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Legume cover crop management on nitrogen dynamics and yield in grain corn systems

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ABSTRACT

The N contribution of a legume cover crop may reduce fertilizer N inputs to subsequent grain corn (*Zea mays* L.). However, the best cover crop management options to maximize N to subsequent crop, as well as alternatives to red clover are largely unknown. A field study was conducted at two locations on two contrasting soil types in 2012–2013 and 2013–2014 to assess N dynamics and grain corn yield in a cover crop-corn rotation. Treatments included 1) cover crop; red clover (*Trifolium pretense* L.), crimson clover (*Trifolium incarnatum* L.), alfalfa (*Medicago sativa* L.) and no cover crop (no-cc); 2) cover crop seeding rate (3.36, 6.73, and 13.5 kg ha^{-1}); and 3) cover crop termination timing (fall and spring). Plots were in a split-split plot arrangement. The following spring, no-cc plots were split into three with 0, 112 or 224 kg N ha^{-1} calcium ammonium nitrate applied (no-cc0N, no-cc112N, no-cc224N, respectively) to the corn crop but no fertilizer N was applied to plots with planted cover crops. Plant available N (PAN) was analyzed by measuring the sum of soil mineral N (SMN) in 0–60 cm depth and plant aboveground N content. In October SMN was 10 kg N ha^{-1} lower with the legume cover crop treatments compared to no-cc, suggesting these cover crops may mitigate N losses over the winter. The following May in spring-terminated plots, PAN was 20 kg N ha^{-1} lower in no-cc compared to red clover and alfalfa. At corn harvest, spring terminated plots had 14 kg N ha^{-1} higher PAN as compared to fall terminated cover crops. At corn harvest, PAN and corn grain yield were significantly higher by 21 kg N ha^{-1} and 1.0 Mg ha^{-1}, respectively, in the highest (13.5 kg ha^{-1}) cover crop seeding rate compared to the lowest rate (3.35 kg ha^{-1}). Red clover or alfalfa sown at 6.7 kg ha^{-1} with spring termination is recommended to maximize N availability to subsequent corn crop. These observed effects were related to aboveground cover crop growth of alfalfa ≥ red clover > > crimson clover but only alfalfa and red clover had a positive impact on corn yield in one of two years. Management practices that improve crimson clover establishment and growth, as well as, a cost analysis associated with legume cover cropping are needed.

1. Introduction

Numerous benefits of using cover crops have been demonstrated, including, but not limited to, improved soil stability (Dapaah and Vyn, 1998), reduced weeds (Fisk et al., 2001; Sarrantonio and Gallandt, 2008; O'Reilly et al., 2011), and increased overall soil N content in the following growing season (Burket et al., 1997; Vyn et al., 2000; O'Reilly et al., 2012). The main deterrents for using cover crops in a field or vegetable cropping system are the indirect and direct costs of establishment and management as well as potential economic losses (Snapp et al., 2005). Two meta–analyses of cover crop usage (Miguez and Bollero, 2005; Sarrantonio and Gallandt, 2008) concluded that the number of advantages of using cover crops is greater than potential disadvantages. In addition, when used prior to corn, there was either a neutral or positive effect on grain yield (Miguez and Bollero, 2005; O'Reilly et al., 2012) and profit margins (O'Reilly et al., 2012). Consequently, additional studies are needed to further demonstrate the benefits of cover crops and determine the effect of legume cover crops on grain corn when used the previous growing season.

Studies have demonstrated that N cycling can be improved to mitigate potential field losses through cover crop usage (Delgado et al., 2010; O'Reilly et al., 2012). But non-legume cover crops may

Abbreviations: SMN, soil mineral nitrogen; PAN, plant available nitrogen; no-cc, no cover crop control treatment; no-cc0N, no-cc112N, no-cc224N, no cover crop treatment with 0, 112, 224 kg N ha^{-1} respectively, fertilizer applied to corn crop.

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Table 1
Weather data from 2012 to 2014 and 30-year mean at Ridgetown, ON.[a]

	Mean Temperature (°C)				Total Precipitation (mm)			
Month	2012	2013	2014	30-yr mean	2012	2013	2014	30-yr mean
Jan.	−1.8	−2.6	−8.7	−3.7	55.3	71.5	53.9	61
Feb.	−0.3	−4.0	−9.1	−2.4	32.4	68.2	57.9	54
Mar.	7.7	0.3	−3.9	2.0	51.8	25.9	26.9	60
Apr.	7.0	6.2	6.6	8.3	31.8	102	66.1	77
May	15.5	15.1	13.8	14.8	34.0	63.9	97.0	75
June	22.6	18.6	19.9	20.2	45.0	102	48.0	83
July	22.1	21.2	19.1	22.5	156	78.3	130	86
Aug.	19.8	19.3	19.4	21.4	73.4	53.2	35.8	86
Sep.	15.5	16.1	15.7	17.6	67.4	89.1	159	93
Oct.	10.2	11.6	10.5	11.2	102.8	92.5	54.9	69
Nov.	3.4	2.4	1.8	4.8	20.6	29.5	54.0	73
Dec.	1.3	−3.6	0.4	−1.2	54.7	64.7	24.2	52

[a] Data obtained from the Environment Canada weather station located at Ridgetown, ON.

not release N in synchronicity with the N requirements of a following crop and therefore do not provide an N credit (Vyn et al., 2000; O'Reilly et al., 2012; Thilakarathna et al., 2015). However, legume cover crop species have been found to supply significant quantities of N to subsequent crops (Vyn et al., 2000; Snapp et al., 2005; Sarrantonio and Gallandt, 2008; Ketterings et al., 2015; Gaudin et al., 2013, 2015; Thilakarathna et al., 2015), which may make them the optimal choice if N supply is the main reason for growing the legume cover crop (Miguez and Borello, 2005).

Of particular interest are alfalfa, red clover, and crimson clover legume cover crops but differences in perennial (alfalfa and red clover) vs. winter annual (crimson clover) life cycles may influence the amount of growth prior to winter and consequently N contribution to the following crop. Alfalfa is the most prevalent forage legume in the Northern United States (Entz et al., 2002). As a forage crop, alfalfa deceased fertilizer N input requirements of the following crop (Hoeppner et al., 2006) and increased N pools by up to 121 kg N ha^{-1} (Kelner and Vessey, 1995). However, the applicability of forage research to the use of alfalfa as a winter cover crop, while promising, is limited (Kelner et al., 1997).

Results of using crimson clover as a cover crop in the season preceding corn have been mixed. Crimson clover in the southern United States increased N availability (Wilson and Hargrove, 1986; Wagger, 1989a,b) and corn grain yield (Torbert et al., 1996). In contrast, Frye and Blevins (1989) reported no increase in corn grain yield and the use of crimson clover did not reduce the need for N fertilizer. The studies described above were not representative of a humid, temperate climate and therefore the use of crimson clover, as compared to other legume cover crops, should be studied to determine the differences among species. For instance, similar aboveground biomass and N content was observed with red clover, alfalfa and crimson clover in a seed corn production system (Belfry and Van Eerd, 2016) but comparisons of the impact various agronomic management practices and N contribution to the following crop represents a gap in knowledge.

Based on the current knowledge of red clover, and its ability to lower fertilizer N inputs to following corn crop (Ketterings et al., 2015; Gaudin et al., 2013), it can be used as a standard for comparing the effectiveness of other winter legume cover crops, such as alfalfa and crimson clover. Red clover has proven benefits when undersown in wheat in rotation (Dapaah and Vyn, 1998; Henry et al., 2010; Gaudin et al., 2013; Ketterings et al., 2015); however, comparing results among studies is somewhat difficult due to inconsistent cover crop management (Miguez and Borello, 2005; Sarrantonio and Gallandt, 2008) and there are few studies on other legume cover crops (Ketterings et al., 2015). For instance, seeding rates for red clover, and other legume cover crops, are not directly compared and are inconsistent across studies (Gaudin et al., 2013). Cover crop can be terminated in the fall or spring via mechanical tillage or herbicide. While no difference in corn grain yield has been reported between fall mechanical tillage and spring herbicide termination (Vyn et al., 2000), there was a reported difference in red clover aboveground N content at termination, which could influence total amount of N in the corn growing season. Thus, lack of information on the influence of seeding rate and termination timing of red clover on N dynamics in subsequent crops and the limited research on other legume cover crops, such as alfalfa or crimson clover, does not provide farmers with adequate knowledge to useconfidently.

In a humid, temperate climate, the objectives of this study were to evaluate the influence of legume cover crop management (species, seeding rate and termination timing) on plant available N (PAN) and subsequent grain corn yield. It was hypothesized that there would be greater N availability and higher grain corn yield with spring termination of the cover crop versus fall termination and that there would be a positive correlation between cover crop seeding rate and available N in the system. Through better understanding of how legume cover crops can influence N dynamics, and what effect various management practices have on N availability, recommendations to growers can be made with increased confidence.

2. Materials and methods

2.1. Experimental design

Field experiments were conducted on two different soil types at the University of Guelph Ridgetown Campus in Ridgetown, ON (lat. 42°46′N, long. 81°88′W) in 2012–2013 and 2013–2014 at separate locations each year. Temperature and precipitation was collected via an Environment Canada weather station at Ridgetown Campus (Table 1). Sites were a loam Orthic Humic Gleysol and a sandy loam Typic Hapludofts based on the Canadian Soil Classification. Select soil characteristics taken in 2012 from a 0–15 cm depth, composite sample (30 cores) were 7.4 and 6.2 pH (1:1 v/v method), 41 and 33 g kg^{-1} organic matter (modified Walkley Black method), 26 and 6.8 Meq 100 g^{-1} cation exchange capacity (estimated based on ammonium acetate extraction and pH), 36 and 32 mg kg^{-1} P (Olsen bicarbonate extraction method), 59 and 107 mg kg^{-1} K, 4634 and 872 mg kg^{-1} Ca, 169 and 119 mg kg^{-1} Mg (atomic absorption via ammonium acetate extraction) of the loam (47:44:09) and sandy loam (76:17:07) textured soils (sand:silt:clay, hydrometer method), respectively (Carter and Gregorich, 2008).

Plots were arranged in a split-split plot design with four replications, with each experimental unit 4.6 or 6.1 m (six or eight corn rows) wide and 5.0 m in length. The whole plot factor was