POLYMER-COATED UREA (ESN) FOR CORN

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Introduction

Improved nitrogen (N) management in corn production is needed to optimize economic returns to farmers and minimize environmental concerns associated with agricultural N use. Nitrogen losses through nitrate leaching can reduce the efficiency of N fertilizers and contribute to elevated nitrate concentrations in groundwater. Concerns about nitrate leaching are particularly relevant in areas with course-textured soils receiving N fertilizer inputs for intensive, irrigated crop production, such as the Central Sands Region of Wisconsin. Several strategies have been used to control N leaching losses on sandy soils including use of delayed (sidedress) or multiple split applications of N and the use of nitrification inhibitors with ammonium forms of N fertilizers to delay the conversion of ammonium N to nitrate which is susceptible to loss by leaching. Slow-release N fertilizers have been available for many years, but their higher cost has usually limited their use to high value specialty crops. Recently, a polymer-coated urea product (ESN) has become available at a lower cost than traditional slow-release N fertilizers. This product may have potential for controlling N leaching losses from applied N and could allow greater flexibility in the timing of N fertilizer applications relative to conventional fertilizer materials. The polymer coating on the ESN material allows water to diffuse into the capsule, dissolve the urea and allows urea to diffuse back into the soil solution over an extended period of time. Typically, release of urea from the polymer-coated granules is complete in about 6 weeks after application. The release process is also temperature dependent so that the rate of urea release increases as temperature increases. The delayed release of urea from the polymer-coated material could help to avoid N leaching losses during the early part of the growing season and could allow application of the fertilizer material earlier in the growing season without greatly increasing the risk of N loss.

Since little is known about the relative performance of polymer-coated urea compared to the traditional N management methods typically used on sandy irrigated soils, such as split sidedress N timings and addition of nitrification inhibitors to fertilizer N, this study was initiated to provide that information. The objectives of this study were to determine optimum times and rates of several N fertilizer materials (including polymer-coated urea) for corn production on sandy irrigated soils. Use of a nitrification inhibitor with selected N sources and times of application was also evaluated.

Materials and Methods

Research to accomplish project objectives was conducted during 2003 to 2006 on sprinkler irrigated Plainfield loamy sand soils (sandy, mixed, mesic Typic Udipsamments) at the University of Wisconsin Agricultural Research Station at Hancock, WI (44^o,7'N, 89^o,32'W). The experiments were located where the preceding crop was a non-legume (potato, field corn, or sweet corn) to avoid legume N contributions to the test crop.

Treatments were arranged in a split plot design with four replications. Nitrogen source and timing were the main plot treatments and N rate was the sub-plot treatment. Nitrogen fertilizer sources, application times, and rates used in the 2004-2006 experiments are summarized in Table 1. Treatments in 2003 used 28% urea-ammonium nitrate (UAN) solution in place of urea, and

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ESN was not applied using the sidedress at 4 wk and the split-sidedress (4 & 6 wk) application times.

Table 1. Nitrogen treatments evaluated in the 2004 to 2006 N management experiments at Hancock, WI.

I. Control (0 lb N/acre) + 40 lb S/acre †

II. Polymer-Coated Urea (ESN)
   A. Preplant: 100, 150, 200, and 250 lb N/acre + 40 lb S/acre †
   B. Split (Preplant & 4 wk): 100, 150, 200, and 250 lb N/acre + 40 lb S/acre †
   C. Sidedress at 4 wk: 100, 150, 200, and 250 lb N/acre + 40 lb S/acre †
   D. Split-sidedress (4 & 6 wk): 150 and 200 lb N/acre + 40 lb S/acre †

III. Ammonium Sulfate (AS)
   A. Preplant: 150 and 200 lb N/acre
   B. Preplant + nitrification inhibitor (DCD): 150 and 200 lb N/acre
   C. Sidedress (4 wk): 150 and 200 lb N/acre
   D. Split-sidedress (4 & 6 wk): 100, 150, 200, and 250 lb N/acre

IV. Urea
   A. Preplant: 150 and 200 lb N/acre + 40 lb S/acre †
   B. Sidedress (4 wk): 150 and 200 lb N/acre without S
   C. Sidedress (4 wk): 150 and 200 lb N/acre + 40 lb S/acre †

† S source = gypsum

Because the ammonium sulfate (AS) contains sulfur, a preplant broadcast application of gypsum ($CaSO_4$) providing 40 lb S/acre was made to treatments where the N source was not AS. The only exception to this was the 4-wk sidedress urea treatment which had a "with" and "without" S treatment to confirm potential response to sulfur. The preplant gypsum and N treatments were applied before planting following moldboard plowing and disking. The entire site was disked again and planted on in late April or early May. Individual plots were 12 ft (4 rows) wide and 35 ft long. An adapted corn hybrid was planted at 32, 200 seeds/acre and starter fertilizer (100 lb/acre of 5-10-30) was applied in a band 2 inches below and 2 inches laterally from the seed at planting. After emergence, plant stands were thinned to a uniform density of 31,500 plants/acre. Conventional herbicides were applied to control weeds.

Preplant N treatments consisted of broadcast applications of polymer-coated urea (ESN), AS, and urea. For the AS preplant plus nitrification inhibitor treatment, dicyandiamide (DCD) was surface broadcast applied on top of the AS at a rate of 10 lb a.i./acre using a backpack sprayer. For the ESN preplant + 4 wk treatment, 50% of the N was applied preplant and 50% about four weeks after planting. For the split sidedress application of AS, 50% of the total N rate was applied four weeks after planting and the remaining 50% about six weeks after planting. The 4- and/or 6-wk sidedress applications were made by placing the fertilizer materials (ESN, AS, and urea) in a band about 4 to 6 inches deep between corn rows and immediately covering the materials with soil. The split sidedress application timing is the standard N application method used by growers in the region, and a full range of N rates were included to obtain a complete N response curve for the ESN preplant, the ESN preplant plus 4-wk sidedress, the ESN 4-wk sidedress, and for the AS split-sidedress (4- and 6-wk) treatments. A full range of rates was included for the ESN treatments, except the split-sidedress, since this material has not been previously evaluated.

Treatment effects on dry matter yield and total plant N uptake were determined by hand-harvesting six corn plants from each plot at physiological maturity using the method of Walters (personal communication). The ears (cob and grain) were removed, dried in a force-draft dryer at 160^{o}F, shelled, and dry weights of the cob and grain were recorded. Plants (excluding ears) were weighed, chopped, sub-sampled, and dried. All tissue samples were ground to pass a 1-mm mesh screen, and analyzed for total N as described by Nelson and Sommers (1973) using automated analysis.

Grain yield and moisture content was determined by machine harvesting the middle two rows of each plot using a plot combine equipped with a Harvestmaster Graingage moisture and weighing system. Data were subjected to an analysis of variance to determine the treatment effects and their interactions on all measured parameters using PROC ANOVA (SAS Institute, 1992). Mean separation analysis (LSD) was done where main effect means were significant and at each level of the interacting factor if main effect interactions were significant at the 0.05 probability level. The economic optimum N rate was determined using regression analysis using treatment means (PROC REG) and adjusted for the price of N fertilizer and corn grain appropriate for the years when the experiments were conducted.

Precipitation and irrigation amounts varied widely among the four growing seasons (Table 2), and these differences likely influenced the performance of the N treatments evaluated. Irrigation amounts in 2003 through 2006 were 14, 10.3, 10, and 13.7 inches, respectively. In general, the 2003 and 2006 growing seasons had substantially below normal precipitation. In both of these years, May rainfall was above normal, but all of the subsequent months were below normal. The 2004 season was characterized by excessive rainfall during May and June with below normal rainfall during the following months. In 2005, rainfall was near normal for the growing season with only July having above normal monthly precipitation.

Table 2. Monthly precipitation amounts during the growing season 2003-2006, Hancock, WI.

Month	2003	2004	2005	2006
	------------	------------ inches	------------	------------
May	4.62 (1.35) †	6.42 (3.15)	2.86 (-0.41)	5.1 (1.7)
June	3.21 (-0.43)	6.98 (3.34)	3.18 (-0.46)	1.4 (-2.4)
July	2.13 (-1.47)	2.82 (-0.78)	5.59 (1.99)	2.6 (-1.0)
August	0.58 (-3.34)	2.92 (-1.00)	3.34 (-0.58)	2.8 (-1.1)
September	2.75 (-1.44)	0.50 (-3.69)	3.91 (-0.28)	3.3 (-0.89)
Total	13.29 (-5.33)	19.64 (1.02)	18.88 (0.26)	15.2 (-3.69)

† Numbers in parentheses are the departure from the 30-yr average.

Results and Discussion

Average corn grain yields obtained with the 150 and 200 lb N/acre N rates applied using various N sources and times of application are shown in Table 3. The control plot yields (no N applied) indicate that a strong response to added N occurred each year with fertilized yields about two times greater than those in the control treatment. In 2003 and 2006, no significant differences occurred among the N treatments used reflecting the very low nitrate leaching potential in these two years with substantially below normal growing season rainfall.

Table 3. Effect of N source and timing on corn grain yield, Hancock, WI, 2003-2006.

N source	N timing	Year 2003	2004	2005	2006
		--------------------- Yield, bu/acre†			--------------------------
None		107	115	96	95
ESN‡	Preplant (PP)	204 a	167 c	186 ab	182 NS
	PP & 4 wk	205 ab	180 b	189 a	182
	4 wk	--	--	185 ab	176
	4 wk & 6 wk	--	--	183 ab	177
Am. Sulfate	PP	196 ab	132 e	175 b	180
	PP + NI	202 ab	136 e	183 ab	189
	4 wk	--	181 b	180 ab	176
	4 wk & 6 wk	194 abc	196 a	182 ab	182
Urea‡	PP	--	141 de	154 c	181
	4 wk	--	151 d	181 ab	180
without S	4 wk	--	151 d	177 b	175

† Average of yields obtained with 150 and 200 lb N/acre rates.
‡ 40 lb S/acre applied preplant as gypsum.

In 2004, substantial nitrate leaching likely occurred due to the excessive early season rainfall. Daily precipitation records indicate that 6.6 inches of rain occurred during the 4 wk following planting and that an additional 6.4 inches was received during the next two weeks. This means that N treatments applied preplant and at 4 wk after planting were subjected to substantial leaching pressure, but little rainfall occurred after the 6-wk N application timing. In this environment, preplant ESN performed much better than either preplant ammonium sulfate (AS) or urea. The preplant-sidedress ESN treatment had higher yields than with preplant ESN. Using the nitrification inhibitor DCD with preplant AS apparently had no effect on controlling nitrate leaching since yields with this treatment were similar to those with preplant AS alone. Potentially, the DCD leached below the N fertilizer or out of the root zone and was ineffective in controlling nitrification of the AS. The split sidedress (4 wk & 6 wk) application of AS was more effective than the 4 wk sidedress AS treatment and the split PP & 4 wk ESN treatment. This is probably due to little leaching potential after the 6 wk application time. Preplant urea was similar to preplant AS in that both treatments likely experienced substantial leaching losses. Urea applied sidedress at 4 wk was less effective than AS applied at 4 wk or the PP & 4 wk split ESN treatment. In general, the results show that under heavy leaching pressure, preplant ESN was superior to other N sources applied preplant. However, a 4 wk & 6 wk split sidedress treatment with AS gave higher yields and was apparently more effective in controlling leaching losses than the other treatments.

In 2005, a year with near normal growing season rainfall but with above normal rainfall in July, substantial yield differences occurred among N sources at the preplant application time. Preplant ESN was more effective that either preplant AS or urea, and preplant urea was less effective than preplant AS. However when all or part of the N was applied sidedress, there were no significant corn yield differences among the N sources. It should be noted that preplant ESN was as effective as sidedress or split sidedress application of either AS or urea. Adding the nitrification inhibitor DCD to AS gave yields equal to those with preplant ESN or with sidedress or split sidedress AS or urea treatments.

Economic optimum N rates (EONR) and corn yields at the EONR are shown in Table 4 for ESN and AS treatments. In general, lower EONR values suggest that a treatment is more efficiently used by the corn crop. For the ESN treatments, EONR usually decreased between preplant and split or sidedress treatments, indicating greater efficiency with the split or sidedress treatments. In the high leaching year of 2004, EONR was lower for the split sidedress AS treatment than for the two ESN treatments, again suggesting greater efficiency with the AS treatment.

Table 4. Economic optimum N rates (EONR) and corn yields at the EONR for several polymer-coated urea and ammonium sulfate treatments.

Year	Polymer-coated urea (ESN)			Ammon. sulfate
	Preplant	Preplant & 4 wk	4 wk	4 wk & 6 wk
	------------------------------- EONR †, lb N/acre ------------------------------			
2003	200 (218)	181 (207)	--	189 (196)
2004	227 (173)	215 (190)	--	193 (202)
2005	165 (189)	158 (193)	152 (187)	167 (184)
2006	123 (182)	115 (185)	102 (174)	90 (181)

† EONR based on relationship between N rate and corn yield obtained with five N rates (0-250 lb N/acre. Values in ( ) are yields (bu/acre) obtained at the EONR.

In an attempt to summarize the effectiveness of the various N treatments evaluated during the 4-year study, average yields and apparent fertilizer N recovery for the N source and timing treatments are shown in Table 5. The N recovery values shown are based on total above ground N uptake by corn in the treatment specified and provide an indication of the extent of N loss by leaching since N that is not recovered by the crop during the growing season is most likely lost. In comparing preplant N treatments, ESN has a yield advantage and slightly higher N recovery compared to AS or AS with a nitrification inhibitor. Preplant urea is much less effective than the other preplant treatments and is apparently subject to much greater N loss with only 19% of the applied N recovered by the crop. The split and sidedress treatments applied as ESN or AS generally had higher yields and recoveries than the same materials applied preplant, but urea had lower yields and recoveries than the ESN or AS treatments. In fact, preplant ESN had higher yields and recoveries than sidedress urea. The 4 wk & 6 wk split sidedress AS treatment had similar yields as the ESN preplant & 4 wk application, but N recoveries were somewhat better with the AS treatment. Compared to the AS 4 wk sidedress treatment, the ESN preplant & 4 wk application had higher yields but similar N recovery.

Table 5. Average yields and % recovery of fertilizer N with various N sources and times of N application, Hancock, WI, 2003-2005.†

Treatment	Yield, bu/acre	% N recovery
ESN, preplant	185	44
Ammonium sulfate, preplant	171	41
Amm. Sulf. +NI‡, preplant	178	43
Urea, preplant	159	19
ESN, preplant & 4 wk	189	49
Amm. Sulf. , 4 wk	179	50
Amm. Sulf. , 4 wk & 6 wk	189	56
Urea, 4 wk	171	35

† Apparent recovery of fertilizer N calculated by subtracting N uptake in control (no N) from total N uptake in treatment ÷ amount of fertilizer N applied x 100. Average control yield (2003-2005) = 103 bu/acre, Control N uptake = 67 lb N/acre.

‡ NI=Nitrification inhibitor, DCD.

Summary and Conclusions

In years with normal or below normal precipitation, a single preplant application of ESN is as or more effective than sidedress or split applications of AS or urea. Preplant ESN performed better than other preplant N sources (AS and urea) in terms of yield and fertilizer N recovery. Yields and fertilizer N recovery with preplant AS were higher than those with preplant urea. Using a nitrification inhibitor with preplant AS increased yields and fertilizer N recovery some years, but not in a year with excessive early season rainfall. Our 4 years of data show that ESN is much better as a preplant treatment in wet years than conventional fertilizers; however, split applications of AS are superior to preplant ESN in high rainfall years. This means that relying on preplant ESN as a general practice would involve risk of reduced performance in wet years. With and without sulfur comparisons did not show a corn yield response to added S in any of the four years.

References

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