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Enhancing Continuous Corn Production under High-Residue Conditions With Starter Fluid Fertilizer Combinations and Placements

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ABSTRACT

Continuous corn production using conservation tillage often results in less uniform and smaller early season growth along with lower grain yields and profitability. This is especially true on fine-textured and poorly drained soils in the northern part of the Corn Belt where decomposition of surface residues is slower and soil temps are colder. The primary objective of this study was to determine the effects of fluid starter fertilizer combinations and placement of 10-34-0 (APP), 28-0-0 (UAN), and 12-0-0-26 (ATS) on second-year corn production in reduced tillage/high-residue conditions. Two field experiments, one on a Webster-Canisteo-Glencoe clay loam soil complex at Waseca and another on an Mt Carroll silt loam near Rochester, were established in April of 2012. Twelve of the 14 total treatments comprised a factorial arrangement of rates of three fluid starter fertilizers: 0 or 4 gal/ac of APP, 0 or 8 gal/ac of UAN, and 0, 2, and 4 gal/ac of ATS. The APP was applied in-furrow with the seed while UAN and ATS were applied as a dribble band on the soil surface within 2" of the seed row. Corn was planted at 35,000 seeds/ac on May 1 at Waseca and April 24 at Rochester. At the V2 growth stage UAN was injected 3" deep midway between the rows to give a total (at planting + V2) N rate of 200 lb/ac on all plots. At V6 growth stage, 8 corn plants from each plot were harvested to determine dry matter yield and N, P, K and S concentration. Grain yield and moisture content were determined by combine harvesting. Grain samples were analyzed for N, P, K and S concentration. A warm spring resulted in early planting and rapid early growth and development of corn. However an exceptionally dry July and August stressed corn and reduced yield potential at Waseca. Crop response to treatments in 2012 varied between locations. Early plant growth (plant heights and dry matter yields) was enhanced when N, P and S starter fertilizers as UAN, APP and ATS were applied at both sites, but to a greater extent at Waseca. At Rochester, grain yields were reduced 6 bu/ac with 4 gal/ac of APP (16 lb P_2O_5/ac) applied in-furrow at planting, when averaged across UAN and ATS treatments. No grain yield responses to N, P, and S starter fertilizer treatments were found at Waseca in 2012.

INTRODUCTION

Crop rotations in the Midwest have changed from the traditional corn-soybean rotation to more corn-intensive rotations. Due to the expanding demand for corn to supply the ethanol industry and the increasing insect and disease challenges facing soybean producers, some farmers are switching to a corn-corn-soybean rotation or for some, continuous corn. These rotations produce large amounts of biomass (corn stover) that often remain on the soil surface with present day tillage systems. This is good in terms of erosion control, but can be a significant problem from the standpoint of seedbed preparation, early corn growth, and yield.

Corn dominated crop rotations present a huge tillage challenge to corn producers on many poorly drained, colder soils of the northern Corn Belt because corn yields following corn are generally reduced significantly when conservation tillage practices are used. Research by Randall and Vetsch (2010) has shown many of the early growth and yield problems associated with corn after corn could be eliminated by using conventional tillage (i.e. moldboard plow) in combination with fluid starter fertilizers. Generally, for most northern Corn Belt farmers the moldboard plow is not an option, because of increased potential for erosion, lack of equipment, or the labor/time needed to plow large acreages. This research also showed fluid starter fertilizers [APP (10-34-0) applied in furrow or APP and UAN (28-0-0) dribbled on the soil surface] significantly increased early growth of corn by 13 to 43% and corn yield by 5 to 7 bu/ac. This study did not address a commonly asked question, would dual placement (APP in furrow and UAN dribbled on the soil surface) further enhance corn production.

Continuous corn generally shows slow early growth, pale spindly plants, and reduced yields with reduced tillage systems. Sulfur deficiency in corn has contributed to some of these pale looking plants. Corn yield responses to sulfur have been reported on medium and fine-textured soils in Minnesota and Iowa. In Minnesota we have very little data on the optimum rate and placement of sulfur containing fluid starter fertilizers for corn. With increased costs and price volatility of fertilizers, farmers have questions about what products, placements, and rates give them the most "bang for their buck".

The objectives of this study were to: 1) determine the effects of fluid starter fertilizer combinations and placement of 10-34-0 (APP), 28-0-0 (UAN), and 12-0-0-26 (ATS) on second-year corn production in reduced tillage/high-residue conditions and 2) provide management guidelines on placement and rates of UAN, APP, and ATS combined as a starter for crop consultants, local advisors, and the fertilizer industry as they serve corn producers trying to meet the growing needs for corn grain by the ethanol industry and livestock producers.

EXPERIMENTAL PROCEDURES

Two field experiments were established in April of 2012. One on a Webster-Canisteo-Glencoe (complex) clay loam soil at the Southern Research and Outreach Center, Waseca, MN and another on Mt Carroll silt loam four miles east of Rochester, Minnesota. The Rochester site was soybean in 2010 and corn in 2011; whereas the Waseca site had been corn since 2009. Both sites were fall chisel plowed after harvest in 2011. Fourteen total treatments were arranged in a randomized, complete-block design with four replications. Twelve of the 14 treatments comprised a factorial combination of sources and rates of three fluid starter fertilizers: 0 or 4 gal/ac of APP (5+16+0, lb/ac of N, P_2O_5, and S, respectively); 0 or 8 gal/ac of UAN (24+0+0); and 0, 2, and 4 gal/ac of ATS (2 gal = 3+0+5.8 and 4 gal = 5+0+11.5). The APP fluid starter was applied in-furrow with the seed while UAN and ATS were applied as a dribble band on the soil surface 2 inches from the seed row. Two additional treatments were included to measure crop response when adding 1 gal/ac of ATS in-furrow with 4 gal/ac of APP with and without 8 gal/ac of UAN dribbled on the soil surface. Each plot was 10 ft. wide (4 30-inch rows) by 50 ft. long (40 ft. long at Rochester). Soil samples (0-6 inch depth) were taken from each rep to characterize the research plot areas. Soil tests at Waseca averaged: pH = 7.0, organic matter = 7.2%, Bray P_1 = 23 ppm (very high) and exchangeable K = 221 ppm (very high) and at Rochester pH = 7.5, organic matter = 4.7%, Bray P_1 = 16 ppm (high) and exchangeable K = 137 ppm (high).

Corn (DeKalb 52-43VT3 at Waseca and DeKalb 51-85RIB at Rochester) was planted at 35,000 seeds/ac on May 1 (Waseca) and April 24 (Rochester). Weeds were controlled with a combination of pre (SureStart®) and post emergence (glyphosate) herbicides at labeled rates of application. Surface residue accumulation after planting averaged 54 and 56 at Waseca and Rochester, respectively. In late May stand counts were taken on the center two rows of each plot and plant stands were thinned to a uniform plant population. At V2 (May 23 at Rochester and May 30 at Waseca), UAN was injected 3 inches deep midway between the rows to give a total (at planting + at V2) N rate of 200 lb/ac on all plots. On June 8 at Waseca and June 7 at Rochester (V6 stage) 8 random plants from each plot were cut at ground level, dried, weighed to determine dry matter yield, ground, and analyzed for N, P, K and S concentration in plant tissue. On the same dates extended leaf plant heights from 10 random plants per plot were also measured. Because visual potassium deficiency symptoms were evident on June 26, 60 lb K_2O/ac was top dressed on June 28 (V11 growth stage) at Rochester. At R1 (July 12) SPAD meter readings were taken from the ear leaf of 30 plants in each plot. Relative leaf chlorophyll content (RLC) was calculated from these measurements. Grain yield and moisture content were determined on September 18-19 (Waseca) and October 1 (Rochester) by harvesting the center two rows of each plot with a research plot combine equipped with a weigh cell and moisture sensor. Grain yields were calculated at 15.5% moisture. Grain samples were saved, dried, ground, and analyzed for N, P, K and S.

Analysis of variance was used to determine significance of treatment means. A 0.10 level of significance is used throughout, except for interaction terms in the 3-yr (2010-2012) analysis, where a 0.05 level was *used. Because of distinct differences in soils, each location (Waseca and Rochester) was analyzed separately. A mixed model with block and year (year only for three-year data) as random effects and starter fertilizer treatments as a fixed effect was fitted to the data. Statistical analyses were performed using SAS Proc Mixed (SAS® 9.2, SAS Institute).*

RESULTS AND DISCUSSION

2012 Waseca location

Weather data characterizing the 2012 growing season at Waseca are presented in Table 1 and Figure 1. These data were taken from the SROC weather station located 0.5 miles from the research site. A record warm March and warmer-than-normal April and May resulted in early planting, warm soil temperatures and very rapid early growth and development of corn. May precipitation was 1.81 inches greater-than-normal. Excess rainfall in May is usually problematic in Minnesota, not so in 2012 because a warm and dry March and April meant corn planting was nearly complete. Moreover, a dry fall in 2011 left stored soil moisture well below normal, thus the wet May aided soil moisture recharge. On June 15th, 2.55 inches of precipitation were recorded at the SROC weather station another 1.00 inch fell on June 21st. The remainder of the growing season from June 22 through September 30 was very dry. Only 4.51 inches of precipitation fell during the period. Growing season (May-September) rainfall totaled 14.48 inches or 6.98 inches less-than-normal. Air temperatures from May–July were greater than normal and growing degree units (GDUs) for the season were 8% more than normal.

The drought reduced yields somewhat and dramatically increased variability in the data. Data from one replication were discarded prior to statistical analysis because of variability. Yields in that rep ranged from 152 to 216 bu/ac. The yield variability was NOT treatment related, it was related to moisture stress from subtle differences in elevation and soil type.

Treatment effects on plant height, coefficient of variation (CV) of plant height and whole plant dry matter yield are presented in (Table 2). Plant height was increased about 10% when APP was applied in-furrow and about 16% when UAN was applied as a surface band. Plant height CV, a measure of variability in plant height (lower CV = less variable plant height), was greatly reduced with UAN application. A significant APP×UAN interaction for plant height showed UAN increased plant height more than APP. Whereas a significant APP×ATS interaction for plant height showed APP increased plant height more than ATS, when only one of the two were applied. These data show how nitrogen in starter fertilizer enhanced early growth and plant uniformity in continuous corn grown with conservation tillage practices. Whole plant dry matter yields were increased 21, 42, and 12-18% by the main effects of APP, UAN and ATS application, respectively. Greatest dry matter yields were obtained when all three starter fertilizers were applied (treatment # 11 and 12). Dry matter yields of V6 corn plants that received a starter containing APP, UAN and ATS were nearly double the yield of the control treatment. One gal/ac of ATS plus 4 gal/ac of APP applied in-furrow did not affect V6 plant heights or yields compared with 4 gal/ac of APP alone. The application of fluid fertilizers at planting resulted in dramatic visual differences (greater early growth and plant uniformity and a darker green color) in May and June of 2012.

Nutrient concentrations and uptakes in V6 corn plants were affected by at least one treatment main effect in this study (Table 2). Generally, applying APP and UAN at planting reduced nutrient concentrations (likely due to the dilution effect), or had no effect. The dilution effect occurs when early growth increases dramatically, thus causing concentrations of some nutrients to decline. The significant APP×UAN and APP×ATS interactions for N concentration and APP×UAN interaction for S concentration were a result of the dilution effect as greatest nutrient concentrations occurred with the control treatment, which had the least amount of early growth. The significant APP×ATS interaction for S concentration showed the greatest S concentration with the control treatment (least growth), the lowest concentration with 4 gal/ac of APP alone and other treatment combinations being intermediate. Sulfur concentrations were marginally low (less than 0.20%) in some treatments. Numerically the lowest S concentration occurred with 4 gal/ac of APP + 1 gal/ac of ATS applied in-furrow + 8 gal/ac of UAN applied as a surface dribble band treatment (# 14). Potassium concentration increased slightly with ATS application, when averaged *across APP and UAN treatments. Generally, all starter treatments (APP, UAN and ATS) increased nutrient uptake of V6 corn plants. These data show how dramatically enhanced early growth from fluid starter fertilizer application can result in greater nutrient uptake regardless of nutrient concentration. No significant interactions for nutrient uptake were found.*

Treatment effects on grain moisture, grain yield, initial plant stand, final plant population and relative leaf chlorophyll are presented in Table 3. The summer drought resulted in grain that was very dry at harvest, especially considering the early harvest date (September 19). Grain moisture was reduced about 0.5 percentage points by the main effects of APP and UAN application at planting. Corn grain yields were not affected by APP, UAN and ATS application at planting and there were no significant interactions. The dramatic differences in early growth that occurred early in the growing season did not result in increased yields in this warm and dry growing season. An analysis of all 14 treatments found no significant differences for grain moisture and/or yield. Yields ranged from 205 to 216 bu/ac. Initial plant stand, final plant population (after thinning) and RLC were not affected by any of the treatments at this location in 2012.

Treatment effects on the concentration and uptake of N, P, K and S in corn grain are presented in Table 4. Generally, starter fertilizer treatments had little or no affect on grain nutrient concentrations and uptakes at Waseca. Grain P concentration was increased slightly (0.01 ppm) by the main effect of APP application, when averaged across UAN and ATS main effects. Grain S increased with increasing rate of ATS, when averaged across APP and UAN treatments. However, grain P and S uptake/removal were not affected by APP and ATS application, respectively. A significant APP×UAN interaction for grain S showed grain S was least with 0 gal of APP + 8 gal/ac of UAN treatments and greater with treatments where neither or both APP and UAN were applied. The authors have no logical explanation for the significant three-way (APP×UAN×ATS) interactions for grain P concentration and uptake.

2012 Rochester location

The 2012 growing season at Rochester, like Waseca, was considerably warmer than normal (data not shown). Unlike Waseca, Rochester received significantly greater rainfall in July and August, which resulted in excellent crop growth and development (Table 1 and Figure 1). Growing season precipitation totaled only 2.47 inches less than normal for the period May through September.

Plant heights and whole plant dry matter yields were affected by two of the main effects in the factorial analysis of treatments 1-12 (Table 5). When averaged across APP and ATS main effects, heights and yields of V6 corn plants were increased slightly with UAN application. Dry matter yields were greater with APP application, when averaged across UAN and ATS rates. An analysis of all 14 treatments found no significant differences among treatments for plant height, plant height CV and dry matter yield. Moreover, these data show the Rochester location (well drained silt loam soil) was somewhat less responsive to starter fertilizers compared with the Waseca location (poorly drained clay loam soil). A significant APP×UAN interaction for plant height showed plant heights were least when APP and UAN were not applied. Plant height CV was not affected by the main effects at Rochester. However, a significant APP×UAN interaction for CV showed CV was greatest (heights were more variable) when APP and UAN were not applied.

Generally, nutrient concentrations in V6 corn plants were not affected by the treatment main effects at this location (Table 5). Except for S concentration which increased slightly with 4 gal/ac of ATS compared with 0 and 2 gal/ac of ATS. Nitrogen, P and S uptake increased slightly with APP application, when averaged across UAN and ATS main effects. Nitrogen uptake was increased with UAN application, when averaged across APP and ATS main effects. Increases in nutrient uptake were primarily a result of increased dry matter yield as concentrations were not affected by treatments. An analysis of all 14 treatments found only N uptake had significant differences due to treatments. These data are contrary to what was found at Waseca and result from smaller differences in dry matter yield at Rochester.

Treatment effects on grain moisture, grain yield, initial plant stand, final plant population and relative leaf chlorophyll content are presented in Table 6. Corn grain was very dry at harvest. It ranged from 15.9 to 17.3% among treatments. A significant APP×UAN interaction for grain moisture showed moisture was greatest when APP and UAN were not applied and less when either or both were applied. Corn grain yield decreased 6 bu/ac with 4 gal/ac of APP compared with 0 gal/ac of APP, when averaged across UAN and ATS treatments. No significant interactions were found for corn grain yield. Initial plant stand was reduced 500-600 plant/ac with UAN and APP application and after thinning final plant populations were slightly (300 plant/ac) less with UAN application. It's unlikely the small final plant population differences reduced yields at this location. However, the combination of initial stand and grain yield reductions with APP suggest some negative effects of in-furrow placement on this silt loam soil. Non uniform rainfall distribution early in the growing season may have contributed to these responses (Figure 1). About 3.5 inches of precipitation fell in the 14-day period after planting, while the next 18 days brought only 0.1 inches. Then 3.3 inches of precipitation was recorded in 3 days, followed by a 19-day period with only 0.5 inches. It's possible the 6 bu/ac yield reduction with APP and the plant stand reduction with APP and UAN application could be a result of salt injury during these extended dry periods. Significant UAN×ATS and APP×UAN×ATS interactions for plant stand showed stand was reduced about 1000 plants/ac when two (UAN+ATS) or all three starter fertilizers were applied at planting. These data suggest the distance from the row to the location of the surface dribble band should be greater than the 2-inch distance used in this study. An analysis of all 14 treatments found adding 1 gal/ac of ATS in-furrow with 4 gal/ac of APP (treatment # 13) did not reduce initial plant stand compared with APP alone (# 7). However, the 4 gal/ac of APP + 1 gal/ac of ATS applied in-furrow + 8 gal/ac of UAN as surface dribble band treatment (# 14) did reduce stand about 1400 plants/ac compared with the 4 gal/ac of APP + 8 gal/ac of UAN + 0 gal/ac of ATS treatment (# 10). No significant interactions were found for final plant population. Relative leaf chlorophyll content at R1 was increased by the main effects of UAN and ATS application.

Treatment effects on the concentration and uptake of N, P, K and S in corn grain are presented in Table 7. Similar to the Waseca location in 2012, corn grain concentration and uptake/removal at Rochester was only minimally affected by starter fertilizer treatments. Of the three significant differences found, only one was of any consequence. Nitrogen concentration in corn grain was reduced slightly with ATS application, when averaged across APP and UAN treatments. Nutrient removal in corn grain averaged 125, 27, 45 and 10.5 lb of N, P (62 lb of P_2O_5), K (54 lb K_2O), and S per acre, respectively.

2012 SUMMARY

A record warm spring produced rapid early growth and development of corn in 2012. A summer drought resulted in increased yield variability at Waseca. Early growth responses to starter fertilizer treatments varied between locations, while yield responses were similar. At Waseca early growth and plant to plant uniformity of corn were greatly enhanced with fluid starter fertilizers but grain yields were not affected; whereas, at Rochester early growth responses were smaller, less frequent and positive yield responses were not observed. Key observations from the third year of this study include:

1) *Early plant growth (plant height and dry matter yield at V6) was greatly enhanced when N, P and S fluid starter fertilizers as UAN, APP and ATS were applied at Waseca*
2) *Four gal/ac of APP applied in-furrow and 8 gal/ac of UAN + 4 gal/ac of ATS applied as a surface band increased dry matter yield of V6 corn plants 98% compared with the control treatment at Waseca.*
3) *Application of APP and UAN modestly increased early growth of V6 corn at Rochester.*
4) *Grain yields were not affected by APP, UAN and ATS application at Waseca in 2012. A summer drought increased variability and likely limited yield potential at this site.*
5) *Grain yields were reduced 6 bu/ac with APP application at Rochester.*
6) *Applying UAN and ATS did not affect grain yields at Rochester in 2012.*
7) *Grain moisture was reduced slightly with APP and UAN application at Waseca.*
8) *Initial plant stands were reduced by fluid starter fertilizer application at Rochester. Small differences in final plant population should not have caused any yield reduction.*

9) *Results from the 2010 and 2011 years of the study are available online.*

2010–2012 SUMMARY

Waseca location

Words to describe the weather during the 2010 – 2012 growing seasons at Waseca would be unusual and record breaking. It's highly unlikely we could go through a three-year period and find three more contrasting years for research. In 2010, the growing season and June + July precipitation was the wettest on record. Two thousand eleven was a fairly typical spring in southern Minnesota. It started out cool and wet and then turned warm, but unfortunately it was too dry later in the year for optimum corn production. The 2012 growing season got an early start because of record warm temperatures in March. Excellent conditions for planting and early crop growth were observed in April, May and June, however July and August brought very little rainfall. Drought significantly affected crops throughout the Corn Belt and in southern Minnesota.

Treatment effects on plant height, CV of plant height and whole plant dry matter yield for the period 2010 – 2012 are presented in (Table 8). Plant heights were increased 8, 9 and 5% by the main effects of APP, UAN and ATS application, respectively, when averaged across other main effects. Moreover, CV of plant height was reduced by one percentage point with APP application and trended two percentage points lower with UAN application (P value = 0.114). A significant APP×UAN interaction for plant height showed plant heights were greatest with APP and UAN application, intermediate with APP or UAN application and considerably less without APP or UAN application. A significant APP×UAN interaction for plant height CV showed CV was greatest without APP and UAN application and was considerably less with APP and/or UAN application. Whole plant dry matter yields were increased 16 and 14% by the main effects of APP and ATS application, respectively, when averaged across other main effects. Dry matter yields were 24% greater with UAN application, however it was not statistically significant (P value = 0.114). An analysis of all 14 treatments found: numerically the greatest dry matter yields were obtained when all three starter fertilizers were applied (treatment # 11 and 12). Yields of V6-7 corn plants were 78% greater in these plots (N+P+S) compared with the control treatment. These data showed how fluid starter fertilizers (APP, UAN and ATS) enhanced early growth and plant uniformity of continuous corn grown with conservation tillage practices on poorly drained glacial till soils in Minnesota. Adding 1 gal/ac of ATS to 4 gal/ac of APP applied in-furrow did not affect plant heights or yields compared with 4 gal/ac of APP alone.

Treatment effects on nutrient concentration and uptake in V6-7 corn plants for the period 2010 – 2012 are presented in Table 8. Sulfur concentration decreased slightly by the main effect of UAN application, when averaged across APP and ATS treatments. No other significant differences were found for nutrient concentration in V6-7 corn plants. However, significant APP×ATS interactions were found for N, K and S concentration. The interaction for N showed N concentration was greatest without APP and ATS application (less early growth greater concentration) and less with other treatment combinations (greater early growth lower concentration – dilution effect). The differences in K concentration were very small and not agronomically important. A significant APP×ATS interaction for S showed S concentration was least with 4 gal/ac of APP + 0 gal/ac of ATS treatments and greater with other treatment combinations. Sulfur concentrations were low or marginal in some treatments. Numerically the lowest S concentration (0.166%) occurred with the 4 gal/ac of APP, 8 gal/ac of UAN and 0 gal/ac of ATS treatment (# 10). This treatment had excellent early growth, but did not receive S (ATS) fertilizer. The main effects of APP and ATS application increased nutrient uptake of V6-7 corn plants. However, these responses were primarily due to increased dry matter yields as concentrations were not different. These data show how dramatically enhanced early growth from fluid starter fertilizer application can result in greater nutrient uptake of small corn plants. A significant APP×ATS interaction for K uptake showed K uptake was greatest with APP and ATS application, intermediate with APP or ATS application and least when APP and ATS were not applied.

Treatment effects on grain moisture, grain yield, initial plant stand, final plant population and relative leaf chlorophyll content for the period 2010 – 2012 are presented in Table 9. Grain moisture was reduced 0.7 percentage points with APP application, when averaged across UAN and ATS treatments. No significant interactions for grain moisture were found. Averaged across years, corn grain yields were not affected by the main effects of APP, UAN and ATS application at planting and there were no significant interactions. Yields were numerically greater (4 bu/ac) with ATS application. Dramatic differences in early growth that occurred early in the growing season each year did not result in increased grain yields, when averaged across years. However, 2 of the 3 years (2011 and 2012) had moderate drought stress late in the growing season, which reduced yields and increased yield variability. Initial plant stand, final plant population and relative leaf chlorophyll content were not affected by treatment main effects at this location. A significant UAN×ATS interaction for RLC showed RLC was greatest in treatments that contained ATS and considerable less (3 percentage points) in treatment combinations without ATS. An analysis of all 14 treatments found no significant treatment effects for grain moisture, grain yield, initial plant stand, final plant population and relative leaf chlorophyll content.

Treatment effects on the concentration and uptake of N, P, K and S in corn grain for the three-year study period (2010 – 2012) are presented in Table 10. When averaged across years, concentration and uptake/removal of N, P and K in corn grain were not affected by treatment main effects. Grain S concentration and uptake increased slightly with ATS application, when averaged across APP and UAN treatments. There were no significant ($P \leq 0.05$) interactions found for grain nutrient concentration and uptake. . Nutrient removal in corn grain averaged 122, 26, 37 and 8.4 lb of N, P (61 lb of P_2O_5), K (44 lb K_2O), and S per acre, respectively.

Rochester location

The growing season weather at Rochester was extraordinarily wet in 2010, wet early in 2011 which resulted in late planting and aside from a few extended dry periods, nearly ideal in 2012. Unlike Waseca, Rochester received significantly greater rainfall in summer of 2011 and 2012, which resulted in excellent crop growth and development and less yield variability.

Treatment effects on plant height, plant height CV and whole plant dry matter yield for the period 2010 – 2012 are presented in (Table 11). Plant heights and dry matter yields of V6-8 corn plants increased slightly with UAN application, when averaged across APP and ATS treatment main effects. Plant height CV was reduced slightly with ATS application. A significant APP×UAN interaction for plant height showed plant heights were greatest with application of APP and UAN or APP alone, intermediate with UAN alone and least when APP and UAN were not applied. An analysis of all 14 treatments found significant differences among treatments for plant heights and dry matter yields. Numerically, the greatest plant heights and dry matter yields were obtained with the 4 gal/ac of APP, 8 gal/ac of UAN and 4 gal/ac of ATS treatment (# 12); whereas, the smallest heights and yields were found when only 2 gal/ac of ATS (# 2) was applied. Averaged across the three years, an N, P and S starter fertilizer (# 12) increased dry matter yields of V6-8 corn plants about 50%, compared with the control treatment. These data showed starter fertilizers generally enhanced early growth and dry matter yield of continuous corn grown with conservation tillage practices on a well drained loess soils in southeast Minnesota. However, the early growth response was somewhat less and not as consistent as on the poorly drained glacial till soil at Waseca. Adding 1 gal/ac of ATS to 4 gal/ac of APP applied in-furrow did not affect V6-8 plant heights or yields compared with 4 gal/ac of APP alone.

Treatment effects on nutrient concentration and uptake in V6-8 corn plants for the period 2010 – 2012 are presented in Table 11. Sulfur concentration increased with increasing ATS rate, when averaged across APP and UAN treatment main effects. No other significant differences were found for nutrient concentration in V6-8 corn plants. Nitrogen and P uptake increased with UAN application, when averaged across APP and ATS treatment main effects. Sulfur uptake was slightly greater with the 4 gal/ac rate of ATS compared with the 0 gal/ac rate of ATS. An analysis of all 14 treatments found significant differences among treatments for S concentration and N, P and S uptake in V6-8 corn plants.

Sulfur concentration was numerically greatest with the 4 gal/ac rate compared with the 2 gal/ac rate in all treatment combinations. Averaged across 3 years, S concentrations were generally sufficient in all treatments, suggesting greater S availability in loess soils with about 4% organic matter compared with glacial till soils with about 7% organic matter. However, hybrid and environmental differences may have contributed to this observation. Numerically the greatest N, P and S uptake in V6-8 corn plants occurred with the 4 gal/ac of APP + 8 gal/ac of UAN + 4 gal/ac of ATS treatment (# 12). Nitrogen, P and S uptake with this treatment (# 12) was 48, 45, and 59% greater than the control treatment, respectively.

Treatment effects on grain moisture, grain yield, initial stand, final plant population and relative leaf chlorophyll content for the period 2010 – 2012 are presented in Table 12. Grain moisture was reduced slightly by the main effects of UAN and ATS application and was numerically lower with APP application. Significant interactions for grain moisture generally showed moisture was greatest when no starter fertilizer was applied and least when only APP was applied or APP and ATS were applied. Averaged across years, corn grain yields were not affected by the main effects of APP, UAN or ATS application at planting and there were no significant interactions. An analysis of all 14 treatments found no significant differences for grain yield. When averaged across years, yields ranged from 211 to 216 bu/ac.

Initial plant stand and final plant population were reduced slightly with APP application, when averaged across UAN and ATS treatment main effects (Table 12). Although these differences were small and likely did not affect grain yields, they did occur in 2 of 3 years at this location (data not shown). A significant APP×UAN interaction for final plant population showed populations were reduced about 270 plants/ac in treatments with APP compared to treatments without APP and UAN. An analysis of all 14 treatments found significant differences for initial plant stand and final plant populations. Numerically the lowest plant stands and populations were observed with the 4 gal/ac of APP + 1 gal/ac of ATS applied in-furrow + 8 gal/ac of UAN applied as a surface dribble band treatment (# 14). The final plant population for this treatment (# 14) was significantly less than any other treatment. These data suggest combinations of fluid starter fertilizers that contain 1 gal/ac of ATS in-furrow with 4 gal/ac of APP may reduce stands on silt loam soils in Minnesota. Relative leaf chlorophyll content was increased about 1.2 percentage points with ATS application, when averaged across APP and UAN treatment main effects. An analysis of all 14 treatments showed RLC was least with the 0 gal/ac of APP + 8 gal/ac of UAN + 0 gal/ac of ATS treatment (# 4) and generally RLC was greater in treatments with ATS.

Treatment effects on the concentration and uptake of N, P, K and S in corn grain for the three-year study period (2010 – 2012) are presented in Table 13. When averaged across years, concentration and uptake/removal of N, P, K and S in corn grain were not affected by treatments at this location. A significant APP×ATS interaction for grain N concentration showed grain N was reduced slightly when either 4 gal/ac of APP or 4 gal/ac of ATS were applied compared with when neither was applied. A significant APP×UAN interaction for P concentration was of no agronomic importance as differences were very small. Nutrient removal in corn grain averaged 120, 26, 38 and 8.9 lb of N, P (60 lb of P_2O_5), K (46 lb K_2O), and S per acre, respectively.

2010 – 2012 SUMMARY (TREATMENT MAIN EFFECTS)

Waseca location

The application of 4 gal/ac of APP in-furrow on a glacial till soil at Waseca: (1) did not affect grain yield on these very high P-testing soils with pH≤7.0; (2) reduced grain moisture in 2 of 3 yr (individual year data from 2010 and 2011 not shown in this report) and for the 3–yr average; and (3) increased plant height and/or dry matter yield in 3 of 3 yr and for the 3-yr average while also reducing plant height CV (variability in plant height).

The application of 8 gal/ac of UAN in a surface dribble band about 2 inches from the corn row: (1) reduced grain moisture in 2 of 3 yr; (2) did not affect corn grain yield; (3) increased plant height and DM yield in 3 of 3 yr and for the 3-yr average; and (4) trended the 3-yr average CV of plant height lower (P value = 0.118).

The application of ATS at 2 or 4 gal/ac in a surface dribble band: (1) reduced grain moisture in 1 of 3 yr; (2) increased grain yield in 1 of 3 yr (6-9 bu/ac in 2010); and (3) increased plant height and/or DM yield in 3 of 3 yr and for the 3-yr average.

Rochester location

The application of 4 gal/ac of APP in-furrow on a loess soil at Rochester (southeast Minnesota): (1) increased grain yield in 1 of 3 yr and decreased yield in 1 of 3 yr; (2) reduced grain moisture in 2 of 3 yr (individual year data from 2010 and 2011 not shown in this report); and (3) increased plant height and/or dry matter yield in 3 of 3 yr.

The application of 8 gal/ac of UAN in a surface dribble band about 2 inches from the corn row: (1) reduced grain moisture in 1 of 3 yr; (2) did not affect corn grain yield; and (3) increased plant height and DM yield in 2 of 3 yr and for the 3-yr average.

The application of ATS at 2 or 4 gal/ac in a surface dribble band: (1) reduced 3-yr average grain moisture; (2) increased grain yield in 1 of 3 yr (8 bu/ac with 4 gal/ac rate in 2011); and (3) reduced 3-yr average CV of plant height.

CONCLUSIONS

The response of corn to fluid starter fertilizer was inconsistent in this study. However, starter fertilizers containing N, P and S applied as UAN, APP and ATS generally increased early growth and reduced plant variability of corn grown after corn in reduced tillage. Application of APP, UAN and ATS either independently or in combination were shown to reduce grain moisture at harvest. Yield responses to APP, UAN and ATS starter fertilizers were also inconsistent during this study period. Moreover, these data suggest yield responses to fluid starter fertilizer may be more likely on poorly drained glacial till soils in south-central MN, compared with well drained loess soils of southeast MN.

Although only a few positive corn grain yield responses were found in this study, consistent responses in early growth and reduced plant to plant variability were observed, especially on the poorly drained glacial till soil at Waseca. Collectively these responses should increase yield potential of corn after corn grown in high residue environments and help to narrow the yield gap between corn after corn and corn after soybean.

ACKNOWLEDGEMENT

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Table 1. Precipitation at Waseca and Rochester and growing degree units (GDUs) at Waseca in 2012.

		Precipitation					
		Waseca		Rochester		Waseca GDUs	
Month		2012	Normal[1/]	2012	Normal[1/]	2012	Normal[1/]
		- - - - - inches - - - - -		- - - - - inches - - - - -			
May		5.74	3.93	6.24	3.66	410	332
June		4.25	4.69	4.29	4.34	584	538
July		2.10	4.42	3.76	4.53	790	655
Aug.		1.45	4.75	2.98	4.66	577	597
Sept.		0.94	3.67	1.11	3.66	326	348
May-Sept.	Total	14.48	21.46	18.38	20.85	2687[2/]	2470

[1/] 30-Yr normal, 1971-2010.

Table 2. Early growth, yield, nutrient concentration and uptake of V6 corn plants at Waseca.

				V6	CV of	Whole Plant Samples at V7 (June 8)								
	Fertilizer rate			Plant	Plant		Concentration				Uptake			
Trt	APP	UAN	ATS	height	height	Yield	N	P	K	S	N	P	K	S
#	----	gal/ac	-----	inch	%	lb/ac	--------------	%	--------------		----------	lb/ac	-----------	
1	0	0	0	22.3	10.7	291	3.58	0.407	3.46	0.226	10.4	1.18	10.0	0.66
2	0	0	2	20.7	14.3	291	3.30	0.400	3.82	0.216	9.6	1.17	11.1	0.63
3	0	0	4	24.6	11.3	374	3.11	0.411	3.87	0.214	11.6	1.53	14.4	0.80
4	0	8	0	27.3	5.9	412	3.42	0.396	3.66	0.208	14.1	1.63	15.1	0.85
5	0	8	2	27.9	7.4	513	3.17	0.374	3.74	0.185	16.1	1.91	19.2	0.94
6	0	8	4	28.8	5.4	519	3.02	0.379	3.94	0.184	15.7	1.94	20.5	0.95
7	4	0	0	26.9	8.0	393	2.86	0.398	3.66	0.191	11.3	1.56	14.4	0.75
8	4	0	2	26.2	9.1	418	2.95	0.396	3.90	0.189	12.3	1.66	16.4	0.79
9	4	0	4	26.8	10.1	431	2.92	0.410	3.79	0.194	12.5	1.76	16.4	0.82
10	4	8	0	28.4	8.6	513	3.06	0.381	3.71	0.189	15.7	1.96	19.0	0.97
11	4	8	2	29.9	5.6	576	3.19	0.366	3.54	0.194	18.4	2.10	20.3	1.12
12	4	8	4	28.8	7.5	576	3.20	0.362	3.76	0.204	18.5	2.09	21.6	1.18
13	4	0	1*	28.5	6.3	443	2.98	0.369	3.57	0.190	13.2	1.63	16.0	0.85
14	4	8	1*	29.2	6.6	456	3.07	0.385	3.91	0.182	13.9	1.75	18.0	0.82
<u>Stats for RCB design (all 14 treatments)</u>														
P > F:				0.001	0.005	0.001	0.005	0.271	0.120	0.008	0.001	0.002	0.001	0.001
Average LSD(0.10):				1.8	3.4	94	0.27	NS	NS	0.019	3.1	0.36	4.1	0.18
<u>Stats for a Factorial Design (Treatments 1-12)</u>														
APP (10-34-0) applied in-furrow														
None				25.3	9.2	400	3.27	0.394	3.75	0.205	12.9	1.56	15.0	0.80
4 gal/ac				27.8	8.2	484	3.03	0.385	3.72	0.193	14.8	1.85	18.0	0.94
P > F:				0.001	0.992	0.001	0.002	0.320	0.719	0.016	0.014	0.001	0.002	0.003
UAN (28-0-0) applied as a surface dribble band														
None				24.6	10.6	366	3.12	0.404	3.75	0.205	11.3	1.48	13.8	0.74
8 gal/ac				28.5	6.7	518	3.18	0.376	3.72	0.194	16.4	1.94	19.3	1.00
P > F:				0.001	0.002	0.001	0.407	0.005	0.681	0.024	0.001	0.001	0.001	0.001
ATS (12-0-0-26) applied as a surface dribble band														
None				26.2	8.3	402	3.23	0.396	3.62	0.203	12.9	1.58	14.6	0.81
2 gal/ac				26.2	9.1	450	3.15	0.384	3.75	0.196	14.1	1.71	16.7	0.87
4 gal/ac				27.3	8.6	475	3.06	0.390	3.84	0.199	14.6	1.83	18.2	0.94
P > F:				0.127	0.798	0.030	0.148	0.571	0.031	0.415	0.142	0.062	0.009	0.046
Average LSD (0.10):				NS	NS	44	NS	NS	0.13	NS	NS	0.17	1.8	0.08
Interactions (P > F)														
APP×UAN				0.003	0.062	0.620	0.012	0.627	0.156	0.003	0.610	0.391	0.314	0.328
APP×ATS				0.079	0.127	0.652	0.013	0.959	0.237	0.070	0.750	0.644	0.487	0.823
UAN×ATS				0.082	0.308	0.405	0.910	0.492	0.090	0.955	0.433	0.521	0.858	0.550
APP×UAN×ATS				0.821	0.587	0.778	0.998	0.962	0.820	0.544	0.809	0.789	0.641	0.575

* One gal/ac rate of ATS applied in-furrow with seed and 10-34-0. P values = 0.001 were <0.001.

Table 3. Grain moisture and yield, plant stand, final plant population, and relative leaf chlorophyll at Waseca.

						Initial	Final	R1
	Fertilizer rate			Grain	Grain	Plant	Plant	Leaf
Trt	APP	UAN	ATS	H_2O	Yield	Stand	Pop.	Chloro
#	-------	gal/ac	-------	%	bu/ac	plants×10^3/A		%
1	0	0	0	16.1	206	33.0	33.0	98.4
2	0	0	2	16.3	205	33.5	33.1	95.6
3	0	0	4	16.1	220	33.5	32.9	98.3
4	0	8	0	15.5	216	32.8	32.8	96.9
5	0	8	2	15.4	221	33.1	33.0	96.4
6	0	8	4	15.6	214	33.9	33.5	96.6
7	4	0	0	15.6	213	33.3	33.0	97.3
8	4	0	2	15.6	209	33.1	33.0	96.8
9	4	0	4	15.5	209	33.1	33.1	96.6
10	4	8	0	15.3	213	33.4	33.2	96.4
11	4	8	2	15.1	209	33.0	32.8	99.2
12	4	8	4	15.7	216	33.5	33.3	97.3
13	4	0	1*	15.2	210	33.2	33.1	97.7
14	4	8	1*	15.5	211	32.7	32.6	95.4
Stats for RCB design (all 14 treatments)								
P > F:				0.315	0.997	0.956	0.981	0.697
Average LSD (0.10):				NS	NS	NS	NS	NS
Stats for a Factorial Design (Treatments 1-12)								
APP (10-34-0) applied in-furrow								
None				15.8	214	33.3	33.1	97.0
4 gal/ac				15.4	212	33.3	33.1	97.3
P > F:				0.069	0.732	0.809	0.908	0.736
UAN (28-0-0) applied as a surface dribble band								
None				15.9	210	33.3	33.0	97.2
8 gal/ac				15.4	215	33.3	33.1	97.1
P > F:				0.031	0.468	0.926	0.799	0.951
ATS (12-0-0-26) applied as a surface dribble band								
None				15.6	212	33.1	33.0	97.3
2 gal/ac				15.6	211	33.2	33.0	97.0
4 gal/ac				15.7	215	33.5	33.2	97.2
P > F:				0.813	0.861	0.545	0.671	0.970
Average LSD (0.10):				NS	NS	NS	NS	NS
Interactions (P > F)								
APP×UAN				0.212	0.697	0.724	0.908	0.303
APP×ATS				0.913	0.910	0.505	0.791	0.230
UAN×ATS				0.544	0.886	0.674	0.621	0.283
APP×UAN×ATS				0.856	0.561	0.957	0.771	0.876

* One gal/ac rate of ATS applied in-furrow with seed.

Table 4. Nutrient concentration and uptake in the corn grain at Waseca.

	Fertilizer rate			Grain concentration				Nutrient uptake in grain			
Trt	APP	UAN	ATS	N	P	K	S	N	P	K	S
#	------ gal/ac -------			-------------- % --------------				------------- lb/ac -------------			
1	0	0	0	1.34	0.20	0.32	0.082	130	19.8	30.9	8.1
2	0	0	2	1.24	0.20	0.32	0.087	121	19.4	30.7	8.5
3	0	0	4	1.33	0.23	0.34	0.093	138	24.1	35.5	9.6
4	0	8	0	1.25	0.20	0.31	0.079	128	20.9	32.4	8.1
5	0	8	2	1.27	0.24	0.35	0.083	132	25.0	36.2	8.7
6	0	8	4	1.24	0.21	0.32	0.087	126	21.3	32.8	8.8
7	4	0	0	1.26	0.23	0.34	0.085	127	23.3	33.9	8.6
8	4	0	2	1.28	0.24	0.35	0.083	127	24.1	34.4	8.2
9	4	0	4	1.31	0.23	0.34	0.088	130	22.9	33.3	8.7
10	4	8	0	1.28	0.26	0.37	0.083	129	26.4	36.8	8.4
11	4	8	2	1.26	0.20	0.31	0.087	124	19.5	30.4	8.6
12	4	8	4	1.27	0.23	0.34	0.089	130	23.8	35.0	9.2
13	4	0	1*	1.30	0.21	0.33	0.083	129	20.7	32.9	8.3
14	4	8	1*	1.26	0.25	0.35	0.084	126	24.3	35.3	8.5
Stats for RCB design (all 14 treatments)											
P > F:				0.707	0.054	0.400	0.063	0.990	0.117	0.684	0.827
Average LSD (0.10):				NS	0.03	NS	0.006	NS	NS	NS	NS
Stats for a Factorial Design (Treatments 1-12)											
APP (10-34-0) applied in-furrow											
None				1.28	0.22	0.33	0.085	129	21.8	33.1	8.6
4 gal/ac				1.28	0.23	0.34	0.086	128	23.4	34.0	8.6
P > F:				1.000	0.024	0.179	0.599	0.774	0.128	0.530	0.930
UAN (28-0-0) applied as a surface dribble band											
None				1.29	0.22	0.33	0.086	129	22.3	33.1	8.6
8 gal/ac				1.26	0.22	0.33	0.085	128	22.8	33.9	8.6
P > F:				0.132	0.929	0.956	0.247	0.892	0.593	0.566	0.958
ATS (12-0-0-26) applied as a surface dribble band											
None				1.28	0.23	0.33	0.082	129	22.6	33.5	8.3
2 gal/ac				1.26	0.22	0.33	0.085	126	22.0	32.9	8.5
4 gal/ac				1.29	0.23	0.34	0.089	131	23.1	34.2	9.1
P > F:				0.569	0.797	0.867	0.002	0.685	0.706	0.769	0.127
Average LSD (0.10):				NS	NS	NS	0.003	NS	NS	NS	NS
Interactions (P > F)											
APP×UAN				0.413	0.488	0.801	0.057	0.927	0.474	0.676	0.498
APP×ATS				0.685	0.073	0.203	0.340	0.996	0.138	0.363	0.629
UAN×ATS				0.433	0.359	0.655	0.705	0.679	0.482	0.731	0.830
APP×UAN×ATS				0.306	0.006	0.048	0.610	0.464	0.020	0.125	0.626

* One gal/ac rate of ATS applied in-furrow with seed and 10-34-0.

Table 5. Early growth, yield, nutrient concentration and uptake of V6 corn plants at Rochester.

				V6	CV of	Whole Plant Samples at V6 (June 7)								
	Fertilizer rate			Plant	Plant		Concentration				Uptake			
Trt	APP	UAN	ATS	height	height	Yield	N	P	K	S	N	P	K	S
#	---- gal/ac -----			inch	%	lb/ac	-------------- % --------------				---------- lb/ac -----------			
1	0	0	0	22.8	10.0	247	3.69	0.384	1.49	0.241	9.1	0.95	3.66	0.59
2	0	0	2	23.8	6.8	256	3.78	0.413	1.76	0.247	9.6	1.05	4.50	0.63
3	0	0	4	23.6	8.3	290	3.64	0.382	1.92	0.259	10.5	1.11	5.74	0.75
4	0	8	0	23.9	7.6	290	3.81	0.380	1.83	0.241	10.9	1.11	5.56	0.69
5	0	8	2	26.2	6.8	313	3.72	0.394	1.83	0.239	11.6	1.24	5.89	0.75
6	0	8	4	25.0	6.4	309	3.80	0.384	1.76	0.247	11.6	1.19	5.83	0.75
7	4	0	0	24.8	6.4	323	3.82	0.404	1.65	0.252	12.2	1.32	5.61	0.81
8	4	0	2	24.4	7.7	280	3.85	0.414	1.63	0.252	10.8	1.17	4.92	0.71
9	4	0	4	24.6	6.7	332	3.71	0.398	1.96	0.255	12.3	1.33	6.67	0.84
10	4	8	0	25.0	9.2	332	3.76	0.392	1.79	0.243	12.5	1.30	6.00	0.81
11	4	8	2	24.5	6.6	342	3.85	0.389	1.54	0.242	13.1	1.32	5.43	0.82
12	4	8	4	24.7	7.4	323	3.90	0.399	1.38	0.261	12.5	1.30	4.77	0.84
13	4	0	1*	25.5	5.9	313	3.63	0.399	1.72	0.241	11.3	1.24	5.66	0.75
14	4	8	1*	24.1	9.1	313	3.88	0.387	1.35	0.246	12.2	1.23	4.39	0.77
Stats for RCB design (all 14 treatments)														
P > F:				0.113	0.150	0.243	0.349	0.923	0.736	0.365	0.079	0.421	0.851	0.145
Average LSD(0.10):				NS	NS	NS	NS	NS	NS	NS	2.1	NS	NS	NS
Stats for a Factorial Design (Treatments 1-12)														
APP (10-34-0) applied in-furrow														
None				24.2	7.6	284	3.74	0.389	1.76	0.245	10.6	1.11	5.20	0.69
4 gal/ac				24.7	7.3	322	3.82	0.399	1.66	0.251	12.2	1.29	5.57	0.80
P > F:				0.247	0.626	0.014	0.113	0.252	0.420	0.168	0.002	0.008	0.531	0.004
UAN (28-0-0) applied as a surface dribble band														
None				24.0	7.6	288	3.75	0.399	1.74	0.251	10.8	1.15	5.18	0.72
8 gal/ac				24.9	7.3	318	3.81	0.389	1.69	0.245	12.0	1.24	5.58	0.78
P > F:				0.030	0.631	0.048	0.213	0.260	0.729	0.150	0.017	0.177	0.506	0.146
ATS (12-0-0-26) applied as a surface dribble band														
None				24.1	8.3	298	3.77	0.390	1.69	0.244	11.2	1.17	5.21	0.72
2 gal/ac				24.7	7.0	298	3.80	0.402	1.69	0.245	11.3	1.20	5.19	0.73
4 gal/ac				24.5	7.2	313	3.76	0.391	1.76	0.255	11.7	1.23	5.75	0.80
P > F:				0.421	0.183	0.614	0.806	0.403	0.883	0.037	0.605	0.752	0.678	0.198
Average LSD (0.10):				NS	NS	NS	NS	NS	NS	0.008	NS	NS	NS	NS
Interactions (P > F)														
APP×UAN				0.061	0.076	0.520	0.741	0.767	0.319	0.750	0.479	0.412	0.225	0.644
APP×ATS				0.097	0.659	0.590	0.868	0.608	0.649	0.960	0.643	0.506	0.622	0.542
UAN×ATS				0.720	0.834	0.320	0.187	0.489	0.167	0.777	0.467	0.624	0.311	0.450
APP×UAN×ATS				0.736	0.107	0.847	0.536	0.988	0.906	0.307	0.756	0.918	0.928	0.846

* One gal/ac rate of ATS applied in-furrow with seed and 10-34-0.

Table 6. Grain moisture and yield, plant stand, final plant population, and relative leaf chlorophyll at Rochester.

						Initial	Final	VT-R1
	Fertilizer rate			Grain	Grain	Plant	Plant	Leaf
Trt	APP	UAN	ATS	H_2O	Yield	Stand	Pop.	Chloro
#	------ gal/ac -------			%	bu/ac	plants×10^3/A		%
1	0	0	0	17.3	239	35.5	34.4	97.5
2	0	0	2	16.4	238	35.4	34.4	98.5
3	0	0	4	16.6	239	35.9	34.4	99.0
4	0	8	0	16.7	238	35.4	34.1	98.2
5	0	8	2	16.1	240	35.0	34.0	99.1
6	0	8	4	16.4	237	34.2	34.0	98.7
7	4	0	0	16.4	234	34.5	34.2	98.6
8	4	0	2	16.9	233	35.5	34.4	98.6
9	4	0	4	15.9	234	34.5	34.0	98.4
10	4	8	0	16.5	231	35.2	34.2	98.4
11	4	8	2	16.3	237	34.0	33.9	99.0
12	4	8	4	16.9	230	34.3	34.0	99.1
13	4	0	1*	16.4	232	34.0	33.6	99.6
14	4	8	1*	16.8	228	33.8	33.3	99.1
Stats for RCB design (all 14 treatments)								
P > F:				0.477	0.568	0.007	0.096	0.011
Average LSD (0.10):				NS	NS	1.0	0.6	0.8
Stats for a Factorial Design (Treatments 1-12)								
APP (10-34-0) applied in-furrow								
None				16.6	239	35.2	34.2	98.5
4 gal/ac				16.5	233	34.6	34.1	98.7
P > F:				0.975	0.035	0.010	0.252	0.258
UAN (28-0-0) applied as a surface dribble band								
None				16.6	236	35.2	34.3	98.4
8 gal/ac				16.5	236	34.7	34.0	98.7
P > F:				0.335	0.875	0.025	0.031	0.080
ATS (12-0-0-26) applied as a surface dribble band								
None				16.7	236	35.1	34.2	98.2
2 gal/ac				16.4	237	35.0	34.2	98.8
4 gal/ac				16.4	235	34.7	34.1	98.8
P > F:				0.904	0.793	0.290	0.650	0.008
Average LSD (0.10):				NS	NS	NS	NS	0.4
Interactions (P > F)								
APP×UAN				0.068	0.894	0.329	0.380	0.944
APP×ATS				0.518	0.912	0.938	0.890	0.238
UAN×ATS				0.178	0.614	0.028	0.583	0.798
APP×UAN×ATS				0.248	0.912	0.054	0.638	0.092

* One gal/ac rate of ATS applied in-furrow with seed.

Table 7. Nutrient concentration and uptake in the corn grain at Rochester.

	Fertilizer rate			Grain concentration					Nutrient uptake in grain			
Trt	APP	UAN	ATS	N	P	K	S		N	P	K	S
#	------ gal/ac -------			-------------- % --------------					------------- lb/ac -------------			
1	0	0	0	1.17	0.24	0.39	0.092		133	26.7	44.1	10.4
2	0	0	2	1.10	0.27	0.44	0.096		124	30.9	49.4	10.8
3	0	0	4	1.08	0.23	0.38	0.094		122	25.8	43.0	10.6
4	0	8	0	1.18	0.23	0.40	0.094		131	26.0	45.4	10.4
5	0	8	2	1.10	0.28	0.43	0.097		124	31.5	49.3	11.0
6	0	8	4	1.14	0.25	0.39	0.096		128	28.1	44.0	10.8
7	4	0	0	1.13	0.26	0.41	0.096		125	28.8	45.9	10.6
8	4	0	2	1.09	0.25	0.40	0.095		122	29.5	46.3	10.5
9	4	0	4	1.10	0.24	0.38	0.094		121	26.3	42.1	10.4
10	4	8	0	1.12	0.24	0.41	0.096		122	26.6	44.7	10.5
11	4	8	2	1.13	0.23	0.38	0.094		127	25.7	42.6	10.6
12	4	8	4	1.13	0.23	0.38	0.098		123	25.5	41.9	10.6
13	4	0	1*	1.14	0.25	0.41	0.093		125	27.4	44.9	10.1
14	4	8	1*	1.11	0.24	0.37	0.095		119	24.5	40.0	10.3
Stats for RCB design (all 14 treatments)												
P > F:				0.221	0.503	0.454	0.383		0.443	0.343	0.342	0.745
Average LSD (0.10):				NS	NS	NS	NS		NS	NS	NS	NS
Stats for a Factorial Design (Treatments 1-12)												
APP (10-34-0) applied in-furrow												
None				1.12	0.25	0.41	0.094		127	28.2	46.3	10.6
4 gal/ac				1.12	0.24	0.40	0.095		124	27.5	44.3	10.6
P > F:				0.312	0.418	0.327	0.348		0.073	0.350	0.196	0.509
UAN (28-0-0) applied as a surface dribble band												
None				1.13	0.25	0.41	0.095		126	28.8	46.0	10.6
8 gal/ac				1.12	0.24	0.40	0.095		125	27.0	44.5	10.6
P > F:				0.133	0.746	0.913	0.163		0.471	0.508	0.733	0.584
ATS (12-0-0-26) applied as a surface dribble band												
None				1.11	0.24	0.38	0.094		124	26.7	43.0	10.6
2 gal/ac				1.15	0.24	0.40	0.094		128	27.0	45.0	10.5
4 gal/ac				1.10	0.26	0.41	0.095		124	29.4	46.9	10.7
P > F:				0.016	0.264	0.150	0.641		0.236	0.102	0.082	0.499
Average LSD (0.10):				0.03	NS	NS	NS		NS	NS	NS	NS
Interactions (P > F)												
APP×UAN				1.000	0.337	0.577	0.850		0.891	0.201	0.407	0.886
APP×ATS				0.093	0.076	0.096	0.090		0.195	0.246	0.324	0.411
UAN×ATS				0.301	0.696	0.772	0.414		0.459	0.648	0.794	0.717
APP×UAN×ATS				0.543	0.963	0.985	0.703		0.739	0.883	0.945	0.965

* One gal/ac rate of ATS applied in-furrow with seed and 10-34-0.

Table 8. Early growth, yield, nutrient concentration and uptake of V6-7 corn plants as affected by starter fertilizer treatments at Waseca (three-year average, 2010-2012).

				V6-8	CV of	Whole Plant Samples at V6-8								
	Fertilizer rate			Plant	Plant		Concentration				Uptake			
Trt	APP	UAN	ATS	height	height	Yield	N	P	K	S	N	P	K	S
#	---- gal/ac -----			inch	%	lb/ac	-------------- % --------------				---------- lb/ac -----------			
1	0	0	0	27.0	10.1	432	3.64	0.408	4.31	0.200	15.8	1.77	19.2	0.84
2	0	0	2	28.1	10.6	519	3.50	0.413	4.38	0.196	18.5	2.17	23.6	1.00
3	0	0	4	31.2	8.5	609	3.42	0.431	4.58	0.202	21.4	2.64	29.5	1.20
4	0	8	0	32.2	6.0	637	3.62	0.411	4.34	0.189	23.3	2.62	28.4	1.19
5	0	8	2	32.9	6.8	707	3.47	0.406	4.24	0.188	25.4	2.90	30.8	1.35
6	0	8	4	33.2	6.3	694	3.21	0.403	4.55	0.183	22.9	2.83	32.3	1.29
7	4	0	0	31.8	7.3	571	3.32	0.416	4.37	0.183	19.4	2.37	25.5	1.03
8	4	0	2	33.2	7.1	673	3.43	0.427	4.48	0.186	23.6	2.90	30.9	1.24
9	4	0	4	33.0	7.8	659	3.40	0.419	4.42	0.196	22.8	2.76	29.9	1.28
10	4	8	0	33.5	7.4	720	3.24	0.394	4.53	0.166	23.5	2.90	33.9	1.20
11	4	8	2	34.1	6.7	770	3.40	0.404	4.34	0.185	26.5	3.15	34.1	1.42
12	4	8	4	34.8	5.5	766	3.33	0.395	4.34	0.195	25.7	3.05	33.6	1.48
13	4	0	1*	33.3	7.0	649	3.38	0.409	4.35	0.185	22.3	2.68	29.0	1.20
14	4	8	1*	32.9	7.6	686	3.21	0.412	4.51	0.173	22.2	2.85	31.8	1.17
Stats for RCB design (all 14 treatments)														
P > F:				0.001	0.008	0.001	0.102	0.412	0.251	0.011	0.009	0.001	0.001	0.001
Average LSD(0.10):				1.7	1.9	78	NS	NS	NS	0.014	4.1	0.45	4.2	0.20
Stats for a Factorial Design (Treatments 1-12)														
APP (10-34-0) applied in-furrow														
None				30.8	8.0	600	3.48	0.412	4.40	0.193	21.2	2.49	27.3	1.15
4 gal/ac				33.4	7.0	693	3.35	0.409	4.41	0.185	23.6	2.85	31.3	1.28
P > F:				0.001	0.015	0.001	0.163	0.618	0.828	0.107	0.003	0.008	0.001	0.025
UAN (28-0-0) applied as a surface dribble band														
None				30.7	8.6	577	3.45	0.419	4.42	0.194	20.3	2.43	26.4	1.10
8 gal/ac				33.5	6.5	716	3.38	0.402	4.39	0.184	24.5	2.91	32.2	1.32
P > F:				0.066	0.118	0.114	0.593	0.323	0.539	0.069	0.249	0.266	0.146	0.222
ATS (12-0-0-26) applied as a surface dribble band														
None				31.1	7.7	590	3.46	0.407	4.39	0.185	20.5	2.42	26.8	1.07
2 gal/ac				32.1	7.8	667	3.45	0.412	4.36	0.189	23.5	2.78	29.8	1.25
4 gal/ac				33.0	7.0	682	3.34	0.412	4.47	0.194	23.2	2.82	31.3	1.31
P > F:				0.019	0.229	0.001	0.121	0.713	0.581	0.499	0.017	0.001	0.012	0.044
Average LSD (0.10)				1.0	NS	30	NS	NS	NS	NS	1.7	0.15	2.2	0.14
Interactions (P > F)														
APP×UAN				0.003	0.005	0.166	0.797	0.285	0.781	0.486	0.163	0.201	0.409	0.354
APP×ATS				0.185	0.486	0.296	0.002	0.388	0.018	0.001	0.756	0.158	0.004	0.771
UAN×ATS				0.379	0.983	0.070	0.580	0.427	0.138	0.243	0.164	0.053	0.105	0.265
APP×UAN×ATS				0.078	0.078	0.276	0.606	0.470	0.757	0.155	0.219	0.248	0.343	0.113

* One gal/ac rate of ATS applied in-furrow with seed and 10-34-0. P values=0.001 were <0.001

Table 9. Grain moisture and yield, plant stand, final plant population, and relative leaf chlorophyll at Waseca (three-year average, 2010-2012).

						Initial	Final	VT-R1
	Fertilizer rate			Grain	Grain	Plant	Plant	Leaf
Trt	APP	UAN	ATS	H_2O	Yield	Stand	Pop.	Chloro
#	--------	gal/ac	---------	%	bu/ac	plants×10^3/ac		%
1	0	0	0	18.3	201	33.5	33.2	95.3
2	0	0	2	18.0	207	33.4	32.8	96.0
3	0	0	4	17.4	211	32.6	32.3	98.7
4	0	8	0	17.5	209	33.6	33.2	94.6
5	0	8	2	17.2	211	33.1	32.7	97.0
6	0	8	4	17.5	206	32.9	32.5	97.7
7	4	0	0	17.4	205	33.0	32.7	95.4
8	4	0	2	17.2	210	33.3	33.0	96.4
9	4	0	4	17.1	211	33.3	33.0	97.7
10	4	8	0	17.3	204	33.2	33.1	95.3
11	4	8	2	16.5	207	32.5	32.1	98.6
12	4	8	4	16.7	209	32.9	32.8	97.1
13	4	0	1*	17.4	209	32.6	32.5	97.0
14	4	8	1*	17.1	201	32.0	31.9	95.8
Stats for RCB design (all 14 treatments)								
P > F:				0.584	0.478	0.371	0.256	0.290
Average LSD (0.10):				NS	NS	NS	NS	NS
Stats for a Factorial Design (Treatments 1-12)								
APP (10-34-0) applied in-furrow								
None				17.7	207	33.2	32.8	96.6
4 gal/ac				17.0	208	33.0	32.8	96.8
P > F:				0.007	0.860	0.571	0.981	0.578
UAN (28-0-0) applied as a surface dribble band								
None				17.6	207	33.2	32.8	96.6
8 gal/ac				17.1	208	33.0	32.8	96.7
P > F:				0.153	0.891	0.508	0.667	0.766
ATS (12-0-0-26) applied as a surface dribble band								
None				17.6	205	33.3	33.1	95.2
2 gal/ac				17.2	209	33.1	32.7	97.0
4 gal/ac				17.2	209	32.9	32.6	97.8
P > F:				0.838	0.278	0.628	0.475	0.381
Average LSD (0.10):				NS	NS	NS	NS	NS
Interactions (P > F)								
APP×UAN				0.753	0.269	0.478	0.338	0.223
APP×ATS				0.850	0.912	0.470	0.300	0.166
UAN×ATS				0.329	0.408	0.479	0.361	0.002
APP×UAN×ATS				0.372	0.414	0.722	0.331	0.803

* One gal/ac rate of ATS applied in-furrow with seed.

Table 10. Nutrient concentration and uptake in the corn grain as affected by starter fertilizer treatments at Waseca (three-year average, 2010-2012).

	Fertilizer rate			Grain concentration					Nutrient uptake in grain			
Trt	APP	UAN	ATS	N	P	K	S		N	P	K	S
#	------	gal/ac	-------	--------------	%	--------------			-------------	lb/ac	-------------	
1	0	0	0	1.24	0.26	0.36	0.082		118	24.3	34.1	7.8
2	0	0	2	1.22	0.26	0.37	0.085		120	25.8	35.9	8.4
3	0	0	4	1.26	0.28	0.38	0.093		126	27.5	37.7	9.3
4	0	8	0	1.22	0.26	0.37	0.082		121	26.0	36.8	8.1
5	0	8	2	1.23	0.28	0.38	0.084		124	27.6	38.3	8.4
6	0	8	4	1.20	0.27	0.38	0.090		117	26.2	37.2	8.8
7	4	0	0	1.25	0.27	0.39	0.081		122	26.1	37.4	7.9
8	4	0	2	1.25	0.27	0.38	0.083		125	27.3	37.3	8.3
9	4	0	4	1.25	0.27	0.37	0.088		124	26.8	37.2	8.8
10	4	8	0	1.23	0.28	0.38	0.082		119	27.4	37.3	8.0
11	4	8	2	1.24	0.26	0.36	0.086		122	25.3	35.7	8.4
12	4	8	4	1.23	0.27	0.39	0.090		122	26.1	38.1	8.9
13	4	0	1*	1.23	0.27	0.37	0.084		122	26.6	36.6	8.3
14	4	8	1*	1.22	0.27	0.37	0.083		116	25.7	34.8	7.9
Stats for RCB design (all 14 treatments)												
P > F:				0.288	0.604	0.430	0.001		0.263	0.485	0.131	0.001
Average LSD (0.10)				NS	NS	NS	0.004		NS	NS	NS	0.5
Stats for a Factorial Design (Treatments 1-12)												
APP (10-34-0) applied in-furrow												
None				1.23	0.27	0.37	0.086		121	26.2	36.7	8.5
4 gal/ac				1.24	0.27	0.38	0.085		122	26.5	37.2	8.4
P > F:				0.395	0.793	0.623	0.574		0.564	0.685	0.356	0.642
UAN (28-0-0) applied as a surface dribble band												
None				1.25	0.27	0.37	0.085		122	26.3	36.6	8.4
8 gal/ac				1.23	0.27	0.38	0.086		121	26.4	37.3	8.4
P > F:				0.168	0.714	0.158	0.865		0.288	0.818	0.204	0.768
ATS (12-0-0-26) applied as a surface dribble band												
None				1.24	0.27	0.38	0.082		120	25.9	36.4	8.0
2 gal/ac				1.24	0.27	0.37	0.085		122	26.5	36.8	8.4
4 gal/ac				1.24	0.27	0.38	0.090		122	26.7	37.5	8.9
P > F:				0.976	0.877	0.354	0.009		0.489	0.490	0.212	0.017
Average LSD (0.10)				NS	NS	NS	0.003		NS	NS	NS	0.4
Interactions (P > F)												
APP×UAN				0.466	0.442	0.237	0.063		0.654	0.267	0.085	0.486
APP×ATS				0.834	0.072	0.078	0.492		0.985	0.228	0.172	0.872
UAN×ATS				0.208	0.371	0.831	0.741		0.166	0.162	0.667	0.340
APP×UAN×ATS				0.244	0.157	0.251	0.779		0.166	0.212	0.099	0.467

* One gal/ac rate of ATS applied in-furrow with seed and 10-34-0.

Table 11. Early growth, yield, nutrient concentration and uptake of V6-7 corn plants as affected by starter fertilizer treatments at Rochester (three-year average, 2010-2012).

				V6-8	CV of	Whole Plant Samples at V6-8								
	Fertilizer rate			Plant	Plant		Concentration				Uptake			
Trt	APP	UAN	ATS	height	height	Yield	N	P	K	S	N	P	K	S
#	----	gal/ac	-----	inch	%	lb/ac	--------------	%	--------------		----------	lb/ac	-----------	
1	0	0	0	29.1	7.9	695	3.60	0.347	2.91	0.214	24.9	2.71	25.93	1.42
2	0	0	2	29.0	6.2	669	3.62	0.358	2.52	0.224	24.0	2.52	19.24	1.42
3	0	0	4	29.5	6.8	704	3.61	0.349	2.57	0.231	25.3	2.64	20.33	1.57
4	0	8	0	29.7	7.0	780	3.64	0.345	2.79	0.217	27.7	2.91	26.60	1.63
5	0	8	2	31.1	6.4	822	3.57	0.350	2.46	0.220	28.9	2.98	23.30	1.75
6	0	8	4	30.8	5.8	776	3.68	0.349	2.40	0.232	28.2	2.85	21.25	1.79
7	4	0	0	31.9	6.0	951	3.56	0.352	2.57	0.214	32.7	3.47	29.72	1.91
8	4	0	2	32.5	6.5	927	3.55	0.365	2.79	0.220	31.4	3.58	34.40	1.90
9	4	0	4	32.9	6.5	989	3.56	0.356	2.58	0.222	34.7	3.67	29.99	2.08
10	4	8	0	32.5	7.3	913	3.57	0.359	2.55	0.212	31.4	3.39	27.77	1.84
11	4	8	2	32.8	5.9	1009	3.63	0.349	2.28	0.220	35.6	3.67	27.88	2.14
12	4	8	4	32.9	6.3	1037	3.70	0.365	2.69	0.231	37.0	3.94	38.47	2.26
13	4	0	1*	32.4	6.4	943	3.53	0.358	2.59	0.213	32.4	3.54	31.59	1.86
14	4	8	1*	32.6	6.7	998	3.63	0.361	2.36	0.218	34.4	3.76	32.00	2.05
Stats for RCB design (all 14 treatments)														
P > F:				0.001	0.440	0.007	0.584	0.865	0.686	0.014	0.001	0.014	0.353	0.001
Average LSD(0.10):				1.7	NS	175	NS	NS	NS	0.010	5.0	0.69	NS	0.30
Stats for a Factorial Design (Treatments 1-12)														
APP (10-34-0) applied in-furrow														
None				29.9	6.7	741	3.62	0.350	2.61	0.223	26.5	2.77	22.78	1.60
4 gal/ac				32.6	6.4	971	3.60	0.358	2.58	0.220	33.8	3.62	31.37	2.02
P > F:				0.148	0.501	0.196	0.767	0.434	0.859	0.556	0.154	0.207	0.330	0.153
UAN (28-0-0) applied as a surface dribble band														
None				30.8	6.7	822	3.58	0.354	2.66	0.221	28.8	3.10	26.60	1.72
8 gal/ac				31.7	6.5	890	3.63	0.353	2.53	0.222	31.5	3.29	27.54	1.90
P > F:				0.001	0.611	0.013	0.264	0.887	0.243	0.744	0.005	0.090	0.663	0.147
ATS (12-0-0-26) applied as a surface dribble band														
None				30.8	7.1	835	3.59	0.351	2.71	0.214	29.2	3.12	27.50	1.70
2 gal/ac				31.4	6.3	857	3.59	0.356	2.51	0.221	30.0	3.19	26.20	1.80
4 gal/ac				31.5	6.4	876	3.64	0.354	2.56	0.229	31.3	3.28	27.51	1.92
P > F:				0.222	0.051	0.516	0.334	0.640	0.506	0.000	0.262	0.344	0.900	0.043
Average LSD (0.10)				NS	0.6	NS	NS	NS	NS	0.004	NS	NS	NS	0.13
Interactions (P > F)														
APP×UAN				0.038	0.389	0.177	0.345	0.622	0.931	0.603	0.322	0.380	0.663	0.214
APP×ATS				0.957	0.408	0.539	0.616	0.706	0.417	0.810	0.428	0.444	0.287	0.620
UAN×ATS				0.570	0.585	0.352	0.315	0.159	0.574	0.305	0.232	0.698	0.471	0.253
APP×UAN×ATS				0.320	0.103	0.752	0.332	0.534	0.375	0.369	0.672	0.707	0.255	0.640

* One gal/ac rate of ATS applied in-furrow with seed and 10-34-0.

Table 12. Grain moisture and yield, plant stand, final plant population, and relative leaf chlorophyll at Rochester (three-year average, 2010-2012).

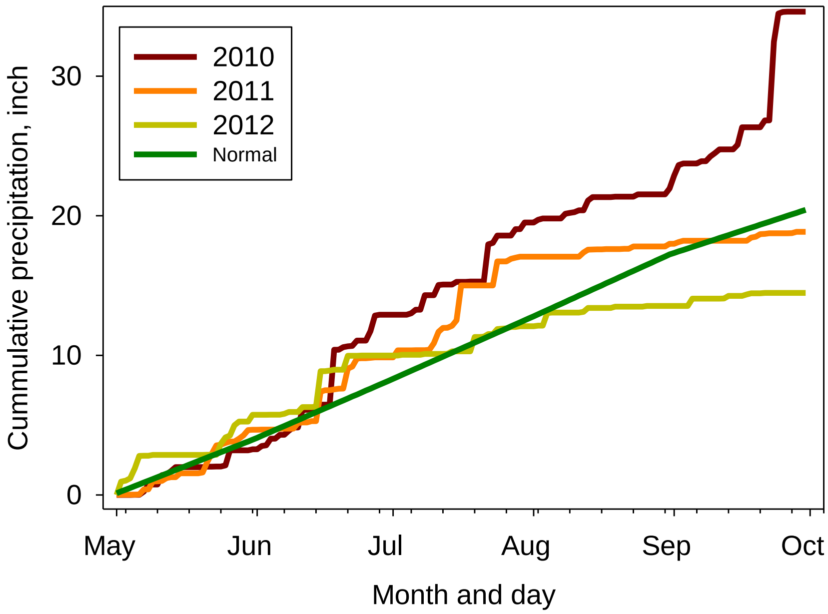
	Fertilizer rate			Grain	Grain	Initial Plant	Final Plant	VT-R1 Leaf
Trt	APP	UAN	ATS	H_2O	Yield	Stand	Pop.	Chloro
#	------	gal/ac	-------	%	bu/ac	plants×10^3/ac		%
1	0	0	0	19.0	213	35.0	34.5	97.3
2	0	0	2	18.5	213	35.4	34.5	98.4
3	0	0	4	18.3	216	35.3	34.4	97.9
4	0	8	0	18.8	211	35.2	34.3	95.8
5	0	8	2	17.9	214	35.1	34.3	98.0
6	0	8	4	18.0	216	34.3	34.1	98.2
7	4	0	0	17.5	213	34.4	34.1	97.4
8	4	0	2	18.2	214	34.8	34.2	97.3
9	4	0	4	17.2	215	34.6	34.3	98.1
10	4	8	0	17.6	212	34.7	34.2	97.5
11	4	8	2	17.3	216	34.8	34.4	98.6
12	4	8	4	18.0	215	34.4	34.2	98.5
13	4	0	1*	17.9	213	34.5	34.0	98.4
14	4	8	1*	17.7	212	33.9	33.6	98.0
Stats for RCB design (all 14 treatments)								
P > F:				0.001	0.927	0.014	0.012	0.044
Average LSD (0.10)				0.6	NS	0.6	0.3	1.2
Stats for a Factorial Design (Treatments 1-12)								
APP (10-34-0) applied in-furrow								
None				18.4	214	35.1	34.3	97.6
4 gal/ac				17.6	214	34.6	34.2	97.9
P > F:				0.200	0.929	0.085	0.049	0.299
UAN (28-0-0) applied as a surface dribble band								
None				18.1	214	34.9	34.3	97.7
8 gal/ac				17.9	214	34.8	34.2	97.8
P > F:				0.062	0.970	0.457	0.424	0.945
ATS (12-0-0-26) applied as a surface dribble band								
None				18.2	213	34.8	34.3	97.0
2 gal/ac				18.0	214	35.0	34.3	98.1
4 gal/ac				17.9	216	34.7	34.2	98.2
P > F:				0.068	0.460	0.424	0.615	0.004
Average LSD (0.10)				0.2150	NS	NS	NS	0.6
Interactions (P > F)								
APP×UAN				0.062	0.914	0.144	0.033	0.072
APP×ATS				0.003	0.757	0.711	0.734	0.238
UAN×ATS				0.001	0.493	0.186	0.646	0.214
APP×UAN×ATS				0.047	0.895	0.704	0.799	0.471

* One gal/ac rate of ATS applied in-furrow with seed.

Table 13. Nutrient concentration and uptake in the corn grain as affected by starter fertilizer treatments at Rochester (three-year average, 2010-2012).

	Fertilizer rate			Grain concentration				Nutrient uptake in grain			
Trt	APP	UAN	ATS	N	P	K	S	N	P	K	S
#	------ gal/ac -------			-------------- % --------------				------------- lb/ac -------------			
1	0	0	0	1.20	0.25	0.37	0.085	121	25.2	37.4	8.6
2	0	0	2	1.17	0.26	0.38	0.086	118	26.2	38.4	8.8
3	0	0	4	1.17	0.24	0.35	0.087	119	24.5	36.0	8.9
4	0	8	0	1.21	0.26	0.38	0.085	120	25.7	38.2	8.6
5	0	8	2	1.19	0.27	0.38	0.087	120	27.1	39.3	8.9
6	0	8	4	1.17	0.26	0.37	0.089	120	26.3	37.6	9.1
7	4	0	0	1.17	0.27	0.39	0.087	118	27.4	39.7	8.8
8	4	0	2	1.17	0.25	0.37	0.086	118	26.0	37.9	8.8
9	4	0	4	1.17	0.26	0.37	0.089	119	26.2	37.8	9.1
10	4	8	0	1.18	0.26	0.38	0.085	118	25.8	37.9	8.6
11	4	8	2	1.19	0.25	0.36	0.087	122	25.4	37.3	9.0
12	4	8	4	1.19	0.25	0.36	0.091	120	25.0	37.0	9.3
13	4	0	1*	1.18	0.27	0.39	0.086	119	27.0	39.0	8.7
14	4	8	1*	1.17	0.26	0.37	0.086	117	25.8	36.8	8.7
Stats for RCB design (all 14 treatments)											
P > F:				0.407	0.476	0.251	0.297	0.873	0.826	0.803	0.312
Average LSD (0.10)				NS	NS	NS	NS	NS	NS	NS	NS
Stats for a Factorial Design (Treatments 1-12)											
APP (10-34-0) applied in-furrow											
None				1.18	0.25	0.37	0.086	120	25.8	37.8	8.8
4 gal/ac				1.18	0.25	0.37	0.088	119	26.0	37.9	8.9
P > F:				0.259	0.998	0.967	0.152	0.881	0.901	0.940	0.402
UAN (28-0-0) applied as a surface dribble band											
None				1.17	0.25	0.37	0.087	119	25.9	37.9	8.8
8 gal/ac				1.19	0.26	0.37	0.087	120	25.9	37.9	8.9
P > F:				0.280	0.860	0.804	0.486	0.233	0.979	0.941	0.452
ATS (12-0-0-26) applied as a surface dribble band											
None				1.19	0.26	0.38	0.085	119	26.0	38.3	8.7
2 gal/ac				1.18	0.26	0.37	0.087	119	26.2	38.2	8.9
4 gal/ac				1.17	0.25	0.36	0.089	119	25.5	37.1	9.1
P > F:				0.509	0.491	0.141	0.328	0.999	0.789	0.577	0.333
Average LSD (0.10)				NS	NS	NS	NS	NS	NS	NS	NS
Interactions (P > F)											
APP×UAN				0.359	0.047	0.067	0.456	0.470	0.122	0.073	0.598
APP×ATS				0.029	0.271	0.248	0.405	0.191	0.417	0.274	0.708
UAN×ATS				0.809	0.766	0.853	0.152	0.455	0.814	0.824	0.106
APP×UAN×ATS				0.959	0.676	0.782	0.479	0.974	0.842	0.919	0.771

* One gal/ac rate of ATS applied in-furrow with seed and 10-34-0.



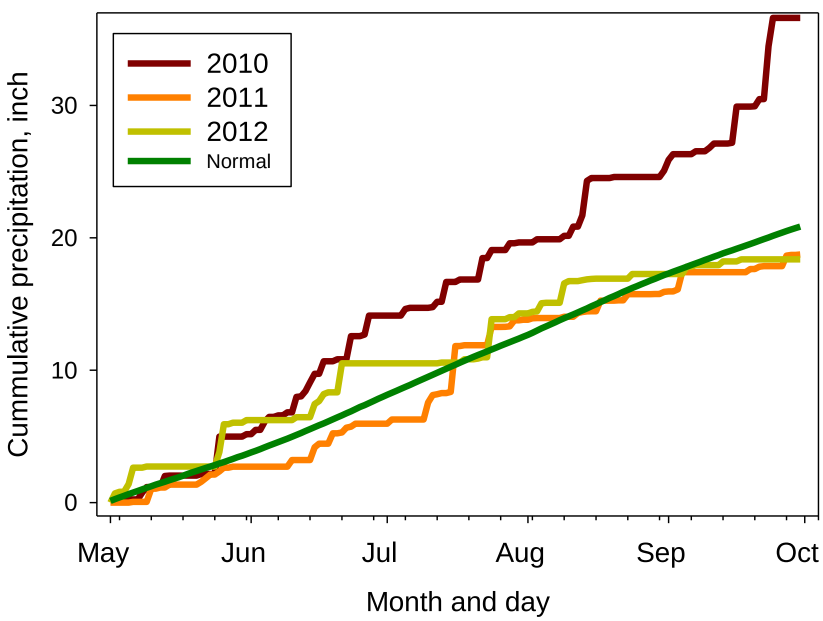


Figure 1. Cumulative growing season precipitation at Waseca (top) and Rochester (bottom).