SLOW-RELEASE FERTILIZER EFFECT ON GROUNDWATER NITROGEN CONCENTRATION IN SANDY SOILS UNDER POTATO PRODUCTION

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Abstract

Current nitrogen (N) fertilizer management practices for potato farming have led to elevated levels of N in the local groundwater. Slow-release fertilizer, specifically Environmentally Smart Nitrogen® (ESN®) polymer coated urea (PCU) may reduce the amount of N leaching to groundwater; however no field scale studies have been performed in Wisconsin to validate these assertions. Field experiments were conducted at the Hancock Agricultural Research Station using Russet Burbank potato, planted in Plainfield Loamy sand. Four fertilizer rates were evaluated: 1) 0 N control, 2) 224 kg ha^{-1} of N as ESN®, 3) 280 kg ha^{-1} of N as ESN®, and 4) 280 kg ha^{-1} of N as a split application of ammonium sulfate and ammonium nitrate (AS-AN). This study included three replicates to create twelve 14.6 m by 15.2 m field plots. Three monitoring wells spaced diagonally across plot were installed and sampled weekly during the growing season. In general, results indicate that ESN® reduced the amount of nitrate leaching to groundwater. Potato growth parameters and yields were maintained with use of ESN®. This demonstrates that use of slow-release ESN® fertilizer is a reasonable alternative to current management practices of AS-AN application.

Introduction

Nitrate contamination from agricultural processes is a significant problem in the Central Sands Area (CSA) of Wisconsin. Given the sandy nature of soils in the CSA they have a small amount of soil organic matter and have limited nutrient and water holding capacity. These characteristics require intensive management of agriculture for adequate crop production. It has been documented that elevated fertilizer rates and to some extent extensive irrigation has contributed to concentrations of nitrate in the groundwater that are 2-4 times the Minimum Contaminant Level (MCL) of 10 ppm as recommended by the U.S. EPA (EPA, 2009). Elevated levels of nitrate from reactive N and its derived pollutants in water may be hazardous to human health via three main pathways. These pathways are the formation of methemoglobin resulting in blue baby syndrome, indirectly by the eutrophication of surface waters, and by the formation of carcinogenic N-nitroso compounds (Wolf and Patz, 2002).

Slow-release fertilizers, in particular ESN® (Agium, Inc, Denver, CO) show promise in reducing the amount of nitrogen reaching groundwater. Previous studies on ESN® have concentrated on the root zone and evaluating the significance of fertilizer type on nitrogen leaching, data from these studies on slow-release nitrogen fertilizer indicate reduced leaching (Wilson et al., 2009). However, determining the impact of slow-release fertilizers and nitrate reaching groundwater has only been inferred from these root-zone measured data (Shrestha et al., 2010), and no study has been conducted that has directly monitored nitrate concentrations in groundwater.

Slow-release fertilizers must produce yields similar to the yields of traditional management methods at comparable cost if it is to be rapidly adopted as a management practice by growers. The use of ESN® effectively increased potato yield and quality when compared to urea applied all at once or in split applications. The ESN® appears to have improved N use efficiency, with reduced rates proving to be more effective than the grower's standard practice full rates. In addition, ESN® has the potential to reduce residual soil nitrate. Therefore, ESN® may result in reduction in groundwater contamination (Monte et al., 2009).

Materials and Methods

A field experiment was conducted at the Hancock Agricultural Research Station in a Plainfield Loamy Sand soil. The study consisted of twelve 14.63 m by 15.24 m plots, in a randomized complete block design, dividing the filed two plots wide by six plots long with four treatments in three blocks. Each replicate consisted of applications of 0 N control, 224 kg ha^{-1} of N as ESN®, 280 kg ha^{-1} of N as ESN®, and 280 kg ha^{-1} of N as AS-AN. In 2010, ESN® was applied 19 DAP and conventional fertilizer was split, with 1/3 applied as ammonium sulfate also at 19 days after plating (DAP) and 2/3 applied as ammonium nitrate 35 DAP. A cool spring in 2011 postponed fertilizing to 28 and 60 DAP respectively. Fertilizer was applied by hand on the top of the hill, incorporated mechanically during hilling. Each plot contained 16 rows of potatoes. Wells were placed in rows 4, 8, and 12, at a distance of 4.9 m, 7.6 m, and 9.8 m respectively from the edge of the plot. Groundwater monitoring wells were installed at a depth of 9.75 m from the soil surface, with 1.5 m screens. Wells were installed approximately 3.35 m below the water table, leaving the top of the screen 2.13 m below the water table. This was done to account for seasonal drawdown of the water table from agricultural activities. The second year wells were installed at a depth of 9.14 m with 2.28 m screens at 1.52 m of depth into the water table. Second year wells were installed to place the water table well inside the range of the well screen.

Laboratory analysis was done using microplate methods. Nitrate determination was completed with the single vanadium chloride reagent method used by Doane and Horwath (2003). Ammonium was conducted using a revised Berthelot method from Stackpoole et al (2008).

Potato yields were obtained by mechanical harvesting of 3.05 m sections of four rows in each plot, and graded at the Hancock Agricultural Research Station. The mechanical grader separated potatoes into B grade, less than 4, 4-6, 6-10, 10-13, 13-16, and greater than 16 ounces, with manual culling. Total yield (all class sizes) and marketable yield (4 oz and greater) are reported.

Results and Discussion

Yield

Potato yields were greater in 2011 compared to 2010. Neither year showed statistically significant differences between yields in treatments receiving N showing ESN® can produce as effectively as conventional practices. In 2010 weather was above average in warmth and above average in precipitation compared with 2011 which was dry and warm. The ESN® release rate is governed by temperature, and with a warmer year, may have released more quickly and then the increased precipitation caused it to leach at a rate faster than plant uptake. This would have also been the case with the AS-AN plots, which could explain why the yield differences are not statistically significant (Table 1). This is important as ESN® gave equivalent yields as conventional techniques in an anomalous weather year. The dry 2011 most likely helped minimize leaching and yields increased as compared with 2010. Previous studies show ESN® has produced generally higher yields (of potato) than conventional management practices (Wilson et al. 2009).

Nitrate

While not all sampling dates were significantly different, measured groundwater nitrate concentrations show that plots with conventional management practices maintained greater concentrations than the 0 N control and both rates of ESN® (Fig. 1). Surprisingly, the 224 kg ha^{-1} rate of ESN® accumulated more nitrates and surpassed the higher ESN® rate near the end of the growing season, during the first week of August. The depth to water table has increased steadily in the CSA since 1973 (Weisenberger, 2009). However 2010 observed a recovery of the water table elevation. After years of constant decline, the water table elevation increased by 1.0 m during growing season. This resulted in the well screens being approximately 3 m below the surface of the groundwater. The nitrate measurements for 2010 are therefore of the bulk groundwater, not the nitrate reaching the water table surface (the interface of the saturated and unsaturated zones). Absolute numbers of nitrogen concentrations in 2010 are 100-200% greater than the EPA recommended MCL of 10 mg L^{-1}. A large flush of nitrates is shown during the spring thaw, and as noted by Zvomuya et al (2003) this may occur as a PCU may release nitrogen after crop removal and be seen with spring thaw. Groundwater flow from plot to plot also contributes to increases seen in zero nitrogen plots. The potato field in 2011 had lower initial nitrate concentrations as compared with 2010. Several wells were under the EPA MCL. All N treatments showed similar increases in groundwater N concentration (Fig. 2), however plots with conventional fertilizer showed the largest concentrations. Groundwater nitrate concentrations below the zero N control plot remained constant throughout the year. Although not statistically significant, ESN® resulted in lower peak nitrate concentrations compared to conventional fertilizer. However, the benefit of ESN® on groundwater quality is evident in that the same rate as conventional fertilizer showed smaller increases in groundwater nitrate concentration, and use of slow-release fertilizer will result in less nitrate reaching to the groundwater.

Ammonium

Ammonium-N concentrations for both years were very small, accounting for between 0.085 and 0.350 mg L^{-1} in the groundwater with no significant differences. Plant use, volatilization, cation retention, or microbial assimilation most likely kept ammonium from leaching deeper than the root zone.

Organic Nitrogen

Organic N, similar to ammonium, contributed little proportionally to total N, normally between 0.102 and 1.00 mg L^{-1} during both years. There were three weeks during which sharp increases in organic N concentration occurred in 2010. These spikes were still a small proportion of total N, with the highest peak concentration at 2.78 mg L^{-1}. All of these spikes occurred early in the season, and are potentially the result of the spring thaw and a flushing of organic material to the water table which then quickly dissipated. Organic N concentrations in 2011 were more static and showed only one small summer spike, however this concentration was small with respect to the 2010 data.

Conclusions

The slow-release product ESN® shows promise in limiting the amount of nitrate that accumulates in the bulk groundwater. However, monitoring methods and well positioning are critical for accurate assessment of leaching to the water table surface. This reduction of accumulated nitrates was done without significantly altering yield. Management practices using slow-release fertilizers should be adopted by potato farmers in sandy soils requiring intensive fertilization. The benefits of reducing nitrate contamination into the groundwater are clear, and ESN® provides a cost effective way to accomplish this goal.

Table 1. Average marketable and total potato yield from different nitrogen sources in 2010 and 2011.

	2010		**2011**	
Treatment	Marketable	Total	Marketable	Total
		Mg ha^{-1}		
280 kg ha^{-1} AS-AN	39.9 a	48.7 a	49.9 ab	54.5 ab
280 kg ha^{-1} ESN®	41.8 a	50.8 a	50.8 a	56.4 a
224 kg ha^{-1} ESN®	39.2 a	47.7 a	51.9 a	56.4 a
0 N	21.6 b	30.9 b	41.1 b	48.6 b

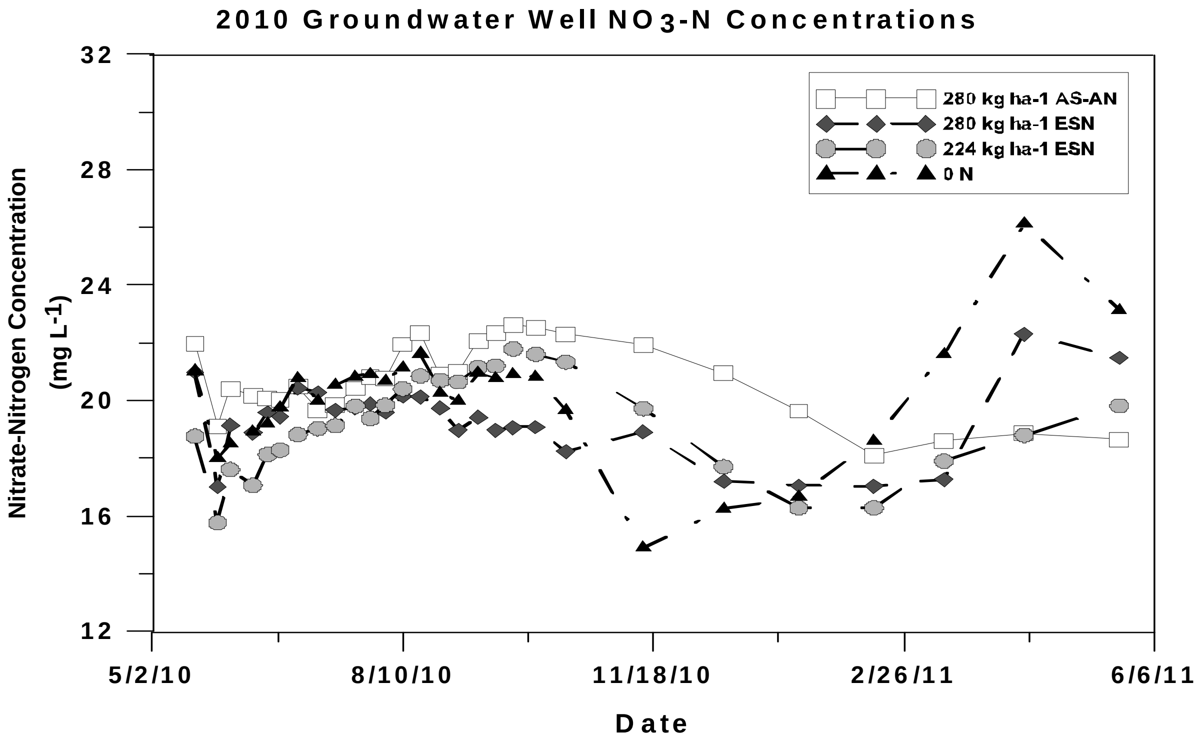

Figure 1. Groundwater nitrate concentrations in 2010 below potato production managed with different forms of nitrogen.

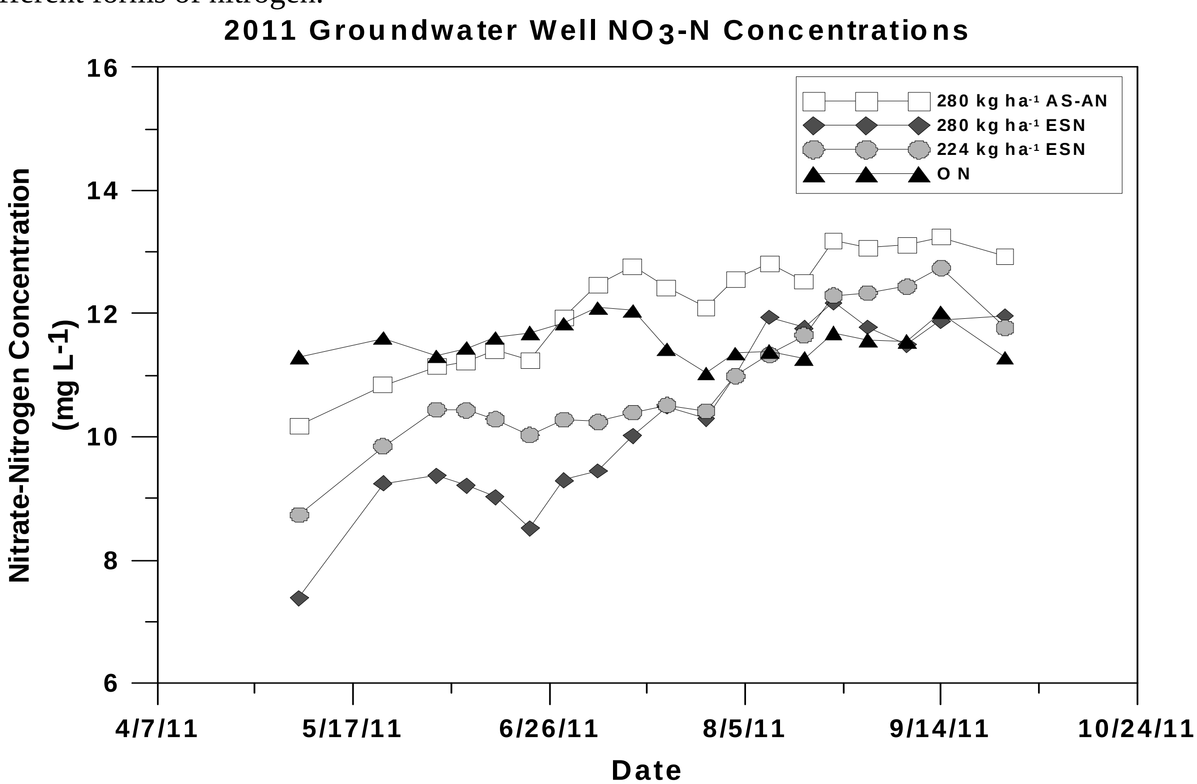

Figure 2. Groundwater nitrate concentrations in 2010 below potato production managed with different forms of nitrogen.

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