Enhancing Continuous Corn Production in Conservation Tillage with Nitrogen, Phosphorus, and Sulfur Starter Fluid 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 clay loam soil at Waseca and another on a Mt Carroll silt loam near Rochester, were established in April of 2010. Twelve of the 14 total treatments were comprised of a factorial combination 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 3 at Waseca and April 27 at Rochester. At V2-3 UAN was injected 3" deep midway between the rows to give a total (at planting + V2-3) N rate of 180 lb/ac on all plots. At V7-8 stage corn plants were harvested from each plot to determine dry matter yield, and the plant tissue was analyzed for 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 record wet June and July at Waseca stressed corn and may have reduced yield potential. Crop response to treatments varied markedly between locations. Early plant growth (plant heights and dry matter yields) were enhanced when N, P and S starter fertilizers as APP, UAN and ATS were applied at the Waseca site. Whereas only APP application affected early plant growth at Rochester. Grain moisture was reduced about 1.0 percentage points when APP or UAN were applied at Waseca, while moisture was reduced 1.5 and 2.5 percentage points with the 2 and 4 gal/ac rate of ATS, respectively, compared with 0 gal/ac. At Rochester, grain moisture was reduced about 1 percentage point with APP, slightly with UAN, and was not affected by ATS application. Corn grain yields were 6 to 9 bu/A greater with ATS (sulfur fertilization) at Waseca, when averaged across APP and UAN treatments. A significant UAN×ATS interaction for grain yield showed when UAN was not applied at planting, grain yields increased about 18 bu/ac with ATS fertilization. When UAN was applied, no yield response to ATS was observed. At Waseca adding 1 gal/ac of ATS to 4 gal/ac of APP applied in-furrow increased grain yields 12 bu/ac compared with APP alone and final plant populations were not reduced significantly. No grain yield responses to N, P, and S starter fertilizer treatments were found at Rochester.

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.

The switch back to corn dominated rotations presents 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, equipment, or labor (time). 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. One on a Webster clay loam soil at the Southern Research and Outreach Center, Waseca, MN and another on a Mt Carroll silt loam five miles east of Rochester (southeast) MN. Both sites were planted to corn in 2009 and were fall chisel plowed after harvest. 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 of 8 gal/ac or 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 within 2" of 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' wide (4 30-inch rows) by 50' long. Soil samples (0-6" depth) were taken from each rep to characterize the research plot areas. Soil tests averaged: pH = 5.5, organic matter = 6.1%, Bray P_1 = 42 ppm (VH) and exchangeable K = 191 ppm (VH) at Waseca and pH = 7.3, organic matter = 4.8%, Bray P_1 = 22 ppm (VH) and exchangeable K = 170 ppm (VH) at Rochester.

Corn (DeKalb 52-43 at Waseca and 48-37 at Rochester) was planted at 35,000 seeds/ac on May 3 (Waseca) and April 27 (Rochester). Weeds were controlled with a combination of pre [Harness (1.5 pt/ac) and Callisto (5 oz/ac)] and post [glyphosate (32 oz/ac)] emergence herbicide applications. Surface residue accumulation after planting averaged about 40-45%. In early June stand counts were taken on the center two rows of each plot and plots were thinned to a uniform plant population. At V2-3 on June 3 at Waseca and June 7 at Rochester, UAN was injected 3" deep midway between the rows to give a total (at planting + at V2-3) N rate of 180 lb/ac on all plots. On June 21 at Waseca and June 24 at Rochester (V7-8 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. At R1 (July 20 at Waseca and July 16 at Rochester) SPAD meter readings were taken from the ear leaf of 30 plants in each plot. Relative leaf chlorophyll content was calculated from these measurements. At physiological maturity (black layer) corn stover yield was obtained by machine harvesting 15' of one row after removing the ear (Waseca site only). A subsample of the stover was dried, ground, and analyzed for N, P, K and S concentration. Grain yield and moisture content were determined on October 4 (Waseca) and

12 (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.

RESULTS AND DISCUSSION

The 2010 growing season was warm and wet. Two months [June (9.64", 5.42" greater-than-normal) and September (12.66", 9.47" greater-than-normal)] set 96-year records for precipitation at Waseca (Table 1). The June + July total precipitation (16.25") and the growing season total (34.61") were also records. Growing season precipitation at the Rochester location was about 50% greater-than-normal. With much of the excess falling during the months of June, August, and September. At Waseca growing degree units (GDU) for the entire growing season May 1 through October 3 (first frost) totaled 2,606 which was 8% greater-than-normal.

The extremely wet conditions in June and July at Waseca were conducive to N loss via denitrification and leaching. These research sites and many farmer fields in Southern Minnesota would have benefited from supplemental N applications. Unfortunately, these research sites and many farmer fields did not receive supplemental N because: many fields had standing water or were too wet for equipment traffic; by the time fields dried out corn was too large for conventional sidedress equipment; and some corn was already in reproductive stages and the benefit of N applied this late was questioned.

Waseca site

Plant heights and whole plant dry matter yields were affected by all three of the treatment main effects in the factorial analysis of treatments 1-12 (Table 2). Heights and yields were increased when APP was applied in-furrow and when UAN and ATS were applied as a surface band. The 4 gal/ac rate of ATS did not increase heights or yields above the 2 gal/ac rate, when averaged across APP and UAN treatment main effects. A significant APP×UAN interaction for plant height was explained by the magnitude of the response in plant height when fertilized with one vs both of these nutrients. Plant heights increased about 4" when fertilized with either UAN or APP, compared with plots without UAN and APP. Whereas plant heights increased only 2" when fertilized with both UAN and APP, compared with either UAN or APP. The 1 gal/ac of ATS plus 4 gal/ac or APP applied in-furrow treatment increased V7 plant heights and yields compared with 4 gal/ac of APP alone. The application of fluid fertilizers at planting resulted in dramatic visual (early growth, vigor, and color) differences as shown in Figure 1.

A few nutrient concentrations and nearly all nutrient uptakes in V7 corn plants were affected by the treatment main effects in this study (Table 2). Nitrogen and S concentrations were reduced when 4 gal/ac of APP was applied in-furrow compared with 0 gal/ac of APP (likely due to dilution), when averaged across UAN and ATS treatments. Sulfur concentration increased as the rate of S fertilizer (ATS) increased, when averaged across UAN and APP treatments. However, adding 1 gal/ac of ATS to 4 gal/ac of APP applied in-furrow, did not affect S concentration in V7 corn plants, compared with 4 gal/ac of APP alone. Applying 4 gal/ac of APP in-furrow increased N, P, and K uptake, when averaged across UAN and ATS treatments. Nitrogen, P, K and S uptake in corn plants were increased when UAN and ATS were applied at planting. Generally, the nutrient uptake responses to treatment main effects found in this study were a result of small plant DM yield responses to treatments and not to increased nutrient concentrations. Several significant APP×UAN interactions for nutrient concentration and uptake were found. The APP×UAN interaction for P concentration showed when APP or UAN were applied at planting, P concentration in whole plants increased compared with the control (when neither were applied). However when APP and UAN were applied together, P concentration declined slightly (data not shown). An APP×UAN interaction for S concentration showed S concentration was reduced slightly when both APP and UAN were applied, whereas when APP or UAN were applied S concentrations were similar to the control (data not shown). Significant APP×UAN interactions for N, P and S uptake in V7 corn plants were a result of increased growth and have the same explanation as the APP×UAN interaction for plant height in the previous paragraph (data not shown).

Treatment effects on grain moisture and grain, stover, and silage yields are presented in Table 3. Grain moisture was reduced 0.9 percentage points with APP (4 gal/ac vs 0 gal) and UAN (8 gal/ac vs 0 gal) application. Grain moisture was reduced 1.5 and 2.5 percentage points with the 2 and 4 gal/ac rate of ATS, respectively, compared with 0 gal of ATS and averaged across APP and UAN treatments. The driest grain (16.5%) was obtained when N, P, and S were applied at planting (treatment # 12). The wettest grain (20.7%) was found in the control plot (treatment # 1). Corn grain, stover, and silage yields were not affected by the application of APP or UAN at planting, although APP and UAN application enhanced early growth and reduced grain moisture. Grain yields were 9 bu/ac greater than the control with 2 gal/ac of ATS, when averaged across APP and UAN treatments. Yields were not different between the 2 and 4 gal/ac rates of ATS. Applying 1 gal/ac of ATS and 4 gal/ac of APP in-furrow increased yields 12 bu/ac compared with APP alone (treatments 13 vs 7). A significant UAN×ATS interaction for grain yield showed a 19 bu/ac response to ATS when UAN was not applied, but no response to ATS when 8 gal/ac of UAN was applied at planting (Figure 2). Sulfur fertilization (ATS) increased stover and silage yields, when averaged across UAN and APP treatments. Stover yields were greatest with the 4 gal/ac rate of ATS, whereas silage yields were not significantly different between the 2 and 4 gal/ac rate.

Treatment effects on plant stand, final population and relative leaf chlorophyll content (RLC) are presented in Table 3. Initial plant stand was reduced slightly (500 plants/ac) with APP fertilization, when averaged across UAN and ATS treatments. Initial stand and final plant population were affected by ATS application in this study, but the differences were generally very small and would not have affected corn production. When 1 gal/ac of ATS and 4 gal/ac of APP were applied in-furrow (treatment # 13), initial plant stand and final plant population trended lower, but they were not significantly less than 4 gal/ac of APP alone (treatment # 7). Significant interactions for final plant population were found, but the differences were small about 300 plants/ac and would not have influenced corn production. Relative leaf chlorophyll content at VT-R1 increased slightly with 8 gal/ac of UAN applied at planting compared with 0 gal of UAN, when averaged across APP and ATS treatments. The 2 and 4 gal/ac rates of ATS increased RLC 5.0 and 7.7 percentage points, respectively, compared with the control (0 gal/ac), when averaged across APP and UAN treatments. One gal/ac of ATS and 4 gal/ac of APP applied in-furrow increased RLC significantly compared with 4 gal/ac of APP alone. No difference in RLC was found when the 1 gal/ac of ATS plus 4 gal/ac of APP applied in-furrow treatment (# 13) was compared to the 4 gal/ac of APP applied in-furrow plus 2 gal/ac of ATS applied as a surface dribble band treatment (# 8). The significant APP×ATS interaction for RLC showed without ATS, APP increased RLC slightly (1-2 percentage points). Whereas with ATS at 2 or 4 gal/ac, APP application had no affect on RLC (data not shown). The significant UAN×ATS interaction for RLC was similar to the APP×ATS interaction. It showed at the 0 and 2 gal/ac rates of ATS, UAN application increased RLC slightly, whereas at the 4 gal/ac rate of ATS, UAN application had no affect on RLC (data not shown). These data show a small amount of N at planting, either from APP applied in-furrow or UAN applied as a surface dribble band, increased VT-R1 RLC values slightly in the absence of ATS. However when ATS was applied, the response in RLC was significantly large and masked any effect of APP or UAN. Interestingly, the 1 and 2 gal/ac rates of ATS resulted in corn plants that were pale (significantly less RLC) when compared to the 4 gal/ac rate, but these treatments produced similar grain yields as the 4 gal/ac treatments. This suggests at this site only a small amount of S (1 gal/ac of ATS = 2.9 lb S/ac) applied in the seed furrow at planting was needed to get a yield response on this high organic matter soil.

Treatment effects on the concentration of N, P, K and S in corn stover, harvested at physiological maturity (black layer), and corn grain are presented in Table 4. Generally APP did not affect nutrient concentrations in corn stover or grain on this very high P testing site. Stover N and K concentration declined slightly when 8 gal/ac of UAN was applied at planting compared with 0 gal/ac, when averaged across APP and ATS treatments. This response could be a result of greater N loss during the wet period in June and July when 24 lb N/ac was applied at planting, which limited N supply later during grain fill, thus requiring the plant to utilize more of the N in the stalk to fill grain in August and early September. Averaged across APP and UAN treatments, 2 gal/ac of ATS increased stover N compared with the control; however, stover N concentration was not different between the 0 (control) and 4 gal/ac rate of

ATS. Stover P concentration declined slightly when 2 gal/ac or ATS was applied compared with 0 gal/ac. Sulfur concentration in corn grain increased with increasing ATS rate. No plausible explanation exists for the significant three-way interaction for stover K concentration and no other significant interactions were found. The 1 gal/ac of ATS and 4 gal/ac of APP treatment applied in-furrow increased grain S concentration compared with 4 gal/ac of APP alone.

The treatment effects on stover, grain, and total nutrient uptake are presented in Table 5. Total K uptake increased slightly with APP application, when averaged across UAN and ATS treatment main effects. However APP did not affect any other nutrient uptakes on this very high P testing site. Application of 8 gal/ac of UAN at planting decreased stover and total N and K uptake, when averaged across APP and ATS treatments. Averaged across APP and UAN treatments, stover, grain and total N uptake increased with ATS application, however no differences were found between the 2 and 4 gal/ac rates. Total N uptake was greatest (176 lb/ac) with treatments that contained very little N at planting and 2 gal/ac of ATS (treatment #'s 2 and 8). Total N uptake was 10-12 lb/ac less with treatments 11 and 12, even though they had greater early growth (V7 dry matter yield) and greater RLC. Treatments 11 and 12 contained the greatest amount of N (31 and 34 lb N/A, respectively) at planting in combination with P and S. These data show less total N was taken up by corn when more N was applied at planting and less N was applied at V2. This suggests greater N loss occurred during the wet period in June and July on treatments that received more N at planting. A reduction in N uptake probably reduced yield potential in these treatments in 2010 a high N stress growing season. Stover and total uptake of K was greatest with the 4 gal/ac rate of ATS compared with 0 or 2 gal/ac rates, when averaged across APP and UAN treatments. Generally, stover, grain, and total S uptake increased with increasing rate of ATS. Total S uptake in the corn plant increased only 2.1 lb/ac for the 4 gal/ac rate of ATS (11.5 lb S/ac) compared with the control, when averaged across APP and UAN treatments.

Several significant ($P <= 0.10$) interactions were found for stover, grain and total nutrient uptake (Table 5). An APP×UAN interaction for stover K showed K uptake was reduced about 11 lb/ac when UAN was applied without APP, while other combinations of APP and UAN (with UAN and with APP, no UAN and no APP, and no UAN with APP) had similar K uptake (data not shown). The significant UAN×ATS interactions for grain N, P and S uptake and total P uptake were similar to and a result of the same interaction for yield (Figure 2). Moreover greatest nutrient uptake values were obtained with 2 or 4 gal/ac of ATS without UAN, when UAN was applied uptake values across all rates of ATS were similar (data not shown). The APP×UAN interactions for grain P and K uptake were similar and showed P and K uptake was greatest when either APP or UAN were applied, while uptake was reduced when both were applied (data not shown). An APP×ATS interaction for total P uptake showed when APP was not applied P uptake was 37, 39. and 41 lb/ac for the 0, 2, and 4 gal/ac rates of ATS, respectively. However, when APP was applied P uptake was 40, 39, and 38 for the 0, 2, and 4 gal/ac rates, respectively (data not shown). Generally these small differences in nutrient uptake from one-site year of data would not raise much concern. However, these data suggest a potential for negative consequences when combinations of fluid fertilizers are applied at planting. Whether that potential is realized will depend on the interactions expressed in years 2 and 3 of this study. Consistent and repeated responses would lead to more definitive conclusions. The significant three-way interaction for K uptake in grain has no plausible explanation.

Rochester site

Treatment effects on early growth of small corn plants harvested on June 24 (V7-8 stage) are presented in Table 6. Plant heights and dry matter yields were increased with 4 gal/ac of APP applied in-furrow compared with 0 gal/ac, when averaged across UAN and ATS treatments. Plant heights and dry matter yields were not affected by the main effects of UAN and ATS application, and there were no significant interactions. This suggests the early growth response at this site was primarily due to P in the APP starter. Adding 1 gal/ac of ATS to 4 gal/ac of APP in-furrow had no effect on plant height and dry matter yield compared with APP alone. Nitrogen and S concentrations in V7-8 corn plants were reduced with APP application, averaged across UAN and ATS treatments. This response is likely a result of the *"dilution effect". The dilution effect occurs when early growth increases dramatically, thus causing concentrations of some nutrients to decline. The large increase in dry matter yield with APP fertilization observed in this study, resulted in increased N, P, K, and S uptake compared with plots that did not get APP. When UAN was applied at planting, P concentration in small plants decreased slightly, while S concentration and uptake increased. Four gal/ac of ATS increased N concentration in small plants compared to the 0 and 2 gal/ac treatments, when averaged across APP and UAN treatments. Sulfur concentration increased as ATS rate increased, but no differences in S uptake were found. Adding 1 gal/ac of ATS to 4 gal/ac of APP in-furrow, generally did not affect nutrient concentrations or uptakes in small corn plants compared with APP alone. The highly significant APP×ATS interactions for K concentration and uptake in V7-8 corn plants showed without APP, K concentration and uptake declined when ATS was applied. Whereas with APP, K concentration and uptake increased as the rate of ATS increased (data not shown). Lowest K concentrations and uptakes were found when APP was not applied and 4 gal/ac of ATS was applied (data not shown). These results were not found at the S-responding Waseca site. Three other interactions had P values slightly less than alpha = 0.10 level of significance. However, the author feels they are of little consequence and do not warrant further discussion.*

Treatment effects on grain moisture, grain yield, initial plant stand, final plant population, and relative leaf chlorophyll content are presented in Table 7. Grain moisture was reduced 0.9 percentage points with 4 gal/ac of APP compared with 0 gal/ac, when averaged across UAN and ATS treatments. Application of UAN reduced grain moisture slightly (0.3 percentage points), when averaged across APP and ATS treatments. Three significant interactions (APP×ATS, UAN×ATS and APP×UAN×ATS) were found for corn grain moisture. Generally these interactions showed when APP was not applied, grain moisture was reduced with ATS with or without UAN. However when APP was applied, the grain moisture response to ATS with or without UAN was erratic. Corn yields only ranged from 207 to 213 bu/ac across all 14 treatments in this study. No significant differences were found among treatments, and there were no interactions. No differences in final plant population were found among treatment main effects. At VT-R1 RLC ranged from 94.6 to 99.1% and was not affected by the main effects of APP and UAN application. The 2 and 4 gal/ac rates of ATS increased RLC about 1 percentage point compared with the 0 gal/ac rate of ATS, when averaged across APP and UAN main effects. The author has no plausible explanation for the significant three-way interaction for RLC.

Treatment effects on corn grain nutrient concentration and uptake are presented in Table 8. Significant differences among the 14 treatment means were not found for any of the nutrient concentrations or uptakes in corn grain. The very small differences in S concentration and uptake found in main effects were insignificant.

SUMMARY

An early and warmer-than-normal spring in 2010 appeared ideal for growing corn. Extreme wet conditions in June and July at Waseca, when soil temperatures were warm, were conducive to N loss via denitrification and leaching and probably reduced yield potential. Crop response to the treatments varied markedly between locations. The Waseca site responded more to S (ATS application), whereas the Rochester site had few responses and those were usually due to P (APP application). The primary observations from the first year of this 3-year study were:

1) *Early plant growth (plant heights and dry matter yields) were enhanced when N, P and S starter fertilizers as APP, UAN and ATS were applied at the Waseca site, but only APP application affected early plant growth at Rochester.*
2) *Grain moisture was reduced about 1.0 percentage points when APP or UAN were applied at Waseca. The grain moisture response was similar for APP, but less for UAN at Rochester. Grain moisture was reduced 1.5 and 2.5 percentage points with the 2 and 4 gal/ac rate of ATS, respectively, compared with 0 gal/ac of ATS at Waseca. Grain moisture was not affected by ATS application at Rochester.*

3) *Corn grain yields were 6 to 9 bu/A greater with ATS (sulfur fertilization) at Waseca, when averaged across APP and UAN treatments. A significant UAN×ATS interaction for grain yield showed when UAN was not applied at planting, grain yields increased about 18 bu/ac with ATS fertilization. When UAN was applied, no yield response to ATS was observed. This interaction data along with N uptake data suggest N loss was greater during the very wet June and July period and N supply was less when UAN was applied at planting, which probably reduced yields on those treatments.*
4) *At Waseca in-furrow application of 1 gal/ac of ATS and 4 gal/ac of APP increased grain yields 12 bu/ac compared with 4 gal/ac of APP alone.*
5) *No yield responses to N, P and S starter fertilizers were found at Rochester. This site has a recent (2 years ago) history of fertilization with beef manure. It's likely mineralization from past manure applications provided adequate nutrients for corn in 2010 at the Rochester location.*

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REFERENCES

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

		Precipitation					
		Waseca		Rochester		Waseca GDUs	
Month	Year	2010	Normal[1/]	2010	Normal[1/]	2010	Normal[1/]
		- - - - - inches - - - - -		- - - - - inches - - - - -			
May	2010	3.27	3.96	3.72	3.5	363	337
June	2010	9.64	4.22	6.55	4.0	509	532
July	2010	6.61	4.47	3.81	4.6	691	644
Aug.	2010	2.43	4.58	6.49	4.3	698	584
Sept.	2010	12.66	3.19	9.62	3.1	320	322
May-Sept.	Total	34.61	20.42	30.19	19.6	2581[2/]	2419

[1/] 30-Yr normal, 1971-2000.
[2/] May – September total.

Table 2. Growth, nutrient concentration and uptake of V7 corn plants at Waseca.

	Fertilizer rate			V7 Plant	Whole Plant Samples at V7 (June 21)								
						Concentration				Uptake			
Trt	APP	UAN	ATS	height	Yield	N	P	K	S	N	P	K	S
#	------	gal/ac	-------	inch	lb/ac	-------------	%	-------------		----------	lb/ac	-----------	
1	0	0	0	28.4	438	3.85	0.423	4.60	0.200	17.0	1.89	20.3	0.88
2	0	0	2	31.4	593	3.85	0.420	4.77	0.195	22.9	2.50	28.5	1.16
3	0	0	4	31.9	636	3.70	0.445	4.76	0.218	23.6	2.84	30.4	1.39
4	0	8	0	33.9	767	3.88	0.463	4.50	0.195	29.7	3.50	34.6	1.50
5	0	8	2	34.9	815	3.97	0.440	4.59	0.208	32.3	3.58	37.4	1.69
6	0	8	4	35.6	852	3.87	0.463	4.66	0.218	33.1	3.95	40.1	1.86
7	4	0	0	32.9	584	3.62	0.433	4.60	0.193	21.2	2.52	26.8	1.12
8	4	0	2	35.0	730	3.84	0.463	4.74	0.200	28.0	3.37	34.5	1.46
9	4	0	4	35.0	720	3.76	0.433	4.50	0.213	27.3	3.10	32.3	1.53
10	4	8	0	34.9	810	3.65	0.435	4.90	0.175	29.5	3.53	39.6	1.42
11	4	8	2	37.1	913	3.71	0.438	4.72	0.193	33.9	4.00	43.1	1.76
12	4	8	4	36.6	847	3.70	0.430	4.54	0.213	31.2	3.64	37.9	1.80
13	4	0	1*	34.7	749	3.79	0.443	4.68	0.193	28.3	3.31	35.0	1.44
14	4	8	1*	35.0	786	3.69	0.440	4.87	0.185	29.1	3.46	38.6	1.46
Stats for a Factorial Design (Treatments 1-12)													
APP (10-34-0) applied in-furrow													
None				32.7	683	3.85	0.442	4.65	0.205	26.4	3.04	31.9	1.41
4 gal/ac				35.3	767	3.71	0.438	4.67	0.198	28.5	3.36	35.7	1.51
P > F:				0.001	0.005	0.030	0.674	0.844	0.013	0.080	0.026	0.006	0.112
UAN (28-0-0) applied as a surface dribble band													
None				32.4	617	3.77	0.436	4.66	0.203	23.3	2.70	28.8	1.26
8 gal/ac				35.5	834	3.79	0.445	4.65	0.200	31.6	3.70	38.8	1.67
P > F:				0.001	0.001	0.681	0.330	0.916	0.315	0.001	0.001	0.001	0.001
ATS (12-0-0-26) applied as a surface dribble band													
None				32.5	650	3.75	0.438	4.65	0.191	24.3	2.86	30.3	1.23
2 gal/ac				34.6	763	3.84	0.440	4.71	0.199	29.3	3.36	35.9	1.52
4 gal/ac				34.8	764	3.76	0.443	4.61	0.215	28.8	3.38	35.1	1.64
P > F:				0.001	0.003	0.391	0.921	0.742	0.001	0.002	0.005	0.003	0.001
Average LSD (0.10):				0.7	59	NS	NS	NS	0.006	2.41	0.28	2.7	0.13
Interactions (P > F)													
APP×UAN				0.001	0.187	0.189	0.062	0.243	0.072	0.062	0.056	0.452	0.052
APP×ATS				0.593	0.529	0.492	0.151	0.280	0.378	0.680	0.148	0.116	0.637
UAN×ATS				0.353	0.306	0.929	0.552	0.708	0.155	0.395	0.274	0.155	0.825
APP×UAN×ATS				0.383	0.886	0.657	0.840	0.851	0.422	0.922	0.973	0.840	0.916
Stats for RCB design (all 14 treatments)													
P > F:				0.001	0.001	0.655	0.609	0.930	0.001	0.001	0.001	0.001	0.001
Average LSD(0.10):				1.4	91	NS	NS	NS	0.013	3.7	0.44	4.3	0.20

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

Table 3. Grain moisture, grain, stover and silage yields, plant stand, final plant population, and relative leaf chlorophyll at Waseca.

Trt	Fertilizer rate APP	Fertilizer rate UAN	Fertilizer rate ATS	Grain H_2O	Grain Yield	Stover Yield	Silage Yield	Initial Plant Stand	Final Plant Pop.	VT-R1 Leaf Chloro
#	------	gal/ac	-------	%	bu/ac	- ton dm/ac -		plants×10^3/ac		%
1	0	0	0	20.7	202	2.90	7.69	34.6	33.7	89.7
2	0	0	2	19.0	220	3.02	8.21	35.0	33.8	94.8
3	0	0	4	17.5	220	3.23	8.42	33.7	33.2	99.2
4	0	8	0	19.5	213	2.63	7.66	34.6	33.8	90.6
5	0	8	2	18.0	220	2.91	8.11	34.7	33.8	97.1
6	0	8	4	16.9	210	3.24	8.20	34.4	33.8	99.1
7	4	0	0	19.0	207	3.06	7.95	34.4	33.7	91.8
8	4	0	2	18.2	223	3.09	8.36	34.1	33.6	94.9
9	4	0	4	17.2	222	3.19	8.45	34.2	33.6	98.8
10	4	8	0	18.8	212	3.06	8.08	33.5	33.5	92.2
11	4	8	2	16.8	210	2.95	7.92	34.6	33.8	97.5
12	4	8	4	16.5	209	3.39	8.34	33.3	33.2	98.2
13	4	0	1*	18.6	219	3.13	8.31	33.6	33.4	94.2
14	4	8	1*	17.9	209	3.01	7.95	33.4	33.2	92.7
Stats for a Factorial Design (Treatments 1-12)										
APP (10-34-0) applied in-furrow										
None				18.6	214	2.99	8.05	34.5	33.7	95.1
4 gal/ac				17.7	214	3.12	8.19	34.0	33.5	95.6
P > F:				0.001	0.998	0.155	0.230	0.059	0.252	0.223
UAN (28-0-0) applied as a surface dribble band										
None				18.6	216	3.08	8.18	34.3	33.6	94.9
8 gal/ac				17.7	212	3.03	8.05	34.2	33.6	95.8
P > F:				0.002	0.193	0.594	0.261	0.566	0.963	0.022
ATS (12-0-0-26) applied as a surface dribble band										
None				19.5	209	2.91	7.84	34.3	33.7	91.1
2 gal/ac				18.0	218	2.99	8.15	34.6	33.7	96.1
4 gal/ac				17.0	215	3.26	8.36	33.9	33.4	98.8
P > F:				0.001	0.012	0.011	0.003	0.081	0.037	0.001
Average LSD (0.10):				0.5	5.1	0.19	0.23	0.5	0.2	0.8
Interactions (P > F)										
APP×UAN				0.675	0.194	0.452	0.947	0.248	0.035	0.736
APP×ATS				0.341	0.680	0.490	0.414	0.802	0.854	0.032
UAN×ATS				0.649	0.009	0.493	0.492	0.645	0.705	0.018
APP×UAN×ATS				0.488	0.719	0.783	0.622	0.109	0.026	0.872
Stats for RCB design (all 14 treatments)										
P > F:				0.001	0.021	0.195	0.063	0.057	0.022	0.001
Average LSD (0.10):				1.1	10	NS	0.45	0.9	0.4	1.6

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

Table 4. Nutrient concentrations in the corn stover and grain at Waseca.

	Fertilizer rate			Stover concentration				Grain concentration			
Trt	APP	UAN	ATS	N	P	K	S	N	P	K	S
#	------	gal/ac	-------	----------------------------------			%	-----------------------------------			
1	0	0	0	0.61	0.115	1.51	0.063	1.26	0.31	0.39	0.085
2	0	0	2	0.73	0.110	1.41	0.065	1.27	0.32	0.40	0.088
3	0	0	4	0.63	0.118	1.41	0.068	1.27	0.33	0.42	0.100
4	0	8	0	0.58	0.113	1.26	0.068	1.26	0.32	0.42	0.088
5	0	8	2	0.66	0.083	1.30	0.063	1.25	0.32	0.42	0.090
6	0	8	4	0.62	0.110	1.33	0.065	1.27	0.33	0.42	0.098
7	4	0	0	0.63	0.115	1.38	0.063	1.27	0.33	0.45	0.080
8	4	0	2	0.67	0.108	1.37	0.073	1.27	0.33	0.41	0.085
9	4	0	4	0.62	0.088	1.43	0.065	1.25	0.32	0.41	0.093
10	4	8	0	0.57	0.123	1.43	0.063	1.25	0.33	0.42	0.085
11	4	8	2	0.62	0.093	1.45	0.068	1.28	0.31	0.40	0.090
12	4	8	4	0.60	0.105	1.27	0.070	1.27	0.30	0.44	0.095
13	4	0	1*	0.63	0.105	1.55	0.058	1.25	0.32	0.40	0.088
14	4	8	1*	0.61	0.128	1.43	0.068	1.28	0.31	0.38	0.083
<u>Stats for a Factorial Design (Treatments 1-12)</u>											
APP (10-34-0) applied in-furrow											
None				0.64	0.108	1.37	0.065	1.26	0.32	0.41	0.091
4 gal/ac				0.62	0.105	1.39	0.067	1.26	0.32	0.42	0.088
P > F:				0.331	0.643	0.565	0.432	0.889	0.414	0.233	0.092
UAN (28-0-0) applied as a surface dribble band											
None				0.65	0.109	1.42	0.066	1.26	0.32	0.41	0.088
8 gal/ac				0.61	0.104	1.34	0.066	1.26	0.32	0.42	0.091
P > F:				0.033	0.468	0.020	1.000	0.780	0.702	0.272	0.202
ATS (12-0-0-26) applied as a surface dribble band											
None				0.60	0.116	1.39	0.064	1.26	0.32	0.42	0.084
2 gal/ac				0.67	0.098	1.38	0.067	1.27	0.32	0.41	0.088
4 gal/ac				0.61	0.105	1.36	0.067	1.26	0.32	0.42	0.096
P > F:				0.007	0.071	0.720	0.383	0.825	0.988	0.376	0.001
Average LSD (0.10):				0.04	0.013	NS	NS	NS	NS	NS	0.004
Interactions (P > F)											
APP×UAN				0.873	0.214	0.049	1.000	0.676	0.303	0.199	0.391
APP×ATS				0.419	0.269	0.644	0.246	0.680	0.224	0.381	0.721
UAN×ATS				0.502	0.182	0.363	0.445	0.810	0.689	0.683	0.658
APP×UAN×ATS				0.783	0.872	0.073	0.445	0.756	0.988	0.114	0.954
<u>Stats for RCB design (all 14 treatments)</u>											
P > F:				0.096	0.270	0.042	0.412	0.993	0.891	0.100	0.004
Average LSD (0.10):				0.07	NS	0.14	0.009	0.05	0.03	0.03	0.008

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

Table 5. Nutrient uptake in the corn stover, grain and total dry matter at Waseca.

	Fertilizer rate			Nutrient uptake in stover				Nutrient uptake in grain				Total nutrient uptake			
Trt	APP	UAN	ATS	N	P	K	S	N	P	K	S	N	P	K	S
#	------- gal/ac --------			-- lb/acre --											
1	0	0	0	34.8	6.66	86.7	3.60	120	29.7	36.9	8.2	155	36.4	124	11.8
2	0	0	2	44.1	6.51	84.5	3.91	132	33.3	41.1	9.1	176	39.8	126	13.0
3	0	0	4	40.5	7.68	91.4	4.40	132	34.4	43.0	10.4	172	42.1	134	14.8
4	0	8	0	30.4	5.93	66.3	3.58	126	32.5	42.3	8.8	157	38.4	109	12.4
5	0	8	2	38.0	4.87	75.0	3.65	130	33.5	43.1	9.3	168	38.3	118	13.0
6	0	8	4	40.0	7.09	85.5	4.17	125	32.8	41.8	9.6	165	39.9	127	13.8
7	4	0	0	38.8	6.93	84.4	3.81	124	31.8	43.5	7.8	163	38.7	128	11.6
8	4	0	2	41.6	6.56	84.6	4.47	134	34.2	43.2	9.0	176	40.8	128	13.4
9	4	0	4	39.2	5.50	91.0	4.14	131	33.4	42.6	9.7	170	38.9	134	13.9
10	4	8	0	35.1	7.66	86.7	3.83	126	32.6	41.7	8.5	161	40.3	128	12.4
11	4	8	2	36.4	5.46	85.4	3.99	127	30.8	40.0	9.0	164	36.3	125	12.9
12	4	8	4	40.6	7.23	86.2	4.75	125	29.7	43.1	9.4	166	36.9	129	14.1
13	4	0	1*	39.5	6.56	97.1	3.60	130	32.7	40.9	9.1	169	39.2	138	12.7
14	4	8	1*	36.9	7.67	85.6	4.06	127	30.6	37.6	8.2	164	38.3	123	12.2
Stats for a Factorial Design (Treatments 1-12)															
APP (10-34-0) applied in-furrow															
None				38.0	6.46	81.6	3.89	128	32.7	41.4	9.2	166	39.1	123	13.1
4 gal/ac				38.6	6.56	86.4	4.16	128	32.1	42.4	8.9	167	38.6	129	13.1
P > F:				0.668	0.821	0.104	0.115	0.947	0.402	0.210	0.122	0.775	0.581	0.046	0.839
UAN (28-0-0) applied as a surface dribble band															
None				39.8	6.64	87.1	4.06	129	32.8	41.7	9.0	169	39.4	129	13.1
8 gal/ac				36.8	6.38	80.9	3.99	127	32.0	42.0	9.1	163	38.4	123	13.1
P > F:				0.046	0.547	0.037	0.721	0.224	0.250	0.718	0.685	0.052	0.232	0.041	0.938
ATS (12-0-0-26) applied as a surface dribble band															
None				34.8	6.80	81.0	3.71	124	31.7	41.1	8.3	159	38.4	122	12.0
2 gal/ac				40.0	5.85	82.4	4.00	131	32.9	41.8	9.1	171	38.8	124	13.1
4 gal/ac				40.1	6.88	88.5	4.36	128	32.6	42.7	9.8	168	39.5	131	14.1
P > F:				0.008	0.115	0.091	0.014	0.019	0.295	0.258	0.001	0.003	0.646	0.032	0.001
Average LSD (0.10)				3.1	NS	6.0	0.36	4	NS	NS	0.4	6	NS	6	0.5
Interactions (P > F)															
APP×UAN				0.692	0.104	0.058	0.520	0.386	0.080	0.025	0.887	0.752	0.544	0.174	0.628
APP×ATS				0.212	0.179	0.453	0.777	0.892	0.191	0.172	0.938	0.423	0.073	0.260	0.775
UAN×ATS				0.244	0.214	0.781	0.415	0.088	0.037	0.392	0.087	0.369	0.090	0.941	0.256
APP×UAN×ATS				0.986	0.720	0.318	0.432	0.772	0.876	0.059	0.820	0.861	0.742	0.610	0.413
Stats for RCB design (all 14 treatments)															
P > F:				0.076	0.278	0.022	0.194	0.262	0.133	0.008	0.002	0.089	0.345	0.021	0.001
Average LSD (0.10)				6.0	1.87	11.4	0.71	8	2.9	3.0	0.9	11	3.7	11	1.1

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

Table 6. Early growth, yield, nutrient concentration and uptake of V7 corn plants at Rochester.

	Fertilizer rate			V7	Whole Plant Samples at V7 (June 24)								
				Plant		Concentration				Uptake			
Trt	APP	UAN	ATS	height	Yield	N	P	K	S	N	P	K	S
#	----	gal/ac	-----	inch	lb/ac	--------------	%	--------------		----------	lb/ac	-----------	
1	0	0	0	37.2	1464	3.57	0.433	4.35	0.200	52.2	6.33	63.2	2.93
2	0	0	2	35.7	1337	3.59	0.413	3.20	0.205	47.9	5.50	42.3	2.74
3	0	0	4	36.1	1361	3.58	0.415	3.16	0.218	48.8	5.66	43.1	2.96
4	0	8	0	37.3	1629	3.48	0.403	3.89	0.205	56.8	6.55	63.1	3.34
5	0	8	2	37.0	1577	3.50	0.393	3.07	0.213	55.2	6.19	49.8	3.32
6	0	8	4	37.4	1464	3.61	0.403	3.05	0.233	52.9	5.90	44.8	3.40
7	4	0	0	38.9	1897	3.39	0.393	3.48	0.195	64.1	7.45	67.3	3.69
8	4	0	2	40.6	1949	3.28	0.418	4.31	0.198	63.8	8.12	84.8	3.83
9	4	0	4	40.6	1888	3.48	0.405	3.47	0.203	65.8	7.71	66.2	3.85
10	4	8	0	39.3	1756	3.31	0.398	3.45	0.195	58.2	6.99	61.6	3.42
11	4	8	2	39.9	1992	3.45	0.395	3.19	0.210	68.8	7.86	63.5	4.16
12	4	8	4	40.8	2057	3.46	0.408	4.50	0.210	71.0	8.42	94.5	4.30
13	4	0	1*	40.4	1907	3.39	0.400	3.73	0.188	64.1	7.67	74.9	3.55
14	4	8	1*	40.4	1987	3.32	0.398	3.62	0.198	65.5	7.96	76.8	3.90
Stats for a Factorial Design (Treatments 1-12)													
APP (10-34-0) applied in-furrow													
None				36.8	1472	3.55	0.410	3.45	0.212	52.3	6.02	51.0	3.12
4 gal/ac				40.0	1923	3.39	0.403	3.73	0.202	65.3	7.76	73.0	3.88
P > F:				0.001	0.001	0.001	0.165	0.151	0.002	0.001	0.001	0.001	0.001
UAN (28-0-0) applied as a surface dribble band													
None				38.2	1649	3.48	0.413	3.66	0.203	57.1	6.80	61.2	3.33
8 gal/ac				38.6	1746	3.47	0.400	3.53	0.211	60.5	6.98	62.8	3.66
P > F:				0.389	0.213	0.728	0.014	0.483	0.017	0.210	0.572	0.750	0.035
ATS (12-0-0-26) applied as a surface dribble band													
None				38.2	1687	3.44	0.406	3.79	0.199	57.8	6.83	63.8	3.35
2 gal/ac				38.3	1714	3.45	0.404	3.44	0.206	58.9	6.92	60.1	3.51
4 gal/ac				38.7	1693	3.53	0.408	3.55	0.216	59.6	6.92	62.1	3.63
P > F:				0.652	0.954	0.032	0.876	0.324	0.001	0.853	0.964	0.844	0.310
Average LSD (0.10)				NS	NS	0.06	NS	NS	0.007	NS	NS	NS	NS
Interactions (P > F)													
APP×UAN				0.363	0.345	0.220	0.122	0.619	0.693	0.462	0.561	0.804	0.316
APP×ATS				0.174	0.287	0.752	0.096	0.005	0.179	0.226	0.136	0.024	0.290
UAN×ATS				0.914	0.734	0.225	0.422	0.078	0.477	0.546	0.762	0.201	0.489
APP×UAN×ATS				0.660	0.596	0.102	0.320	0.086	0.694	0.652	0.651	0.108	0.637
Stats for RCB design (all 14 treatments)													
P > F:				0.001	0.016	0.001	0.101	0.049	0.000	0.048	0.049	0.049	0.024
Average LSD(0.10):				2.0	389	0.12	NS	0.83	0.012	12.6	1.67	26.3	0.73

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

Table 7. Grain moisture and yield, plant stand, final plant population, and relative leaf chlorophyll at Rochester.

	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/A		%
1	0	0	0	17.9	207	34.4	34.2	96.9
2	0	0	2	17.6	207	35.2	34.4	98.4
3	0	0	4	17.3	211	35.0	34.4	96.8
4	0	8	0	17.6	208	34.4	33.9	94.6
5	0	8	2	17.0	209	34.7	34.3	97.8
6	0	8	4	16.7	207	34.3	33.9	99.1
7	4	0	0	16.3	209	33.9	33.7	97.1
8	4	0	2	17.3	210	34.2	33.9	96.8
9	4	0	4	16.1	210	35.1	34.5	97.9
10	4	8	0	16.5	210	34.2	34.1	98.1
11	4	8	2	16.0	211	35.2	34.5	98.3
12	4	8	4	17.0	211	34.3	34.0	96.9
13	4	0	1*	16.8	209	34.3	34.0	97.7
14	4	8	1*	16.4	213	33.4	33.4	96.2
Stats for a Factorial Design (Treatments 1-12)								
APP (10-34-0) applied in-furrow								
None				17.4	208	34.7	34.2	97.3
4 gal/ac				16.5	210	34.5	34.1	97.5
P > F:				0.001	0.211	0.431	0.550	0.581
UAN (28-0-0) applied as a surface dribble band								
None				17.1	209	34.6	34.2	97.3
8 gal/ac				16.8	209	34.5	34.1	97.5
P > F:				0.081	0.952	0.531	0.595	0.735
ATS (12-0-0-26) applied as a surface dribble band								
None				17.1	209	34.2	34.0	96.7
2 gal/ac				17.0	209	34.8	34.3	97.8
4 gal/ac				16.8	210	34.7	34.2	97.7
P > F:				0.332	0.881	0.058	0.147	0.067
Average LSD (0.10)				NS	NS	0.4	NS	0.9
Interactions (P > F)								
APP×UAN				0.191	0.625	0.134	0.103	0.401
APP×ATS				0.071	0.953	0.824	0.596	0.041
UAN×ATS				0.015	0.767	0.100	0.098	0.414
APP×UAN×ATS				0.031	0.699	0.286	0.419	0.008
Stats for RCB design (all 14 treatments)								
P > F:				0.001	0.938	0.020	0.038	0.031
Average LSD (0.10)				0.7	NS	0.8	0.5	1.8

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

Table 8. 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	1.26	0.28	0.36	0.090	123	27.7	34.9	8.8
2	0	0	2	1.23	0.28	0.34	0.090	120	27.5	33.4	8.8
3	0	0	4	1.25	0.28	0.33	0.090	124	27.7	33.1	9.0
4	0	8	0	1.24	0.30	0.37	0.095	122	29.5	35.9	9.3
5	0	8	2	1.25	0.27	0.34	0.093	124	26.4	33.3	9.1
6	0	8	4	1.22	0.28	0.34	0.095	119	27.6	33.5	9.3
7	4	0	0	1.21	0.28	0.36	0.095	119	27.9	35.4	9.4
8	4	0	2	1.25	0.28	0.35	0.090	124	28.2	34.4	9.0
9	4	0	4	1.24	0.28	0.35	0.095	123	28.0	34.7	9.4
10	4	8	0	1.21	0.30	0.37	0.093	120	29.9	36.9	9.2
11	4	8	2	1.23	0.29	0.36	0.095	123	28.9	35.7	9.5
12	4	8	4	1.24	0.28	0.34	0.095	124	27.4	33.9	9.5
13	4	0	1*	1.23	0.31	0.37	0.090	122	30.4	36.9	8.9
14	4	8	1*	1.22	0.31	0.37	0.093	123	31.2	37.5	9.3
Stats for a Factorial Design (Treatments 1-12)											
APP (10-34-0) applied in-furrow											
None				1.24	0.28	0.35	0.092	122	27.7	34.0	9.1
4 gal/ac				1.23	0.29	0.35	0.094	122	28.4	35.1	9.3
P > F:				0.222	0.647	0.343	0.205	0.992	0.438	0.195	0.069
UAN (28-0-0) applied as a surface dribble band											
None				1.24	0.28	0.35	0.092	122	27.8	34.3	9.1
8 gal/ac				1.23	0.29	0.35	0.094	122	28.3	34.9	9.3
P > F:				0.616	0.576	0.515	0.061	0.738	0.573	0.536	0.078
ATS (12-0-0-26) applied as a surface dribble band											
None				1.23	0.29	0.36	0.093	121	28.8	35.8	9.2
2 gal/ac				1.24	0.28	0.35	0.092	123	27.8	34.2	9.1
4 gal/ac				1.24	0.28	0.34	0.094	123	27.7	33.8	9.3
P > F:				0.559	0.414	0.109	0.489	0.506	0.479	0.163	0.539
Average LSD (0.10)				NS	NS	NS	NS	NS	NS	NS	NS
Interactions (P > F)											
APP×UAN				0.819	0.878	0.960	0.205	0.586	0.764	0.904	0.360
APP×ATS				0.091	0.748	0.910	0.901	0.257	0.727	0.908	0.943
UAN×ATS				0.825	0.535	0.856	0.733	0.635	0.476	0.767	0.686
APP×UAN×ATS				0.231	0.714	0.682	0.271	0.182	0.825	0.832	0.402
Stats for RCB design (all 14 treatments)											
P > F:				0.403	0.671	0.682	0.358	0.701	0.556	0.617	0.378
Average LSD (0.10)				NS	NS	NS	NS	NS	NS	NS	NS

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

Figure 1. *The beneficial effects (greater early growth and vigor and a darker green color) of fluid starter fertilizers at Waseca. On the left no starter on the right 4 gal/ac of APP applied in-furrow plus 8 gal/ac of UAN and 4 gal/ac of ATS applied as a surface dribble band 2" to the side of the row (picture taken on June 21, 2010).*

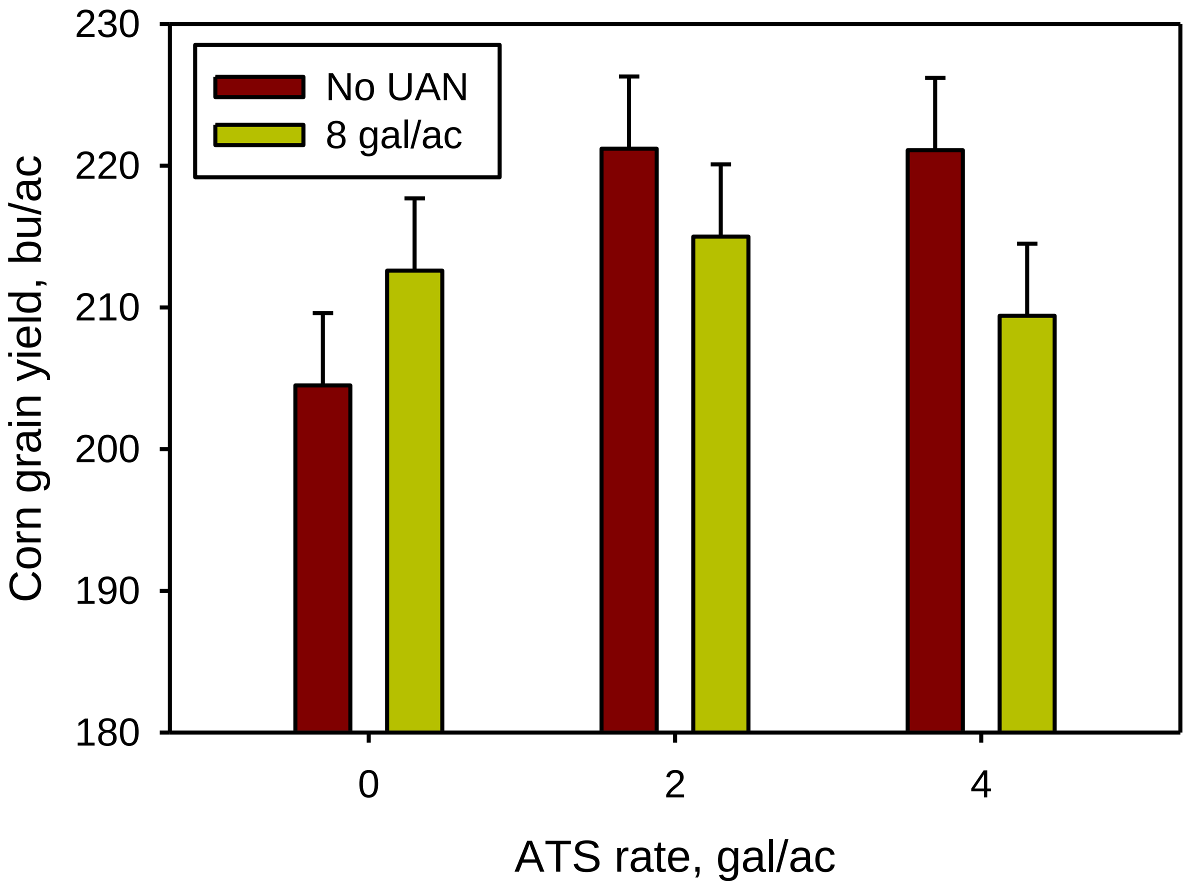

Figure 2. *Corn yield as affected by ATS rate with or without 8 gal/ac of UAN applied at planting at Waseca.*