Response of Annual Crops to Different Sources, Times, and Methods of Applying Nitrogen Fertilizer

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INTRODUCTION

In recent years, numerous research projects have been conducted by various agencies in Western Canada evaluating crop responses to different rates, carriers, methods, and times of applying fertilizer nitrogen. Results of these experiments have been reasonably conclusive to the fact that yields of most stubble seeded crops, in general, and to a certain extent fallow seeded crops are often limited by the amounts of available nitrogen present in the soil. Hence good responses to applied fertilizer nitrogen are attainable. Few definite statements can be made, however, regarding the relative efficiency of different nitrogen carriers and methods, and times of nitrogen application, since experimental results relating to these factors have been, in many cases, inconsistent and often contradictory. Such observations tend to indicate that the relative efficiencies of different fertilizer applications are determined not only by specific soil properties, but also by the type of crop and by environmental conditions present during a given growing season. For example, conclusions drawn in a review (completed in 1973) of available research data comparing the responses of annual crops to urea and ammonium nitrate stated that over a number of years and over a number of different soil types, average yields were similar from both carriers when broadcast or when broadcast and incorporated (2). Included in these averages, however, were results from certain trials in which fairly large differences between the carriers were apparent. Similarly, with regard to the question of nitrogen placement, while it is often thought that side banding is a more effective application technique than broadcasting, and that seed placement is effective only at low rates, results from some trials in some years are not in agreement with these thoughts (3, 5).

At present, relatively little data is available from the Canadian prairies comparing spring and fall nitrogen application. Results from a number of trials conducted in Manitoba between 1967 and 1974 indicate that fall application is, at best, equal to spring application for cereal crops (4). Differences have been noted that can be related to geographic features in that fall applications on the average have been less effective than corresponding spring applications in the Manitoba lowlands, while on the Manitoba uplands, average responses from spring and fall applications have been similar. Results from Alberta in 1974 indicated that, in three out of four trials, yields were consistently larger from spring-applied nitrogen than from fall-applied nitrogen, and in the fourth trial, differences between application times were small (1). Differences between fall and spring applications varied considerably with different nitrogen sources.

In the fall of 1973, a research program was initiated to determine, under Saskatchewan conditions, whether:

a) differences do exist between i) organic urea nitrogen and inorganic ammonium and nitrate-nitrogen; ii) broadcast, side-banded and seed placed nitrogen fertilizers, and iii) fall and spring fertilizer applications;

b) if differences do exist, whether these differences could be related to specific soil and climatic conditions such that reasonable recommendations could be made as to soils and areas in Saskatchewan where certain nitrogen fertilization practices should be followed.

This report presents results obtained from field experiments conducted during the initial year of the project, 1973-74.

EXPERIMENTAL METHODS

In the fall of 1973, six sites were selected for the establishment of field trials. Two sites were on Dark Brown soils (Elstow and Weyburn), three sites were on Black soils (Hoey, Naicam, Yorkton), and one site was on a Grey Wooded soil (Waitville). The Weyburn, Yorkton and Waitville sites represent three soils of glacial till origin, occurring in different soil zones. The Elstow, Hoey and Naicam soil sites represent, respectively, silty lacustrine, modified silty clay lacustrine, and resorted glacial till parent materials. Results of analyses of soil samples taken at the time of plot establishment (fall, 1973) are presents in Table 1. Nitrate-nitrogen contents of the soils at all but one site were in the low and very low category. The Yorkton soil site, which had already grown four crops, contained considerable quantities of NO_3-N in the second foot, the presence of which was verified by sampling at spring seeding time. All but the grey-wooded soil were low in available P.

At each site, small plots of randomized complete block design were established containing fifteen treatments replicated six times. Treatments included (Table 2), aside from the check, two nitrogen carriers (urea and ammonium-nitrate) applied at 2 rates (50 and 100 lbs N/acre) in the fall and at 5 rates (25, 50, 75, 100 and 150 lbs N/acre) in the spring. One site, the Naicam soil site, was chosen to be the "central site", where beyond the 15 basic treatments, additional treatments involving sidebanding and seed placement of both carriers at the five spring application rates were included. Here, also, three separate plots were established adjacent to each other to allow for investigation into the relative responses of three different annual crops.

In the late fall of 1973, the nitrogen was applied to the fall treatments at all sites (Table 3). At all locations except the Hoey soil site, nitrogen was broadcast during snowfall or after one or more inches of snow covered the ground. Due to this fact, at none of the sites was the fertilizer incorporated until normal spring tillage operations were performed. At seeding time, all plots were worked, seeded, and broadcast nitrogen was applied after seeding. Bonanza barley was seeded at all sites with the additional two plots at the Naicam site being seeded to Neepawa wheat and Midas rapeseed. All crops except rapeseed received a blanket application of 40 lb P_2O_5/acre seed placed as mono-ammonium phosphate (11-55-0); rapeseed similarly received phosphate at a rate of 30 lb P_2O_5/acre. All sites were seeded abnormally late (Table 3) due to the extremely wet and cool spring conditions.

A pre-seeding application of triallate (Avadex-BW) for wild oat control was applied and incorporated on all barley plots, while the rapeseed plot received a pre-seeding application of Treflan. Wild oats were successfully controlled at all sites. As required, the barley plots received post-emergent spray applications in the form of Buctril-M, or MCPA and TCA. The wheat and rapeseed plots on the Naicam soil were respectively sprayed with Bactrel M, and TOK/RM mixed with TCA. Weed control at most plots was fairly good. Only slight problems were encountered with green foxtail, since this weed is hard to control in barley with the rate of TCA allowable.

Between seeding and harvest, most plots received reasonable amounts of rainfall (Table 3). The Hoey site, however, received a fairly large amount of total rainfall, while the Naicam site received a relatively small amount. As a result of extremely late seeding, crops on both the Yorkton and Waitville plots were affected by early frosts. The barley on the Waitville site, in particular, was far from mature when the killing frost arrived, and as a result, most heads had not completely filled.

Harvest samples were taken from all plots. These samples were air dried, weighed, threshed, cleaned and yields calculated. Grain and straw samples were retained from all treatments at all sites (replicates bulked) and ground for protein and nitrogen analysis.

Included in each of the plots at all locations was a small sub-plot in which ^{15}N enriched fertilizer materials were utilized to allow for detailed uptake and ballance measurements to be made. The sub-plot consisted of 24 eighteen-inch long, six-inch diameter cylinders driven into the ground. These cylinders represented six treatments replicated four times. Treatments included:

1) Urea-^{15}N fall applied
2) $^{15}NH_4NO_3$ fall applied
3) $NH_4{}^{15}NO_3$ fall applied
4) Urea ^{15}N spring applied
5) $^{15}NH_4NO_3$ spring applied
6) $NH_4{}^{15}NO_3$ spring applied

Each of the fertilizers were applied at the same time as nitrogen was applied on the large plots. The cylinders were "hand worked" and seeded in spring. At harvest, all above-ground plant material was taken from each cylinder, dried, weighed, threshed, ground and retained for total N and ^{15}N measurements. The cylinders were dug up (frozen until processed) and the soil was removed in six-inch increments, weighed, dried, and sub-sampled in preparation for total nitrogen and ^{15}N analyses. Results from these sub-plots are not presented in this preliminary report, as all the detailed analyses have yet to be completed. These results, however, should give a clear indication of the uptake by barley of the different forms of nitrogen and also aid in evaluating nitrogen losses from the different sources and different application times.

RESULTS

Yield results for the various plots are given in Tables 4, 5, 6 and 7. Results in Table 6 for the Grey Wooded Waitville soil site are given in terms of cwt/acre total dry matter yield, as well as bu/acre grain yield, since the crop yields were severely affected by frost and, hence, total weight is probably a better indication of response.

Good responses to applied nitrogen were obtained on the two Dark Brown soil sites where maximum barley yields of slightly greater than 50 bu/acre were obtained at both locations (Table 4). The relatively larger yield increases obtained on the Elstow site probably are due to the initial lower NO_3-N control of the soil (which may in part reflect its nitrogen supplying power with the organic matter content being very low), since rainfall at the two sites was similar. Of the three Black soils, the Hoey site far out-yielded either of the remaining two sites. Here, barley yields doubled from around 42 bu/acre to well over 80 bu/acre (Table 5) with added nitrogen, in spite of the fact that this soil was initially low in NO_3-N. Such yields are probably the result of the high growing season rainfall (13.9 in.) and favorable climate, as well as the high nitrogen supplying power of the soils indicated by the high organic matter content. The relatively poor response obtained on the Yorkton soil is probably due to the large amounts of nitrate present in the second foot of soil. However, the low overall total yield is not fully explainable. Rainfall was adequate during the growing season, however, fall frost may have reduced yields somewhat. The conductivity evident in the fall soil samples was not apparent until the 3 ft. depth in the spring samples. ←, This factor may have contributed to reduced yield potential. The low yields and restricted responses to applied nitrogen of all crops on the Naicam sight (Table 7) was undoubtedly due to the low rainfall obtained during the summer. Although grain yields on the Grey Wooded Waitville soil site were extremely low, due to frost damage, some response to applied nitrogen was evident. This response was quite apparent in the total yield data, and assuming that a grain, straw ratio would have been similar on this site to that obtained on the other sites, yields should have ranged from around 25 bu/acre in the check to well over 50 bu/acre at higher nitrogen application rates.

There is very little indication in the data obtained as to any large consistent yield differences due to the two different nitrogen carriers. On most plots, differences were generally low, variable, and statistically not significant. The only indication of any differences was on the Hoey site where, at all but one application rate, yields from ammonium nitrate were slightly (1.5 to 6.5 bu/acre) higher than those from urea.

Results with regard to differences arising from the two application times are quite small and variable. Data from the two Dark Brown soils clearly indicate that fall-applied ammonium nitrate is at least equal to spring-applied, while with urea there is a slight indication that fall-applied urea may have been slightly less effective when soil nitrate is low (Elstow soil) or low rates of nitrogen are applied. On the Hoey site, yields from fall-applied nitrogen were, in all cases, lower than those from the spring application (between three and eight bu/acre). Here nitrogen-supplying power was probably pushed to the limit, since climate was so favorable, and when sources were less available it was reflected in a lower yield. No differences were noted in the Yorkton soil. On the Naicam soil, in spite of the fact that both yields and response to nitrogen were low, fall-applied nitrogen produced barley yields that were lower than those from the spring application. For wheat, only at the higher rate did spring nitrogen outyield fall-applied nitrogen, while for rapeseed, spring-applied urea outyielded slightly fall-applied urea. Data from the Grey Wooded Waitville site indicate that a slightly more favorable response was obtained from spring broadcast nitrogen, particularly at the 100 lb N/acre rate.

Data from the three trials on the Naicam soil comparing different methods of applying nitrogen show no great yield differences between broadcast and sideband nitrogen. Seed-placed urea nitrogen definitely reduced crop yields at higher application rates, while seed-placed ammonium-nitrate only appeared to seriously reduce the yields of rapeseed. It is apparent that the relative crop tolerance to seed-placed nitrogen fell in the order - barley, wheat, and rapeseed.

CONCLUSIONS

Results from trials on six different soil types in 1974 showed no large differences between spring broadcast ammonium-nitrate and urea. Small differences in favor of ammonium-nitrate were apparent in data from a Deep Black Hoey soil, where growing season rainfall was high.

Differences, where they occurred, between spring and fall applied nitrogen were generally small. The largest difference, between 3 and 10 bu/acre of barley, were found in two Deep Black soils - a Hoey and a Naicam. Climatic conditions, in terms of rainfall, were quite different, with the Naicam site being dry through the growing season, while the Hoey site was quite wet.

Broadcast and sideband nitrogen applications produced similar yields of barley, wheat and rapeseed on one soil type, while seed placed, particularly in the urea form, reduced yields at varying nitrogen application rates.

Considerably more data regarding uptake and losses of specific forms of spring and fall applied nitrogen using ^{15}N techniques are pending, and these results should aid considerably in interpreting the overall relative efficiencies of recovery.

Since one year's data is insufficient to draw definite conclusions, ten plots have been established for seeding in 1975. Climatic conditions in the fall of 1974 were quite different from those encountered in 1973, hence responses to fall-applied nitrogen may be quite different.

DISCUSSION

Question: What type of nitrogen was used - Prills or Granules?

Answer: Granular form.

Question: Did high levels of nitrogen lengthen maturity and cause resulting frost damage?

Answer: No high nitrogen levels didn't appear to lengthen maturity.

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Table 1. Characteristics of Soils from Sites Selected for 1974 Nitrogen Fertilizer Studies[1]

Soil Type/ Texture	Depth (in)	O.M.	Nutrient NO_3-N	Content (lb/acre) P	K	pH	Cond. mmho/cm
Elstow:SiCl	0- 6	2.7	6	5 VL[2]	455	7.3	0.4
Dark Brown	6-12	1.9	1	3	275	7.5	0.4
	12-24		4	4	680	7.8	0.4
			11 VL				
Weyburn:l	0- 6	4.4	10	15 L	865	7.2	0.6
Dark Brown	6-12	2.5	5	7	450	7.1	0.6
	12-24		6	5	760	7.1	1.7
			21 L				
Hoey:SiCl	0- 6	7.7	9	11 L	430	6.5	0.2
Thick Black	6-12	3.8	3	6	265	6.7	0.2
	12-24		6	8	520	7.3	0.6
			18 L				
Naicam:l	0- 6	7.0	12	14 L	290	7.4	0.4
Thick Black	6-12	4.2	5	6	215	7.5	0.3
	12-24		4	8	630	7.8	0.3
			21 L				
Yorkton:l	0- 6	6.2	13	7 VL	235	7.5	1.3
Thick Black	6-12	4.5	4	4	180	7.5	2.3
	12-24		46	4	390	7.7	2.6
			63 VH				
Waitville:l	0- 6	3.6	1	23 H	275	7.0	0.2
	6-12	1.6	3	11	275	6.7	0.2
	12-24		2	20	530	7.1	0.6
			6 VL				

[1] Results of samples taken in fall, 1973.

[2] Nutrient availability categories as designated by the Saskatchewan Soil Testing Laboratory.
VL - very low; L - low; M- medium; H - high; VH - very high.

Table 2. Treatments[1] included in 1974 Nitrogen Fertilizer Trials

Nitrogen Application (lb/acre)	Nitrogen Sources	Time of Application
0		
25	A.N., U.	S
50	A.N., U.	S, F
75	A.N., U.	S
100	A.N., U.	S, F
150	A.N., U.	S

A.N. - Ammonium Nitrate

U. - Urea

S. - Spring

F - Fall

[1]At the Naicam soil site, all spring treatments were applied in broadcast, sideband, and seed-placed placement. At the remaining sites, treatments were broadcast only.

Table 3. Dates of Fall Fertilization, Spring Seeding and Harvest, and Amounts of Seasonal Precipitation for 1974 Nitrogen Fertilizer Trials

Site	Fall Fertilization	Seeding	Harvest	Seasonal Precip. (in)
Elstow	Nov. 1/73*	May 17/74	Aug. 20/74	7.3
Bradwell	Nov. 1/73*	May 31/74	Aug. 19/74	7.4
Hoey	Oct. 30/73	June 7/74	Sept. 5/74	13.9
Naicam				
-Barley	Nov. 1/73*	June 6/74	Sept. 6/74	
-Wheat	Nov. 1/73	June 4-5/74	Sept. 7/74	
-Rapeseed	Nov. 1/73	June 4/74	Sept. 9/74	
Yorkton	Oct. 31/73*	June 12/74	Sept. 17/74	8.7
Waitville	Oct. 31/73*	June 9/74	Sept. 18/74	9.2

*Fall fertilizer applied during or after snowfall

Table 4. Effect of Spring and Fall Broadcast Nitrogen on Yields of Barley on Two Dark Brown Soils

Nitrogen Application (lb/acre)	Yield (bu/acre)				
	Ammonium Nitrate			Urea	
	Spring	Fall		Spring	Fall
A) ELSTOW SOIL					
0			20.5		
25	31.5			32.1	
50	42.7	43.3		43.6	39.4
75	44.9			42.6	
100	44.9	52.1		52.8	49.7
150	49.0			51.6	
B) WEYBURN SOIL					
0			37.9		
25	44.1			50.6	
50	51.6	55.0		47.2	45.9
75	55.8			48.8	
100	51.5	51.7		52.2	53.0
150	48.1			53.3	

Table 5. Effect of Spring and Fall Broadcast Nitrogen on Yields of Barley on Two Black Soils

Nitrogen Application (lb/acre)	Yield (bu/acre) Ammonium Nitrate Spring	Fall		Urea Spring	Fall
C) HOEY SOIL					
0			42.3		
25	61.5			54.9	
50	72.6	66.0		73.0	65.0
75	79.2			75.2	
100	81.7	78.8		79.6	73.0
150	86.0			84.4	
D) YORKTON SOIL					
0			33.3		
25	37.7			37.5	
50	35.1	36.0		39.7	38.3
75	40.5			39.1	
100	39.2	36.2		38.3	39.1
150	41.8			41.0	

Table 6. Effect of Spring and Fall Applied Nitrogen on the Grain and Dry Matter Yields of Barley on Waitville Grey Wooded Soil

Nitrogen Application (lb/acre)	Yield: Ammonium Nitrate Spring	Ammonium Nitrate Fall		Urea Spring	Urea Fall
A) GRAIN - Bu/acre					
0			16.1		
25	21.0			21.8	
50	25.7	23.0		23.8	21.5
75	30.7			25.8	
100	27.2	20.6		29.8	19.7
150	25.7			27.4	
B) TOTAL DRY MATTER - Cwt/acre					
0			22.5		
25	30.9			29.6	
50	40.4	39.4		34.9	34.5
75	43.9			41.4	
100	42.4	39.7		44.3	38.4
150	41.1			44.4	

Table 7. The Effect of Different Times and Methods of Nitrogen Application on the Yields of Barley, Wheat and Rapeseed on Naicam Soil

Nitrogen Application (lb/acre)	Yield (bu/acre) Ammonium Nitrate					Urea			
	Broad-cast	Side-band	Seed Placed	Fall		Broad-cast	Side-band	Seed Placed	Fall
A) BARLEY									
0					22.6				
25	30.6	28.8	30.0			34.5	31.1	30.1	
50	33.1	34.0	32.3	26.1		33.8	34.2	32.2	28.2
75	36.3	39.4	34.6			38.7	38.4	31.0	
100	35.7	38.9	32.4	29.8		36.1	37.1	28.2	27.6
150	32.1	35.1	33.1			37.2	37.0	18.6	
B) WHEAT									
0					16.0				
25	17.3	19.5	19.5			18.6	19.5	19.9	
50	20.3	18.3	23.3	20.6		22.0	20.4	13.8	20.0
75	21.8	23.6	21.5			20.4	22.3	5.3	
100	20.1	23.5	23.2	18.1		24.8	24.5	7.4	20.6
150	23.2	24.7	22.8			21.3	25.0	4.4	
C) RAPESEED									
0					6.7				
25	8.5	14.5	10.4			11.0	12.4	6.0	
50	13.7	15.9	9.1	15.1		14.6	15.1	5.8	11.8
75	16.8	16.9	12.0			15.5	17.8	4.7	
100	17.3	16.8	8.9	16.6		18.7	16.3	5.5	15.4
150	18.2	18.1	4.9			14.9	16.9	0	