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Nitrogen fertilizer management for Alberta

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Nitrogen fertilizer management for Alberta

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The map on the cover has dots representing Agriculture Canada research establishments.

ONE HUNDRED YEARS OF PROGRESS

The year 1986 is the centennial of the Research Branch, Agriculture Canada.

On 2 June 1886, *The Experimental Farm Station Act* received Royal Assent. The passage of this legislation marked the creation of the first five experimental farms located at Nappan, Nova Scotia; Ottawa, Ontario; Brandon, Manitoba; Indian Head, Saskatchewan (then called the North-West Territories); and Agassiz, British Columbia. From this beginning has grown the current system of over forty research establishments that stretch from St. John's West, Newfoundland, to Saanichton, British Columbia.

The original experimental farms were established to serve the farming community and assist the Canadian agricultural industry during its early development. Today, the Research Branch continues to search for new technology that will ensure the development and maintenance of a competitive agri-food industry.

Research programs focus on soil management, crop and animal productivity, protection and resource utilization, biotechnology, and food processing and quality.

SUMMARY

Experimental evidence was collected from across Alberta on the effects of nitrogen fertilizers on cereal production and the influence of various management practices on the effectiveness of nitrogen fertilizers. Adding the fertilizers in concentrated areas, such as by banding or nesting, increased the yield responses to the fertilizers. No significant differences were found among fertilizers placed in concentrated bands. However, differences were found in the effectiveness of fertilizers broadcast on the soil surface. Late fall application of fertilizers did not result in large losses of nitrogen in the southern parts of the province, but could result in significant losses in the central and northern areas of Alberta.

RESUME

Des données expérimentales ont été recueillies dans diverses parties de l'Alberta sur les effets de la fumure azotée sur la production des céréales, et sur l'influence de diverses pratiques agronomiques sur la valorisation des engrais azotés. L'épandage des engrais en zones concentrées, soit en bandes ou en paquets, a accru la réponse des cultures à la fertilisation. On n'a pas relevé de différences significatives de rendement entre les divers engrais localisés en bandes concentrées, mais il y en a eu pour les engrais épandus à la volée à la surface du sol. La fumure réalisée en fin d'automne n'a pas donné lieu à de fortes déperditions d'azote dans le sud de l'Alberta, mais cette pratique pourrait entraîner des pertes significatives dans le centre et le nord de la province.

Not all nitrogen (N) fertilizers will have equal effects on crop yields. The form of N fertilizer can affect yields, especially under controlled conditions where only N is limiting. Under field conditions, the method of applying N can have as much or greater effect on crop yields as the form of N. Another important aspect of fertilizer management is the time of addition (i.e., spring vs fall) and its effect on losses of N.

The use of fertilizers in western Canada has increased more than fifteen-fold during the past 25 years and is still increasing. The ratio of $N:P_2O_5$ in the fertilizer sold in western Canada has increased from approx. 0.5 in 1960 to approx. 2.0 at the present. This reflects the relatively recent and increased interest in N and questions related to N efficiency.

FERTILIZER FORMS

Nitrogen fertilizers are made from one or more chemical forms (Table 1) to produce a variety of fertilizer products (Table 2). However, most of the N sold in western Canada is in the form of urea, ammonium nitrate, and anhydrous ammonia. There have been shifts in the N supply patterns during the past 25-year period (Fig. 1). In the 1960's, ammonium nitrate accounted for 75% of the N sold. At the present time this product only accounts for 12% of the market, while anhydrous ammonia and urea hold 45% and 40% respectively.

Table 1. Chemical forms of nitrogen in fertilizers.

Ammonia: NH_3	- toxic gas that is compressed to form a liquid normally referred to as anhydrous ammonia. Application requires injection below soil surface. Ammonia volatilizes quickly into a gaseous form, but in the soil, it reacts quickly to form ammonium.
Ammonium: NH_4^+	- positively charged; it is attracted to and held by clays in the soil and resists movement in the soil water. In soil, it can be quickly converted to nitrate unless protected from microbial attack.
Nitrate: NO_3^-	- negatively charged; it moves easily in the soil water which can lead to losses by runoff or deep percolation of water. It is the form that plants absorb most readily. If the soil is wet, lack of oxygen may result in denitrification of nitrate by soil microorganisms, and N gases may be produced.
Urea: $CO(NH_2)_2$	- a man-made product resulting from the combination of ammonia with carbon dioxide. In soil, it is relatively unavailable to plants until it is broken down to ammonia by enzymes.

Table 2. Types of nitrogen fertilizers.

Common name	Analysis	Form of N Provided	Comments
Anhydrous ammonia	82-0-0	NH_3	
Aqua ammonia	20-0-0	NH_4^+	Ammonia dissolved in water
Urea	46-0-0	$CO(NH_2)_2$	
Ammonium nitrate	34-0-0	NH_4^+ and NO_3^-	
Solution N	28-0-0	NH_4^+, NO_3^- and $CO(NH_2)_2$	Equal amounts of ammonium nitrate and urea dissolved in water
Ammonium sulphate	21-0-0	NH_4^+	Provides N plus sulfur (24% S)
Calcium nitrate	17-0-0	NO_3^-	Available only in limited quantities in Canada

Because of the different chemical characteristics of the compounds, the action of fertilizers will initially depend on their constituent parts. However, the forms of N are in constant change due to the activity of soil microorganisms. The series of conversions is summarized in Figure 2.

Thus, although N is added in one form, the plant can usually absorb N in the form it prefers. Since nitrate is used by the denitrifying organisms, it is the form most susceptible to N loss. The longer the N is present in the soil as nitrate, the greater the potential for N loss. The more thoroughly a fertilizer is incorporated into a soil (i.e., increased soil-fertilizer contact), the more rapid the conversion of ammonium to nitrate and the greater the potential loss by leaching and denitrification. By placing an ammonium-forming fertilizer in a tight compact band, the rate of conversion to nitrate is slowed and the potential for loss is reduced.

AMMONIUM NITRATE VS UREA

Barley yield increases resulting from broadcast application of urea and ammonium nitrate in the spring are shown for irrigated land in the southern part of the province (Fig. 3). Ammonium nitrate was more effective than urea, except at the high levels of application. Note that the X-axis of Fig. 3 is SOIL+ADDED N, so the level of available N in the

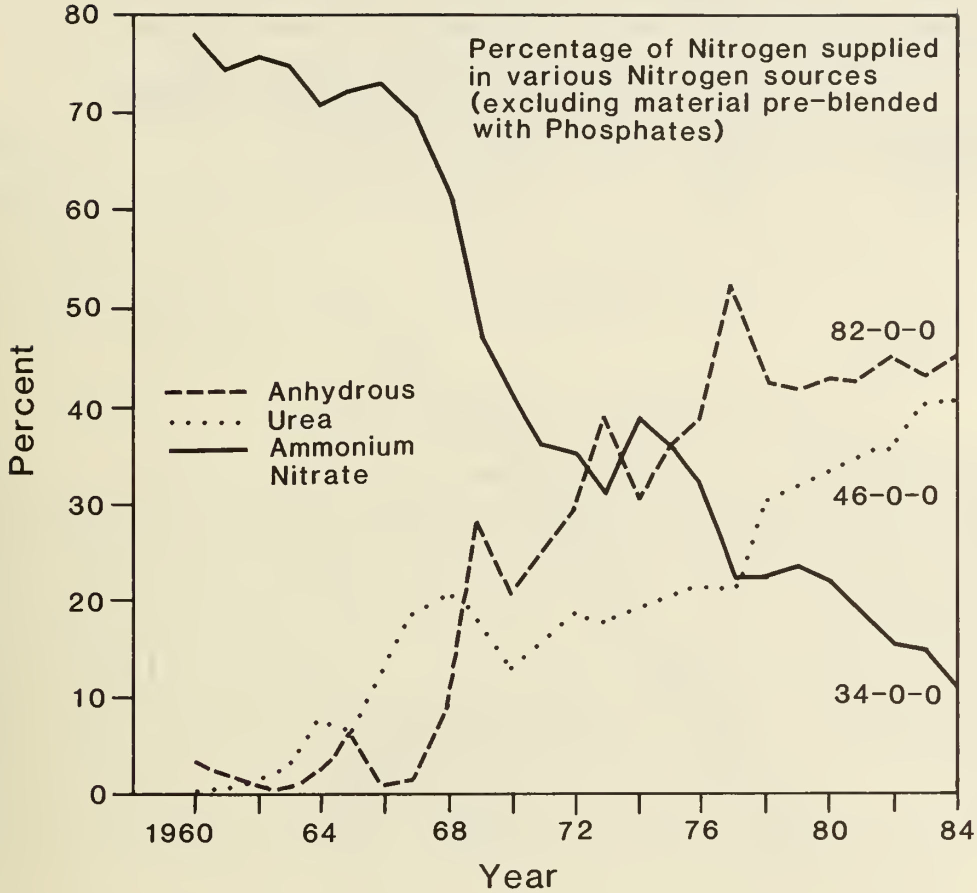

Fig. 1. Market share of the three main N sources over a 25-year period in western Canada.

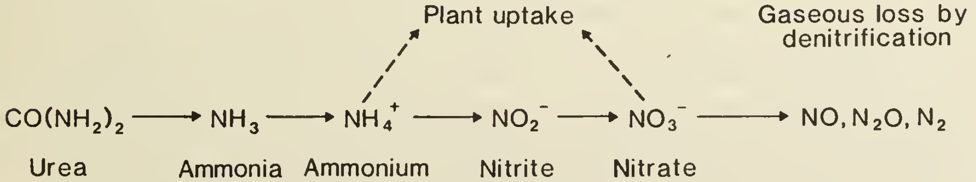

Fig. 2. Products of the conversion of N fertilizer in the soil.

soil (soil-test N) should be subtracted from the value to derive N added. Also note that the Y-axis is YIELD INCREASE, i.e., the increased crop yield resulting from N addition. The differences between the lines are important because the ammonium nitrate line is very close to the N fertilizer recommendation curve. Thus, if broadcast methods are used, particularly if fertilizer is not or can not be incorporated, then ammonium nitrate is the form with less potential for losses and hence greater effectiveness. If urea is to be used, the increased amounts needed to achieve optimum yields can be calculated from Fig. 3.

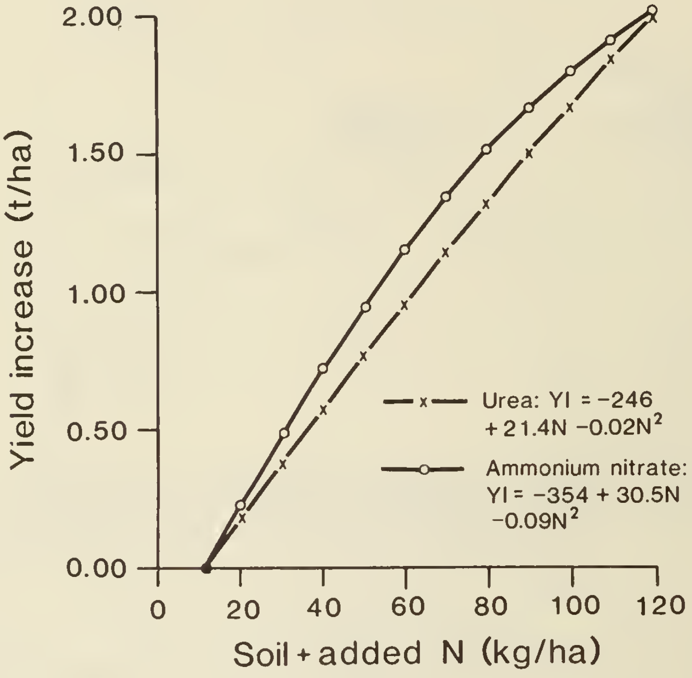

Fig. 3. Barley yield increases from spring-applied, broadcast N fertilizers in southern Alberta. YI = yield increase relative to unfertilized yields; N = soil test N + added fertilizer N.

All urea-based fertilizers will be subject to the same effects if applied to the surface. On dryland, ammonium nitrate is more effective than urea if the moisture conditions are adequate. For example, in central and north-central Alberta where soil moisture in general is not a limiting factor for crop growth, broadcast application of urea was less effective in increasing grain yield of barley than similarly applied ammonium nitrate (Table 3). However, when the N fertilizers were broadcast and incorporated into the soil to a depth of 10 to 12 cm, there were slight yield differences between the two N fertilizers. Under dryland conditions, differences between fertilizers will be minimal because water, not N, is the factor limiting crop growth.

Table 3. Yield increase of barley from spring-applied urea and ammonium nitrate in central Alberta*

	Yield increase (kg/ha)	
	Urea	Ammonium nitrate
Broadcast	990	1200
Broadcast and incorporated (10-12 cm)	1280	1340

*56 kg N/ha applied, average of 4 experiments.

METHODS AND TIME OF APPLICATION

Interest in banding of N has raised questions with regard to the effectiveness of banded N relative to broadcast N and how this might affect N fertilizer recommendations based on soil tests. Research has shown that if N fertilizers are banded 15 cm below the surface, no differences in effectiveness are found. Thus, anhydrous ammonia, urea and ammonium nitrate can result in the same yield. Furthermore, the yield increases obtained are greater than those obtained with broadcast forms added at the same rates. The relative yields from N application by banding and broadcasting are shown in Fig. 4. If the spring broadcast curve in Fig. 4 is considered to be the response curve for the standard method of adding N fertilizer, then the spring-banded curve clearly shows that yields can be increased by banding the same N rate. Conversely, N additions can be decreased, if N is banded, without reduction in yields.

Figure 4 also shows the yields obtained from fall application of N. Basically, it shows that at low to moderate rates of N addition, there was little reduction in yield from fall treatments relative to the spring-applied treatments. At higher levels of N addition, yields are less from fall treatments. Care must be used in interpreting these curves because the data are from an experiment in which the fall-applied N was added very late in the season. The soil temperature at the time of N application was below 5°C. On some soils, application earlier in the fall can result in 20-30% losses of N before winter. If fall application can be made late in the season, then the amounts needed to compensate for the losses can be calculated from Fig. 4. The losses are greater in areas of greater rainfall i.e., central and northern Alberta. For example, in northern Alberta, substantial amounts of mineral N were lost from fall-applied urea when it was incorporated into soil in field experiments. Consequently, fall-applied treatments gave significantly lower yields of grain than did similar applications of urea in the spring. Delaying applications from early to late fall increased yields relative to the earlier application. The relative efficiency of fall- vs. spring-applied urea was approx. 30% for urea applied in late September and approx. 70% for urea applied in late October under these conditions.

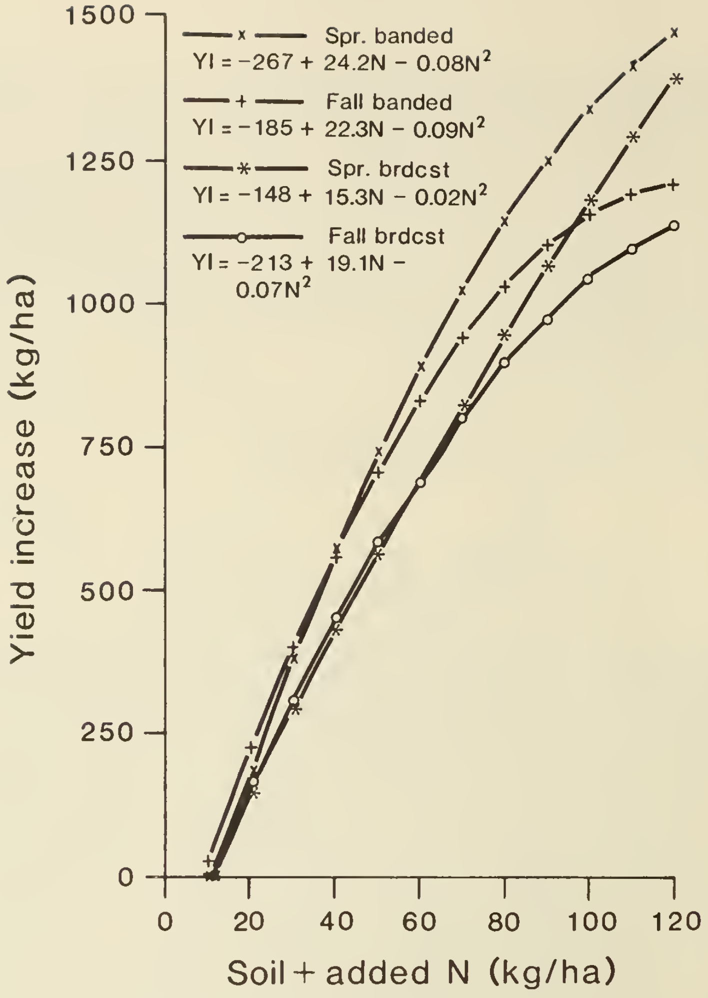

Fig. 4. Barley yield response to N fertilizer applied to southern Alberta soils. YI = yield increase relative to unfertilized yields; N = soil test N + added fertilizer N.

In a second set of experiments, the method of N application was shown to have a marked effect on the efficiency of fall-applied urea. Banding N, or placing it in concentrated "nests" (spot application), improved the yields of grain (Table 4). The yields from fall-applied bands or nests were greater than from fall-applied broadcast-and-incorporated treatments, but were still lower than from spring-applied treatments. This indicates that losses of fall-applied N can be reduced if the time of addition is delayed until close to freeze-up and if the N is placed in bands or concentrated nests.

As illustrated by a different set of data (Table 5) based on a number of field trials located throughout Alberta, fall banding was the most effective of the four options available for applying fertilizer, particularly in years with low soil moisture supplies. These findings are in agreement with an Alberta Agriculture survey of the cultural practices used by the farmers achieving top yields of barley and canola in central Alberta. Higher yields were achieved by deep banding N fertilizers in the fall of the year than by broadcasting and incorporating N in the spring. Surveyed farmers cited problems with moisture loss and delayed seeding with spring fertilization as key reasons for the superiority of fall fertilization.

Table 4. Effect of N placement and time of addition on barley grain yield increase in central Alberta.

Method of addition*	Time of addition	Yield increase (kg/ha)
Broadcast and incorporated	Fall**	830
Banded (5 cm depth 46 cm apart)	Fall	1140
Nested (1 spot in 46 x 46 cm area, 5 cm depth)	Fall	1480
Broadcast and incorporated	Spring	1710

*N added at 56 kg N/ha, average of 20 experiments

**Fall application between Sept. 27 and Oct. 23

Table 5. Relative performance of fall- and spring-applied N fertilizer in situations where soil moisture conditions were less than optimal.

	Barley yield increase (kg/ha)**	
	Fall	Spring
Broadcast and incorporated*	672	717
Banded	907	806

*N added at 56-67 kg N/ha as 34-0-0 or 46-0-0, incorporated 5-7 cm.

**Average of 15 trials.

CONCLUSIONS

1. If broadcast methods are used, ammonium nitrate results in greater yields than equivalent rates of urea N. Fertilizer prices will determine which form is most economical to use.

2. Fall-applied N, especially in the Black and Dark Grey soils of Alberta, was not as effective in increasing crop yields as spring-applied N. N losses from fall-applied N can be reduced by banding or nesting N and delaying the time of application until late fall.

3. Banding of granular N or anhydrous ammonia results in greater yields than equivalent rates of broadcast granular N. All fertilizers tested were equally effective if banded to a depth of 15 cm. Increased costs of banding application, or increased horsepower requirements of banding equipment, will have to be included in a determination of whether this practice will be economically feasible.

4. Fall application of N, if made after soil temperatures fall to 5°C, does not result in significant losses of N relative to spring-applied N in the southern part of the province. In the central and northern parts of Alberta, N broadcast in the late fall is still subject to losses. Late-fall banded or nested N is almost as effective as spring-applied N and, in cases where spring soil moisture is limited, fall application may prove to be more effective than spring application.

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