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Prepared by

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## I. Introduction and Project Orientation

The year 1985 was a year of great scientific achievement in some areas of our research effort, and a year of frustration in others. Good scientific progress was made in researching certain additives (ammonium polyphosphate, APP, and ammonium thiosulfate) as inhibitors of ammonia loss from urea-ammonium nitrate (UAN). Since the PPI is very interested in new uses of APP, reprints on this research is added to the Appendix, even though the research was not directly funded by PPI.

Poor environmental conditions limited the amount of useful information obtained on our KCl-plant disease research. Winterkill, crusting, drouth or grasshopper predation affected every site in one way or another. In spite of these problems, some highly significant KCl-disease interactions were demonstrated. The report will cover the following subjects:

- 1) Effect of KCl on common root rot of durum wheat.
- 2) Effect of KCl on tan spot of zero-till winter wheat.
- 3) Residual effects of deep-placed APP applied to established alfalfa.
- 4) An Appendix containing reprints on our work on the effect of APP on ammonia loss from UAN.

## II. Effect of KCl on Common Root Rot of Durum Wheat

Common root rot (CRR) is a widespread cereal disease, incited by Cochliobolus sativus. Our research team has shown that CRR can be significantly reduced in barley by chloride fertilization<sup>1</sup>. An appropriate extension of these concepts is to determine how other species susceptible to CRR respond to KCl fertilization. Durum wheat (Triticum durum) can be attacked by CRR, although its susceptibility is generally felt to be intermediate between barley and spring wheat.

Treatments imposed were 3 KCl rates (0, 25, and 100 lb K<sub>2</sub>O/A) by 2 durum varieties (Ward vs. Vic). Ward is generally considered to be more susceptible to CRR than Vic. Measurements reported here are CRR severity at 2 growth stages and final grain yield. Numerous plant and soil analyses are not complete at this writing.

Site description is given in Table 1. All sites, except Fortuna, were quite low in soil Cl. All sites were impacted by unfortunate environmental events of one type or another. Minot and Flaxton received heavy rainfall just prior to emergence and had reduced stands due to crusting. Fortuna was abandoned at the milk stage because of severe grasshopper damage (eg. all leaves, awns, and half the glumes were eaten). Williston had a good stand, but yields were severely limited by a near-record drouth. However, our CRR data was of sufficient precision to make conclusions as to the experimental treatments.

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<sup>1</sup> Timm, C. A., R. J. Goos, B. E. Johnson, and F. J. Sobolik. 1986. Effect of potassium fertilizers on malting barley infected with common root rot. Agron. J. (In press, scheduled to be in the Jan-Feb 1986 issue).

The effect of KCl fertilization on CRR severity at the boot stage is shown in Table 2. These were significant reductions in CRR severity from KCl fertilization at Minot. There were no effects of KCl at the other sites. There were significant variety effects at Minot and Williston. There were no KCl or varietal effects at Flaxton or Fortuna.

The effect of KCl fertilization on CRR severity at the dough stage is shown in Table 3. There was no overall KCl effect at Minot, although the disease tended to be decreased by KCl fertilization with the variety Vic. The lack of a significant KCl effect at Minot at the second sampling date contradicts our earlier experience with barley. With barley, our observation has always been that any effect of KCl on CRR was, if anything, strengthened as the season (and the disease) progressed. We have not, until now, ever observed a crop "growing out" of a KCl effect on CRR. The data were more scattered at Flaxton. The F test for variety was significant (.05 level) but this was probably a spurious result because of the significant KCl x variety interaction. The varieties were not significantly different at the earlier sampling. The overall means between Ward vs. Vic were different by < 0.2 CRR unit, a difference seldom detectable statistically. There were no significant KCl effects on CRR at Williston, although the variety effects were highly significant.

Grain yields were not dramatically influenced by KCl fertilization. The yield of Vic at Minot was increased 2.2 bu/A by 100 lb K<sub>2</sub>O/A, an amount not probably statistically or economically significant, but at least in line with the previous disease observations. Grain yields were not influenced by KCl or variety at the other sites. Perhaps it is premature to make this conclusion, but it appears that KCl fertilization for CRR reduction is more successful on barley than durum wheat. In previous years (1983-1984) we have observed significant KCl effects on CRR in most (eg. 7 of 8) trials at both sampling dates (boot and dough). Overall CRR levels in the durum wheat were high enough for a KCl response to be expressed, but KCl effects were observed at only one sampling date in 1 of 4 trials.

We are not fully certain where to take this research. An obvious avenue is to compare the effect of KCl vs. seed-applied fungicides for the control of CRR of barley. This is where we plan to go in 1986. At the end of 1986, our position with respect to KCl fertilization and CRR will have to be fully evaluated and new directions planned.

The KCl x variety data from 1984 and 1985 will be written up for a journal article as soon as the plant analyses are done. It is projected that the paper will be completed by 1 April 1986.

### III. Effects of KCl Fertilization on Leaf Disease Severity of Zero-till Winter Wheat.

Winter wheat is often a good crop for North Dakota, as winter wheat is a good weed competitor, and winter wheat can yield better than spring wheat. Also, winter wheat allows a North Dakota farmer to spread out his farm work load. The three major problems with winter wheat in North

Dakota are: 1) winterkill, 2) poor agronomic characteristics associated with winter hardy varieties (eg. tall straw, disease susceptibility), and 3) the increase of diseases associated with zero-tillage, the one cultural practice known to greatly increase winter survival odds. Of these diseases, of greatest concern are wheat streak mosaic virus, tan spot, and leaf rust. Other diseases such as Cochliobolus sativus leaf spot (same organism that causes CRR), and various bacterial leaf diseases can also occur on zero-till wheat fields. We observed in 1983 reductions in spot blotch of barley (incited by C. sativus) by KCl application and Dr. Fixen and colleagues at SDSU measured leaf rust and tan spot reductions in spring wheat in 1984. The purpose of this research is to measure the effect of KCl fertilization on leaf disease severity of winter wheat.

Simple KCl rate experiments were begun in the spring of 1985. Topdressed applications of 0, 25, 100 and 200 lb K<sub>2</sub>O/A were applied to surviving winter wheat stands in the early spring. The winter of 84-85 had been difficult and even though over a dozen farmer's fields were surveyed, none of the sites chosen were totally acceptable for use, as no site could be found with a perfect stand throughout an area large enough for research purposes. Such is a common problem with winter wheat research in North Dakota. Each of the 6 sites selected had six replications. Complete soil test data has not been completed by the graduate student at this writing. However, all sites were relatively low in soluble Cl, ranging from 4-30 lb Cl/A in the 0-2 foot layer. It is expected that all sites will be "high" in exchangeable K.

Dramatic effects of KCl on tan spot were observed at the Cuba site (Table 5). With one exception (the flag leaf position at the 6-20 sampling), all leaf positions showed highly significant reductions in disease with KCl fertilization. What was most encouraging is that the lowest rate (25 lb K<sub>2</sub>O/A) was usually an adequate rate for significant reductions, although the disease severity tended to be depressed further by higher rates.

Some significant KCl effects were also observed at the 6-4 sampling at the Spiritwood east site (Table 6). Later samplings did not indicate significant disease repression. However, it is encouraging to note that significant disease repression was observed at a second site. Later in the season some patterns showed up in the plots, presumably from the farmer's previous tillage practices, which increased the site variability. These streaks were not obvious when the KCl was applied (about the 2-3 leaf stage).

No significant disease effects were observed at the other sites (Tables 7-10). There were some problems at the other sites which certainly could have increased data variability. Minot suffered from growth regulator drift from an adjacent experiment, the Guelph site was also infected with wheat streak mosaic virus, and the grower at Ayr forgot to exclude the plot area from his first fungicide application. Grain yields were not significantly increased by KCl fertilization (Table 11), although the upward trend in yield at the Cuba site was consistent with the previous disease observations. All sites had less-than-perfect stands for reasons already discussed, and variability was higher than desired.

Some curious effects of KCl were observed on crop height and maturity. At several sites, especially Minot and Cuba, KCl application visibly speeded maturity and reduced crop height. This effect has been commonly observed in maturity, but I had not observed this effect on height before.

This research is to be continued for two more growing seasons. Greenhouse work is being done to further understand these relationships. Also, a new Ph.D. candidate in Plant Pathology will be beginning her research on chloride-disease interactions this winter, to complement the field and greenhouse work being done by Ms. Holmes for her dissertation. We hope to come up with a better explanation for these effects and why chloride effects are not always observed, even with uniformly low-Cl soils. It is hoped, with the heavy- and long-lasting snowfalls obtained this winter, that better stands will be available for testing in 1986.

#### IV. Residual Value of Injected 10-34-0 Applied to Established Alfalfa.

In the fall of 1982, 4 experiments were established to compare the agronomic efficiencies of injected 10-34-0 to surface-applied 0-45-0 as P sources for established alfalfa. The first-year results were published, as a marked superiority of the injected treatment was observed<sup>2</sup>. This experiment will be continued through 1986, so that a minimum of 4 years' data can be compiled. The data after four years will be published, probably in the Journal of Fertilizer Issues.

One site was lost to winterkill the first winter (82-83) and the Hettinger site was lost to winterkill this past winter (84-85). Only the Mandan and Dickinson sites remain. Only one cut was obtained this year, and yields were particularly poor at Dickinson. Forage % P values are not available at this writing.

Dry matter yields for 1985, and cumulative yields are presented in Table 12. Yields did not appear to be influenced by treatment at either site. Cumulative yields still show a general yield increase due to P fertilization, and a possible superiority of deep placement at the Dickinson site, even though two of the three years of this study have been quite dry for alfalfa production. Off-season precipitation has been favorable at Dickinson, so yields will probably be much better in 1986.

In past years, P uptake data has shown a marked superiority due to deep placement, and it is anticipated that these differences will continue.

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<sup>2</sup> Goos, R. J., B. E. Johnson, and C. A. Timm. 1984. Deep placement of phosphorus fertilizer into established alfalfa. J. Fert. Issues 1:19-22.

V. Effect of APP on Ammonia Loss from Surface-Applied UAN.

Two reprints are attached which document most of the progress achieved in 1985 with the use of APP as an inhibitor of ammonia loss from surface-applied UAN. In general, the effects can be quite significant. A complete article will be published in the spring issue of the Journal of Fertilizer Issues.

Table 1. Site characteristics.

Site	0-6 inch			0-24 inch	
	pH	Olsen P	NH <sub>4</sub> OAc-K	NO <sub>3</sub> -N	Cl*
	----- 1b/A -----				
Minot	6.4	23	870	130	16
Flaxton	6.5	17	982	119	14
Williston	6.2	45	840	248	12
Fortuna	7.9	19	725	149	162

\* Considerable error may exist in these values (except Fortuna). Most titration values were < 0.05 ml greater than the reagent blank.

Table 2. Effect of KCl and Variety on CRR severity, boot stage, North Dakota, 1985.

Variety	KCl rate 1b K <sub>2</sub> O/A	Site			
		Minot	Flaxton	Williston	Fortuna
		----- CRR Severity Index -----			
Ward	0	2.5	1.7	1.9	1.7
	25	2.4	1.7	2.0	1.8
	100	2.3	1.7	1.9	1.8
Vic	0	1.9	1.8	1.7	1.6
	25	1.8	1.9	1.6	1.7
	100	1.7	1.8	1.7	1.5
Sig. of F					
KCl		*	NS	NS	NS
Var		**	NS	**	NS
KCl x Var		NS	NS	NS	NS
C.V., %		7.9	11.0	9.5	8.0

Table 3. Effect of KCl and variety on CRR severity, dough stage, North Dakota, 1985.

Variety	KCl rate 1b K <sub>2</sub> O/A	Site		
		Minot	Flaxton	Williston
		----- CRR Severity Index -----		
Ward	0	3.3	2.3	3.0
	25	3.2	2.6	2.9
	100	3.3	2.2	2.9
Vic	0	2.8	2.8	2.7
	25	2.6	2.4	2.6
	100	2.5	2.4	2.5
Sig. of F				
KCl		NS	NS	NS
Var		**	*	**
KCl x Var		NS	**	NS
C.V., %		7.7	8.4	7.3

Table 4. Effect of KCl and variety on grain yield, North Dakota, 1985.

Variety	KCl rate 1b K <sub>2</sub> O/A	Site		
		Minot	Flaxton	Williston
		----- bu/A -----		
Ward	0	74.2	38.8	11.3
	25	72.1	42.5	10.5
	100	74.7	41.3	11.0
Vic	0	73.0	38.0	11.4
	25	72.3	36.0	10.7
	100	75.2	37.1	11.3



Table 5. Effect of KCl fertilization on tan spot severity, Cuba site, North Dakota, 1985.

KCl rate	Leaf Position†									
	6-5-85				6-20-85				7-2-85	
	F	F-1	F-2	F-3	F	F-1	F-2	F-3	F	F-1
lb K <sub>2</sub> O/A	----- % leaf area necrotic from tan spot -----									
0	0.4a	2.8a	7.1a	30.5a	2.1a	5.7a	36.6a	92.5a	12.8a	58.7a
25	0b	0.4b	2.2b	23.7ab	1.3a	3.5b	16.9b	76.3b	5.6b	43.9b
100	0b	0.2b	1.6b	14.9b	1.2a	3.3b	20.2b	81.7b	5.6b	39.5b
200	0b	0.3b	1.3b	11.7b	1.9a	3.7b	16.5b	78.8b	4.2b	35.4b

Sig. of F

KCl rate \* \*\* \*\* + NS \* \*\* \* \*\* \*\*

† F = flag leaf; F-1 = leaf below flag leaf; etc. Data in the same column followed by different letters are significantly different at the .05 level by Duncan's test.

Table 6. Effect of KCl fertilization on tan spot severity, Spiritwood-east site, North Dakota, 1985.

KCl rate	Leaf Position						
	6-4-85				6-19-85		7-1-85
	F	F-1	F-2	F-3	F	F-1	F
lb K <sub>2</sub> O/A	----- % leaf area necrotic from tan spot -----						
0	0.1a	1.6a	5.7a	49.6a	21.7a	59.7a	36.8a
25	0a	0.4b	1.8b	38.9a	28.8a	53.8a	32.4a
100	0a	0.3b	1.4b	45.5a	20.8a	55.6a	32.9a
200	0a	0.3b	1.5b	30.8a	21.1a	55.9a	30.5a

Sig. of F

KCl rate NS \* \* NS NS NS NS

Table 7. Effect of KCl fertilization on tan spot severity, Spiritwood-west site, North Dakota, 1985.

KCl rate	Leaf Position					
	6-4-85			6-19-85		7-1-85
	F-1	F-2	F-3	F	F-1	F
	----- % leaf area necrotic from tan spot -----					
0	0.7	8.2	73.9	3.9	22.7	37.8
25	0.3	5.1	56.3	2.8	25.1	30.3
100	0.5	6.9	60.2	3.4	24.1	27.5
200	0.5	4.0	54.7	3.2	20.6	38.6

Sig. of F

KCl rate	NS	NS	NS	NS	NS	NS
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Table 8. Effect of KCl fertilization on tan spot and leaf rust severity, Minot site, 1985, North Dakota.

KCl rate	Leaf Position						
	Tan Spot			Leaf Rust			
	F	F-1	F-2	F	F-1	F-2	F-3
1b K <sub>2</sub> O/A	----- % leaf area affected -----						
0	0.1	2.7	22.6	0.2	1.6	3.8	6.5
25	1.8	3.5	27.9	0.1	1.4	4.1	7.0
100	2.6	4.4	24.9	0.1	1.5	4.4	7.6
200	0.9	3.7	17.8	0.1	1.3	4.7	7.4

Sig. of F

KCl rate	NS	NS	NS	NS	NS	NS	NS
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Sampling date 24 June 1985. Site was also affected by inadvertent growth regulator drift.

Table 9. Effect of KCl fertilization on tan spot severity, Guelph site, 1985, North Dakota.

KCl rate lb K <sub>2</sub> O/A	Leaf position	
	F	F-1
	- % leaf area affected by tan spot -	
0	17.2	70.0
25	18.6	74.9
100	22.2	74.6
200	16.8	72.7
Sig. of F		
KCl rate	NS	NS

Sampled 7-15-85. Site was badly infected with wheat streak mosaic virus.

Table 10. Effect of KCl rate on tan spot severity, Ayr site, 1985, North Dakota.

KCl rate lb K <sub>2</sub> O/A	Leaf Position					
	6-17-85				7-3-85	
	F	F-1	F-2	F-3	F	F-1
0	0.2	2.9	28.2	54.7	20.0	70.5
25	4.3	5.3	26.3	56.3	27.8	78.7
100	0.5	1.2	18.5	53.4	20.7	70.0
200	4.3	5.4	21.5	52.7	20.2	74.9
Sig. of F						
KCl rate	NS	NS	NS	NS	NS	NS

Site inadvertently sprayed with fungicide by cooperater on 6-2-85.

Table 11. Effect of KCl rate on grain yield, all sites, North Dakota, 1985.

KCl rate	Site					
	Cuba	Sp.-E	Sp.-W	Minot	Guelph	Ayr
	bu/A					
0	37.5	29.6	28.6	42.2	17.2	46.2
25	37.7	29.2	31.8	41.6	19.5✓	45.1
100	39.5	30.9✓	28.7	42.5✓	18.3	46.6✓
200	43.0✓	29.2	32.8✓	36.7	19.1	46.4

Sig. of F

KCl rate	NS	NS	NS	NS	NS	NS
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Table 12. Effect of P rate and mode of application on alfalfa yields, North Dakota, 1983-1985.

P Rate	Source and Placement	Time of Application	1985		1983-1985	
			Mandan	Dickinson	Mandan	Dickinson
lb P <sub>2</sub> O <sub>5</sub> /A			lb DM/A			
0	APP	October	2495	1063	6450	3972
20	Injected only	1982	2535	1199✓	6940	4515
40		only	2594	1085	7054	4808✓
80			2622✓	1141	7078✓	5126
0		October	2409	1201	6602	4170
20		1982	2372	1103	6837	4370
40		only	2578✓	1217	7165✓	4540
80			2494	1232✓	6987	4952✓
0		October	2508	1198	6561	4193
10		1982-1984	2562	1167	6893✓	4392
20			2499	1247	6709	4609
40			2567✓	1327✓	6699	4954✓

# Urea Hydrolysis and Ammonia Volatilization Characteristics of Liquid Fertilizer Mixtures. I. Laboratory Studies<sup>1</sup>

R. J. Goos<sup>2</sup>

## ABSTRACT

The effect of ammonium thiosulfate (ATS, 12-0-0-26) and ammonium polyphosphate (APP, 10-34-0) on the urea hydrolysis and ammonia volatilization characteristics of urea-ammonium nitrate (UAN, 28-0-0) was studied under laboratory conditions. Incubation time was 5 days at 25°C. A polyfoam ammonia trapping technique was used on a loam soil. Additions of 1-25% volume/volume (v/v) ATS to UAN significantly retarded urea hydrolysis and ammonia volatilization. Addition of 5% (v/v) ATS to UAN inhibited urea hydrolysis by 27% and reduced ammonia volatilization by 45% compared to UAN alone. A second experiment showed that addition of 10-20% (v/v) APP to UAN had little effect on urea hydrolysis or ammonia volatilization. Fertilizer droplet size was 0.025 ml in this experiment. At larger fertilizer droplet sizes, however, APP additions significantly reduced ammonia volatilization, presumably by a pH-buffering effect. With the largest fertilizer droplet size tested, 0.5 ml, addition of 2% (v/v) ATS reduced ammonia volatilization by 61%, addition of 20% (v/v) APP reduced ammonia volatilization by 27%, and addition of both 2% ATS and 20% APP reduced ammonia volatilization by 72%. It was concluded that the interactive effects of droplet size, ATS, and APP on ammonia volatilization deserve field evaluation.

*Additional index words:* Ammonium thiosulfate, Ammonium polyphosphate, Urea-ammonium nitrate, Urease inhibition.

UREA-AMMONIUM nitrate (UAN) is often applied to soil surfaces without immediate incorporation. There is always concern that a portion of applied urea will be lost via ammonia volatilization whenever UAN is applied in this manner. Adding a urease inhibitor to urea-containing fertilizers has long been appreciated as a method for reducing ammonia loss (for reviews, see Mulvaney and Bremner, 1981; Terman, 1979). Although some highly effective inhibitors have been found, such as phenyl phosphorodiamidate (PPD),

at present there are no safe, effective, and economical urease inhibitors available for general farm use. Recently, Goos (1985) demonstrated that common ammonium thiosulfate fertilizer (ATS, 12-0-0-26 S) possessed some ability to inhibit soil urease activity. Although the levels of inhibition observed with ATS were less than have been shown for PPD (Byrnes *et al.*, 1983), ATS could still have utility as a urease inhibitor because of its low cost, wide commercial availability, and convenient use with fertilizers such as UAN.

The first objective of this study was to determine if addition of ATS to UAN would reduce ammonia losses under laboratory conditions. It was felt that observed reductions in ammonia loss under laboratory conditions were needed to justify field evaluation of this concept.

The second objective was to determine if addition of common ammonium polyphosphate fertilizer (APP, 10-34-0) to UAN could also reduce ammonia losses. The theory advanced is that because APP is a highly concentrated (ca 6 M with respect to P) solution buffered at a pH level of 6-7, perhaps addition of APP to UAN could temporarily moderate the high pH levels that result when urea is hydrolyzed. Phosphoric acid has been shown to reduce ammonia losses from urea (Bremner and Douglas, 1971) but the effect of APP on ammonia losses from UAN does not appear to have been studied. Other pH buffers, such as aluminum hydroxide, have been shown to reduce ammonia losses from soil (Ferguson *et al.*, 1984).

## MATERIALS AND METHODS

### General

All experiments were performed with a Williams loam soil (Typic Argiboroll, pH 6.8, 2.2% organic matter). All soil incubations were performed in 250 ml French square bottles fitted with ammonia traps. The ammonia traps consisted of 3.8 x 3.8 x 2.5 cm polyfoam sponges inserted into the mouth of the bottle. The polyfoam was prepared by saturating and then wringing out the sponges at least twice with tap water, twice with 0.4 N H<sub>2</sub>SO<sub>4</sub>, and twice with a glycerol-phosphoric acid solution. The glycerol-phosphoric acid solution consisted of 500 ml glycerol, 50 ml phosphoric acid and 450 ml distilled water. The polyfoam ammonia traps allowed for air exchange and a slow drying of the soil during incubation, which was considered beneficial as ammonia volatilization is enhanced by soil drying.

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After incubation the ammonia traps were removed and extracted by repeated saturation and wringing out with 50 ml of 0.2 N H<sub>2</sub>SO<sub>4</sub> and a 20 ml aliquot analyzed for ammonia by a standard steam distillation technique (Bremner, 1965). Soils were analyzed for residual urea by extraction with a saturated gypsum solution containing 5 ppm phenylmercuric acetate and the filtrates analyzed by the procedure of Watt and Chrisp (1954). None of the fertilizer solutions used in this study contained substances which interfered with this procedure. All experiments were performed in triplicate in a growth chamber at 25 °C.

### Fertilizer Solutions

Reagent-grade UAN (28-0-0) was made with urea (300 g), ammonium nitrate (400 g), and distilled water (300 ml). Commercial-grade ATS (11.7-0-0-26.0 S) was obtained from J. R. Simplot, Brandon, Manitoba. The ATS was of high quality, having an assay of 59.5% (NH<sub>4</sub>)<sub>2</sub>S<sub>2</sub>O<sub>8</sub>, a pH of 8.0 and less than 1% ammonium sulfate, ammonium sulfite, or free ammonia. The APP (10.3-34.2-0) was manufactured by Fert-L-Flow, Crookston, MN using Becker "superacid" and contained 40% of its P in polyphosphate forms, and had a diluted pH of 6.7. Mixtures of these fertilizers, as used in the following experiments, are outlined in Table 1.

Table 1. Fertilizer mixtures used in laboratory experiments.

UAN	ATS	APP	Water	Mixture designation
ml				
75	0	0	25	UAN alone
75	1	0	24	UAN + 1% ATS
75	2	0	23	UAN + 2% ATS
75	5	0	20	UAN + 5% ATS
75	10	0	15	UAN + 10% ATS
75	25	0	0	UAN + 25% ATS
75	0	10	15	UAN + 10% APP
75	2	10	13	UAN + 2% ATS + 10% APP
75	5	10	10	UAN + 5% ATS + 10% APP
75	0	20	5	UAN + 20% APP
75	2	20	3	UAN + 2% ATS + 20% APP
75	5	20	0	UAN + 5% ATS + 20% APP

### Experiment 1

This experiment was to test the effect of different levels of ATS addition to UAN on urea hydrolysis and ammonia volatilization. Five ml of water was placed in French square bottles then 20 g of soil was added, shaken to level and allowed to come to moisture equilibrium. Next, four 0.025 ml droplets of mixed fertilizer solutions were placed on the soil surface approx-

imately 2 cm apart from each other. Fertilizer solutions employed were no fertilizer, UAN alone, UAN + 1% ATS, UAN + 2% ATS, UAN + 5% ATS, UAN + 10% ATS, and UAN + 25% ATS. The vessels were fitted with ammonia traps, capped for two days (to allow for urea hydrolysis) and left uncapped for three days (to allow for soil drying and ammonia volatilization). The soil and ammonia trapping sponges then were analyzed as previously described. The soil had dried to approximately 10% moisture after the three-day evaporation period.

### Experiment 2

This experiment was identical to Experiment 1, except that different fertilizer solutions were employed to test the effect of both ATS and APP on urea hydrolysis and ammonia volatilization. A factorial combination of three ATS levels (0%, 2%, 5%) and three APP levels (0%, 10%, 20%) was used plus a no fertilizer control.

### Experiment 3

This experiment was performed to determine how the effects of ATS and APP on urea hydrolysis and ammonia volatilization are influenced by fertilizer droplet sizes larger than 0.025 ml. Ten ml of water and 40 g of soil were allowed to come to equilibrium. Then a single drop of liquid fertilizer was placed on the soil surface. The experiment was a factorial combination of two droplet sizes (0.1 and 0.5 ml) by two ATS levels (0 and 2%) by two APP levels (0 and 20%) plus a no-fertilizer control. Procedure was as described for Experiment 1, except that the ammonia traps associated with the largest droplet size (0.5 ml) were changed after three days, to assure that the ammonia absorbing capacity of the traps was not exceeded.

## RESULTS AND DISCUSSION

### Experiment 1

The effect of ATS on urea hydrolysis and ammonia volatilization is shown in Table 2. Urea hydrolysis was essentially complete (97%) in the absence of ATS, however, addition of as little as 1% ATS significantly slowed urea hydrolysis. Urea hydrolysis was increasingly inhibited with increasing levels of ATS, which agrees with the observations of Goos (1985). At the highest level of ATS addition (25%), only 55% of the original urea application has been hydrolyzed. Ammonia volatilization was also significantly decreased by small additions of ATS to UAN. Minimum ammonia loss occurred at an addition of 5% ATS, which reduced

ammonia loss by 45% compared to UAN alone. Ammonia loss increased somewhat at higher rates. It is possible that at higher levels of ATS there can be ammonia loss from the ATS itself. This would be expected, as the ATS product used had a high pH (8.0). This increase in ammonia loss between 5-25% ATS might not have occurred had a lower pH ATS product been used.

Table 2. Effect of rate of addition of ATS to UAN on urea hydrolysis and ammonia volatilization.

Addition of ATS to UAN	Urea hydrolysis <sup>†</sup>	Ammonia volatilization
% (v/v)	%	mg N
0	97	3.6
1	80	2.7
2	76	2.2
5	71	2.0
10	62	2.2
25	55	2.4
SE <sup>‡</sup>	1	>0.1

<sup>†</sup> Expressed as percentage of the original urea application hydrolyzed.

<sup>‡</sup> Standard error.

### Experiment 2

The effect of ATS and APP on urea hydrolysis and ammonia volatilization is shown in Table 3. In general, ATS inhibited urea hydrolysis and ammonia volatilization as shown in Experiment 1, but APP had no effect on either parameter. This was an unexpected result, as APP had consistently reduced ammonia losses in preliminary experiments (data not shown). The major difference between Experiment 2 and these preliminary experiments was in droplet size, with larger droplet sizes (0.1-0.4 ml) being used in the preliminary experiments. Thus, Experiment 3 was designed to ascertain the influence of droplet size, ATS, and APP on urea hydrolysis and ammonia volatilization. Perhaps APP can only influence ammonia volatilization when in *very* large concentrations, as would exist in a surface "dribble" application, where droplets greater than 1 ml in size are common.

### Experiment 3

The effects of droplet size, ATS, and APP on urea hydrolysis and ammonia volatilization are shown in Table 4. Urea hydrolysis was complete with all fertilizer solutions applied at the 0.1 ml droplet size. Thus, the effects of ATS and APP on urea hydrolysis cannot be determined. Because of the greater soil mass employed in Experiment 3, the soil was not as completely dried

at the end of the incubation period, allowing for more vigorous urea hydrolysis than observed in Experiments 1 and 2. At the 0.5 ml droplet size 2% ATS markedly slowed urea hydrolysis from 83% with UAN alone to 48% with UAN + 2% ATS. Addition of APP had only a slight influence on urea hydrolysis. Ammonia volatilization was significantly reduced by either ATS and APP, with the combination of ATS and APP giving the lowest ammonia losses. Reductions in ammonia loss were most impressive with the 0.5 ml droplet size. Addition of 2% ATS reduced ammonia loss by 61%. Addition of 20% APP reduced ammonia loss by 27% and addition of both ATS and APP reduced the loss by 72%.

Table 3. Effect of rate of addition of ATS and APP on urea hydrolysis and ammonia volatilization.

Rate of Addition		Urea hydrolysis <sup>†</sup>	Ammonia volatilization
ATS	APP		
—% (v/v)—		%	mg N
0	0	97	3.6
2	0	76	2.2
5	0	71	2.0
0	10	99	4.1
2	10	74	2.2
5	10	65	2.1
0	20	98	3.9
2	20	75	2.1
5	20	66	1.7
SE <sup>‡</sup>		2	0.1

<sup>†</sup> Expressed as a percentage of the original urea application hydrolyzed.

<sup>‡</sup> Standard error.

Table 4. Effect of droplet size, ATS, and APP on urea hydrolysis and ammonia volatilization.

Rate of addition		Droplet size	Urea hydrolysis <sup>†</sup>	Ammonia volatilization
ATS	APP			
—% (v/v)—		ml	%	mg N
0	0	0.1	100	1.7
2	0		100	1.2
0	20		100	1.4
2	20		100	1.0
SE <sup>‡</sup>			—	0.1
0	0	0.5	83	12.7
2	0		48	5.0
0	20		74	9.3
2	20		45	3.5
SE <sup>‡</sup>			1	0.4

<sup>†</sup> Expressed as percentage of the original urea addition hydrolyzed.

<sup>‡</sup> Standard error.

## CONCLUSIONS

These experiments show that two common liquid fertilizers — ATS and APP — hold promise to reduce ammonia losses from surface-applied UAN. However, large droplet sizes as obtained in a "dribble" system may be needed to obtain maximum effect of ATS and any effect of APP. The effect of addition of soluble KCl to UAN was not investigated in this study, but further reductions in ammonia loss may be possible with addition of KCl (Rappaport and Axley, 1984). As promising as these laboratory results seem, the effects of ATS and APP on ammonia loss under field conditions await testing, and caution is advised in extending these lab results to field conditions until the appropriate field trials have been performed. It would indeed be ironic, at least for the liquid fertilizer dealer, after so much research into reducing ammonia losses from urea if practical additives for reducing these losses had been unknowingly used for years.

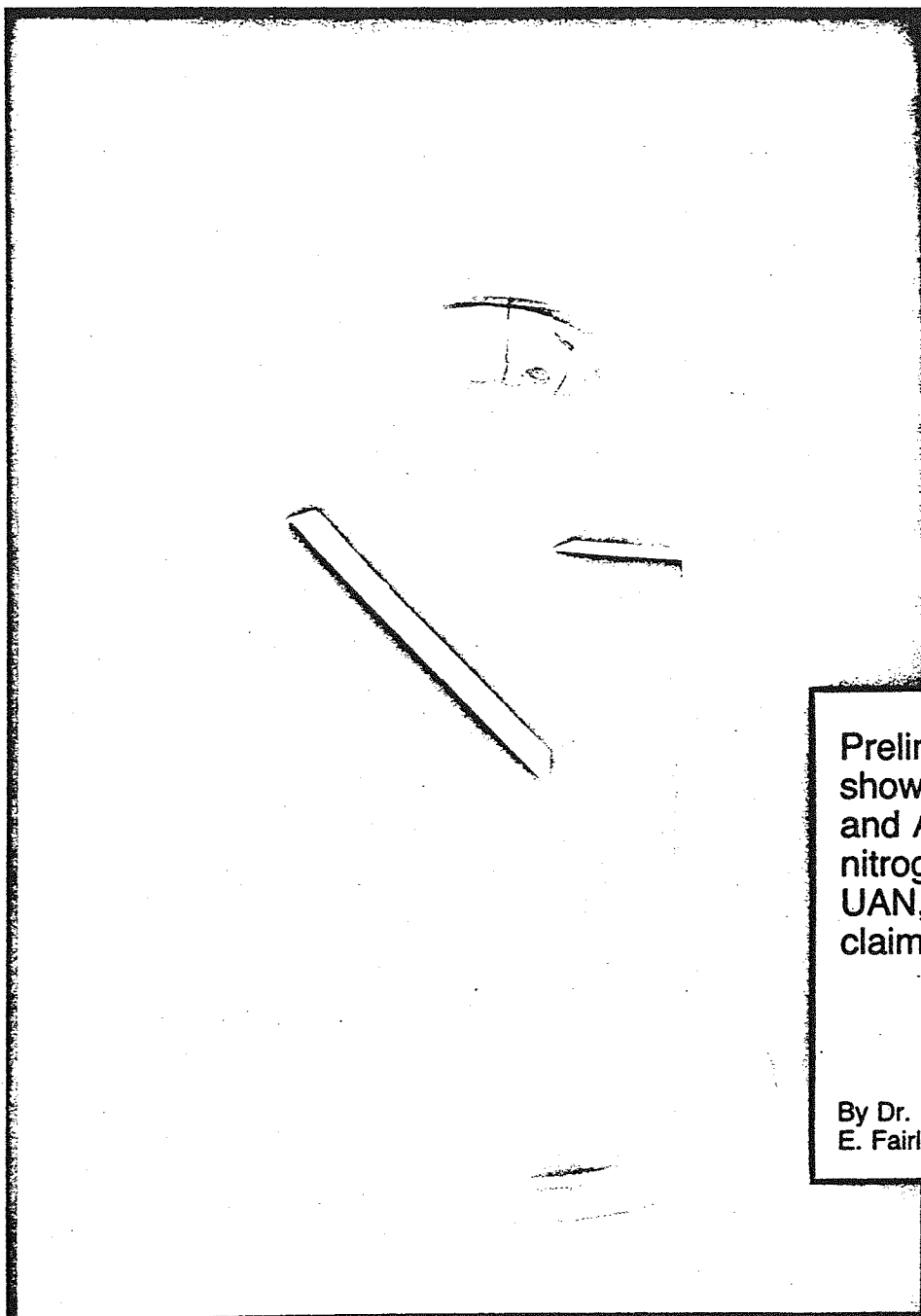
## ACKNOWLEDGEMENTS

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Preliminary research shows that both ATS and APP can reduce nitrogen losses from UAN, university experts claim

By Dr. R. J. Goos, R. P. Voss, T. E. Fairlie and B. E. Johnson

# CONTAINING N LOSS

**A**mmonium thiosulfate (ATS, 12-0-0-26S) and ammonium polyphosphate (APP, 10-34-0) are mainstays of the liquid fertilizer industry. These two fertilizers have long been appreciated as good sources of sulfur, phosphorus and nitrogen. What has not been appreciated, until recently, is that these two fertilizers can change the way that nitrogen fertilizers, such as urea-ammonium nitrate (UAN), react with the soil, and that mixtures of UAN, ATS and APP promise to reduce certain losses of N from the soil.

### ATS As Nitrification Inhibitor

**Lab results.** Nitrification inhibitors slow the conversion of ammonium ( $\text{NH}_4^+$ ) to nitrate ( $\text{NO}_3^-$ ). Such inhibitors may have agronomic value when conditions for nitrate leaching or denitrification occur after fertilizer application. While hundreds of potential nitrification inhibitors have been screened, only nitrapyrin ("N-Serve") is widely used. Initial laboratory tests have shown that the thiosulfate ion ( $\text{S}_2\text{O}_3^{2-}$ ) can significantly slow nitrification (Figure 1) and that the effect could last for 28 days after N application.

A second lab study, using commercial-grade UAN (28-0-0) and ATS, showed that UAN-ATS mixtures nitrified much more slowly than UAN alone (Figure 2). These findings have caused a stir in the fertilizer industry. ATS has been used as a fertilizer for decades with no thought that thiosulfate may have other beneficial reactions in the soil. Dramatic as these results seemed, field studies were necessary to confirm whether what we observed in the laboratory could work in the field.

**Field results.** From the beginning, we were concerned that the water-soluble and anionic nature of the thiosulfate ion could limit its effectiveness as a nitrification inhibitor in the field. Anions (negatively charged ions such as  $\text{NO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ) are usually repelled by soil clays, which are also negatively charged. Cations, such as  $\text{NH}_4^+$ , are held by the clays by the process of cation exchange. Thus, we were

concerned that perhaps thiosulfate could be leached away from the applied ammonium by excess rainfall.

In a greenhouse study using soil columns, ATS was an effective nitrification inhibitor when not subjected to leaching. Application of 1.5 inches of water moved the thiosulfate below the ammonium band and no nitrification inhibition was observed.

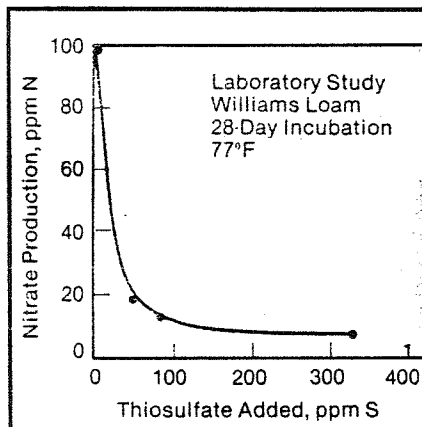


Figure 1. Effect of thiosulfate on nitrification by a Williams loam soil.<sup>1</sup>

ATS was ineffective as a persistent nitrification inhibitor in field studies in 1984. In 1985, ATS inhibited nitrification in 1 of 4 trials. In both 1984 and 1985, considerable rainfall fell soon after fertilizer application, which probably separated the thiosulfate from the ammonium (as in the column study).

Our soils in North Dakota are generally neutral or alkaline and have a very low anion retention capacity. However, acid soils high in iron oxides or kaolinite often "adsorb" anions and prevent them from leaching. ATS as a nitrification inhibitor should be tested in states that have such soils. For example, chloride ( $\text{Cl}^-$ ) has been shown to significantly inhibit nitrification on certain acid soils with significant anion retention capacity. Perhaps ATS would be an effective nitrification inhibitor on similar soils.

### ATS As Urease Inhibitor

**Lab results.** While much work has been done to find effective nitrification inhibitors, a considerable amount of research has also been

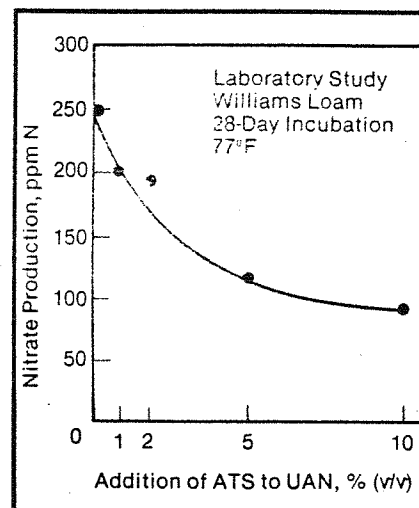


Figure 2. Effect of ATS on nitrification by a Williams loam soil.<sup>1</sup>

performed to find effective urease inhibitors. Urease is an enzyme, found in microorganisms, plants, crop residues and humus. It speeds the conversion of urea to ammonia (see Figure 3).

Whenever a urea-based fertilizer is applied to a soil surface without incorporation, there is a possibility that a portion of the urea applied could be lost to the atmosphere via ammonia volatilization. Slowing down urease activity allows for the soil to absorb more of the ammonia produced, thus less is lost. Slowing down the urease enzyme also allows for more time for the urea to be incorporated into the soil by either rainfall or tillage. These principles should be of particular interest to liquid fertilizer dealers because of the widespread practice of surface spraying of UAN as in a "Weed and Feed" operation.

There have been hundreds of potential urease inhibitors tested to date, but none has proven environmentally or economically feasible. However, our recent research has shown that the thiosulfate ion can also significantly inhibit the urease enzyme and significantly reduce ammonia losses from surface-applied UAN.

The first experiment (Figure 4) shows that the conversion of urea

Dr. Goos is assistant professor, Voss and Fairlie are graduate students and Johnson is an instructor in the Department of Soil Science at North Dakota State University in Fargo, North Dakota.

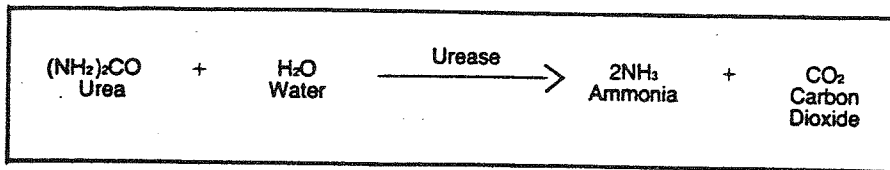


Figure 3. Conversion of urea to ammonia.

Rates of addition		Droplet size ml	Urea hydrolysis† %	Ammonia volatilization mg N
ATS %	APP (v/v)			
0	0	0.5	83	12.7
2	0		48	5.0
0	20		74	9.3
2	20		45	3.5
SE††			1	0.4

†Williams loams soil, 5-day incubation. Expressed as a percentage of original urea application hydrolyzed.  
 ††Standard error.

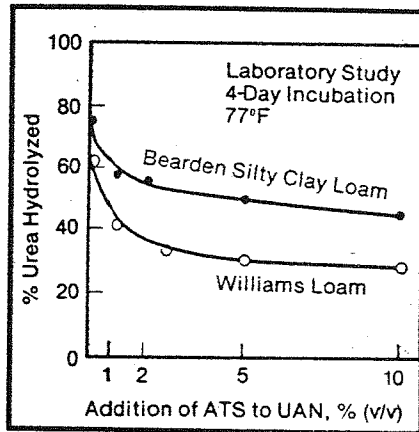


Figure 4. Effect of ATS on hydrolysis of urea from UAN by two soils.<sup>1</sup>

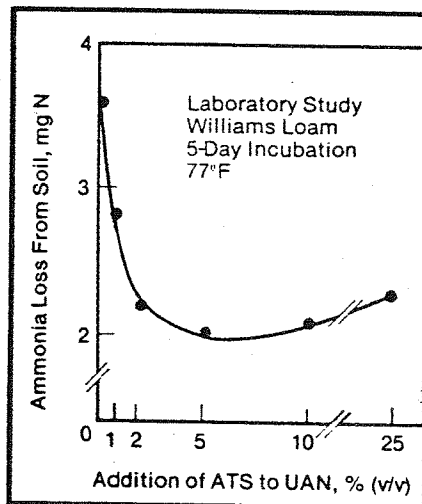


Figure 5. Effect of ATS on ammonia loss from a Williams loam soil.<sup>2</sup>

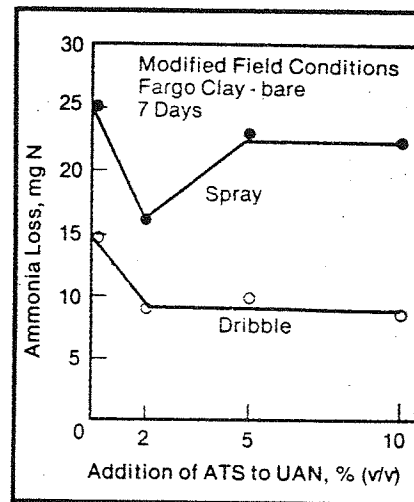


Figure 6. Effect of method of application and ATS on ammonia loss from a Fargo clay.<sup>3</sup>

to ammonia is significantly inhibited by adding as little as 1 or 2 parts of ATS in 100 parts of mixed fertilizer.

In a separate laboratory experiment, ammonia loss was reduced significantly by adding ATS to UAN (Figure 5). Ammonia loss increased as the level of ATS added to UAN surpassed 5 percent. This is because there can be ammonia loss from the ATS itself. However, higher levels of ATS were very effective in suppressing soil urease activity:

Another interesting finding we have made is that common APP (10-34-0) can reduce ammonia loss from UAN as well—particularly when fertilizer is dribbled on the surface. APP does not directly affect soil urease. Instead it acts as a pH buffer that helps keep ammonia in the non-volatile ammonium form. Addition of 2 percent ATS and 20 percent APP to UAN reduced ammonia losses dramatically when applied as a large droplet to the soil surface (Table 1).

**Field results.** Our subsequent field studies on ammonia loss have employed a cylinder or "semi-open" system that allows for a precise measure of ammonia loss. Results from this system are only proportional to that lost under actual field conditions, as humidity and temperature conditions within the cylinders used are not equal to unexposed field conditions.

Figure 6 shows that ammonia loss from UAN-ATS mixtures is related to method of placement (spray vs. dribble) and rate of ATS addition. With spray application, ammonia loss was significantly reduced by adding 2 percent ATS, while losses were higher with 5-10 percent ATS. Ammonia loss with dribble application was also reduced by adding 2 percent ATS, but there was not an increase in loss with higher levels of ATS.

Figure 7 illustrates a complex interaction on ammonia loss that involves method, ATS, and APP. ATS and APP were both effective in reducing ammonia loss with dribble applications. With spray applications, the situation was more complex. Only the 2 percent ATS treatment reduced N loss with spray applications without APP. However, with spray applications including 20 percent APP, ammonia losses were reduced by adding either 2 or 5 percent ATS.

Figures 6 and 7 are only samples of several experiments we have performed with UAN-ATS-APP mixtures.

### Further Testing Needed

In conclusion, we have learned:  
 1) Ammonia losses are less with dribble than with spray applications

2) If ATS is added to UAN for reduction of ammonia loss, a 2 percent addition has given consistent benefits. With spray applications, ATS additions above 2 percent may lose measurable amounts of ammonia from the ATS itself, unless APP is present as well

3) In all of our studies, the least amount of ammonia loss has been from solutions containing both ATS and APP. This has been true for both dribble and spray applications.

Our preliminary conclusion is that there seem to be valid reasons to routinely add 2 percent ATS to UAN that is going to be surface-applied, especially if the UAN is not going to be incorporated within a few days. Even if the sulfur applied is not needed nutritionally, the cost of the practice is quite small. For example, if 60 pounds of N per acre were to be applied as a spring application to grass or winter wheat, the extra cost of adding 2 percent ATS (subtracting the value

of the N in the ATS) would be less than 40 cents per acre. Only 2 pounds of N per acre need to be saved to pay for the ATS application. Of course, if both nitrogen and sulfur were needed by the crop, additional benefits (due to the effects of ATS on nitrogen loss) would be free. However, these are still preliminary conclusions and further testing of these concepts by other researchers is urged.

Above all, adding ATS or APP to UAN will never take the place of other management factors (e.g., incorporation) in reducing ammonia losses. But when UAN is applied and incorporation is not feasible (e.g., grass, no-till, etc.) adding ATS and APP to reduce ammonia losses may play a proper role in a fertilizer program.

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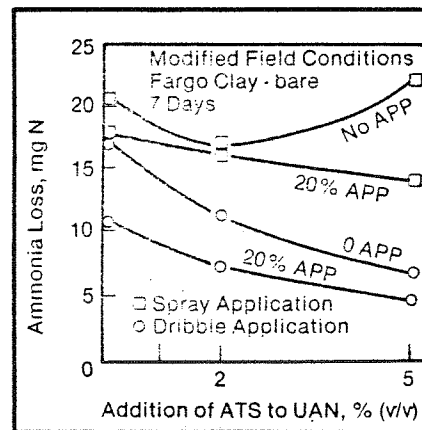


Figure 7. Effect of method of application, ATS, and APP on ammonia loss from a Fargo clay.<sup>3</sup>

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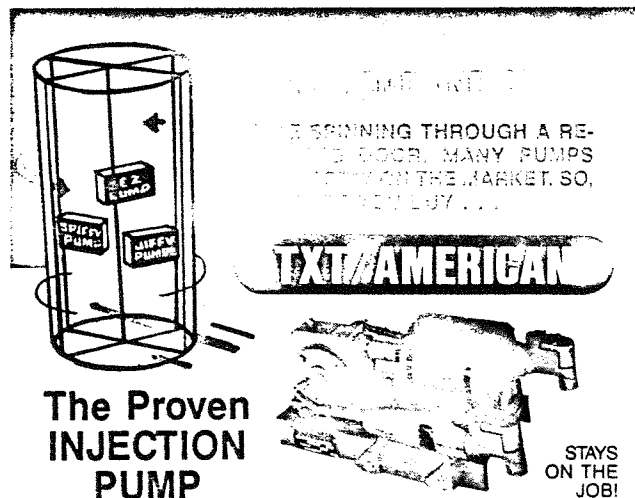
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