understanding of this phenomenon, rye could be managed with a goal of "breaking even" in terms of N needs.
4. Initial cellulose in rye tissue was a very important predictor of decomposition. Improved predictive equations may allow development of practical tissue tests to provide growers with information relating to management of rye cover crops.