MANAGING TRADE-OFFS OF WINTER RYE AS A COVER CROP

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ABSTRACT

Winter rye (Secal cereale L.) is a commonly used cover crop in Wisconsin due to its effectiveness in reducing soil erosion, scavenging nitrogen, and improving soil health. However, the potential trade-offs of using grass cover crops are decreases in corn yield driven by nitrogen uptake and immobilization. The study aims to determine the single year effect of rye seeding rate on rye biomass and optimum nitrogen rate of the subsequent corn (*Zea mays* L.) crop, while also evaluating the relationship between biomass and decomposition rate. Rye cover crop was planted in fall at five seeding rates (0, 30, 60, 90, 120 lb ac-1) following corn silage harvest and liquid dairy manure application at Arlington Agriculture Research Station in WI. Corn was planted following chemical termination of rye and fertilized with eight nitrogen rates (0, 40, 80, 120, 160, 200, 240, 320 lb-N ac-1). In contrast to previous research at this location, maximum corn yield was not affected by the rye. However, additional nitrogen fertilizer needed to be applied to reach optimum corn yield as rye biomass increased. Knowing how to accurately adjust nitrogen fertilization after a cover crop is critical to ensure optimum corn yield while still gaining the soil health and water quality benefits of winter rye.

INTRODUCTION

Cover crops are a common agricultural management practice used as living cover to protect the soil from erosion, prevent loss of nutrients, and build soil health (Kaspar & Singer, 2015; Sharma et al., 2018; Snapp & Surapur, 2018). The use of cover crops becomes increasingly important as environmental concerns with corn (*Zea mays L.)* production continue to increase . Corn silage is an integral crop to dairy production systems and is grown on about 10% of Wisconsin's crop production land (USDA NASS, 2017). However, this dairy production system has an environmental cost due to high in-season corn nitrogen requirements, lack of residue post-harvest, and fall manure application. Winter rye (*Secal cereale* L.) is an effective addition to this system due to its winter-hardiness and ability to scavenge soil nitrogen that could otherwise be leached from the system (West et al., 2020).

Potential trade-offs of using a grass cover crop are soil nitrogen immobilization and decreases in corn yield (Martinez-Feria et al., 2016; Pantoja et al., 2016). Rye biomass accumulates nitrogen that is then unavailable to the subsequent corn crop. However, the effects of this relationship between biomass accumulated and corn yield can be quite variable (Martinez-Feria et al., 2016). This study aims to better understand the relationship between winter rye biomass, soil nitrogen pools, and nitrogen requirements of the subsequent corn crop. The objectives of this study were to i) to determine how the seeding rate of winter rye effects root and shoot biomass, ii) to determine the effect of rye biomass on soil nitrogen pools, and iii) to determine the effect of rye cover crop biomass on subsequent corn yield and optimum nitrogen rate.

MATERIALS AND METHODS

The two-year field study was conducted at University of Wisconsin Arlington Research Station (43º18’9.47”N, 89 º 20’43.32”W) from 2020-2022 on a Plano silt loam (fine-silty, mixed, superactive, Mesic Typic Argiuodoll). Each year of the study was conducted at a different field site located within 5 km of one another. The experimental design was randomized complete block split-plot replicated five times. Whole block treatments were rye seeding rates of 0, 30, 60, 90, 120 lb ac^{-1} (15 ft x 320 ft, six corn rows wide). Split plot treatments were nitrogen fertilizer application rates of 0, 40, 80, 120, 160, 200, 240, 320 lb-N ac^{-1} (15 ft x 40 ft), surface applied at corn growth stage V3. Liquid dairy manure was surface applied after corn silage was harvested in fall, and winter rye was planted as a cover crop two weeks later. Rye was terminated in early spring and corn was planted two weeks later.

Soil samples for plant available nitrogen analysis were collected as a composite bulk sample of eight cores per plot at a depth of 0-1’ and 1-2’ in fall before the first hard frost and in spring at time of rye termination. Rye biomass was sampled from two 0.25-m^2 quadrats (three rye rows) per plot for carbon and nitrogen analysis. Rye root biomass was measured only in spring of year 2. In each plot, two 4.25” diameter soil cores were taken per plot to a depth of 2”, one directly in a rye row and one between. Cores were stored in plastic sleeves until time of analysis when cores were soaked and roots were carefully separated from soil and organic matter using a sieve and tweezer. Biomass and soil samples were dried and ground before analysis.

RESULTS AND DISCUSSION

Winter rye biomass

Aboveground rye biomass increased as seeding rate increased, with more biomass accumulated in the second year (Figure 1). Carbon to nitrogen ratio of rye shoot biomass was low across all treatments but was least at the 30 lb ac^{-1} seeding rate. This difference in C:N was driven by %N in biomass, with greater values when rye seeding rates were low. With C:N ranging from 10-13, rye residue at all seeding rates is considered high quality and should not lead to additional nitrogen tie up throughout the growing season due to immobilization of plant available nitrogen (Table 1). Nitrogen

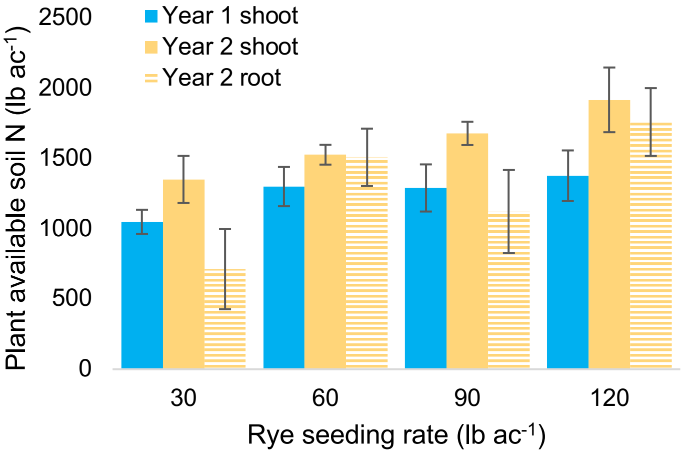

Figure 1. Winter rye cover crop shoot biomass in years 1 and 2. Root biomass was only sampled in year 2. Error bars represent standard deviation.

yield increased as seeding rate increased and was greater in year 2 when more rye biomass was accumulated.

Rye root biomass was sampled in year 2 only and followed the same trends as aboveground biomass (Figure 1). However, rye root biomass had a greater C:N ratio that could lead to potential immobilization throughout the growing season as rye roots decompose. Root biomass nearly doubles the amount of total plant biomass that is otherwise unaccounted for when only aboveground biomass is measured. This additional 12-26 lb ac^{-1} of N uptake caused by root biomass is important to account for in future nitrogen budgeting work when a nitrogen demanding crop is following a grass cover crop (Table 1).

Table 1. Summary of cover crop biomass nutrient content across rye seeding rate treatments in year 1 and 2. Root biomass was measured in year 2 only. ANOVA results as affected by seeding rate treatment are reported for each year. Within each column, means followed by the same letter are not significantly different at α=0.05.

Seeding rate (lb ac^{-1})	**Year 1**		**Year 2**				
	Shoot		Shoot		Root		Total
	C:N	N yield (lb ac^{-1})	C:N	N yield (lb ac^{-1})	C:N	N yield (lb ac^{-1})	N uptake (lb ac^{-1})
30	10b	41	10b	51b	24	12b	62b
60	12a	44	12a	53b	22	24a	73a
90	12a	43	12a	60ab	29	16b	76a
120	13a	44	13a	65a	27	26a	91a

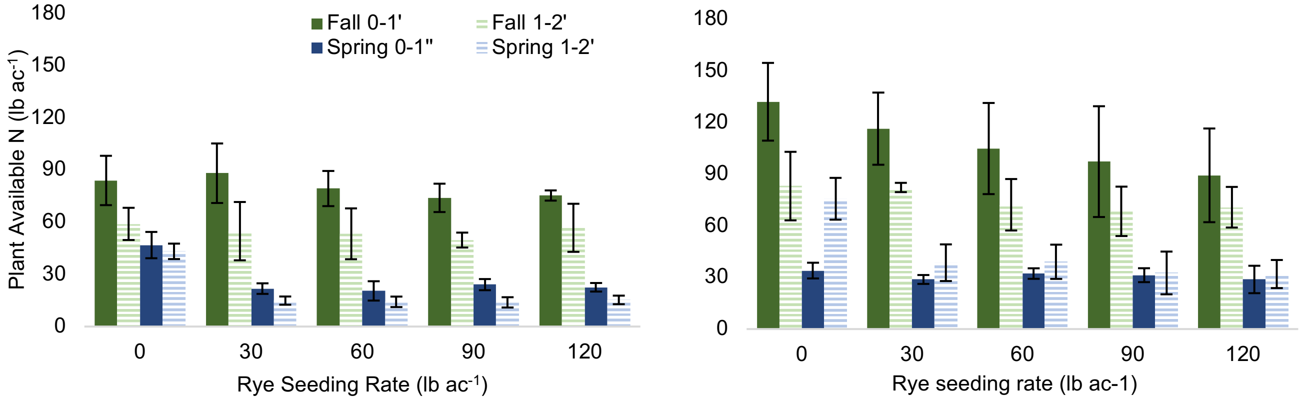

Figure 2. Plant available soil nitrogen (sum of nitrate-N and ammonium-N) in year 1 and 2 across rye seeding rate treatments. Solid bars indicate the sampling depth of 0-1’ and slotted bars indicate sampling depth of 1-2’. Error bars represent standard deviation.

Soil nitrogen

Fall soil nitrogen decreased in the 0-1’ depth as seeding rate increased, and this trend was more evident in year 2 due to a greater amount of rye biomass accumulated fall (Figure 2). In spring of year 1, all rye treatments had less plant available soil nitrogen in at both depths. The difference in soil nitrogen from fall to spring indicates that rye at all seeding rates was able to scavenge soil nitrogen that may have otherwise leached from the field. In spring of year 2 we see this same trend, but only in the 1-2’ depth. This difference is greatest where rye was not present, indicating that from fall to spring the nitrogen moved into the second foot, but the cover crop was still able to take up this nitrogen (Figure 2)

Corn yield response

Bootstrapped residuals of the quadratic plateau model for corn yield were used to calculate optimum nitrogen fertilizer rates and maximum yield. Based on the plateau, maximum corn yield for rye seeding rate treatments of 30 and 60 lb ac^{-1} were higher than the other treatments (Figure 3). The lowest corn yield occurred following rye seeding rate of 120 lb ac^{-1}, indicating that corn yield was not able to recover even at high nitrogen rates due to greater rye biomass accumulation. However, this yield was only 2 bu ac^{-1} different than the treatment without rye, so this difference is not economically significant (Table 2). More nitrogen was needed to reach maximum yield as seeding rate of rye increased, but this trend was not observed at the 60 lb ac^{-1} seeding rate which only required 104 lb ac^{-1} to reach maximum yield (Figure 4). This response is not expected because at the 60 lb ac^{-1} seeding rate rye accumulated a similar amount of biomass as the seeding rates of 90 and 120 lb ac^{-1}.

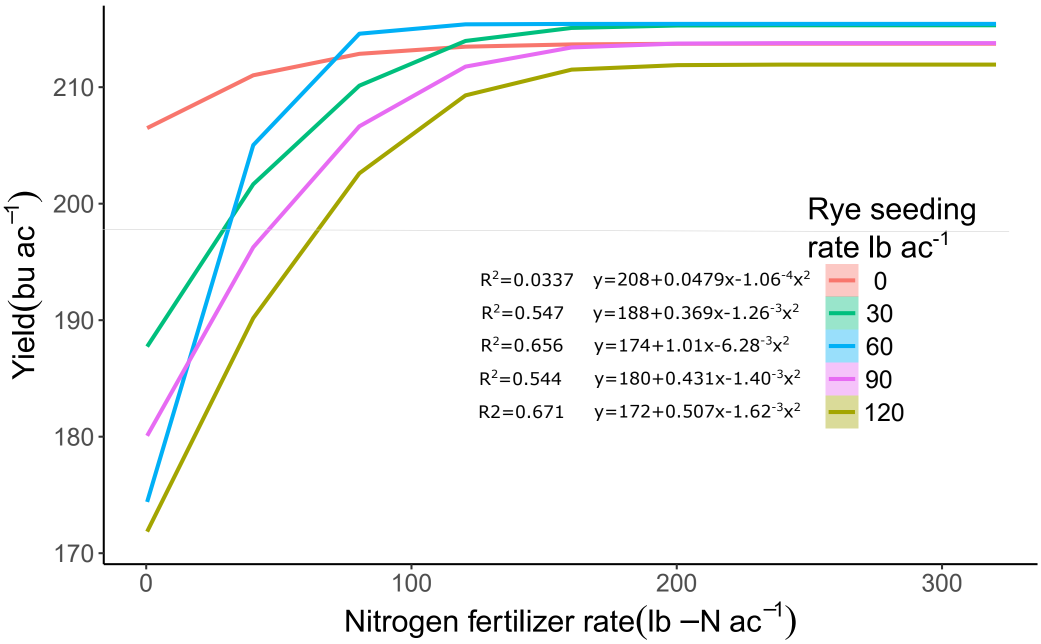

Figure 3. Year 1 corn yield fertilizer response curves determined by bootstrapping residuals of seeding rate treatments. Equations and R^2 represent fit of quadratic plateau model to the bootstrapped data.

Table 2. Year 1 economic and agronomic optimum corn grain yield and nitrogen rate following winter rye cover crop based on parameter estimates from quadratic plateau model of original data. Economic optimum values calculated using a nitrogen fertilizer to corn price ratio of 0.1.

	Economic optimum		Agronomic optimum	
Rye seeding rate	Nitrogen fertilizer rate	Corn yield	Nitrogen fertilizer rate	Corn yield
lb ac^{-1}	lb ac^{-1}	bu ac^{-1}	lb ac^{-1}	bu ac^{-1}
0	0	208	149	213
30	106	213	180	215
60	72.7	214	104	215
90	118	211	190	213
120	126	210	197	211

When corn was grown following the treatment without rye, grain yield was greatest at the 0 N fertilizer at 208 bu ac^{-1}, but did not plateau until N fertilizer rate of 149 lb ac^{-1} (Figure 3, Table 2). However, the economic optimum rate of nitrogen fertilizer is 0. This outcome indicates that corn yield was non-responsive to nitrogen fertilizer following the no rye treatment, and that starter fertilizer and plant available soil nitrogen provided enough nitrogen to the corn to reach the economically optimum grain yield.

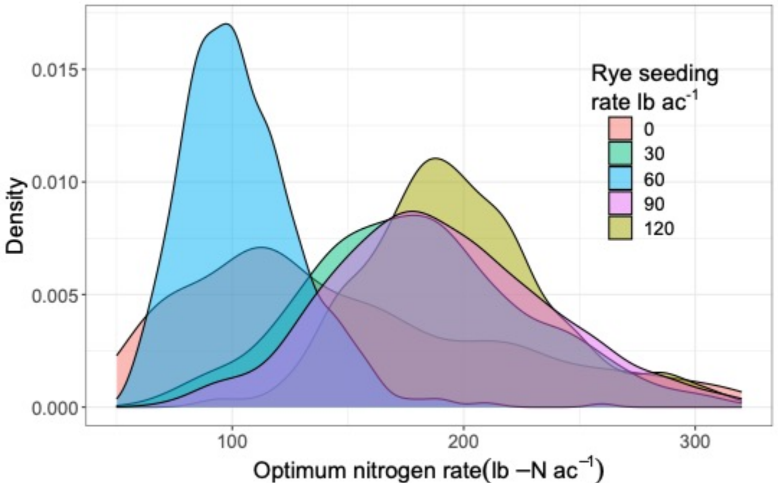

Figure 4. Density plot of optimum N fertilizer rate based on corn yield from year 1 of rye seeding rate treatments. The density plots are constructed with results from bootstrapping residuals with data resampled 1000 times.

CONCLUSION

When corn is grown following a winter rye cover crop, a lack in soil nitrogen leads to a yield decline at low nitrogen rates, but these yields recover upon additional nitrogen fertilizer application, and maximum grain yield was not negatively impacted. There appears to be little benefit to seeding rye at a rate above 60 lb/ac. Rye seeding rates of 30-60 lb ac^{-1} had less of a yield effect compared to rates of 90 and 120 lb ac^{-1}, and economic optimum yields recovered with the addition of 73-106 lb-N ac^{-1}. Even though we see a nitrogen effect occurring with corn following rye, all seeding rates of rye effectively scavenged nitrogen from the field and provided water quality benefits through nitrogen uptake. Thus, there is a clear tradeoff in-terms of nitrogen cycling with rye cover crop use with manure, as water quality benefits are obtained at the cost of agronomic benefit of the applied manure.

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