Making Urea Work in No-till: Final Report

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Executive Summary

The main findings from this three-year (2004-2006) project include:

- Agrotain treatment of urea was the most promising and consistent way to improve performance of broadcast, unincorporated urea in no-till wheat and corn.
- Topdress nitrogen timing had a strong influence on wheat yield.
  - March topdress gave the highest yields, averaging 20 bu/acre higher than January topdress and 13 bu/acre higher than February topdress (averaged over the N sources urea, urea + Agrotain, ammonium nitrate, and SuperU).
- Polymer coating of urea (trade name ESN) produced a substantial yield benefit when wheat was topdressed in January or February.
  - Yield benefit over urea was 16 bu in January, 10 bu in February.
  - Polymer coating protected N from early-season loss (leaching?).
  - But yield with polymer-coated urea in January/February was still 5 bu less than urea in March, and 9 bu less than ammonium nitrate in March.
  - Polymer coating of urea reduced yield by 4 bu for March topdressing.
    - Availability was too slow and plants were visually N-deficient.
- Agrotain treatment of urea gave a yield benefit and an economic benefit for wheat, and gave a yield benefit for corn that was economically borderline.
  - Average wheat yield benefit from Agrotain use was 4 bu/acre.
    - This benefit did not depend on whether N was topdressed in January, February, or March.
    - Treatment cost is about $4/acre and economic benefit was clear.
  - Average corn yield benefit from Agrotain use was also 4 bu/acre.
    - There was not much problem with broadcast urea in 2 of 3 years as indicated by little or no yield difference between broadcast urea and broadcast ammonium nitrate. This was related to either rainfall within a few days of broadcast application, or drought that limited yield and need for N.
    - Treatment cost is about $8/acre and about equal to value of added yield based on historical corn prices. With current high corn prices, there is an economic benefit.
    - Over 15 experiments (including these three) with Agrotain treatment of urea for corn production in Missouri, average yield benefit has been 6 bu/acre and economic benefit is clear.
- Agrotain added to UAN solution was beneficial for corn (average 6 bu/acre) but not for wheat (average 1 bu/acre).
- Polymer coating of urea (ESN) produced no yield benefit in corn.
- Starch gel coating of urea (Nurea) produced no yield benefit in corn or wheat.
- Knife injection of urea produced no yield benefit in corn.
  - Availability of all knifed N treatments was slower than for broadcast treatments according to in-season crop color measurements.
- Tillage to incorporate urea produced a 5 bu/acre yield advantage over broadcast urea for corn. This is the classical way to manage urea.

Objective:

- The objective of this project is to evaluate several strategies to reduce the risk of ammonia volatilization loss from urea applied to no-till corn and wheat.
  - Strategies to be evaluated include:
    - Urea treated with Agrotain volatilization inhibitor
    - Urea coatings: polymer (ESN) or starch (Nurea)
    - Knife-injected urea
  - Yield and economic outcomes from these strategies will be compared with broadcast urea and with other N sources.

Procedures:

- Two experiments were conducted each year from 2004-2006 on Bradford Research Farm near Columbia
  - Each year one wheat and one corn experiment were conducted.
  - Total of three wheat and three corn experiments over the duration of the project.

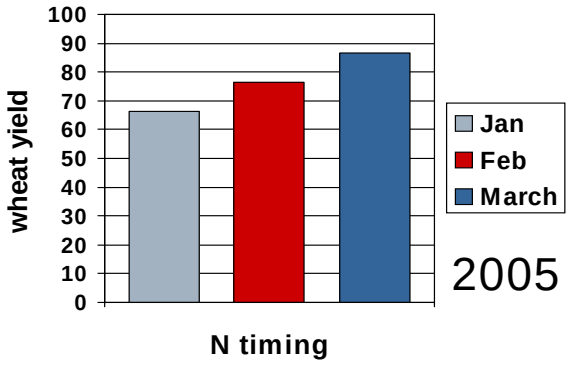
- Treatments were nitrogen fertilizer sources and placement.
  - All treatments were applied at rates of 140 lb N/ac for corn, 70 lb N/ac for wheat.
  - Broadcast treatments
    - Urea
    - Urea + tillage (corn only)
    - Urea with Agrotain volatilization inhibitor
    - SuperU (urea with Agrotain + DCD)
    - Polymer-coated urea (ESN)
    - Starch gel coated urea (Nurea)
    - Ammonium nitrate
    - 30% urea-ammonium nitrate solution
    - 30% urea-ammonium nitrate solution + Agrotain
    - 30% urea-ammonium nitrate solution + Agrotain + DCD
  - Knife-injected treatments (corn only)
    - Urea
    - Anhydrous ammonia
    - Ammonium nitrate
    - 30% urea-ammonium nitrate solution
  - An unfertilized check treatment was also included so that the size of the yield response to N fertilizer could be determined.

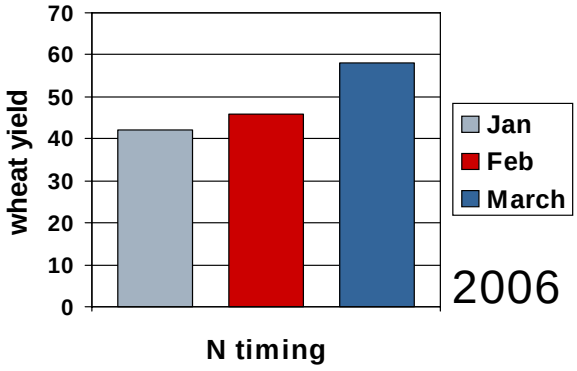
- In 2005 and 2006, the wheat experiments included a timing factor, with all dry treatments applied in either January, February, or March. (All liquid treatments were applied only in March, along with all treatments in 2004.)

- Each treatment was replicated eight times.

Results for wheat:

- Wheat yields averaged 62 bu/acre for dry N sources applied in March over the three years of the study, which is fairly good. However, yields were highly variable between years:
  - 39 bu/acre in 2004
  - 88 bu/acre in 2005
  - 58 bu/acre in 2006
- Average yield response to nitrogen fertilizer (for dry N sources applied in March) was 29 bu/acre and the years followed a similar pattern:
  - 17 bu/acre in 2004
  - 41 bu/acre in 2005
  - 28 bu/acre in 2006
- The most surprising and important result of the wheat experiments was that N timing was the factor that had the biggest effect on wheat yield. This result was consistent between the two years when a timing factor was included (2005 & 2006). On average, February topdress produced 7 bu/acre higher yield than January topdress, and March topdress produced 20 bu/acre higher yield than January topdress.
  - Topdress timing was added to the experiment in 2005 after receiving industry comments that volatilization from urea shouldn't be a problem in cold weather.





- All N sources except polymer-coated urea (ESN) followed this pattern. Wheat yield with ESN was not affected by topdress timing (Table 1).
  - Apparently the polymer coating was able to protect the N from whatever processes were causing N loss in the other N sources.
  - As a result, ESN gave the highest wheat yield among dry fertilizers for January or February topdressing (Table 1).
  - It also gave the lowest yield among dry fertilizers for March topdressing. Low yields with March-applied ESN were associated with persistent slight N deficiency that was visible through most of the season compared to other plots. It appears that N release was too slow to meet wheat N uptake timing when ESN was applied in March.
  - Although January applications of N were clearly undesirable in this experiment, producers sometimes want to apply N at this time. ESN may provide a lower-risk alternative for January N applications to wheat.

- Agrotain increased no-till wheat yield by a 3-year average of 4 bu/acre when applied to urea.
  - This effect did not depend on topdress timing. Average yield response to Agrotain was 5 bu/acre in January, 3 bu/acre in February, and 3 bu/acre in March, but these differences were not statistically significant.
  - This brought yields with urea up to being equivalent to yields with ammonium nitrate.
  - It appears that Agrotain was effective in preventing ammonia volatilization loss of N from broadcast urea.
  - There was no difference in yield between (urea + Agrotain) and (urea + Agrotain + DCD) (trade name SuperU), suggesting that DCD made no contribution to reducing loss of N. Even though we found no evidence that SuperU gave higher yields than urea + Agrotain, it clearly gave the same benefits and may be preferable for some dealers since mixing is not required (as it is to coat Agrotain on urea).
- UAN solution (with or without additivies) produced lower yields than dry N sources in all three years
  - Average yield penalty for broadcast UAN was 11 bu/acre (5 bu in 2004, 23 bu in 2005, 6 bu in 2006).
  - This agrees with previous Missouri research showing that UAN solution broadcast on residue in no-till systems performs poorly.
  - Average yield penalty in previous Missouri research was 8 bu/acre for broadcasting UAN in no-till wheat.
  - Tie-up of UAN droplets on residue is thought to be the reason for this poor performance.

Table 1. Average wheat yields from 2005 and 2006 experiments for different broadcast spring N fertilizer sources and application timings.

Fertilizer treatment	**Yield with treatment applied in:**		
	January	February	March
Urea	**50**	**59**	**72**
Urea + Agrotain	**56**	**62**	**76**
Urea + Agrotain + DCD (SuperU)	**56**	**64**	**74**
Polymer coated urea (ESN)	**66**	**68**	**68**
Starch gel coated urea (Nurea)	**51**	**58**	**72**
Ammonium nitrate	**57**	**64**	**76**
UAN solution*			**59**
UAN solution + Agrotain*			**61**
UAN solution + Agrotain + DCD*			**60**
Unfertilized check	**39**	**39**	**39**

Least Significant Difference (95% confidence) between yields = 4 bu/acre

*Treatments based on UAN solution were only applied in March

- Agrotain added to UAN solution produced an average yield 1.4 bu/acre higher than UAN alone, but this difference was not statistically significant.
- Starch gel coating of urea (Nurea) did not increase wheat yield for any year or timing.

Results for corn:

- Average yield with ammonium nitrate as the N source was 110 bu/acre. Corn yields, like wheat yields, varied widely over the three study years:
  - 161 bu/acre in 2004
  - 58 bu/acre in 2005
  - 112 bu/acre in 2006
- Average yield response to N was 69 bu/acre. Yield response to N followed the same pattern as yield over the three years:
  - 101 bu/acre response in 2004
  - 37 bu/acre response in 2005
  - 69 bu/acre response in 2006
  - The 140 lb N/acre rate that we used is barely enough to support the 101 bu/acre response seen in 2004 and treatments with N loss would be expected to also have yield loss. In the same vein, yield differences between treatments would be expected to be small in 2006 and nonexistent in 2005, and this is what we observed.

Table 2. Two-year average corn yields for different N fertilizer sources & placements (2005 excluded due to drought)**.**

Fertilizer treatment	Yield
Urea (broadcast)	123
Urea + Agrotain (broadcast)	130
Urea + Agrotain + DCD (SuperU) (broadcast)	127
Polymer-coated urea (ESN) (broadcast)	123
Starch gel coated urea (Nurea) (broadcast)	123
Urea (broadcast + till)	131
Urea (knife)	122
Ammonium nitrate (broadcast)	137
Ammonium nitrate (knife)	136
Anhydrous ammonia (knife)	136
UAN solution (broadcast)	112
UAN solution + Agrotain (broadcast)	117
UAN solution + Agrotain + DCD (broadcast)	113
UAN solution (knife)	121
Unfertilized check	56

Least Significant Difference (95% confidence) between yields = 7.5 bu/acre

- Agrotain treatment of urea was the best strategy for improving urea performance in no-till corn.
  - Agrotain increased corn yield by 7 bu/acre (88% confidence) when applied with urea (Table 2).
  - This response was obtained by coating the Agrotain on the urea shortly before broadcasting.
  - Using SuperU (in which the Agrotain is cogranulated with urea and the nitrification inhibitor DCD) gave a similar but smaller yield response (Table 2).
  - Coating the urea on the Agrotain is generally cheaper, but SuperU provides an option for dealers without mixing equipment to provide a safer urea product for notill.
  - Agrotain treatment typically costs about $8/acre and appears to be economical when urea is used for no-till corn in Missouri.
- The DCD (dicyandiamide) nitrification inhibitor component of SuperU did not appear to provide any yield advantage in these experiments.
- Agrotain treatment only made up about half of the yield difference between broadcast urea and broadcast ammonium nitrate.
  - This is in contrast to the wheat study, where urea with Agrotain gave yields equivalent to yields with ammonium nitrate.
  - Averaged over 11 corn studies in Missouri, Agrotain made up 60% of the yield difference between urea and ammonium nitrate.
  - Averaged over 39 corn studies in Missouri, ammonium nitrate outyield urea by an average of 14 bu/acre. If Agrotain made up 60% of the difference on average, 60% of 14 bu/acre is 8 bu/acre. This agrees well with the yield benefit due to Agrotain seen in this study.
  - Cost of urea with Agrotain and ammonium nitrate is generally comparable.
  - Ammonium nitrate may still be preferable to urea with Agrotain where it is available and where the quality is good enough to allow even spreading.
- Neither polymer (ESN) nor starch gel (Nurea) coating of urea produced yield benefits to corn in this study.
  - Polymer coating of urea did slow down urea release and availability to the corn, as indicated by color measurements of the corn taken in early and mid-June (Figure 2).
  - This slower release of urea N apparently did not prevent N loss associated with urea.
  - Starch gel coating did not appear to affect N release rate based on corn color measurements.
- Knife injection of urea was not effective in increasing yield, but tillage was.
  - Either practice should prevent volatile loss of ammonia from the urea.
  - Average yield response to light tillage to incorporate urea was 8 bu/acre.
  - Knife application of all N forms (urea, ammonium nitrate, UAN solution, anhydrous ammonia) resulted in slower N availability to the crop than broadcast N applications, as indicated by corn color measurements taken in early and mid June (Figure 2).
  - Slower availability could possibly explain why injection of urea did not increase yield even though it would prevent volatile N loss. However, this explanation does not fit well with the higher yields seen with injected anhydrous ammonia and ammonium nitrate, which were also more slowly available to the crop.

- Consistent with previous Missouri research, broadcast UAN solution was a poor N source for no-till corn.
  - Average yield was 25 bu/acre less than with ammonium nitrate.
  - This is exactly matches the average 25 bu/acre difference seen in 20 previous experiments in Missouri.
  - Tie-up of N on residue is thought to be the main reason for poor performance of broadcast solution in no-till.
  - Broadcast solution results in much more contact between residue and N than other sources & methods.
- Agrotain addition to UAN produced a 5 bu/acre yield increase (75% confidence).
  - This yield increase is clearly large enough to be profitable.
  - The fact that the yield increase was only 1 bu/acre when both Agrotain and DCD were added to UAN solution suggests that maybe the true yield response to Agrotain was smaller.
  - The average yield increase for both treatments with Agrotain added to UAN, 3 bu/acre, is probably a safer estimate of the benefit from Agrotain.
- Knife application of UAN solution produced a 9 bu/acre yield advantage over broadcast UAN (94% confidence). Knife application avoids contact between residue and fertilizer, and reduces tie-up problems.
  - Knife application appears to be more effective than Agrotain as a tool for improving performance of UAN in no-till corn.
  - Regardless of what management strategies we used for UAN, all other N sources were economically superior in these experiments.

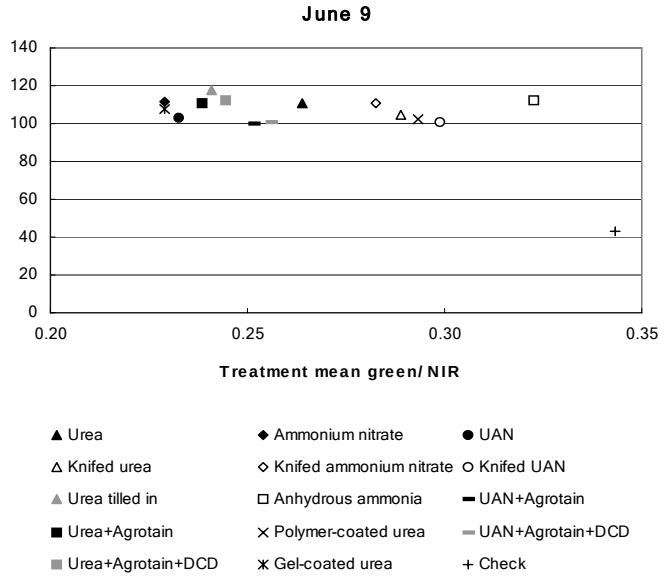


Figure 2. Color (reflectance) measurements indicated that polymer-coated urea (ESN) (shown as an 'x') and all knife-injected treatments (shown as open or hollow symbols) were more slowly available to corn than broadcast-applied treatments (solid symbols). Data points to the right were lighter green and those to the left were darker green on June 9, 2006.