A Look at the Economic Benefits of Enhanced Efficiency Nitrogen Fertilizers

In addition to highest possible crop return per dollar, study also considered evaluation of environmental benefits.

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Summary: *Field studies evaluated the effects of various enhanced efficiency nitrogen (N) fertilizers on spring wheat emergence, yield, and protein content as affected by soil type, slope position, and seeding date. Emergence of hard red spring wheat was not affected by fertilizer management, indicating no damage or benefit from the various fertilizer sources. Late seeding stand was higher than at early seeding at both the Phillips and Brandon locations and was higher on the upper slope than on the lower slope positions at the Brandon site. There was no consistent effect of slope position on biomass yield at either site. Cool conditions delayed emergence and early June frost may have reduced biomass production with the early seeding date. At the Phillips site, biomass yield tended to be higher at the upper slope position with early seeding but not with late seeding. The upper slope would be better-drained with somewhat warmer soil temperatures than the lower slope, therefore would perform better with early seeding than would the lower slope. Biomass yield at heading increased with N applications at both locations, but there were generally no benefits from use of enhanced efficiency fertilizers as compared to spring banding of the untreated urea. Split applications tended to produce lower yields than application of all N as an in-soil band at the time of seeding. Grain yield was higher with late seeding than early, which is in contrast to the normal pattern for this region and to the results observed in the first two years of the study. Grain yield with fall-banded control release urea (CRU) was similar to that of spring-banded urea, while fall-banded urea frequently produced lower yield than spring-banded urea, indicating that CRU could improve performance of fall-applied N.*

It is essential that producers use N efficiently in order to attain the highest possible crop return per dollar invested in fertilizer. Excess N in agricultural systems can also have a major negative impact on environmental quality. During microbial conversion in the soil, N can release nitrous oxide, a gas with a greenhouse effect approximately 300 times that of carbon dioxide. Groundwater may also be polluted by nitrate leaching.

In order to increase nitrogen use efficiency (NUE), one must reduce the amount of N lost to the air and water and increase the proportion used by the crop. Nitrogen is lost from the plant/soil system through four major pathways: volatilization, immobilization, denitrification, and leaching. Ammonia or ammonium-producing sources of N can be lost via volatilization.

The longer N is present in the soil solution before the crop takes it up, the more risk there is of the N being lost to the air or water. Synchronizing the amount and timing of N availability with N requirements of the crop will reduce environmental losses of N while optimizing crop productivity. Therefore, N efficiency should be improved if N supply is closely matched with crop demand, both in terms of amount and timing of supply.

One method of supplying N at a gradual rate is the use of controlled-release fertilizer products. Polymer-coated urea products are available that release N at a rate controlled by soil temperature.

Efficiency of urea N use may also be improved by slowing the conversion of urea to ammonium and ammonium to nitrate. Urease inhibitors slow the conversion of urea to ammonium, while nitrification inhibitors slow the conversion of ammonium to nitrate.

Producers may also choose the use of split applications of N to reduce the initial investment in N fertilizers in environments where crop yield is highly variable. With this strategy, use of in-crop assessment of crop N status would be valuable to determine if the additional N was needed by the crop. A number of different systems are available for assessing in-crop N status. These include tissue N analysis and estimation of plant chlorophyll content using the SPAD meter or the Greenseeker™.

Benefits of CRU, urease or nitrification inhibitors, or split applications vary with environment. If soils are dry, N losses from denitrification and leaching will be low, reducing the potential benefit from split applications or CRU. However, split applications to reduce initial N investment could still reduce economic risk. If soils are wet, losses can be higher and potential benefit greater.

Objectives of this study were to determine:

- Economic benefits of using split N applications, CRU, or urease and nitrification inhibitors

- Effect of microclimate on the relative effectiveness of various N management practices
- If N management strategies should be altered, depending on seeding date
- The ability of various methods of in-crop determinations of N status to predict an economic response to in-crop N applications.

Measuring variability

Climate. The 2009 growing season was wet and cool throughout. Seeding was slightly later than normal and crop emergence was slow due to the cool temperatures. Frosts occurred at the end of the first week of June, adding to crop stress. Crop growth was slow and crop maturity was delayed. A period of relatively dry weather occurred in early September, but crops were not mature. Wet conditions through late September and much of October delayed harvest. Warm, dry weather in November allowed final harvest, approximately six weeks behind schedule. However, crop yields were high due to the prolonged growing season.

Stand density. Crop emergence was good due to ample moisture after seeding (data not presented). Crop emergence was not consistently affected by fertilizer treatments, indicating no damage or benefit from the various fertilizer sources. Stand was higher with late than early seeding at both the Phillips and Brandon locations. Stand was also higher on upper than the lower slope positions at the Brandon site. There was an interaction between seeding date and slope position at the Brandon site, with a larger benefit in stand density, due to seeding date, occurring on the upper slope position (240 vs 277 plants m^{-2}) than on the lower slope position (233 vs 240 plants m^{-2}). The Brandon site is a poorly-drained, heavy-textured location and the restricted drainage in the lower slope position may have affected stand density.

Biomass yield. Biomass yield at heading was assessed by harvesting two 1-meter lengths of row, drying at 60 C, then weighing. Biomass yield at heading was affected by treatment at both locations. There was no consistent effect of slope position on biomass yield at either location, although biomass yield at heading was higher with late rather than early seeding at the Brandon site. On the

Table 1. Effect of nitrogen source, rate and timing on biomass yield at heading (T ha^{-1}) of upper and lower slope positions, with early and late seeding dates, Brandon 2009

			Lower			Upper			
Source	Rate	Timing	Early	Late	Mean	Early	Late	Mean	Mean
Control	0	Control	5.37	5.86	5.62	5.26	6.10	5.68	5.65
Urea	1	Fall Band	5.40	6.11	5.75	5.15	6.07	5.61	5.68
CRU	1	Fall Band	5.66	5.86	5.76	5.68	6.52	6.10	5.93
Urea	0.5	Spring Band	5.63	6.23	5.93	5.13	6.24	5.68	5.81
Urea	1	Spring Band	5.31	5.85	5.58	5.30	6.30	5.80	5.69
Urea	1.5	Spring Band	6.14	5.75	5.94	5.93	6.55	6.24	6.09
CRU	0.5	Spring Band	6.11	5.96	6.04	5.31	6.07	5.69	5.86
CRU	1	Spring Band	5.48	5.86	5.67	5.97	5.99	5.98	5.82
CRU	1.5	Spring Band	5.84	6.92	6.38	5.51	6.51	6.01	6.20
SuperU	1	Spring Broadcast	5.65	5.66	5.66	5.50	6.14	5.82	5.74
Agrotain	1	Spring Dribbled	5.75	6.26	6.01	5.41	6.74	6.07	6.04
Urea-UAN	1	Split-Early	5.31	5.78	5.55	4.68	5.88	5.28	5.41
Urea-UAN	1	Split-Late	4.97	4.94	4.95	4.75	5.64	5.19	5.07

Table 2. Effect of nitrogen source, rate and timing on biomass yield at heading (T ha^{-1}) of upper and lower slope postions, with early and late seeding dates, Phillips 2009

			Lower			Upper			
Source	Rate	Timing	Early	Late	Mean	Early	Late	Mean	Mean
Control	0	Control	3.70	3.98	3.84	4.98	4.90	4.94	4.39
Urea	1	Fall Band	5.17	5.58	5.38	5.92	5.57	5.74	5.56
	1	Fall Band	5.30	5.46	5.38	6.00	5.45	5.72	5.55
Urea	0.5	Spring Band	4.96	4.90	4.93	4.83	5.08	4.96	4.94
Urea	1	Spring Band	5.53	5.81	5.67	5.81	5.70	5.75	5.71
Urea	1.5	Spring Band	5.50	6.12	5.81	5.60	6.08	5.84	5.83
CRU	0.5	Spring Band	5.00	5.05	5.03	5.40	4.84	5.12	5.07
CRU	1	Spring Band	5.16	5.60	5.38	5.45	5.23	5.34	5.36
CRU	1.5	Spring Band	5.28	5.65	5.46	5.82	5.10	5.46	5.46
SuperU	1	Spring Broadcast	5.13	5.39	5.26	5.35	5.15	5.25	5.25
Agrotain	1	Spring Dribbled	5.51	5.73	5.62	5.96	5.43	5.70	5.66
Urea-UAN	1	Split-Early	5.14	4.68	4.91	5.68	4.61	5.15	5.03
Urea-UAN	1	Split-Late	4.63	4.90	4.76	4.62	4.43	4.52	4.64

Table 3. Effect of nitrogen source, rate and timing on wheat grain yield (bu/A) of upper and lower slope postions, with early and late seeding dates, Brandon 2009

			Lower			Upper			
Source	Rate	Timing	Early	Late	Mean	Early	Late	Mean	Mean
Control	0	Control	42.7	61.3	52.0	41.5	63.9	52.7	52.0
Urea	1	Fall Band	51.1	70.8	61.0	39.0	66.8	52.9	61.0
CRU	1	Fall Band	50.3	67.1	58.7	48.5	69.8	59.2	58.7
Urea	0.5	Spring Band	46.7	66.2	56.4	40.7	68.8	54.7	56.4
Urea	1	Spring Band	52.5	65.0	58.7	42.3	67.6	54.9	58.7
Urea	1.5	Spring Band	55.0	66.9	61.0	44.6	73.7	59.1	61.0
CRU	0.5	Spring Band	42.2	64.2	53.2	42.5	66.2	54.3	53.2
CRU	1	Spring Band	49.7	69.4	59.5	47.8	68.3	58.1	59.5
CRU	1.5	Spring Band	55.2	74.8	65.0	41.6	70.9		65.0
SuperU	1	Spring Broadcast	50.1	66.2	58.1	42.7	68.7	55.7	58.1
Agrotain	1	Spring Dribbled	45.9	65.6	55.8	48.3	74.3	61.3	55.8
Urea-UAN	1	Split-Early	45.0	68.1	56.6	45.0	71.9	58.5	56.6
Urea-UAN	1	Split-Late	51.6	69.4	60.5	44.4	65.9	55.2	60.5

heavier-textured Brandon site, the upper slope position may have drained and warmed sufficiently by the late seeding date to allow rapid, uniform emergence, as indicated by the higher stand density, while the lower slope position may still have contained excess moisture. At the Phillips site, biomass yield tended to be higher at the upper slope position with early seeding, but not with late seeding. The upper slope position would be better drained with somewhat warmer soil temperatures than the lower slope position, therefore would perform better with early seeding than would the lower slope position.

Biomass yield at heading increased with N application at both locations, but the magnitude of the increase was small at the Brandon site (Table 1). At the Brandon site the split application of N, with the in-crop N applied late in the growing season, produced a lower biomass yield than when all N was applied at seeding on the late-seeded lower slope. The same trend occurred in the other slope positions and seeding dates, so the effect was significant overall. The half rate of N applied as urea at seeding gave yield similar to the full rate, so the reduction in biomass yield from the late split application may have been due to foliar burn. On the upper slope position, biomass yield at heading was also higher with CRU than with the early split application.

There was greater response of biomass yield at heading to N application at the Phillips farm, particularly on the lower slope position, reflecting lower available N at this site (Table 2). The yield with the split application was similar to that with the half rate of N, indicating that the extra N added in-crop with the split application was not used efficiently by the crop.

Grain yield. Grain yields at both locations were average to above average due to the adequate moisture and relatively cool growing conditions.

On the Brandon site, the early seeding date produced significantly lower yields than the late seeding date (Table 3). In the preceding years, early seeding led to higher yields, so the abnormal results in this season were likely related to the unusual environmental condition that occurred in 2009. Very cool early-season temperatures and late-spring fronts led to poor early growth, which translated into reduced final grain yields with early seeding. There was no significant difference in grain yield between the upper and lower slope positions, however there was a slope-by-date interaction where the grain yield was particularly low on the early seeding date on the upper slope position. Grain yield only increased with N application at late seeding and there were no significant differences among N treatments.

Table 4. Effect of nitrogen source, rate and timing on wheat grain yield (bu/A) of upper and lower slope postions, with early and late seeding dates, Phillips 2009

			Lower			Upper			
Source	Rate	Timing	Early	Late	Mean of Lower	Early	Late	Mean of Upper	Site Mean
Control	0	Control	32.4	35.8	34.1	37.9	42.7	40.3	37.2
Urea	1	Fall Band	43.4	46.1	44.8	47.6	44.3	45.9	45.4
CRU	1	Fall Band	46.2	47.1	46.6	46.2	47.4	46.8	46.7
Urea	0.5	Spring Band	40.6	42.5	41.5	43.4	43.6	43.5	42.5
Urea	1	Spring Band	47.6	48.8	48.2	45.8	51.1	48.5	48.3
Urea	1.5	Spring Band	51.9	54.4	53.2	48.0	53.1	50.6	51.9
CRU	0.5	Spring Band	42.8	44.6	43.7	45.3	44.6	45.0	44.3
CRU	1	Spring Band	48.3	46.2	47.3	47.4	44.3	45.9	46.6
CRU	1.5	Spring Band	54.1	52.7	53.4	43.4	47.3	45.3	49.4
SuperU	1	Spring Broadcast	47.5	43.5	45.5	47.7	44.2	45.9	45.7
Agrotain	1	Spring Dribbled	41.9	45.0	43.5	43.6	45.3	44.5	44.0
Urea-UAN	1	Split-Early	45.3	43.6	44.4	46.2	43.6	44.9	44.7
Urea-UAN	1	Split-Late	45.7	50.4	48.0	45.0	43.9	44.5	46.2

"Controlled release urea (CRU) may be a more efficient form of N when banded in the fall."

Grain yield was increased with N application at the Phillips site at all positions and with all seeding dates, but there were interactions between treatment and date and treatment and slope position (Table 4). On the lower slope position, grain yield increased with each increment of spring-banded urea up to the 1.5 times rate. Grain yield was higher when N was banded in the spring than in the fall. The fall-banded CRU produced grain yields that fell between the fall-banded and spring- banded urea, indicating that there was some benefit using CRU for fall application. Grain yield with broadcast Super U was lower than with spring-banded urea with the late seeding on the lower slope position. Similarly, use of Agrotain and surface-banded UAN produced lower yields than the spring-banded urea, with early seeding on the lower slope position. Application of half of the N as UAN in an early split application produced lower grain yield than spring-banded urea on the lower slope position with late seeding. Surprisingly, the late split application produced similar grain yields to the spring-banded urea. The spring-banded CRU produced higher grain yield than the Agrotain-treated surface dribble-banded UAN. Yields were similar with spring-applied urea and fall-applied CRU, indicating a benefit of the CRU in reducing losses. The spring-applied CRU produced lower yields than the similar rate of untreated urea. With late seeding, delays in release of CRU may have reduced yield potential. Yields were also lower with Super U and Agrotain Plus than with the untreated urea, indicating that the surface applications led to poorer efficiency than the in-soil banding, even with the use of inhibitors. When averaged over seeding dates and slope positions, use of the enhanced efficiency products did not provide an advantage over in-soil banded urea at the time of seeding on the Phillips site in 2009.

Straw yield. Straw yield on the Brandon site was higher with late seeding than early seeding and higher on the upper than lower slope position (Table 5). Straw yield increased with N application but there were no significant differences among N treatments.

On the Phillips site, straw yield was not affected by slope position, but was higher with late- than early-seeding (Table 6). The exceptions were on the lower slope position, the late split application producing lower straw yields with the early seeding date, and the early split application producing lower straw yields with the late seeding date, as compared with spring-banded urea. Fall-banded CRU also produced higher straw yields than the fall-banded urea with late seeding on the upper slope position. On the lower slope position with late application, the CRU at the half and full rate of application gave higher protein content than the urea at the same rates, but the effect did not occur at the other slope-seeding date combinations.

Generally, use of either split applications or enhanced efficiency fertilizers did not provide a significant benefit over the use of in-soil banded urea applied at the time of seeding. However, the CRU may be a more efficient form of N when fertilizer is banded in the fall.

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Table 5. Effect of nitrogen source, rate and timing on straw yield of upper and lower slope postions, with early and late seeding dates, Brandon 2009

			Lower			Upper			
Source	Rate	Timing	Early	Late	Mean	Early	Late	Mean	Mean
Control	0	Control	3.86	4.41	4.14	3.72	3.80	3.80	3.80
Urea	1	Fall Band	3.47	4.51	3.99	3.97	4.31	4.31	4.31
CRU	1	Fall Band	3.71	4.59	4.15	4.30	4.42	4.42	4.42
Urea	0.5	Spring Band	3.78	4.60	4.19	3.91	4.24	4.24	4.24
Urea	1	Spring Band	3.25	4.27	3.76	4.01	4.30	4.30	4.30
Urea	1.5	Spring Band	3.69	4.54	4.12	4.22	4.52	4.52	4.52
CRU	0.5	Spring Band	4.03	5.16	4.60	4.05	4.13	4.13	41.3
CRU	1	Spring Band	3.75	4.35	4.05	4.21	4.39	4.39	4.39
CRU	1.5	Spring Band	3.41	4.41	3.91	4.10	4.59	4.59	4.59
SuperU	1	Spring Broadcast	3.28	4.77	4.03	4.08	4.37	4.37	4.37
Agrotain	1	Spring Dribbled	3.55	4.70	4.13	4.61	4.55	4.55	4.55
Urea-UAN	1	Split-Early	3.57	4.56	4.07	3.74	4.31	4.31	4.31
Urea-UAN	1	Split-Late	3.86	4.41	4.14	4.08	4.36	4.36	4.36

Table 6. Effect of N source, rate and timing on straw yield of upper and lower slope postions, with early and late seeding dates, Phillips 2009

			Lower			Upper			
Source	Rate	Timing	Early	Late	Mean	Early	Late	Mean	Mean
Control	0	Control	2.60	2.74	2.67	2.61	3.66	3.14	2.90
Urea	1	Fall Band	3.29	3.92	3.61	3.82	3.80	3.81	3.71
CRU	1	Fall Band	3.40	3.60	3.50	3.60	4.79	4.20	3.85
Urea	0.5	Spring Band	2.99	3.64	3.32	3.43	4.07	3.75	3.53
Urea	1	Spring Band	3.47	3.91	3.69	3.50	4.21	3.86	3.77
Urea	1.5	Spring Band	3.89	4.33	4.11	3.72	5.03	4.38	4.24
CRU	0.5	Spring Band	2.85	3.37	3.11	3.58	3.58	3.58	3.35
CRU	1	Spring Band	3.41	3.68	3.55	3.51	3.58	3.55	3.55
CRU	1.5	Spring Band	3.71	4.33	4.02	3.22	4.36	3.79	3.91
SuperU	1	Spring Broadcast	3.54	3.62	3.58	3.66	4.04	3.85	3.72
Agrotain	1	Spring Dribbled	3.12	3.65	3.39	3.23	4.15	3.69	3.54
Urea-UAN	1	Split-Early	3.36	3.35	3.36	3.57	3.99	3.78	3.57
Urea-UAN	1	Split-Late	3.34	4.03	3.69	3.43	3.82	3.63	3.66