ON-FARM ASSESSMENT OF NITROGEN USE AND MANAGEMENT IN IRRIGATED CORN PRODUCTION IN NEBRASKA

Dr. Patricio Grassini
University of Nebraska, Lincoln, Nebraska

High-yield irrigated crops have large nitrogen (N) requirements. For example, N uptake of a corn crop that yields 207 bu ac^{-1} (~13 t/ha) is about 180 lb N ac^{-1} (200 kg N ha^{-1}). The amount of N that is not provided by indigenous sources (mineralization of previous crop residue and soil organic matter) needs to be supplied by crop producers through N fertilizer. High-yield irrigated corn accounts for 74% of total annual corn production of 1260 million bushels in Nebraska. With approximately 70,000 center pivots and more than 100,000 active irrigation wells, irrigation provides stability in terms of corn yield, especially in years with below-average precipitation. At the same time, water quality concerns arise from the relatively large amounts of N fertilizer applied to irrigated corn. However, neither the N fertilizer use nor the efficiency by which it is used to produce grain has been well documented. In the present study, we used a database collected by the Nebraska Natural Resources Districts (NRDs) to assess on-farm N fertilizer use and efficiency in irrigated corn production in Nebraska.

The NRD database contains data on field coordinates, grain yield, applied N fertilizer, applied irrigation, [$N\text{-}NO_3^-$] in irrigation water, and residual soil N collected from irrigated corn fields. For the present study, we defined six areas of study that portray well the variability in weather, soil, and management across the irrigated production area in Nebraska (Fig. 1). Data from six crop seasons (2006-2011) were used to determine average N fertilizer rates and partial factor productivity for N (PFP_N, bu lb^{-1} N fertilizer). Because non-fertilizer N in irrigation water represents an important N input in irrigated systems, PFP_N was also calculated as the ratio between grain yield and N inputs, the latter calculated as the sum of N fertilizer and N in irrigation water.

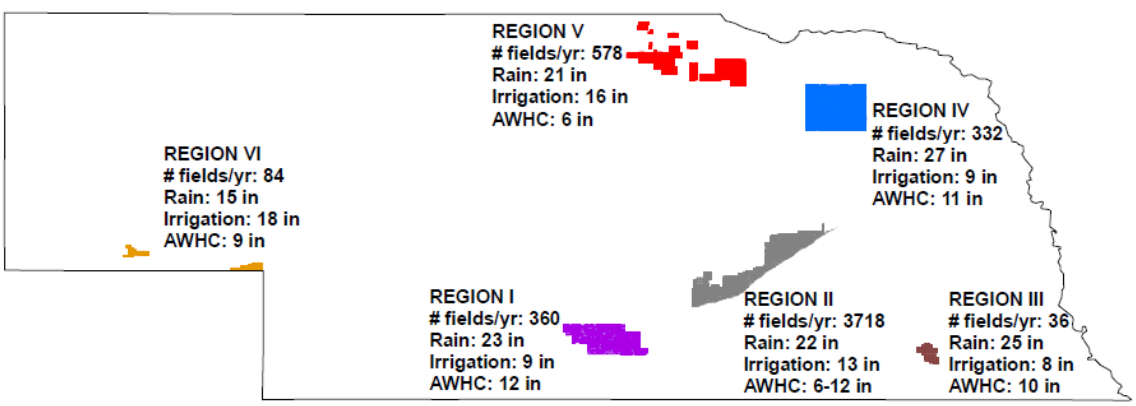

Fig. 1. *Map showing the six study areas in Nebraska. Average (2006-2011) number of reporting fields per years (# fields/yr), annual precipitation (inches), applied irrigation (inches), and soil available water holding capacity (AWHC, inches) are shown.*

Average N fertilizer rate ranges from 149 to 184 lb N ac^{-1} across regions (Fig. 2). In five of the six regions, average N fertilizer rate was higher than the average N fertilizer rate for US corn of

135 lb N ac^{-1}. However, average irrigated corn yields were much higher than US average corn yield of 150 bu ac^{-1}, ranging from 165 to 207 bu ac^{-1} across regions (Fig. 2). Highest and lowest average irrigated yields were observed in south-east (Region I) and west (Region V) regions of Nebraska. Irrigated yields were very stable across years, with coefficient of variations ≤7% in all regions. Trends in irrigated corn yield and N fertilizer from 2006 to 2011 indicate (i) no detectable increase in average irrigated corn yield in the six regions, and (ii) slightly increase in N fertilizer rate in 3 of the 6 regions, perhaps associated with a parallel increase in the grain-to-oil price ratio during the same time interval. Total N input (N fertilizer plus N in irrigation water) averaged 210 lb N ac^{-1}. On average, 82% of total N input was accounted by N fertilizer and the other 18% by irrigation water N. Geospatial variation in N inputs was associated to differences in yield potential, soil N-supply capacity, or both, ranging from 185 lb N ac^{-1} in the low-yield western region (Region VI) to 259 lb N ac^{-1} in the sandy north-central region (Region V).

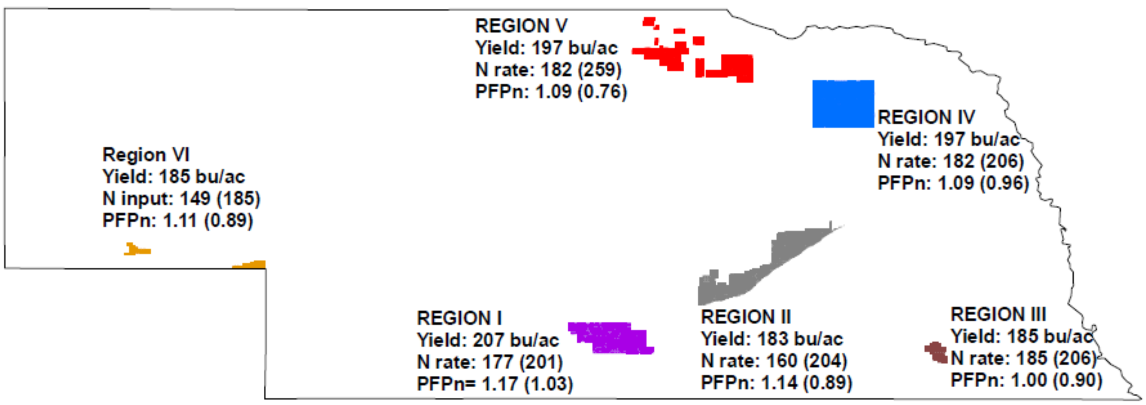

Fig. 2. *Map showing average (2006-2011) yield (bu ac^{-1}), N fertilizer rate (lb N ac^{-1}), and partial factor productivity for N (PFP$_N$, bu lb^{-1} N fertilizer). N input (N fertilizer plus N irrigation water) and PFP$_N$ calculated based on total N input are shown in parenthesis.*

PFP$_N$ calculated based on N fertilizer was high (average: 1.10 bu lb^{-1} N fertilizer), ranging from 1.17 bu lb^{-1} N fertilizer in the high-yield, fertile south-central region (Region I) to 1.00 bu lb^{-1} N fertilizer in the southeastern region (Region III) (Fig. 2). Despite fertilizer N rate is 27% higher in Nebraska compared with US average N rate for corn (172 vs. 135 lb N ac^{-1}), PFP$_N$ of irrigated corn in Nebraska achieves is high and similar, if not higher in some cases, to the average PFP$_N$ for U.S. corn (~1.11 bu lb^{-1} N fertilizer) while producing much higher yields (189 vs. 150 bu ac^{-1} for Nebraska and USA, respectively). However, comparison of PFP$_N$ between Nebraska and other states is biased because of (i) differences in manure application, which is less common in Nebraska compared with other major corn producing states like Iowa (for example, state average applied N manure is 7 lb N ac^{-1} in Nebraska vs. 38 lb N ac^{-1} in Iowa) and (ii) non-fertilizer N input through irrigation water in irrigated corn In Nebraska, with a (2006-2011) average of 38 lb N ac^{-1} across the six regions shown in Fig. 2. When PFP$_N$ is expressed based on N inputs (N fertilizer plus N in irrigation water), the values are still high (average: 0.91 bu lb^{-1} N input), ranging from 1.03 bu lb^{-1} N input in the high-yield, fertile south-central region (Region I) to 0.73 bu lb^{-1} N input in the sandy northeastern region (Region V) (Fig. 2).

Without data from non-fertilized fields (or omission plots) it is not possible to determine the efficiency by which N fertilizer is being used to produce grain because differences in soil N-supply capacity among regions can easily bias the analysis. However, data on residual soil N and comparison of actual vs. recommended N rates can serve as proxies to diagnose current N management. For example, the region with highest PFP_N calculated based on N inputs (Region I) also exhibited the lowest soil residual N (6-y average of 3.6 ppm N-NO_3^- in the upper 3 feet) while the actual N rate was similar (if not lower in many cases) than the recommended N rate estimated using the N-fertilizer rate calculator developed by the University of Nebraska-Lincoln, which accounts for yield goal and contribution of N from indigenous sources such as residual soil N, N in irrigation water, and N credits from previous crop, manure, and soil organic matter. In contrast, the region with lowest PFP_N (Region V) exhibited relatively high residual soil N (6-y average of 8.4 ppm N-NO_3^- in the upper 3 feet) and actual N fertilizer rates were consistently higher than those estimated with the University of Nebraska N-calculator. Hence, although PFP_N is relatively high in all regions, it seems that there is room to improve N-use efficiency in some regions by improving the congruency between crop N demand and N supply.

Besides better balance between N input and N supply, synchronization of N fertilizer application to match crop N demand provided another opportunity to increase PFP_N at the same N level or maintain the same yield level using less N fertilizer. To test this hypothesis, we analyzed data from a relatively small area within the Lewis and Clark NRD in north-eastern Nebraska, located north from Region IV (Fig. 1). The unique feature about N management in this area is that crop producers have to follow the following regulations implemented by the local NRD: (i) producers must attend district education programs on best management practices to minimize pollution, (ii) deep soil N is tested annually and used by producers to determine N fertilizer rates, (iii) no fall or winter N fertilizer applications are allowed, and (iv) spring N applications greater than 100 lb ac^{-1} are encouraged through split applications. All these programs are cost-share, that is, they fully or partially covered by the local NRD. As a result of these regulations and incentives, the spring N application was split into pre- and post-planting applications in 77% of the irrigated corn fields and, on average, >62% of total N dose was applied post-planting in 3+ splits. Also, N inhibitor products were used in ~50% of fields and average actual N rate matched closely the recommended N rate (170 vs. 164 lb N ac^{-1}). The improved N management in this district was reflected on the highest PFP_N observed across NRDs (1.33 bu lb^{-1} N fertilizer and 1.10 bu lb^{-1} N input), while achieving an average yield of 199 bu ac^{-1}, which was 5% higher than the yield average across the other six regions, despite using 15% less N fertilizer (150 lb N ac^{-1})

Overall, this study indicates that irrigated corn in Nebraska achieves very high and stable yields with high efficiency in the use of N fertilizer. PFP_N of irrigated corn in Nebraska is comparable (and similar in some cases) to the average PFP_N for US corn, despite using larger N fertilizer rates, while producing much higher yields. There is, however, room for improvement, especially by better congruency between N supply and crop N supply and a better temporal synchronization between N supply and demand which can help achieve higher yields with the same level of N fertilizer, same yield level with less fertilizer, or both. On-farm databases provide an excellent opportunity to diagnose N management and efficiency in cropping systems and prioritize research on areas that deserve further investigation in controlled experimental trials. In turn, the usefulness of on-farm databases can be substantially improved by inclusion of few variables that are required for a better understanding of on-farm nitrogen-use efficiency including yield in omission plots where no fertilizer is applied, timing of N application, and type of N fertilizer.

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PROGRAM CHAIR:

Carrie Laboski
University of Wisconsin
1525 Observatory Dr.
Madison, WI 53706-1207
(608) 263-2795
laboski@wisc.edu

PUBLISHED BY:

International Plant Nutrition Institute
2301 Research Park Way, Suite 126
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