NITROGEN AND WATER MANAGEMENT[1]

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Abstract

It is difficult to separate N and water management when developing improved management systems for irrigated corn production. This is because adequate supplies of both N and water are critical for crop growth, but excesses of either or both can threaten ground water quality. Several N and water management systems were established at the Nebraska Management Systems Evaluation Area (MSEA) project to evaluate the impact of improved irrigation and N fertilizer management practices on production and/or the potential for nitrate leaching. The type of irrigation system and related uniformity of water application governed the flexibility available to N management. Management systems that provided for uniform application of irrigation water were also candidates for fertigation. Both surge-flow furrow irrigation and center-pivot sprinkler irrigation conserved water compared to the conventional management system. Chlorophyll meters were used to schedule fertigation. Yield and N uptake data showed that while fertigation is a good N management practice, monitoring crop N status requires a plan that accounts for field variability. Therefore, scheduling fertigation becomes both an economic and environmental decision.

Introduction

Crop management systems require a comprehensive and integrated approach if they are to be environmentally sound and remain profitable. Therefore, all sources of crop N must be considered as well as the various factors and physical forces that move nitrate to ground water. Complications arise because the complexity of factors affecting crop N availability may result in an N supply that is poorly synchronized with crop N needs. For these reasons, it is frequently less risky for producers to consider fertilizer N as the primary source of crop N and only give credit for other N sources when they are a sure thing. Nitrogen made available through mineralization of soil organic matter and crop residues can be a significant source of crop N, but its release is slow and affected by climatic conditions. Since growing corn has so many uncontrollable "risks", producers tend to operate on the safe side whenever possible by controlling inputs that maintain adequate supplies of nutrients and water for crops.

Irrigation systems that provide for a high degree of uniformity in water application offer the same potential for N fertilizer application via fertigation. Fertigation and sidedress N applications allow producers to reduce the potential for spring leaching losses, but still require a procedure to determine how much and when to apply the fertilizer. Tissue testing using chlorophyll

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meters is one approach to evaluate crop N status and to schedule fertigation (Schepers et al., 1992). Producers who adopt the tissue testing/fertigation approach to N management open themselves to routine time commitments for monitoring crop N status because such measurements represent a "point in time" value. These values change with crop N needs and the soils' ability to supply available forms of N. In contrast, a N management strategy based on soil testing information incorporates some aspects of past and future N availability that can not be measured with a real time tissue test. The trade off is that soil tests must be calibrated for each soil and climate to make fertilizer N recommendations.

Conceptually, N management based on "real time" N and water considerations probably has the greatest potential to minimize nitrate leaching. Economically, cropping systems based on sidedress N application, fertigation, or variable rate N application technologies may not be superior to existing cropping systems until producers learn to reallocate their time and resources to take advantage of new and integrated technologies.

Methods and Materials

This research was conducted at the Management Systems Evaluation Area (MSEA) project site that is located in the second terrace of the Platte River Valley near Shelton, Nebraska. The alluvial soils in the area form a nearly level landscape that has been graded to facilitate furrow irrigation. The Hall (fine-silty, mixed, mesic pachic argiustoll) and Hord (fine-silty, mixed, mesic cumulic haplustoll) surface soils overlay sand and gravel at 4 to 6'. Ground water used for irrigation is pumped from a shallow aquifer with a water table at 16 to 23'. Nitrate-N concentration in ground water used for irrigation ranges for 30 to 32 ppm. Precipitation in the area averages 24" annually, with about one-third of it coming between April 1 and June 15 .

Two types of studies were initiated in 1991 to address different aspects of N and water management. In one case, three N fertilizer/water management scenarios for monoculture corn were established on individual 33 acre fields. These large fields were used so that changes in ground water quality could be monitored over time. The second approach involved a corn/soybean rotation where small plots were used to evaluate the dynamics of the N cycle as influenced by fertilizer rate and crop residues.

Monoculture Corn: Three square 33 acre irrigated corn fields with individual irrigation wells were established in 1990. These adjacent fields had been under corn or soybean production for over two decades. Each of the fields received a preplant application of 150 lb N/a as anhydrous ammonia in 1990 and were planted to corn that received 30 lb N/a as a starter fertilizer at planting. Flow meters were installed on the wells and fields were furrow irrigated according to traditional producer practices. Average grain yields were similar for all three fields and averaged 196 bu/a. Irrigation application ranged from 36 to 48" in 1990.

In the fall of 1990 and spring of 1991 two of the fields were modified to accommodate different types of irrigation systems to represent a modestly priced improved furrow irrigation system that offered some opportunities for improved N management (*surge-flow furrow irrigation with sidedress N or* *fertigation)* and a more costly sprinkler irrigation system that offered maximum flexibility in terms of N management *(center-pivot sprinkler irrigation with fertigation)*, which were compared to a traditional approach to irrigation for the area *(conventional furrow irrigation)*. Prior to planting, soils from each field were sampled to a depth of 4' for residual soil N. Fertilizer N rates for a 200 bu/a expected yield were based on University of Nebraska recommendations after adjusting for residual N and nitrate in irrigation water assuming 9.5" application at 32 ppm nitrate-N.

Three adequately fertilized test strips (six rows wide receiving 150 lb/a as sidedress N) were established in each field for comparison purposes to evaluate crop N status in the surge-flow and sprinkler irrigated fields. Chlorophyll meters (SPAD 502 manufactured by Minolta Corp.) were used to routinely monitor crop N status (Dwyer et al., 1991; Piekielek et al., 1992; Peterson et al., 1993; Schepers et al., 1992). Fertigation was triggered when the average chlorophyll meter reading for the bulk field was less than 95% of the average value from the adequately fertilized reference strips. Sufficiency index values below 95% at the VT growth stage according to Hanway (1971) have been shown to reduce corn yields while values above ~95% had similar yields but grain protein content increased with the sufficiency index.

Corn/Soybean Rotation: This study was initiated in 1991 under a linear-drive irrigation system to accommodate comparisons between monoculture corn, a corn/soybean rotation (each grown each year), and monoculture soybean. Corn stalks from the previous growing season were shredded and the entire area was disked twice before planting. Four corn hybrids differing in yield potential, maturity, and stay green characteristics were selected for use in both the monoculture and rotation systems in combination with five N fertilizer rates. All hybrids were planted on 15 May 1991 and 25 April 1992 in 8-row plots using a 36" row spacing at approximately 30,000 seeds/a. Soybean in the soybean/corn rotation was planted at the same time as the corn in 1991 and on 15 May 1992. In early June, N fertilizer treatments as NH_4NO_3 were broadcast on the soil surface and immediately incorporated with ~0.25" irrigation. In-season N status was monitored on a weekly basis using chlorophyll meters starting at the V9 stage and continuing through R2. Chlorophyll meter readings were taken from the uppermost mature leaf until the VT growth stage . After that stage the ear leaf was measured. All measurements were taken on 30 plants within each plot. Final grain yield was determined at physiological maturity.

Results

The conventional furrow irrigation system for monoculture corn at the Nebraska MSEA site offers no opportunity to correct a N deficiency and therefore a relatively large amount of preplant N fertilizer was applied to the land (Table 1). This management system requires the producer to be highly proactive and make a number of assumptions such as how much and when irrigation will be required, how much N credit should be given for nitrate in the irrigation water, will mineralization follow normal patterns, and to what extent will leaching and denitrification reduce crop N availability. The integrated response to these questions addresses the concern about synchrony between soil N availability and crop needs. Uncertainties associated with these assumptions are usually translated into higher preplant fertilizer N application rates.

Table 1. Nitrogen and water management characteristics and yield at the Nebraska MSEA site.

Irrigation system	Residual soil N*	N fertilizer**	Water applied	Water N	Grain yield
	(lb/a)	(lb/a)	(in)	(lb/a)	(bu/a)
1991					
Conventional	95	150 (PP)	37	179	199
Surge-Flow	154	80 (SD)	18	110	196
Center-Pivot	85	0 (FG)	13	30	194
1992					
Conventional	108	140 (PP)	29	170	207
Surge-Flow	121	0 (FG)	9	65	200
Center-Pivot	70	0 (FG)	8	42	175

* Residual N to a depth of 3'. Credit for NO_3-N in irrigation water of 69 lb N/a.

** Starter fertilizer N of 30 and 19 lb/a in 1991 and 1992, respectively.
PP = preplant, SD = sidedress, FG = fertigate

Corn yields for the conventional furrow irrigation system where excellent in 1991 and 1992. Limited yellowing of lower leaves with the approach of senescence suggests an adequate to excessive supply of N throughout the growing season. The relatively large application of irrigation water and associated nitrate significantly contributed to crop N availability during grain fill. This apparent over irrigation is attributed to the furrow irrigation system that provided adequate water to all parts of the field, but resulted in excessive applications to some areas because a dike at the lower end ensured no water was allowed to leave the field.

The surge-flow furrow irrigated system provided moderate flexibility to the producer in terms of N management options because sidedress N application was used in 1991 and fertigation in 1992. In both cases, the opportunity for early season nitrate leaching was minimized. The sidedress option requires the N application amount be determined by mid June, which is about two months later than the preplant application for the conventional management system. Sidedress N applications allow producers to evaluate early season mineralization, compensate for spring leaching and denitrification, and assess crop appearance before deciding how much fertilizer N to apply. The fertigation option used in 1992 was not available in 1991. While fertigation allows producers to delay the decision to apply N fertilizer until it is needed by the crop, it can also increase the risk of encountering a N deficiency if excessive precipitation limits the opportunity for furrow irrigation. This situation could necessitate fertigation of an adequately moist soil, which would promote nitrate leaching.

The center-pivot sprinkler-irrigated system produced a nearly comparable average yield to the conventional management system in 1991 with considerably lower fertilizer N and water inputs. Difficulties with the irrigation system delayed the first sprinkler application, which probably caused the slight yield differences.

An important component of any effective N management system is synchronizing N availability with crop N needs. Achieving reasonable synchrony requires a technique to evaluate N status of the growing crop so that a N deficiency can be detected early enough to allow addition of fertilizer N to correct the apparent problem. The chlorophyll meter used to monitor crop N status indicated no apparent N deficiency for the surge-flow or center-pivot irrigated field in 1991. Aerial photographs taken at silking failed to identify the three adequately fertilized reference strips in either field that received additional N fertilizer. The slightly lower average yield from the surge-flow irrigated field compared to the conventional field is attributed to a small portion of the field where topsoil was removed during the laser-grading operation. The same N deficient area was identified in a 1992 aerial photograph at silking, but the adequately fertilized test strips were still difficult to identify. Earlier in the 1992 growing season chlorophyll meters indicated an approaching N deficiency, which triggered the fertigation treatment.

Chlorophyll meter readings collected weekly from the sprinkler-irrigated field during the 1992 growing season showed mixed signs of a N deficiency for the three sets of reference strips. Fertigation was only applied once to this field in 1992. Aerial photographs taken at silking were not available for examination until after harvest, but for the first time revealed considerable spatial variability in terms of crop N status for this field. The photograph also revealed an old test strip established in 1991 that was adjacent to one of the 1992 test strips. The intent was to use the same area for the test strips year after year. Comparison of chlorophyll meter readings between the 1991 and 1992 test strips resulted in faulty information that in turn failed to trigger the need for fertigation. Significant yield reductions for the sprinkler-irrigated system in 1992 illustrate the implied risk to profitability of corn production associated with a N deficiency.

Application of additional N fertilizer to a few reference strips through the field has been shown to be a reasonable way to calibrate chlorophyll meters over time (Schepers et al, 1992; Peterson et al, 1993). However, these data illustrate the importance of selecting representative areas of the field when making relative comparisons to evaluate crop N status. The combined use of chlorophyll meters and aerial photographs seems to provide adequate information for making intelligent decisions regarding the need for fertigation.

The inability of a cropping system to respond to fluctuations in N availability caused by the dynamics of the N cycle usually forces producers to adapt longer term N management strategies. Climatic factors that affect N losses typically have a similar effect on cropping systems. Long term N management strategies tend to be more "proactive" out of necessity because opportunities to be "reactive" are frequently limited. The reactive features of N management within a cropping system are likely to be the most obvious under situations where climatic conditions or management practices lead to extreme situations. This is because atypical climatic conditions can result in everything from above normal mineralization rates to excessive soil water that can lead to large N losses by denitrification and leaching.

Crop rotations involving legumes frequently show signs of enhanced nutrient availability, hence the recognition and assignment of legume credits when making N fertilizer recommendations. The term "legume N credits" may actually be a misnomer in that comparison is usually made to monocrop systems that involve different kinds and amounts of residue. Therefore, mineralization rates are likely to be different for rotation and monocrop production systems. Soils containing legume residues tend to become "net mineralizers" before those with corn, sorghum, or wheat residues. These differences affect synchronization of N availability with crop N needs and therefore affect the way producers manage their N fertilizers.

Results from the crop rotation study will feature the 1992 data because 1991 was the first year of the study that contained both crops. Each hybrid used in the crop rotation study responded similarly to applied N as indicated by chlorophyll meter readings and grain yield (Table 2), but average values for both parameters were consistently greater for the rotation system than for continuous corn. Higher chlorophyll meter readings at silking demonstrate the enhanced N status of corn following soybean compared to continuous corn (Figure 1). The highest rate of N fertilizer (143 lb N/a applied shortly after planting) under continuous corn showed comparable N status to much lower N rates under the rotation system. These differences were evident throughout the growing season and only began to converge near senescence.

Table 2. Influence of N fertilizer on average in-season chlorophyll meter readings and grain yield of four irrigated corn hybrids in monoculture and soybean/corn cropping systems at Shelton, Nebraska in 1992*.

N rate	Chlorophyll meter readings						Grain yield	
	July 2		July 16		July 30			
	CC	SB/C	CC	SB/C	CC	SB/C	CC	SB/C
lb/a							-- bu/a --	
0	42.3	49.6	46.4	51.9	48.4	53.1	107	143
36	46.7	51.2	50.5	53.9	53.1	56.6	126	153
71	49.7	53.1	52.7	54.9	56.7	58.7	139	161
107	50.7	52.8	54.1	55.7	58.7	59.3	142	159
143	51.5	53.6	54.2	55.5	59.3	59.5	146	158

* CC=Continuous corn, SB/C=Soybean/Corn

A time sequence of chlorophyll meter readings for the check plot and the 107 lb/a N rate illustrates the dynamics of N availability for cropping systems involving legume rotations (Figure 2). Residue from the previous soybean crop probably mineralized sooner than corn residue and apparently was better synchronized with N need of the subsequent corn crop. These findings could also be related to improved soil tilth following the soybean crop, which could promote more extensive rooting, fewer plant pathogens, and more vigorous plant growth.

The net positive effect of the previous soybean crop on chlorophyll meter readings existed throughout the growing season for the check plots. Early season benefits of the previous soybean crop were detected with the chlorophyll meter even at the 107 lb N/a fertilizer rate. By mid season the benefit of the previous soybean crop had disappeared in the presence of adequate N fertilizer, however, grain yield at the 107 lb/a N rate was greater for the corn/soybean rotation. These data illustrate the importance of adequate early season N nutrition on corn yields.

Conclusions

Cropping systems that allow producers to make N management decisions and apply N fertilizer during the growing season reduce the number of assumptions that go into cropping strategies that are limited to preplant fertilizer applications. Interactive decision making opportunities that integrate nutrient availability, crop growth, and climatic conditions allow producers to sustain profitability and minimize the risk of environmental contamination by nitrate.

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Figure 1. Effect of N rate on chlorophyll meter readings for an irrigated soybean/corn rotation and monoculture corn at silking.

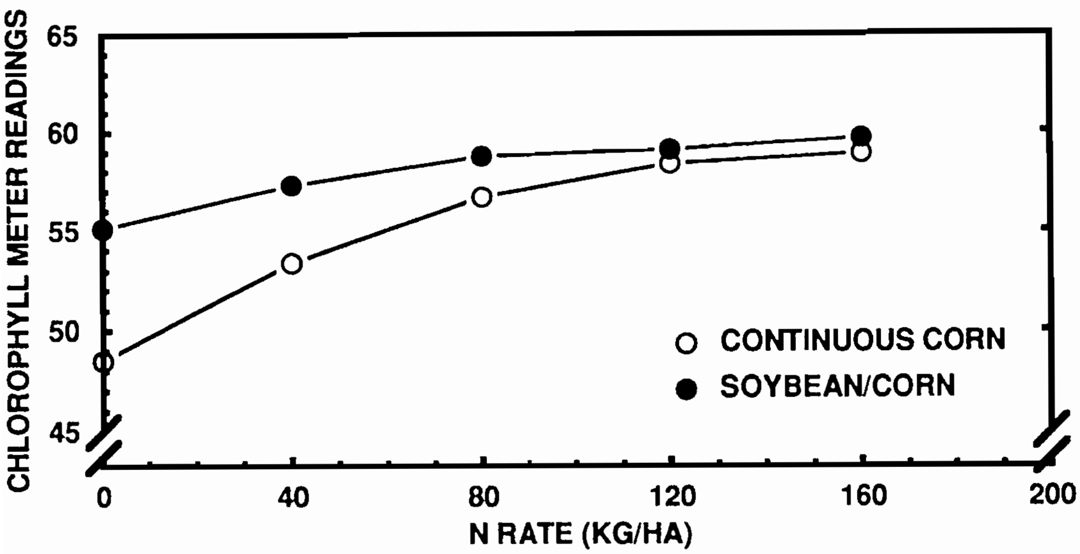
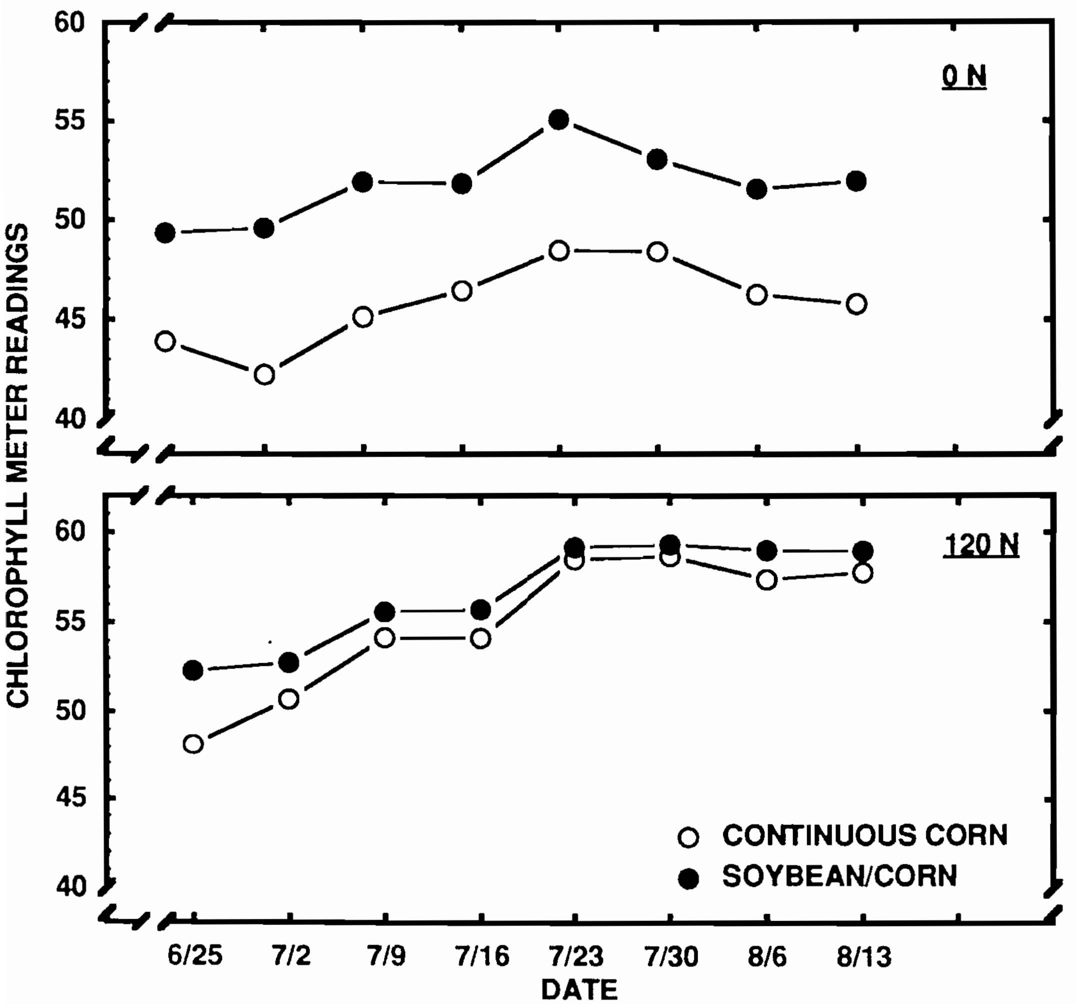


Figure 2. Changes in chlorophyll meter readings during the growing season for an irrigated corn/soybean rotation and monoculture corn at two fertilizer N rates.



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