WINTER RYE COVER CROP BIOMASS PRODUCTION, DEGRADATION, AND N RECYCLING

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Abstract

Winter rye (*Secale cereale* L.) as a cover crop can take up residual inorganic N between annual row crops and therefore be used to help reduce NO_3^-–N loss from fields and movement to water systems. However, does the rye N uptake affect N recycling to soil and add to plant available N? The rye carbon:nitrogen (C:N) ratio could also influence N recycling. The objectives of this study were to evaluate rye biomass degradation and N recycling after spring rye termination in a no-till corn (*Zea mays* L.) - soybean [*Glycine max.* (L.) Merr.] rotation. A two year experiment (2010-2011) was conducted at four Iowa sites. Treatments included N rate applied to prior year corn (0, 135, and 225 kg N ha^{-1}) and time for rye degradation after rye control. Only time was considered for rye following soybean. Rye was collected from representative plots, put into nylon mesh bags, and placed on the surface of corresponding plots. Bags were collected after 1, 3, 9, and 15 weeks to measure remaining rye biomass dry matter (DM), C, and N. The average rye biomass production and rye N uptake were low and variable across sites and years (average $<$ 2300 kg DM ha^{-1} and $<$ 45 kg N ha^{-1}, respectively). Rye biomass, C and N consistently decreased across the 15 weeks, with the rate of degradation slower as time progressed. An average 64% of the rye following corn and 60% of the rye following soybean was decomposed after 15 weeks. Nitrogen recycling due to rye biomass decomposition was greater when following soybean (77%) than when following corn (60%), and this is probably due to its lower C:N ratio (14 vs. 20, respectively). Coupled with the low total rye N content, the amount of N released from the rye residue was only 13 and 21 kg N ha^{-1}, respectively following corn and soybean. The low rye N uptake and net N release from rye residue indicates there would be only a small influence on plant available soil N during the growing season or on optimal N fertilization rate for corn.

Introduction

Cover crops are used to help reduce environmental issues such as soil erosion, surface nutrient runoff, and NO_3^-–N leaching loss (Kaspar et al., 2001). They can also be used for improving nutrient cycling and management (Tonitto et al., 2006), such as capturing residual NO_3^-–N between annual row crops (Sainju et al., 2005). Price incentives to grow corn are resulting in more corn production and greater N application, and hence there is greater potential for increasing NO_3^-–N in water systems and opportunity for cover crops. Due to its relatively low seed cost, seed availability, flexibility in establishment, winter hardiness, early spring growth, and potential to utilize NO_3^-–N (Feyereisen et al., 2006), winter cereal rye is an often used cover crop in the Midwest. However, despite the benefits of winter rye as a cover crop, questions remain about the effect on crop yields and effective recycling of accumulated N to following crops.

Research has shown no detrimental effect of a rye cover crop before soybean, but has documented reduction in corn yield (Dhima et al., 2006; Pantoja et al., 2010; Vaughan and Evanylo, 1998). Producers attempt to reduce the negative corn yield impact by controlling rye early in the spring so there is small rye growth and to allow timely corn planting. However, that practice would diminish the potential of winter rye to utilize residual NO_3^-–N.

Due to concerns about NO_3^-–N delivery to the Gulf of Mexico and meeting local drinking water standards, various agencies are increasing programs that provide incentives to producers to implement cover crops in corn and soybean fields. Therefore, interest by producers in use of winter rye as a cover crop is increasing. However, producers have questions about the rye biomass degradation and supply of accumulated NO_3^-–N to corn. Is that recycling important, is it substantial, does the N become plant available and if so when during the growing season, and should N fertilization rates be adjusted? The objectives of this study were to evaluate rye biomass degradation and N recycling across time after spring rye termination in a no-till corn-soybean rotation.

Materials and Methods

A 15 week (late April to early Aug.) experiment was conducted in 2010 and 2011 at four Iowa sites; the Agricultural Engineering and Agronomy Research farm in Central Iowa near Ames, the Research and Demonstration Farm in southeast Iowa near Crawfordsville, the Armstrong Research Farm in southwest Iowa near Lewis, and the Research and Demonstration Farm in northeast Iowa near Nashua. The sites were in corn-soybean rotation with a winter rye cover crop each year. The winter cereal rye cover crop cultivar was Wheeler and was seeded in the fall after harvest of the annual crop at a rate of 70 kg ha^{-1}. Monthly mean temperature and precipitation across the study sites (Fig. 1) were calculated from data collected at weather stations at each research farm.

In the spring and before chemical control of the rye with glyphosate, rye aboveground biomass was sampled (0.093 m^2 PVC square at six random locations) to determine rye biomass production and accumulation of C and N on an area basis. Following corn, rye biomass was collected from plots that had received 0, 135, and 225 kg N ha^{-1}, whereas sampling following soybean was only by replicate (no N treatment). The collected rye was split into sub-samples, fresh weight measured, placed into nylon mesh bags, and the bags placed on the soil surface in the middle of corresponding previous-year corn plots or soybean replicates. Corn and soybean were planted as in previous years, following the corn-soybean rotation. One set of bags was collected at 1, 3, 9, and 15 weeks. The collected samples were oven-dried at 60 ºC and weighed to estimate remaining rye biomass DM. Then samples were ground to pass a 2 mm sieve and a sub-sample analyzed for total C and N by dry combustion (LECO CHN-2000 analyzer, LECO Corp., St. Joseph, MI). The amount of biomass DM, C, and N remaining at each sample time was calculated on an area basis by relating the fraction initially added to the mesh bag that remained at each sample date to the amount per area determined before rye control.

Analyses of variance (ANOVA) was performed with PROC MIXED (SAS Institute, Cary, NC) to investigate significance ($P \leq 0.05$) of N rate applied to prior corn on rye biomass production and C and N accumulation at each site (across years). Mean differences were identified with the

Fisher Protected Least Significant Difference (FLSD). The PROC GLM procedure was used to fit quadratic regression models describing rye biomass, C, N, and C:N ratio of the remaining rye residue across time on an area basis. The lower and upper confidence limits (90%) of model parameters (intercept, linear coefficient, and quadratic coefficient) were used to aid in model comparison across time, with models parameters considered not different when the parameter estimates were within the confidence intervals of both equations being compared.

Results and Discursion

During the period of the study, 2010 was on average 1ºC warmer and had 3 cm more precipitation than the historical average of the last 15 years, especially with high rainfall in June (Fig. 1). In 2011, temperature and precipitation was near the historical average. The differences in weather conditions, along with variation in rye planting date, length of spring growth before control, and site location influenced rye biomass production (Tables 1 and 2).

Rye biomass production was relatively low due to seeding after row crop harvest, cold temperatures in the fall, and the short spring time-period for rye growth (Tables 1 and 2). The Crawfordsville site in southeast Iowa consistently had the largest rye biomass production. Across sites and years, biomass production was the same for rye following corn receiving 0 or 135 kg N ha^{-1} and for rye following soybean (average 1000 kg DM ha^{-1}), but was 28% greater with application of 225 kg N ha^{-1} to the prior corn crop (average 1280 kg DM ha^{-1}). Carbon and N accumulation followed the same trend as the rye biomass production (Tables 1 and 2). As a result of the low biomass production, N uptake was also low (< 45 kg N ha^{-1}, with an average 21 kg N ha^{-1} following corn and 27 kg N ha^{-1} following soybean).

Biomass DM, C, and N remaining in the rye residue decreased across the 15 weeks (Figs. 2, 3, and 4), with the rate of degradation slower as time progressed, and with the majority of C and N recycled from the rye residue by 9 weeks. The amount of N remaining in the rye residue following soybean decreased faster compared to the N remaining in the rye residue following corn. The amount of N remaining in the rye residue following corn where 225 kg N ha^{-1} had been applied was greater at all sampling dates than the N remaining in the rye with no N or the 135 kg N ha^{-1} rate. The rate of N decrease was similar for each corn N fertilization rate. Across sites and years, the rye following corn released < 3 kg N ha^{-1} by 3 weeks, and the rye following soybean released 5 kg N ha^{-1} during that 3 week period. An average of 64% (650 kg ha^{-1}) biomass DM of the rye following corn and 60% (640 kg ha^{-1}) of the rye following soybean was degraded after 15 weeks. The release of N from the degrading rye residue was 60% (13 kg N ha^{-1}) with rye following corn and 77% (21 kg N ha^{-1}) with rye following soybean during the 15 weeks period. Neither of these are large amounts of N.

The more rapid release of N in the rye following soybean could be a result of the initial high amount of N and lower C:N ratio compared to the rye following corn (Fig. 5). This rye was controlled on average two weeks before the rye following corn, and hence had less time to grow and accumulate C rich compounds. The 225 kg N ha^{-1} application to the prior year corn resulted in a lower rye C:N ratio and an increased amount of N recycling compared to the rye following corn with no N or 135 kg N ha^{-1} application rate.

Summary

Rye biomass production and N accumulation were not large. Application of 225 kg N ha^{-1} to the prior year corn, the highest applied rate in the study, had the highest rye biomass production and the greatest amount of C and N. That rate also had more N recycled across the 15 weeks than rye with no N or the 135 kg N ha^{-1} rate. This indicates larger residual profile NO_3^--N with the high N application, and resultant greater rye N uptake. Rate of rye biomass degradation and C and N release were quite consistent across the 15 weeks after rye termination when rye followed corn, but the rate of N release was greater when rye followed soybean. The rate difference appeared related to the lower C:N ratio of the rye following soybean. On average, only 60% of the N recycled from the rye following corn and 77% from the rye following soybean. Coupled with the low total rye N content, the amount of N released from the rye residue was only 13 and 21 kg N ha^{-1}, respectively following corn and soybean. These results indicate only a small influence would be expected on plant available soil N during the growing season or influence on optimal N fertilization rate for corn.

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Table 1. At the time of rye control in the spring, influence of N rate applied to the previous corn crop on aboveground rye biomass dry matter (DM), total C, and total N. Mean across years at each site.

N rate	Ames	Crawfordsville	Lewis	Nashua
kg N ha^{-1}	- - - - - - - - -	kg ha^{-1}	- - - - - - - - -	
		Rye biomass DM		
0	760 a[†]	1,920 b	700 a	500 b
135	770 a	2,130 ab	690 a	510 b
225	930 a	2,910 a	560 a	710 a
		Total C		
0	310 a	800 b	280 a	210 b
135	320 a	880 b	280 a	210 b
225	380 a	1,220 a	230 a	290 a
		Total N		
0	16 b	28 b	15 a	12 b
135	18 b	31 b	16 a	13 b
225	25 a	44 a	15 a	20 a

[†] Means followed with the same letter within a column are not different ($P > 0.05$).

Table 2. At the time of rye control in the spring, aboveground rye biomass dry matter (DM), total C, and total N following soybean. Mean across years at each site.

	Ames	Crawfordsville	Lewis	Nashua
	- - - - - - - -	kg ha^{-1}	- - - - - - - -	
Rye biomass DM	1,125	1,230	910	710
Total C	460	500	370	280
Total N	30	29	27	23

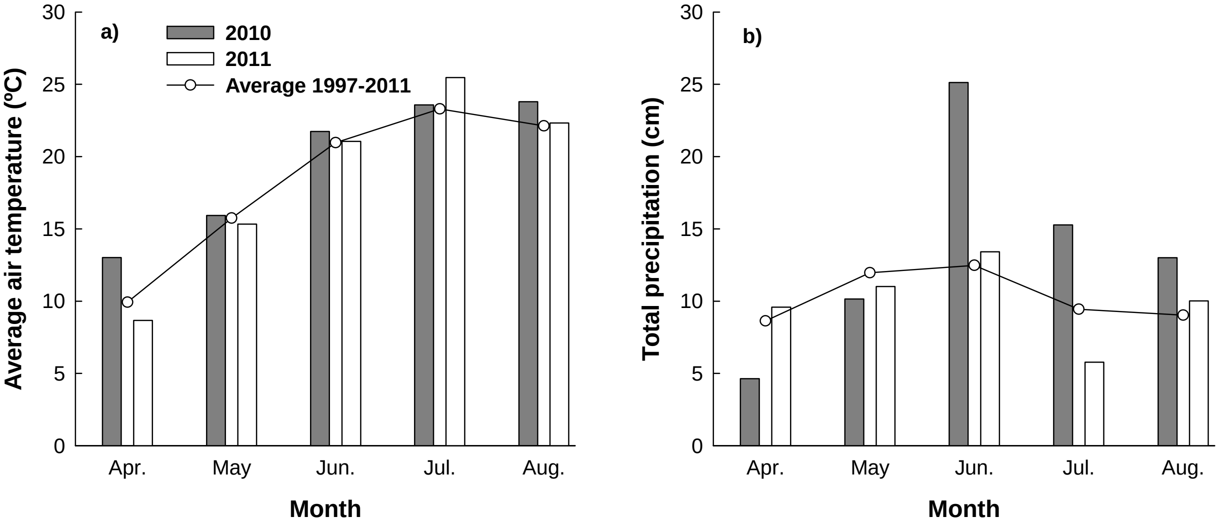

Figure 1. Mean monthly air temperature (a) and precipitation (b) across sites.

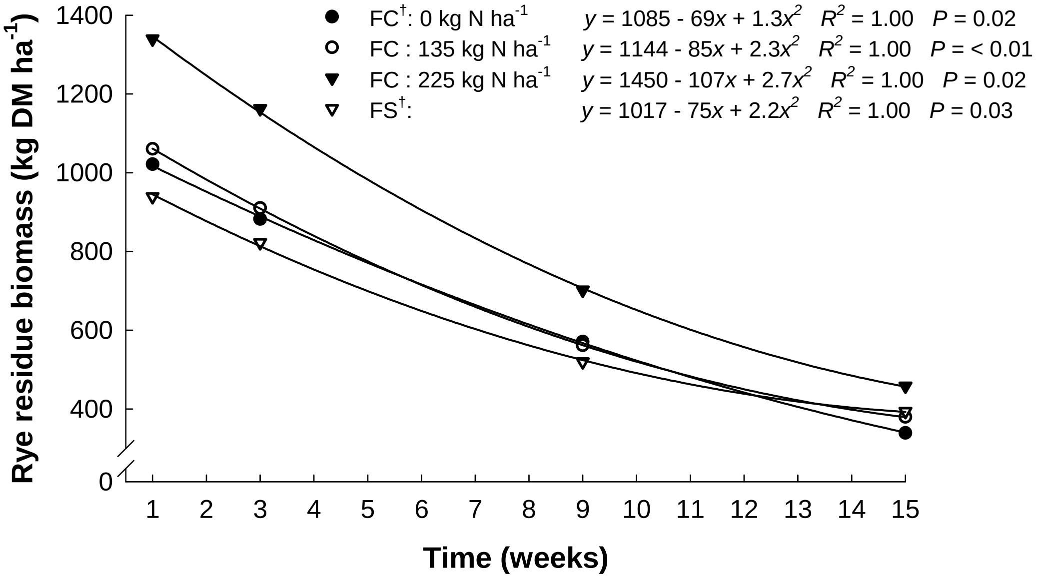

Figure 2. Rye residue biomass dry matter (DM) remaining with time after spring control, across sites and years. The N rates for the rye following corn were applied to the prior year corn. † FC, following corn; FS, following soybean.

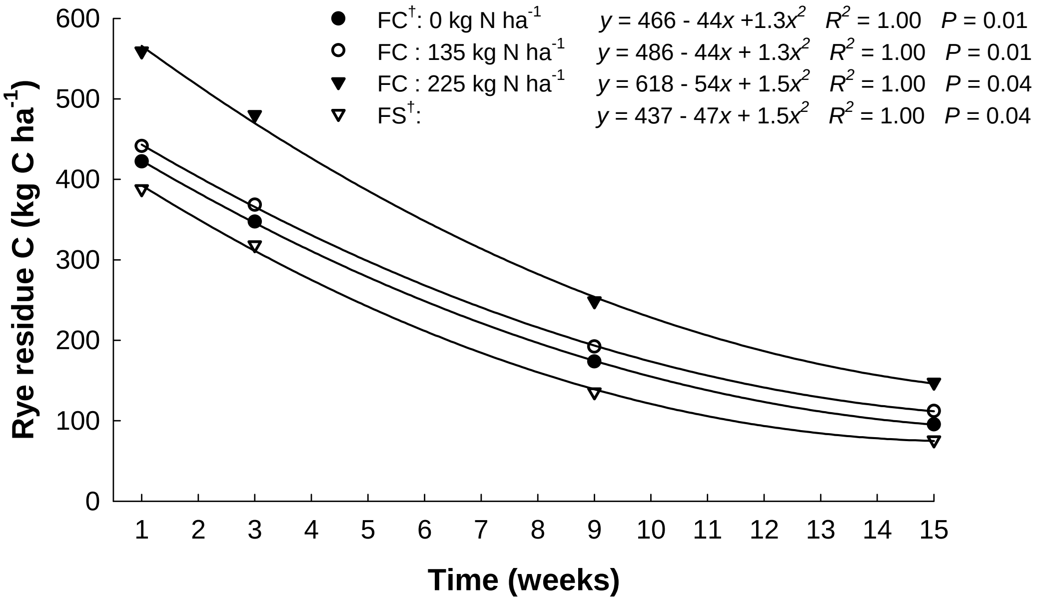

Figure 3. Rye residue C remaining with time after spring control, across sites and years. The N rates for the rye following corn were applied to the prior year corn.
† FC, following corn; FS, following soybean.

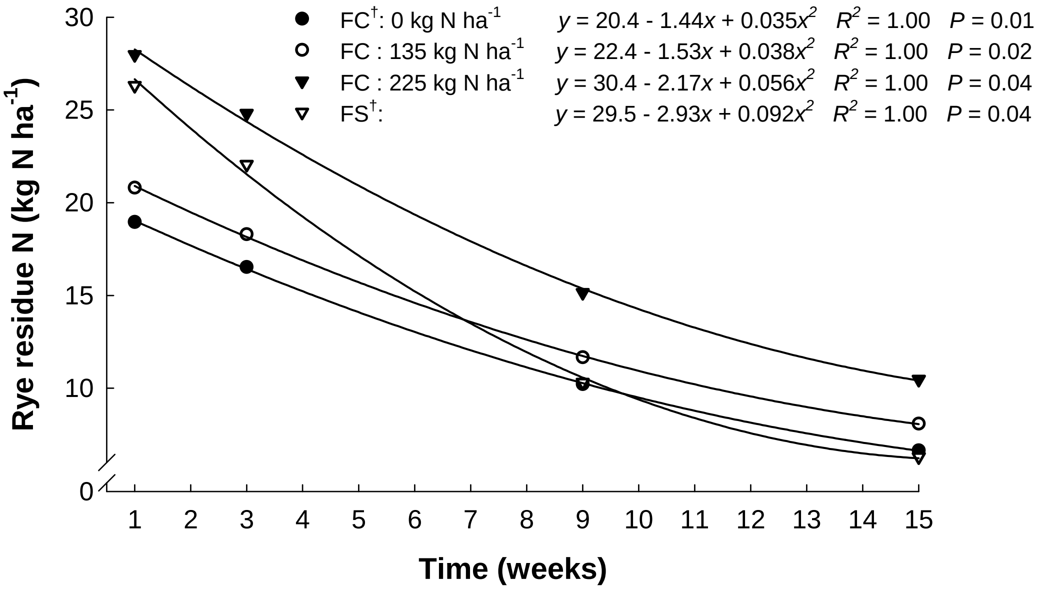

Figure 4. Rye residue N remaining with time after spring control, across sites and years. The N rates for the rye following corn were applied to the prior year corn.
† FC, following corn; FS, following soybean.

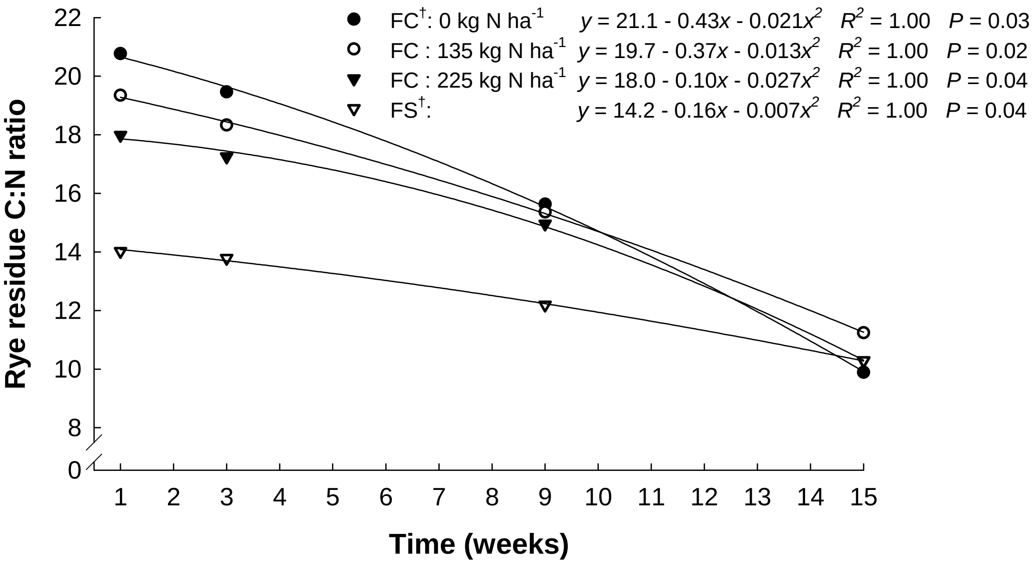

Figure 5. Rye residue C:N ratio with time after spring control across sites and years. The N rates for the rye following corn are rates applied to the prior year corn.

† FC, following corn; FS, following soybean.

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