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The Impact of Fall Cover Crops on Soil Nitrate and Corn Growth

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Abstract: Incorporating cover crops into current production systems can have many beneficial impacts on the current cropping system including decreasing erosion, improving water infiltration, increasing soil organic matter and biological activity but in water limited areas caution should be utilized. A field study was established in the fall of 2007 to evaluate the impact of incorporating cover crops into a no-till crop production system in Central South Dakota. Cover crops utilized in the experiment were: cowpea (*Vigna sinensis*), lentils (*Lens culinaris*), canola (*Brassica napus)*, cow/can/len, cow/can, can/len, radish (*Raphanus sativus*)/cow/can/len and turnip (*Brassica napa)*/cow/len/can combos all compared to no-cover crop. Cover crops were allowed to grow throughout the fall and winter killed. Cover crop biomass was collect prior to a killing frost. The following spring corn was planted and in-season growth and grain yield was evaluated. When cover crops were incorporated into the production practices there was a significant increase in grain yield compared to the no cover crop treatment without additional nitrogen. While when nitrogen was applied to the corn crop yields did not increase as dramatically compared to the no cover crop treatment. Fall cover crops had the ability to scavenge residual soil nitrate and make it plant available for the following crop providing a positive environmental benefit beyond the above mentioned benefits.

Key words: Organic matter, cover crops, corn, nitrogen, production, South Dakota

INTRODUCTION

Inadequate precipitation is one of the most limiting factors to crop production in the great plains. There have been numerous improvements in agricultural production practices for the past decades while these improvements have lead to increases in crop yield there is also negative environmental impacts associated with these improved practices. To increase crop yield in the central and western portions of South Dakota, a fallow period was utilized to conserve soil moisture. This fallow period lead to increase till age operations which had a negative impact on soil carbon and soil erosion.

VNo-till crop production was introduced as a method of removing this fallow period from crop production. The success of no-till production is based upon having adequate crop residue on the soil surface, decreasing soil erosion while improving water infiltration. Ensuring adequate crop residue in central and western South Dakota can be problematic. One way to overcome this lack of crop residue would be to plant a fall cover crop following the harvest of the cash crop. Many of the advantages of no-till crop production to soil quality and water utilization are derived from the residue mulch that remains on the soil surface after grain harvest and cover crops are an excellent source of plant residue. The residue mulch protects the soil from wind and water erosion but also delays soil warming in the spring (Swan *et al*., 1996). Cooler soil slows seed germination, reduces uptake of non-mobile soil nutrients and decreases early crop growth (Barber, 1984; Griffith and Wollenhaupt, 1994). Under no-till conditions, Drury *et al.* (1999) found that a fall-seeded cover crop (red clover) planted after wheat harvest allowed the following corn crop to have seedling emergence and yield equal to that of a corn crop following wheat under tilled conditions. In contrast, Raimbault *et al.* (1990) found that grain yields were consistently lower under no-till treatments as compared with tilled treatments when the cash crop followed a cover crop (winter rye) but that yield was unaffected by tillage in the absence of cover crops.

A more comprehensive knowledge of soil and crop specific responses to crop rotation, tillage/residue management practices and cover crops is critical to

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understanding and improving the economics of production (Reeves, 1994). The objective is to evaluate a number of individual cover crops and combination of cover crops as a way of increasing crop residue on the soil surface and the impact on the following crop yield and quality.

MATERIALS AND METHODS

A field study was initiated in the fall of 2007 on an Agar silt loam (fine-silty, mixed, superactive, mesic typic argiustolls) in Gettysburg South Dakota. The experimental design was a randomized complete block design with three replications. The cover crop treatments were applied to 12 m by 60 m plot areas. Cover crops were planted following wheat harvest on August 7, 2007. Cover crops utilized in the experiment were: cowpea (cow), lentils (len), canola (can), cow/can/len, cow/can, can/len, radish (rad)/cow/can/len and turnip (turn)/cow/len/can combos all compared to no-cover crop. Cover crops were allowed to grow throughout the fall and winter killed.

Cover crop biomass was collect prior to a killing frost on October 24, 2007 by collecting 3 randomly 1 m by 1 m quadrates. The different types of cover crops have distantly different above and below ground growth character.

To evaluate the different cover crop impact on the following cash crop corn crop was planted at a seeding rate of 54,000 seeds ac^{-1} on May 13, 2008. Producer hybrid 56-23 RRCB was planted to the entire area. At planting 120 kg nitrogen ha^{-1} was applied to half (12×30 m) of the cover crop experimental area (12×60 m) with the remaining not receiving any additional nitrogen fertilizer. In season corn biomass was collected by sampling (1 m of row length) at growth stage V6 (July 1, 2008) and R1 (August 5, 2008). Samples were dried for 120 h in a forced-air oven at 60°C and then weighed to obtain estimates of dry matter production. Samples were ground to pass a 2 mm sieve. Plant nitrogen concentration was determined on all samples using dry combustion techniques (Schepers *et al*., 1989).

At crop maturity whole plant samples were collected from the 2 middle rows by collecting 1.5 m of each row. At the time of whole plant sampling corn ears within the two rows were collected and hand shelled and grain moisture and test weight was determined and was utilized to calculate grain yield.

Corn yield was adjusted to 15.5 g kg^{-1} moisture for further analysis. A portion of the grain yield samples were ground using a Knife Tec (Foss North America, Eden Prairie, MN) oven-dried a 60°C and analyzed for nitrogen concentration as described above. Spring soil samples were collected several times during the duration of the experiment (August 21, 2007; October 24, 2007; April 29, 2008; July 1, 2008 and August 5, 2008) to determine residual soil nitrate. Soil samples were collected by taking two soil cores per plot (4.45 cm diameter) to a depth of 60 cm. Samples were split into 4 increments: 0-15, 15-30, 30-45 and 45-60 cm, air dried at ambient temperature and ground to pass a 2 mm screen.

Samples were extracted using 2 M KCl and analyzed for NO_3-N using automated flow injection analysis. Soil moisture was also measured for the October 2007 and April 2008 sampling dates. Samples were collected to the depth of 30 cm by collecting 2 crores per plot that were compiled and a subsample taken. The sub-sample wet weight was recorded and then dried at 80°C for 72 h and weighed again to obtain percent soil moisture for each plot. Statistical analysis of data over years was performed using the Proc Mixed procedures in SAS Institute (1999) utilizing $p = 0.05$.

RESULTS AND DISCUSSION

Fall cover crop growth: Growth of fall cover crop was quite variable between the different cover crop treatments with the canola and canola\cowpea treatments having the largest fall production and average of 1050 kg ha^{-1} and the lowest fall growth obtained from the canola\cowpea\lentil and radish\cowpea\lentil treatments and average of 658 kg ha^{-1} (Fig. 1). The remaining cover crop treatments had an average fall biomass production of about 800 kg ha^{-1}. In contrast, the cover crop with the largest fall production also had the lowest biomass nitrogen concentration and the treatments of either lentil alone or lentils in the cover crop combinations had higher nitrogen concentrations. The cover crop combination treatments with the largest biomass production resulting in the highest nitrogen concentration due to the inclusion of lentils a legume crop which has the ability to fix atmospheric nitrogen into plant available nitrogen. As more biomass was produced, there should be more nitrogen fixed resulting in an increase in nitrogen concentration.

One of the potential benefits of utilizing a cover crop is that they can scavenge residual soil nitrate that might otherwise be leached from the soil profile. The addition of a legume can add additional nitrogen to the soil environment for the following cash crop. To estimate the amount of nitrogen taken up by the cover crops or fixed through biological nitrogen fixation total nitrogen uptake was determined (Fig. 2). The greatest amount of nitrogen taken up by the cover crop treatments were the lentil alone treatment and the turnip\cowpea\lentil treatment with an average of 245 kg N ha^{-1} being taken up in the above ground biomass, this nitrogen could be available

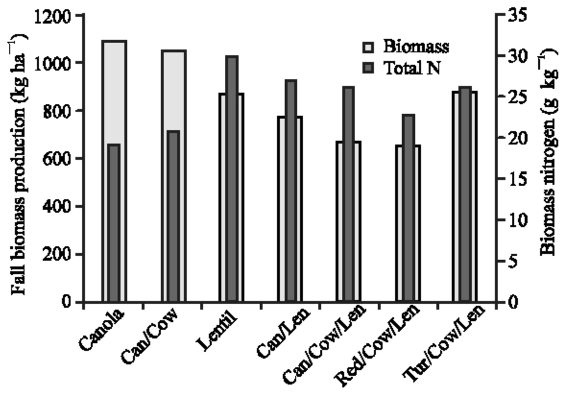

Fig. 1: Fall cover crop biomass production and nitrogen concentration by cover crop treatment, Gettysburg, SD 2007-2008

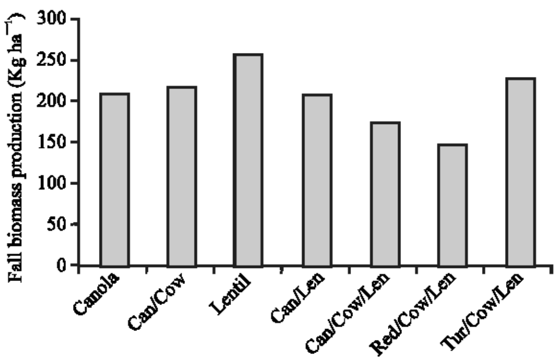

Fig. 2: Fall cover crop biomass nitrogen uptake by cover crop treatment, Gettysburg, SD 2007-2008

through mineralization to the following cash crop. The cover crop treatments of either canola or in combination with canola had the average lower nitrogen uptake. The fall October residual soil nitrate results showed that several of the cover crop treatments had a lower nitrate level compared to the no cover crop treatment and the lentil only treatment (Table 1). The following spring the preplant soil nitrate levels were all greater compared to the fall sampling with the largest levels from the lentil alone and turnips.

Corn in-season growth and yield: The following spring corn was planted in the cover crop and wheat stubble to evaluate what impact cover crops have on the following crop growth and yield. Separate plant biomass samples were collected at V6 and R1 growth stages for all cover crop treatments with the different nitrogen application amounts.

Average corn biomass production and nitrogen concentration increased with the addition of nitrogen fertilizer for both sampling growth stages (Table 2).

Table 1: Fall and pre-plant soil nitrate-N concentration by cover crop treatment and sampling depth, Gettysburg, SD, 2007-2008

	October soil nitrate-N		Preplant soil nitrate-N	
Cover crop	0-15 cm	15-30 cm	0-15 cm	15-30cm
No cover crop	8.87^{abc}	11.08^{ab}	11.92^{ab}	8.43^{ab}
Canola	8.90^{ac}	7.98^{bc}	9.63^{b}	10.11^{a}
Cowpea	7.59^{abc}	11.13^{ab}	9.89^{b}	6.97^{b}
Canola/cowpea	8.75^{abc}	9.95^{abc}	11.82^{ab}	8.05^{ab}
Lentil	9.69^{a}	6.48^{c}	14.29^{a}	7.00^{b}
Canola/lentil	7.08^{bc}	9.16^{abc}	10.57^{a}	7.32^{b}
Canola/cowpea/lentil	8.69^{abc}	11.98^{a}	11.37^{ab}	7.30^{b}
Radish/cowpea/lentil	6.71^{c}	8.15^{bc}	9.54^{b}	7.04^{b}
Turnip/cowpea/lentil	6.83^{bc}	7.66^{bc}	14.19^{a}	6.92^{b}

Although, there was an increase in average corn biomass production at the V6 growth stage with the addition of nitrogen, this increase was a result of a significant increase in the no cover crop canola and cowpea treatments while the cover crop combinations and lentil treatment did not show a significant increase in biomass production (Table 2).

All the radish/cowpea/lentil treatment had an increase in plant nitrogen concentration at the V6 growth stage when nitrogen was applied compared to no nitrogen being applied.

In contrast at the later sampling data all of the cover crop treatment except for the canola/cowpea/lentil treatment had significantly higher biomass production when nitrogen was applied compared to no nitrogen being applied (Table 2), possibly indicating that early in the growing season of corn production that nitrogen which was either scavenged by the fall cover crop or fixed through nitrogen fixation was being mineralized and made available for the following corn growth. And that later in the growing season nitrogen became somewhat limited and the amount of production for the areas not receiving nitrogen fertilizer were not able to maintain production levels as illustrated by average nitrogen concentration of the biomass at the R1 sampling growth stage (15.9 compared to 13.2).

Within the different nitrogen application, there was a significant increase in biomass production for all sampling date with and without nitrogen for some of the cover crop treatments compared to the no cover crop treatment. Plant nitrogen concentration was increased for all cover crop treatments at both sampling dates when no nitrogen was applied regardless of the cover crop treatment.

One of the major concerns with growing cover crop prior to corn is that they may utilize too much soil moisture therefore limiting the following corn growth and yield. To evaluate this aspect, preplant soil moisture was determined to a depth of 45 cm and compared to final grain yield. There was very little difference in preplant soil moisture with a range between 22.8 and 23.9%. There

Table 2: In-season corn biomass and nitrogen concentrationby cover crop treatment with and without additional in season nitrogen added, Gettysburg, SD, 2007-2008

	Normal fertility		No additional nitrogen	
Cover crop	V6 biomass (kg ha^{-1})	V6 nitrogen (g kg^{-1})	V6 biomass (kg ha^{-1})	V6 nitrogen (g kg^{-1})
No cover crop	102^{ab}	33.2^{d}	85^{b}	32.8^{b}
Canola	178^{a}	40.2^{abc}	128^{ab}	33.0^{b}
Cowpea	182^{a}	39.8^{abcd}	98^{ab}	38.9^{a}
Canola/cowpea	129^{ab}	44.4^{a}	137^{a}	36.7^{ab}
Lentil	139^{ab}	45.5^{a}	153^{ab}	36.1^{ab}
Canola/lentil	114^{ab}	42.8^{abc}	126^{ab}	37.2^{a}
Canola/cowpea/lentil	117^{ab}	43.3^{ab}	118^{ab}	37.6^{a}
Radish/cowpea/lentil	87^{b}	35.7^{bcd}	103^{ab}	36.3^{ab}
Turnip/cowpea/lentil	111^{ab}	34.8^{cd}	91^{ab}	34.1^{b}
Average	128	39.3	115	35.8
Cover crop	R1 biomass (kg ha^{-1})	R1 nitrogen (g kg^{-1})	R1 biomass (kg ha^{-1})	R1 nitrogen (g kg^{-1})
No cover crop	5854^{ab}	14.3^{bc}	4432^{b}	11.6^{b}
Canola	6002^{ab}	15.5^{abc}	4749^{ab}	13.3^{ab}
Cowpea	4940^{b}	16.7^{ab}	4076^{b}	12.5^{b}
Canola/cowpea	5161^{b}	18.5^{a}	3986^{b}	14.6^{a}
Lentil	6486^{a}	17.2^{ab}	4267^{b}	13.2^{b}
Canola/lentil	5464^{ab}	17.8^{ab}	5703^{a}	14.3^{ab}
Canola/cowpea/lentil	6089^{ab}	16.5^{ab}	4778^{ab}	12.5^{b}
Radish/cowpea/lentil	5708^{ab}	12.4^{c}	4792^{ab}	12.2^{b}
Turnip/cowpea/lentil	5177^{b}	14.7^{abc}	4056^{b}	12.4^{b}
Average	5653	15.9	4537	13.2

Table 3: Corn grain yield and grain nitrogen concentration by cover crop treatment with and without additional in season nitrogen added, Gettysburg, SD, 2007-2008

	Normal fertility		No additional nitrogen	
Cover crop	Grain yield (kg ha^{-1})	Nitrogen (g kg^{-1})	Grain yield (kg ha^{-1})	Nitrogen (g kg^{-1})
No cover crop	9692de	12.2^{ab}	6978^{h}	9.5^{b}
Canola	10008^{bc}	12.3^{ab}	8407^{f}	9.7^{b}
Cowpea	9642de	12.2^{ab}	8774^{e}	9.6^{b}
Canola/cowpea	10114^{ab}	13.2^{a}	10651^{a}	11.2^{a}
Lentil	10201^{ab}	11.9$_{ab}$	8875de	10.1^{ab}
Canola/lentil	9782^{cd}	12.9^{a}	9097^{c}	10.4^{ab}
Canola/cowpea/lentil	9486^{e}	12.0^{ab}	9012^{cd}	9.5^{b}
Radish/cowpea/lentil	9585de	10.7^{b}	9872^{b}	9.2^{b}
Turnip/cowpea/lentil	10354^{a}	12.7^{ab}	7434^{g}	9.5^{b}
Average	9873	12.2	8789	9.8

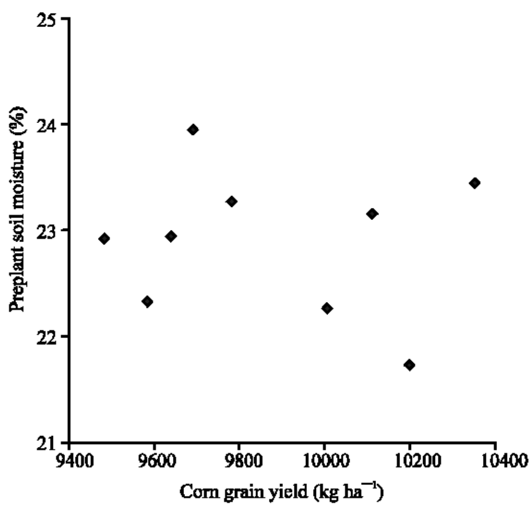

Fig. 3: Relationship between pre-plant soil moisture and the following corn crop grain yield, Gettysburg, SD 2007-2008

was no relationship between these soil moisture values and grain yield (Fig. 3), indicating that in this experiment cover crops did not utilized enough soil moisture to be a detriment to corn yield. On average corn yields increased by 1000 kg ha^{-1} for the plots receiving nitrogen fertilizer compared to no fertilizer (Table 3). The average increase in grain yield for the no cover crop treatment with nitrogen fertilizer compared to no nitrogen fertilizer was 28% compared to an average increase of only 9% for the cover crop treatments receiving nitrogen fertilizer compared to no nitrogen fertilizer. Canola canola/cowpea, turnip/cowpea/lentil treatments had the largest yields >10,000 kg ha^{-1} and the lowest yield from the no cover crop and the canola/cowpea/lentil treatment when nitrogen was added (Table 3). Without the addition of nitrogen fertilizer the lowest yield was obtained from the no cover crop treatment with yield increases for the other cover crop treatments as high as 10,651 kg ha^{-1} for the canola/cowpea treatment.

CONCLUSION

Although, fall cover crop was quite variable within the different cover crop treatments, they scavenged residual soil nitrate levels as indicated through preplant and October soil nitrate values. There were on average 200 kg nitrogen ha^{-1} either scavenged or fixed by the cover crop treatments that were available for the following corn crop. Addition of a cover crop in this no-till production system did not deplete the soil of moisture for the following corn crop. With the additions of nitrogen fertilizer yields were either equal to or significantly increased compared to the no fertilizer treatment while without the addition of nitrogen fertilizer all cover crop treatments had grain yields significantly greater than the no cover crop treatment. Incorporating cove crops into a diversified cropping system has the potential to decrease the amount of nitrogen needed for the following cash crop by having a positive impact on yields.

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