Utility of Polymer-Coated Urea as a Fall-Applied N Fertilizer Option for Corn and Wheat

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INTRODUCTION

Management strategies to reduce soil N loss include improved timing of N fertilizer applications, better use of soil and plant testing procedures to determine N availability, application of nitrification or urease inhibitors, and use of N fertilizer sources that are suitable for local environmental conditions (Dinnes et al., 2002). The use of slow-release nitrogen (N) fertilizer for corn and wheat may be a cost-effective management practice to increase crop performance and allow for a single N fertilizer application in the fall or early spring.

Prior research has indicated that deep banding of fall-applied polymer coated urea (PCU) may outyield deep banded urea, broadcast applied PCU, and anhydrous ammonia (Randall, personal communication). Nitrogen release in Missouri over the winter was less than 30% for fall applied PCU applications and there was more consistent N release when PCU was deep banded than when surface applied (Nelson and Motavalli, 2007b). Reduced efficiency of surface applied PCU may be due to gaseous N losses over the winter months during freeze-thaw events. Deep banding PCU with strip tillage should improve efficiency and make it a cost-effective alternative to applying anhydrous ammonia.

Wheat research in MO has evaluated application timings (Medeiros et al., 2005) and fall compared to split applications of PCU (Nelson and Motavalli, 2007a). Applications of PCU later than February resulted in grain yields less than other N sources (Medeiros et al., 2005). In four years of research, fall-applied PCU had the greatest N uptake and grain yields when compared to fall-applied urea alone (Nelson and Motavalli, 2007a). No research has evaluated fall application timings of PCU compared with other N sources to determine if a single fall application at the time of planting wheat or later had yields similar or greater than standard applications of ammonium nitrate. A single fall application would save farmers application cost of a split application in the fall and spring. Spring applications of N on wheat are usually challenging due to wet conditions and risk of N loss. In addition, research is needed to evaluate the response of wheat to blends of urea and PCU.

The objectives of this research have been to: 1) evaluate yield response of fall-applied PCU compared with non-coated urea and anhydrous ammonia with and without N-serve for corn and 2) evaluate the effect of fall-applied timings of PCU and blends of PCU with non-coated urea (NCU) on wheat yields when compared to non-coated urea and ammonium nitrate. An additional objective which was initiated in 2009 was to determine the relative cumulative soil nitrous oxide (N_2O) loss with treatments of different pre-plant N fertilizer sources and fertilizer application/tillage methods. Reducing soil N_2O losses may increase N use efficiency and decrease the potential loss of an important greenhouse gas.

MATERIALS AND METHODS

Research was conducted at the Greenley Research Center near Novelty, MO in 2008 and 2009. For the corn studies, two field trials with three replications at each trial were established at

the Greenley Research Center in plots 10 by 70 ft. One trial followed soybean residue and the other followed red clover residue that was frost-seeded into wheat the previous year. Treatments included PCU and non-coated urea (NCU) at 125 lbs N/acre broadcast surface applied and deep banded using a Yetter® 2984 strip-till system equipped with high residue Maverick® units with a rolling basket and dry fertilizer application tubes. A Gandy Orbit Air ground drive fertilizer applicator was used to deliver PCU and NCU for the strip-tilled treatments. Dry fertilizer was placed approximately 8 inches deep in the strip tilled region. Nitrogen treatments were applied in the fall, early preplant (approximately 1 month before planting), and prior to planting. A non-treated and standard anhydrous treatment at 125 lbs N/acre was included as controls. The N application rate was reduced to determine the most efficient N sources.

Soil nitrous oxide N flux was determined periodically during the growing season using a vented PVC collection chamber (5 inches high and 8 inch inside diameter) based on the GRACEnet standard protocol recommended by the USDA-Agricultural Research Service (Baker et al., 2003). Head space gas samples were taken using a 10 ml syringe at 0, 30 and 60 minutes after capping to determine gas flux. The gas samples were then injected into pre-evacuated 5 mL serum bottles for storage and transport to the laboratory. Soil temperature was measured in triplicate around each chamber during the gas collection process with a digital thermometer at the 2 inch depth. Soil samples to a 2 inch depth were also taken in triplicate within 20 inches from the center of the chamber for determination of gravimetric soil water content and soil inorganic N (NH_4^+-N + NO_3^--N). Gas samples were analyzed using a gas chromatograph (GC) (Buck Scientific Inc., East Norwalk, CT, USA) fitted with an electron capture detector (ECD). The ECD temperature was 300°C, and the standing current was 350 milliamps. The make-up gas was ultra-high purity dinitrogen. Carrier gas (high purity helium) flow rate (through a 1.8 m Porapak Q column at 50°C) was 18 mL min^{-1}. The concentration of the sub-sampled gas was determined based on a standard curve using incremental aliquots of a 10 µL L^{-1} N_2O standard gas (Scott Specialty Gases, Plumsteadville, PA, USA).

The soybean residue study was planted to 'DKC63-42' at 30,000 seeds/acre on 6 May 2008 and 23 Apr. 2009. In the clover residue study, 'DKC61-69' was planted at 30,000 seeds/acre on 29 May 2008 and 23 Apr. 2009. The planter was equipped with Shark-tooth® residue cleaners used in tandem with a no-till coulter. The residue cleaners performed well in heavy residue of the no-till plots and provided a smooth seedbed above in strip-tilled plots. Grain yields were determined and grain collected to evaluate for starch, protein, and oil concentration. Grain moisture was adjusted to 15% prior to analysis. A gross margin will be calculated for each treatment to compare relative returns of fall compared with preplant treatments at the conclusion of the experiment.

For the wheat studies, the research was arranged as a randomized complete block design with five replications in 10 by 30 ft plots. 'Pioneer 25R56' was no-till drilled following an application of 20-50-100 on 30 October 2008 at 120 lbs/acre in 7.5 in. rows. PCU release was determined using mesh bags that were deployed on nine different dates and recovered at subsequent dates, washed in cold water, dried, weighed, and percent release calculated. Polymer coated urea (PCU, ESN, Agrium), non-coated urea (NCU, fast release), 75:25 PCU:NCU, and 50:50 PCU:NCU fertilizer treatments were applied at 75 and 100 lbs N/acre on 7 application

dates in 2009. Plots were harvested with a small-plot combine. Grain moisture was adjusted to 13% prior to analysis. All data were subjected to analysis of variance and means separated using Fisher's Protected LSD (P=0.05).

RESULTS

The first two years (2008 and 2009) of this three-year field trial had above average rainfall during the growing seasons resulting in wet soil conditions.. These conditions would also be expected to promote environmental N loss due to nitrate leaching, lateral flow, and denitrification.

Corn following soybean residue. The soils within the strip-tilled bands appeared to be drier than soil under no-till management (personal observation). Among the treatments, anhydrous ammonia with and without N-Serve and deep banded PCU with strip-till at all application dates had the highest corn grain yields (Fig. 1). Deep banded NCU with strip-till averaged 53 bu/acre higher grain yield compared to broadcast NCU in no-till over all application dates (Fig. 1). Use of N-Serve with anhydrous ammonia and the deep banded PCU with strip till had the highest yields among the fall-applied treatments and did not show any significant difference with yields observed for the same treatments applied in early spring (March) or pre-plant (April). Corn grain yield was ranked anhydrous ammonia = anhydrous ammonia plus N-serve = PCU strip-till $\geq$ NCU strip-till > PCU broadcast $\geq$ NCU broadcast > untreated strip-till = untreated no-till.

Corn following clover residue. As was observed with the corn following soybean, corn following clover had the highest grain yields with treatments of anhydrous ammonia with and without N-Serve and deep banded PCU with strip-till (Fig. 2). However, the deep banded NCU with strip till did not show as much of a yield advantage over broadcast NCU under no-till with fall application as compared to the early spring and pre-plant applications. Corn grain yield when averaged over application timing was ranked anhydrous ammonia plus N-serve = PCU strip-till = anhydrous ammonia $\geq$ NCU strip-till > PCU broadcast $\geq$ NCU broadcast = untreated strip-till = untreated no-till.

Nitrous oxide loss. Cumulative soil N_2O loss ranged from 1.5 to 3.1 % of the fertilizer N applied (Fig. 3). As expected, cumulative loss with N fertilizer treatments was significantly higher than that of the untreated plots. Higher losses tended to occur when the N fertilizer was broadcast applied under no-till as compared to deep banded fertilizer with strip-till. Although the PCU no-till/broadcast treatment appeared to have higher N_2O loss compared to the NCU no-till broadcast treatment, this difference is not statistically significant, possibly due to the high variation in soil N_2O flux measurements among the replicates of the same treatment.

Wheat. As was observed in the previous cropping year, rainfall was above average in the fall and spring of 2008 and 2009. Over 50% of PCU applied from October to February was released by 15 June 2009 (Fig. 4). The non-treated check grain yield was 53 bu/acre in 2008 (data not presented) and 30 bu/acre in 2009. There was a significant grain yield to response to all N treatments in 2008 and all but 100% PCU applied in April, 2009 (data not presented). Grain yields at 100 lbs N/acre averaged 5 bu/a greater than 75 lbs N/acre in 2008 while there was

virtually no difference between rates in 2009 when averaged over all application timings (data not presented).

In 2008, wheat yield was ranked PCU = 75:25 PCU:NCU $\geq$ 50:50 PCU:NCU $\geq$ NCU for the October, November, December, January, February and March application timings (data not presented). However, the April 14 application timing resulted in grain yield rankings of 50:50 PCU:NCU = NCU $\geq$ 75:25 PCU:NCU > PCU. Icy conditions at the December application timing and frozen conditions at the February application timing probably contributed to lower yields for these application timings. In general, there was a rate response to decreasing amounts of PCU for the October, January, and February application timings.

Head scab, Septoria leaf blotch, and common rust was prevalent in 2009 which reduced overall grain yields and test weight (data not presented). PCU applied at planting was similar or greater than all application timings of PCU alone which was related to reduced release later in the season (Fig. 5). A mixture of PCU with NCU was required at the April application timing in 2009. Fall applications of PCU or a blend of PCU:NCU at 75:25 had yields similar to or greater than spring applied N in 2008 while a 50:50 blend of PCU:NCU had the most consistent yields in 2009.

SUMMARY

Corn

- In wet years, deep banding NCU or PCU under strip tillage has shown more consistent advantages in crop performance.

- Fall application of anhydrous ammonia plus N-Serve and deep banded PCU under strip tillage may reduce N losses associated with fall N applications and improve crop yields compared to broadcast PCU and NCU under no-till.

- Soil nitrous oxide losses from pre-plant N applications may range as high as 3% of fertilizer N applied under wet soil conditions as experienced in 2009.

Wheat

- Fall applied PCU or as a blend of PCU:NCU in ratios of 50:50 or 75:25 is an option for wheat production in northeastern Missouri.

- PCU applications in Northeast Missouri from mid-March and later should include a greater amount of NCU in the blend to maintain maximum grain yields based on our results in 2008 and 2009.

- Grain yields prior to mid-March were more variable in the NCU treated wheat when compared to PCU or blends of NCU with PCU.

Timetable:

October-December 2009	Prepare treatments, plot preparation, and apply fall application timings for corn and wheat studies
April-September 2010	Apply preplant N treatments soil sample in the spring and prior to harvest.
September 2010	Harvest
Oct-Dec 2010	Analyze and summarize results for final report.

References:

Baker, J. et al. 2003. GRACEnet: Chamber-based trace gas flux measurement protocol. Agricultural Research Service, U.S. Dept. of Agriculture. Washington, DC.

Dinnes, D.L., D.L. Karlen, D.B. Janes, T.C. Kaspar, J.L. Hatfield, T.S. Colvin, and C.A. Cambardella. 2002. Nitrogen management strategies to reduce nitrate leaching in tile-drained Midwestern soils. Agron. J. 94:153-171.

Medeiros, J.A.S., P. Scharf, and L. Mueller. 2005. Making urea work in no-till. Abstr. Am. Soc. Agron. Madison, WI. [non-paginated CD-ROM].

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Proposed Budget:

CATEGORIES	2010 Year 3	TOTAL*
A. Salaries		
M.S. Graduate Research Assistant (50%)	$14,670	$42,875
B. Fringe Benefits		
Fringe for graduate student	$2,095	$5,990
TOTAL SALARIES AND FRINGE BENEFITS	$16,765	$48,583
C. Travel		
Travel to field site	$623	$1,869
Travel to professional meeting	$500	$1,000
TOTAL TRAVEL COSTS	$1,123	$2,869
D. Equipment	$0	$0
TOTAL EQUIPMENT COSTS	$0	$0
E. Other Direct Costs		
Laboratory reagents and supplies	$1,000	$3,000
Field supplies	$1,500	$4,500
Soil processing and analysis	$2,000	$6,000
Publications/Documentation	$500	$1,000
TOTAL OTHER DIRECT COSTS	$5,000	$14,500
TOTAL REQUEST	$22,888	$65,952

*Includes 2008 Year 1 and 2009 Year 2 budgets

Justification:
Salaries and Fringe Benefits: Funds are requested for support of a graduate research assistant (50% time) based on set rates at the University of Missouri. Fringe benefits for the graduate student cover the cost of health insurance. If the graduate student does not require a third year then the requested funds will be used to partially fund a technician during that year.

Travel: Covers cost of travel to Greenley Farm at a rate of 44.5 ¢/mile. In the second and third years, $500 is requested to cover cost of travel and board for one researcher to attend a professional conference for presentation of results.

Laboratory Reagents and Supplies: Covers cost of laboratory reagents, sample containers, and other materials used in soil and plant tissue analyses.

Field Supplies: Cost of fertilizer, seed, plot preparation, planting, weed control and harvesting, soil samplers, flags, pots and other field supplies and operations.

Soil Processing and Analysis: Covers cost of drying, grinding and analysis of soil samples for ammonium and nitrate-N.

Publications/Documentation: Defrays cost of publication and documentation of results and conclusions.

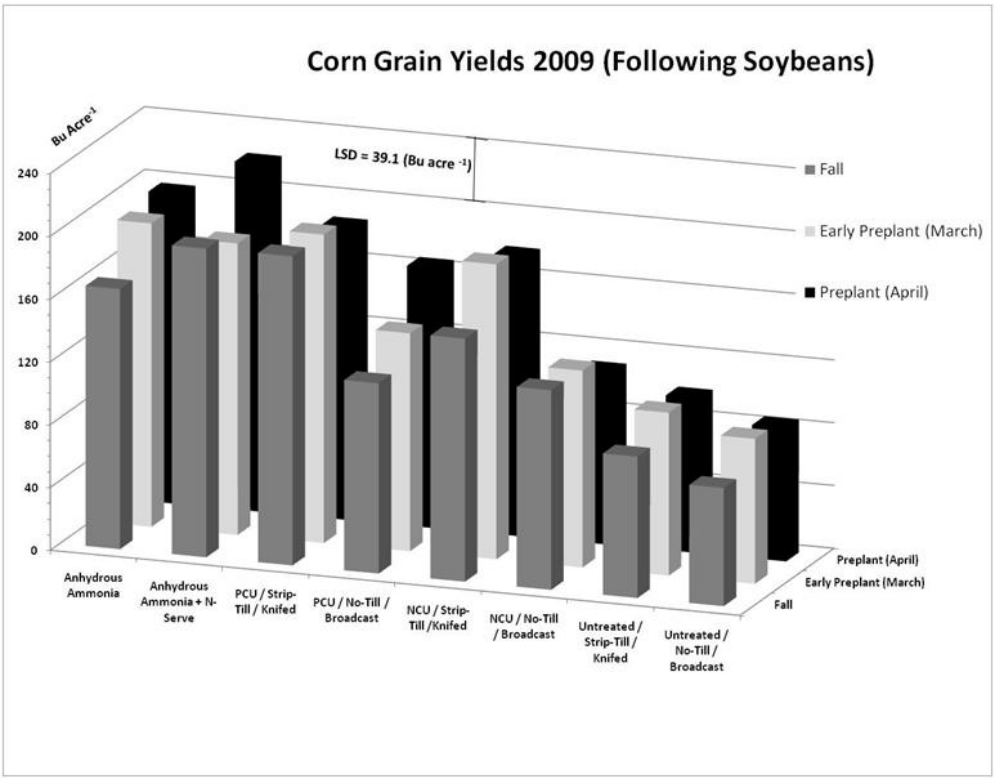

Figure 1. Corn grain yield response to N fertilizer sources applied in the fall, early preplant, and preplant following soybean residue in 2009. LSD ($P \leq 0.05$) was 39 bu/acre.

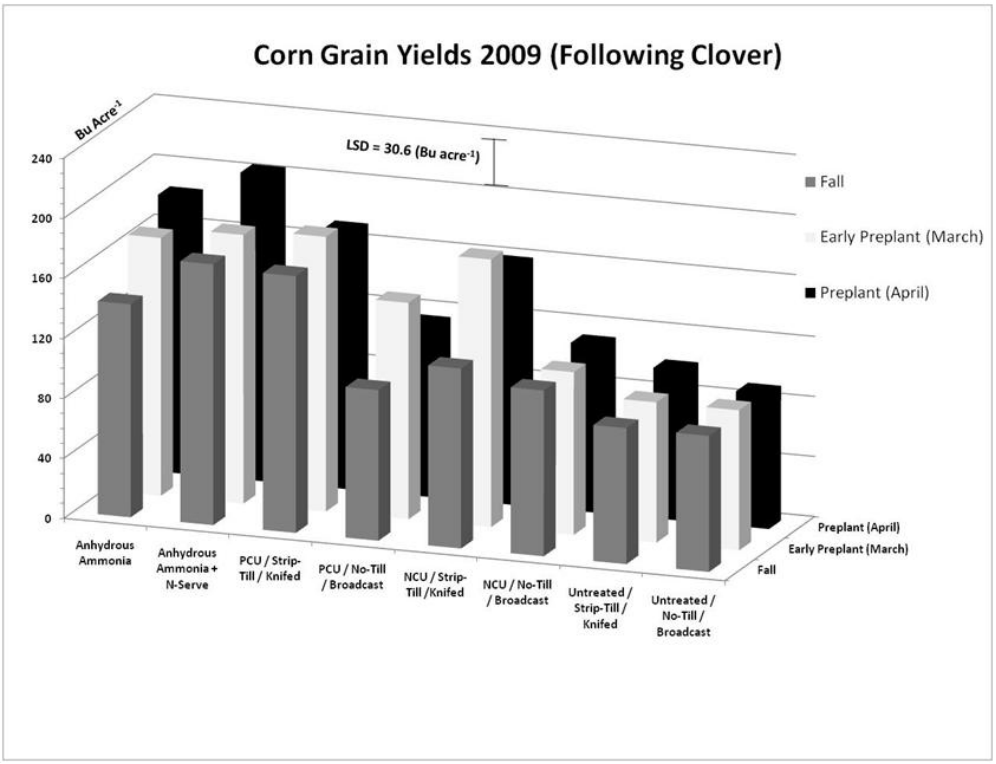

Figure 2. Corn grain yield response to N fertilizer sources applied in the fall, early preplant, and preplant following clover residue in 2009. LSD ($P \leq 0.05$) was 31 bu/acre.

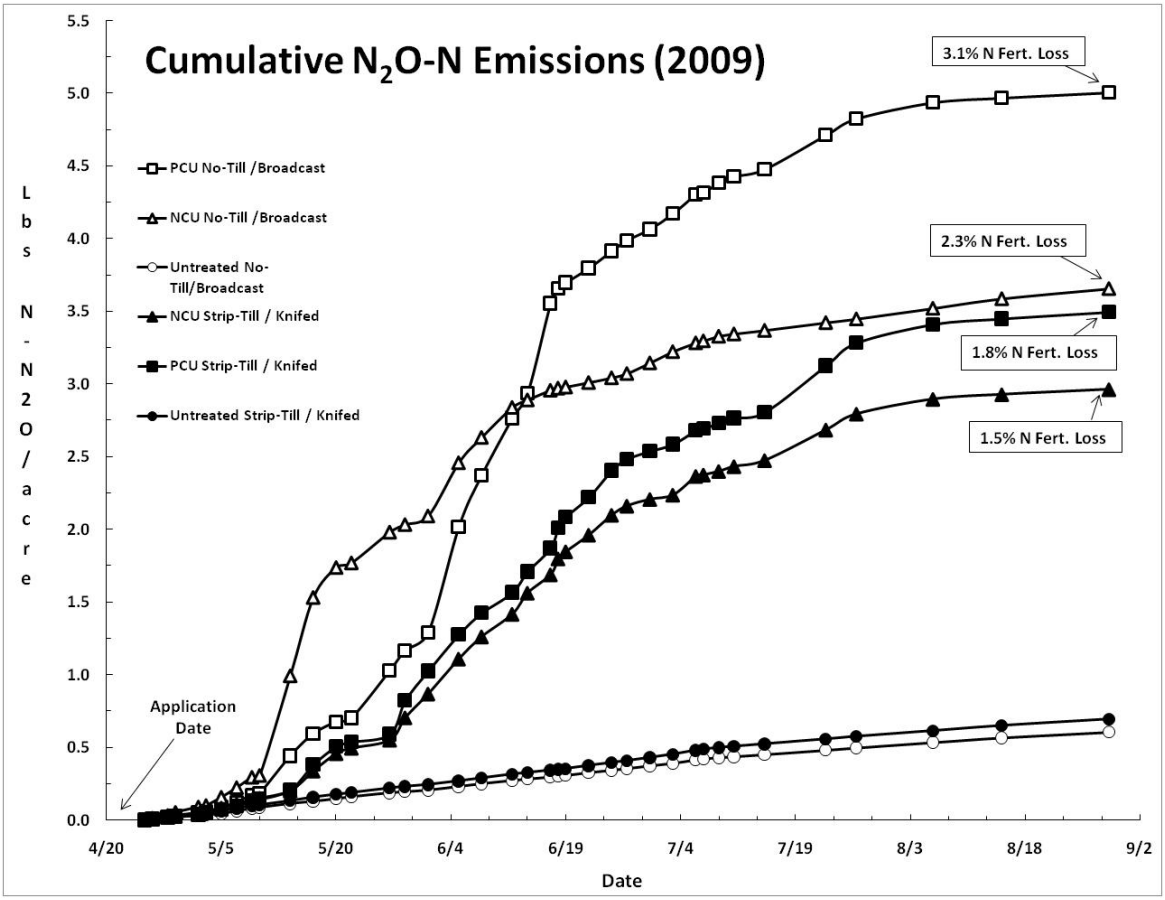

Figure 3. Cumulative nitrous oxide (N_2O-N) gas loss in 2009 due to different preplant N fertilizer sources and methods of application and tillage in a corn crop following soybean. The proportion of total applied fertilizer N lost as nitrous oxide over the growing season is indicated next to each treatment.

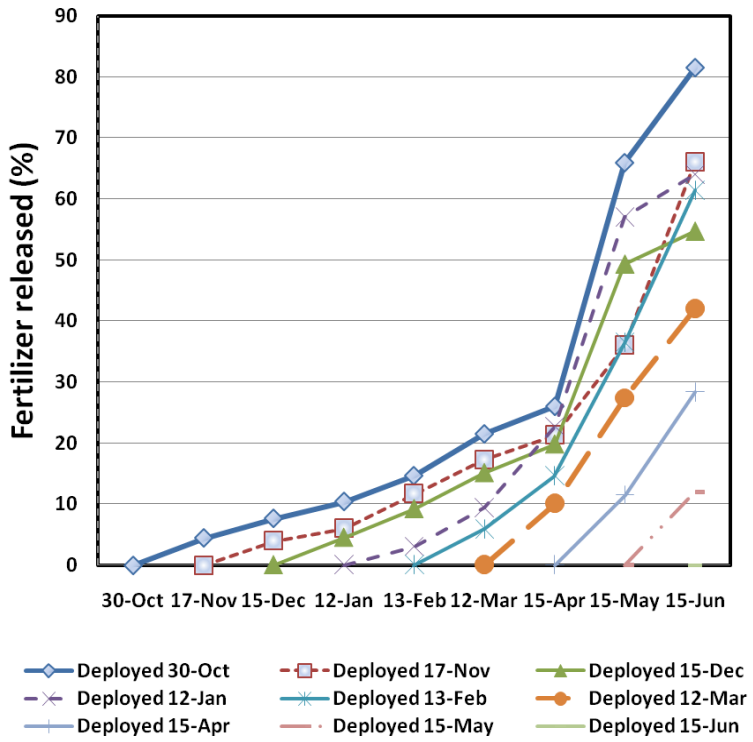

Figure 4. Polymer-coated urea (PCU, ESN) fertilizer release for individual application dates from fall, 2008 to spring, 2009. The LSD ($P \leq 0.05$) was 9.

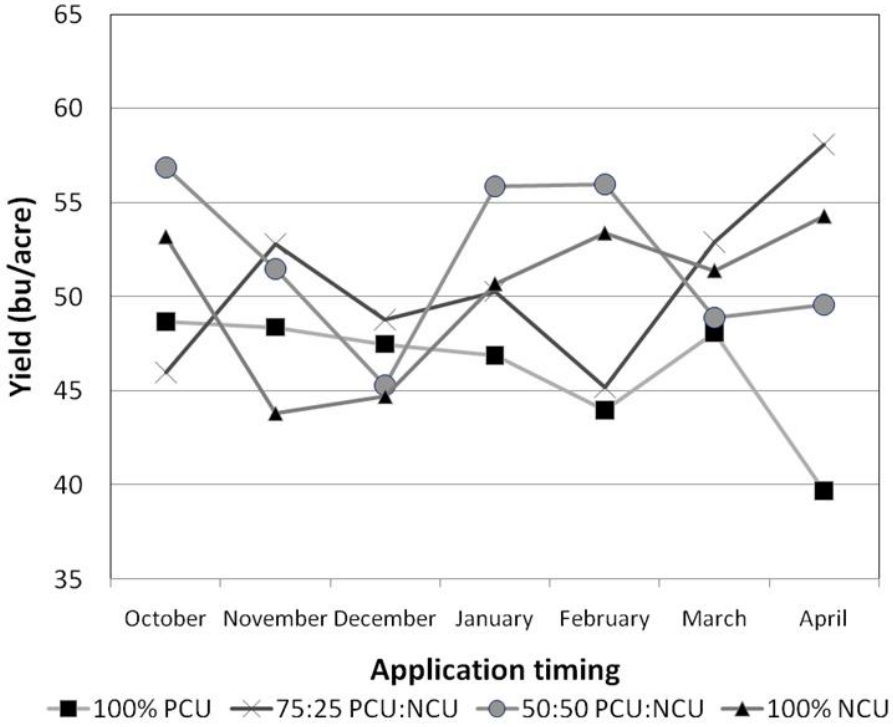

Figure 5. The effect of polymer- (PCU, ESN) and non-coated (NCU) urea application timings and ratios at 100 lbs N/acre on grain yield in 2009. LSD (p=0.05) was 11 bu/acre.