RESIDUAL EFFECTS OF NITROGEN FERTILIZATION ON SOIL NITROGEN POOLS AND CORN GROWTH

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ABSTRACT

Nitrogen (N) fertilization of corn (*Zea mays* L.) may increase, decrease, or not affect the N supplying capacity of the soil. Six field-scale corn N rate trials were established in corn-soybean rotations in diverse soil types across Indiana. Six N rates ranging from about 25 to 270 lb N ac^{-1} were replicated 4 to 6 times at each site and re-applied to the same plots for each of four corn crops. In the fifth corn season, 2015, half of the replications at each location were supplied starter fertilizer only, thus allowing for the determination of residual N from previous N rate treatments. Soil samples were obtained from all starter-only plots at depths of 0-8, 8-16, and 16-24 inches shortly after corn planting. Initial samples (day zero) were analyzed for inorganic N (NH_4-N and NO_3-N) and total N. A 50-day aerobic incubation with soils maintained at 77°F and 0.33 bar moisture tension was used to examine mineralization at days 0, 10, and 50. Results showed unremarkable N rate effects on soil inorganic N, total N, and day 50 total inorganic N from the incubation study. Overall, we concluded that variation in corn N rate as much as 1,000 lb N ac^{-1} over 4 corn growing seasons had negligible effects on soil N concentration and supplying capacity for Indiana corn-soybean rotations.

INTRODUCTION

The application of N to corn is essential to produce economically viable yields, yet detrimental to the environment and producer profit if applied in excess. Nitrogen that is not removed from the field by the harvested corn grain can be incorporated into soil organic matter, lost to ground and surface waters and/or to the atmosphere, or accumulated by the next crop.

Nitrogen fertilization of corn may result in an accumulation or depletion of soil N. Jaynes et al. (2001) suggested soil N and soil organic matter are depleted in corn-soybean rotations when corn is fertilized at the economic optimum N rate. Increasing our understanding of soil N under the primary cropping system of the Midwest will inform producers if they should adjust fertilizer rates for effects on soil organic matter and/or the soil N supplying capacity. The objective of our study was to determine if soil N supply was diminished by N rates below the economic optimum and enriched by N rates above the optimum.

MATERIALS AND METHODS

Since 2007 in alternating years of corn-soybean rotations, large-plot N rate trials were conducted at six Indiana sites diverse in soil type. Nitrogen rates (predominantly applied as urea ammonium nitrate) ranged from starter fertilizer only (about 25 lb N ac^{-1}) to total N rates at or above 225 lb N ac^{-1} (which usually exceeded the economic optimum rate). In each corn cropping year, the same N rate treatments were applied to the same plots. In 2015, half of the replications at each location received only starter fertilizer, allowing evaluation of potential differences in residual N from the previous 4 corn years' N rates and intervening soybean crops. Soil N supply was determined by collecting soil samples post-planting (1-9 days) from each plot at 0-8, 8-16, and 16-24" deep to determine initial levels of total N, nitrate-N (NO_3-N), and ammonium-N (NH_4-N). All soil and plant analyses were conducted on 2015 starter-only replications.

Total N analysis was completed via combustion (Sparks, 1996) using a FlashEA Elemental Analyzer (CE Elantech, Lakewood, NJ). Each soil sample was aerobically incubated for 50-days at optimum conditions for mineralization (77°F and 0.33 bar) to determine N mineralization. Four subsamples of each soil were incubated so that duplicates could be destructively sampled at 0, 10 and 50 days. Soil samples were extracted using a 1:10 ratio of soil to 1 M KCl to determine NO_3-N and NH_4-N. Extracts were colorimetrically analyzed for NO_3-N and NH_4-N with a Discrete AQ2 Analyzer (SEAL Analytical, Wisconsin).

In the field at physiological maturity and prior to combine harvest, six consecutive whole plant samples were collected at two or three representative locations within a plot then dried at 140°F for 5 days. Corn ears were husked, shelled, and separated from stover. Stover was coarsely ground using a wood chipper, subsampled, then finely ground to pass an 18 mesh sieve (0.04"). Dried corn ears were shelled, then ground with a food processor. Stover and grain samples were sent to A&L Great Lakes Laboratories, Inc. for determination of total N (AOAC 990.03). Finally, N content of the above-ground plant (stover plus grain) and whole plot grain yield from the combine was used to estimate crop N removal.

All statistical analysis were performed with SAS 9.3 at $\alpha \leq 0.05$ (SAS Institute Inc., Cary, NC). Locations were analyzed individually. Day zero inorganic N and total N data were analyzed as a split-block design using a two-way ANOVA in PROC MIXED. Incubation study variables — NH_4-N, NO_3-N, and total inorganic N — required log transformation. Log transformed variables were analyzed using three-way ANOVA with PROC GLM, then back transformed for presentation. A single factor ANOVA was completed using PROC GLM on N uptake. Only data from the Pinney Purdue Agricultural Center (PPAC) located in Wanatah, Indiana will be discussed here as results from the other five sites were similar. The soil type at PPAC was a Sebewa loam (fine-loamy over sandy or sandy-skeletal, mixed, superactive, mesic Typic Argiaquoll).

RESULTS AND DISCUSSION

Large differences in N balance from the four previous corn years occurred (Fig. 1). At the starter-only N rate grain removed about 104 lb N ac^{-1} more N than applied, but at the highest N rate 514 lb N ac^{-1} more N was applied than removed (Fig. 1). Despite a difference of 410 lb N ac^{-1} in residual N after four corn seasons, there were no differences in the fifth corn season in initial soil total N (Fig. 2) nor total inorganic-N (data not shown). When soil from the beginning of the 2015 season was incubated for 50 days, no differences in total inorganic-N were found relative to cumulative N rate (Fig. 3) either.

Contrary to our results, a study by Carpenter-Boggs et al. (2000) found a decrease in net mineralization from low to high N treatments in a 189-day incubation. They suggest that immobilization or decreased gross mineralization could occur at high N rates; furthermore, such actions could be the result of non-corn year soil processes where residual N from high N treatments decreases symbiotic fixation in a legume crop. According to Ros et al. (2011), 78% of mineralization is explained by the size of the SOM pool while 8% is explained by a combination of other soil properties. The SOM factor is complex; more does not necessarily mean better since the quality (C:N ratio) and availability (labile or recalcitrant) affect overall mineralization potential. In general, many studies agree that the size of the organic matter pool is the primary driver of mineralization, but the effect of N rate on the organic pool size has yet to be explained.

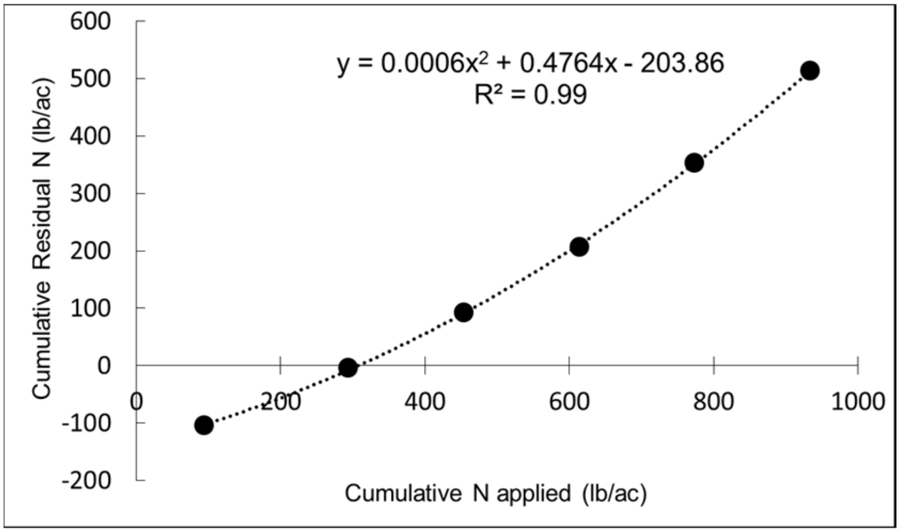

Figure 1. Cumulative residual nitrogen (N fertilizer added – N removed in grain) relative to cumulative N applied to corn in a corn-soybean rotation 2007, 2009, 2011, and 2013 corn years at PPAC. "Cumulative N applied" refers to the sum total of applied fertilizer N for a given N rate treatment over the four preceding corn seasons in a corn-soybean rotation.

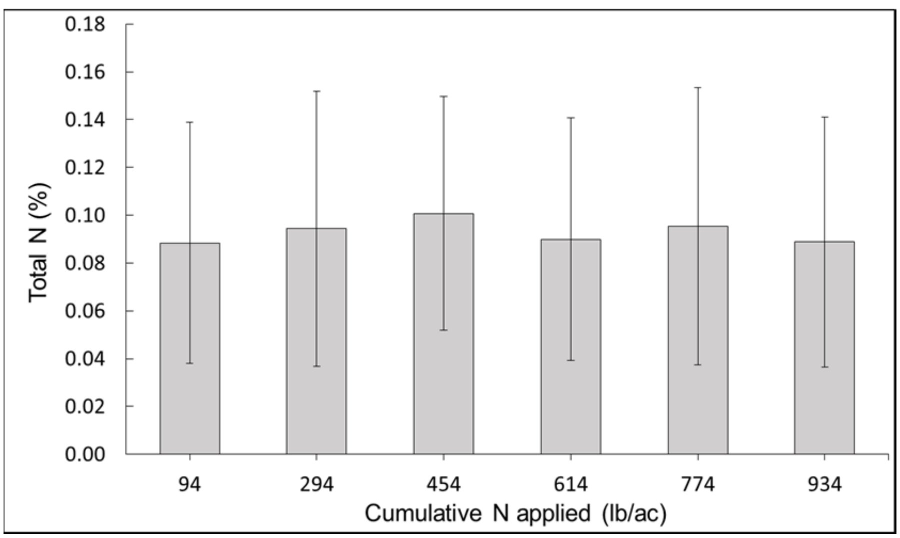

Figure 2. Total soil N (organic plus inorganic-N) at planting in 2015 averaged over depth increments of 0-8, 8-16, and 16-24 inches for each cumulative N rate at PPAC. "Cumulative N applied" refers to the sum total of applied fertilizer N for a given N rate treatment over the four preceding corn seasons in a corn-soybean rotation.

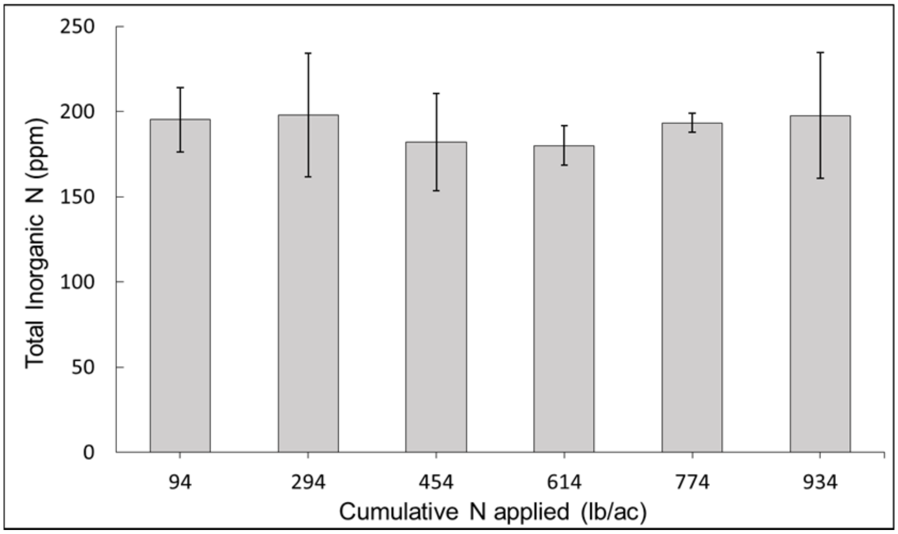

Figure 3. Total inorganic-N (nitrate-N + ammonium-N) concentration in soil after 50 days of incubation at 77°F and 0.33 bar moisture tension summed across depths of 0-8, 8-16, and 16-24 inches for each cumulative N rate at PPAC. Soils were collected shortly after planting corn in 2015. "Cumulative N applied" refers to the sum total of applied fertilizer N for a given N rate treatment over the four preceding corn seasons in a corn-soybean rotation.

At physiological maturity of the fifth corn year there was no effect of the previous four years of different N rates on plant N content (Fig. 4). Timmons and Cruse (1991) conducted a study in Ames, IA to measure residual ^{15}N recovery in continuous corn. Recovery was measured for three years after initial application of 200 lb ac^{-1} labeled (^{15}N) urea-ammonium nitrate; in these three years, corn was fertilized with non-labeled 200 lb N ac^{-1}. Total residual N recovered by the plant during the three years post ^{15}N application was only 2.3, 1.2, and 0.9%, respectively — this is <1% of the cumulative 600 lb N ac^{-1} applied in the three years post ^{15}N application and was not likely significant to crop growth.

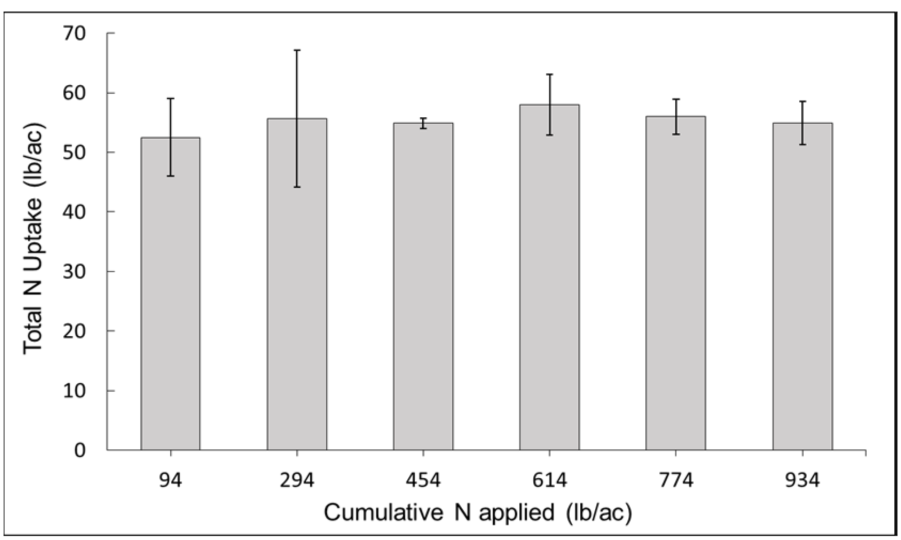

Figure 4. Plant N uptake at maturity in 2015 with starter only N (~25 kg N ha^{-1}) across cumulative N rates at PPAC. "Cumulative N applied" refers to the sum total of applied fertilizer N for a given N rate treatment over the four preceding corn seasons in a corn-soybean rotation.

SUMMARY

Results occurring at the PPAC location (discussed above) were similar to those found at five other locations across Indiana that differed in soil type and climatic conditions. Even though the amount of residual fertilizer N differed substantially due to a range in cumulative N rates over four corn seasons ranging from ~100 to ~1,000 lb N ac^{-1} in a corn-soybean rotation, there were no differences at the beginning of the 5^{th} corn season in soil total N, NO_3-N, or NH_4-N due to cumulative N rate. When soil collected shortly after planting the 5^{th} corn crop was incubated in the laboratory under ideal conditions there were no differences in N mineralization with respect to cumulative N rate. When corn was grown in the 5^{th} corn season with starter-only and the predominant form of N available to the crop was derived from the soil, there were no differences in plant N content relative to cumulative N rate applied in the previous four corn seasons. Nitrogen rates above and below the optimum N rate needed to maximize corn yield in a corn-soybean rotation resulted in no differences in soil N or N supplying capacity in the 5^{th} corn season.

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