EFFICACY OF N USE FROM FALL APPLIED AMMONIATED PHOSPHATES AND AMMONIUM SULFATE

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Introduction

Fall application of a blend of phosphate and potassium fertilizers is a common practice in much of the Corn Belt. The primary sources of phosphate are diammonium phosphate (DAP) and monoammonium phosphate (MAP), two granular fertilizers that are highly water soluble. Ammoniated phosphate fertilizers are often used as they are usually the cheapest source of nitrogen in the marketplace. In addition, there is evidence that the presence of ammonium will result in increased uptake of phosphate.

Fall phosphorus and potassium applications are often made soon after soybean harvest is complete when soil temperatures are warm, greater than 50^{o} F. When temperatures are that warm, microbial activity is high and as a result, nitrification, the conversion of ammonium to nitrate, is high. Work by Mulvaney and Khan (1994) showed that nitrification occurred in the order of urea > DAP > $(NH_4)_2SO_4$ > NH_4NO_3 > MAP. Others, Eno, and Blue (1957); Vilsmeier and Amberger (1980); and Martikainen (1985) have also reported that urea nitrifies faster than $(NH_4)_2SO_4$. This differential in nitrification rate has been attributed to the rise in pH associated with the hydrolysis of urea and DAP early after application in contrast to the drop in pH associated with the application of $(NH_4)_2SO_4$ and MAP.

Accumulation of nitrate (NO_3) resulting from the use of fertilizer materials that are more rapidly nitrified and/or applied for a longer time period before plant uptake (i.e. fall), increases the risk of N loss from denitrification or leaching when soils are excessively wet in the spring of the year prior to rapid N uptake by plants. Denitrification decreased in the order of NH_3 > urea > DAP > $(NH_4)_2SO_4$ > NH_4NO_3 > MAP (Mulvaney and Khan, 1995). They attributed these differences to an effect on soil pH, as denitrification is favored by alkaline conditions (Firestone, 1982). Based on the laboratory work showing that MAP will nitrify slower than DAP and that the resultant nitrate will denitrify slower, it would appear that there would be less potential loss of N from MAP than DAP.

Agronomists have generally assumed that the N from fall application of DAP or MAP would be fully available the next spring. Unfortunately, there are no data to show whether or not that is true. The purpose of this research was to evaluate the efficacy of N from fall applied diammonium phosphate (DAP), monoammonium phosphate (MAP), and ammonium sulfate (AMS), relative to spring application of the same products. In addition, a laboratory study was conducted to evaluate the impact of N source, MAP versus DAP, on the rate of nitrification and denitrification.

Experimental Procedures

Laboratory Incubation Study: Three sources of MAP and one source of DAP were incubated at two N rates, 20 and 40 ppm N; with two soil types, Cisne sil and Drummer sicl; at two moisture levels, 80 and

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120% field capacity for 16 weeks at Urbana, IL. Bulk soil samples of each soil type were collected from the field, sieved to pass a 2 mm screen, and then dried at 25 ^{o}C for five days. A 100-gram sample of dry soil was weighed into individual plastic bags for three replications and eight sampling dates for each treatment. Soils were then rewet to 80% of field capacity and allowed to incubate for two weeks The appropriate amount of fertilizer for each treatment was then added to the individual soil bags, mixed thoroughly, and the soil-fertilizer mixture was then transferred to individual containers and incubated at room temperature at 80% of field capacity for two weeks, after which half of the pots were incubated at 80% of field capacity and the other half were incubated at 120% of field capacity at room temperature. Three individual samples (replications) were taken from each treatment every two weeks. The samples were immediately frozen and kept frozen until being oven dried prior to being analyzed for inorganic N, ammonium and nitrate, using the procedure of Mulvaney (1996).

Field Studies: Field experiments were conducted at the University of Minnesota Southern Research and Outreach Center, Waseca, MN, and at the Crop Sciences Research and Education Center, University of Illinois, Urbana, IL, during the 2004 to 2006 crop seasons. Results from the 2006 crop year had not been compiled in time for inclusion in this paper.

At the Waseca location, a total of 14 treatments, consisting of three N sources (DAP, MAP, and AMS), at two application times (fall and spring) and two N rates (40 and 80 lbs N/A) were applied in a factorial design. Two additional treatments (a zero N control and a 120 lbs N/A as urea) were randomized among the 12 factorial treatments. Triple super phosphate (0-6-0) was applied to all AMS and urea plots to eliminate the possibility of a differential response to P among the treatments. Treatments, replicated four times, were applied on Nov. 10, 2003; April 24, 2004; Oct. 26, 2004; and May 4, 2005 to a Webster clay loam glacial till soil. Corn was planted in the 10 x 50-ft. individual plots on Apr. 28, 2004 and May 4, 2005. Corn hybrid and final plant populations in 2004 were NK N50-P5 at 34,000 plants per acre; and in 2005 were Mycogen 2E522 at 32,800 plants per acre. After treatment application, the entire plot area was tilled by discing to a 3-inch depth in the fall and field cultivating in the spring. Preemergence herbicides (Harness and Callisto) were broadcast applied two days after planting each year. Grain yield and moisture content were taken by combine harvesting the center two rows of each plot on Oct. 19, 2004 and Oct. 11, 2005.

At the Urbana location, a total of 20 treatments, consisting of three N sources (MAP, DAP, and AMS) at two N rates (40 and 80 lbs N/A) , and two times of application were applied in a factorial combination. In addition, 4 AMS rates (0, 120, 160, and 200 lbs N/A) were applied in both fall and spring randomized among the factorial treatments. Triple super phosphate (0-46-0) was applied to all AMS and control plots to minimize the possibility of a differential response to P among the treatments. Treatments were replicated four times on a Drummer sicl soil. Fall treatments were applied on Nov 3, 2003 and Nov. 10, 2004. Spring treatments were applied on April 5, 2004 and April 6, 2005. Corn was planted on April 29, 2004 and May 2, 2005 to Pioneer 34B24 with a final stand of 30,200. Corn grain yield was determined by hand harvesting on Sept. 17, 2004 and Sept 23 and 28th, 2005.

Soil samples were collected at both locations periodically after treatment applications. When possible, samples were collected every two weeks to a 6-inch depth until soils froze in the winter. Sampling resumed in the spring with samples collected every two weeks at depths of 0-6 inches and 6-12 inches. At Illinois, soil samples were kept frozen until time for analysis, when they were dried, ground, and analyzed for inorganic N concentration (Mulvaney 1996). At Minnesota, samples were dried, ground, and sent to a laboratory for NO_3-N and NH_4-N analysis.

Results and Discussion

Laboratory Incubation Study

After two weeks of incubation at room temperature, the differences in ammonium and nitrate recovery were relatively small between MAP and DAP (Figure 1), indicating that there was little difference in rate of nitrification between these two products. The differences that did exist, agreed with previous work showing that MAP nitrifies slightly slower than DAP. At a moisture level below field capacity, the amount of nitrate present in the soil remained relatively constant over a lengthy time period (nearly 14 weeks) irrespective of N source (Figure 2). However, when moisture levels exceeded field capacity, the rate of nitrate loss was very rapid, with as much as 50% of the nitrate being lost in a two-week period. These laboratory results clearly demonstrate that the ammonium in both MAP and DAP will nitrify rapidly at warm temperatures and that once nitrified, it will rapidly denitrify at soil moisture levels above field capacity.

Field Study

Weather: Soil moisture was substantially above normal in May and June in 2004-05 and in those same months plus July in 2003-04 at Waseca (Table 1). At Urbana, soils were excessively wet during March and April 2004, and rainfall was below normal in every month except January 2005 (Table 2). During the first two years of the study, air temperatures were near normal at both locations (Table 3 and 4).

Soil Nitrate, Ammonium, and Total Inorganic N

Waseca, MN

Nitrification of the fall-applied treatments was expected to be minimal due to the cool and dry November, especially with soils freezing early. Consequently, no soil samples were taken until April 4, 2004. Significant nitrification occurred by April 4 with greater concentrations of nitrate for the 80-lb N rate compared to the 40-lb rate. There were, however, no differences in soil NO_3-N among N sources. Ammonium-N concentration was not influenced by N source or rate. Similar results for both nitrate-N and ammonium-N were found in the samples taken on April 20.

Soil samples taken from the 0-6-inch layer for both the fall and spring treatments on May 4, 2004 (10 days after spring application) showed elevated levels of nitrate-N with no statistical differences among N sources or between the fall and spring treatments (Table 5). Nitrification of the spring treatments had occurred quickly. Ammonium-N concentrations were slightly greater for the MAP than for DAP or AMS and were considerably greater for the spring-applied treatments. Nitrate from the fall applications had by then moved down to the 6-12-inch depth, especially for the 80-lb N rate. Ammonium-N concentrations at this depth were not different from the control. The source x time interaction was significant for ammonium-N while the time x rate interaction was significant for both nitrate-N and ammonium-N.

Although 4.86 inches of rain fell between the May 4 and May 28, 2004 sampling dates, nitrate-N and ammonium-N concentrations were quite similar for both sampling times except (1) nitrification during the 24-day interval resulted in ammonium-N concentrations in the N treatments being similar to the 0-N control, and (2) greater levels of nitrate-N were found in the 6-12-inch layer, indicating additional downward movement from all N sources (Table 4). In general, samples taken at this date indicated complete nitrification of all sources of N with no statistical difference among sources. Greatest nitrate-N concentrations were found for the spring-applied and 80-lb treatments. The highly significant time x rate interaction for nitrate-N in the 0-6-inch layer resulted from the much lower concentrations when fall-applied (10.0 and 12.8 ppm for the 40- and 80-lb rates, respectively), the intermediate concentration for the spring-applied 40-lb rate (16.7 ppm), and the highest concentration for the spring-applied 80-lb rate (30.2 ppm). In other words, more nitrate-N was found for the 40-lb spring rate than for the 80-lb fall rate. No interactions involving timing, rate, or source were found in the 6-12-inch samples.

On June 18, 2004 after another 6.65 inches of rain, samples were taken to 24 inches in 12-inch increments to capture nitrate that could have been leached from the top 12 inches. Nitrate-N, ammonium-N, and total inorganic N (TIN) concentrations in the 0-12-inch layer for the N treatments were not greatly different from the 0-N control, indicating substantial denitrification, leaching, and/or immobilization of fertilizer N. There were no significant differences in nitrate-N or ammonium-N concentrations among N sources or between fall and spring application. Two- and three-way interactions were not found except between N source and rate for nitrate-N. Nitrate-N levels increased from 9.2 ppm at the 40-lb rate of MAP to 14.4 ppm at the 80-lb rate, but N rate had no effect on the nitrate-N levels from DAP or AMS. In the 12-24-inch depth, nitrate-N concentrations were greater for DAP compared to MAP or AMS, slightly greater for spring compared to fall application, and greater for the 80-lb N rate. Meaningful two- and three-way interactions were not found.

Soil nitrate data (Table 6) indicate that some nitrification had occurred with all three N sources by November 24, 2004, one month after application. Differences in nitrate N and ammonium-N were not found among the three N sources. On April 11, two weeks after soil thawed, significant nitrification had occurred and by April 28 nitrification appeared to be complete for the 40-lb treatments and for DAP. On May 23, 2005, the spring-applied treatments were three-fold greater in nitrate and ammonium N than the fall applied treatments (Table 7). Nitrate concentrations for all of the fall-applied treatments were substantially lower on May 23 compared to the April 28 sampling. The 4.98 inches of rain that fell in 13 days between May 8 and 22 could have been responsible for the rapid loss of nitrate-N in the 0-6-inch layer. Denitrification and/or leaching are the two most likely processes accounting for the change. On June 13, nitrate-N was not influenced by N source, but was significantly greater when the N was spring applied and for the 80-lb N rate. On June 13, the total inorganic N remaining in the 0-24-inch profile was 66% and 67% less for the fall-applied 40- and 80 lb-N rates, respectively, when applied in the fall compared to spring application.

Urbana, IL

Within three weeks of application, nearly all the ammonium had been nitrified to nitrate in 2003 (Table 8). This rapid conversion occurred irrespective of rate or source of N. Nitrate concentrations in the soil remained relatively constant throughout the early part of the winter, but decreased substantially between December and March and even further between March and April. This decrease in nitrate concentrations in March and April was most likely due to denitrification that occurred while soils were saturated by the excessive precipitation received during these two months. The amount of inorganic N in the 0-6-inch soil zone was substantially higher through the May 25 sampling date for spring as compared to fall applications. For the most part, this differential was not affected by source or rate of application. The significant decrease in nitrate concentration between the May 25 and June 18 sampling dates was most likely the result of the rapid N uptake by the crop.

Even though average monthly temperatures were similar in the fall of 2003 and 2004, the rate of nitrification was more rapid in 2003 (Tables 8 and 9). This differential carried through into early April, with more ammonium remaining in the soil in the spring of 2004 than in the spring of 2003. Neither source nor N rate influenced the nitrification rate. Unlike 2003, when nitrate concentrations decreased in

March and April, in 2004 the levels continued to increase or remained constant into late May. This difference between years was most likely due to the fact that precipitation levels remained at or below the 30-year average for all months, with monthly totals not exceeding 4 inches until July and September. Most of the 2004 growing season was characterized as being moisture deficient. In the two spring samples, there was little, if any, difference in nitrate concentration between fall and spring application, but there was significantly more ammonium present in the soil from spring application. The nitrate levels associated with spring application were higher than that from fall treatments in late May as a result of the nitrification of that ammonium.

The percent recovery of the applied N was estimated by subtracting the total inorganic N in the control plot from that of the treated plots and dividing by the applied N rate. In 2004, recovery of fall-applied N averaged 11% compared to 40% in the 2005 season. In early May, more than 85% of the spring-applied N was recovered in the soil, irrespective of rate or source of N. The difference in recovery of fall-applied treatments between years was attributed to denitrification that likely occurred in the spring of 2004.

Grain Yield

Waseca, MN

Corn grain yields were not significantly different for the three N sources but were greatly affected by time of application and rate of N in both years of the study (Table 10). Yields were increased by 30% to nearly 50 bu/A over the 0-lb control for the 40- and 80-lb N rates, respectively, averaged over the two years across N sources and time of application. Yields were 10 bu/A greater for spring application than for fall application when averaged across N sources and rates in 2004 and 19 bu/A greater with spring application in 2005.

Urbana, IL

In both years of the study, increasing the N rate from 40 to 80 lbs N/A resulted in increases from 20-25 bu/A, depending on the year. As at Minnesota, source of N applied had no impact on grain yield at the end of the season. In contrast to Minnesota, fall-applied N yielded less only in 2005, not in 2004 (Figure 3 and 4). We might have expected the opposite: the 2004 spring was characterized by excessively wet soils for extended time periods which, based on the fact that we found less nitrate in the soil than from spring applications appeared to have increased denitrification. In 2005, there appeared to be little loss of N and there was little difference in the amount of nitrate in the soil in the spring. Seasonal weather was generally more favorable in 2004, and yields were higher, indicating that both water and N availability might have been less limiting in that environment.

Summary

Source of N, including DAP, MAP, or AMS had little influence on soil inorganic N concentration or on grain yield at either location. However, time of application and N rate affected both of these parameters. Because N rates as low as 40 or even 80 pounds per acre typically are lower than that needed to optimize yield in Corn Belt soils, we expected that increasing the N rate from 40 to 80 pounds per acre would result in the observed increase in grain yield. Most agronomists have in the past assumed that there should be little if any loss of N associated with fall-applied ammoniated phosphates, at least if application is delayed until soil temperatures are low enough to slow nitrification. Based on our results, we conclude that such an assumption is not accurate in most years. We found that as much as 70 to 80% of fall-applied N as

DAP or MAP might be lost in years in which nitrification of the ammonium is completed before heavy rains and warmer soils in the spring create conditions that can result in denitrification.

Do the results of these studies indicate that farmers who have used fall-applied ammoniated phosphates have likely experienced significant yield loss in many years? Probably not. The yield losses that were recorded in these studies were at the low end of the response curve (i.e., 40 or 80 lbs N/A). In farmer fields, any loss experienced from the use of fall-applied MAP or DAP would reduce N supply at the higher, less N responsive portion of the N response curve, where some loss in N supply would be expected to have minimal impact on yield. To the extent that excessive spring moisture which results in denitrification is followed by good soil moisture throughout most of the rest of the growing season, more N released from the soil in such favorable conditions might well compensate in part for some of the N that was lost.

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References

Eno, C.F. and W.G. Blue. 1957. The comparative rate of nitrification of anhydrous ammonia, urea, and ammonium sulfate in sandy soils. Soil Sci. Soc. Am. Proc. 21:392-396.

Firestone, M.K. 1982. Biological denitrification. *In* Nitrogen in agricultural soils (F.J. Stevenson et al., ed.) Agronomy Monograph 22. Amer. Soc. Agr., Madison, WI. pp. 289-326.

Martikainen, P.J. 1985. Nitrification in forest soil of different pH as affected by urea, ammonium sulphate and potassium sulphate. Soil Biology & Biochemistry 17: 363-367.

Mulvaney, R.L. 1994. Nitrification of different nitrogen fertilizers. *In* 1994 Illinois Fertilizer Conference Proc. (R.G. Hoeft, ed.). pp. 83-96.

Mulvaney, R.L. and S.A. Khan. 1995. Denitrification of different nitrogen fertilizers. *In* 1995 Illinois Fertilizer Conference Proc. (R.G. Hoeft, ed.). pp. 113-122.

Mulvaney, R.L. 1996. Nitrogen-Inorganic forms. p. 1123-1184. *In* D.L. Sparks et al. (ed.) Methods of soil analysis. Part 3. SSSA Book Ser. 5. SSSA, Madison, WI.

Vilsmeier, K. and A. Amberger. 1980. Umsetzung von Cyanamid, harnstoff und ammonsulfat in abhangigkeit von temperature und bodenfeuchtigkeit. Zietschrift fur Pflanzenernauhr and Bodenkunde 143: 47-54.

Table 1. Precipitation during the time period of the study at Waseca, MN.

Month	2003-2004	2004-2005	30-Year Average
Oct.			
Nov.	1.19	1.17	2.32
Dec.			
Jan.			
Feb			
Mar.			
Apr.	1.76	3.37	3.23
May	5.61	5.96	3.96
June	6.42	5.71	4.22
July	7.08		4.47
Aug	5.73		4.58
Sept.	6.92		3.19
Total	34.71		25.97

Table 2. Precipitation during the time period of the study at Urbana, IL.

Month	2003-2004	2004-2005	2005-2006	30-Year Average
Oct.	1.31	3.71	1.28	2.81
Nov.	4.94	5.16	3.72	3.45
Dec.	3.11	2.02	1.86	2.76
Jan.	2.18	6.20	1.78	1.89
Feb	0.56	2.00	0.52	2.01
Mar.	7.74	1.73	3.46	3.21
Apr.	10.88	3.98	4.41	3.65
May	4.38	0.97	3.06	4.80
June	3.77	2.42	1.65	4.20
July	5.73	4.3	7.85	4.67
Aug	3.59	2.26	3.00	4.37
Sept.	2.19	5.66	3.22	3.22
Total	50.38	40.41	32.59	41.04

Table 3. Average air temperature during the time period of the study at Waseca, MN.

Month	2003-2004	2004-2005	30-Year Average
Oct.			
Nov.	31.6	37	31.4
Dec.			
Jan.			
Feb			
Mar.			
Apr.	48.8	51	44.9
May	57.1	55	58.4
June	64.9	73	67.8
July	69.6		71.3
Aug	64.3		68.9
Sept.	65.7		60.2

Table 4. Average air temperature during the time period of the study at Urbana, IL.

Month	2003-2004	2004-2005	2005-2006	30-Year Average
Oct.	54.5	54.5	55.9	54.5
Nov.	44.8	45.2	43.7	41.5
Dec.	33.1	32.0	24.8	29.8
Jan.	24	27.8	37.9	24.6
Feb	30	34.7	31	29.9
Mar.	44.1	38.3	41.9	40.7
Apr.	53.9	54.7	56.6	51.7
May	65.7	61.3	62.1	62.9
June	69.6	75.0	71.4	72.0
July	72.6	76.1	76.7	75.2
Aug	68.4	75.8	74.0	73.2
Sept.	68.6	70.9		66.3

Table 5. Effect of source, time, and rate of N applied on inorganic N concentration in the 0-6-inch soil zone at Waseca, MN, 2003-2004.

N treatments			May 4		May 28		June 18	
Source	Time	Rate	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
		lbs N/A			ppm			
Contr.	--	0	13.1	8.1	8.4	10.2	9.3	7.3
DAP	Fall	40	21.0	7.3	10.0	9.8	10.8	7.3
DAP	Spr	40	20.7	13.6	17.0	10.5	11.7	7.9
DAP	Fall	80	29.1	8.1	12.8	10.8	11.9	8.2
DAP	Spr	80	27.3	20.3	35.6	10.8	13.0	7.5
MAP	Fall	40	17.3	6.9	10.1	10.3	9.5	7.4
MAP	Spr	40	22.9	18.8	18.5	11.7	9.0	7.6
MAP	Fall	80	33.4	8.0	12.8	9.9	14.2	7.2
MAP	Spr	80	26.5	29.0	31.4	13.5	14.6	7.7
AMS	Fall	40	14.4	7.6	9.9	11.0	9.5	7.8
AMS	Spr	40	25.7	12.2	14.6	11.0	11.7	7.2
AMS	Fall	80	30.8	7.6	12.9	10.2	9.6	7.4
AMS	Spr	80	31.7	16.6	23.7	9.7	12.3	7.2

Table 6. Effect of source, time, and rate of N applied on inorganic N concentration in the 0-6-inch soil zone at Waseca, MN, 2004-2005.

N Treatments			Nov. 24		Apr. 11		Apr. 28	
Source	Time	Rate	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4
					ppm			
Contr.	--	0	6.7	9.8	8.2	8.5	5.9	9.7
DAP	Fall	40	13.9	15.1	17.0	11.6	11.8	10.3
DAP	Fall	80	15.5	27.4	25.8	15.9	18.6	10.2
MAP	Fall	40	14.9	20.1	16.7	11.6	11.0	10.2
MAP	Fall	80	13.4	28.2	24.0	28.2	19.8	20.4
AMS	Fall	40	15.0	17.4	16.3	13.6	13.0	11.2
AMS	Fall	80	15.0	31.7	27.1	26.1	22.9	15.5

Table 7. Effect of source, time, and rate of N applied on inorganic N concentration in the 0-6-inch soil zone at Waseca, MN, 2005.

N treatments			May 23		June 13	
Source	Time	Rate	NO_3-N	NH_4-N	NO_3-N	NH_4-N
		lbs N/A		ppm		
Contr.	--	0	5.5	10.5	9.7	7.5
DAP	Fall	40	6.5	11.6	11.3	8.6
DAP	Spr	40	19.9	18.1	21.9	9.3
DAP	Fall	80	7.6	9.4	14.0	7.8
DAP	Spr	80	33.0	31.5	30.6	12.3
MAP	Fall	40	6.8	9.9	11.6	8.0
MAP	Spr	40	15.7	34.8	24.9	11.1
MAP	Fall	80	9.5	10.9	14.4	9.2
MAP	Spr	80	16.6	46.1	31.7	17.4
AMS	Fall	40	6.5	10.1	12.3	10.3
AMS	Spr	40	20.7	23.8	16.4	7.6
AMS	Fall	80	10.7	11.0	14.1	8.4
AMS	Spr	80	32.1	32.2	28.9	9.2

Table 8. Effect of source, time, and rate of N applied on inorganic N concentration in the 0-6-inch soil zone at Urbana, IL, 2003-2004.

N Treatments			Nov. 21		Dec. 4		Dec 19		Mar 15		Apr. 3	
Source	Time	Rate	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4
		lbs/A					ppm					
Contr.	--	0	13.3	2.5	13.1	4.6	9.8	3.9	10.1	2.1	5.3	2.7
DAP	Fall	40	26.1	3.3	26.9	4.9	22.4	4.2	15.0	1.5	7.2	3.0
DAP	Fall	80	36.0	5.3	37.5	5.1	37.8	4.4	18.3	1.6	9.1	2.6
MAP	Fall	40	25.2	5.1	25.5	5.4	23.2	6.2	15.4	1.8	8.5	3.1
MAP	Fall	80	30.9	5.5	43.3	7.1	33.5	10.0	22.7	3.7	11.2	3.0
AMS	Fall	40	23.2	4.9	25.9	5.2	26.7	4.4	16.4	1.7	8.1	2.8
AMS	Fall	80	32.4	8.5	45.1	6.9	37.0	6.0	23.1	4.6	10.7	4.3
LSD 0.10			4.7	3.4	7.6	2.8	3.8	2.8	3.8	1.7	3.2	1.1
			Apr 16		May 5		May 25		June 18			
Contr.	--	0	9.5	3.2	14.5	3.8	17.0	2.3	8.9	2.5		
DAP	Fall	40	11.3	3.4	16.5	3.9	19.1	2.9	8.2	2.6		
DAP	Spr	40	16.8	5.9	31.9	3.9	24.4	2.7	10.0	2.9		
DAP	Fall	80	12.8	4.4	18.8	3.5	19.9	3.0	9.1	3.2		
DAP	Spr	80	19.0	14.1	38.2	10.8	51.8	3.5	10.7	2.4		
MAP	Fall	40	11.8	3.5	18.3	2.9	20.1	3.1	8.3	2.8		
MAP	Spr	40	11.2	4.0	30.9	6.8	38.8	2.7	14.4	2.7		
MAP	Fall	80	14.9	3.5	22.2	3.7	22.4	2.0	12.2	2.6		
MAP	Spr	80	11.8	4.4	45.2	13.7	58.6	3.9	16.6	2.6		
AMS	Fall	40	12.4	4.8	17.2	3.2	21.5	2.4	11.4	3.0		
AMS	Spr	40	18.7	9.6	29.5	4.6	33.1	3.0	11.9	3.4		
AMS	Fall	80	18.5	3.5	20.6	3.7	28.5	2.7	11.1	2.7		
AMS	Spr	80	23.2	17.6	48.1	13.8	45.0	3.5	20.2	3.1		
LSD			4.8	4.6	6.4	3.6	9.4	ns	4.9	ns		

Table 9. Effect of source, time, and rate of N applied on inorganic N concentration in the 0-6-inch soil zone at Urbana, IL, 2004-2005.

N Treatments			Nov. 20		Dec.1		Mar 15		Apr. 1	
Source	Time	Rate	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4
		lbs/A				ppm				
Contr.		0	7.2	3.4	4.6	3.8	5.4	2.8	5.7	6.2
DAP	Fall	40	12.7	14.4	9.8	14.5	9.4	4.5	13.0	7.4
DAP	Fall	80	14.8	35.9	11.4	31.1	14.2	21.2	23.9	13.4
MAP	Fall	40	13.9	13.8	9.3	13.8	9.3	5.4	12.8	7.3
MAP	Fall	80	13.0	31.6	10.3	26.1	12.8	16.2	21.7	16.0
AMS	Fall	40	14.4	17.5	10.5	17.4	10.9	9.4	16.1	7.8
AMS	Fall	80	14.4	42.1	11.8	36.0	14.0	19.2	24.5	16.9
LSD 0.10			1.9	6.8	0.9	6.3	1.7	4.0	2.2	5.3
			Apr 18		May 1		May 25		June 15	
Contr.	--	0	10.0	2.9	11.2	5.2	15.4	5.3	11.9	3.8
DAP	Fall	40	17.2	2.8	18.5	6.3	21.5	5.0	15.7	3.6
DAP	Spr	40	19.2	14.5	18.8	10.4	30.8	6.6	27.3	5.7
DAP	Fall	80	30.9	8.7	24.9	6.7	33.6	7.0	22.2	5.2
DAP	Spr	80	20.0	29.4	24.1	23.6	41.9	13.5	35.2	8.9
MAP	Fall	40	18.8	3.4	15.1	7.6	22.0	5.9	20.5	4.6
MAP	Spr	40	17.9	9.5	22.4	12.9	33.4	11.6	28.4	8.5
MAP	Fall	80	29.0	7.0	25.9	7.0	32.6	7.3	19.8	4.4
MAP	Spr	80	20.0	16.5	26.5	28.1	41.9	18.0	38.6	13.1
AMS	Fall	40	17.9	3.6	19.6	6.4	24.9	6.2	19.8	4.5
AMS	Spr	40	18.3	16.9	24.2	13.9	33.9	8.9	25.4	5.5
AMS	Fall	80	36.2	12.1	24.8	7.6	33.6	7.8	20.9	4.4
AMS	Spr	80	21.9	35.9	27.6	26.8	42.9	15.3	32.1	8.7
LSD 0.10			4.0	5.3	4.1	4.6	4.9	4.3	9.3	2.8

Table 10. Grain yield as affected by source, time, and rate of N application at Waseca, MN, in 2004 and 2005.

Fertilizer Nitrogen			2004		2005	
Source	Time	Rate	Yield	H_2O	Yield	H_2O
		lbs/A	bu/A	%	bu/A	%
Control	None	0	96.7	31.7	89.3	19.4
DAP	Fall	40	126.4	31.0	126.5	19.0
DAP	Spring	40	130.5	31.3	135.0	19.8
DAP	Fall	80	136.4	30.5	125.0	19.6
DAP	Spring	80	159.3	29.9	153.3	19.3
MAP	Fall	40	117.7	31.1	110.9	19.3
MAP	Spring	40	128.6	30.8	149.6	18.5
MAP	Fall	80	130.7	30.6	139.8	19.8
MAP	Spring	80	154.4	30.0	146.2	19.0
AMS	Fall	40	125.5	31.0	118.9	19.9
AMS	Spring	40	124.9	30.8	136.6	19.0
AMS	Fall	80	141.8	30.6	141.1	19.2
AMS	Spring	80	143.4	30.4	154.0	19.3
Urea	Spring	120	177.1	30.1	152.1	20.6

Figure 1. Recovery of ammonium and nitrate from DAP and MAP at the equivalent rate of 80 lbs N/A, incubated at room temperature.

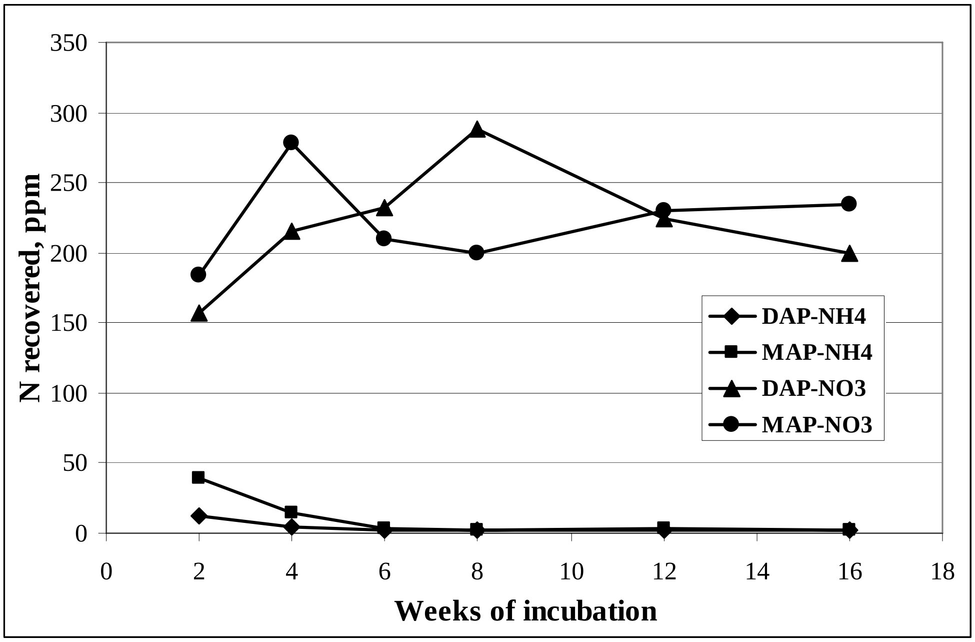

Figure 2. Effect of soil moisture on recovery of nitrate from DAP and MAP, applied at the equivalent rate of 80 lbs N/acre and incubated at room temperature. Soil maintained at 80% of field capacity is designated as "dry", while "wet" soil was maintained at 120% of field capacity.

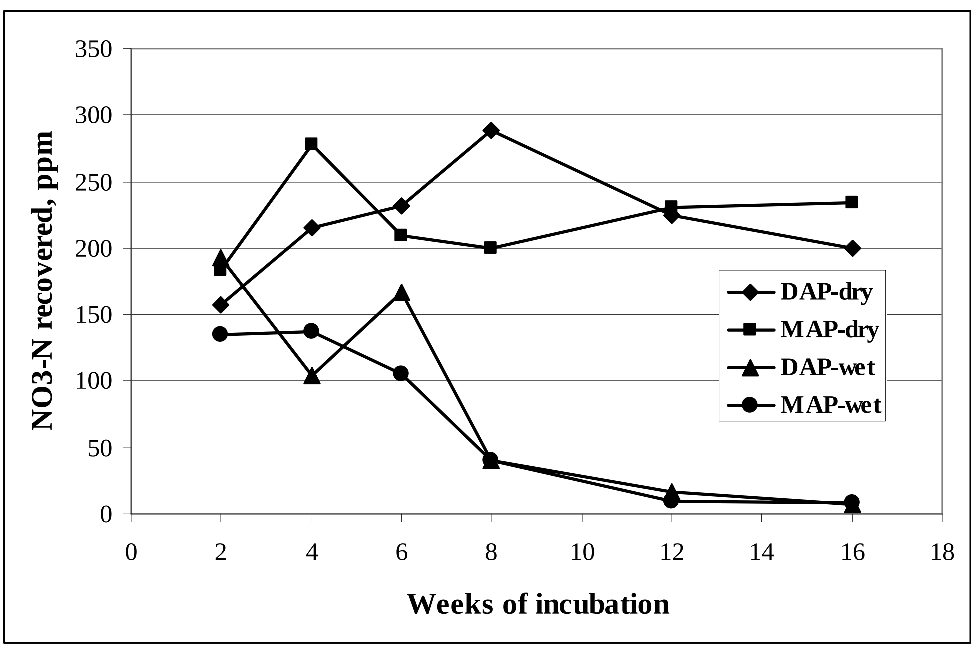

Figure 3. Effect of time, rate, and source of N on corn yield, Urbana, IL, 2004.

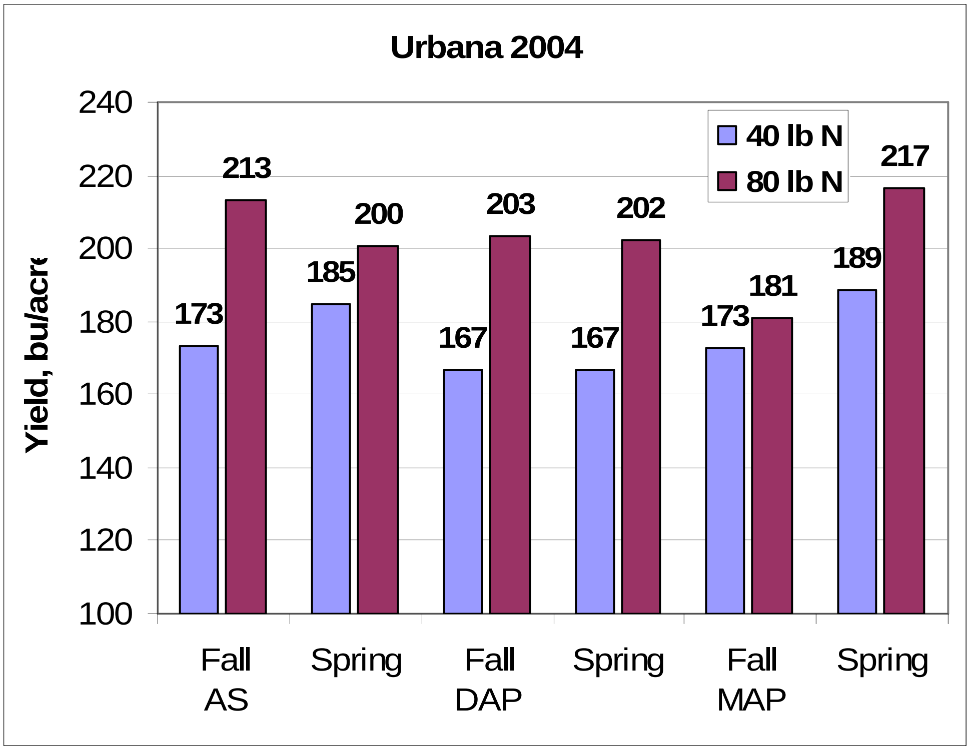

Figure 4. Effect of time, rate, and source of N on corn yield, Urbana, IL, 2005.