Seasonal Soil Nitrogen Mineralization within an Integrated Crop and Livestock System

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Sustainable crop and livestock production systems depend on maintaining soil productivity and health through utilizing and enhancing natural soil processes. Sustainable systems also protect natural resources while maintaining or maximizing crop yield potential. Since a system's sustainability and productivity involves maintaining the soil organic matter and the processes that promote nutrient cycling, research at the North Dakota State University Dickinson Research Extension Center (DREC) is evaluating seasonal soil nitrogen (N) fertility while minimizing fertilizer inputs in an integrated crop and livestock system. The availability of soil N is the greatest limitation in most crop production systems. An integrated system attempts to sustain N availability through crop rotation, cover crops and utilization of livestock grazing and natural manure spreading by livestock while limiting expensive external inputs as fertilizer. The objective of this study is to evaluate soil N cycling related to individual cropping components in and integrated crop and livestock system.

Materials and Methods

The study site is at the DREC Ranch near Manning, ND on a complex of Savage (fine, smectitic, frigid vertic Argiudolls), Daglum (fine, smectitc, frigid vertic Natrustolls), Vebar (coarse-loamy, mixed, superactive, frigid typic Haplustolls), and Parshall (coarse-loamy, mixed, superactive, frigid pachic Haplustolls) soils.

A diverse 5-year crop rotation is being utilized to provide both cash crops as well as summer grazing for livestock. The rotation includes: i) sunflower (SF); ii) hard red spring wheat (HRSW); iii) fall seeded winter triticale-hairy vetch (THV), spring harvested for hay/spring seeded 7-species cover crop (CC); iv) corn (C) (85-90 day var.); and, v) field pea-barley intercrop (PBY). The HRSW and SF are harvested as cash crops and the PBY, C, and CC are harvested by grazing cattle. The THV is hayed and fed to the livestock. No supplemental fertilizer N is being applied. All cropping treatments are replicated three times in a randomized complete block arrangement with the blocks arranged by soil type. All of the crops are managed as no-till crops. Triplicate plots in nearby undisturbed grassland pastures with similar soils are also being monitored as a control in this study. The vegetative cover in the pasture is dominated by western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love), blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), and Switchgrass (*Panicum virgatum* L.).

During the 2014 growing season, soil N was monitored by collecting multiple soil samples in each treatment plot to a depth of 2 feet (24 inches) as recommended by the NDSU Soil Testing Laboratory and NDSU Extension Service. Samples were collected on a 15 day schedule except where weather (extreme soil wetness) interfered with sampling. Once the crops were established, three 8-inch aluminum rings were randomly driven into the ground to a depth of 2 feet in each plot to provide sampling areas where crop roots are excluded from N uptake. This was to establish an index of the total N mineralized without plant uptake. However, the N in the isolated areas was still subject to natural leaching, volatilization or immobilization processes in the N cycle. The soil samples were analyzed by the NDSU Soil Testing Laboratory for ammonium-N (NH_4-N) and nitrate-N (NO_3-N). A total of 8 sampling times were evaluated. Soil organic matter was also evaluated on the samples from the initial sampling date.

Results and Discussion

The seasonal changes are shown for NO_3-N, NH_4-N, and total mineral N (NH_4-N + NO_3-N) in Figures 1 through 3, respectively.

Figure 1 shows soil NO_3-N availability across the growing season. The grassland began the season with an availability of 22 lbs NO_3-N/A, then declined slightly, but remained relatively constant throughout the growing season. This is to be expected because the grasslands have reached a relative equilibrium between organic matter deposition and decomposition in the absence of soil disturbance. The average cropland NO_3-N levels were 47 lb /Ac at the beginning of the growing season but decreased to levels near the grassland levels by mid-July. This represents a period of rapid crop growth and N uptake. After mid-July, a slight increase occurred till early September and then showed a slight decrease. The slight increase may have been due to heavy rainfall during August stimulating N mineralization during a time of the year that is normally dry. The NO_3-N in the samples collected from the isolated plots spiked to 67 lb/Ac by mid-August and then declined during the rest of the season. Due to the extremely wet weather during August and early September, the decline in the isolated plots may represent leaching and or denitrification during the wet period.

Figure 2 presents a summary of NH_4-N levels in the soil across the growing season. The NH_4-N levels at the beginning of the growing season were 63 and 105 lb N/Ac for the grassland and cropping system plots, respectively. These levels rapidly dropped to less than half of the original levels by the next two sampling dates. A spike occurred at the mid-July sampling but then dropped to relatively low levels for the rest of the season. The July spike may have been due to rainfall events which stimulated microbial activity resulting in an increase in mineralization of organic matter. From July on, the NH_4-N levels in the cropped and grassland were similar and paralleled each other. The NH_4-N in the isolation plots was similar to the non-isolated areas across the remainder of the season.

Figure 4 illustrates the relationship between soil organic matter (SOM) and average seasonal available mineral N. The relationship shows that each % increase in SOM is equivalent to approximately 8 lb N/Ac However, the relationship is relatively weak because due to the location and climate of soils in western North Dakota are highly variable but relatively stable regarding the soil biological environment.

Figure 3. A seasonal summary of total soil mineral N (NH_4 + NO_3-N) availability comparing the cropping systems with grassland pasture. The isolated N average is from areas in the cropping systems that are isolated from crop root uptake.

Summary and Conclusions

The data shown in these figures illustrates the fact that significant amounts of N are available in the soil across the growing season. However, not all of the N is available to plants at a given point in time. Each sampling point is a point in time and the N values for that sampling date would be what the plant has available at the time of sampling. Plant growth stage influences root development and distribution so that plants cannot access soil N where roots are not growing. In addition, new roots do not grow in dry soil so that, again, plants cannot access N in dry soil. Plants also do not access N well in excessively wet soils because of a lack of soil oxygen affects root activity. Wet or dry weather (soil) changes the potential for microbial mineralization, immobilization, or N transformations in soil as well as N movement into or out of the rooting zone as soil moisture conditions change. All of these affect the availability of N to crops. Further research is necessary to better establish how the N availability changes from season to season in response to changing conditions over time.

Figure 1. A seasonal summary of soil NO_3-N availability comparing the cropping systems with grassland pasture. The isolated N average is from areas in the cropping systems that are isolated from crop root uptake

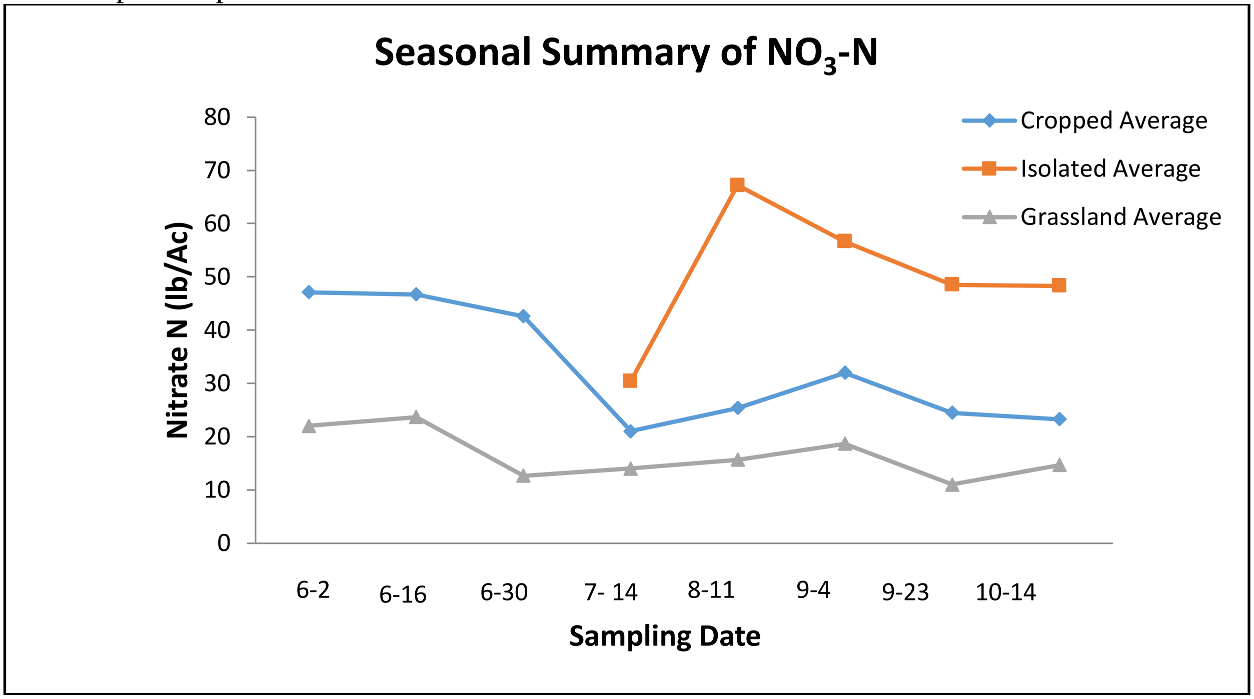

Figure 2. A seasonal summary of soil NH_4-N availability comparing the cropping systems with grassland pasture. The isolated N average is from areas in the cropping systems that are isolated from crop root uptake

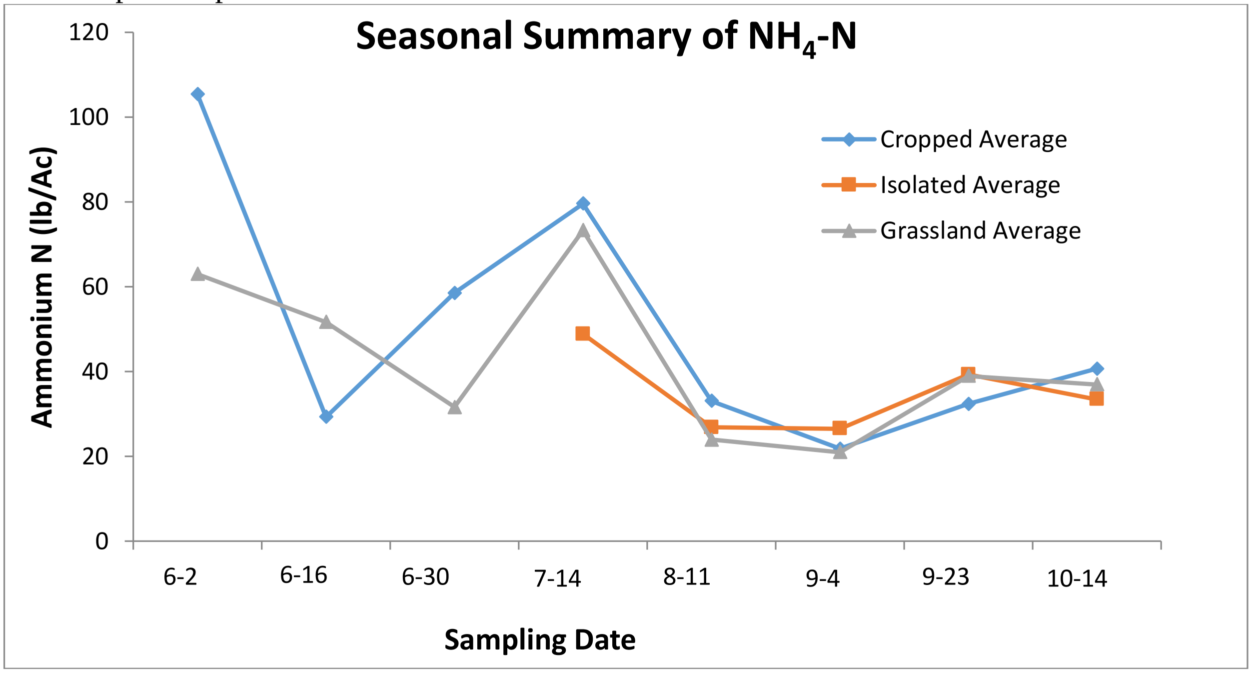

Figure 3. Shows the sum of the total plant available NH_4-N and NO_3-N in the soils across the growing season. The differences between the cropped plots and grassland and cropped plots and isolated plots reflect the combined information from Figures 1 and 2

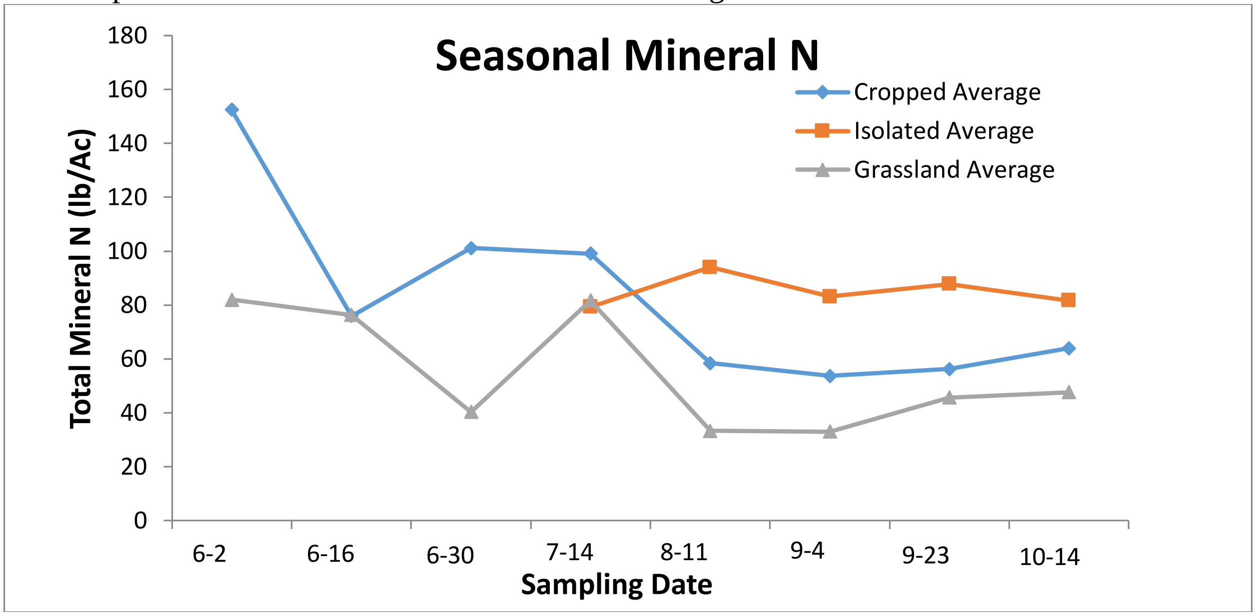

Figure 4. The relationship between soil organic matter and average soil mineral N