# Effect of Rotation and Nitrogen application on Corn and Soybean Yields and Determining the Soybean Nitrogen Equivalent Contribution on Sandy Soils in Holt County

# Final Report (2004-2009)

**Investigators:** C. A. Shapiro, W. L. Kranz, and M. Pavlik
**Technical assistance:** M. Mamo, M. Mainz, J. Scott, UENRD Staff
**Cooperator:** Eugene Zuhlke

**Location:** SW ¼ Section 33 T28N R6W Antelope County
(Sheet 10, Antelope County Soil Survey)

## EXECUTIVE SUMMARY

This report summarizes a five year study designed to determine the rotation effect of soybean on corn and the value of both a corn/soybean and corn/corn/soybean rotation on sandy loams soils. The specific objectives and what we found are listed below:

*1. Estimate the 'N credit' of soybean for the following corn crop.* How this is determined depends on several factors, but the economic optimum N rate might be different by about 10 lbs of N per acre when the N rate is determined by the UNL procedures and when a corn/nitrogen price ratio is similar to the long term value of 8 ($3.20/bu corn, $0.40/lb N).

*2. Determine if there is a difference in potential yield due to soybean in a corn/soybean and corn/corn/soybean sequence compared to corn/corn/corn.* The 3 year rotation has very little agronomic effect on the second year of corn, except that there was about 4 bu/ac more yield than in continuous corn.

*3. Determine the effect of continuous soybean on soybean yields.* Continuous soybean (60.9 bu/ac) yielded the same statistically but less than soybean in the corn/soybean rotation which averaged 63.4 bu/ac over the length of the experiment. Soybean every third year averaged 61.9 bu/ac. Since continuous corn is unlikely, the difference between soybeans every other year and every third year is minimal, and beyond the precision of this experiment to differentiate. However, we only measured the second cycle of the rotation. A longer experiment might find more differences.

*4. Determine the effect of nitrogen application during early reproductive stage to soybean.* There has been no yield response to nitrogen in any of the five years. Average yields were 64 bu/ac where only the nitrogen contained in irrigation water was applied, which was the highest yielding treatment compared to the average of the other nitrogen applications.

## INTRODUCTION

When producers plant corn in a corn-soybean rotation system, the University of Nebraska nitrogen calculator currently gives a 45 lb N credit for a '*good*' soybean crop, defined as over 25 bu/ac. When soybean yields are less than 25 bu/ac, the credit is 1 lb N per bushel of soybean yield. These credits are relatively low when compared to the calculated rates from research results. However, most of the rotation research has been conducted on silt loam and silty clay loam soils in rainfed areas of eastern Nebraska. Some irrigated rotation studies in the central part of the state have shown similar or higher credits, but none in the irrigated sands of the UENRD.

Soybean yields, while greater than in other parts of the state, may be difficult to sustain on the low organic matter, coarse texture soils in parts of the UENRD. Producers are asking whether two years of corn and one year of soybean is a more economical and sustainable rotation than a corn/soybean rotation. There has been no documentation of the yield effects or soil quality effects of either rotation on sandy soils.

Nitrogen application to soybean during the growing season has been shown to increase yields in Kansas; research results in Nebraska have been variable and unpredictable. Replicated research that documents the impact of adding nitrogen in years with soybean has not been conducted on sandy soils.

There may be significant nitrogen leaching implications to all these practices.

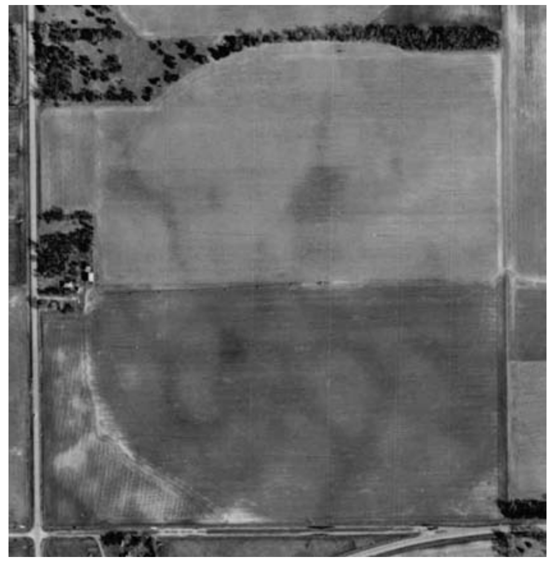


**Figure 1**. Aerial photo of the demonstration site prior to initiating the project.

## OBJECTIVES

Determine the rotation effect of soybean on corn and the value of both a corn/soybean and corn/corn/soybean rotations on sandy loam soils.

*Sub-objectives:*

1. Estimate the 'N credit' of soybean for the following corn crop.
2. Determine if there is a difference in potential yield due to soybean in a corn/soybean and corn/corn/soybean ratation compared to corn/corn/corn.
3. Determine the effect of continuous soybean on soybean yields.
4. Determine the effect of nitrogen application during early reproductive stage to soybean.

## PROCEDURES

Conducting a rotation experiment is complicated by the need to have every year of the rotation in each cropping year. In a soybean/corn evaluation, there needed to be both corn and soybean every year so that there was always a treatment with corn following soybean. With the proposed study, the corn-corn-soybean (C/C/SB) rotation means that there will be three experimental units in each replication each year so that there will always be all three phases of the rotation to compare.

The rotations used in this study are presented in Table 1 below. In experimental design jargon, the crop rotations are main plots (strips in Figure 2) and the nitrogen rates within the rotations are split plots. Each rotation treatment was split with six N rates (Figure 2). The N treatments applied to the corn part of the study were 0, 50, 100, 150, 200, and 250 lbs N/ac. Soybean received 0, 20, 40, 60, 80, and 100 lbs N/ac. Each year one set of plots were treated as bulk corn plots for the subsequent year as depicted in Figure 2. Nitrogen was applied both by hand and with fertilizer spreaders. Yields and data were collected from the inner two rows. Subplot length is 30 ft. Due to the need to avoid continuous treatments with lower N rates than optimum, creating a permanent deficit plot, the rotation blocks were split into two 6-row subplots. One side received a constant, optimum N rate and the other side received one of the 6 N rates. These areas were switched every year so the N rate plots would be on ground that was treated uniformly the previous year. The uniform rate applied was slightly below the UNL recommendation so excess nitrogen did not carry over to the future year.

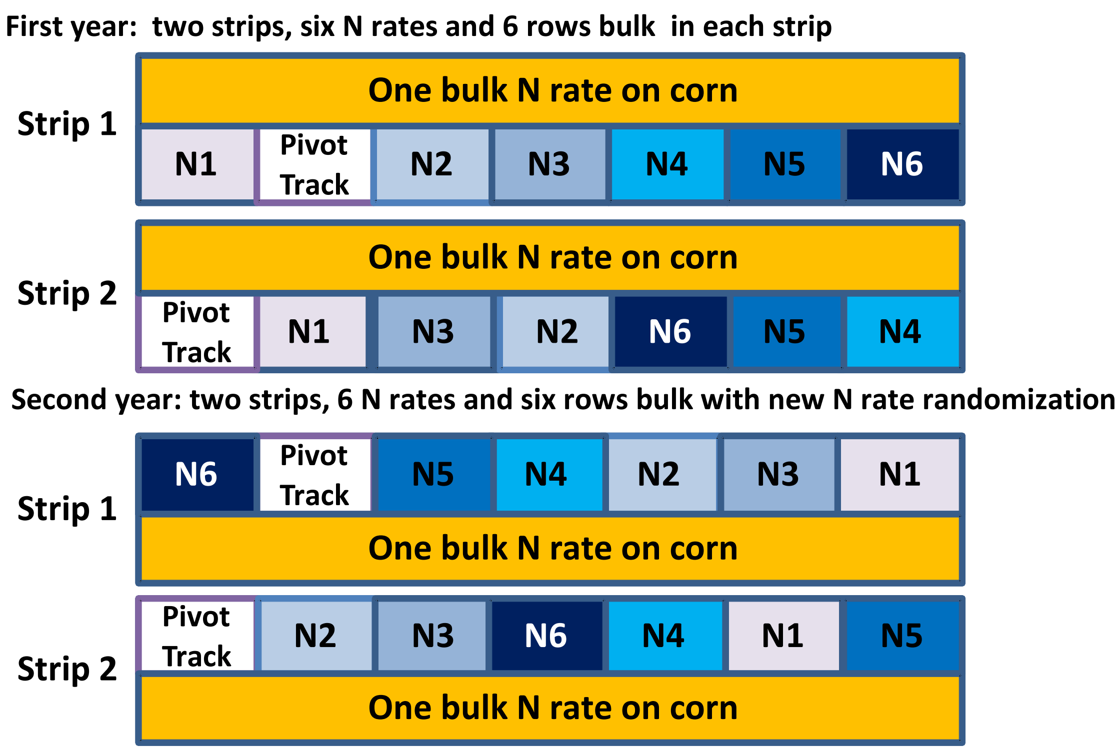



**Figure 2.** Schematic drawing of the test plot layout for one partial replication (Strip 1 and 7, Table 1) over a 2-year period. Note that the location of the N application rates is re-randomized and that the bulk N plots were relocated each year. The first set of two strips would be for Year 1 of the study and the second two strips would be for Year 2.

Soil samples were collected from the field area prior to the initial year of research. Table 2 presents the results of the laboratory analysis of those samples. Based on the soil sample results, 1200 lbs/ac of pelleted lime was broadcast applied over the plot area on April 15, 2005 to help increase the soil pH. Soil samples were collected each year of the project and analyzed for nitrate content, pH, organic matter, Bray P1, and Potassium. Results of the sample analysis are presented in Appendix I of this report.

**Table 1.** Crop rotation treatment set for each year of a 6-year study.

| Strip[1] | Treatment | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|
| 1 | C/C/C | Soybean | Corn | Corn | Corn | Corn | Corn |
| 2 | C/SB | Soybean | Corn | Soybean | Corn | Soybean | Corn |
| 3 | SB/C | Soybean | Soybean | Corn | Soybean | Corn | Soybean |
| 4 | SB/SB/SB[2] | Soybean | Soybean | Soybean | Soybean | Soybean | Soybean |
| 5 | SB/C/C | Soybean | Soybean | Corn | Corn | Soybean | Corn |
| 6 | C/SB/C | Soybean | Corn | Soybean | Corn | Corn ($2^{nd}$) | Soybean |
| 7 | C/C/SB | Soybean | Corn | Corn | Soybean | Corn ($1^{st}$) | Corn |

Notes:
[1] Crop strips were 12 30-inch rows wide. Wide enough to avoid the border effect between corn and soybean strips.
[2] Continuous soybean is not a practical treatment, but was needed for statistical design and long-term information.

The University of Nebraska corn calculator was used each year to calculate the 'bulk' N rate in the 6 rows not in the study that year. The UNL recommended N rate was determined using an irrigation water nitrate concentration of 19.4 ppm**,** average nitrogen in the soil of less than 30 lbs N/ac, 1% organic matter and a 220 bu/ac yield goal. The resulting nitrogen recommendations for continuous corn were 215 lbs N/ac and 170 lbs N/ac for corn following soybean. The applied N to the bulk plots differed from year to year, but ranged from 150 to 180 lbs N/ac. The intent was to grow a decent crop, but not over apply and leave a large residual N amount.

Nitrogen rates were applied to soybean as a surface broadcast treatment of 34-0-0 at the R1 stage in all years. Nitrogen was applied to corn in the treatment areas three times during the season. Each nitrogen rate was split with 40% spread pre-emergence (Early May), 30% spread at V6 (Mid-June), and the remaining 30% spread at V11 (Early July). The N form used was ammonium nitrate to avoid potential volatilization problems. The nitrogen was not incorporated by tillage after application.

On the bulk strips, nitrogen was usually applied twice; at the same time as a pre-emergent N application and at one time between V6 and V11. Usually the bulk application was UAN 32-0-0, applied with a knife applicator. Nitrogen in the irrigation water and nitrogen applied as an adjuvant with the herbicide added about 50 lbs N/ac to each treatment. All corn in the bulk strips received the same nitrogen rate, regardless of whether it was following soybean or not.

**Table 2.** Summary of soil sample analyses for soils collected prior to initiation of the field study near Brunswick, NE in 2004. (cores per sample, by replicate)

| Rep | Sample Depth | pH | Buffered pH | Ag Lime required | K | Bray P1 | OM | Nitrate | Texture |
|---|---|---|---|---|---|---|---|---|---|
| | | | | lbs/ac | ppm | ppm | % | ppm | |
| 1(NW) | 0-8” | 5.8 | 6.8 | 2000 | 207 | 40 | 0.8 | 2.8 | SL |
| | 8-24” | 5.0 | 6.7 | 3000 | 147 | 31 | 0.8 | 3.8 | SL |
| | 24-48” | 5.9 | 6.9 | 1000 | 160 | 4.5 | 0.6 | 4.2 | L |
| 2(SW) | 0-8” | 5.3 | 6.8 | 2000 | 235 | 42 | 1.2 | 3.8 | L |
| | 8-24” | 5.0 | 6.6 | 4000 | 131 | 15 | 0.9 | 5.2 | L |
| | 24-48” | 5.9 | 6.8 | 2000 | 144 | 6.8 | 0.6 | 3.6 | SL |
| 3(NE) | 0-8” | 5.1 | 6.6 | 4000 | 148 | 67 | 0.8 | 1.9 | L |
| | 8-24” | 4.9 | 6.6 | 4000 | 94 | 18 | 0.7 | 1.7 | SL |
| | 24-48” | 5.9 | 6.9 | 1000 | 87 | 5.9 | 0.3 | 2.7 | SL |
| 4(NW) | 0-8” | 6.1 | 6.6 | 4000 | 132 | 34 | 0.9 | 3.3 | SL |
| | 8-24” | 5.4 | 6.7 | 3000 | 75 | 13 | 0.7 | 2.3 | SL |
| | 24-48” | 5.2 | 6.9 | 1000 | 75 | 5.4 | 0.4 | 3.8 | SL |
| | Overall Sample Averages | | | | | | | | |
| | 0-8” | 5.58 | 6.7 | 3000 | 181 | 45.8 | 0.93 | 3.0 | L, SL |
| | 8-24” | 5.08 | 6.7 | 3500 | 112 | 19.3 | 0.78 | 3.3 | SL |
| | 24-48” | 5.73 | 6.9 | 1250 | 117 | 5.7 | 0.48 | 3.6 | L, SL |

**Note:** Each sample is based on 4 cores. SL = sandy loam; L= loam;

**Table 3.** 2004 Irrigation water analysis results.

| Water Analysis | | | |
|---|---|---|---|
| | | ppm | lbs/ac ft |
| $NO_3$-N | | 19.4 | 52.8 |
| Phosphate-P | | 0.18 | 0.5 |
| K | | 3 | 8.2 |
| Sulfate-S | | 2.06 | 5.6 |
| Ca | | 33 | 89.8 |
| Mg | | 6 | 16.3 |
| Na | | 3 | 8.2 |
| Cl | | 5 | 13.6 |
| HCO3 | | 76 | |
| EC | (mmhos/cm) | 0.26 | |
| pH | | 7.52 | |
| SAR | | 0.3 | |
| SAR (adj) | | 0.4 | |
| Hardness | | 62 | |
| Lime | | | 169 |

Since one source of N to a growing crop is from the irrigation water, chemical analysis was performed to determine the amount of N supplied per inch of water applied. Results of the laboratory analyses are presented in Table 3 above. The nitrate-nitrogen concentration of 19.4 ppm would deliver 4.4 lbs N/ac-in of water applied. The water pH is slightly basic so it should help maintain the soil pH at a level near 7.

Cultural practices are not summarized here, however we used practices that were typical of the area. Adapted hybrids were used from various seed companies. Typical relative maturity and herbicide resistant varieties were chosen to fit the planting and harvesting schedule of the cooperating-producer. Either Roundup Ready® or Liberty Link® corn was used in alternative years to control volunteer corn and to allow the same chemical to be sprayed to both the soybean and corn without fear of drift problems.

Rain gauges were installed to record the water applied (precipitation + irrigation). Crop water use (ET) was estimated for each crop using weather data collected at the Brunswick location about 4 miles from the field site. Data were recorded by the High Plains Regional Climate Center and ET was calculated using the Modified Penman equation and crop-specific coefficients. Irrigation was scheduled based on the needs of the crop surrounding the experiment which rotated between corn and soybeans. A summary of water applied and ET is given in Appendix I-2**.**

Corn grain yields were recorded by machine harvesting 2-3 rows from each of the corn treatment plots and 1-2 rows from the soybean plots. Grain yields were converted to 15.5% moisture content for corn and 13% moisture for soybean. Regression equations were calculated from the average yields (2006-2008) from the N rate data for each regression using PROC REG in SAS.

Dry matter samples were collected shortly after physiological maturity from all the corn nitrogen treatments in 2007 and 2008 and selected N rates in 2006. To determine nitrogen in the stover, percent nitrogen was multiplied by the pounds of plant dry matter (non-grain) harvested at physiological maturity. Nitrogen uptake was calculated for the grain by dividing protein levels by 6.25 and multiplying by the pounds grain harvested and converted to 0% moisture. The stover and grain dry matter samples were combined for the total N uptake.

Stalk N samples were collected in 2007 and 2008 at approximately physiological mature to document the adequacy of the nitrogen application rates (Shapiro and DeLoughery, 2001). In addition chlorophyll meter readings were recorded 1-4 times per season to document the N status in the corn treatments (Shapiro et al., 2006).

## RESULTS

Soil sampling throughout the project indicated that soil pH was low and the pelleted lime applications did not have a significant impact on soil pH levels at this site. The agricultural lime recommendation based on the April 21, 2007, analysis indicated a need for another 5000 lbs/ac. The last lime application was 500 lbs/ac pelleted lime applied into the standing crop June 19, 2006. Although the pH was low and called for additional applications, and most agronomists would recommend a pH of 6.5, the potential yield improvement may be low. The yields in the lime studies that were conducted on the same quarter do not show much pH change or yield response to added lime (Tarkalson et al., 2010).

Soil potassium (K) and phosphorus (P) levels were consistently above the University of Nebraska critical levels of 125 and 15 ppm, respectively. In order to maintain a soil fertility balance, sulfur (S) was spread most years as $CaSO_4$ at a rate of about 20 lbs S/ac. However, sampling in the spring of 2009 after the experiment ended indicated that the final pH averaged 6.4, K was 138, Bray P was 16, and soil organic matter was 1.0 %. Most interesting are the soil organic numbers by rotation. There was no statistical difference but the trends indicate that the continuous soybeans had reduced organic matter compared to continuous corn, with the rotations in between (Table 4).

**Table 4.** Effect of rotations on soil chemical measurements in top 6 in after two cycles. (2009). Brunswick, NE.

| **Rotation** | **pH** | **K** | **P** | **OM** |
|---|---|---|---|---|
| | **----------------ppm------------------** | | | **%** |
| Continuous corn | 6.45 | 142 | 14.8 | 1.12 |
| Corn/corn/beans | 6.32 | 140 | 15.4 | 1.04 |
| Corn/beans | 6.47 | 131 | 16.0 | 1.08 |
| Continuous beans | 6.65 | 140 | 19.4 | 0.99 |
| Prob >F | 0.1896 | 0.8273 | 0.1085 | 0.7270 |

## Corn

### Rotation effects on grain yield

Statistical analysis over-years show that the last three years were consistent with relation to grain yield; the C/C/C treatment produced less grain yield than the C/SB rotation (Table 5). Average corn grain yield was between 14 and 32 bu/ac greater for rotations with soybean compared to continuous corn (Table 5, Column 7). Yields increased from continuous corn in the following order: C/C/C < SB/C/**C** < SB/**C**/C < SB/C.

### Nitrogen effects

Nitrogen increased grain yields for all corn rotations, and there is evidence that the second year corn in the SB/C/**C** rotation requires the greatest N rate for maximum yields (Line 4,Table 6). Table 6 is based on the statistical regression of grain yield and N rate for each crop rotation. Column 5 of the table gives the N application rate that would be required to produce the maximum grain yield based on the best fit quadratic equations shown in Figure 3. For the SB/C/**C** rotation, 288 lbs N/ac were required to produce 216 bu/ac (Column 4). However, the other rotations with soybean required approximately 70 lbs N/ac less to reach the maximum yield which was similar to the C/C/C treatment. Although the recommended N rates for the C/C/C, SB/C, and SB/**C**/C rotations were similar (212, 214, and 208, respectively), the grain yield was greater for the rotations with soybean (191 vs 217 and 204 bu/ac, respectively).

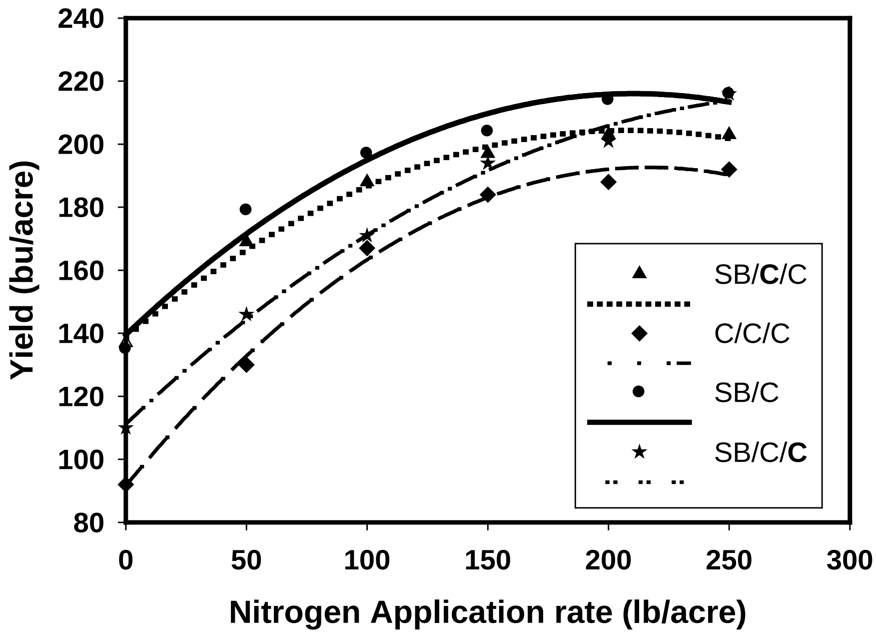
**Table 5.** Effect of rotation and N rate on corn grain yield in each strip. Brunswick, NE 2004-2008.

| Strip | Rotation | 2004 | 2005 | 2006 | 2007 | 2008 | Avg 06-08 |
|---|---|---|---|---|---|---|---|
| | | -----------------------------------bu/ac[1] | ----------------------------------------- | | | | |
| (1) | Cont. Corn | 186.6 | 169.7 | 168.7 | 162.7 | 145.2 | 158.8 |
| (2) | SB-C | 199.4 | ---[2] | 200.6 | ---[2] | 185.3 | 190.8[3] |
| (3) | C-SB | ---[2] | 179.1 | ---[2] | 186.6 | ---[2] | |
| (5) | SB-C-C | ---[2] | 177.7 | 193.1 | ---[2] | 180.7 | 183.8[4] |
| (6) | C-SB-C | 185.6 | ---[2] | 186.9 | 171.4 | ---[2] | 172.2[5] |
| (7) | C-C-SB | 184.6 | 156.0 | ---[2] | 183.8 | 154.1 | |
| **Rotation Mean** | | **189.9** | **170.9** | **193.5** | **180.6** | **173.3** | |
| Pr>F | | 0.1729 | 0.1278 | 0.0166 | 0.0417 | 0.0004 | |
| LSD (0.05) | | 15.4 | 21.5 | 18.0 | 17.5 | 14.1 | |
| Applied N rate[6] | | 2004 | 2005 | 2006 | 2007 | 2008 | Avg 06-08 |
| | 0 lb/a | 143.5 | 120.2 | 130.1 | 125.0 | 89.9 | 115.0 |
| | 50 lb/a | 170.3 | 152.8 | 167.3 | 162.3 | 136.3 | 155.3 |
| | 100 lb/a | 192.8 | 173.5 | 194.0 | 182.4 | 167.4 | 181.3 |
| | 150 lb/a | 207.9 | 187.5 | 207.4 | 192.3 | 190.6 | 196.8 |
| | 200 lb/a | 212.8 | 197.5 | 209.3 | 195.7 | 203.8 | 202.9 |
| | 250 lb/a | 206.9 | 192.3 | 215.8 | 199.0 | 209.7 | 208.2 |
| **N Rate Mean** | | **189.0** | **170.6** | **187.3** | **176.1** | **166.3** | |
| Pr>F | | 0.0001 | 0.0001 | <.0001 | <.0001 | <.0001 | |
| LSD (0.05) | | 14.7 | 11.9 | 10.3 | 11.1 | 13.8 | |

[1]Grain yield in bu/ac at 15.5% moisture.
[2]Corn crop was not in the strip that year.
[3]Average of corn for the three years of corn following soybeans (strips 2 and 3).
[4]Average of corn for the three years of corn, first year after soybeans, but followed by corn.
[5]Average of corn for the three years of corn, second year after soybeans.
[6]Approximately 50 lbs N applied through pivot as nitrate in the groundwater in addition to what was applied as treatments.

Column 6 of Table 6 presents the N application rate that would be necessary to produce the maximum grain yield that was produced in the continuous corn rotation (191 bu/ac). For example, an application of 89 lbs N/ac in the SB/C treatment would produce approximately 191 bu/ac, the SB/**C** /C would require 113 lbs N/ac and the SB/C/**C**/ would require only 148 lbs N/ac. Thus, the value of the SB/C rotation was equivalent to 123 lbs N/ac (C/C/C– SB/C) or (212 – 89 = 123 lbs N/ac) in reduced N required for maximum corn production.

**Figure 3.** Graph of best-fit quadratic equations for each of the 3-year rotations for the 2006-2008 growing seasons. Goodness-of-fit values for each rotation are presented in Table 6. (*Approximately 50 lbs N was applied through pivot as nitrate in the groundwater in addition to what was applied as treatments*.)




**Other effects of nitrogen rate and rotation on corn**

Appendix I-2.1 contains the 2006-2008 rotation by nitrogen rate means for grain yield, stover N, stover dry matter at physiological maturity, grain N and stalk nitrates at physiological maturity. For most of the variables the results are similar to the yield relationships. Continuous corn had the lowest values for most nitrogen rates, and the corn following soybeans had the highest values.

Stalk nitrate values ranged from the very low of 53 ppm where no fertilizer nitrogen was applied to 4252 ppm at 250 lbs N/ac. All rotations were below the adequate value of 700 when 100 lbs N/ac was applied. Only the corn following soybeans had a value over 2000 ppm at 150 lbs N/ac applied. All rotations had what would be categorized as excessive N at the 200 and 250 lbs N/ac rates. However, yields increased for some of these rotations even at the 250 lb application rate, so the 2000 ppm value does not indicate maximum yield. Only the continuous corn and the second year corn after soybeans had higher stalk nitrate values at 250 lbs N/ac than at 200 lbs N/ac. It is possible that more calibration work needs to be done for the stalk N test on sandy soils.

**Table 6.** Regression results for grain yield versus N application rate for the 2006-2008 growing seasons.

| 3-Year Crop Rotation[1] | Quadratic Equation[2] | R-sq | Maximum Yield[3] | Nitrogen Rate[4] | N Required To Equal C/C/C[5] | N savings when applied at C/C/C rate[6] |
|---|---|---|---|---|---|---|
| | | | bu/ac | lb/ac | lb/ac | lb/ac |
| SB/**<u>C</u>**/C | 138.7 + 0.6306N - $0.0015N^2$ | 0.99 | 204.5 | 208 | 113 | 99 |
| C/C/C | 91.50+ 0.9341N - $0.00216N^2$ | 0.99 | 190.7 | 212 | 0 | 0 |
| SB/C | 139.50 + 0.7276N - $0.00173N^2$ | 0.97 | 217.4 | 214 | 89 | 123 |
| SB/C/**<u>C</u>** | 111.86 + 0.7264N - $0.00126N^2$ | 0.99 | 216.0 | 288 | 148 | 64 |

[1] 2 or 3-Year crop rotations for the 2006-2008 period. Example: SB/C/C = Soybean in 2006, Corn in 2007, and Corn in 2008. The bold underline **<u>C</u>** indicates the phase of the rotation for the two corn years following soybeans. The two C/SB rotations are combined into the SB/C presented in Line 3 and the two SB/C/C rotations are included in Line 4.
[2] Coefficients for the statistical best-fit quadratic equation for corn grain yield versus N application rate as graphed in Figure1. The best fit equation is of the form Yield = $aN^2 + bN + C$.
[3] Predicted maximum grain yield using the best-fit quadratic equations in Column 2.
[4] Predicted N rate needed to produce the maximum grain yield in Column 4 using the best-fit equations in Column 2.
[5] Predicted N rate needed to produce the equivalent level of corn yield for the C/C/C rotation of 191 bu/ac using the best-fit equations in Column 2.
[6] Savings in N to reach maximum C/C/C yields.
**<u>Note:</u>** *Approximately 50 lbs N/ac was applied through pivot as nitrate in the groundwater in addition to what was applied as treatments. This was not accounted for in the regressions.*

## Soybean

### Rotation effect on grain yield

Over the life of the project there were no significant yield differences among the three soybean rotations (Table 7). Over the last 3-years of the project, soybean yields were 63.5, 63.9, and 61.4 bu/ac the SB/SB/SB, SB/C, and SB/C/C rotations, respectively. Note that the soybean rotation with corn every other year produced the greatest soybean yield. This is the same rotation that produced the greatest corn yield discussed above. Thus, the positive effect of the C/SB/C rotation is exhibited in the yield for both corn and soybean planted the following year. These data provide clear evidence that the corn-soybean rotation would be the best management practice from an economic perspective. This assumes returns to corn and soybeans are generally similar.

There were no effects of nitrogen application rate on soybean yield except for 2007. Nitrogen did not increase yield, with the no nitrogen treatment having the second greatest average yield (64.1 bu/ac) except for the 100 lbs N/ac treatment yield (64.2 bu/ac) which was not an economic yield increase. In 2008, there was nearly an interaction between the rotations and the nitrogen rates (P>0.05). Based on 5 years of data for this sandy soil site, the addition of nitrogen as a dry broadcast treatment does not increase soybean yield at any level of N. However, approximately 53 lbs N/ac were applied in the irrigation water which may have masked the impact of adding dry fertilizer at the R1 stage.

**Table 7.** Effect of rotations and nitrogen on soybean yield. Brunswick, NE (2004-2008).

| Treatments | Yield 2004 | Yield 2005 | Yield 2006 | Yield 2007 | Yield 2008 | Mean 2006-2008 |
|---|---|---|---|---|---|---|
| **Rotation effects:** | | | **bu/ac** | | | |
| Continuous Soybean | 63.9 | 63.8 | 66.1 | 63.6 | 60.9 | 63.5 |
| Corn/Soybean | --- | 61.7 | 70.8 | 57.7 | 63.4 | 63.9 |
| Corn/Corn/Soybean | --- | --- | 68.0 | 60.8 | 61.9 | 61.4 |
| $LSD_{0.05}$ | --- | 7.6 | 2.2 | 5.5 | 6.1 | |
| Prob,>F | | 0.6469 | 0.1109 | 0.0968 | 0.6517 | |
| **Nitrogen rates effects:[1]** | | | | | | |
| 0 | 62.9 | 60.9 | 69.5 | 61.8 | 61.0 | 64.1 |
| 20 | 64.2 | 61.3 | 67.6 | 61.3 | 61.6 | 63.5 |
| 40 | 64.1 | 62.2 | 67.3 | 59.0 | 62.5 | 63.0 |
| 60 | 65.0 | 62.7 | 69.0 | 61.4 | 61.3 | 63.9 |
| 80 | 65.4 | 62.8 | 67.6 | 59.1 | 63.7 | 63.5 |
| 100 | 66.0 | 63.0 | 68.9 | 61.7 | 62.1 | 64.2 |
| **Mean** | **64.6** | **62.2** | **68.3** | **60.7** | **62.1** | |
| $LSD_{0.05}$ | 3.1 | 2.0 | 3.06 | 3.3 | 2.2 | |
| CV (%) | 5.8 | 3.9 | 5.5 | 6.5 | 4.2 | |
| Rotation (Prob.>F) | ---- | 0.6469 | 0.1109 | 0.0968 | 0.6517 | |
| N rate (Prob.>F) | 0.4292 | 0.1881 | 0.5766 | 0.2902 | 0.1626 | |
| N rate x Rotation (Prob.>F) | ---- | 0.9397 | 0.2672 | 0.6211 | 0.0565 | |

[1] *Approximately 50 lbs N applied through pivot as nitrate in the groundwater in addition to what was applied as treatments.*

### Weather and Estimated Crop Water Use

Appendix I-2 contains average annual values for the main weather related variables used to estimate crop water use for corn and soybean. Average values across years show corn using about one more inch of water per year than soybean (23.9 vs. 23.1 inches). Average ET for corn and soybean was within the 22-24 inch range that is typical for the area. Another consideration is that with the emergence dates for the two crops being nearly the same for this project, it is expected that water usage would be similar. Thus, even though long term average ET levels would suggest about a 2-inch differential between the two crops, these data are more representative of the production practices currently in use by producers.

## DISCUSSION

The data is clear that yields from the continuous corn are less than corn following soybean, and it takes more nitrogen to produce that yield. Table 6, Figure 3, and Appendix I-2 show the difficulty we have in calculating a soybean N credit since both the maximum yield and the N needed to grow that yield are different for corn following corn and for corn following soybeans. We can approach the 'N' credit three ways:

1. How much corn is grown with zero N applied as fertilizer. At the zero applied N the corn yields at zero applied N show that for the two corn following soybean rotations the yield is an average of 136 bu/ac. The lowest yield is for the continuous corn (92 bu/ac) which is 38 bu/ac less than following soybeans. For the second year corn after soybeans (110 bu/ac) the yield difference is only 26 bu/ac. Roughly the 'N credit' could be about 1 lb N/yield difference.
2. The second way to calculate the N credit is the nitrogen rates needed to produce maximum yield. As we pointed out in the results section, for three of the rotations there was little difference in N recommendations which ranged from 208 to 214 lbs N/ac. The second year corn after soybeans was much greater (288 lb N/ac) because the 250 lb N rate yields were greater than the 200 lb N rate, which made the regression maximum be outside the bounds of the data.
3. The third way to calculate the N credit is the one we did for the last column in Table 6 where the N needed to get to the maximum continuous corn yield. With this method there is a range of 'N' credits from 64 to 123 lbs N/ac.

The question is which one to use. There is no correct answer because one has to define the objectives. Most farmers recognize that maximum yield is not what they are aiming for, but the economic optimum. Therefore the answer is related to the price of corn and the price of nitrogen, and the 'credit' is not fixed. If we examine the continuous corn and the corn following soybean N response function and add economics to it we can construct Table 8. When nitrogen is inexpensive compared to corn (a high Corn:N ratio), in this example we used 12, the difference in N rate is 10 lbs more N in continuous corn compared to corn following soybeans. The yield difference is about 22 bushels, and return to N difference is $85.75/ac when using a corn price of $3.20/bu. Surprisingly the N needed to apply to corn following soybeans to make the return to fertilizer N the same with SB/C as continuous corn is 15 lbs N/ac. At the more normal ratio of 8, the N applied for maximum return to fertilizer is 10 lbs less for corn following soybeans, this produced 23 bu/ac bushels more and an increase in $79/ac return to N fertilizer use. The N needed for equivalent return to fertilizer use is 55 lbs N/ac.

It would seem that under these conditions the difference in N fertilization for corn following soybeans would be 10 lbs N/ac less than corn following corn. However, returns to fertilizer dollars can still be greater within a corn/soybean rotation with a much larger decrease in N rates.

**Table 8.** Effect of crop rotation on N rate, corn yield, and return to N application at three corn price to nitrogen price (C:N) ratios.

| Rotation | N rate[1] | Yield[2] | Return to Fertilizer N[3] | N for equivalent Cont. Corn profit |
|---|---|---|---|---|
| | lbs N/ac | bu/ac | $ | lbs N/ac[4] |
| CN[5] ratio 4 | | | | |
| C/SB | 140 | 208 | 552 | 15 |
| C/C | 160 | 187 | 466 | |
| CN ratio 8 | | | | |
| C/SB | 175 | 214 | 614 | 55 |
| C/C | 185 | 190 | 535 | |
| CN ratio 12 | | | | |
| C/SB | 185 | 215 | 638 | 67 |
| C/C | 195 | 192 | 561 | |

1 N rate based on equations in Table 5 that produce maximum return to fertilizer N
2 Yield at the N rate for maximum return to fertilizer
3 At the CN ratio the value of corn produced after fertilizer subtracted, for example at CN ratio of 4: Return= (208 x $3.20) – (140 x $0.80); note values in table may be rounded.
4 How much N is needed for the corn following soybeans return to fertilizer N to equal the continuous corn returns, for example it will take 15 lbs N on corn following soybeans to give a return of $466, it is not in the table but the N rate would be 150 lbs N/ac.
5 Corn price to nitrogen price ratio, for example: $3.20/bu corn and $0.80 per lb N equals a CN ratio of 4; all returns in table based on a constant $3.20/bu corn with the price of N varied.

**Note:** *Approximately 50 lbs N applied through pivot as nitrate in the groundwater in addition to what was applied as treatments. This was not accounted for in the regression calculations.*

## REFERENCES


Tarkalson, D., C. A. Shapiro, and J. Peterson. 2010. Use of fly ash as a liming material of corn and soybean production on an acidic sandy soil. Online. Crop Management. Doi:10.1094/CM-2010-0426-01-RS.

Shapiro, Charles A., and Richard L. DeLoughery. 2001. The Corn Stalk Nitrate Test. University of Nebraska Extension NF01-491. Available at: http://digitalcommons.unl.edu/extensionhist/1023/

Shapiro, Charles A., James S. Schepers, Dennis D. Francis, and John F. Shanahan. 2006. Using a chlorophyll meter to improve N management. University of Nebraska-Lincoln Extension G1632. Available at: http://www.ianrpubs.unl.edu/epublic/live/g1632/build/g1632.pdf

## APPENDIX I-1
## Soil Sample Analyses Results for 2005-2008

**Table App. I-1.1** Soil chemical properties averaged by crop sampled by replication in the fall of 2005.

| Crop | Rep | Results for 0-8 inch soil samples | | | | | 0-8” | 8-24” | 24-48” | 0-48” |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Water | Buffered | Potassium | Bray P | %OM | ------------$NO_3$-N----------- | | | Total N |
| | | pH | pH | --------PPM--------- | | LOI | ------------ PPM------------- | | | lbs/ac |
| Corn | 1 | 5.5 | 6.6 | 227 | 27.0 | 0.94 | 1.30 | 0.91 | 2.90 | 28.37 |
| Soybean | 1 | 5.4 | 6.5 | 264 | 44.4 | 2.33 | 3.60 | 0.84 | 2.38 | 29.81 |
| Corn | 2 | 5.5 | 6.6 | 246 | 31.1 | 1.14 | 0.86 | 0.90 | 1.94 | 20.35 |
| Soybean | 2 | 5.4 | 6.5 | 230 | 33.5 | 1.20 | 1.77 | 1.59 | 3.41 | 36.43 |
| Corn | 3 | 5.1 | 6.5 | 146 | 35.4 | 0.74 | 0.90 | 0.57 | 0.84 | 10.94 |
| Soybean | 3 | 5.7 | 6.5 | 162 | 33.2 | 0.88 | 1.58 | 1.50 | 0.83 | 16.97 |
| Corn | 4 | 5.3 | 6.5 | 160 | 29.1 | 0.85 | 1.59 | 1.11 | 1.49 | 19.87 |
| Soybean | 4 | 6.2 | 6.8 | 158 | 30.0 | 0.77 | 1.54 | 0.72 | 1.62 | 18.82 |
| Overall Averages | | | | | | | | | | |
| Corn | | 5.4 | 6.5 | 194.8 | 30.6 | 0.9 | 1.2 | 0.9 | 1.8 | 19.9 |
| Soybean | | 5.7 | 6.6 | 203.5 | 35.3 | 1.3 | 2.1 | 1.2 | 2.1 | 25.5 |

**Note:** In 2005 the rotations were not established and so there were just two crops following the 2004 crop (which was soybeans).

**Table App. I-1.2** Soil chemical properties averaged by crop sampled by replication in the fall of 2006.

| Rotation[1] Number | Rep | Water pH | Buffered pH | Potassium PPM | Bray P PPM | %OM LOI | 0-8" $NO_3$-N PPM | 8-24" $NO_3$-N PPM | 24-48" $NO_3$-N PPM | 0-48" Total N lbs/ac |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Results for 0-8 inch soil samples | | | | | | | | |
| 2 | 1 | 5.43 | 6.51 | 292 | 32.3 | 1.60 | 4.12 | 4.29 | 4.44 | 62 |
| 1 | 1 | 5.48 | 6.61 | 204 | 26.5 | 1.02 | 2.39 | 0.66 | 1.45 | 19 |
| 4 | 1 | 5.46 | 6.52 | 182 | 36.0 | 0.79 | 2.38 | 2.15 | 2.78 | 36 |
| 4 | 2 | 5.57 | 6.51 | 292 | 50.4 | 1.45 | 2.70 | 2.00 | 5.08 | 53 |
| 2 | 2 | 5.32 | 6.51 | 298 | 54.5 | 1.44 | 2.78 | 1.63 | 3.83 | 42 |
| 1 | 2 | 5.68 | 6.79 | 168 | 32.1 | 0.87 | 1.49 | 1.05 | 1.44 | 19 |
| 2 | 3 | 5.21 | 6.59 | 165 | 25.4 | 0.90 | 2.18 | 1.04 | 0.77 | 16 |
| 1 | 3 | 5.18 | 6.64 | 133 | 17.1 | 0.92 | 1.62 | 0.83 | 0.43 | 11 |
| 4 | 3 | 5.39 | 6.70 | 151 | 37.8 | 0.76 | 2.21 | 1.49 | 2.86 | 33 |
| 1 | 4 | 5.19 | 6.66 | 130 | 20.0 | 0.70 | 1.70 | 0.71 | 1.16 | 16 |
| 4 | 4 | 5.71 | 6.80 | 146 | 10.8 | 0.69 | 2.12 | 1.20 | 2.51 | 29 |
| 2 | 4 | 6.51 | 7.00 | 192 | 46.4 | 1.03 | 2.28 | 1.01 | 1.95 | 24 |
| | | | | | Overall Rotational Average | | | | | |
| 1 | | 5.38 | 6.67 | 158.8 | 23.9 | 0.88 | 1.80 | 0.81 | 1.12 | 16 |
| 2 | | 5.62 | 6.65 | 236.8 | 39.7 | 1.24 | 2.84 | 1.99 | 2.75 | 36 |
| 4 | | 5.53 | 6.63 | 192.8 | 33.8 | 0.92 | 2.35 | 1.71 | 3.31 | 38 |

[1] Rotation 1 = continuous corn
Rotation 2 = corn/soybean rotation
Rotation 4 = continuous soybean rotation

**Table App. I-1.3** Soil chemical properties averaged by crop sampled by replication in the fall of 2007.

| Rotation[1] Number | Rep | Results for 0-8 inch soil samples: Water pH | Buffered pH | Potassium (PPM) | Bray P (PPM) | %OM LOI | 0-8" $NO_3$-N (PPM) | 8-24" $NO_3$-N (PPM) | 24-48" $NO_3$-N (PPM) | 0-48" Total N lbs/ac |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 1 | 5.39 | 6.49 | 333 | 29.5 | 1.05 | 13.67 | 4.86 | 2.84 | 77 |
| 5 | 1 | 5.49 | 6.60 | 330 | 65.88 | 1.66 | 2.83 | 1.00 | 1.07 | 19 |
| 2 | 1 | 5.09 | 6.40 | 176 | 22.8 | 1.39 | 1.60 | 1.79 | 2.04 | 27 |
| 6 | 1 | 4.85 | 5.44 | 177 | 34.3 | 1.04 | 1.84 | 1.38 | 1.78 | 24 |
| 1 | 1 | 4.96 | 5.10 | 155 | 29.8 | 0.85 | 2.33 | 1.29 | 2.03 | 26 |
| 4 | 1 | 5.54 | 6.67 | 203 | 42.8 | 0.80 | 2.39 | 1.24 | 2.65 | 31 |
| 7 | 1 | 5.06 | 6.29 | 255 | 70.2 | 1.59 | 3.22 | 2.41 | 3.44 | 44 |
| 4 | 2 | 5.20 | 6.41 | 322 | 42.4 | 1.68 | 11.06 | 5.02 | 2.97 | 72 |
| 2 | 2 | 5.09 | 6.33 | 228 | 79.0 | 1.19 | 1.43 | 1.12 | 0.96 | 16 |
| 1 | 2 | 5.56 | 6.66 | 120 | 17.4 | 0.76 | 1.91 | 1.26 | 1.96 | 25 |
| 6 | 2 | 6.34 | 7.00 | 123 | 12.6 | 0.75 | 1.51 | 1.02 | 2.08 | 24 |
| 5 | 2 | 5.89 | 6.71 | 117 | 70.4 | 0.74 | 1.74 | 1.20 | 1.66 | 22 |
| 7 | 2 | 6.36 | 7.00 | 195 | 20.1 | 0.81 | 4.20 | 1.36 | 3.09 | 39 |
| 3 | 2 | 6.40 | 7.00 | 134 | 27.2 | 0.80 | 2.90 | 1.05 | 1.71 | 24 |
| 5 | 3 | 5.22 | 6.47 | 100 | 12.7 | 0.92 | 1.58 | 0.77 | 1.02 | 15 |
| 6 | 3 | 5.28 | 6.53 | 120 | 35.9 | 0.90 | 1.66 | 0.91 | 1.42 | 19 |
| 3 | 3 | 5.60 | 6.57 | 151 | 21.8 | 0.99 | 2.94 | 1.07 | 1.80 | 25 |
| 2 | 3 | 5.43 | 6.52 | 150 | 31.1 | 1.05 | 1.81 | 1.15 | 1.06 | 18 |
| 1 | 3 | 5.37 | 6.51 | 160 | 22.9 | 0.78 | 1.25 | 0.71 | 1.09 | 14 |
| 4 | 3 | 5.85 | 6.74 | 141 | 37.8 | 0.82 | 2.38 | 1.03 | 1.70 | 23 |
| 7 | 3 | 5.37 | 6.50 | 131 | 13.3 | 0.95 | 2.25 | 1.02 | 1.81 | 23 |
| 6 | 4 | 5.01 | 6.53 | 124 | 14.2 | 0.84 | 2.01 | 1.10 | 1.12 | 18 |
| 1 | 4 | 4.97 | 6.25 | 119 | 27.4 | 0.76 | 1.62 | 0.58 | 1.14 | 15 |
| 5 | 4 | 5.23 | 6.49 | 130 | 30.3 | 0.97 | 2.06 | 1.03 | 1.40 | 20 |
| 7 | 4 | 5.77 | 6.68 | 156 | 9.6 | 0.88 | 3.21 | 1.22 | 2.77 | 34 |
| 3 | 4 | 6.64 | 7.00 | 191 | 21.4 | 0.82 | 2.29 | 1.13 | 1.79 | 24 |
| 4 | 4 | 5.92 | 6.62 | 137 | 39.1 | 0.71 | 1.22 | 0.97 | 2.18 | 23 |
| 2 | 4 | 5.39 | 6.51 | 161 | 24.9 | 0.80 | 1.76 | 1.07 | 1.19 | 18 |
| | | | | Overall Rotational Averages | | | | | | |
| 1 | | 5.21 | 6.13 | 138.5 | 24.4 | 0.79 | 1.78 | 0.96 | 1.56 | 20 |
| 2 | | 5.25 | 6.44 | 178.8 | 39.4 | 1.11 | 1.65 | 1.28 | 1.31 | 20 |
| 3 | | 6.01 | 6.76 | 202.3 | 25.0 | 0.91 | 5.45 | 2.03 | 2.03 | 37 |
| 4 | | 5.63 | 6.61 | 200.8 | 40.5 | 1.00 | 4.26 | 2.06 | 2.38 | 37 |
| 5 | | 5.46 | 6.57 | 169.3 | 44.8 | 1.07 | 2.05 | 1.00 | 1.29 | 19 |
| 6 | | 5.37 | 6.38 | 136.0 | 24.2 | 0.88 | 1.75 | 1.10 | 1.60 | 21 |
| 7 | | 4.51 | 5.29 | 147.4 | 22.6 | 0.85 | 2.58 | 1.20 | 2.22 | 28 |

[1] **Rotation 1** = continuous corn; **Rotation 2** = soybean/corn rotation; **Rotation 3** = corn/soybean rotation; **Rotation 4** = continuous soybean; **Rotation 5** = soybean/corn/corn rotation; **Rotation 6** = corn/soybean/corn rotation; **Rotation 7** = corn/corn/soybean rotation

**Table App. I-1.4** Soil chemical properties averaged by crop sampled by replication in the fall of 2008.

| Rotation | Rep | 0-8” | 8-24” | 24-48” | 0-48” |
|---|---|---|---|---|---|
| | | ------------------- | $NO_3$-N | ------------------- | Total N |
| | | ------------------- | PPM | ------------------- | lbs/ac |
| 3 | 1 | 1.35 | 2.66 | 5.39 | 55 |
| 5 | 1 | 2.66 | 5.39 | 1.85 | 46 |
| 2 | 1 | 5.39 | 1.85 | 1.81 | 35 |
| 6 | 1 | 1.85 | 1.81 | 1.95 | 27 |
| 1 | 1 | 1.81 | 1.95 | 2.14 | 29 |
| 4 | 1 | 1.95 | 2.14 | 4.24 | 45 |
| 7 | 1 | 2.14 | 4.24 | 2.53 | 44 |
| 4 | 2 | 4.24 | 2.53 | 1.39 | 32 |
| 2 | 2 | 2.53 | 1.39 | 1.67 | 25 |
| 1 | 2 | 1.39 | 1.67 | 2.72 | 31 |
| 6 | 2 | 1.67 | 2.72 | 1.50 | 28 |
| 5 | 2 | 2.72 | 1.50 | 2.15 | 29 |
| 7 | 2 | 1.50 | 2.15 | 2.09 | 29 |
| 3 | 2 | 2.15 | 2.09 | 1.66 | 27 |
| 5 | 3 | 2.09 | 1.66 | 1.59 | 24 |
| 6 | 3 | 1.66 | 1.59 | 3.39 | 36 |
| 3 | 3 | 1.59 | 3.39 | 1.76 | 33 |
| 2 | 3 | 3.39 | 1.76 | 1.65 | 28 |
| 1 | 3 | 1.76 | 1.65 | 1.65 | 24 |
| 4 | 3 | 1.65 | 1.65 | 2.03 | 27 |
| 7 | 3 | 1.65 | 2.03 | 1.66 | 26 |
| 6 | 4 | 2.03 | 1.66 | 1.39 | 23 |
| 1 | 4 | 1.66 | 1.39 | 1.39 | 21 |
| 5 | 4 | 1.39 | 1.39 | 1.61 | 22 |
| 7 | 4 | 1.39 | 1.61 | 1.90 | 25 |
| 3 | 4 | 1.61 | 1.90 | 2.68 | 32 |
| 4 | 4 | 1.90 | 2.68 | 1.72 | 30 |
| 2 | 4 | 2.68 | 1.72 | 2.97 | 36 |
| | | Overall Rotational Averages | | | |
| 1 | | 1.65 | 1.66 | 1.98 | 26 |
| 2 | | 3.50 | 1.68 | 2.02 | 31 |
| 3 | | 1.68 | 2.51 | 2.87 | 37 |
| 4 | | 2.43 | 2.25 | 2.34 | 34 |
| 5 | | 2.22 | 2.48 | 1.80 | 30 |
| 6 | | 1.80 | 1.94 | 2.06 | 28 |
| 7 | | 1.34 | 2.01 | 1.64 | 25 |

[1] **Rotation 1** = continuous corn; **Rotation 2** = soybean/corn rotation; **Rotation 3** = corn/soybean rotation; **Rotation 4** = continuous soybean; **Rotation 5** = soybean/corn/corn rotation; **Rotation 6** = corn/soybean/corn rotation; **Rotation 7** = corn/corn/soybean rotation

**Table App. I-1.5** Soil chemical properties averaged by crop sampled by rotation. April, 2009. Brunswick, NE.

| Crop Rotation | Data | 0-6" Sample | |
|---|---|---|---|
| Continuous Corn | Water pH | | 6.45 |
| | Buffer pH | | |
| | K (ppm) | | 1.42 |
| | P (ppm) | | 14.8 |
| | OM LOI (%) | | 1.10 |
| | Pounds N (48 in) | | 16 |
| | | **C/B** | **CC/B** |
| Corn/ Soybean or Corn/Corn/ Soybean | Water pH | 6.47 | 6.32 |
| | Buffer pH | | |
| | K (ppm) | 131 | 140 |
| | P (ppm) | 16.0 | 15.4 |
| | OM LOI (%) | 1.04 | 1.08 |
| | Pounds N (48 in) | 19 | 22 |
| Continuous Soybean | Water pH | | 6.65 |
| | Buffer pH | | |
| | K (ppm) | | 140 |
| | P (ppm) | | 19.4 |
| | OM LOI (%) | | 0.99 |
| | Pounds N (48 in) | | 26 |

**NOTE:** Samples were taken in the 2008 'bulk' treatments in Spring 2009, 2 cores per sample, one sample per rotation/replication strip.

## Appendix I-2
## Corn crop yield components analysis results for 2006-2008

**Table App. I-2.1** Effect of rotation and N rate on corn grain yield, stover N uptake, stover DM, grain N uptake, and stalk nitrates. Brunswick, NE 2006-2008.

| Rotation | Applied nitrogen (lbs N/ac): 0 | 50 | 100 | 150 | 200 | 250 | Rotation Mean |
|---|---|---|---|---|---|---|---|
| | **Grain Yield (bu/ac)** | | | | | | |
| (1) Cont. Corn | 92 | 130 | 167 | 184 | 188 | 192 | 159 |
| (3) SB/Corn | 135 | 179 | 197 | 204 | 214 | 216 | 191 |
| (6) SB/Corn/Corn | 110 | 146 | 171 | 194 | 201 | 216 | 163 |
| (7) Corn/SB/Corn | 137 | 169 | 188 | 197 | 203 | 203 | 185 |
| **Mean** | **119** | **156** | **181** | **195** | **202** | **207** | |
| | **Stover N (lbs/ac: 100 and 200 N rates not sampled in 2006)** | | | | | | |
| (1) Cont. Corn | 28.2 | 37.4 | | 51.8 | | 63.2 | 47.5 |
| (3) SB/Corn | 34.8 | 47.9 | | 57.5 | | 74.0 | 54.2 |
| (6) SB/Corn/Corn | 34.4 | 40.0 | | 55.8 | | 67.4 | 49.4 |
| (7) Corn/SB/Corn | 43.8 | 46.7 | | 59.2 | | 70.1 | 58.0 |
| **Mean** | **35.3** | **43.0** | | **56.1** | | **68.1** | |
| | **Stover DM (Mg/ha: 2007-2008 only)** | | | | | | |
| (1) Cont. Corn | 5.0 | 6.3 | 8.2 | 7.1 | 7.8 | 7.7 | 7.0 |
| (3) SB/Corn | 5.8 | 8.0 | 7.6 | 8.4 | 9.2 | 8.4 | 7.9 |
| (6) SB/Corn/Corn | 5.9 | 7.0 | 7.7 | 7.5 | 8.4 | 8.6 | 7.4 |
| (7) Corn/SB/Corn | 5.4 | 6.8 | 7.4 | 8.2 | 8.3 | 8.2 | 7.5 |
| **Mean** | **5.5** | **7.0** | **7.7** | **7.8** | **8.4** | **8.2** | |
| | **Grain N Uptake (lbs/ac)** | | | | | | |
| (1) Cont. Corn | 55 | 78 | 105 | 118 | 123 | 129 | 102 |
| (3) SB/Corn | 80 | 109 | 123 | 133 | 142 | 144 | 122 |
| (6) SB/Corn/Corn | 66 | 90 | 108 | 126 | 133 | 147 | 97 |
| (7) Corn/SB/Corn | 89 | 109 | 127 | 136 | 146 | 147 | 126 |
| **Mean** | **73** | **96.5** | **116** | **128** | **136** | **142** | |
| | **Stalk nitrates (2007-2008 only: ppm)** | | | | | | |
| (1) Cont. Corn | 55 | 51 | 484 | 1400 | 2731 | 4328 | 1508 |
| (3) SB/Corn | 33 | 181 | 660 | 2494 | 5358 | 5217 | 2324 |
| (6) SB/Corn/Corn | 51 | 82 | 457 | 1040 | 2930 | 4250 | 1509 |
| (7) Corn/SB/Corn | 26 | 84 | 432 | 1911 | 3918 | 3215 | 1468 |
| **Mean** | **41** | **100** | **508** | **1711** | **3734** | **4252** | |

**Note:** *Approximately 50 lbs N/ac was applied through pivot as nitrate in the groundwater in addition to what was applied as treatments. Interpretation of stalk nitrate numbers is the following: 0-250 ppm, low; 250-700 marginal; 700-2000, optimal; >2000, Excess.*

**Table App. I-2.2** Effect of rotation and N rate on chlorophyll meter readings. Brunswick, NE 2006.

| Rotation | 0 | 50 | 100 | 150 | 200 | 250 | Rotation Mean |
|---|---|---|---|---|---|---|---|
| | **Applied nitrogen (lbs N/ac)** | | | | | | |
| | **Chlorophyll Meter** | | | | | | |
| | | | **V10/ (7/6)[1]** | | | | |
| (1) Cont. Corn | 33.3 | 35.9 | 38.6 | 42.1 | 44.6 | 45.0 | 39.9 |
| (2) SB/Corn | 32.6 | 35.5 | 39.2 | 41.9 | 44.0 | 45.2 | 39.7 |
| (5) SB/Corn/Corn | 34.2 | 36.7 | 39.0 | 42.9 | 45.2 | 46.0 | 40.6 |
| (7) Corn/SB/Corn | | | Not available this year | | | | |
| **Mean** | **33.4** | **36.0** | **38.9** | **42.3** | **44.6** | **45.4** | **40.1** |
| ANOVA: Rotation, Prob > F = 0.66; Nrate, Prob>F = <0.001; Rotation x Nrate, Prob>F = 0.98; | | | | | | | |
| | | | **V20 / (8/3)** | | | | |
| (1) Cont. Corn | 40.5 | 47.6 | 51.0 | 55.4 | 53.6 | 56.6 | 50.8 |
| (2) SB/Corn | 41.7 | 49.3 | 53.0 | 55.6 | 56.9 | 57.0 | 52.3 |
| (5) SB/Corn/Corn | 41.3 | 49.6 | 53.0 | 55.6 | 56.9 | 57.0 | 51.7 |
| (7) Corn/SB/Corn | | | Not available this year | | | | |
| **Mean** | **41.2** | **48.8** | **52.3** | **55.5** | **55.8** | **56.9** | **51.6** |
| ANOVA: Rotation, Prob > F = 0.22; Nrate, Prob>F = <0.0001; Rotation x Nrate, Prob>F = 0.03; | | | | | | | |

[1] Growth stage and date of sampling

**Note:** *Approximately 50 lbs N/ac was applied through pivot as nitrate in the groundwater in addition to what was applied as treatments.*

**Table App. I-2.3** Effect of rotation and N rate on chlorophyll meter readings. Brunswick, NE 2007.

| | **Applied nitrogen (lbs N/ac)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 50 | 100 | 150 | 200 | 250 | Rotation |
| Rotation | **Chlorophyll Meter** | | | | | | Mean |
| | | | **V15 / (7/11)[1]** | | | | |
| (1) Cont. Corn | 35.3 | 41.2 | 46.9 | 48.6 | 49.3 | 48.9 | 45.0 |
| (3) SB/Corn | 35.5 | 43.2 | 46.5 | 48.8 | 49.8 | 50.8 | 45.8 |
| (6) SB/Corn/Corn | 35.9 | 43.3 | 47.3 | 48.0 | 49.5 | 48.7 | 45.4 |
| (7) Corn/SB/Corn | 34.6 | 43.6 | 47.8 | 48.3 | 50.6 | 49.9 | 45.7 |
| **Mean** | **35.3** | **42.8** | **47.1** | **48.4** | **49.8** | **49.5** | |
| ANOVA: Rotation, Prob > F = 0.043; Nrate, Prob.>F = <0.0001; Rotation x Nrate, Prob>F=0.63; | | | | | | | |
| | | | **R1 (silking) / (7/20)** | | | | |
| (1) Cont. Corn | 37.7 | 47.1 | 53.1 | 51.2 | 57.5 | 56.8 | 50.6 |
| (3) SB/Corn | 38.5 | 50.0 | 55.4 | 57.5 | 58.5 | 58.9 | 53.1 |
| (6) SB/Corn/Corn | 37.4 | 48.8 | 54.6 | 56.3 | 58.4 | 57.2 | 52.1 |
| (7) Corn/SB/Corn | 41.9 | 49.0 | 54.0 | 57.1 | 59.1 | 59.2 | 53.4 |
| **Mean** | **38.8** | **48.7** | **54.3** | **55.5** | **58.4** | **58.0** | |
| ANOVA: Rotation, Prob > F = 0.01; Nrate, Prob>F = <0.0001; Rotation x Nrate, Prob>F =0.84; | | | | | | | |
| | | | **R3 / (8/9)** | | | | |
| (1) Cont. Corn | 40.1 | 49.0 | 563.8 | 59.6 | 60.8 | 61.3 | 54.6 |
| (3) SB/Corn | 40.6 | 52.6 | 56.2 | 59.9 | 61.4 | 61.5 | 55.3 |
| (6) SB/Corn/Corn | 40.3 | 51.2 | 57.8 | 58.5 | 61.0 | 61.3 | 55.0 |
| (7) Corn/SB/Corn | 40.0 | 52.0 | 57.6 | 59.5 | 60.6 | 62.2 | 55.3 |
| **Mean** | **40.2** | **51.2** | **57.1** | **59.4** | **60.9** | **61.6** | |
| ANOVA: Rotation, Prob > F = 0.84; Nrate, Prob>F = <0.0001; Rotation x Nrate, Prob>F = 0.94; | | | | | | | |
| | | | **R4 / (8\20)** | | | | |
| (1) Cont. Corn | 39.2 | 47.0 | 53.1 | 56.0 | 58.0 | 57.8 | 51.8 |
| (3) SB/Corn | 40.2 | 51.5 | 54.2 | 57.1 | 57.5 | 58.2 | 53.1 |
| (6) SB/Corn/Corn | 40.9 | 48.0 | 53.4 | 56.0 | 56.3 | 57.7 | 52.0 |
| (7) Corn/SB/Corn | 39.5 | 50.0 | 53.7 | 56.5 | 56.9 | 58.6 | 52.5 |
| **Mean** | **39.9** | **49.1** | **53.6** | **56.4** | **57.2** | **58.0** | |
| ANOVA: Rotation, Prob > F = 0.86; Nrate, Prob>F =<0.0001; Rotation x Nrate, Prob>F =0.99; | | | | | | | |

[1]Growth stage and date of sampling

**Note:** *Approximately 50 lbs N/ac was applied through pivot as nitrate in the groundwater in addition to what was applied as treatments.*

**Table App. I-2.4** Effect of rotation and N rate on chlorophyll meter readings. Brunswick, NE 2008.

| Rotation | 0 | 50 | 100 | 150 | 200 | 250 | Rotation Mean |
|---|---|---|---|---|---|---|---|
| | ---------------Applied nitrogen (lbs N/ac)------------------- | | | | | | |
| | --------------------- Chlorophyll Meter----------------------- | | | | | | |
| | | | **V11 / (7/9)[1]** | | | | |
| (1) Cont. Corn | 37.0 | 44.5 | 47.4 | 49.2 | 51.0 | 51.2 | 46.7 |
| (2) SB/Corn | 41.0 | 48.6 | 50.2 | 52.3 | 51.0 | 51.0 | 49.0 |
| (6) SB/<u>Corn</u>/Corn | 38.0 | 45.6 | 47.4 | 49.7 | 51.0 | 51.8 | 47.3 |
| (5) SB/Corn/<u>Corn</u> | 39.9 | 48.8 | 50.2 | 51.2 | 50.6 | 53.2 | 49.0 |
| **Mean** | **39.0** | **46.9** | **48.8** | **50.6** | **50.9** | **51.8** | |
| ANOVA: Rotation, Prob > F = 0.003; Nrate, Prob>F = <0.0001; Rotation x Nrate, Prob>F = 0.08; | | | | | | | |
| | | | **V17 / (7/23)** | | | | |
| (1) Cont. Corn | 31.9 | 42.2 | 48.4 | 50.1 | 50.3 | 51.4 | 45.7 |
| (2) SB/Corn | 35.7 | 45.5 | 51.8 | 51.1 | 53.6 | 52.9 | 48.4 |
| (6) SB/<u>Corn</u>/Corn | 32.4 | 44.9 | 48.3 | 50.6 | 52.0 | 52.9 | 46.9 |
| (5) SB/Corn/<u>Corn</u> | 32.4 | 46.3 | 51.2 | 53.0 | 53.1 | 55.1 | 48.5 |
| **Mean** | **33.1** | **44.7** | **49.9** | **51.2** | **52.2** | **53.1** | |
| ANOVA: Rotation, Prob > F = 0.03; Nrate, Prob>F = <0.0001; Rotation x Nrate, Prob>F = 0.80; | | | | | | | |
| | | | **R1-2 / (8/12)** | | | | |
| (1) Cont. Corn | 29.6 | 36.0 | 47.9 | 51.1 | 55.7 | 54.5 | 45.8 |
| (2) SB/Corn | 36.2 | 45.3 | 51.6 | 52.6 | 55.5 | 54.8 | 49.3 |
| (6) SB/<u>Corn</u>/Corn | 31.7 | 38.7 | 48.1 | 49.8 | 53.2 | 53.9 | 45.9 |
| (5) SB/Corn/<u>Corn</u> | 32.0 | 44.4 | 50.8 | 53.0 | 55.5 | 55.3 | 48.5 |
| **Mean** | **32.4** | **41.1** | **49.6** | **51.6** | **55.0** | **54.6** | |
| ANOVA: Rotation, Prob > F = 0.001; Nrate, Prob>F =<0.0001; Rotation x Nrate, Prob>F = 0.02; | | | | | | | |
| | | | **R3-4 / (8/25)** | | | | |
| (1) Cont. Corn | 26.5 | 34.4 | 45.8 | 50.3 | 55.4 | 55.7 | 44.7 |
| (2) SB/Corn | 37.4 | 48.1 | 53.2 | 52.9 | 54.8 | 57.6 | 50.6 |
| (6) SB/<u>Corn</u>/Corn | 25.9 | 37.1 | 47.3 | 51.6 | 55.8 | 55.9 | 45.6 |
| (5) SB/Corn/<u>Corn</u> | 27.4 | 44.9 | 50.3 | 53.1 | 56.4 | 57.1 | 48.2 |
| **Mean** | **29.3** | **41.1** | **49.1** | **52.0** | **55.6** | **56.5** | |
| ANOVA: Rotation, Prob > F = ; Nrate, Prob.>F = ; Rotation x Nrate, Prob>F = 0.16; | | | | | | | |

[1]Growth stage and date of sampling

**Note:** *Approximately 50 lbs N/ac was applied through pivot as nitrate in the groundwater in addition to what was applied as treatments.*

# Appendix I-3

**Table App. I-3.1** Summary of weather information for 2004-2008 (Brunswick, NE station).

| | | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Data** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Average** |
| **2004** | Avg $T_{max}$ ( $^oF$ ) | 28.8 | 34.3 | 53.7 | 64.8 | 72.1 | 77.6 | 83.0 | 81.4 | 78.9 | 62.4 | 46.3 | 40.4 | **60.3** |
| | Avg $T_{min}$ ( $^oF$ ) | 8.6 | 15.8 | 29.5 | 36.9 | 49.0 | 54.4 | 60.5 | 55.5 | 52.8 | 38.1 | 26.9 | 17.9 | **37.2** |
| | Accumulated GDD's | | | | | 204 | 688 | 1337 | 1904 | 2424 | 2501 | | | **2501** |
| | Avg Soil temp ( $^oF$ ) | 29.7 | 31.5 | 42.3 | 54.3 | 63.7 | 71.6 | 77.3 | 74.0 | 48.4 | 53.6 | 40.8 | 31.4 | **51.6** |
| | Avg Wind Sp (mi $hr^{-1}$) | 9.9 | 11.6 | 11.9 | 10.6 | 12.5 | 8.6 | 7.5 | 8.2 | 11.4 | 9.6 | 9.2 | 11.0 | **10.2** |
| | Avg Solar Rad (Langleys) | 160 | 237 | 324 | 437 | 476 | 505 | 505 | 461 | 365 | 240 | 175 | 128 | **334** |
| | Sum of Prec (inch) | | | | | 4.1 | 2.9 | 3.9 | 1.5 | 6.5 | 0.3 | | | **19.2** |
| | Sum of Corn ET (inch) | | | | | 1.4 | 3.5 | 6.9 | 7.5 | 5.5 | 0.3 | | | **25.2** |
| | Sum of Soybean ET (inch) | | | | | | 2.2 | 5.5 | 8.1 | 7.2 | 1.4 | | | **24.3** |

| | | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Data** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Average** |
| **2005** | Avg $T_{max}$ ( $^oF$ ) | 38.7 | 46.4 | 56.0 | 61.7 | 75.3 | 86.1 | 88.0 | 83.7 | 72.2 | 62.9 | 42.8 | 35.5 | **62.4** |
| | Avg $T_{min}$ ( $^oF$ ) | 18.1 | 22.8 | 31.2 | 40.8 | 52.1 | 62.9 | 62.4 | 60.0 | 45.5 | 34.4 | 16.2 | 19.5 | **38.8** |
| | Accumulated GDD's | | | | | | 585 | 1325 | 1980 | 2491 | | | | **2491** |
| | Avg Soil temp ( $^oF$ ) | 30.4 | 35.9 | 44.7 | 55.1 | 65.6 | 79.8 | 80.5 | 75.8 | 47.3 | 50.6 | 36.6 | 33.2 | **53.0** |
| | Avg Wind Sp (mi $hr^{-1}$) | 10.2 | 10.1 | 11.0 | 12.1 | 9.8 | 9.7 | 8.6 | 9.2 | 9.6 | 9.5 | 11.9 | 10.4 | **10.2** |
| | Avg Solar Rad (Langleys) | 167 | 276 | 336 | 418 | 504 | 614 | 539 | 464 | 354 | 273 | 162 | 152 | **355** |
| | Sum of Prec (inch) | | | | | | 6.1 | 4.1 | 6.8 | 4.8 | 0.1 | | | **21.8** |
| | Sum of Corn ET (inch) | | | | | | 3.7 | 8.8 | 6.8 | 4.2 | | | | **23.5** |
| | Sum of Soybean Et (inch) | | | | | | 3.8 | 8.8 | 6.8 | 3.8 | | | | **23.2** |

**Table App. I-3.1** Summary of weather information for 2004-2008 (Brunswick, NE station). (continued)

| | | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Data** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Average** |
| **2006** | Avg $T_{max}$ ( $^oF$ ) | 38.3 | 45.2 | 62.6 | 69.5 | 85.0 | 88.4 | 88.0 | 71.4 | 62.0 | 53.9 | 38.7 | 35.1 | **61.5** |
| | Avg $T_{min}$ ( $^oF$ ) | 16.1 | 22.2 | 39.0 | 45.1 | 58.9 | 61.6 | 63.2 | 50.7 | 38.3 | 26.0 | 18.9 | 23.2 | **38.6** |
| | Accumulated GDD's | | | | | 200 | 806 | 1564 | 2227 | 2496 | | | | **2496** |
| | Avg Soil temp ( $^oF$ ) | 33.3 | 37.5 | 50.7 | 60.0 | 73.2 | 80.0 | 79.9 | 66.1 | 41.5 | 41.5 | 32.0 | 31.9 | **52.3** |
| | Avg Wind Sp (mi $hr^{-1}$) | 11.3 | 10.9 | 13.2 | 11.5 | 9.6 | 8.3 | 8.9 | 9.0 | 9.9 | 9.3 | 9.9 | 7.0 | **9.9** |
| | Avg Solar Rad (Langleys) | 243 | 338 | 400 | 503 | 554 | 614 | 507 | 339 | 266 | 205 | 141 | 78 | **349** |
| | Sum of Prec (inch) | | | | | 1.2 | 6.7 | 2.3 | 2.4 | 4.6 | 1.0 | | | **18.1** |
| | Sum of Corn ET (inch) | | | | | 1.4 | 5.7 | 10.2 | 6.7 | 1.7 | | | | **25.6** |
| | Sum of Soybean ET (inch) | | | | | 1.4 | 5.7 | 10.2 | 6.7 | 1.2 | | | | **25.2** |

| | | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Data** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Average** |
| **2007** | Avg Tmax ( oF ) | 29.2 | 27.1 | 53.9 | 58.4 | 73.7 | 81.6 | 88.2 | 83.9 | 76.4 | 65.1 | 49.2 | 29.2 | **59.7** |
| | Avg Tmin ( oF ) | 12.0 | 10.4 | 32.0 | 35.8 | 52.1 | 58.7 | 63.5 | 63.5 | 50.4 | 42.5 | 24.7 | 11.9 | **38.1** |
| | Accumulated GDD's | | | | | 79 | 677 | 1427 | 2134 | 2503 | | | | **2503** |
| | Avg Soil temp ( oF ) | 29.8 | 28.5 | 41.8 | 48.7 | 64.0 | 68.8 | 80.2 | 76.7 | 48.5 | 54.3 | 41.3 | 31.9 | **51.2** |
| | Avg Wind Sp (mi $hr^{-1}$) | 12 | 11 | 13 | 11.8 | 11.7 | 9.7 | 7.9 | 7.8 | 11.2 | 11.2 | 11.1 | 8.8 | **10.6** |
| | Avg Solar Rad (Langleys) | 189 | 244 | 326 | 421 | 467 | 551 | 607 | 412 | 370 | 260 | 209 | 142 | **350** |
| | Sum of Prec (inch) | | | | | 3.1 | 5.5 | 8.5 | 9.1 | 4.4 | 3.8 | | | **34.3** |
| | Sum of Corn ET (inch) | | | | | 0.8 | 4.19 | 8.54 | 5.5 | 2.55 | | | | **22.2** |
| | Sum of Soybean ET (inch) | | | | | 1.2 | 4.2 | 8.5 | 5.1 | 1.7 | | | | **20.8** |

**Table App. I-3.1** Summary of weather information for 2004-2008 (Brunswick, NE station). (continued)

| | | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Data | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Average |
| **2008** | Avg Tmax ( $^oF$ ) | 29.0 | 32.0 | 44.7 | 56.2 | 67.2 | 79.8 | 85.7 | 83.6 | 75.0 | 60.4 | 42.7 | 28.1 | **57.0** |
| | Avg Tmin ( $^oF$ ) | 8.8 | 10.7 | 23.3 | 31.8 | 44.4 | 56.3 | 62.0 | 58.4 | 50.3 | 37.9 | 26.1 | 7.5 | **34.8** |
| | Accumulated GDD's | | | | | 93 | 634 | 1348 | 1988 | 2412 | 2482 | | | **2482** |
| | Avg Soil temp ( $^oF$ ) | 29.4 | 27.8 | 33.1 | 42.6 | 57.6 | 73.5 | 80.1 | 79.2 | 46.8 | 52.1 | 38.7 | 30.8 | **49.3** |
| | Avg Wind Sp (mi $hr^{-1}$) | 11.0 | 11.1 | 11.0 | 13.5 | 10.9 | 8.3 | 7.8 | 7.7 | 9.3 | 9.7 | 11.6 | 12.7 | **10.4** |
| | Avg Solar Rad (Langleys) | 195 | 277 | 339 | 465 | 443 | 548 | 514 | 493 | 360 | 228 | 146 | 151 | **347** |
| | Sum of Prec (inch) | | | | | 6.5 | 4.8 | 9.5 | 6.5 | 2.0 | 2.0 | | | **31.4** |
| | Sum of ETCORN (inch) | | | | | 1.0 | 3.6 | 7.1 | 7.3 | 3.8 | 0.3 | | | **23.0** |
| | Sum of ETBEANS (inch) | | | | | 1.0 | 4.1 | 7.3 | 7.9 | 1.8 | | | | **22.0** |

**Note:** Sum of Precip, where irrigation data is available, includes irrigation and rainfall amounts.

Accumulated GDD's are Growing Degree Days calculated from corn emergence until maturity using the $86^o$ - $50^o$ method.

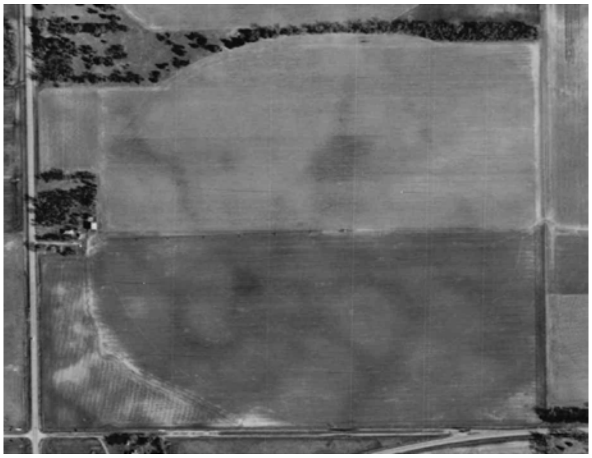
## AVERAGE PROJECT WEATHER DATA 2004-2008

| Data | 2004 | 2005 | 2006 | 2007 | 2008 | AVERAGE | 10-YR AVG |
|---|---|---|---|---|---|---|---|
| Avg $T_{max}$ ( $^oF$ ) | 60.3 | 61.0 | 62.0 | 59.7 | 57.0 | **60.0** | **60.7** |
| Avg $T_{min}$ ( $^oF$ ) | 37.2 | 38.5 | 38.5 | 38.1 | 34.8 | **37.4** | **38.1** |
| Accumulated GDD's | 2501 | 2491 | 2496 | 2503 | 2482 | **2495** | **2647** |
| Avg Soil temp ( $^oF$ ) | 51.5 | 52.4 | 52.0 | 51.2 | 49.3 | **51.3** | **51.2** |
| Avg Wind Sp (mi $hr^{-1}$) | 10.2 | 10.1 | 10.2 | 10.6 | 10.4 | **10.3** | **9.8** |
| Avg Solar Rad (Langleys) | 335 | 354 | 353 | 350 | 347 | **348** | **334** |
| Sum of Prec (inch) | 19.2 | 21.8 | 18.1 | 34.3 | 31.4 | **25.0** | **15.7** |
| Sum of Corn ET (inch) | 25.2 | 23.5 | 25.6 | 22.2 | 23.0 | **23.9** | |
| Sum of Soybean ET (inch) | 24.3 | 23.2 | 25.2 | 20.8 | 22.0 | **23.1** | |

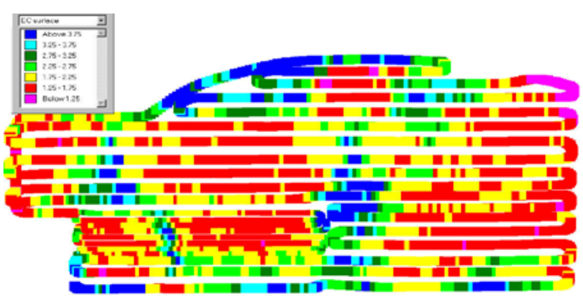
**Note:** 10-year average values represent the entire weather data history for this location.

**APPENDIX II   Aerial Photos**

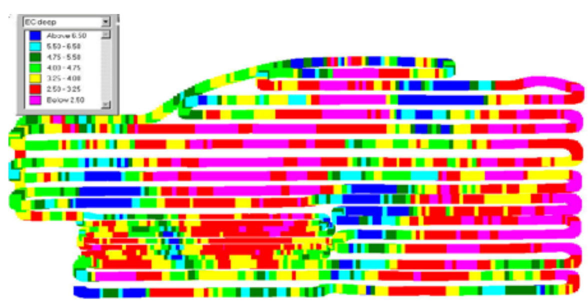
# 2004



# 2004 Veris Maps

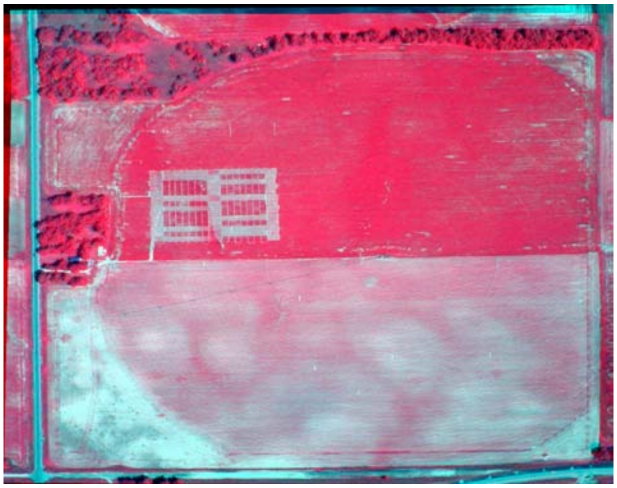



**Surface Veris**

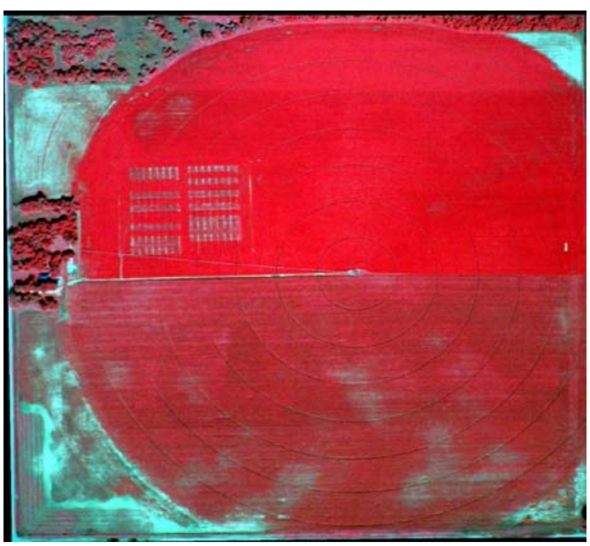


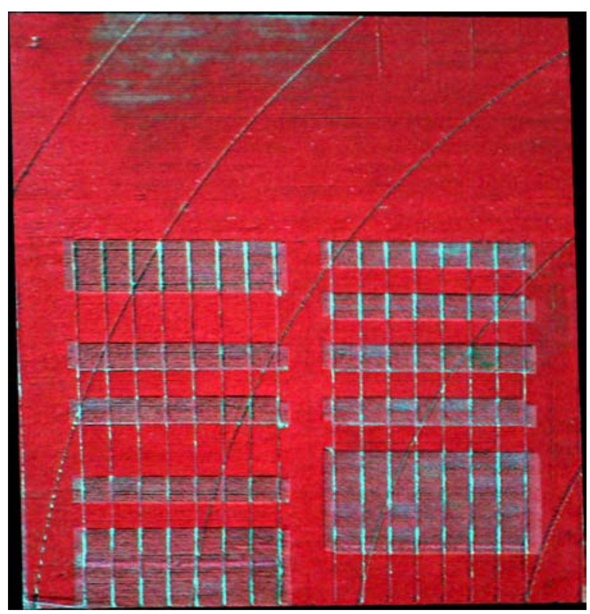

**Deep Veris**

# 2004 (7-11-2004)



# 2005, infrared; 8-29-05

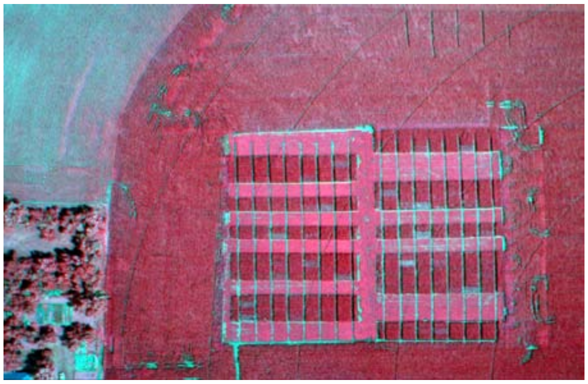




# 2006 (07-30-2006)

# 2007 (07-07-2007)

# 2008 (07-27-2008)




# 2008 Field Day