Review of Research Results with Anhydrous Ammonia and Aqua Ammonia

W. E. Johnson

Use of anhydrous ammonia in western Canada dates from about 1954. Field tests conducted in Alberta and Saskatchewan from 1954 to 1956 showed that responses to anhydrous ammonia were about the same as that for other nitrogen sources at similar rates of nitrogen applied.

The volume of anhydrous ammonia did not increase substantially until the last ten years. In 1975-76 over 100,000 tons of anhydrous ammonia was used in western Canada with 75 per cent of that tonnage used in Alberta. The growth in the use of anhydrous ammonia over a fairly wide geographic area in Alberta suggests that farmers have found it to be a satisfactory source of nitrogen.

It is unfortunate that the early tests in Saskatchewan and Alberta were often done without using any phosphate application. Satisfactory soil test data is not available, and soil characteristics or weather conditions are frequently lacking as well.

The results of the early tests do, however, suggest generally the requirements for satisfactory use of anhydrous ammonia. The depth of injection required appeared to be in the range of 4 to 6 inches. Moisture content of the soil, texture, and cation exchange capacity are important in assessing injection requirements. There was little work on spacing of injection points but results on corn at Lethbridge would suggest that 16 inches in probably a maximum satisfactory spacing. This is, of course, supported by analysis of the distribution of ammonia around the point of injection.

Table 1 shows increases in yield for tests conducted by the Department of Soil Science, University of Alberta in 1955.

Table 1

N Source	N Rate lbs/acre	Increases in Yield bus/acre		
		Wheat (3)	Oats (4)	Barley (8)
82-0-0	33	16.1	26.3	15.9
82-0-0	67	21.2	25.9	14.1
33.5-0-0	33	14.7	33.4	12.9
33.5-0-0	67	16.7	40.2	11.1
Chiselled Only		1.4	1.1	-0.3

( ) Number of Tests

The tests reported in Table 1 were carried out without phosphate application. There was a wide variation in results. There might be a question as to whether oats and wheat responded better than barley, but the phosphate requirements for barley are more critical than for wheat and oats. The control plots where the applicator was used without anhydrous ammonia showed largely non-significant, random, small increases and decreases in yield.

There were a number of tests in southern Alberta which included phosphate application. Table 2 shows the data for one test on a dark brown clay loam soil in 1954.

Table 2

N Source	N Rate lbs/acre	Barley Yield Increase bus/acre
82-0-0	33	2.0
82-0-0	67	3.6
82-0-0	100	14.5
33.5-0-0	33	3.1
33.5-0-0	67	5.3
33.5-0-0	100	5.2
33.5-0-0	100 + 11-48-0 @ 50	2.7

Phosphate application in this test did not improve the yield results. In general, there appeared to be little difference between the two nitrogen sources 82-0-0 and 33.5-0-0, without phosphate, although on average 33.5-0-0 would probably show a little better response without phosphate than 82-0-0. There were suggestions in some promotion for anhydrous ammonia that it would increase phosphorus availability more than other nitrogen sources. This is certainly not supported by the early data.

A set of four wheat tests conducted by the Research Station at Lethbridge in 1955 tend to show the effect of texture on anhydrous ammonia efficiency. Results are shown in Table 3.

Table 3

N Source	N Rate lbs/acre	Wheat Yield Increases bus/acre	
		Loam-Clay Loam	Sandy Loam
		3 Tests	1 Test
33.5-0-0	30	9.0	0.7
33.5-0-0	60	11.0	3.9
82-0-0	30	7.1	-1.2
82-0-0	60	9.0	-1.2

Yield increases for 33.5-0-0 were also low on the sandy loam soil but there was actually a negative effect of anhydrous ammonia. It might be expected that deeper placement of both sources would have improved the response on the sandy loam soil.

One test on winter wheat in 1955 showed an interesting result as shown in Table 4.

Table 4

Brown Loam Soil
NH_3 Applied in Spring

Treatment lbs/acre	Yield bus/acre	Increase bus/acre
Check	28.9	
30 lbs. N	31.0	2.1
60 lbs. N	38.4	9.5
90 lbs. N	33.5	4.6
Chiselled Only	42.0	13.1

Chiselling only, gave a higher increase in yield than any nitrogen rate. The 30 lb. rate was unsatisfactory using anhydrous ammonia. The optimum rate of 60 lbs. of N per acre in this test showed in a number of trials in Alberta. This result would probably have been modified considerably on phosphorus-deficient soils if phosphate had been applied as well.

There is little satisfactory data on anhydrous ammonia for forage production. The Department of Soil Science had a few trials in 1955. In all but one of these tests the anhydrous ammonia was applied near June 1, followed by dry weather and results on these tests were essentially negative where as ammonium nitrate gave fair yield increases. On the one test which showed positive results for anhydrous ammonia, response to ammonium nitrate was 35 to 45 per cent higher.

Table 5 shows the results for one Lethbridge test in 1954 for intermediate wheat grass on a black loam soil.

Table 5

Intermediate Wheat Grass

N Source	N rate	N-applied in Spring Yield tons/acre
82-0-0	30	0.78
	60	1.05
	90	0.66
	120	0.94
	Chiselled Check	1.07
33-0-0	33	1.20
	67	1.19
	100	1.39
	Check	0.84

As was the case for winter wheat, anhydrous ammonia gave yields lower than the chiselled check. During this period, there were some tests in Alberta placing phosphorus, and other nitrogen sources at 2 to 3 inches for forage. Results were largely negative, as compared to surface broadcast application and use of anhydrous ammonia on forage will require further work on time and depth of application. The benefits of positional availability did not seem to show in this earlier Alberta work at the moderately shallow depths tested.

The Department of Soil Science, University of Saskatchewan, had a number of field tests on cereals and flax in 1956. Results are shown in Table 6. Nitrogen was applied both fall and spring as indicated.

Table 6

N Source	N Rate	Yield Increase bus/acre			
		Flax (1)	Wheat (4)	Barley (3)	Oats (2)
33.5-0-0	40-F	6.4	8.3	10.5	9.0
	40-S	6.2	6.8	9.2	11.2
82-0-0	40-F	4.2	8.4	10.4	12.6
	40-S	3.8	7.6	16.8	20.8

Note: No phosphate applied

( ) Number of Tests

It is interesting to note that there was little consistency in fall versus spring application for either source. Anhydrous ammonia gave as good or better results than ammonium nitrate, except for the one test on flax.

Although there were satisfactory yield responses to application of nitrogen alone, some tests showed that phosphate application was, of course, necessary on deficient soils to obtain satisfactory response to nitrogen. Table 7 shows results of one trial on barley in the Foam Lake area in 1955.

Table 7

Treatment	Barley Yield bus/acre
Check	37.7
NH_3 @ 50	40.4
A.N. @ 125	41.4
A.N. @ 125 + 11-48-0 @ 40	56.3
NH_3 @ 50 + 11-48-0 @ 40	56.2
11-48-0 @ 40	48.3

Response to nitrogen alone in this test was very low although the vegetative response was remarkable.

A report prepared on the tests in Saskatchewan indicated that there were obvious losses of ammonia from fine-textured soils which were very dry at the time of application in the fall of 1955. It was also suggested that applicator points would need to be at a depth of 6 to 7 inches on wet clay soils.

Partridge and Ridley (5) and Ridley (9) have reported results with anhydrous ammonia in comparison with other nitrogen sources in Manitoba. The data for 34-0-0 and 82-0-0, along with 28-0-0 solution in 1975, have been selected and presented in Tables 8 and 9.

Table 8

1974 Barley Yields cwt/acre

N Source and time	Darling Ford CL	Almasippi LFS	Holland CL	Wellwood SCL	Newdale CL	Carrol CL
34-0-0 F	29.2	21.9	19.3	17.8	23.6	24.3
S	26.8	28.3	21.8	17.0	24.5	26.1
82-0-0 F	26.4	24.0	17.7	19.0	28.2	25.7
S	27.8	28.6	22.8	17.3	25.8	27.3

NOTE - All Plots Received 40 lbs. of P_2O_5 per acre at seeding.
- Data selected are for 34-0-0 incorporated.

N Rate - 52 lbs/acre

Table 9

1975 Barley Yields cwt/acre

N Source and time	Wellwood FSCL	Darling Ford CL	Holland CL	Newdale CL	Portage CL	Almasippi LFS
34-0-0 F	24.9	24.8	21.9	15.8	28.5	18.3
S	26.3	26.4	24.3	17.0	29.7	23.1
28-0-0 F	24.4	24.4	19.4	11.7	27.3	18.0
S	25.5	26.2	19.6	16.2	29.2	20.1
82-0-0 F	24.9	26.0	21.6	16.8	30.3	21.1
S	24.8	26.9	19.9	15.3	28.3	23.2

NOTE - All plots received 40 pounds of P_2O_5 per acre at seeding and data selected are for 34-0-0 and 28-0-0 incorporated.

In general, there are not large differences in nitrogen sources. The data does tend to indicate that both soil characteristics and environmental conditions are important to the best management of nitrogen fertilizers. The data for the coarse-textured almasippi soil shows that spring application is best for all sources, including anhydrous ammonia. On the medium-textured soils the difference is less consistent and fall application gave equal or better responses at a number of test sites.

Brandon data for barley and corn is shown in Tables 10 and 11.

Table 10

N Source at 50 lbs. N/acre		Barley Yields lbs/acre 1969-70 CL	1969-70 SL	1970-71 CL
82-0-0	F	4820	3060	3123
	S	4920	2910	3147
34-0-0	F	5010	2850	2956
	S	4900	2650	3003
46-0-0	F	4710	2480	2856
	S	4900	2810	2772

Table 11

		Corn Yields lbs/acre		
		Assiniboine CL 1971		1972
N Source	N Rate	Silage	Grain	Silage
82-0-0	50 (F)	4843	2386	8190
	100 (F)	5788	2872	7886
	200 (F)	7320	2651	8319
34-0-0	50 ()	4611	1992	7445
	100 (S)	5606	1933	7344
	200 (S)	5493	2243	7290

NOTE - 55 lbs. of P_2O_5 per acre side-banded.

The barley data in Table 11 shows some inconsistency in effect of application time for all sources and again suggests that soil and environment characteristics are important. The corn yield data in Table 12 shows a fairly marked superiority of anhydrous ammonia applied in the fall over ammonium nitrate applied in the spring. The anhydrous ammonia data also suggests that optimum rates for silage production may be higher than those for grain.

Western Co-operative Fertilizers (3) have obtained data on anhydrous ammonia and placement of other sources in recent years as well as a comparison of anhydrous, aqua ammonia and 28-0-0 in 1976. Results are shown in Tables 12, 13 and 14.

Table 12

Yield cwt/acre Average of 5 barley - 2 durum wheat trials	
34-0-0 (Post-seeding)	17.9
82-0-0 (Pre-plant)	19.9
Check	14.4

NOTE - N rate according to soil test.

Table 13

Yield cwt/acre
Average of 5 Barley and Wheat Trials

Check	12.3
34-0-0 (Broadcast)	18.4
46-0-0 (Broadcast)	18.0
34-0-0 (Shanked in 4 - 5 inches)	20.9
46-0-0 (Shanked in 4 - 5 inches)	20.1

Table 14

1976 Yield (cwt/acre)
Average of 17 Barley and Wheat Trials

Check	13.9
82-0-0	19.3
20-0-0 (Aqua)	19.2
28-0-0 (Shanked)	18.7
28-0-0 (Sprayed)	18.2

NOTE - 82-0-0, 20-0-0 and 28-0-0 shanked, injected at 5 to 6 inches.

The results in Tables 12 and 13 indicate that the yield advantage of anhydrous ammonia over other sources is reduced when the other sources are placed at greater depths. The data for 28-0-0 in Table 14 suggests that differences were less marked or possibly again that environmental conditions are important.

As would be expected, the data for anhydrous ammonia and aqua ammonia show no differences when injected at 5 to 6 inches. Further work is needed to determine whether or not the depth requirement for aqua ammonia is any less than that for anhydrous.

McDowell and Smith (4) studied ammonia losses following anhydrous ammonia application to three textures of soil at different moisture levels.

Results of their work is shown in Table 15.

Table 15

NH_3 Losses 36 Hours After
Application - Rate 100 lbs. N/Acre

Depth of Application inches	Width of Rows inches	Soil Moisture: Dexter SL		Putman SIL		Houston CLAY	
		2%	10%	2%	10%	2%	17%
3	40	18.1	12.0	11.7	1.4	0.31	0.15
3	16	7.4	2.4	4.0	0.7	0.19	0.06
6	40	8.8	1.8	5.1	0.8	0.20	0.09
6	16	3.5	0.8	2.1	0.3	0.08	0.02

These results show that depth, spacing, moisture, and soil characteristics are all important to satisfactory retention of ammonia. With the exception of fine textured soils, 4 inches might be considered a minimum depth of placement and moisture content should be just below field capacity.

The authors indicated that the application of anhydrous ammonia caused a temporary highly dispersed condition of the soil. They conjectured that the yellow-coloured extract from the soil indicated probable solubilization of the fulvic acid component of the organic matter. They also reported increased manganese solubility.

Smika and Grabouski (10) have reported some interesting results using anhydrous ammonia on winter wheat in Nebraska, Table 16.

Table 16

Grain Yield and Protein Content
Silt Loam Soil
Winter Wheat

	Grain (kg/ha)	Protein (%)
Check	2755	11.7
September 8 - First Summer	3629	14.5
May 30 - Second Summer	3293	13.9
June 15 - Second Summer	3494	13.3
July 15 - Second Summer	3494	13.1
July 30 - Second Summer	3024	13.2
August 15 - Second Summer	3091	12.1

Anhydrous ammonia was applied at a depth of 10 to 15 centimeters. Summerfallow extends over a 14-month period from July, to September the next year. Maximum yields and protein content were obtained by applying anhydrous ammonia in September of the year before seeding. Results for a sandy loam showed highest yields and protein content when anhydrous ammonia was applied in mid-June of the second summer.

These results show a potential for developing much more site-specific, environment-specific fertility management recommendations.

RESEARCH NEEDS

The requirements for satisfactory retention of anhydrous ammonia seem to be reasonably clear. Injection to a depth of 4 to 6 inches at spacings of 16 inches or less, in soil with a moisture content just under field capacity for medium to coarse textured soils, and slightly drier for clay soils. There are indications in the research to date that spring application may be best on very coarse-textured soils.

Field testing should be directed to assessing soil and environment characteristics in relation to application requirements. Moisture, texture, organic matter and cation exchange ranges should be included.

It is possible that requirements for aqua ammonia could be more or less stringent than anhydrous ammonia. Under optimum soil conditions, depth requirements might be less but dry soil conditions could possibly lead to as great or greater losses from aqua ammonia with shallow incorporation.

The long term effect of optimum to maximum rates of ammonia application should be assessed. Farmers are asking questions based on reports from the U.S.A. The extent of solubilization of organic matter and the effect on soil physical conditions has not been fully investigated.

The ammonium ion forms soluble complex ions with trace elements like copper and zinc and this may have some effect on mobility and availability of some trace elements.

Optimum nitrogen rates on soils border-line for potassium supply will increase the need for potassium additions. Anhydrous ammonia application may be more severe than other sources in this regard due to blocking of exchangeable potassium by the ammonium ion. Potassium requirements should probably be studied under continuing high rates of anhydrous ammonia on soils moderately low in potassium.

There is potential for increased use of nitrogen-herbicide combination for soil application. Anhydrous ammonia or aqua ammonia are unsuitable for such combinations. In addition, there are possibilities that the high pH and ammonia concentration in the injection band might not be compatible with herbicides. At depths of injection recommended for anhydrous ammonia there might be no problem, but any placement at 3 inches or less could cause adverse interactions with herbicides.

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