

Continuous Corn Yields Enhanced via NPS Combinations

Starter fluid combinations in conservation-till boost early plant growth and yields.

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The Fluid Journal • Official Journal of the Fluid Fertilizer Foundation • Early Spring 2012 • Vol. 20, No. 2, Issue# 76



Figure 1. On left no starter. On right 4 gal/A of APP applied in-furrow plus 8 gal/A of UAN and 4 gal/A of ATS applied as a surface dribble band 2 inches to the side of the row (June 21, 2010).

Summary: Early plant growth (plant heights and dry matter yields) was enhanced when nitrogen (N), phosphorus (P), and sulfur (S) starter fertilizers as 10-34-0 (APP), 28-0-0 (UAN) and 12-0-0-26 (ATS) were applied at the Waseca site, but only APP application affected early plant growth at the Rochester site. 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 x ATS interaction for grain yield showed when UAN was not applied at planting. Grain yields increased about 18 bu/A 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. At Waseca, in-furrow application of one gallon of ATS and 4 gallons/A of APP increased grain yields 12 bu/A, compared with 4 gal/A of APP alone. No yield responses to NPS starter fertilizers occurred in Rochester. The 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.

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 because of 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. Our 2010 research has shown that 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, they don't own one anymore or have anyone who is skilled at operating one, or finally, they don't have the time themselves to plow. 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,

Table 1. Growth, nutrient concentration and uptake of V7 corn plants at Waseca.													
				V7	Whole Plant Samples at V7 (June 21)								
Fertilizer rate				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	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

significantly increased early growth of corn by 13 to 43 percent and corn yield by 5 to 7 bu/A. 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 in reduced-till systems. Sulfur deficiency in corn has contributed to some of these pale-looking plants. Corn yield responses to S have been reported on medium

“ATS increased grain yields about 18 bu/A”

and fine-textured soils in Minnesota and Iowa. In Minnesota, we have very little data on the optimum rate and placement of S containing fluid starter fertilizer 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-till/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.

A Wet 2010

The 2010 growing season was warm and wet. At the Waseca site June precipitation was 5.42 inches above normal, at 9.64 inches, and September was 9.47 inches above normal, at 12.66 inches, setting a 96-year record (our weather records at SROC go back to 1914). The June plus July precipitation at 16.25 inches and the growing season total at 34.61 inches were also records. At the Rochester site, growing season precipitation was about 50 percent above normal with much of the excess rain falling during the months of June, August, and September. At Waseca, growing degree units (GDU) for the entire growing season (May 1 through first frost of October 3) totaled 2,606, which was 8 percent above 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. Some corn was

already in reproductive stages and the benefit of N applied at this late date was questioned.

Waseca site

Plant height and whole plant dry matter yields were affected by all three of the treatment main effects in the factorial analysis of treatments 1 through 12 (Table 1). 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/A rate of ATS did not increase height nor yields above the 2 gal/A rate, when averaged across APP and UAN treatment main effects. A significant APPxUAN 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 inches when fertilized with either UAN or APP, compared with plots without UAN and APP, whereas plant heights increased only 2 inches when fertilized with both UAN and APP, compared with either UAN or APP. The 1 gal/A of ATS plus 4 gal/A of APP applied in-furrow increased V7 plant heights and yields compared with 4 gal/A 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.

Nutrient concentration. A few nutrient concentrations and nearly all nutrient uptakes in V7 corn plants were affected by the treatment’s main effects in this study (Table 1). Nitrogen and S concentrations were reduced when 4 gal/A of APP were applied in-furrow compared with 0 gal/A 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/A of ATS to 4 gal/A of APP applied in-furrow, did not affect S concentration in V7 corn plants, compared with 4 gal/A of APP alone. Applying 4 gal/A 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 was 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 dry matter (DM) yield responses to treatments and not to increased nutrient concentrations. Several significant APPxUAN interactions for nutrient concentration and uptake were found. The APPxUAN interaction for P concentrations showed when APP or UAN was applied at planting. Phosphorus concentration in whole plants increased compared with the control (when neither APP nor UAN was applied). However, when APP and UAN were applied together, P concentration declined slightly (data not shown). An APPxUAN interaction for S concentration showed S concentration was reduced slightly when both APP and UAN were applied, whereas when APP or UAN was applied S concentrations were similar to the control (data not shown). Significant APPxUAN interactions for N, P, and S uptake in V7 corn plants were a result of increased growth and have the same explanation as the APPxUAN interaction for plant height in the previous paragraph (data not shown). Generally, APP did not affect nutrient concentrations in corn stover or grain on this very high P-testing site (Table 2). Stover N and K concentration declined slightly when 8 gal/A of UAN was applied at planting compared with 0 gal/A 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 lbs N/A was applied at planting, which limited N supply later during grain fill, thus requiring the plant to use more of the N in the stalk to fill grain in August and early September. Averaged across APP and UAN treatments, 2 gal/A of ATS increased stover N compared with the control; however, stover N concentration was not different between the 0 (control) and 4 gal/A rate of ATS. Stover P concentration declined slightly when 2 gal/A of ATS was applied compared with 0 gal/A. 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/A of ATS and 4 gal/A of APP treatment applied in-furrow increased grain S concentration compared with 4 gal/A of APP alone.

Grain moisture. Treatment effects

Table 2. Nutrient concentrations in the corn stover and grain at Waseca.												
Trt #	Fertilizer rate			Stover concentration					Grain concentration			
	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

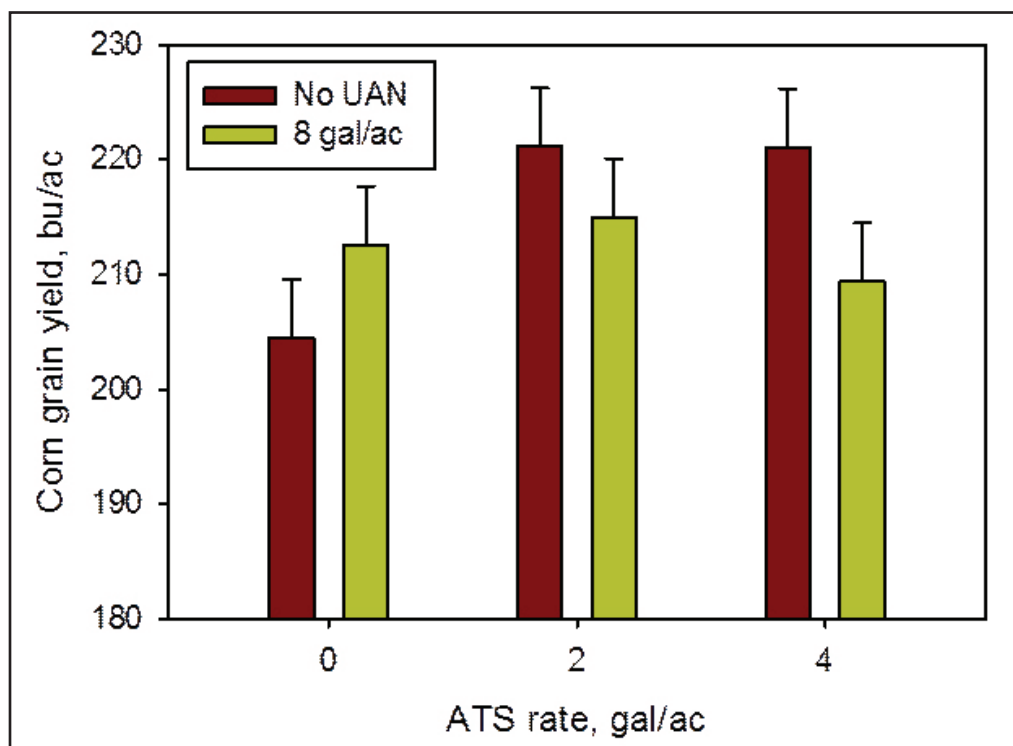


Figure 2. Corn yield as affected by ATS rate with or without 8 gal/ac of UAN applied at planting at Waseca.

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/A vs. 0 gal) and UAN (8 gal/A vs. 0 gal) application. Grain moisture was reduced 1.5 and 2.5 percentage points with 2 and 4 gal/A 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.

Yield. Grain yields were 9 bu/A greater than the control with 2 gal/A of ATS when averaged across APP and UAN treatments. Yields were not different between the 2 and 4 gal/A rates of ATS. Applying one gal/A of ATS and 4 gal/A of APP in-furrow increased yield 12 bu/A compared with APP alone (treatment 13 vs. 7). A significant UANxATS interaction for grain yield showed a 19 bu/A response to ATS when UAN was not applied but

no response to ATS when 8 gal/A 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/A rate of ATS, whereas silage yields were not significantly different between the 2 and 4 gal/A rate.

Plant stand. Treatment effects on plant stand, final population and relative leaf chlorophyll (RLC) content are presented in Table 3. Initial plant stand was reduced slightly (500 plants/A) 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/A of ATS and 4 gal/A 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/A of APP alone (treatment #7). Significant interactions for final plant population were found, but the differences were small (about 300 plants/A) and would not have influenced corn production.

RLC. Relative leaf chlorophyll (RLC) content at VT-R1 increased slightly with 8 gal/A of UAN applied at planting compared to 0 gallon of UAN when averaged across APP and ATS treatments. The 2 and 4 gal/A rates of ATS increased RLC 5.0 and

7.7 percentage points, respectively, compared with the control (0 gal/A), when averaged across APP and UAN treatments. One gal/A of ATS and 4 gal/A of APP applied in-furrow increased RLC significantly compared with 4 gal/A of APP alone. No difference in RLC was found when the one gal/A of ATS plus 4 gal/A of APP applied in-furrow treatment (#13) was compared to the 4 gal/A of APP applied in-furrow plus 2 gal/A of ATS applied as a surface dribble band treatment (#8). Significant APPxATS interaction for RLC showed without ATS. APP increased RLC slightly (1-2 percentage points), whereas with ATS at 2 or 4 gal/A, APP application had no effect on RLC (data not shown). The significant UANxATS interaction for RLC was similar to the APPxATS interaction. It showed at the 0 and 2 gal/A rates of ATS, UAN application increased RLC slightly, whereas at 4 gal/A of ATS, UAN application had no effect 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/A rates of ATS resulted in corn plants that were pale (significantly less RLC) when compared to the 4 gal/A rate, but these treatments produced grain yields similar to the 4 gal/A treatments. This suggests at this site only a small amount of S (1 gal/A of ATS = 2.9 lbs S/A) applied in the seed furrow at planting was needed to get a yield response on this high organic matter soil.

Uptake. Total K uptake increased slightly with APP application when averaged across UAN and ATS treatment main effects (Table 4). However, APP did not affect any other nutrient uptakes on this very high P testing site. Application of 8 gal/A 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/A rates. Total N uptake was greatest (176 lbs/A)

Table 3. Grain moisture, grain, stover and silage yields, plant stand, final plant population, and relative leaf chlorophyll at Waseca.										
Fertilizer rate				Grain	Grain	Stover	Silage	Initial	Final	VT-R1
Trt	APP	UAN	ATS	H2O	Yield	Yield	Yield	Plant	Plant	Leaf
#	----- gal/ac -----			%	bu/ac	- ton	dm/ac -	plants×103/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

Table 4. 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			N	P	K	S	N	P	K	S	N	P	K	S
#	-gal/ac-		----- lb/acre -----											
1	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	44.1	6.51	84.5	3.91	132	33.3	41.1	9.1	176	39.8	126	13.0
3	0	0	40.5	7.68	91.4	4.40	132	34.4	43.0	10.4	172	42.1	134	14.8
4	0	8	30.4	5.93	66.3	3.58	126	32.5	42.3	8.8	157	38.4	109	12.4
5	0	8	38.0	4.87	75.0	3.65	130	33.5	43.1	9.3	168	38.3	118	13.0
6	0	8	40.0	7.09	85.5	4.17	125	32.8	41.8	9.6	165	39.9	127	13.8
7	4	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	41.6	6.56	84.6	4.47	134	34.2	43.2	9.0	176	40.8	128	13.4
9	4	0	39.2	5.50	91.0	4.14	131	33.4	42.6	9.7	170	38.9	134	13.9
10	4	8	35.1	7.66	86.7	3.83	126	32.6	41.7	8.5	161	40.3	128	12.4
11	4	8	36.4	5.46	85.4	3.99	127	30.8	40.0	9.0	164	36.3	125	12.9
12	4	8	40.6	7.23	86.2	4.75	125	29.7	43.1	9.4	166	36.9	129	14.1
13	4	0	39.5	6.56	97.1	3.60	130	32.7	40.9	9.1	169	39.2	138	12.7
14	4	8	36.9	7.67	85.6	4.06	127	30.6	37.6	8.2	164	38.3	123	12.2

with treatments that contained very little N at planting and 2 gal/A of ATS (treatment 2 and 8). Total N uptake was 10-12 lbs/A 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 lbs/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 during a high N stress growing season in 2010. Stover and total uptake of K was greatest with the 4 gal/A rate of ATS compared with 0 or 2 gal/A 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 lbs/A for the 4 gal/A rate of ATS (11.5 lbs S/A) compared with the control when averaged across APP and UAN treatments.

Interactions. Several significant ($P < 0.10$) interactions were found for stover, grain, and total nutrient uptake. An APPxUAN interaction for stover K showed K uptake was reduced about 11 lbs/A 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 UANxATS 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/A of ATS without UAN. When UAN was applied, uptake values across all rates of ATS were similar (data not shown). The APPxUAN interactions for grain P and K uptake were similar and showed P and K uptake was greatest when either APP or UAN was applied, while uptake was reduced when both were applied (data not shown). An APPxATS interaction for total P uptake showed, when APP was not applied, P uptake was 37, 39, and 41 lbs/A for the 0, 2, and 4 gal/A rates of ATS, respectively. However, when APP was applied, P

uptake was 40, 39, and 38 for the 0, 2, and 4 gal/A rate, 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

Plant height. Plant heights and dry matter yields were increased with 4 gal/A of APP applied in-furrow compared with 0 gal/A 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 that the early growth response at this site was primarily due to P in the APP starter. Adding 1 gal/A of ATS to 4 gal/A of APP in-furrow had no effect on plant height and dry matter yield compared with APP alone.

Nutrient concentration. 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 NPK 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/A of ATS increased N concentration in small plants compared to the 0 and 2 gal/A 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/A of ATS to 4 gal/A of APP in-furrow generally did not affect nutrient concentrations or uptakes in small corn plants compared with APP

alone. The highly significant APPxATS interactions for K concentration and uptake in V7-8 corn plants showed that 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/A of ATS was applied (data not shown). These results were not found at the S-responding Waseca site. The 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.

Grain moisture. Grain moisture was reduced 0.9 percentage points with 4 gal/A of APP compared with 0 gal/A 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 (APPxATS, UANxATS, and APPxUANxATS) were found for corn grain moisture. Generally, these interactions showed that when APP was not applied, grain moisture was reduced with ATS with or without UAN. However, when APP was applied, grain moisture response to ATS with or without UAN was erratic.

Yields. Corn yields only ranged from 207 to 213 bu/A 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.

RLC. At VT-R1, relative leaf chlorophyll ranged from 94.6 to 99.1 percent and was not affected by the main effects of APP and UAN application. The 2 and 4 gal/A rates of ATS increased RLC about one percentage point compared with the 0 gal/A 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.

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