Evaluation of *in situ* Soil N Mineralization Rate to Improve N Input Timing and Use for Corn

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Introduction: The purpose of this trial was to evaluate the dynamics of N mineralization under field conditions, and how this affects N uptake by corn fertilized with urea and manure at different N rates. This trial began in 2012, and was sponsored by the North Dakota Corn Utilization Council in 2013, and will be continued for a third year in 2014. **Objectives:** (i) To estimate N mineralization rate during corn growth in plots applied with urea and fresh and composted cattle manure, and (ii) To evaluate the relationship between rate of N mineralization and N uptake and yield.

Materials and Methods: In 2012 corn was seeded in conventionally-tilled plots arranged in a randomized complete block design with four replicates except for the check treatment, which was replicated three times within each block, for a total number of 12 plots per block. The N treatments consisted of urea (0, 90, 150, 180, and 240 lbs N), cattle manure (90, 150, 180 lbs N), and composted manure (90, 180 lbs N). The manure treatments were a one-time application for the first year only, and therefore received no added N in 2013. The above-target N levels for urea-treated plots were reached by adding to the respective residual soil test levels (Table 1). Two of the three check plots (treatments 11 and 12) received flat 180 lbs N as urea with and without corn residue removal, respectively, to verify if residue removal would affect grain yield. Corn was seeded very late on the same footprints of 2012 (but no-till), on June 11 following poor emergence after planting in May. Data collected included aboveground biomass N (4-, 12-leaf, maturity), soil N mineralization excluding roots (inside rings) and without root exclusion, and soil moisture and temperature. We used Plant Root Simulator Probes (PRS™ by Western Ag Innovations) also called resin membranes to adsorb soil mineralized N (NO_3^- and NH_4^+) to determine N supply rate in the top six inches of the first three replicates except treatments 3, 5, 11, and 12 (table 1). Data were collected every two weeks over an 8-week period. At harvest, grain yield, moisture, protein and starch data were collected. Test weight could not be determined because of very high grain moisture above 30 percent.

Results: Grain yields were very low with maximum mean yield of 112 bu/ac for the 240 lbs manure treatment and minimum yield at 68 bu/ac, for the check (Table 1). This reflects the impact of late planting, and drought stress from late June to August. Despite these challenges, significant grain yield, protein, and N uptake responses to fertilizer treatments were observed (Table 1). N mineralization was influenced by soil temperature and moisture (data not shown) as can be observed from the declining rate that coincided with low rainfall and crop water deficit from around June 21 until past mid-August. Nitrogen supply rate inside rings (figure 1, exclusion of roots) was significantly higher ($p<0.0001$) than outside rings (figure 2, near roots), suggesting that outside the rings, plants were competing with PRS probes reducing the amount to mineralize and being adsorbed onto the PRS probes. Nitrogen mineralization was significantly higher ($p<0.05$) for all urea treatments compared to the check, near roots, while the manure treatments did not differ from the check plots. At higher N rates, N mineralization increased. These graphs do not tell how much total N was mineralized on an acre basis; however, they give us an indication that soil N levels and source contribute significantly to the amount of N being mineralized, which varies with soil condition. They are indicative of temporal patterns of N release by inorganic and organic sources. A good correlation was observed between grain N content (uptake), yield, soil N at planting, and N supply rate (figure 3). Grain yields showed strong relationships with N levels when evaluated either as urea or manure, but weaker when treatments were considered together (figure 4). This is because manure treatments were applied once, in 2012, and even at those rates, soil test levels at the start of the 2013 season showed as little as 30 percent of the N applied the year before was remaining in the soil. Soil organic matter levels were not significantly different (average 3.3%) amongst treatments. A strong linear relationship (figure 4) was observed between plant biomass N content (R1 growth stage), grain N content, and soil N (residual N + added N). Aboveground biomass N data at harvest were not available at the time of reporting. However, R1 stage biomass N plus grain N at harvest showed a strong linear relationship with grain protein and yield (figure 5). The strength of these relationships improves with urea N rates only, but weakens when 180 lbs N was applied to treatments with and without removal of residue. Surprisingly, the 180 lb N treatment with residue removed, which showed the most vigorous growth during the season, produced lower yields than when residue was left on the soil. We suspect that when residue was removed, soil moisture was lost faster thus the plants suffered drought stress during the severe shortage of rainfall more than the rest of the treatments where residue was retained. Nitrogen uptake response of biomass and grain to soil N levels and mineralization was strong as was the response for yields. The relatively good yields from manure treatments compared to the rest of the plots indicate that available N was not the only factor (e.g. lower soil moisture tension observed) that affected grain yields since residual N was very low (table 1) from soil tests in spring. The relatively lower yields from compost compared to manure treatments are likely due to N availability. Another year of data is necessary to determine the extent to which N mineralization rates affect grain yield and quality in this study.

Table 1. Nitrogen fertilizer treatment effect on grain yield and quality of corn.

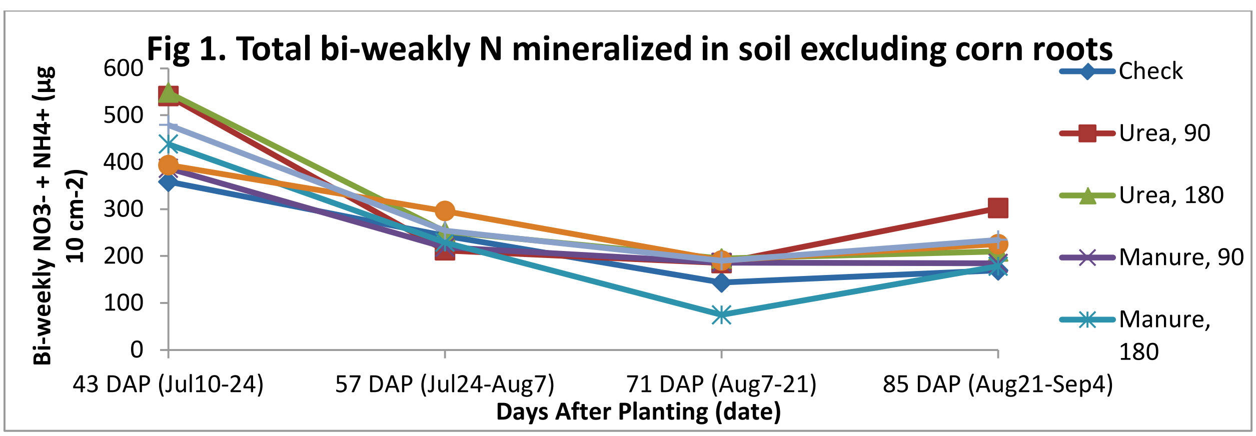
Trt	N Source	Residual Soil N lb/ac	N Applied lb/ac	Yield bu/ac	Grain Protein %	Starch lb/ac	Grain N Uptake lb/ac
1	0	27	0	68 c[2]	6.85 e[2]	75 ab[2]	75 e[2]
2	Urea 90 lbs	29	61	96 abc	8.40 bcd	73 ab	130 abcd
3	Urea 150 lbs	56	94	94 abc	8.55 ab	75 ab	129 abcd
4	Urea 180 lbs	97	83	94 abc	9.65 ab	73 ab	148 ab
5	Urea 240 lbs	97	143	105 ab	10.43 a	73 ab	177 a
6	Manure[1]	33	0	90 abc	7.78 cde	76 a	114 bcde
7	Manure	55	0	104 ba	8.15 bcde	75 ab	136 abcd
8	Manure	90	0	112 a	9.38 ba	73 ab	148 ab
9	Compost[1]	29	0	77 abc	7.03 de	75 ab	89 cde
10	Compost	35	0	70 bc	7.38 cde	75 ab	84 de
11	Urea 180 lbs, no residue	N/A	180	82 abc	10.78 a	74 ab	141 abc
12	Urea 180 lbs + residue	N/A	180	88 abc	9.53 ab	72 b	134 abcd
Mean				90	8.67	74	127
Tukey-Kramer's MSD				35.01	1.50	3.80	53.52
Treatment differences, *P>F*[*]				<.0014	<.0001	0.0216	<0.0001
C.V.				15.67	16.96	2.067	16.96

[1]All manure and compost at target levels were applied once, in spring 2012, i.e., no added N in 2013

[2]Grain N uptake was determined by dividing % protein in grain by a factor of 6.0, and multiplying by grain yield

[3] Mean values followed by the same letter in each column are not significantly different from each other

* Probability of observing an F-statistic > the observed; Indicative of the significance of treatment differences at α = 0.05



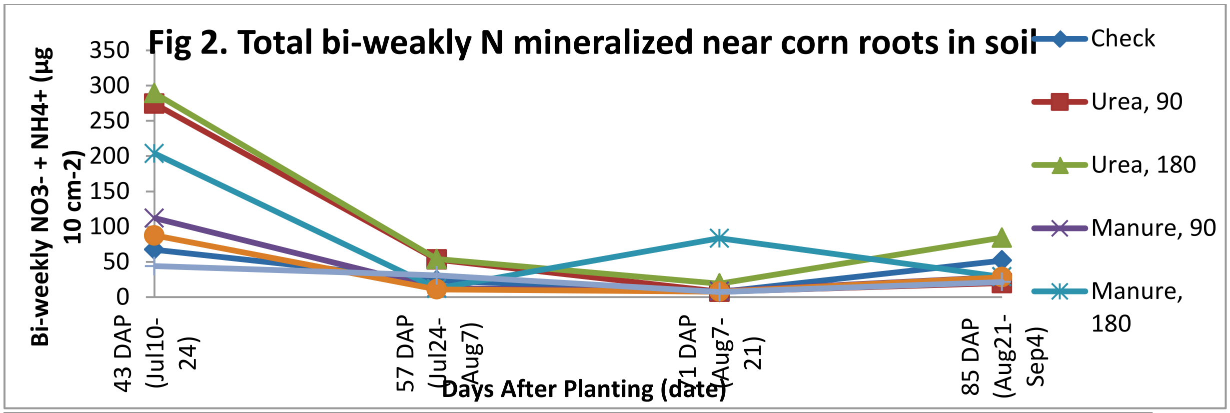


Fig 2. Total bi-weakly N mineralized near corn roots in soil
Bi-weekly NO3- + NH4+ (µg 10 cm-2)
350
300
250
200
150
100
50
0
43 DAP (Jul10-24)
57 DAP (Jul24-Aug7)
71 DAP (Aug7-21)
85 DAP (Aug21-Sep4)
Days After Planting (date)
Check
Urea, 90
Urea, 180
Manure, 90
Manure, 180

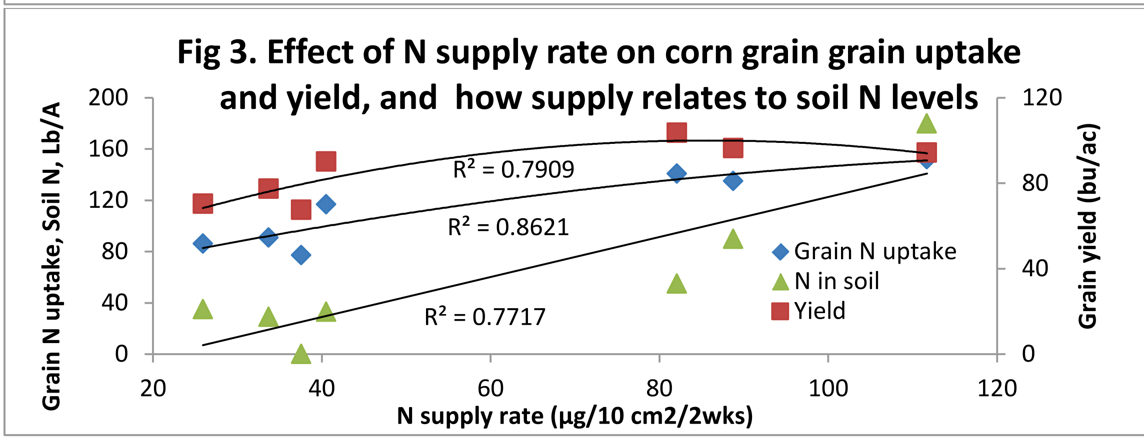


Fig 3. Effect of N supply rate on corn grain grain uptake and yield, and how supply relates to soil N levels
Grain N uptake, Soil N, Lb/A
200
160
120
80
40
0
Grain yield (bu/ac)
120
80
40
0
R² = 0.7909
R² = 0.8621
R² = 0.7717
Grain N uptake
N in soil
Yield
20
40
60
80
100
120
N supply rate (µg/10 cm2/2wks)

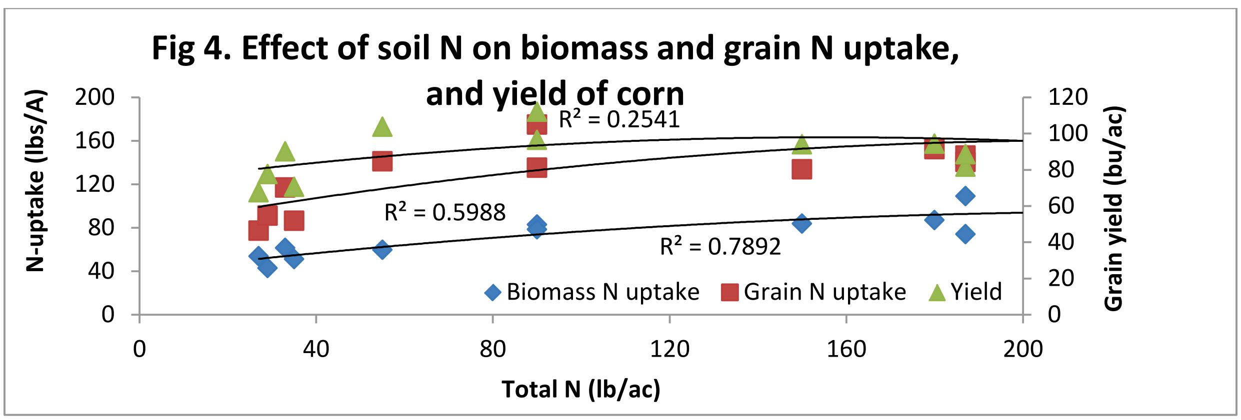


Fig 4. Effect of soil N on biomass and grain N uptake, and yield of corn
N-uptake (lbs/A)
200
160
120
80
40
0
Grain yield (bu/ac)
120
100
80
60
40
20
0
R² = 0.2541
R² = 0.5988
R² = 0.7892
Biomass N uptake
Grain N uptake
Yield
0
40
80
120
160
200
Total N (lb/ac)