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FEASIBILITY of a ONE-PASS SEEDING and FERTILIZING SYSTEM for WINTER WHEAT

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EXECUTIVE SUMMARY

EXPERIMENT #1 NITROGEN AND PHOSPHORUS STUDY

The objective was to determine the feasibility of a one-pass seeding and fertilizing system for winter wheat by comparing the performance of urea side-banded at seeding time versus the standard recommendations of broadcasting ammonium nitrate early in the spring combeined with different rates of side-banded P on grain yield and grain protein concentration.

1995

Ammonium nitrate produced more grain than urea at the two Indian Head locations while no difference was observed at the Brandon location. Higher levels of grain protein were obtained with ammonium nitrate than urea at all locations. Varying the levels of P applied at seeding did not improve the results with urea. In fact, the responses to P were better with ammonium nitrate than urea. Yield improvements with P were observed at all sites. Based on the results, the benefits of using urea side-banded at seeding time were inferior to ammonium nitrate for grain protein at all sites and for grain yield at two of the three sites.

1996

Increasing the rate of nitrogen did not have a large effect on grain yield, even though the nitrate levels were not high indicating substantial release from the soil during the growing season. There was no response to phosphorus fertilizer at either of the locations. In terms of fertilizer form, an effect was observed on the Oxbow loam site but not the heavy clay soil site where yield and grian protein concetnration were greater when ammonium nitrate was used instead of urea. There was no effect due to fertilizer form on the heavy clay soil for grain yield and grain protein. It should be noted that the latter site was seeded on September 25 vs September 1 for the Oxbow loam site.

Conclusion

In the two years of research, ammonium nitrate broadcast in the spring gave better yields than side-banded urea at seeding time on three of the five station years. It appears also that the differences due to fertilizer form may be due to seeding date. Ammonium nitrate performed better on the earlier seeding dates. Urea never performed better than ammonium nitrate. It would appear that the feasibility of putting all the nitrogen down in a side-band placement may not be the best way to proceed. However, there may be some potential in doing a split application to take some pressure off in the spring. The difference in price between the two forms warrant higher rates of urea however, from an environmental perspective, this may not be acceptable.

EXPERIMENT #2 NITROGEN FORM, NITROGEN RATE, SULFUR AND FOLIAR APPLIED N STUDIES.

Part A: Nitrogen Form and Nitrogen Rate Studies

Three forms of nitrogen, urea, anhydrous ammonia (NH_3) and ammonium nitrate (AN) and three rates of nitrogen (50, 75 and 100 lbs/acre) were investigated. Urea and NH_3 were side-banded at seeding time and AN was broadcast early in the spring.

1995

Plant densities were not adversely affected by side-banding the fertilizer at seeding time on the heavy clay soil but was reduced relative to ammonium nitrate on the Oxbow loam soil. Grain yield followed the order: AN>urea>NH_3 on the heavy clay soil but no difference on the Oxbow loam soil. In experiment 1, urea produced less grain than AN on the Oxbow loam. The lack of an effect due to fertilizer form in this experiment is probably due to the high soil nitrogen levels. Grain protein was highest for AN than urea or NH_3 on both soil types. As in experiment #1, improvements in yield were not obtained by side-banding urea or NH_3 at seeding time relative to AN. Grain protein concentration was highest with AN.

1996

At the Indian Head location, grain yields were lower with ammonium nitrate than urea or anhydrous ammonia while no differences were observed on the Oxbow loam site. The heavy clay site gave lower grain protein levels with anhydrous ammonia while the Oxbow loam site gave lower grain protein levels with urea.

Conclusion

As with the previous study, the feasibility of applying all the nitrogen requirements for the crop during the seeding operation using urea or anhydrous ammonia may not necessarily be the best method for managing nitrogen. As with the conclusion for the previous study, other factors have to be taken into consideration such as price differential for each fertilizer form and ability to apply the nitrogen fertilizer in the spring when required by the crop.

Part B: Foliar applied N Study.

1995

Liquid nitrogen, using a foliar application, was sprayed at two different times, just prior to heading and after anthesis to determine if grain protein concentration could be increased. On the heavy clay soil, the foliar application of nitrogen resulted in an increase of between 1 and 1.2% in grain protein concentration with no differences between the two times of application. No effects on grain yield were observed. On the Oxbow loam, the effects of foliar applied N had no effect on grain protein concentration although an improvement in yield was observed with the application just prior to heading. The lack of a response to foliar applied nitrogen at this site is probably due to the high soil residual N levels masking the effects. Based on the results observed in 1995, it would appear that there are some merits in applying liquid nitrogen to increase grain protein concentration.

1996

Late season applications of nitrogen resulted in a significant grain yield and grain protein increase on the Oxbow loam site and a significant yield increase but not effect on grain protein for the heavy clay soil site.

Conclusion

The positive results obtained with late season foliar applications of nitrogen for increasing grain protein warrants more detailed investigations to refine the technique and in the process, try to reduce the risk associated with it.

Part C: Sulfur study

1995

Sulfur was applied to the plots to try and address a potential deficiency with this nutrient based on visual observations and results from tissue analysis. Sulfur had no positive effects on grain yield but grain protein concentration was increased by 0.6% on the heavy clay soil. On the heavy clay soil, the response of grain protein to sulfur was greatest at the 75 and 100 lbs/acre nitrogen rates and for ammonium nitrate. The lack of response on the Oxbow loam site may be due to the high soil residual N levels. We also noted that the tissue sulfur levels were lowest with urea and NH_3. It is postulated that applying all the nitrogen at seeding time may have actually reduced the deficiency. This may indicate the need to apply some sulfur at seeding time or else broadcast it in the spring at the same time as the nitrogen application.

1996

The addition of sulfur resulted in a significant grain yield and grain protein increase on the heavy clay soil but a decrease in yield on the Oxbow loam site and no effect on grain protein. There is no explanation as to why a yield decrease with the addition of sulfur on the Oxbow loam site.

Conclusion

In both years, on the heavy clay soil, the addition of sulfur resulted in a significant increase in grain protein. An increase in yield was observed in one of the two years. This supports the concept of the importance of sulfur to help convert nitrogen into grain protein.

CONCLUSIONS

The major reason for this study was to determine if it is possible to apply all the nitrogen requirements of the winter wheat crop at seeding time. This is to ensure that the crop doesn't lack nitrogen in the event that the spring broadcast application is delayed due to inclement weather or wet soil conditions. The results obtained in 1995 and 1996 were not very positive towards this new approach. However, some interesting observations were made. At the two sites where a negative response was observed, this was combined with very dry fall conditions while the other site, which received adequate fall precipitation, there was no difference. We also observed that differences due to fertilizer form were more noticeable at the earlier than later seeding dates. Since it is highly recommended that winter wheat be seeded early, this may mean applying the fertilizer at seeding time even more risky or questionable. We also observed some tissue deficiency for sulfur with urea and NH_3 but not to the same extent with ammonium nitrate in 1995. It is possible that a sulfur deficiency was induced because of all the nitrogen being put down at seeding time combined with the very dry fall conditions. The study was repeated in 1996 with very good moisture conditions experienced in the fall of 1995.

Introduction

There is a resurgence of interest in the winter wheat crop on the eastern side of Saskatchewan because of:

(1) the delayed harvest conditions experienced with spring crops due to cooler and wetter spring conditions in the past few years

(2) the problem with the wheat midge which caught many producers by surprise, especially during 1994 and 1995

(3) the problems associated with tombstone is causing producers to look at other cereal crops to try and avoid the problem in southern Manitoba

(4) the large adoption rate of direct seeding means that many producers have the necessary seeding equipment to manage winter wheat well.

Given all of the above reasons, it is interesting to note that winter wheat can address in whole or in part many of these problems. The brisk sales of winter wheat during the past fall is a strong indication that this crop will be making a come back in many parts of western Canada in the next few years. Ducks Unlimited's goal is to get winter wheat acreage up to 500,000 acres in Saskatchewan in five years.

The most commonly asked question regarding winter wheat in the summer of 1994 was whether or not all of the nitrogen fertilizer could be side-banded during the seeding operation. The current recommendations for N-fertilizer management is to broadcast ammonium nitrate fertilizer in early spring. Ammonium nitrate is the most expensive form of N-fertilizer and fertilizer N had to be applied very early in the spring in order to maximize yields. However, this is not always practical and possible.

Previous work under controlled environment conditions has shown that high rates of N interfered with the cold-hardiness process (Tyler et al., 1981). However, because of the use of nutrient solution culture, it is difficult to determine at what levels of nitrogen the cold-hardiness process is interfered with and how it relates to a field situation. On the other hand, high levels of P tend to increase winter survival, dry matter production, root growth and recovery from low temperature injury (Tyler et al., 1981; Fowler and Gusta, 1982; Chen et al, 1983). Their study did not determine if the effects of high rates of N could be offset by using higher rates of P. More recently, unpublished work by Gusta (University of Saskatchewan) has shown that high rates of N under field conditions doesn't necessarily affect the cold acclimation process as such but can cause a more rapid de-hardening of the plants during the January to February time period making it more vulnerable to winter kill at high rates of N. There is a definite need to determine the levels of N that can safely be side-banded during the seeding operation without adversely affecting the winter survival and whether or not the effect of high nitrogen levels can be altered with phosphorus fertilizer.

OBJECTIVES

The overall objective is to evaluate the feasibility of using a one-pass system (seeding and fertilizing) for winter wheat on three different soils over a two year time frame.

(1) To evaluate the potential of increasing phosphorus fertilizer at seeding time with urea fertilizer to offset the negative effects that high rate of N fertilizer can have on winter survival by comparing it to the standard practice of broadcasting ammonium nitrate early in the spring

(2) To examine the feasibility of side-banding urea or anhydrous ammonia at seeding time compared to broadcasting ammonium nitrate early in the spring.

MATERIALS AND METHODS

Experiment #1: To examine if changes in rates of fertilizer P can offset the negative effects of high rates of urea N when side-banded at seeding time versus the standard practice of broadcasting ammonium nitrate in the spring.

Treatments:

Fertilizer Form: Urea and ammonium nitrate

Nitrogen Fertilizer Rates: 0. 50. 75. 100 lbs N/ac.

Phosphorus Fertilizer Rates using 12-51-0: 0, 20 and 40 lbs of P_2O_5/acre at seeding time

Timing of Nitrogen Application: Urea side-banded during the seeding operation vs ammonium nitrate broadcast early in the spring

Field Design: Factorial randomized complete block design with 4 replicates

Plot Size: 15' x 50'

Soil Types (2): Oxbow loam (Indian Head), Indian Head Heavy Clay Soil (Indian Head)

Variables Measured: Plant Counts (Fall and Spring), Yield Components (Spike numbers, kernels per spike, 1000 seed weight), Straw N and Grain N at maturity, and Grain Yield.

Refer to Table 1 for details on other agronomic information.

Table 1. Agronomic information pertinent to Experiment 1 in 1996.

Location	Seeding Date	Harvest Date	N levels 0-24" kg/ha	P levels 0-6" kg/ha	Plant Counts Date	Dry matter sampling dates	Spring N Broadcast
Indian Head	Sept. 25/95	Aug. 15/96	24.7	68.9	--	Aug. 13/96	May 6/96 (Rep 1) May 1/96 (Reps 2,3,& 4)
Vale Farms	Sept. 1/95	Aug. 14/95	23.4	47.7	Sept. 29/95	Aug. 14/96	May 1/96

[1] The soil analysis was done but the results were not available at the time of printing the report.

Experiment #2:

Part a. To compare the use of urea and anhydrous ammonia at seeding time with the standard early spring broadcast of ammonium nitrate.

Treatments:

Fertilizer Form: Urea, anhydrous ammonia and ammonium nitrate.

Nitrogen Fertilizer Rates: 0, 50, 75, 100 lbs N/ac.

Phosphorus Fertilizer Rates using 12-51-0: 40 lbs of P_2O_5/acre at seeding time.

Timing of Nitrogen Application: Urea and anhydrous ammonia side-banded during the seeding operation vs ammonium nitrate broadcast early in the spring.

Field Design: Factorial randomized complete block design with 3 replicates.

Plot size: 15' x 60'

Soil Types (2): Oxbow loam and Indian Head heavy clay soil at Indian Head.

Variables Measured: Plant counts in the fall, yield components (spike numbers, kernels per spike, 1000 seed weight), straw N and grain N at maturity, grain and straw yield.

Refer to Table 2 for details for other agronomic information.

Table 2. Agronomic information pertinent to experiment 2 in 1996.

Variables	Indian Head	Vale
Seeding date	Sept 26/95	Sept. 22/95
Harvest date	Aug. 15/96	Aug. 14/96
Sulfur application	May 6/96	May 1/96
Dry matter sampling data	Aug. 13/96	Aug. 14/96
Foliar N application		
GS 45	June 25/96	June 21/96
GS 69	July 12/96	July 12/96
Soil N levels (0-24")	44.1 kg/ha	76.7 kg/ha
Soil P levels (0-6")	17.6 kg/ha	72.9 kg/ha
Broadcast N date	May 6/96	May 1/96

Part b. To determine the effects of foliar applied N just prior to heading and after anthesis on grain yield and grain protein.

Treatments:

Fertilizer Form: Urea, anhydrous ammonia and ammonium nitrate.

Nitrogen Fertilizer Rates: 0, 50, 75, 100 lbs N/ac.

Phosphorus Fertilizer Rates using 12-51-0: 40 lbs of P_2O_5/acre at seeding time.

Timing of Nitrogen Application: Urea and anhydrous ammonia side-banded during the seeding operation vs ammonium nitrate broadcast early in the spring.

Timing of foliar applied nitrogen and rate: Just prior to heading and after anthesis at a rate of 15 lbs N/acre using a liquid urea/ammonium nitrate solution (28-00-00). A total solution of 10 gallons per acre was applied (4.2 of liquid N and 5.8 of water). The solution was applied using a conventional sprayer.

Field Design: Factorial randomized complete block design with 3 replicates.

Plot size: 15' x 30'

Soil Types (2): Oxbow loam and Indian Head heavy clay soil at Indian Head.

Variables Measured: Grain yield and grain protein.

Refer to Table 2 for details for other agronomic information.

Part c. To determine the effects of applying sulfur on grain protein and grain yield.

Treatments:

Fertilizer Form: Urea, anhydrous ammonia and ammonium nitrate.

Nitrogen Fertilizer Rates: 0, 50, 75, 100 lbs N/ac.

Phosphorus Fertilizer Rates using 12-51-0: 40 lbs of P_2O_5/acre at seeding time.

Timing of Nitrogen Application: Urea and anhydrous ammonia side-banded during the seeding operation vs ammonium nitrate broadcast early in the spring.

Sulfur application and rate: A total of 16 lbs S/acre in the form of ammonium sulfate was broadcast (21-00-00-16) and an equivalent amount of N in the form of ammonium nitrate (20 lbs N/acre) was added to the check plots to balance the nitrogen present with the sulfur.

Field Design: Factorial randomized complete block design with 3 replicates.

Plot size: 15' x 25'

Soil Types (2): Oxbow loam and Indian Head heavy clay soil at Indian Head.

Variables Measured: Grain yield and grain protein.

Refer to Table 2 for details for other agronomic information.

RESULTS

Experiment #1: Nitrogen x Phosphorus Study

Indian Head (Heavy clay soil)

Fertilizer form and fertilizer P had no effect on the variables measured. Fertilizer N had a significant effect on straw N, straw P and grain P. Increasing the rate of nitrogen increased those values. There was a significant N x P interaction for grain protein as indicated in Table 7. At the high rate of N, P had no effect on protein while at the other N rates, P tended to decrease the protein levels somewhat.

Table 3. The effects of nitrogen form and rate on plant density, yield components and grain yield at Indian Head in 1996.

N Rate lbs/ac	Heads m^{-2}		Kernels $spike^{-1}$		1000 seed weight (g)		Grain Yield kg ha^{-1}	
	UR	AN	UR	AN	UR	AN	UR	AN
0	542		14.0		36.8		2792	
50	678	653	19.7	20.5	31.4	31.3	4095	4109
75	701	693	19.6	20.0	30.3	31.2	4086	4246
100	675	744	21.0	19.8	30.0	30.3	4220	4200
Mean	685	696	20.1	19.8	30.6	30.9	4134	4185
s.e.	22.6		0.8		0.7		129.4	
cv	11.4		13.8		7.9		10.8	

Table 4. The effects of nitrogen form and P rate on plant density, yield components and grain yield at Indian Head in 1996.

P_2O_5 Rate lbs/ac	Heads m^{-2}		Kernels $spike^{-1}$		1000 seed weight (g)		Grain Yield kg ha^{-1}	
	UR	AN	UR	AN	UR	AN	UR	AN
0	663	680	20.5	19.8	31.3	31.6	4201	4202
20	687	703	20.5	19.0	30.0	31.3	4169	4113
40	705	707	19.2	20.5	30.5	29.9	4027	4239
Mean	685	696	20.1	19.8	30.6	30.9	4131	4185
s.e.	16.0		0.6		0.5		91.5	
cv	11.4		13.8		7.9		10.8	

Table 5. The effects of nitrogen form and rate on N and P uptake in straw and grain at Indian Head in 1996.

N Rate lbs/ac	Straw N kg/ha		Straw P kg/ha		Grain N kg/ha		Grain P kg/ha		Grain Protein %	
	UR	AN	UR	AN	UR	AN	UR	AN	UR	AN
0	21.7		4.4		44.4		9.8		8.9	
50	29.8	37.9	3.5	3.8	70.1	68.1	14.0	12.9	9.7	9.2
75	46.5	46.8	5.2	4.4	76.8	80.1	13.9	14.1	11.3	11.4
100	42.8	52.2	3.2	4.3	83.3	83.4	13.1	14.1	11.3	11.4
Mean	39.6	45.6	4.0	4.2	76.5	77.2	13.7	13.6	10.6	10.5
s.e.	5.1		0.5		0.5		3.9		0.6	
cv	24.7		32.6		45.9		17.8		15.7	

Table 6. The effects of nitrogen form and P rate on N and P uptake in straw and grain at Indian Head in 1996.

P_2O_5 Rate lbs/ac	Straw N kg/ha		Straw P kg/ha		Grain N kg/ha		Grain P kg/ha		Grain Protein %	
	UR	AN	UR	AN	UR	AN	UR	AN	UR	AN
0	40.3	45.3	3.6	3.7	78.3	80.2	13.5	13.4	10.6	10.9
20	41.1	49.9	4.2	4.6	78.9	77.2	14.1	13.7	10.8	10.8
40	37.5	41.7	4.3	4.2	72.6	74.3	13.6	13.7	10.3	9.8
Mean	39.6	45.6	4.0	4.2	76.5	77.2	13.7	13.6	10.6	10.5
s.e.	3.6		0.3		0.4		2.3		0.4	
cv	24.7		32.6		45.9		17.8		15.7	

Table 7. The effects of nitrogen fertilizer (lbs/acre) phosphorus (lbs P_2O_5/acre) on grain yield and grain protein concentration at Indian Head in 1996.

N Rate	Grain Yield (kg/ha)			Grain protein (%)		
	0	20	40	0	20	40
0	2792	--	--	8.9	--	--
50	4263	4217	3825	9.7	10.3	8.5
75	4232	4095	4169	11.2	10.9	10.3
100	4110	4102	4404	11.4	11.3	11.3
Mean	4201	4140	4132	8.9	10.8	10.0

Oxbow loam (Vale Farms)

Rate of nitrogen and phosphorus had no significant effect on the variables measured. Fertilizer form had a significant effect on some variables. Urea fertilizer resulted in slightly more heads being produced and higher seed weight, but gave lower kernels per spike and lower grain yields. Grain P content was higher with ammonium nitrate than urea. There was a significant fertilizer form x nitrogen rate interaction for seed weight (Table 8).

Table 8. The effects of nitrogen form and rate on plant density, yield components and grain yield at Vale Farms in 1996.

N Rate lbs/ac	Plants m^{-2}		Heads m^{-2}		Kernels $spike^{-1}$		1000 seed weight (g)		Grain Yield kg ha^{-1}	
	UR	AN	UR	AN	UR	AN	UR	AN	UR	AN
0	294		620		16.9		37.0		3734	
50	317	307	645	633	18.9	20.6	35.3	34.9	4319	4529
75	340	347	651	612	17.8	21.4	34.4	34.4	3966	4480
100	315	318	664	618	18.1	21.9	35.5	32.8	4251	4379
Mean	324	324	654	621	18.3	21.3	35.1	34.0	4179	4463
s.e.	24.7		18.5		0.8		0.5		147	
cv	26.4		10.0		13.4		4.9		11.8	

Table 9. The effects of nitrogen form and P rate on plant density, yield components and grain yield at Vale Farms in 1996.

P_2O_5 Rate lbs/ac	Plants m^{-2}		Heads m^{-2}		Kernels $spike^{-1}$		1000 seed weight (g)		Grain Yield kg ha^{-1}	
	UR	AN	UR	AN	UR	AN	UR	AN	UR	AN
0	339	292	658	601	18.6	22.3	35.3	33.6	4301	4471
20	324	303	678	617	18.5	21.4	34.0	34.1	4260	4483
40	310	377	627	645	17.7	20.2	35.8	34.4	3975	4433
Mean	324	324	654	621	18.3	21.3	35.1	34.0	4179	4463
s.e.	17.5		13.1		0.5		0.4		104	
cv	26.4		10.0		13.4		4.9		11.8	

Table 10. The effects of nitrogen form and rate on N and P uptake in straw and grain at Vale Farms in 1996.

N Rate lbs/ac	Straw N kg/ha		Straw P kg/ha		Grain N kg/ha		Grain P kg/ha		Grain Protein %	
	UR	AN	UR	AN	UR	AN	UR	AN	UR	AN
0	14.1		3.0		76.2		13.8		11.6	
50	25.8	30.0	3.1	3.1	86.6	95.6	14.7	15.4	11.4	12.1
75	26.2	28.6	3.1	2.6	83.9	99.6	14.2	15.3	12.0	12.7
100	29.1	35.9	2.9	3.0	88.7	104.6	14.7	14.8	11.9	13.6
Mean	27.0	31.5	3.0	2.9	86.4	99.9	14.6	15.2	11.8	12.8
s.e.	5.4		0.3		0.3		3.0		0.4	
cv	34.8		38.8		40.0		11.3		9.4	

Table 11. The effects of nitrogen form and P rate on N and P uptake in straw and grain at Vale Farms in 1996.

P_2O_5 Rate lbs/ac	Straw N kg/ha		Straw P kg/ha		Grain N kg/ha		Grain P kg/ha		Grain Protein %	
	UR	AN	UR	AN	UR	AN	UR	AN	UR	AN
0	26.8	31.6	3.0	2.7	90	103	14.7	15.0	11.9	13.1
20	27.8	29.6	3.0	2.7	88	100	14.7	15.0	11.8	12.7
40	26.5	33.3	3.0	3.4	81	98	14.3	15.5	11.7	12.6
Mean	27.0	31.5	3.0	2.9	86.4	99.9	14.6	15.2	11.8	12.8
s.e.	3.9		0.2		0.2		2.1		0.3	
cv	34.8		38.8		40.0		11.3		9.4	

Experiment #2: Part a. To compare the use of urea and anhydrous ammonia at seeding time with an early spring broadcast of ammonium nitrate.

Indian Head (Heavy clay soil)

Fertilizer form had a significant effect on grain yield (Table 12), grain nitrogen content and grain protein (Table 13). Grain yield and grain N content were greater for urea dn anhydrous ammonia than ammonium nitrate. With grain protein, urea and ammonium nitrate produced higher yields.

Table 12. The effects of fertilizer form and rate of nitrogen on plant density, yield and yield components on a heavy clay soil in 1996.

N Rate lbs/ac	Heads m^{-2}			Kernels $spike^{-1}$			1000 seed weight (g)			Grain Yield kg ha^{-1}		
	UR	NH_3	AN	UR	NH_3	AN	UR	NH_3	AN	UR	NH_3	AN
Check	578			16.8			34.0			3264		
50	728	493	637	16.6	25.9	17.1	31.0	32.5	32.5	3647	4162	3502
75	733	511	650	19.4	25.6	18.9	31.0	29	31.5	4371	3800	3752
100	635	708	628	20.7	16.2	16.3	31.0	32.7	30.5	4066	3740	2977
Mean	699	604	638	18.9	21.0	17.4	31.0	32.0	31.5	4028	3891	3410
s.e.	58.1			2.3			0.7			211		
cv	15.5			20.9			4.0			9.7		
Contrast AN vs UR+NH_3	ns			ns			ns			*		
Urea vs NH_3	ns			ns			ns			ns		

Table 13. The effects of fertilizer form and rate of nitrogen on grain protein, nitrogen uptake in straw and grain on a heavy clay soil in 1996.

N Rate lbs/ac	Straw N kg/ha			Grain N kg/ha			Grain Protein (%)		
	UR	NH_3	AN	UR	NH_3	AN	UR	NH_3	AN
Check	213			55.4			9.7		
50	36.6	24.4	41.7	74.8	82.1	71.7	11.7	11.3	11.7
75	32.5	40.6	29.4	93.3	80.2	80.7	12.2	12.0	12.3
100	30.4	31.6	69.4	86.1	73.6	65.1	12.1	11.2	12.4
Mean	33.2	30.7	46.8	84.8	77.5	72.5	12.0	11.4	12.1
s.e.	12.2			4.8			0.2		
cv	57.1			10.6			3.3		
Contrast AN vs UR+NH_3	ns			*			ns		
Urea vs NH_3	ns			ns			*		

Indian Head (Oxbow loam)

Fertilizer form had a significant effect on seed weight (Table 14) and grain protein concentration (Table 15) but no effect on grain yield. All other variables measured were not influenced by fertilizer form.

Table 14. The effects of fertilizer form and rate of nitrogen on plant density, yield and yield component on an Oxbow loam soil in 1996.

N Rate lbs/ac	Heads m^{-2}			Kernels $spike^{-1}$			1000 seed weight (g)			Grain Yield kg ha^{-1}		
	UR	NH_3	AN	UR	NH_3	AN	UR	NH_3	AN	UR	NH_3	AN
Check	564			22.1			33.3			4137		
50	551	585	481	21.5	23.0	22.6	32.7	31.3	34.3	3876	4129	3736
75	601	578	544	21.7	22.6	23.2	31.3	30.0	32.7	4030	3896	4106
100	523	587	594	24.2	23.2	20.9	31.3	31.7	31.3	3946	4308	3870
Mean	558	583	539	22.5	22.9	22.2	31.8	31.0	32.8	3951	4111	3904
s.e.	29.8			1.2			0.8			178		
cv	9.2			2.0			4.6			7.8		
Contrast AN vs UR+NH_3	ns			ns			*			ns		
Urea vs NH_3	ns			ns			ns			ns		

Table 15. The effects of fertilizer form and rate of nitrogen on grain protein, nitrogen and phosphorus uptake in straw and grain on an Oxbow loam soil in 1996.

N Rate lbs/ac	Straw N kg/ha			Grain N kg/ha			Grain Protein (%)		
	UR	NH_3	AN	UR	NH_3	AN	UR	NH_3	AN
Check	4.9			86.7			12.0		
50	31.1	32.1	31.3	76.4	92.8	75.6	11.2	12.8	11.5
75	40.4	48.1	30.0	87.3	90.4	92.4	12.4	13.2	12.8
100	31.5	41.6	37.2	89.1	94.0	93.1	12.9	12.4	13.7
Mean	34.3	40.6	32.8	84.3	92.4	87.0	12.1	12.8	12.7
s.e.	7.7			4.9			0.4		
cv	37.0			9.6			26.4		
Contrast AN vs UR+NH_3	ns			ns			ns		
Urea vs NH_3	ns			ns			*		

Part b. To determine the effects of foliar applied N just prior to heading and after anthesis on grain yield and grain protein.

Late season applications of nitrogen were studied to determine the feasibility for boosting grain protein. The tests were conducted on a heavy clay soil and an Oxbow loam soil. The results at Indian Head showed a significant yield increase with the later application of foliar nitrogen but no difference in grain protein, probably due to the dilution effect with the extra yield (Table 16). On the Oxbow loam site, the extra nitrogen applications resulted in a significant yield increase and an increase in grain protein on the order of 0.4% (Table 17).

Table 16. The effects of foliar applied N on grain yield and grain protein content applied at two different growth stages at Indian Head in 1996 on a heavy clay soil.

N Rate	Grain Yield (kg/ha)				Grain protein (%)			
	Check	45	69	Mean	Check	45	69	Mean
0	3265	2680	3147	2956	9.6	9.1	9.8	9.5
50	3770	3690	4349	3911	11.5	9.1	11.4	10.7
75	4009	3624	4334	3933	12.2	10.5	12.1	11.6
100	3614	4069	4197	3967	11.6	10.6	11.7	11.3
Mean	3776	3788	4289	3951	11.7	10.3	11.7	11.2
s.e.	345				0.4			
cv	15.2				9.5			
Contrasts None vs foliar	ns				*			
GS45 vs GS69	**				**			

Table 17. The effects of foliar applied N on grain yield and grain protein content applied at two different growth stages at Indian Head in 1996 on an Oxbow loam soil.

N Rate	Grain Yield (kg/ha)				Grain protein (%)			
	Check	45	69	Mean	Check	45	69	Mean
0	4137	4269	4220	4209	12.0	11.7	12.0	11.9
50	3914	4078	4570	4187	11.8	12.2	12.3	12.1
75	4010	4151	4607	4256	12.8	12.8	13.2	12.9
100	4041	4194	4542	4259	13.0	12.7	13.4	13.0
Mean	3988	4141	4574		12.5	12.6	12.9	
s.e.	125				0.2			
cv	8.9				5.2			
Contrasts None vs foliar	**				ns			
GS45 vs GS69	**				*			

Part c. To determine the effects of applying sulfur on grain protein and grain yield on two soil types at Indian Head in 1996.

The effects of sulfur were investigated on winter wheat at two locations. The addition of sulfur resulted in a significant increase in grain yield and grain protein on the heavy clay soil but a reduction in yield on the order of 7% and no effect on grain protein on the Oxbow loam soil (Table 18). The effects of fertilizer form and rate, as a function of sulfur on grain protein are given in Table 19. Fertilizer form had no effect on grain yield (Table 20).

Table 18. The effects of sulfur on grain yield and grain protein on two soil types at Indian Head in 1996.

Soil Type	Grain Yield (kg/ha)			Grain Protein (%)		
	-sulfur	+sulfur	p level	-sulfur	+sulfur	p level
Heavy clay	3629	4267	**	10.5	11.2	0.018
Oxbow loam	4195	3900	**	12.5	12.2	ns

Table 19. The interaction of fertilizer form by sulfur and nitrogen rate by sulfur at Indian Head in 1996 on grain protein (%).

Fertilizer Form	Indian Head Heavy Clay		Oxbow Loam	
	-S	+S	-S	+S
Urea	10.8	11.3	12.4	12.1
NH_3	10.3	11.2	12.7	12.5
Ammonium Nitrate	11.1	11.6	12.6	12.4
Nitrogen Rate (lbs/ac)	-S	+S	-S	+S
50	10.5	10.9	12.1	11.8
75	10.6	11.3	12.7	12.3
100	11.2	11.8	12.8	12.9

Table 20. The effects of nitrogen form on grain yield for two soil types at Indian Head in 1996.

Soil Type	Grain Yield[1] (kg/ha)			Contrasts	
	Urea	NH_3	Ammonium Nitrate	Urea vs NH_3	Ammonium nitrate vs urea and NH_3
Heavy clay	4095	3982	4070	ns	ns
Oxbow loam	4013	4036	4096	ns	ns

[1] Check yields on the heavy clay and Oxbow loam were 3008 and 4038 kg/ha, respectively.

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