COMBINING NITRIFICATION INHIBITOR TECHNOLOGIES[1]

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ABSTRACT

Techniques exist for the partial control of nitrification, but few studies have determined the effectiveness of combining more than one technique. A series of experiments compared the nitrification rate of urea granules as influenced by granule size (0.01, 0.1, and 1.0 g/pellet) and dicyandiamide (DCD) addition (0, 1, 2, 5, and 10% of N). A second series of experiments measured the interactive effects of DCD and ammonium thiosulfate (ATS) on nitrification of liquid fertilizers. Both experiments compared the nitrification rate of these fertilizers to 0.01 g urea pellets impregnated with nitrapyrin or liquid fertilizers with nitrapyrin added. The studies were conducted in the field at 10 locations. The conclusions of the two experiments are as follows: 1. The nitrification rate of 0.01 g pellets containing 5% of N as DCD is comparable to urea impregnated with nitrapyrin. 2. The nitrification rate of 0.1 g pellets containing 1% of N as DCD was usually slower than urea impregnated with nitrapyrin. 3. One g urea pellets nitrified at a slower rate than urea impregnated with nitrapyrin. 4. A 1.0 g pellet with $\geq$2% of N as DCD is vastly superior to conventional urea impregnated with nitrapyrin. 5. ATS inhibited nitrification at 6 of 10 sites, but the effect of ATS was not as consistent or long-lasting as observed with DCD. 6. ATS-DCD mixtures outperformed DCD alone at 3 of 10 locations. This study shows that the influence of a single nitrification inhibitor such as DCD can be significantly strengthened by combining with other fertilizer application options, especially by application techniques which concentrate the fertilizer material in the soil application zone.

INTRODUCTION

Soil scientists have sought effective and inexpensive methods of inhibiting nitrification for years. After decades of study and after the evaluation of hundreds of potential compounds, only two nitrification inhibitors--nitrapyrin and DCD--are commercially available.

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Nitrapyrin and DCD have drawbacks as nitrification inhibitors. Nitrapyrin is volatile and also can bind to organic matter. Its effectiveness is also influenced by soil texture. The breakdown products of nitrapyrin do not add appreciably to the available N pool. DCD must be used at higher rates than nitrapyrin. DCD breaks down eventually into available nitrogen, but is phytotoxic at higher concentrations. The soil mobility of DCD can also influence its effectiveness.

An alternative to nitrification inhibitors is localized fertilizer placement. Numerous studies in Canada have shown that substantial nitrification inhibition can be obtained by urea banding, larger pellet sizes, or by grouping conventionally-sized urea pellets into "nests". Also, ammonium thiosulfate (ATS) is a mild nitrification inhibitor when added to larger fertilizer droplets.

The purpose of our field investigations was to test the nitrification rate of urea as influenced by combining two existing nitrification inhibitor technologies.The first study looked at the interaction of urea pellet size and DCD level in the pellet. DCD is an expensive product, and it was of interest to see if the DCD requirements for inhibition of nitrification could be reduced when the fertilizer was applied in more concentrated zones. The second study looked at the interaction of ATS and DCD as additives to liquid fertilizers. A major fertilizer company has introduced a commercial product containing urea, DCD, and ATS, and we desired to see if ATS would complement the effects of DCD on nitrification.

METHODS

The first study was a factorial combination of three urea pellet sizes (0.01, 0.1 and 1.0 g/pellet, corresponding to conventional, forestry-grade, and supergranule) by five levels of DCD addition (0, 1, 2, 5, and 10% of the N as DCD). The fertilizers were made with a pharmaceutical tablet press by George Jones of the TVA.

Our method of measuring nitrification was to measure recovery of N fertilizer as ammonium (urea + ammonium when residual urea was present) when the fertilizer was incubated in the field with soil held in nylon mesh bags. The mesh bags allowed for free air and water movement and root penetration. Spring applications were typically made in late April or May. Each site was planted to wheat or barley. Samplings for residual (urea + ammonium) were taken 4 and 8 weeks later. Fall applications were typically made in late September or early October, and sampled either at fall freeze-up or first spring thaw, and a month later. No crop was planted on the fall application sites. Our recovery values indicate the relative nitrification tendencies of the fertilizers, since plant uptake, diffusion of ammonium, and mass flow of urea out of the bags could have occured.

The spring 1988 applications were made at 4 sites, the fall 1988 applications were made at 3 sites, and the spring 1989 applications were made at 3 sites. Clay, sandy loam, and loam soils were represented at each application time. Each experimental site contained three replicates.

RESULTS

The influence of urea pellet size and DCD on recovery of N fertilizer as ammonium is found in Table 1. The spring of 1988 was quite dry, and nitrification was somewhat slower than usually observed for the first 4 weeks. At the first sampling, 13% of the applied N was recovered as ammonium with conventionally-sized urea pellets without DCD. This was increased to 28% recovery with a 5% DCD addition. Recovery of N as ammonium was much higher for the 0.1 g pellets than the 0.01 g pellets, ranging from 24% without DCD to 43% with 1% DCD. Recovery of N as ammonium was the highest with the 1.0 g pellets, ranging from 51-56%, with little influence of DCD. Conventionally-sized granules impregnated with nitrapyrin gave 28% recovery, about the same as 0.01 g pellets with 5% DCD, but vastly inferior to the larger pellets with DCD.

The results of the second sampling after the spring 1988 application follow the same trends as for the first sampling, except that the overall levels of recovery are much lower. The added N was virtually all nitrified with the 0.01 g pellets without DCD. The recovery was increased to 5-8% with the addition of DCD. The effect of DCD was more dramatic with the 0.1 g pellets. Adding DCD increased recovery from 4 to 13-16%. The recovery of N as ammonium was superior with the 1.0 g pellets containing $\geq$2% DCD.

The results of subsequent applications were very similar to results observed with the spring 1988 application. In every case a 1.0 g urea pellet nitrified more slowly than 0.01 g pellets impregnated with nitrapyrin, and a 1.0 g pellet with $\geq$2% DCD gave the slowest nitrification. These results show that the level of DCD needed to dramatically slow nitrification could be reduced to quite low levels if the fertilizer was also placed in a concentrated zone. These results should have immediate application with the liquid fertilizer industry. The most obvious application is with liquid fertilizer applications that lead to large droplets being applied. Techniques include surface dribble applications, many knifed applications, and spoke-wheel injection as examples. The level of DCD needed to inhibit nitrification may be less than previously thought with such application methods.

The influence of ATS and DCD on the nitrification of solubilized urea is found in Table 2. It is difficult to generalize about these studies as results varied from site to site. There was a general increase in ammonium recovery by adding 10% (vol/vol) ATS to solubilized urea. This effect was significant at 5 of the 10 sites. Adding 2% of the N as DCD increased ammonium recovery at 9 of the 10 sites. The effect of DCD was stronger than observed for ATS, except with the fall 1988 applications. Using both ATS and DCD increased ammonium recovery above that observed with DCD alone at 3 of the 10 locations.

The results in Table 2 illustrate that some inhibition of nitrification can be observed by adding ATS, but that DCD is a more consistent nitrification inhibitor. However, if the farmer has an agronomic need for sulfur and if the farmer is concerned about nitrogen losses, then it would seem reasonable to recommend ATS as the preferred sulfur fertilizer.

The use of ATS has been criticized based on laboratory studies that have shown that ATS use can increase soil nitrite levels. Our laboratory research has indicated that ATS can indeed lead to some nitrite accumulation, but when ATS is used in conjunction with even small amounts of DCD that the nitrite does not accumulate. The soil samples from these field studies will be analyzed for nitrite in the coming months to determine if ATS use leads to nitrite accumulation in the field.

Table 1. Effect of urea pellet size and DCD on the recovery of added N as ammonium, North Dakota, 1988-1989.

Pellet Size	DCD	Time of application and sampling+					
		Spring 1988		Fall 1988		Spring 1989	
		First	Second	First	Second	First	Second
g	% of N	------% of added N recovered as ammonium------					
0.01	0	13	1	23	1	2	1
	1	24	5	38	4	22	2
	2	26	6	41	3	23	3
	5	28	8	38	5	22	2
	10	28	7	40	10	22	4
0.10	0	24	4	38	3	4	3
	1	43	13	56	12	25	11
	2	41	14	58	23	26	11
	5	41	16	63	26	32	13
	10	39	16	54	21	34	11
1.0	0	51	18	56	22	33	12
	1	56	25	58	36	38	24
	2	56	31	59	39	43	27
	5	53	34	57	40	44	30
	10	51	35	55	37	41	29
0.01 + NP++		28	8	43	17	24	5

+The spring 1988 and 1989 applications were made at seeding time of small grain, with samplings 4 and 8 weeks later. The fall 1988 application was made in late September or early October with the first sampling occuring either at fall freeze-up or spring thaw and the second sampling about 4 weeks after spring thaw.
++0.01 g pellets impregnated with nitrapyrin.

ATS	DCD	Time of application and sampling+					
		Spring 1988		Fall 1988		Spring 1989	
		First	Second	First	Second	First	Second
----%++---		------% of added N recovered as ammonium------					
0	0	25	3	44	3	18	6
10	0	35	9	61	10	30	10
0	2	46	11	62	21	39	15
10	2	44	13	66	27	38	11
Pellets + NP+++		28	8	43	17	24	5
Liquid + NP++++		-	-	-	-	39	8

+The spring 1988 and 1989 applications were made at seeding time of small grain, with samplings 4 and 8 weeks later. The fall 1988 application was made in late September or early October with the first sampling occuring either at fall freeze-up or spring thaw and the second sampling about 4 weeks after spring thaw.
++ATS rate expressed as % of the total liquid ferilizer volume, DCD rate expressed as the % of the total N as DCD-N.
+++ 0.01 g pellets impregnated with nitrapyrin.
++++ Nitrapyrin applied with liquid fertilizer.

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