Effect of time and rate of application of anhydrous ammonia and urea with or without a nitrification inhibitor on the yield and quality of a barley-wheat-canola rotation

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Abstract

A project was initiated in the fall of 2006 to compare the effect of early (mid-September) and late (mid to late October) fall, and spring application of anhydrous ammonia and urea on the yield of barley, wheat and canola in barley-wheat-canola-wheat rotation. The experiment now in its third year is being carried out in two locations (Watrous and Lake Lenore) and involves four rates of N (0, 30, 80 and 120 kg N ha^{-1}) with or without treatment with a nitrification inhibitor (N-Serve) annually applied on the same plots and four replicates for a total of 39 treatments. Consistent significant differences in all six-site years were responses to N and anhydrous vs. urea, the latter being a result of the inefficiency of the low N rate (40 kg ha^{-1}) when applied as anhydrous ammonia. Overall, there were no differences due to time of application.

Introduction

Fall banding of nitrogen (N) fertilizer has long been advocated as a desirable time to fertilize soils, especially in areas of the prairies, where spreading of the workload and reduction in spring tillage operations is desirable, while at the same time taking advantage of historically lower fertilizer prices in the fall. Late fall applications, when temperatures are normally less than 7-10^{o}C are normally recommended (Alberta Agriculture and Rural Development 2002, Manitoba Agriculture, Food and Rural Initiatives 2009, Saskatchewan Agriculture 2009).

Recently, Tiessen et al. (2008) working on different fields as well as different landscape positions within the same fields in the Red River region of Manitoba demonstrated that, overall, selection of suitable timing for application of fertilizer N to optimize crop yields was much more critical for poorly drained fields, and for poorly drained areas within a field, than for better drained land. In the high landscape positions, there were no real differences in increased grain yield and fertilizer NUE among the fertilization treatments. In the low landscape positions, increases in grain yield from late fall and spring-banded fertilization treatments were significantly higher than those from early fall, mid fall and early fall with inhibitors (Figure 1).

Tiessen et al. (2008) concluded that adding a nitrification and a urease inhibitor (DCD and NBPT, respectively) to urea, in addition to delaying the date of fall banding, albeit inconsistent for early fall-banded urea, slowed nitrification and increased the proportion of fertilizer N remaining in the ammonium form at freeze-up; further, timing of banding (at planting or during the fall) was not critical for well-drained areas in the fields, but early fall banding was detrimental to fertilizer efficiency in low areas, compared to banding in late fall or at planting. Overall, the average wheat yield increase from early fall banded N in low areas was 25% less than for spring applied N; in well-drained areas of the fields the yield increase from early fall banded N was at least as large as for spring banded N.

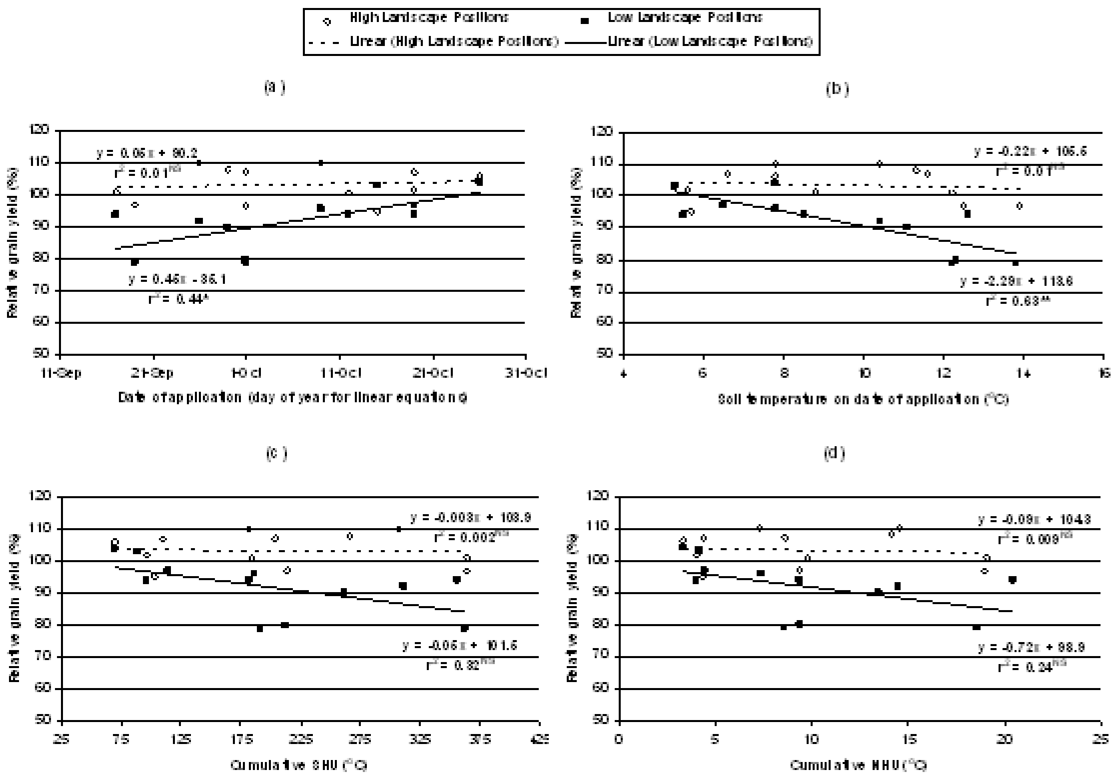

Figure 1. Example of the linear regression relationships of relative wheat grain yield (i.e., grain yield from fall-banded urea relative to grain yield from spring-banded urea) at high and low landscape positions with (a) date of N application in the fall, (b) soil temperature on date of application, (c) cumulative soil heat units (SHU) and (d) cumulative nitrification heat units (NHU). Statistical differences between the slopes of the linear regressions at high vs. low landscape positions: (a) p = 0.067†; (b) p = 0.018*; (c) NS; (d) NS. Note: †, *, and ** indicate significance at the 0.1, 0.05, and 0.01 probability levels, respectively. (Tiessen et al. 2008)

The objective of this project was to evaluate the impact of date of application, form of N fertilizer with and without fertilizer additives, and fertilizer rate on the efficiency of fall-banded N fertilizer on well-drained soils.

Materials and Methods

An experiment was established in the fall of 2006 at two locations in Saskatchewan to assess the 4R Nutrient Stewardship principle (Right Source at the Right Time, Right Place and Right Rate) on nitrogen (N) fertilizer, in particular anhydrous ammonia (AA, 82-0-0).

Right Place: Application of AA predicates that this form is applied in bands; hence, no other placement options were assessed; consequently, the remaining 3R's were examined.

Right Source: Application of AA was contrasted to that of UREA (46-0-0) in the presence or absence of a nitrification inhibitor (NI, N-Serve). N-Serve was applied at the recommended rate of 1 US Quart/acre (2.34 L ha^{-1}) independently of the rate of N application. Nitrogen products were applied by Prairie Agricultural Machinery Institute (PAMI) in 30.5 cm (12 inch) spacing (Figure 2). A modification of the equipment was required to accommodate an attachment that allowed direct injection of the nitrification inhibitor into the AA stream (Figure 3). UREA was treated with N-Serve prior to application.

Figure 2. Modified drill for AA application at 10.5 cm (12 inches) spacing.

Figure 3. Attachment to allow direct injection of N-Serve into the AA stream.

Right Time: Nitrogen fertilizer was applied at two dates in the fall mid-September and mid-October, and one time in the spring just prior to seeding. Unfavourable conditions in the fall of 2006 prevented early and late application of fertilizers, hence, and early and late spring application was employed in 2007 to maintain the experimental design, as all fertilizer treatments were superimposed on the same plots each year. The fertilization schedule is outlined in Table 1.

Table 1. Fertilization schedule.

Crop Year	Site	Fall application Early	Late	Spring application
2007	Watrous	September 27	N/A	April 30 & May 14
	Lake Lenore	September 29	N/A	May 1 & May 15
2008	Watrous	September 17&18	October 15	May 5
	Lake Lenore	September 19	October 16	May 9
2009	Watrous	September 15	October 16	May 6
	Lake Lenore	September 17	October 17	May 4&5

Right Rate: To ascertain the optimum fertilization rate, four N fertilizer rates were applied, namely, 0, 40, 80 and 120 kg ha^{-1} (36, 71 and 107 lb N/acre).

Experimental Sites

Two sites were selected, one in the Dark Brown Soil Zone (Watrous, 31-24 W2) and one in the Black Soil Zone (Lake Lenore, 39-21 W2). The sites were selected to contain deficient N levels (15 and 34 kg ha^{-1} -13 and 31 lb/acre, respectively in the 0-60 cm - 0-24 inch depth). Recommended rates for the crops in the three-year rotation followed in this experiment based on the above soil N levels are provided in Table 2. Each site occupied approximately 5.5 acres (2.2 hectares) to accommodate manoeuvring between replicates.

Table 2. Target yields and corresponding N recommendations for 25, 50 and 75 % probability of precipitation.

	Watrous[1]				Lake Lenore[2]			
	Target Yield		N rate		Target Yield		N rate	
Crop	bu/acre	kg ha^{-1}	lb N/acre	kg ha^{-1}	bu/acre	kg ha^{-1}	lb N/acre	kg ha^{-1}
Barley	73	3924	93	104	81	4354	82	92
	51	2742	76	85	60	3225	71	80
	29	1559	28	31	35	1881	22	25
Wheat	48	3225	100	112	53	3561	89	100
	32	2150	76	85	37	2486	69	77
	17	1142	24	27	21	1411	18	20
Canola	38	2128	107	120	42	2352	96	108
	26	1456	84	94	31	1736	83	93
	15	840	34	38	18	1008	28	31

[1]9, 6.5 and 3.6 inches or 229, 165 and 91 mm of precipitation in May, June and July for 25, 50 and 75 % probability of precipitation and default spring available soil moisture of 2.8 inches or 71 mm.
[2]9, 6.8 and 3.7 inches or 229, 173 and 94 mm of precipitation in May, June and July for25, 50 and 75 % probability of precipitation and default spring available soil moisture of 3.0 inches or 76 mm.

Experimental Design

All fertilizer treatments were arranged in a Randomized Complete Block Design as outlined in Table 3.

Table 3. Treatments involved in the experiment.

Time	Source	Rate, kg N ha^{-1}	Inhibitor	No. of treatments
Early		Control (0)		1
	Ammonia	40, 80, 120	-, +	6
	Urea	40, 80, 120	-, +	6
Mid		Control (0)		1
	Ammonia	40, 80, 120	-, +	6
	Urea	40, 80, 120	-, +	6
Spring		Control (0)		1
	Ammonia	40, 80, 120	-, +	6
	Urea	40, 80, 120	-, +	6
			Total	39

A four year rotation (barley, wheat, canola 9555, wheat) was adopted, of which the first three years are reported here (Table 4).

Table 4. Seeding and harvest dates and growing season precipitation at the two experimental sites.

Year	Site	Date of Seeding	Date of Harvest	May, June, July Precipitation mm	May, June, July Precipitation inches	Probability %
2007	Watrous	May 18	August 28	119.2	4.7	50-75
	Lake Lenore	June 1	September 14	229.3	9.0	75
2008	Watrous	May 8	September 5	167.4	6.6	75
	Lake Lenore	May 15	September 12	134.6	5.3	50-75
2009	Watrous	May 19	September 18	171.2	6.7	75
	Lake Lenore	May 20	September 23	170.5	6.7	75

Each plot was 3.05 m (10 feet) wide and 12.2 m (40 feet) long. All treatments were replicated four times with 18.3 m (60 feet) borders between replicates and the site boundaries. Fertilizer treatments were applied along the length of each plot and seeding was performed across all plots with the same replicate. At maturity, the plots were combined using a Wintersteiger experimental combine and the grain samples were dried at 60°C by forced air and weighed to determine grain yield.

Results and Discussion

Yield

Average barley yields in the Watrous and Lake Lenore sites in 2007 over all treatments were 2817 and 3526 kg ha^{-1} (52 and 66 bu/acre), respectively; in 2008, average spring wheat yields for the corresponding sites were 2245 and 2707 kg ha^{-1} (33 and 40 bu/acre), whereas, canola yields in 2009 were 1766 and 1724 kg ha^{-1} (26.3 and 25.7 bu/acre), respectively.

The only statistically significant effects ($P<0.05$) at both sites and all three years (Table 5) were response to N (Figure 4) and AA vs. UREA (Figure 5).

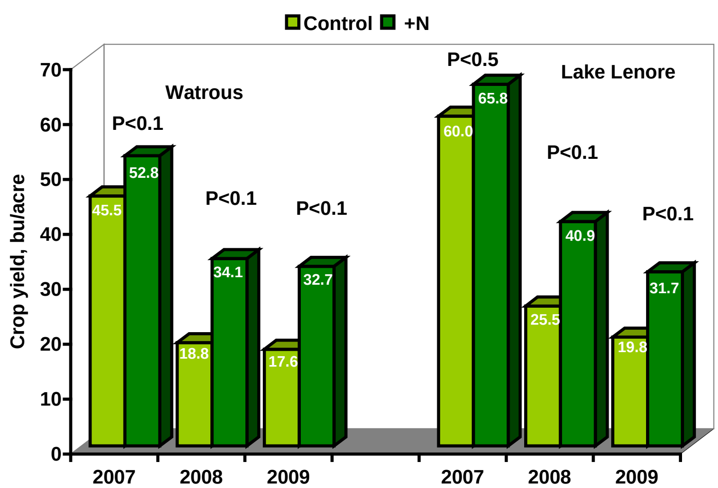

Figure 4. Overall response to N was significant at both sites all three years of the experiment.

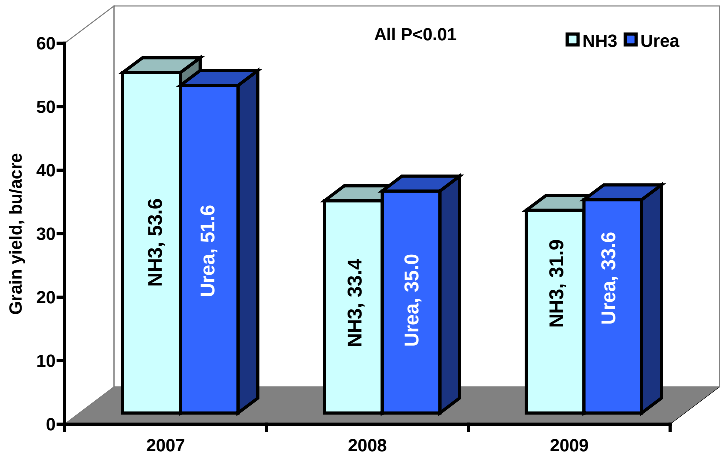

Figure 5. Difference in the overall yield obtained with UREA and AA was significant at both sites and all three years.

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Table 5. Orthogonal comparisons for the separating means of effects

Comparisons	Growing season					
	2007		2008		2009	
	Watrous	Lake Lenore	Watrous	Lake Lenore	Watrous	Lake Lenore
1. Response to N	22.63**	4.59*	233.99**	194.77**	219.48**	94.10**
2. Ammonia vs. Urea	18.81**	25.67**	49.29**	32.59**	50.99**	21.62**
3. Early vs. Late	1.03	1.36	0.15	0.67	0.00	0.87
4. (Early vs. Late) vs. Spring	2.05	0.00	2.98†	0.31	1.77	0.67
5. Inhibitor	2.09	0.45	0.19	3.91†	2.62	0.42
6. N linear	0.00	1.60	86.49**	114.99**	259.27**	132.37**
7. N residual	0.29	0.08	6.85*	3.38†	11.73**	17.00**
8. (Ammonia vs. Urea)(Early vs. Late)[1]	3.21†	0.11	6.96**	0.17	0.08	1.31
9. (Ammonia vs. Urea)[(Early vs. Late)[1] vs. Spring[	3.67†	0.60	1.25	1.16	2.48	0.03
10. (Ammonia vs. Urea)(Inhibitor)	0.07	0.08	0.08	0.00	0.44	0.05
11. (Ammonia vs. Urea)(N Linear)	0.06	0.33	5.74*	5.68*	1.06	0.45
12. (Ammonia vs. Urea)(N Residual)	1.42	1.45	0.60	0.57	0.47	0.03
13. (Early vs. Late)[1] vs. Inhibitor	0.01	0.20	1.85	3.36†	1.23	0.00
14. (Early vs. Late)[1] vs. N linear	5.78*	0.60	0.03	3.74†	1.12	1.27
15. (Early vs. Late)[1] vs. N residual	2.80†	1.32	1.54	0.17	1.32	1.41
16. (Inhibitor)(N linear)	3.38†	0.09	0.80	0.02	0.24	0.45
17. (Inhibitor)(N residual)	2.21	0.32	1.14	0.06	2.94†	5.60*

[1] In 2007 "Early" corresponds to fall application and "Late" to early spring application

**, *, and † = significant at P<0.01, <0.05, and <0.10; otherwise, not significant.

The differences in the overall performance of the two N sources reflected difficulty in achieving accurate applications of low rates (36 lb N/acre) of AA (Figure 6).

(a) (b)

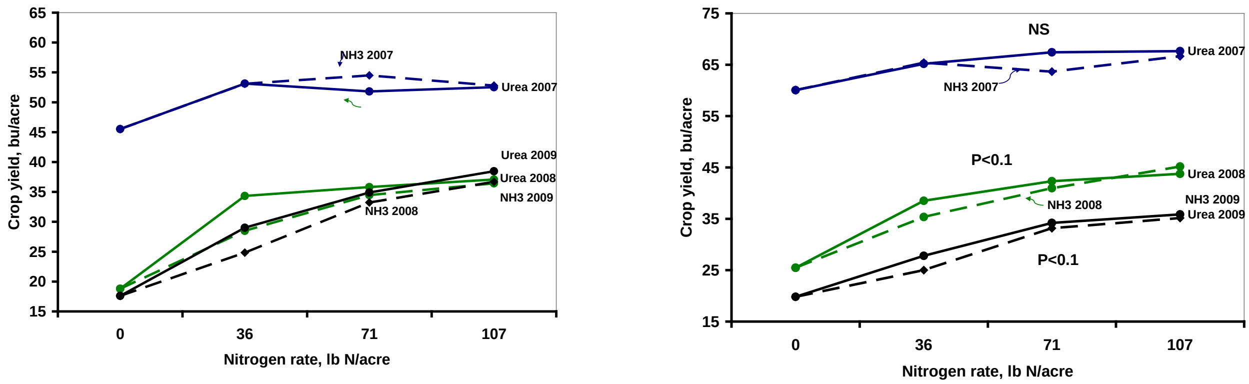

Figure 6. Linear response of crops to N fertilizer rate was only significant in 2008 (a) and 2009 (b) and the interaction noted between UREA and AA was the result of lower yields with AA at the 36 lb N/acre (40 kg ha^{-1}) rate.

There was no significant difference in yields obtained with early vs. late application of either UREA or AA; however, in 2008 at the Watrous site the late application of UREA resulted in significantly higher wheat yield (Figure 7). There were no differences at the Lake Lenore site, neither were there any significant differences between fall and spring applications at both sites over all three years of the experiment.

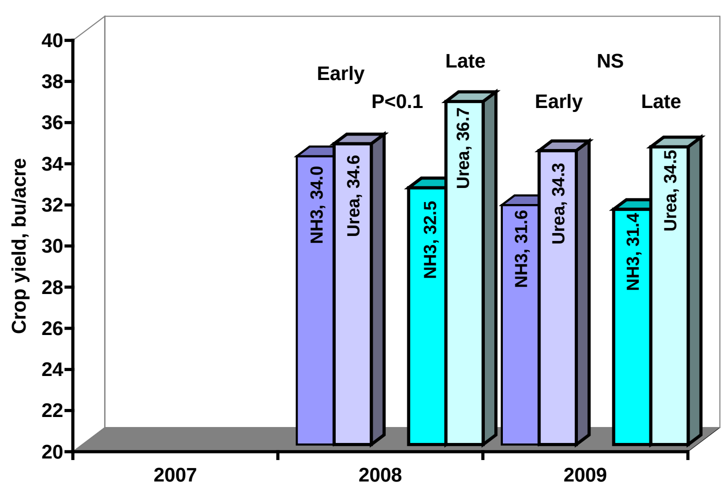

Figure 7. Comparison of overall yields resulting from early vs. late fall application of N at the Watrous site.

Protein

Grain protein of both spring wheat in 2008 and canola in 2009 was significantly affected by the rate of fertilizer N (Figure 8).

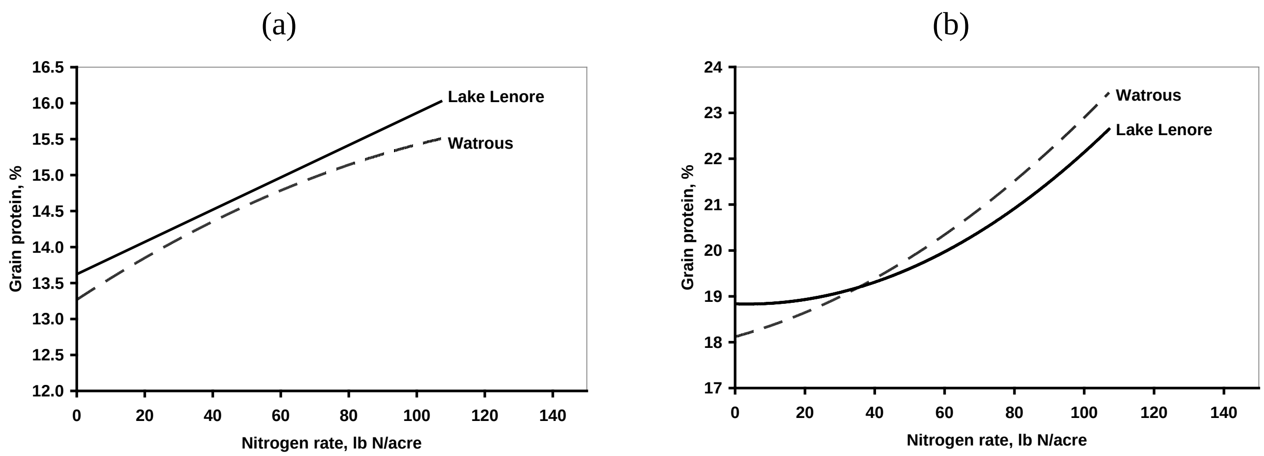

Figure 8. Effect of rate of N application of grain protein of (a) wheat in 2008 and (b) canola in 2009.

Oil

Oil content of canola seeds was significantly ($P<0.01$) affected by N application rates (Figure 9).

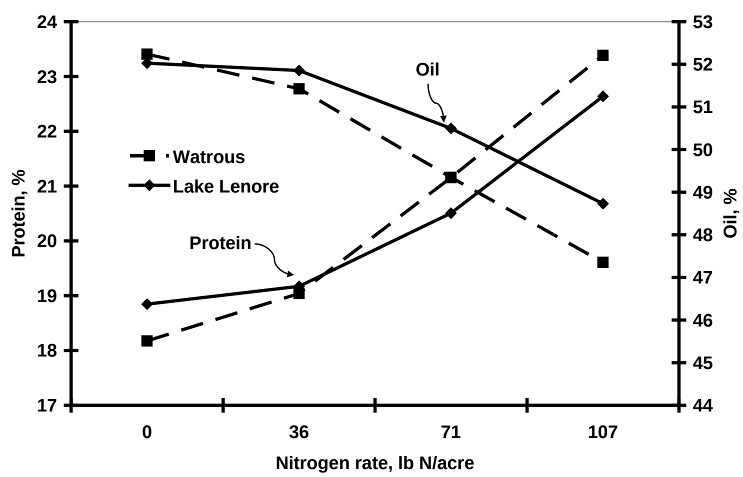

Figure 9. There was an inverse relationship between % oil and % protein content of canola seeds in 2009.

Nitrification Inhibitor

There were no significant effects of N-serve on the grain yield of barley, wheat or canola, or either the protein content of wheat or canola or oil content of canola grain.

Conclusion

Early fall application of Anhydrous Ammonia or Urea on well drained soils resulted in same grain yields of barley-wheat-canola to those with either late fall or spring application of these products. A nitrification inhibitor had no effect on the behaviour of these products at any application time

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