NITROGEN DYNAMICS IN CONVENTIONAL, REDUCED TILLAGE AND ORGANIC IRRIGATED SYSTEMS: RESULTS OF A FOUR-YEAR EXPERIMENT IN WYOMING

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ABSTRACT

Soil nitrogen (N) is critically important for crop production. A field experiment was conducted in eastern Wyoming to evaluate soil mineralizable (mineralized in 14 days incubation) and inorganic N contents as influenced by conventional, organic and reduced-tillage management approaches for cash-crop and forage production in eastern Wyoming. Soil samples were collected from all treatments (2 production systems x 3 management approaches) during 2009-2012 and analyzed for soil mineralizable and inorganic N contents. Soil mineralizable N content was varied significantly among management approaches only in the first year and soil inorganic N content was significantly different among management approaches only in the first and second years in the cash-crop system. In the forage production system, mineralizable N content was not significantly different among management approaches throughout the study and inorganic N content was significantly different among management approaches in the second and fourth years. However, there was 130-345% increase in mineralizable N content and 94-463% increase in inorganic N content in the from the first to the fourth years, relative increase depending on the management approaches and crop rotations. In conclusion, crop rotations positively influenced soil mineralizable and inorganic N contents in soils, relative efficiency of management approaches in conserving mineralizable N, and supplying inorganic N, depending on the crops in rotations and soil fertility management.

INTRODUCTION

Managing the delicate balance of soil N supply to meet goals of economic profitability and environmental quality requires knowledge of soil N dynamics in agroecosystems (Franzluebbers et al., 1995). Soil inorganic N limits crop production when its supply is low in and it contaminates the environment when supply is excessive. To regulate the soil N supply required for crop growth and production, synthetic N fertilizers are applied in conventional farming systems and management practices (Poudel et al., 2002). Sustainability and environmental quality of the conventional production systems, however, is questioned in part because of inefficient N use by crops and significant N loss from agroecosystems (Dell et al., 2012). Therefore, identifying management practices that increase crop production and minimize environmental impacts are highly desired.

There are a range of management practices that increase soil N required for crop growth and minimize environmental impacts (Halvorson et al., 2002; Ghimire et al., 2012; Norton et al., 2012). For example, reduced-tillage management minimizes soil organic matter mineralization and thereby increases soil N reserves compared to soil N under conventional tillage (Al-Kaisi et al., 2005). Cover cropping along with reduced soil disturbance allows slower but more continuous release of inorganic N throughout the growing season (Poudel et al., 2002). Similarly, organic farming (legume based or organic manure / compost based) practices are also conservative of inorganic N, regulating N supply throughout the growing season. In conventionally fertilized systems, on the other hand, N supply occurs in pulses after fertilizer applications, often leading to substantial N loss from agroecosystems.

In semi-arid drylands of the northern and central High Plains regions, water and N are the most limiting factors for crop production (Oleary and Connor, 1997; McCauley et al., 2012). In irrigated agroecosystems, crop production is mostly limited by soil N (Gehl et al., 2005). Soil N as influenced by alternative management strategies is not well understood in the central High Plains region. Therefore, this paper focuses on evaluating soil mineralizable and inorganic N as influenced by conventional, organic and reduced-tillage management approaches for cash-crop and forage production systems in eastern Wyoming.

MATERIAL AND METHODS

The field experiment was conducted in a 15-ha irrigated area under overhead pivot irrigation at the Sustainable Agriculture Research and Extension Centre (SAREC), near Lingle, Wyoming (42° 7'15.03"N and 104°23'13.46"W). The agroecosystem of the study area is characterized by cool temperature and short growing season with an average frost-free period of about 125 days and average annual precipitation of 300-400 mm (Western Regional Climate Center, 2012). In addition, soil at the study site was a Mitchell loam (loamy, mixed, active, mesic Ustic Torriorthent) with low SOM content (<1%), and slightly alkaline soil pH (SoilSurveyStaff, 2012). Before establishment of this experiment, the study site was under continuous corn for at least six years with conventional tillage and chemical soil fertility management.

Conventional, organic and reduced-tillage management approaches of cash-crop and forage production systems were compared in this study. The field was divided into six strips under four blocks. Outer three strips across blocks were assigned to the cash-crop systems whereas inner three strips across blocks were assigned to the forage production systems. Levels of management approaches were randomly assigned to four blocks within each production system. Forage production plots were winter grazed for 3 months during winter 2011/2012. Cash-crop plots under each management approach were 0.40 ha in size.

Four-year-four-crop rotations were evaluated in this study (Table 1). Conventional management applies inputs as needed to maximize production, namely commercial synthetic fertilizer based on soil test recommendations to supply nutrients, and chemical pesticides to control weeds, insects and diseases. These plots are moldboard ploughed, disked, and harrowed, which typically incorporates residues into soils leaving <15% on the soil surface. Reduced-tillage approach involves use of conservation tillage, a non-inversion tillage that leaves >15% residue on the soil surface. In the organic approach, tillage is done as in conventional plots, and pest control and nutrient management are based on practices allowed by the USDA National Organic Program (NOP) standards.

Soil samples were collected from all plots during spring, early and late summer, and fall 2009-2012. Soil samples were collected from 16 sampling points along 50 m long permanent transects set in each plot (3.2 mm diameter x 15.0 cm deep). Soil samples were composited across all 16 subsamples, thoroughly homogenized and ~500-g subsamples were drawn to transport to the laboratory. Sampling points were georeferenced to locate the same place for repeated measurements throughout the study.

Table 1. Crop rotations and grazing management in alternative management approaches of cash-crop and forage production systems.

System	App.	Year				Winter grazing
		2009	2010	2011	2012	
Cash-crop	CV	Pinto bean	Corn	Sugar beet	Corn	No winter grazing
	OR	Alfalfa	Alfalfa	Corn	Pinto bean	
	RT	Pinto bean	Corn	Sugar beet	Corn	
Forage	CV	Alfalfa/grasses	Alfalfa/grasses	Alfalfa/grasses	Corn	Cattle grazed during wither 2011/2012
	OR	Alfalfa/grasses	Alfalfa/grasses	Alfalfa/grasses	Corn	
	RT	Alfalfa/grasses	Alfalfa/grasses	Alfalfa/grasses	Corn	

*App. = management approaches, CV = conventional, OR = organic, and RT = reduced-tillage.

In the laboratory, 10-g soil samples were extracted with 0.5M K_2SO_4 within 24 hrs of sample collection in the field and were used for inorganic N determination. Another set of 20-g soil samples were incubated for two weeks to determine mineralizable N. Total soil N was determined in soil samples from the first and last sampling in 2009 and 2012 respectively. Laboratory analyses included soil Inorganic-N as nitrate (NO_3^-) (Doane and Horwath, 2003) and ammonium (NH_4^+) (Weatherburn, 1967) in a BioTek microplate spectrophotometer (BioTek, Inc., Winooski, VT). Mineralizable N was determined as inorganic N in incubated soil samples. Total soil N was determined in a dry combustion analyzer (EA1100 Soil C/N analyzer, Carlo Erba Instruments, Milan, Italy). Data were analyzed as split plot in time analysis of variance through use of the general linear model (Proc GLM) procedure of the Statistical Analysis System (ver. 9.2, SAS Institute, Cary, NC). Since there was no significant management approach x growing season interactions in all years, results are presented as average of all seasons within a management approach within a year. Mean separations were conducted using fisher's protected LSD ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Soil mineralizable N contents varied significantly among management approaches in the first year in cash-crop production systems but were not in successive years (Figure 1). Soil mineralizable N, however, increased gradually in successive years leading to 203, 345, and 271 % more mineralizable N in conventional, organic and reduced-tillage management approaches, respectively, in the fourth year compared with that in respective management approaches in the first year. In forage production systems, mineralizable N content did not vary significantly among management approaches throughout the study, although there was 345, 132 and 222% increase in mineralizable N in conventional, organic and reduced-tillage management approaches, respectively, in the fourth year compared with that in respective management approaches in the first year.

Soil inorganic N contents were significantly affected by management approaches in the first and second years in cash-crop production system. Comparing first and fourth year of study, there was 223, 463 and 252% increase in inorganic N in the fourth year compared with the first year (Figure 2). In forage production system, soil inorganic N contents were significantly affected by management approaches in the second and the fourth years. In addition, there was 390, 94 and

456% more soil inorganic N in conventional, organic and reduced-tillage management approaches in the fourth year than in respective management approaches in the first year. Total soil N measured at the beginning and end of the experiment did not vary among management approaches at the beginning or end of the experiment.

Figure 1. Soil mineralizable N as influenced by management approaches in cash-crop and forage production systems. CV, OR and RT stands for conventional, organic and reduced-tillage management approaches.

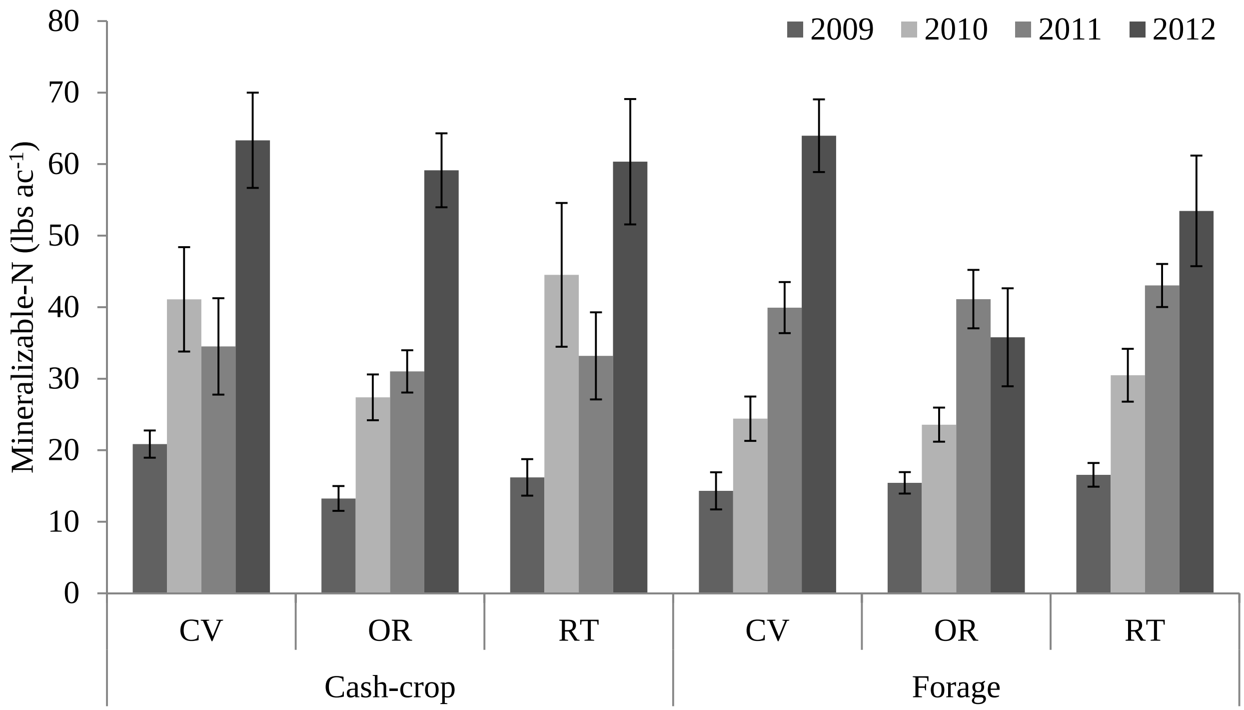
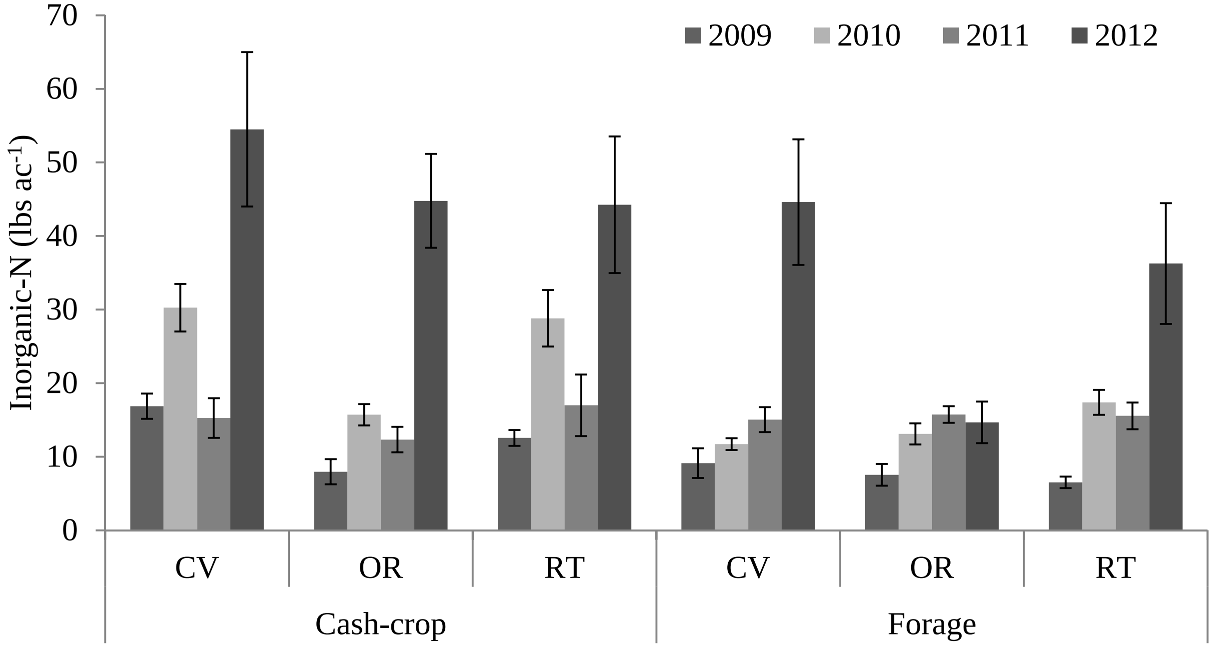


Figure 2. Soil inorganic N as influenced by management approaches in cash-crop and forage production systems. CV, OR and RT stands for conventional, organic and reduced-tillage management approaches.



Processes facilitated by rhizodeposition, legume crops, or organic amendments increase mineralizable N in soils (Rasmussen et al., 1998), which supplies 20-80% of the N required for plant growth and production (Broadbent, 1984). Increase in mineralizable N, therefore, indicates more N-reserve in soils potentially supporting better crop production (Mikha et al., 2006). Disturbance events and increases in temperature and moisture speed up the mineralization process leading to increased inorganic N in soils (Rasmussen et al., 1998; Ghimire et al., 2012). Crop rotations under optimum conditions supply more roots and rhizodeposition, and also create a more favorable environment for microbial activity, potentially increasing both mineralizable and inorganic N. In our study, accumulation of mineralizable and inorganic N, however, depended mainly on the crops in the rotation. In cash-crop systems, with sugar beets in conventional and reduced-tillage management plots in the third year, neither mineralizable nor inorganic N increased as much as in the second year across all management approaches. However, substantial increase in both mineralizable and inorganic N in fourth year suggests that sugarbeet may contribute more N in the subsequent growing season. Our observation is in line with conclusions from Sullivan et al.(1999) that crop residues that are relatively high in N, such as those from alfalfa, cole-crops, sugar beets etc. increases supply of labile-pool N in soils to the next crop in the rotation. In organic cash-crop system, pinto bean was planted on the fourth year, which was incorporated into soils at its early maturity due to severe weed problems. Therefore, this might have contributed significantly increased inorganic N in all plots. In forage production systems, mineralizable and inorganic N increased continuously for four years in conventional and reduced-tillage management approaches but did not increase in organic management (Figure 1 and 2) suggesting relatively less efficient N contribution from organic amendments applied in organic plots compared to other two chemical fertilizer based plots. Organic management slowly releases N throughout the growing season (Franzluebbers et al., 1994).

SUMMARY

Nitrogen is critical for crop production and environmental health. Good crop rotation plan and soil management strategies increase mineralizable and inorganic N in soils providing more N available for crop growth and production. Effects of crop-rotation in this four year study were modified by management practices followed under alternative management approaches. Mineralizable and inorganic N contents were comparable in conventional and reduced-tillage management approaches in all years but organic management had slightly less mineralizable and inorganic N than other two management approaches, indicating relatively slow turnover of N in the organic management system compared to other two management systems.

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