NITROGEN FERTILIZATION FOR WHEAT GROWN ON WET SOILS

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Introduction:
Kentucky wheat production has declined from 530,000 acres in 1996 to 320,000 acres currently. During this time, the state average yield has increased at a rate of approximately 1.5 bushels per acre per year reaching a record high of 71 bu/a this year (USDA NASS, 2006). While some of the increased yield can be attributed to genetic improvements, much of the positive yield response is due to producers removing marginal soil from production. With the projection of higher wheat prices, many Kentucky wheat growers are considering increasing their wheat acreage by placing marginal soil back into wheat production.

The Purchase Region (extreme Western Kentucky) and the Ohio, Green, and Pond River bottoms are the areas currently not in wheat production, mainly due to wet soil conditions in the early spring. In the Purchase Region, fragipans dominate the landscape, while in the river bottoms poor internal drainage is the greater issue. As Kentucky growers bring these soils back into production, the main agronomic challenge is timely nitrogen application. In the more productive areas (well-drained soils) of the state, spring nitrogen application is generally split with about 30% applied at Feekes 3 and 70% applied at Feekes 5 with a total application of 110-120 lbs/a (Lime and Nutrient Recommendations for Kentucky, 2006-07). Naturally, one would assume that split applications would also be required for maximum production on a less than well drained soil. Unfortunately, more often than not, even a timely single application is difficult or impossible in these wet regions.

This study was designed to examine N fertilizer options for wheat grown on wet soils; specifically, using polymer coated urea (PCU) (ESN manufactured by Agrium Inc.) to protect N applied earlier than recommended. Two other goals of this study are: 1) to determine the appropriate N application rate for N applied later than recommended, and 2) to determine the potential economic penalty for untimely N applications.

Materials and Methods:

First Study Year
The study was initiated in the fall of 2002 on imperfectly drained soils located near Lexington and Princeton, KY. In the first year, the main objective was to determine optimal application timing of PCU and urea for wheat production on imperfectly drained soils. Comparing N sources was also a central focus, therefore a single and less than optimal rate of nitrogen was used (60 lb N/a) for all treatments. Fall treatments consisted of incorporated and non-incorporated PCU, urea, or ammonium nitrate. Other treatments were top-dressed PCU or urea applied in January (dormant application), February (Feekes 3), or March (Feekes 5). A blend of 1/3 urea and 2/3 PCU was

applied at Feekes 3 and was compared to a split application of 1/3 urea at Feekes 3 and 2/3 urea at Feekes 5 for a total of 14 treatments plus a 0 lb N/a control. The fall ammonium nitrate treatments were included to determine if fall N loss was due to ammonia volatilization. Pioneer varieties 25W60 on October 23 and 25R47 on October 11 were planted at the Lexington and Princeton sites, respectively. Data collected included dry matter and N uptake at Feekes 10.5 (flowering) and grain yield, moisture, test weight and grain N content at maturity. Nitrogen removal was calculated by multiplying pounds of grain by N%, and nitrogen use efficiency (NUE) was calculated by subtracting N removal in the check plot from N removal in the treatment and then dividing by applied N (60 lbs/a). Higher NUE means more of the applied N was taken up by the crop.

Subsequent Study Years

In subsequent years, studies were established on somewhat-poorly drained soils in Caldwell, Calloway, and Fayette Counties (KY) to determine the effect of N sources and application timing on wheat yield. The two sources used were urea and PCU (ESN, Agrotain Int.). Nitrogen application rates of 0, 40, 80, and 120 lbs N/acre were applied at seven different times: fall, January, Feekes 3, Feekes 6, Feekes 7, Feekes 8, and Feekes 9 growth stage. The fall application was made within three weeks of planting and the January application was done when the ground was frozen. Polymer coated urea was not applied at the Feekes 7, 8, and 9 applications. The plots were 4 x 15 feet and were harvested with a plot combine.

The last year of the study was a complete factorial of N source (urea and PCU) by N rate (0, 50, 100 lbs N/a) by application time (planting, Jan 15, Feb 1, Feb 15, March 1, March 15, and April 1). Sites were again located near Lexington and Princeton, KY, but severe disease prevented the reporting of useful data from the Lexington site.

Results and Discussion:

In the first year of the study, temperature and precipitation from planting to jointing was slightly colder and slightly drier for both locations, indicating that overall nitrogen loss potential was slightly less than normal. At Feekes 5, the fall applied PCU exhibited greater growth and had a darker green color than the fall applied urea or either source applied in February. We inferred from this data that fall applied PCU release characteristics minimized the fall N loss, but N was readily available early in the spring.

There was a high amount of variability in dry matter and N uptake measurements taken at flowering. Generally, N uptake at this stage was higher for PCU than urea when comparing pre-plant application treatments (data not shown). Considering that only 60 lbs N/a was applied to the plots, grain yield for this study was very high. At the Lexington location, yield of the pre-plant PCU treatment was significantly higher than pre-plant urea or ammonium nitrate, indicating that the polymer coating did help decrease some N losses (Table 1). Urea applied in February produced lower yields than urea applied in either January or March, therefore we inferred that some of the February urea was lost via denitrification, leaching, or ammonia volatilization. Regardless of the loss mechanism, February PCU yields were not statistically different than January or March yields, therefore PCU was not subject to as much N loss. At this site, NUE followed similar trends as yield. Nitrogen use efficiency was higher in the fall PCU treatment when compared to the other fall treatments. As anticipated, very low NUE was observed for the fall urea and ammonium nitrate treatments with an average of only 25% of the applied N in the grain at harvest; while the fall applied PCU had more than 50% of the applied N in the grain at harvest. A maximum NUE of 88% was measured at the Lexington site when urea was applied prior to spring green-up.

Grain yield results for the Princeton site are also given in Table 1. Like the Lexington location, we were surprised by the high yields with only 60 lbs N/a. The yields of all treatments were statistically higher than the no N check. Generally, yields of the pre-plant treatments were not statistically different than the post-plant treatments, indicating that conditions at Princeton during this growing season were not as conducive to N loss mechanisms. Of the pre-plant applications, grain yield of the incorporated ammonium nitrate was higher than the non-incorporated PCU treatment. The overall highest yielding treatment was the split product (1/3 urea – 2/3 PCU) application, and it was significantly higher than all of the other post-plant applications, except for urea applied in March. At this site, the yield of the urea/PCU mix was over 8 bu/a higher than the traditional split application of urea. In addition to the yield increase, the producer (using the blended product) would have also saved the charge for the second nitrogen application – making this treatment even more economical. Nitrogen use efficiency at this site varied from 34 to 82 %. The average NUE for the pre-plant treatments was 37% while the post-plant treatments averaged 56%. The maximum NUE was measured when a mix of 1/3 urea and 2/3 PCU was applied in February.

Subsequent Years

The study was expanded after the first year to include urea timing by rate effects and a source comparison for early N application treatments. The results of the urea timing by rate portion of the study (averaged over the four site-years) are given in Figure 1. There was not a significant timing by rate interaction. For these somewhat poorly drained soils, a single N application at Feekes 3 consistently produced the highest yield and highest economic return compared to the other application times. Applications made after Feekes 6 dramatically reduced yield. The N rate required to obtain maximum yield could not be established for most of the application times, because yield increased in a near linear fashion up to the highest N rate (120 lbs/a). For the treatments where N application was delayed until Feekes 8, there was no yield benefit to adding greater than 80 lbs N/a, and if N applications were delayed until Feekes 9, yield was maximized with only 40 lbs of N/a.

The results for the treatments comparing the source affects for 2004 and 2005 are given in Fig. 2 and 3, respectively. As one might expect, PCU increased yield when compared to urea for the early application times, but only in years when N loss potential was high (e.g. Calloway 2004). In years when N loss potential was low (due to dryer than normal winters), yield for the urea treatments was generally higher than the PCU (Lexington 2005). Yields were generally lower for PCU if it was applied at Feekes 3 or later which was likely due to incomplete release. The exception to this occurred in 2006 at the Princeton location (Fig. 4). Polymer coated urea was superior to urea at nearly every application time. Early in the growing season, denitrification was likely the predominate N loss mechanism, however volatilization was probably responsible for N loss in the March 15 and April 1 application times.

Conclusions:

When wheat is grown on less than well drained soils in Kentucky, N application timing is critically important. If a farmer is using uncoated urea and a single application time, then it is best to apply the N at Feekes 3 (early green-up). On average (for site years) applications made before or after Feekes 3 resulted in yield reductions of 5 bu/a or more. Significant yield losses were obtained when N applications were delayed to Feekes 7 or later, however significant yield increases above the check were obtained even when N was applied as late as Feekes 9.

When nitrogen loss potential was high, PCU out-yielded uncoated urea. However, in years with excessive winter precipitation and above normal precipitation, wheat yields for treatments receiving PCU were not significantly higher than the check. This likely indicates that the PCU released too quickly, causing N loss. Later applications (Feekes 6) of PCU resulted in lower wheat yield likely due to incomplete N release. Nevertheless, in 2006 when weather conditions favored volatilization loss at the last two application times, the yield from PCU treatments were higher than uncoated urea. This suggests that PCU might also reduce volatilization losses. However, more research is needed to verify this observation.

Table 1. Grain yield and N use efficiency of wheat as affected by fertilizer application timing, source, and incorporation for the Lexington and Princeton sites (2003).

-------------------- Treatment --------------------			Lexington		Princeton	
			Yield	N Use Efficiency	Yield	N Use Efficiency
Fertilizer*	Growth Stage	Incorporation	bu/a	%	bu/a	%
Check			42.5		68.3	
PCU	Pre-plant	Yes	70.9	42	89.2	34
PCU	Pre-plant	No	80.9	65	88.8	43
NH_4NO_3	Pre-plant	Yes	51.2	11	95.9	53
NH_4NO_3	Pre-plant	No	63.2	33	94.3	52
Urea	Pre-plant	Yes	58.9	34	91.4	48
Urea	Pre-plant	No	61.1	23	89.7	44
PCU	Feekes 2	No	78.3	64	85.3	36
Urea	Feekes 2	No	80.1	88	89.7	41
PCU	Feekes 3	No	73.4	53	87.1	42
Urea	Feekes 3	No	64.8	35	89.7	40
PCU	Feekes 5	No	79.2	77	92.9	62
Urea	Feekes 5	No	80.0	74	95.8	55
PCU/Urea	67/33% Feekes 3	No	76.8	57	101.3	82
Urea	33% Feekes 3 67% Feekes 5	No	82.0	80	92.5	54
		$LSD_{(0.10)}$	8.6	19	6.3	14

* All treatments except the check received a total of 60 lbs N/a.

** Dry matter and N uptake at Feekes 10.5.

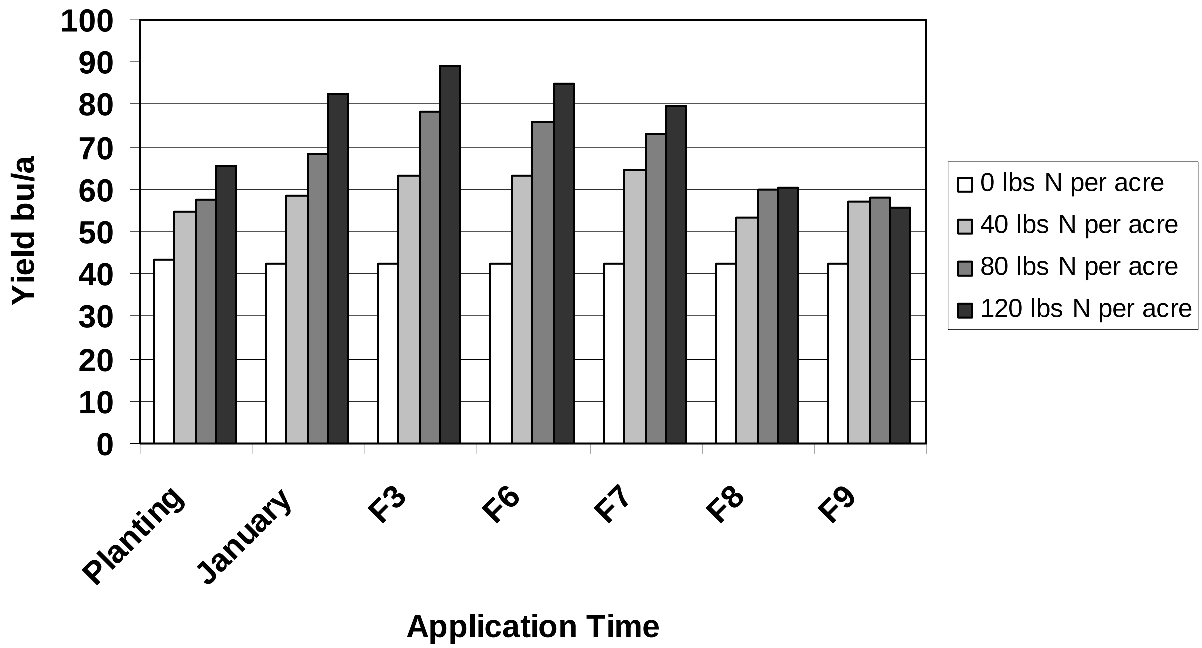

Figure 1. Average wheat yield response to urea application time when planted on less than well-drained soils (4 site years).

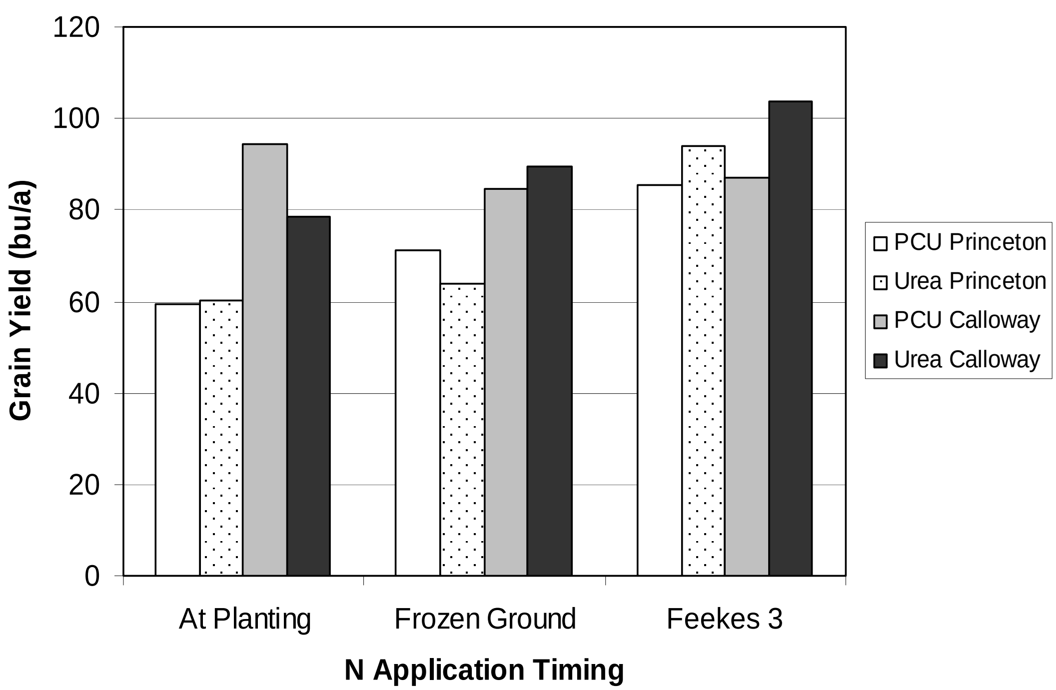

Figure 2. Wheat response to PCU and urea applications (80 lbs/a) in 2004 (somewhat-poorly drained).

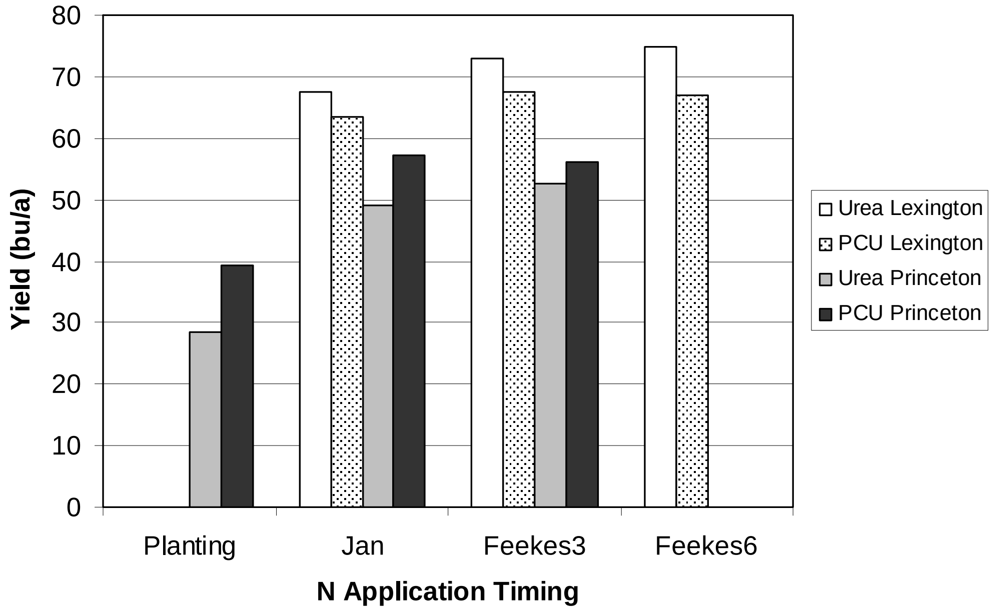

Figure 3. Wheat response to PCU and urea applications (80 lbs/a) in 2005 (somewhat-poorly drained).

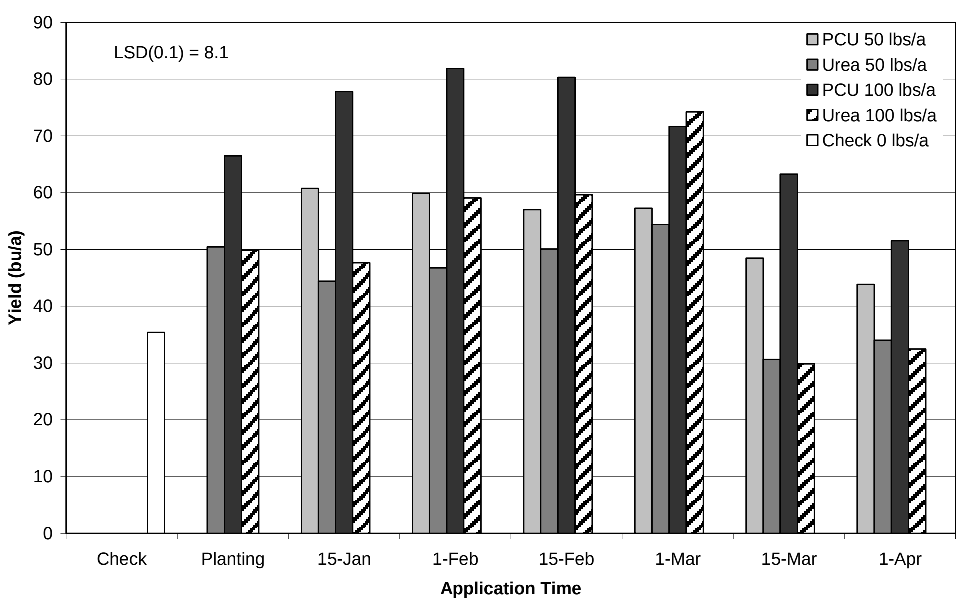

Figure 4. Wheat yield response to urea and PCU application rate and timing (Princeton, 2006).