# DO LEGUME COVER CROPS HELP MINERALIZE SOIL NITROGEN?

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## ABSTRACT

Nitrogen (N) dynamic is dependent on multiple factor all of which influence in-season plant N availability. Inclusion of a cover crop can have additional impacts on N dynamic by utilizing fall residue soil N, reducing the potential of N leaching. Legume cover crops also have the potential to add additional N to the soil through N fixation. The objective of this study was to evaluate N dynamic of different cover crops (legume and nonlegume) compared to no cover crop (NCC) and the impact on the following corn yield in a three-year field study. The treatments were NCC, sweet clover (*Melilotus officinalis*), winter cereal rye (*Secale cereale*), and hairy vetch (*Vicia Villosa* Roth.) in a randomized complete block design with four replications under no-till condition in a winter wheat/cover crop–corn rotation in Brookings, SD. Soil N mineralization using *in-situ* soil cores with ion exchange resin were measured in three different periods during corn growing season in the field. Results showed rye treatment had the lowest corn yield, however, legume mineralized greater amount of N, especially during the corn V6–R3 growth stage, when crop N demand was high. Nitrogen availability to corn following treatments ranked sweet clover > hairy vetch > NCC > rye depending on weather conditions. Results found that all measured variable were highly dependent on environmental. Hence, to better understand the impact of cover crops on soil N dynamic, additional long-term research is needed to account for yearly variability under different environmental conditions.

## INTRODUCTION

In corn production, N is an essential element and one of the most limiting factors in crop growth and yield. Management of N is very challenging because N cycle is dependent on multiple factors in the soil not just a balance of input and output. Cover crops can be grown to provide multiple ecosystems services including, utilizing residual soil N, adding N to the system through fixation, protecting the soil from erosion, feed for livestock and/or weed control.

Utilization of cover crops to influence N dynamic have been evaluated with mixed results, multiple researchers have found that mineralization or immobilization is dependent on residue decomposition and timing of release when synchronizing uptake with the following crop (Wagger, 1989; Sievers and Cook, 2018). So far, no specific cover crop has been shown to consistently achieve both objectives. One common method to estimate soil N mineralization is to use aerobic or anaerobic incubation in the laboratory, but a field incubation (*in-situ*) might have more reliable estimation since N transformation are strongly site-specific (Kolberg et al., 1997; Khanna and Raison, 2013). Our research objective was to evaluate N dynamic of different cover crops compared NCC and the following impact on corn yield after cover crops.

## MATERIALS AND METHODS

Research plots were located at three different sites, site 1 (RF) was conducted at the Eastern South Dakota Soil and Water Research Farm and two experiments were conducted approximately 1 mile away at the USDA–ARS North Central Agricultural Research Laboratory

(A2 and A3) near Brookings, SD under no-till soil management. These locations receive an average precipitation of 24-inches and average temperature of 42 °F (1981–2010) (NOAA, 2019). The experiments were a randomized complete block design with four replications. Cover crop treatments included, NCC, white sweet clover, winter cereal rye, and hairy vetch. Planting rate for sweet clover, cereal rye and hairy vetch were 20, 103, and 30 lb $ac^{-1}$, respectively, and were drilled into wheat stubble. Cover crop were allowed to over-winter and were chemically killed before corn planting. Corn hybrid (DeKalb 44-92) was planted at 20-inch row spacing with a seeding rate of 25,000 seeds $ac^{-1}$ and treated with Trifloxystrobin. Ammonium polyphosphate with 14 lb N $ac^{-1}$, 16 lb P $ac^{-1}$ and 10 lb K $ac^{-1}$ as dry fertilizer as a starter fertilizer and additional of 50 lb N $ac^{-1}$ as ammonium nitrate was applied sidedress at corn growth stages (GS) V6. Corn yield were harvested using a plot combine (MF8-XP) and yield was adjusted to 15.5 % moisture content (Fig. 2).

The top 6-inches soil has high organic matter (~3.7 %), with 7.3 pH, 1.3 % $NO_3$–N (2 M KCl extraction), 5 % P ($NaHCO_3$ method), and 2.2 % total C (dry combustion techniques). Cumulative precipitation and weekly averaged soil temperature at top 2-inches with 30-year averages of precipitation and air temperature were presented in Fig. 1(a, b).

Nitrogen mineralization were measured *in-situ* using intact cores deployed with ion exchange resins (DiStefano and Gholz, 1986) as modified by Kolberg et al. (Kolberg et al., 1997) during three periods. Period 1, corn planting until sidedress fertilization at corn GS V6; period 2, V6–R3; and period 3, R3–R6. Two pairs of undisturbed *in-situ* cores (total of four cores) were placed between the corn rows in each plot by driving an aluminum cylinder (4-inches depth, 1.9-inches diam.) into ground. The lower 0.4-inches of the soil cores was excavated and filled with a nylon mesh bag containing approximately 0.5 oz of 50:50 mixture of anion and cation exchange resins (Sybron Ionac ASB-1, C-249, Sybron Chemicals, Birmingham, NJ). This served to capture both $NO_3$-N and $NH_4$-N leaching from the soil core which contains equal amount of $Na^+$ saturated cation and $Cl^-$ saturated anion exchange (DiStefano and Gholz, 1986; Kolberg et al., 1997). The complete assembly was returned to the same hole in each period of incubation. Detailed information regarding the incubation duration of the *in-situ* soil cores incubation were reported in Table 1. Additionally, eight soil cores (diam. 1.3-inches) were collected at the beginning of each incubation to determine the initial soil inorganic N content. After each incubation period, pairs of *in-situ* soil cores and resin were removed and bagged separately in plastic bags and stored at 37 °F. All soil samples were extracted using 2 M KCl method for soil inorganic $NO_3$–N and $NH_4$–N within a week. Resin were extracted five times to recover more than 85 % of N. Net N mineralization ($N\text{min}_t$) were calculated during each period ($t$) then normalized into per day basis as follows: $N\text{min}_t = N\text{core}_t + N\text{resin}_t - N\text{soil}_t$; where $N\text{core}_t$ is inorganic N in the soil core at the end of period $t$, $N\text{resin}_t$ is inorganic N in the resin bag at the end of period $t$, and $N\text{soil}_t$ is inorganic N in the soil core collected at the beginning of period $t$ (Raison et al., 1987). The total accumulative N mineralized reported in Fig. 3 as multiple 100-day to approximate the growing season for corn in this region.

## RESULTS AND DISCUSSION

In general, legume cover crops treatment had better corn yield compared to rye or NCC except at site RF, and rye had the lowest corn yield. Some researchers have found that corn following rye can reduced yield possible due to N immobilization, soil water depletion or allelopathy associated during rye biomass decomposition (Eckert, 1988; Holderbaum et al., 1990; Raimbault and Vyn, 1991; Decker et al., 1994). Sainju and Singh (1997) reported the crop yield and N uptake after nonlegume might be equivalent to or less than without a cover crop, which is similar to what we found at A2 (Fig. 2). The overall corn yield at A2 was significantly lower and only produced about half of South Dakota state 5-yr averages (2005–2009) corn yield (124 bu $ac^{-1}$) while the other site years were within range of the state average. Precipitation amounts during reproductive stage of corn (Jul–Oct) at RF, A3, and A2 were 124, 113, and 60 inches, respectively, compared to 116 inches on 30-yr averages (1981–2010) which could have reduced over all corn yields. NeSmith and Ritchie (1992) found significant physiological damage and 15–25 % yield loss when long-term (18–21d) water stress is like the conditions during the A2 growing season.

The legume cover crops had greater amount of mineralizable N in the experiment compared to the rye cover crops, but the NCC treatment varied with the different site years (Fig. 3). This could explain why legume cover crop treatments had higher corn yield (Fig 2; two out of three locations) compared to rye treatment. Nitrogen availability was synchronize with the plant N needs. Legume cover crops mineralized more N than rye cover crop but not necessary more compare to the NCC using *in-situ* incubation measurement at all sites.

Interestingly, the relationship between net mineralization rates from *in-situ* incubation was inverse correlation to the N use efficiency of corn (Figs. 3 and 4). This could be explained as the lower N mineralization occurred in the soil after cover crop treatment, the higher of grain produced per unit of input from the soil. Another possible explanation could be as more organic N was available for corn to take up during the growing season, which were not measured in these studies.

## CONCLUSIONS

In conclusion, legume cover crop treatments had higher corn yield even in the drought year except RF. *In-situ* incubation data also supported legumes mineralized more N and the total N mineralized from legume were significantly higher than rye. Corn yield were higher at RF due to favorable precipitation during the growing season, however A2 only produced half of SD state 5-yr averages (124 bu $ac^{-1}$) due to deficit precipitation, especially during the critical reproductive stage in corn (Jul–Oct). Rye cover crop had the lowest corn yield possibly due to low N immobilization.

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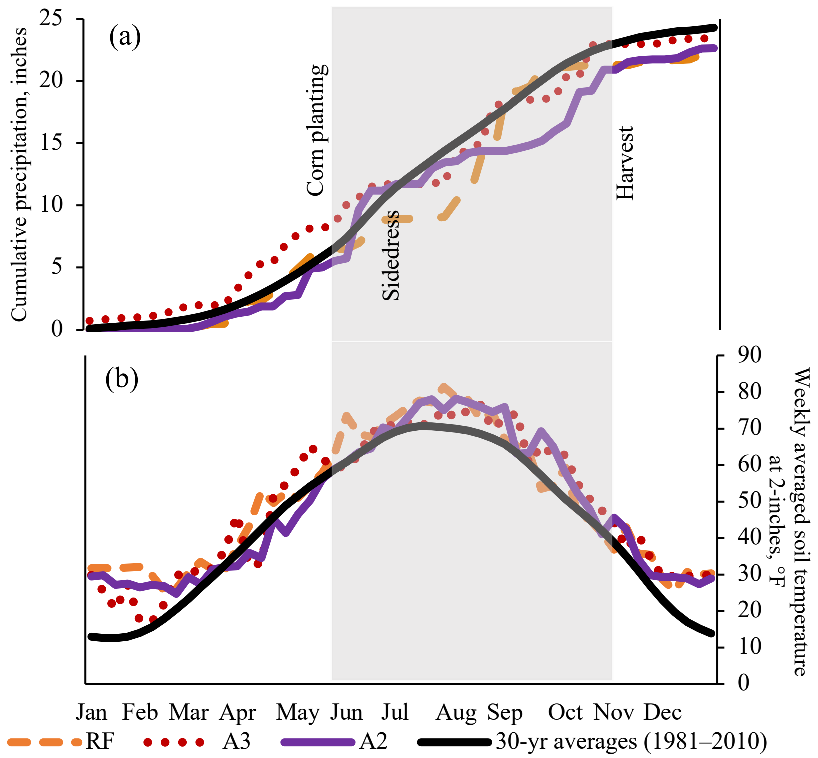
**Table 1**. The starting and ending date for *in-situ* soil intact cores for nitrogen mineralization measurements at the USDA–ARS NCARL and the Eastern South Dakota Soil and Water Research Farm near Brookings, SD at RF, A3 and A2.

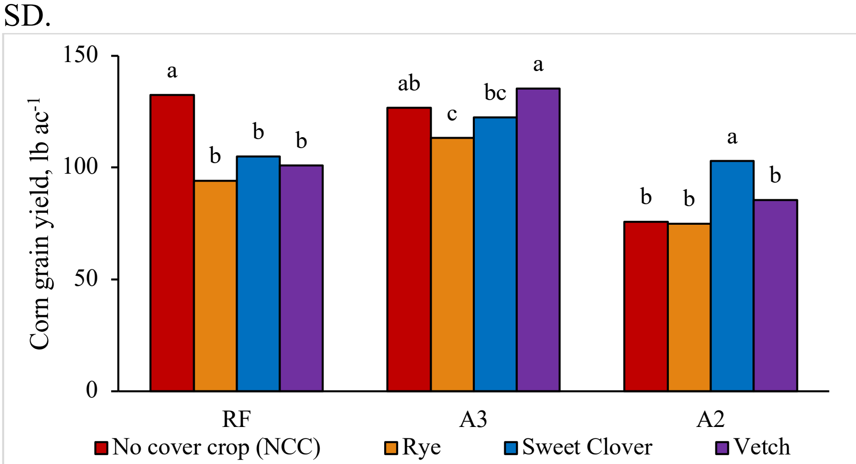
| Location | Period 1 | | Period 2 | | Period 3 | |
|---|---|---|---|---|---|---|
| | **Start** | **End** | **Start** | **End** | **Start** | **End** |
| RF | 6-Jun-06 | 27-Jun-06 | 29-Jun-06 | 10-Aug-06 | 11-Aug-06 | 10-Oct-06 |
| A3 | 31-May-07 | 20-Jun-07 | 29-Jun-07 | 26-Jul-07 | 26-Jul-07 | 30-Aug-07 |
| A2 | 5-Jun-08 | 30-Jun-08 | 7-Jul-08 | 31-Jul-08 | 31-Jul-08 | 1-Oct-08 |

**Figure 1.** (a) Cumulative precipitation (in) (b) weekly averaged soil temperature (°F) at top 2-in and 30-year averages (1981–2010) at USDA–ARS NCARL and Eastern South Dakota Soil and Water Research Farm near Brookings, SD at RF, A3 and A2.



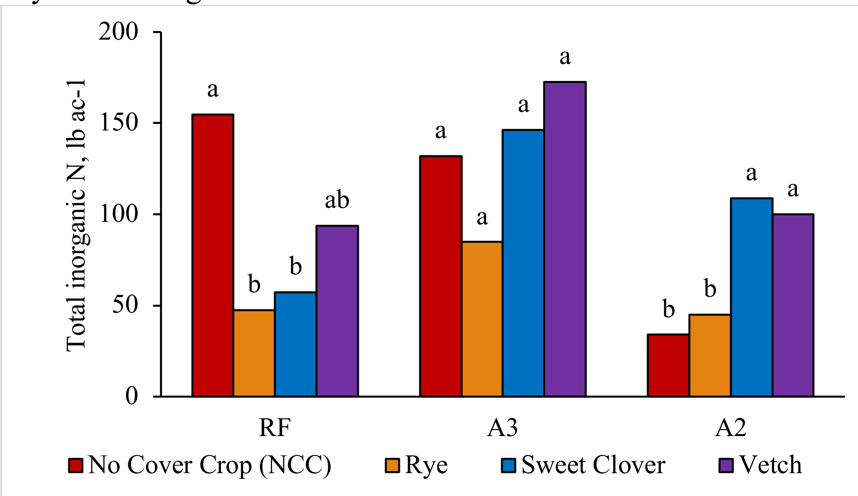

Note: Gray shaded area indicates the time period for corn growing season/*in-situ* incubation; weather data for daily cumulative precipitation (mm) and weekly averaged soil temperature (°C) and 30-yr averages of air temperature and cumulative precipitation (1981–2010) from NOAA (2019).

**Figure 2.** Corn grain yield (bu $ac^{-1}$) following cover crop collected at harvest near Brookings, SD.



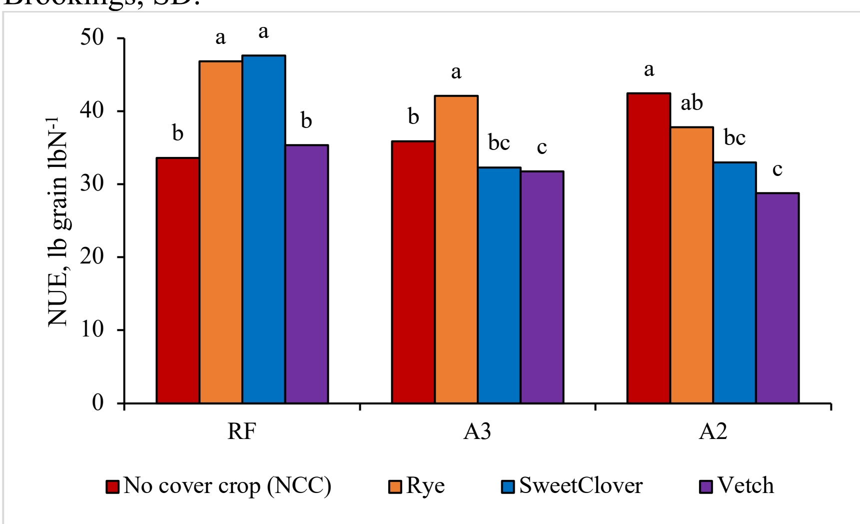

Mean within a site followed the same letter are not significantly different at α = 0.10, PDIFF option.

**Figure 3.** The accumulative amount of N mineralization from period 1 to 3 (lb N $ac^{-1}$) for 100-days corn using *in-situ* soil cores incubation measurement near Brookings, SD.




Mean within a site followed the same letter are not significantly different at α = 0.10, PDIFF option

**Figure 4.** Nitrogen use efficiency (NUE) (lb grain $lbN^{-1}$) in corn following cover crops near Brookings, SD.




Mean within a site followed the same letter are not significantly different at α = 0.10, PDIFF option