Urea vs. Ammonium Nitrate - A Review

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1. Introduction

In recent years, as fertilizer use has become a much more important aspect of crop production in Western Canada, considerable controversy has arisen over the relative efficiencies of various nitrogen fertilizer materials for various crops. In particular, concern is often expressed over the relative efficiency of urea compared to the inorganic ammonium and nitrate-nitrogen fertilizers such as ammonium nitrate. Questions have also been posed as to what the most effective times and methods of applying nitrogen fertilizers are in order to realize economic returns in crop yield increases from money spent on nitrogen fertilization. Results of numerous experiments conducted by various agencies throughout the prairies attempting to evaluate different nitrogen sources and nitrogen fertilizer application techniques have often been inconclusive and contradictory. This is probably one of the major causes of differences in opinion arising over these topics.

At present, none of the agencies responsible for formulating fertilizer recommendations in the prairie provinces make any distinction between different nitrogen sources when broadcast, with the exception that the Alberta Soil and Feed Testing Laboratory does not recommend the broadcast application of urea to forage crops when other commonly used nitrogen sources are available. Recommendations however are more specific regarding the placement of nitrogen fertilizers. For the most part, for crops other than cereals, it is generally recommended that nitrogen fertilizers not be placed with the seed. In the case of cereal crops, nitrogen may be seed drilled, however, most recommendations place a limit on the amount of nitrogen that should be placed with the seed under certain conditions. Often the limit set for the amount of urea containing fertilizers that may be seed placed is lower than that set for other nitrogen fertilizer materials.

The objectives of this review were to determine whether, in the light of data presently available from experiments conducted in the Canadian prairies, any conclusions could be drawn regarding the relative efficiency of urea compared to ammonium nitrate and the different methods of applying these fertilizers. This, in turn, would reflect on whether present nitrogen fertilizer recommendations being made relating to these considerations appear satisfactory. For the purpose of this report, it was decided to deal solely with comparisons made on major field crops other than forages since most work relating to forage crops has been conducted by the Agriculture Canada Research Station at Scott, and this work was to be presented in another review paper.

2. Methods of Investigation

Data were collected from as many sources as possible that contained results of experiments recently conducted on the prairies in which comparisons were made between urea and ammonium nitrate and between different methods of applying these fertilizers to various crops. The major agencies having conducted such experiments and from which data were available included the University of Saskatchewan, University of Manitoba, Agriculture Canada Research Stations, Sherritt-Gordon Mines Ltd. and Cominco Ltd. All work from which information was extracted has been performed since 1965. Only data from experiments which contained direct comparisons between the variables under study and which contained a valid check treatment were used.

Initially, data from all of the experiments conducted by an individual agency or research worker on a specific crop were grouped together and summarized. The summary results were tabulated in terms of the average yield of the check treatments and the average yield increase over the check of the different nitrogen treatments. Individual averages were calculated for each carrier and for each rate and method of nitrogen application. Subsequently, for each crop on which sufficient data were available, the results of all the experiments from all the sources were drawn together and overall

summaries, similar to those mentioned, were prepared. Where possible graphs were drawn to show the average yield increases over the check vs. rate of nitrogen applied for the two nitrogen sources and different application methods. Several attempts were made to subdivide the overall data into different categories on the basis of differences in various soil properties (soil zones, pH, textures, NO_3-N levels, etc.) to see if more specific comparisons could be made. However, since only small amounts of data generally fell into any category such comparisons were impossible.

3. Presentation of Results

The majority of experiments conducted in Western Canada comparing urea and ammonium nitrate have used barley as a test crop. Considerably fewer trials have been run comparing these fertilizers as nitrogen sources for wheat, rapeseed, and flax. Very few experiments have been performed directly comparing crop responses to different methods of applying these fertilizers.

3.1 Responses of barley to urea and ammonium nitrate

Summaries of results of individual works comparing urea and ammonium nitrate on barley are presented in Table 1 (a) to Table 1 (e). There is only one case where there appears to be consistent differences between the two carriers, and that is in the work conducted by Toews and Soper in Manitoba in 1968 and 1969. In these experiments average yields from ammonium nitrate were greater than those from urea in both seed placed and broadcast and incorporated applications, with only one exception (the 20 lb N/acre rate - broadcast and incorporated). In all other work there is either very little difference in yields obtained from the two carriers or else where differences do occur they are not consistent, sometimes favouring ammonium nitrate and sometimes favouring urea.

Results obtained when all of the data from all sources were grouped together and summarized are presented in Table 1 (e). Graphs

Table 1

Summary of experiments comparing response of barley to urea and ammonium nitrate

Rate of N applied	Placement	Ave. check yield (bu/acre)	Ave. Yield increase (bu/acre)		No. of trials
			NH_4NO_3	Urea	
(a) Summary of experiments by Soper et al. (Manitoba, 1965-1969)					
20	Drilled	30.8	7.9	5.9	8
30		30.8	15.9	11.9	8
40		30.8	23.4	15.3	8
60		30.8	29.1	12.0	8
20	(Broadcast +	30.8	5.2	5.6	8
40	Incorporated)	30.8	17.3	15.9	8
60		30.8	28.0	23.8	8
90		30.8	35.2	32.9	8
120		30.8	36.3	36.3	8
240		33.3	30.3	29.1	4
(Above work conducted in 1968-69 by Toews and Soper)					
40	Broadcast	33.1	11.4	12.3	7
60		33.1	20.2	15.8	7
(Above work conducted in 1965-67 by Soper et al.)					
(b) Summary of experiments by Ridley (Manitoba, 1968-1972)					
30	Broadcast	26.1	14.5	16.2	6
60		29.1	26.5	24.4	7
30	(Broadcast +	26.1	14.4	13.6	6
60	Incorporated)	29.1	22.4	23.8	7
30	(Combined	26.1	14.5	14.9	12
60	above)	29.1	24.5	24.1	14

Table 1 (cont'd)

Rate of N Applied	Placement	Ave. Check Yield (bu/acre)	Ave. Yield Increase (bu/acre)		No. of Trials
			NH_4NO_3	Urea	
(c) Summary of experiments by Agriculture Canada (Scott, 1969-71)					
40	(Broadcast +	33.7	13.2	13.3	9
80	Incorporated)	32.7	21.1	19.1	10
(d) Summary of experiments by Cominco (Man., Sask., Alta., 1967-1968)					
30	(Broadcast +	34.4	9.6	11.9	9
60	Incorporated)	33.6	15.6	14.5	14
60	Broadcast	23.1	14.0	13.5	2
(e) Summary of experiments by Sherritt-Gordon (Man., Sask., Alta., 1968-70)					
30	(Broadcast +	34.3	5.1	5.7	23
40	Incorporated)	35.8	8.2	6.4	11
60	"	34.8	13.1	13.6	34
90		34.3	21.1	20.2	23
(f) Summary of all experiments					
20	Drilled	30.8	7.9	5.9	8
30		30.8	15.9	11.9	8
40		30.8	23.4	15.3	8
60		30.8	29.1	12.0	8
30	Broadcast	26.1	14.5	16.2	6
40		33.1	11.3	12.3	7
60		30.0	22.3	19.3	16
20	(Broadcast +	30.8	5.2	5.6	8
30	Incorporated)	33.1	7.6	8.4	38
40		33.6	12.4	11.3	28
60		33.4	16.6	16.3	63
80		32.7	21.1	19.1	10
90		33.4	24.7	23.4	31

Table 1 (cont'd)

Rate of N applied	Placement	Ave. Check Yield (bu/acre)	Ave. Yield Increase (bu/acre)		No. of Trials
			NH_4NO_3	Urea	
120		30.8	36.3	36.3	8
240		33.3	30.3	29.1	4
20	(Combined	30.8	5.2	5.6	8
30	Broadcast	33.1	8.6	9.5	44
40	and	33.5	12.2	11.5	35
60	Broadcast +	33.1	17.7	16.9	79
80	Incorporated)	32.7	21.1	19.1	10
90		33.4	24.7	23.4	31
120		30.8	36.3	36.3	8
240		33.3	30.3	29.1	4

of these results are given in Figures 1, 2 and 3. The only experiments conducted comparing seed drilled urea and ammonium nitrate were those of Toews and Soper and, as indicated, these results showed more favourable yields from ammonium nitrate particularly at higher application rates. Relatively few experiments have been conducted comparing the two sources when broadcast, but a large number have been performed comparing them when broadcast and incorporated. For both placements, however, overall averages indicate relatively small differences between the two carriers, generally slightly in favour of urea at the lower application rates (40 lbs N/acre or less) and slightly in favour of ammonium nitrate at higher rates. When results from the two methods of application were combined and averaged, the same trends were apparent.

3.2 Responses of wheat, rapeseed, and flax to urea and ammonium nitrate

Results of the relatively few individual groups of experiments with wheat, rapeseed and flax are summarized in Table 2(a) to (f) for

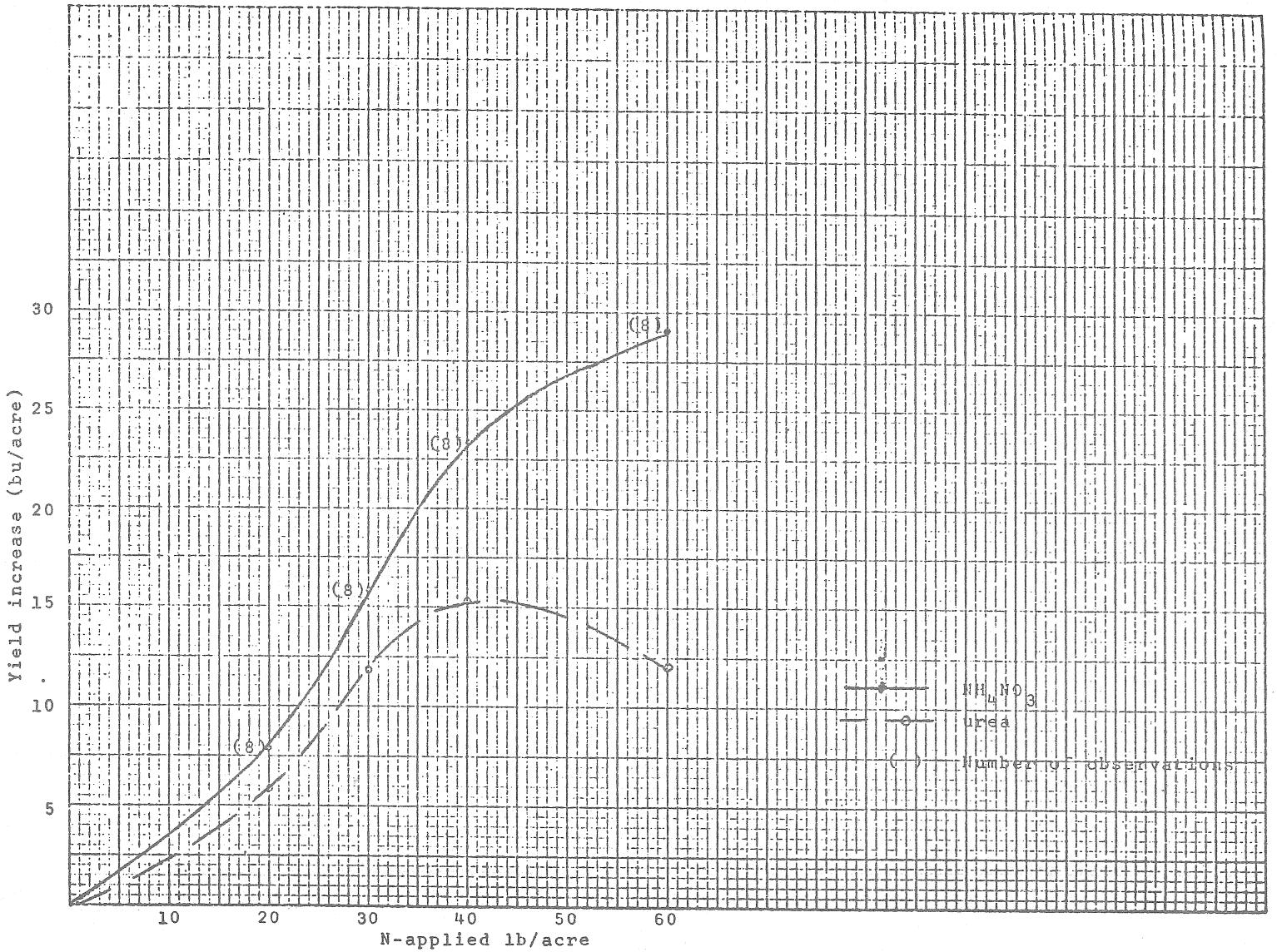

Figure 1. Response of barley to seed placed nitrogen.

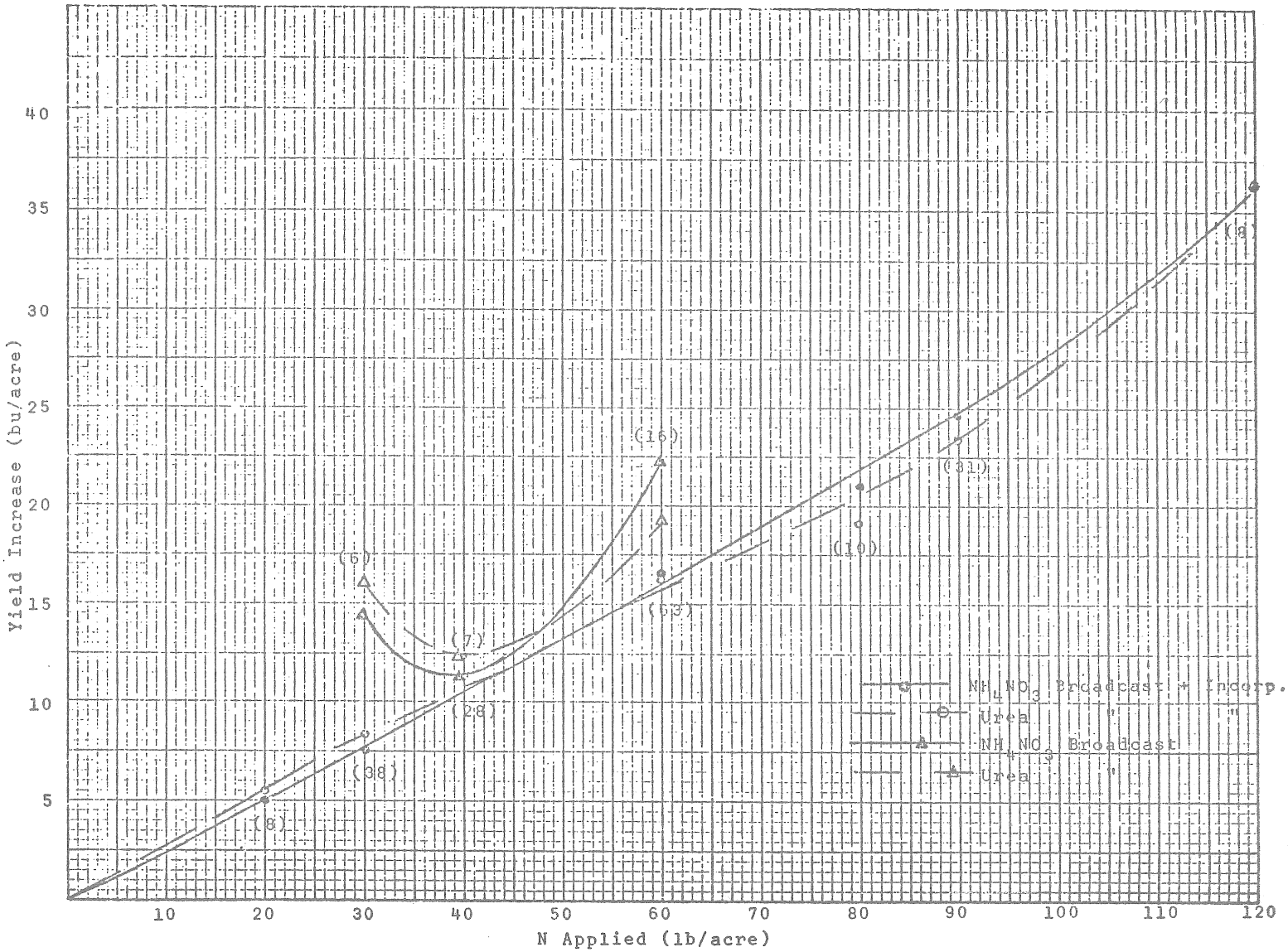

Figure 2. Response of barley to broadcast and broadcast and incorporated nitrogen.

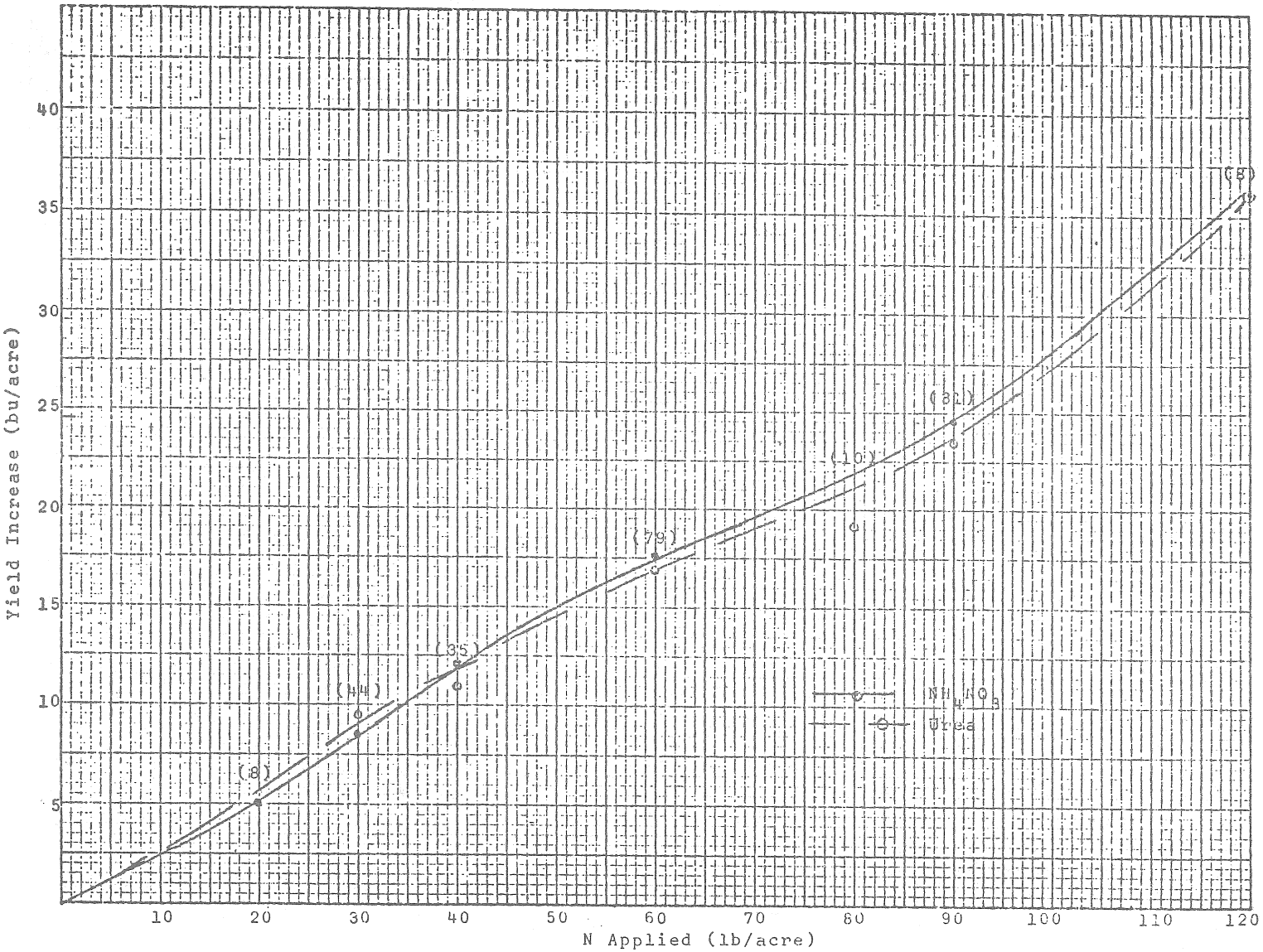

Fig. 3. Response of barley to broadcast and broadcast and incorporated nitrogen.

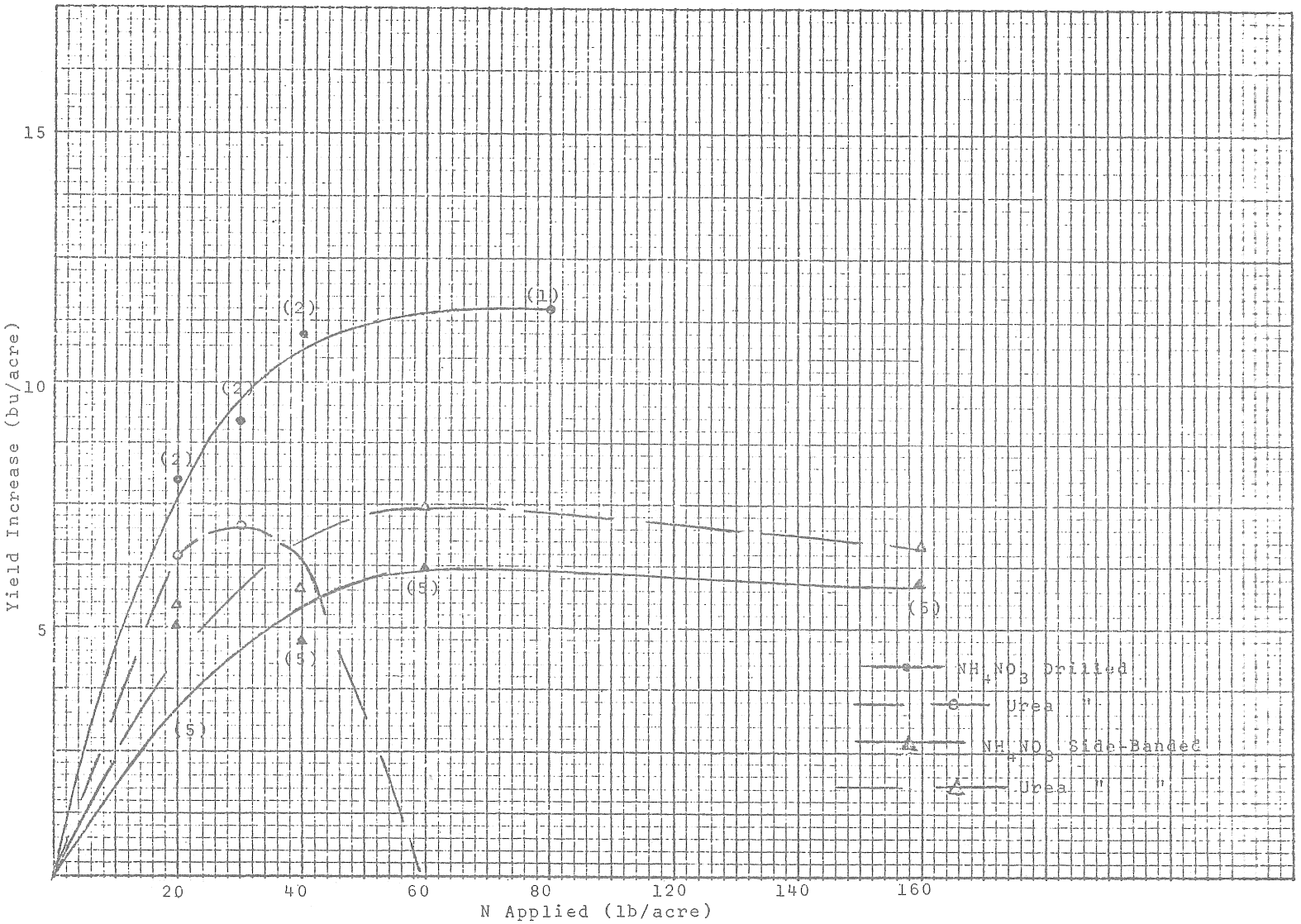

Figure 4. Response of wheat to drilled and side-banded nitrogen.

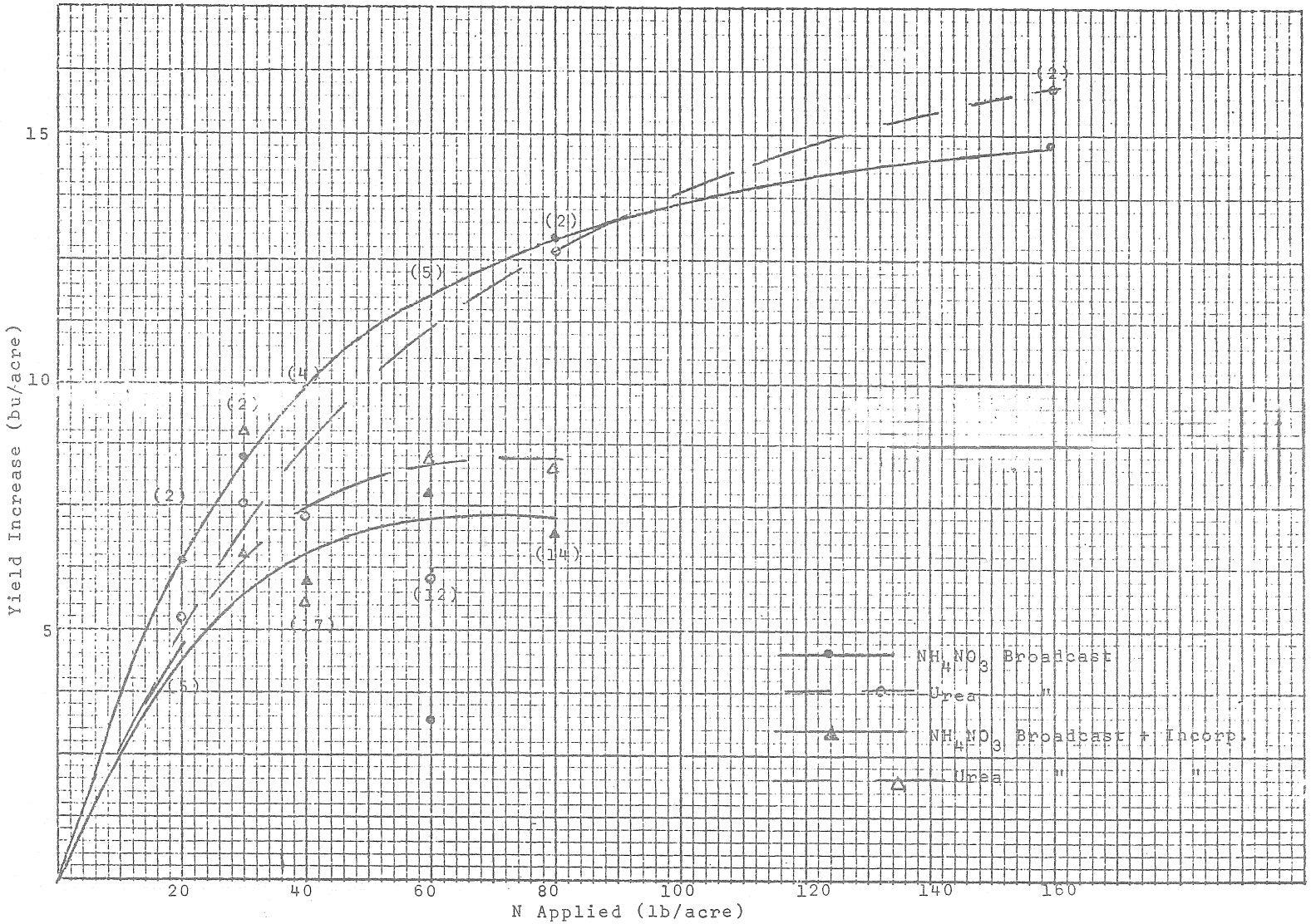

Fig. 5. Response of wheat to broadcast and broadcast and incorporated nitrogen

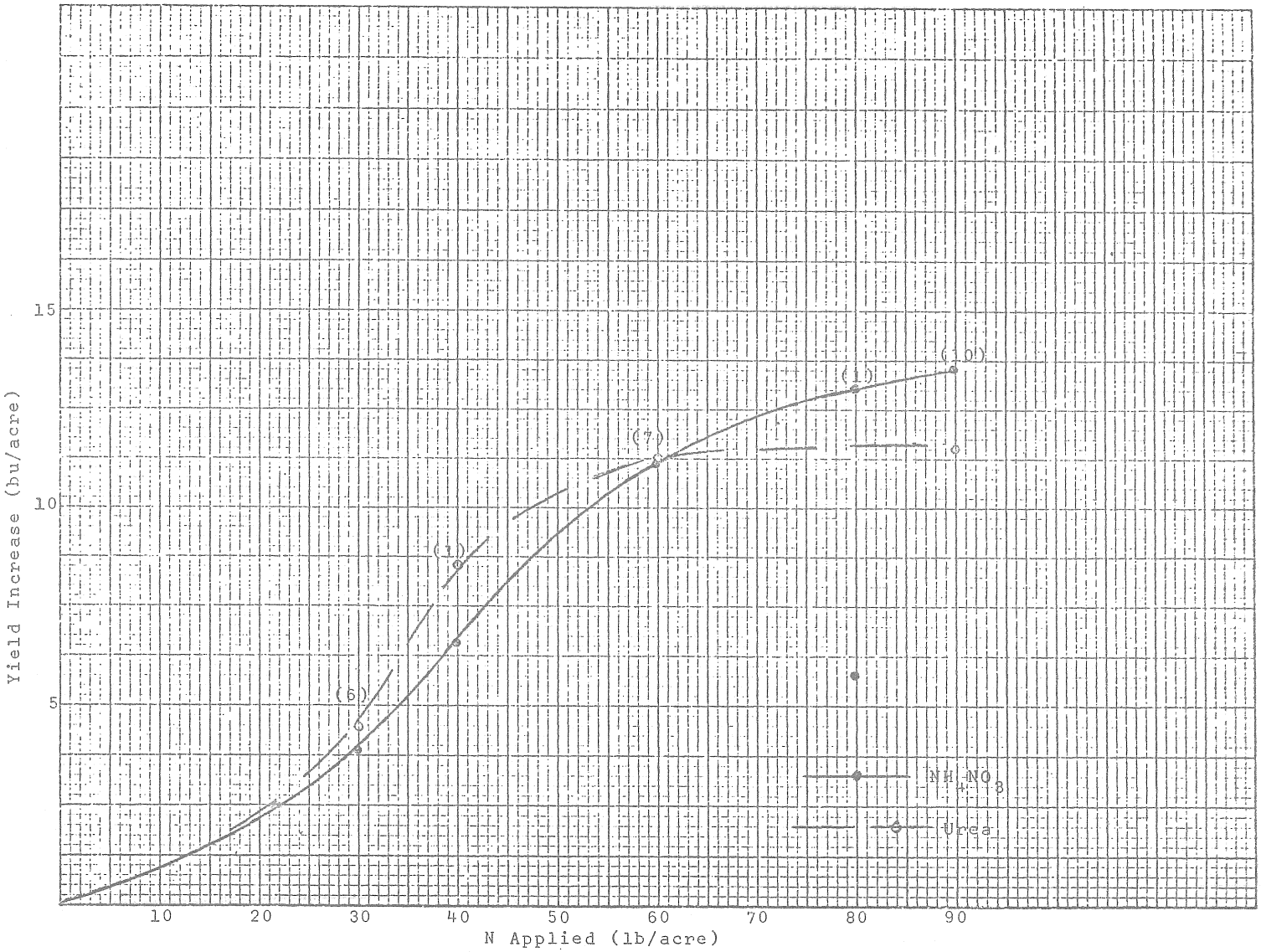

Fig. 6. Response of rapeseed to broadcast and broadcast and incorporated nitrogen.

Table 2

Summaries of experiments comparing responses of wheat to urea and ammonium nitrate

Rate of N applied	Placement	Ave. Check Yield (bu/acre)	Ave. Yield Increase (bu/ac)		No. of Trials
			NH_4NO_3	Urea	
(a) Summary of experiments by the University of Saskatchewan (1970)					
20	Drilled	19.8	8.0	6.4	2
30		19.8	9.2	7.1	2
40		19.8	11.0	6.3	2
80		24.7	11.5	-12.8	1
20	Broadcast	19.8	6.4	5.2	2
30		19.8	8.5	7.6	2
40		19.8	10.5	6.9	2
80		19.8	12.9	12.7	2
160		19.8	14.8	15.9	2
(b) Summary of experiments by Agriculture Canada (Scott, 1969-71)					
40	(Broadcast +	22.0	5.9	5.1	14
80	Incorporated)	22.0	6.9	8.1	14
(c) Summary of experiments by Sherritt-Gordon (Alberta, 1968)					
40	(Broadcast +	22.5	6.6	7.9	3
60	Incorporated)	22.5	10.0	11.0	3
(d) Summary of experiments by Cominco (Man., Sask., Alta., 1967-68)					
30	(Broadcast +	23.6	6.6	9.0	5
60	Incorporated)	25.4	7.0	7.4	9
60	Broadcast	24.2	0.9	2.5	3
(e) Summary of experiments by Soper et al. (Manitoba, 1966)					
40	Broadcast	17.7	9.3	7.6	2
60		17.7	6.7	11.5	2

Table 2 (Cont'd)

Rate of N applied	Placement	NH_4NO_3 (bu/acre)		Urea (bu/acre)		No. of Trials
		Ave. Check	Increase	Ave. Check	Ave. Increase	
(f) Summary of experiments by Agriculture Canada - Melfort (1967-69)						
20	Side-band	33.2	5.1	32.6	5.4	5
40		33.2	4.7	32.6	5.8	5
60		33.2	6.2	32.6	7.4	5
120		33.2	5.9	32.6	6.7	5

Rate of N applied	Placement	Ave. Check Yield (bu/acre)	Ave. Yield Increase (bu/ac)		No. of Trials
			NH_4NO_3	Urea	
(g) Summary of all experiments					
20	Broadcast	19.8	6.4	5.2	2
30		19.8	8.5	7.6	2
40		18.7	9.9	7.3	4
60		21.1	3.2	6.1	5
80		19.8	12.9	12.7	2
160	"	19.8	14.8	15.9	2
30	(Broadcast +	23.6	6.6	9.0	5
40	Incorporated)	22.1	6.0	5.6	17
60		24.7	7.8	8.3	12
80		22.0	6.9	8.1	14
20	(Combined	19.8	6.4	5.2	2
30	Broadcast	22.5	7.1	8.6	7
40	and	21.5	6.8	5.9	21
60	Broadcast +	23.6	6.4	7.6	17
80	Incorporated)	20.5	7.7	8.7	16
160		19.8	14.8	15.9	2

wheat, Table 3(a) to (c) for rapeseed, and Table 4(a) and (b) for flax. No consistent trends were apparent in these data favouring either one of the nitrogen carriers for any of these crops. Results of only the experiments conducted with seed placed nitrogen on wheat, those of the University of Saskatchewan, indicated that yields from ammonium nitrate were higher than those from urea particularly at higher fertilization rates. On the other hand data from experiments of the Agriculture Canada Research Station at Melfort comparing these carriers when side-banded showed average yields from urea to be slightly greater. Results of the remaining groups of experiments with wheat in which the fertilizers were either broadcast or broadcast and incorporated give fairly inconsistent results, with in some cases urea being favoured and in other cases ammonium nitrate being favoured. The same inconsistencies remained when all of the data on wheat from the different sources were summarized together.

Similarly, from the limited amount of data from experiments conducted with rapeseed and flax, no obvious consistent differences were apparent in the yields obtained from the two sources.

3.3 Responses of crops to different placements of urea and ammonium nitrate

Data from only three groups of experiments were located in which comparisons were made between seed drilled and away from the seed placement of urea and ammonium nitrate. One set of experiments were conducted by Toews and Soper in Manitoba on barley, and two sets were conducted by the University of Saskatchewan, one on Manitou wheat and one on Pitic wheat. Summaries of these experimental data are presented in Table 5(a) and (b) and graphed in Figures 7, 8, and 9. Results of all these experiments indicated that at lower application rates (40 lb N/acre or less) seed placement of ammonium nitrate gives equal or slightly to appreciably greater yields than broadcast application. At higher application rates data from the wheat trials showed that broadcasting ammonium nitrate resulted in higher yields than with

Table 3

Summary of experiments comparing responses of rapeseed to urea and ammonium nitrate

Rate of N applied	Placement	Ave. Check Yield (bu/acre)	Ave. yield Increase (bu/ac)		No. of Trials
			NH_4NO_3	Urea	
(a) Summary of experiments by the University of Saskatchewan (1970)					
20	Broadcast	13.6	-0.5	-1.4	1
40		13.6	6.7	8.6	1
60		13.6	11.7	11.7	1
80		13.6	5.8	13.1	1
(b) Summary of experiments by Soper et al. (Manitoba, 1965-67)					
90	Broadcast	9.0	10.3	8.2	4
(c) Summary of experiments by Sherritt-Gordon (Man., Sask., Alta., 1970)					
30	(Broadcast +	12.9	3.9	4.8	6
60	Incorporated)	12.9	11.2	11.1	6
90		12.9	15.8	13.7	6
(d) Summary of all experiments					
20	(Combined	13.6	-0.5	-1.4	1
30	Broadcast	12.9	3.9	4.5	6
40	and	13.6	6.7	8.6	1
60	Broadcast +	13.0	11.3	11.2	7
80	Incorporated	13.6	5.8	13.1	1
90		11.3	13.6	11.5	10

Table 4

Summary of experiments comparing responses of flax to urea and ammonium nitrate

Rate of N applied	Placement	Ave. Check Yield (bu/acre)	Ave. yield increase (bu/ac)		No. of Trials
			NH_4NO_3	Urea	
(a) Summary of experiments by Agriculture Canada-Indian Head (1969-70)					
10	Drilled	11.5	2.1	3.7	2
20	Broadcast	11.5	6.9	9.2	1
30		11.5	9.5	8.5	2
40		11.5	7.6	8.5	1
(b) Summary of experiments by Sherritt-Gordon (Man., Sask., Alta., 1970)					
30	(Broadcast +	15.8	3.2	2.9	6
60	Incorporated)	15.8	3.9	5.0	6
90		15.8	4.4	6.0	6

Table 5

Summary of experiments comparing placements of nitrogen fertilizer

Rate of N applied	Ave. Check yield (bu/acre)	Average Yield Increase (bu/acre)				No. of Trials
		NH_4NO_3		Urea		
		Drilled	Broadcast	Drilled	Broadcast	
(a) Summary of experiments by Toews and Soper comparing seed placed and broadcast and incorporated urea and ammonium nitrate on barley (Manitoba, 1968-69)						
20	30.8	7.9	5.2	5.9	5.6	8
40	30.8	23.4	17.3	15.3	15.9	8
60	30.8	29.1	28.0	12.0	23.8	8
90	28.3	40.1	39.0	-	-	4
(b) Summary of experiments by the University of Saskatchewan comparing seed placed and broadcast urea and ammonium nitrate of Manitou and Pitic wheat (1970)						
		Manitou wheat				
20	19.8	8.0	6.4	6.4	5.2	2
30	19.8	9.2	8.5	7.1	7.6	2
40	19.8	11.0	10.5	6.3	6.9	2
80	19.8	11.7	12.9	-	12.7	2
160	19.8	3.6	14.8	-	15.9	2
		Pitic wheat				
20	25.7	10.3	9.8	10.3	6.7	2
30	25.7	14.3	10.8	11.9	11.9	2
40	25.7	14.2	12.9	8.3	11.0	2
80	25.7	15.1	21.3	-2.0	20.6	2
160	25.7	5.8	21.5	-	20.9	2

Table 5 (cont'd)

Rate of N applied	Ave. Check yield (bu/acre)	Average yield increase (bu/acre)				No. of Trials
		NH_4NO_3		Urea		
		Broad-cast	Broadcast and Incorp.	Broad-cast	Broadcast and Incorp.	
(c) Summary of experiments by Ridley comparing broadcast and broadcast and incorporated urea and ammonium applied in the fall and spring to barley (Manitoba, 1968-72)						
		Spring applied				
30	26.1	14.5	14.4	16.2	13.6	6
60	29.1	26.5	22.4	24.4	23.8	7
		Fall applied				
30	26.1	11.1	10.9	6.3	9.1	6
60	29.1	17.3	18.3	13.4	14.6	8

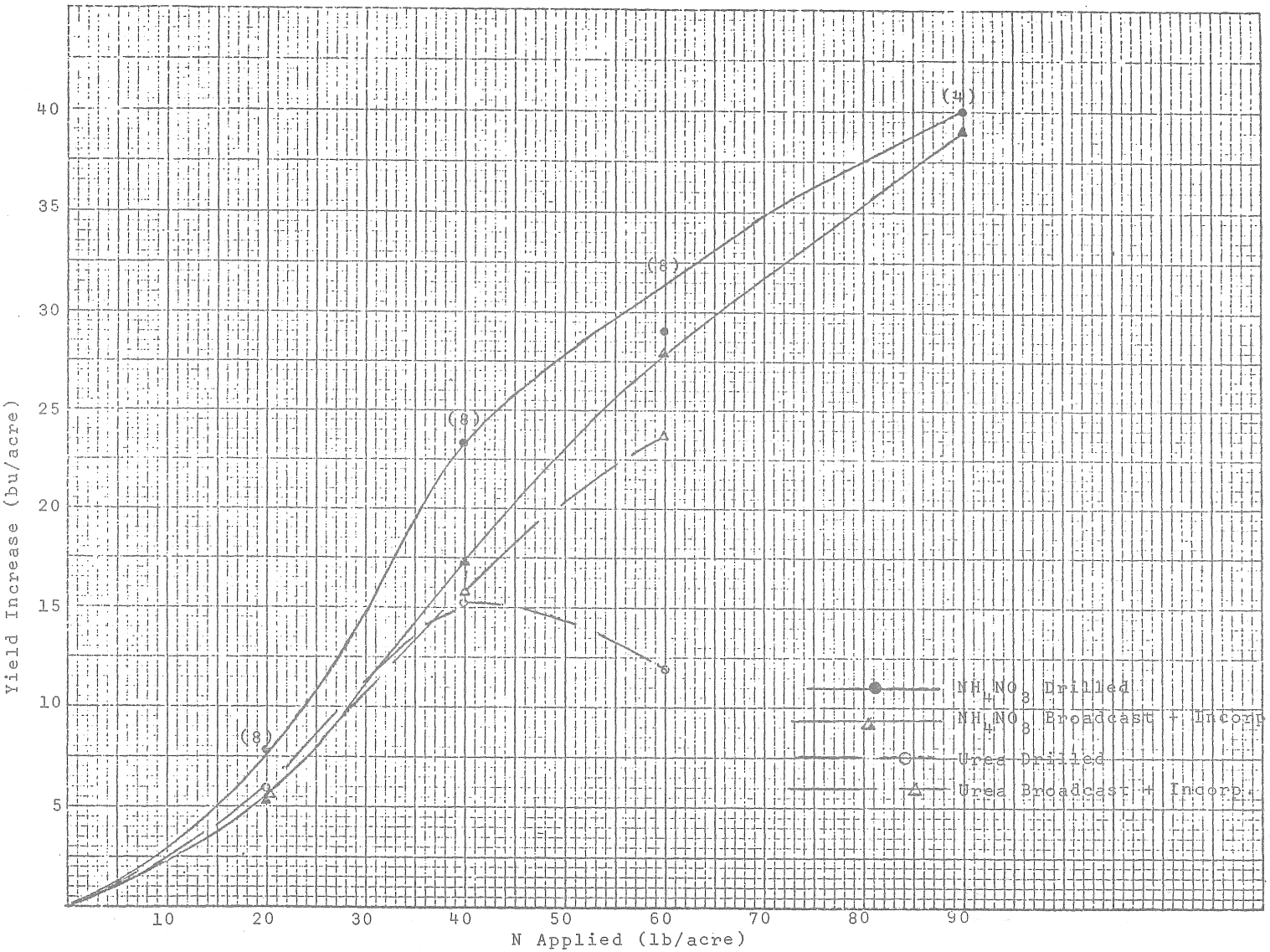

Fig. 7 . Response of barley to seed placed and broadcast and incorporated nitrogen.

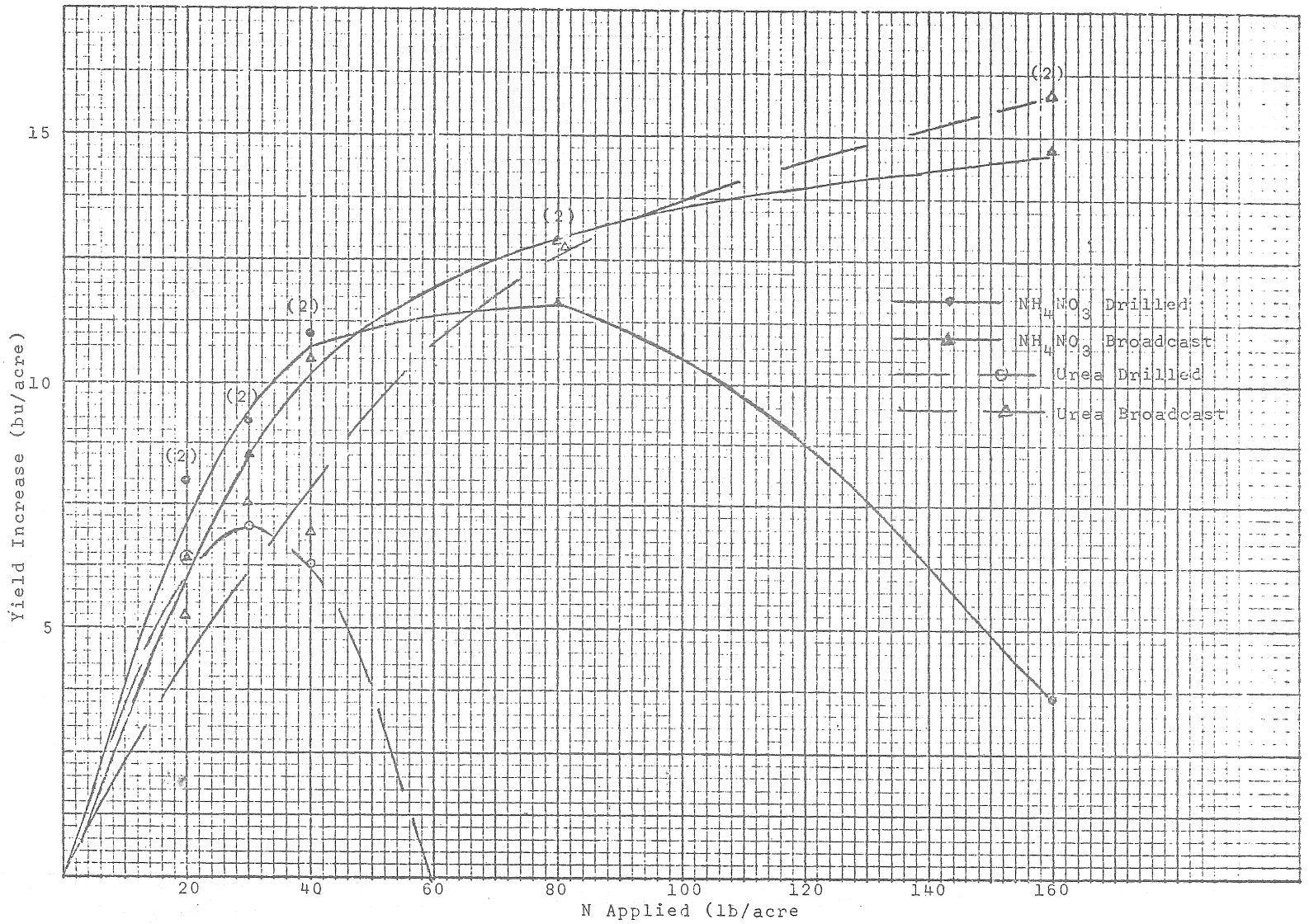

Fig. 8 . Response of Manitou wheat to seed placed and broadcast nitrogen.

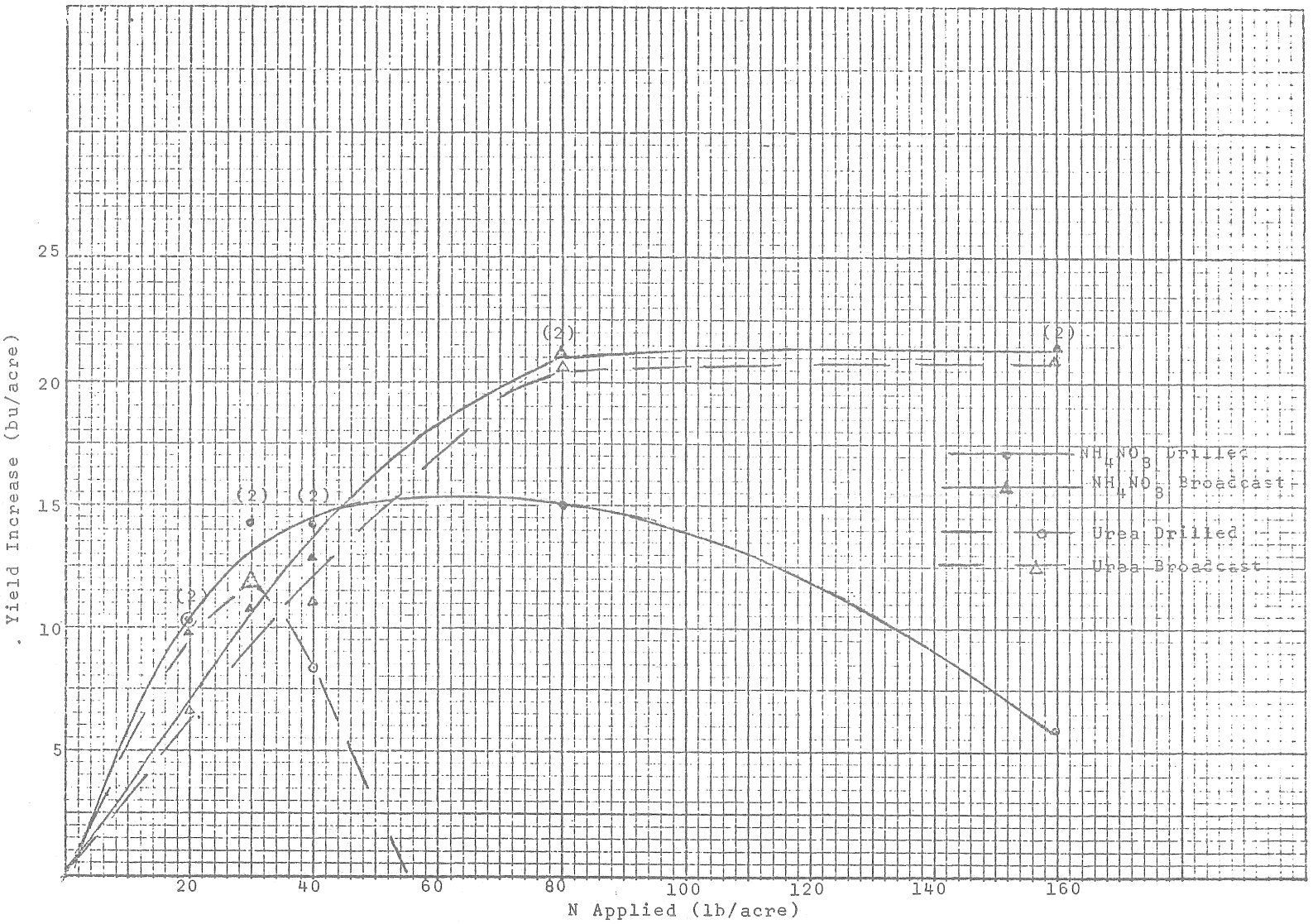

Fig. 9 . Response of Pitic wheat to seed placed and broadcast nitrogen.

seed placement, particularly at the 160 lb N/acre rate where seed placement severely reduced yields. Data from the barley trials, however, indicated that even at application rates of up to 90 lb N/acre seed placement was still more effective than broadcasting. With urea, all the results pointed out that only at application rates of 20 lbs N/acre seed placement is more effective than broadcasting. At higher rates broadcasting results in higher yields, particularly at rates greater than 30 to 40 lbs N/acre where yields from seed placement are considerably reduced.

Results of one major research project were located in which comparisons were made between the yields of barley obtained from broadcast and broadcast and incorporated urea and ammonium nitrate applied in the spring and fall. A summary of this work (conducted by Ridley, University of Manitoba) is presented in Table 5(c). The data indicates that there is no benefit gained from broadcast and incorporating either of the nitrogen carriers over broadcasting when applied in spring, and, average yields were slightly higher from straight broadcasting. The results do, however, indicate that spring application is more efficient than fall application.

4. Summary and Conclusions

Results of this investigation can be summarized as follows:

1) From a large number of experiments conducted over a number of years on a wide range of soil types, there appears to be little difference in the average yields of barley obtained from either urea or ammonium nitrate when broadcast or broadcast and incorporated. If any differences do exist, urea is slightly favoured at lower application rates and ammonium nitrate at higher rates. This does not suggest that in a particular year or on a particular soil type differences do not exist.
2) For other crops such as wheat, rapeseed and flax, if sufficient data were available, similar conclusions could possibly be drawn, since in the data available there is no indication that either of

the nitrogen fertilizer is superior, and also there is no reason to suspect that these crops would respond differently than barley.

3) The limited data available seem to indicate that seed placed ammonium nitrate is more effective than urea for cereals, particularly at higher application rates.

4) Seed drilling of ammonium nitrate at rates of 40 lb N/acre or less is more effective than broadcasting, but at higher rates broadcasting is equally or more effective with less chance of reducing crop yield increases. Seed drilling of urea may be more beneficial than broadcasting at application rates of 20 lb N/acre or less, but at rates of 30 lb N/acre or more broadcasting is more effective. Yield increase reduction from drilling urea occurs at a much lower application rate than from drilling ammonium nitrate.

5) There appears to be no benefit gained from broadcasting and incorporating these fertilizers over broadcasting.

6) Greater yields are obtained from spring fertilizer application over fall application.

Results of the investigation clearly indicate that further work is warranted in several areas of nitrogen fertilization, particularly in areas dealing with comparisons of urea and ammonium nitrate on crops other than barley, and in areas dealing with comparisons of various times and methods of applying these fertilizers. It is further suggested that such work be of a more extensive nature and should investigate the effect of various nitrogen sources and placement techniques. This could be achieved through the conducting of a limited number of detailed experiments on major types of soil which differ in their properties and through the use of such things as ^{15}N enriched fertilizers which would allow detailed nitrogen balance measurements to be made.

Acknowledgements

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