AN OVERVIEW OF NITRIFICATION INHIBITORS AND SLOW RELEASE FERTILIZERS

M. F. Vigil, USDA-ARS; J.C. Yeomans, Univ. of Manitoba; R.E. Lamond and A. J. Schlegel, Kansas State University

1992

ABSTRACT

Sources of nitrogen (N) and methods of placement that synchronize soil N availability with the period of maximum crop N uptake should increase N use efficiency and reduce N loss. A review of the lit-erature and recent research indicates that nitrification inhibitors and slow release fertilizers maintain ammoniacal N in the ammonium (NH_4) form longer than conventional fertilizers, but results are inconsistent with respect to increasing crop yields. Yield increas-es from studies with ammonium thiosulfate (ATS) in Kansas look pro-mising but need further study. Results from studies with large urea pellets have shown increases in plant tissue N, but yield increases have not been consistent. Studies with polyolefin coated urea indi-cate these N sources release N slowly for up to 120 days but are expensive and have not been tested in the Great Plains. This review will examine recent research where both nitrification inhibitors and slow release fertilizers have been evaluated.

INTRODUCTION

Attempts to maximize N availability with crop N demand include the application of N with nitrification inhibitors, urease inhibitors or protective coatings that slowly release inorganic N from the fertilizer. The strategy for using inhibitors and slow release fertilizers is to maintain ammoniacal N as NH_4-N during periods of low crop N demand with a subsequent maximum release of both NH_4-N and NO_3-N during the period of rapid N accumulation by the crop. If much nitrification of fertilizer N occurs during periods of low crop N demand (which may go hand in hand with periods of high rain-fall) the fertilizer NO_3-N will be lost from the root zone through leaching and/or denitrification. These losses reduce N fertilizer use efficiency and can potentially degrade groundwater.

The simplest scheme to maintain fertilizer N as NH_4-N for a longer period is to apply ammoniacal N fertilizers (urea, anhydrous ammonia) in concentrated zones (banded, point injected, or in large urea pellets). In the immediate zone of fertilizer application the pH of the soil reaches values near 9 which is toxic to nitrifiers therefore limiting the conversion of NH_4-N to NO_3-N. In addition the practice minimizes the exposure of fertilizer N to the soil micro-flora (including nitrifiers) and/or crop residues and should theoretically minimize both immobilization and nitrification.

Desirable characteristics for nitrification inhibitors include: no adverse affects on other beneficial soil organisms, higher plants, or animals, in amounts used to inhibit N transformations; easy to apply, stable in storage; not readily inactivated by soil constituents; and economical to use. Inhibition must be of practical duration.

Both natural organic and synthetically produced inhibitors have been studied. In general the natural organics are less effective then synthetically produced chemicals. Of the chemical inhibitors available carbon disulfide, dicyandiamide (DCD), nitrapyrin, etridiazole, and acetylene have been shown to consistently inhibit nitrification in field and laboratory soils. Research in North Dakota (Goos 1985a; 1985b) indicates ammonium thiosulfate (ATS) inhibits both nitrification and urea hydrolysis. Bronson et al. (1991) reported no increases in wheat yield but measured significant increases in fertilizer N immobilization, when DCD was applied broadcast with urea solution. In that study enhanced N immobilization by DCD treatment the first year resulted in a subsequent remineralization of immobilized fertilizer N the second year. Bronson using ^{15}N reported a significant increase in N uptake of first year fertilizer N by a subsequent years crop with DCD treatment. Ferguson et al. (1991) reported greater NH_4-N vs NO_3-N in the zone of fertilizer application 10 days prior to corn anthesis when nitrapyrin was applied with anhydrous ammonia early in the spring. As with the study of Bronson, Ferguson (1991) reported greater N immobilization with nitrapyrin.

A summary of published literature from Missouri, Minnesota, Kansas, and Nebraska indicates chemical inhibitors seldom increase yield (Hergert and Weise) In Illinois, Hoeft (1984) reported an average yield decrease of 1% for spring applied nitrification inhibitors and an average 5% increase for fall applied nitrification inhibitors. Blackmer and Sanchez (1988) showed a positive yield response to nitrapyrin at only 2 of 12 site years. The objectives of the following review of studies is to report on some of the recent applied research conducted in eastern and western Kansas, Nebraska, and Japan dealing with nitrification inhibitors and slow release fertilizers.

MATERIALS AND METHODS

The DCD, calcium carbide study was initiated the spring of 1990 on a Hall Silt Loam at the Management Systems Evaluation Area (MSEA) near Shelton, Nebraska and continued in 1991. Large 1.7g urea pellets were placed 4 inch deep and 4 inch away from rows of V1 stage corn (1990) and V3 stage corn (1991) at 8 inch intervals along the row. Nine treatment combinations of large urea pellets with and without the two nitrification inhibitors DCD (DCD encapsulated in the large urea pellet) and acetylene (applied as wax coated Calcium carbide) were applied at 3 rates of 36, 71, or 107 lbs N/acre. Conventionally banded urea and a check (no fertilizer applied) were also included in the experiment. Microplots within larger field plots were established at all treatment combinations for the 36 and 107 lb N/acre rates. These received ^{15}N labeled urea to allow for the estimation of fertilizer N recovery and plant N derived from fertilizer. Inorganic N levels in the zone of fertilizer application were monitored 7, 32, 43, and 96 days after fertilizer application by taking a 4 inch diameter core directly over previously flagged fertilizer placement zones at the 0-6 and 6-12 inch depths. Grain yields and N uptake data were measured.

The Kansas DCD research was conducted at the Southwest Kansas Research and Extension Center near Tribune. Experimental design was a split plot with combinations of method (broad-cast vs dribbled UAN) and N rates of UAN solution (0, 80, 120, and 160 lb N/acre) as main plots. Subplots were rates of DCD (0, 1.5, and 3% of total N as DCD N). All treatments were applied after planting corn. Soil samples (0-6 and 6-12 inches) and plant biomass samples were collected 3 and 6 weeks after treatment application. Plants were analyzed for total N; soils for inorganic N. The materials and methods for the ATS studies of Lamond et al. (1986, 1987, 1988) can be found in the Kansas fertilizer reports of progress 1986 through 1988. In those studies calcium sulfate was used to balance sulfur additions made by adding 10% ATS volume/volume (v/v) to UAN.

RESULTS AND DISCUSSION

Research in Kansas with ATS has given mixed results (Tables 1 and 2). While measured yields are sometimes higher with ATS additions the differences are not always statistically significant. Data of Fox and Piekielek (1987) was similar, they reported a significant increase in ear leaf N with ATS addition but found no yield increase. Since the addition of ATS to UAN at 10 % v/v is relatively inexpensive further investigations to elucidate the potential yield response to ATS are probably worthwhile.

Table 1. Effect of UAN with and without 10% v/v ATS on bromegrass in Kansas (Lamond et al.,1987 and 1988).

Year	N rate	ATS	Forage yield	Tissue N
	lbs/acre		lbs/acre	%
1987	60	no	6170	1.72
	60	yes	6530	1.67
	120	no	7140	2.10
	120	yes	7150	1.97
LSD(0.05)			920	0.17
1988	60	no	3819	1.73
	60	yes	3929	1.72
	120	no	4764	2.07
	120	yes	4629	2.06
LSD(0.05)			718	0.20

Table 2. Effect of broadcast UAN with and without ATS on no-till sorghum in Kansas (Lamond et al. 1986 and 1987).

Year	N rate	ATS	Yield	Tissue N
	lbs/acre		bu/acre	%
1986	50	no	98	2.06
	50	yes	103	2.17
	100	no	120	2.52
	100	yes	134	2.68
LSD(0.05)			14	NS
1987	50	no	93	1.97
	50	yes	99	1.91
	100	no	122	2.29
	100	yes	114	2.16
LSD(0.05)			NS	NS

Both yield increases (Amberger, 1989) and yield decreases (Reeves and Touchton, 1986) have been reported with the use of DCD. Reeves and Touchton (1986) reported a phytotoxic affect at levels greater than 10% N as DCD. Studies conducted at the Southwest Kansas Research and Extension Center (Tribune) indicate no increase in corn yields due to additions of DCD at 1.5 and 3% (Table 3). In that study, the 3% DCD treatment maintained 16% of the inorganic N in the soil as NH_4-N 3 weeks after application whereas only 10% NH_4-N was measured in the 0% DCD treatment.

Table 3. Effect of DCD rate on grain yield and ear leaf N, A Schelegel (1991).

DCD rate	Grain yield	ear leaf N
-%-	-bu/acre-	-%-
0.0	154	1.88
1.5	146	1.89
3.0	152	1.88
LSD(0.05)	NS	NS

At Nebraska, DCD encapsulated in large urea pellets maintained a greater percentage of N as NH_4-N up to 36 days after fertilizer application (Fig 1.). In 1990 no yield responses were observed to either DCD, calcium carbide, or N (Table 4). An excess of 38 inches of water containing 30 ppm NO_3-N was applied to the field. We estimated that 350 lbs N/acre was added in the irrigation water. So it is not surprising N responses were not observed. In 1991 the study was moved to another site where a significant response to N was mea-sured (Table 4). However, even at this site the application of DCD or calcium carbide did not increase yields. In 1991, a significant increase in yield was measured with large urea pellets without inhibitor as compared to conventionally banded urea, DCD encapsulated with the large pellet, and calcium carbide application with large urea pellets (Table 4 and 5). In 1991 the inhibitor treatments may have been applied late enough (V3 stage) to have reduced the amount of NO_3-N available to the crop during peak N demand. Whereas the dissolution, hydrolysis and subsequent nitrification of NH_4-N from the large urea tablets without inhibitor may have been just rapid enough to match crop N demand resulting in the higher yields.

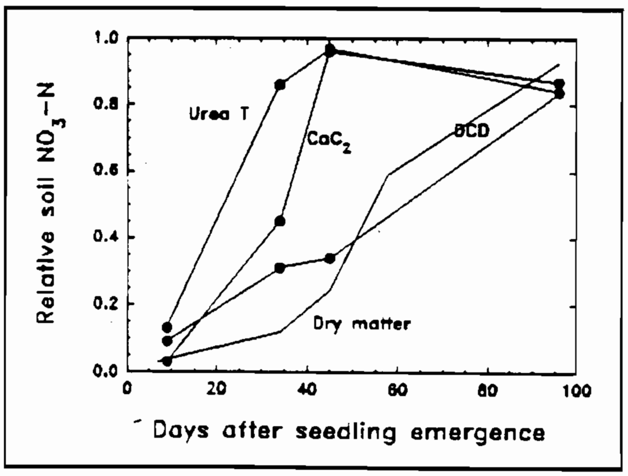

Fig. 1. The percentage of total inorganic N as NO_3-N in the fertilized zone vs days after emergence (Shelton, NE, 1990).

In Kansas with cool season grasses, large urea granules significantly increased tissue N concentration in 5 of 6 studies when top dressed in early spring but didn't increase forage yields when compared with conventional urea fertilizer. In those studies the peak N demand for cool season grasses lasts about 30-35 days from mid-April to mid-May. The slower dissolution and subsequent hydrolysis of the large pellets may have been just slow enough to have missed the peak demand period. Higher plant tissue N with larger urea granules was the result of luxury consumption late in the spring at or near harvest in mid-May.

Table 4. Effect of calcium carbide, DCD, and large urea pellets on irrigated corn Shelton Nebraska. From M.F. Vigil, J.F. Power, J.S. Schepers, and D.D. Francis.

	Grain yields	
Treatment	1990	1991
DCD	195(2.0)†	170(8.3)
CaC_2	195(1.5)	169(7.2)
Urea Tablet	191(1.7)	178(7.9)
Urea Banded	196(1.9)	169(9.0)
N rate		
0	197(2.1)	149(9.9)
36	195(1.5)	160(6.3)
71	194(2.4)	183(7.6)
107	193(1.6)	171(5.9)

† Values in parenthesis are the standard error of the mean.

Table 5. Single degree of freedom orthogonal comparisons (planned F test) for the DCD-calcium carbide study at Shelton Nebraska in 1991.

Contrast		Mean square	F value	Pr > F
Check	vs 72 lb N rate	3543.1	21.7	0.0001
Inhibitor	vs none	240.3	1.5	0.2334
Banded urea	vs precision placement	82.2	0.5	0.4830
36 lb N rate	vs 71 and 107 lb N rate	2883.1	17.6	0.0002
36 lb N rate	vs 71 lb N rate	3843.5	23.5	0.0001
71 lb N rate	vs 107 lb N rate	960.3	5.9	0.0206
71 lb N rate	vs 36 and 107 Lb N rate	2882.0	17.6	0.0002
Urea tablets	vs others treatments w/o check	727.2	4.4	0.0420
Urea tablets 71 lb N rate	vs others at 71 lb N rate	541.4	3.3	0.0772

Fujita et al. (1990) reported on the use of polyolefin coated urea. They reported polyolefin coated urea released N slow enough to match the N demand of field corn for up to 126 days after application. They reported that 80 % of the N in the fertilizer was released by 126 days. These N sources might be useful in areas with high spring rainfall. However, they could have a detrimental effect similar to those reported for nitrification inhibitors by releasing N too slowly during the period of peak N demand.

Barking up the wrong tree ?

There is plenty of credible literature indicating inhibitors inhibit nitrification and slow release fertilizers release inorganic N slower than conventional fertilizers. This doesn't insure higher crop yields or economic benefits. They are not a miracle product. These products have their greatest potential in areas with high spring rainfall and high leaching potential. To be used effectively accurate fertilizer recommendations, and an appreciation of synchronizing the release to match crop N demand is critical.

The authors would like to aknowlege Dr. Jim Schepers, Dr. Dennis Francis, Dr. Jim Power, and Dr. Ardell Halvorson for their assistance with the manuscript.

LITERATURE CITED

Amberger, A. 1989. Research on dicyandiamide as a nitrification inhibitor. Commun. Soil Sci. Plant Anal. 20(19 and 20)1933-1955.

Blackmer, A.M. and C.A. Sanchez. 1988. Response of corn to nitrogen-15-labeled anhydrous ammonia with and without nitrapyrin in Iowa. Agron. J. 80:95-102.

Bronson, K.F., J.T. Touchton, R.D. Hauck, and K.R. Kelley. 1991. Nitrogen-15 recovery in winter wheat as affected by application timing and dicyandiamide. Soil Sci. Soc. Am. J. 55:130-135.

Ferguson R.B., J.S. Schepers, G.W. Hergert, and R.D. Lohry. 1991. Corn uptake and soil accumulation of nitrogen: management and hybrid effects. Soil Sci. Soc. Am. J. 55:875-880.

Fox, R.H. and W.P. Piekielek. 1987. Comparison of surface application methods of nitrogen solution to no-till corn. J. Fert. Issues 4(1):7-12.

Fujita, T., T. Takahashi and S. Shoji. 1990. Development and properties of polyolefin-coated fertilizers. 1990 Agronomy Abstract p. 344.

Goos, R.J. 1985a. Identification of ammonium thiosulfate as a nitrification and urease inhibitor. Soil Sci. Soc. Am. J. 49:232-235.

Goos, R.J. 1985b. Urea hydrolysis and ammonia volatilization characteristics of liquid fertilizer mixtures. I. Laboratory Studies. J. Fert. Issues. 2:38-41.

Hergert, G.W. and R.A. Wiese. 1980. Performance of nitrification inhibitors in the Midwest (West) p. 89-105. In J.J. Meisinger et al. (ed.) Nitrification Inhibitors-Potentials and Limitations. Spec. Pub. 38. ASA, Madison, WI.

Hoeft, R.G. 1984. Current status of nitrification inhibitors in U.S. agriculture. p. 563-569. In R.D. Hauck (ed.) Nitrogen in Crop Production. ASA, Madison, WI.

Lamond, R.E., D. Whitney, J. Hickman and L. Bonczkowski. 1986. Comparisons of nitrogen rates and placement methods on no-till grain sorghum. p. 148-149. In Kansas Fertilizer Research 1986. Kansas Agric. Exp. Stn. Rep. Prog. No. 509.

Lamond, R.E., D. Whitney, J. Hickman and L. Bonczkowski. 1987. Comparisons of nitrogen rates and placement methods on no-till grain sorghum. p. 108-111. In Kansas Fertilizer Research 1987. Kansas Agric. Exp. Stn. Rep. Prog. No. 531.

Lamond, R.E., D. Whitney, J. Hickman and L. Bonczkowski. 1988. UAN management techniques on bromegrass. p. 26-27. In Kansas Fertilizer Research 1988. Kansas Agric. Exp. Stn. Rep. Prog. No. 509.

Reeves, D.W. and J.T. Touchton. 1986. Relative phytotoxicity of dicyandiamide and availability of its nitrogen to cotton, corn, and grain sorghum. Soil Sci. Soc. Am. J. 50:1353-1357.

Schlegel A.J. 1991. Effect of a nitrification inhibitor, nitrogen rate, and method of application on irrigated ridge till corn. In Kansas Fertilizer Research 1991. Kansas Agric. Exp. Stn. Rep. Prog. In press.

Vigil, M.F. and D.E. Kissel. 1987. Nitrogen uptake by cool-season grasses as influenced by urea granule size. p. 28-30. In Kansas Fertilizer Research 1987. Kansas Agric. Exp. Stn. Rep. Prog. No. 531.