UNCONVENTIONAL METHODS OF FERTILIZER PLACEMENT TO REDUCE LOSSES OF FALL APPLIED NITROGEN

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ABSTRACT

In two field experiments conducted in 1978-79, fall application of incorporated urea, or banded aqua ammonia, produced much less increase in yield and N-uptake than did spring application for barley grain. However, when the fall-applied fertilizers were placed in constricted nests (one nest per each 45 cm x 45 cm area) the yield and N-uptake were nearly as great as with spring application. The mechanism by which nests avert losses from fall-applied N is through slowing of nitrification, and possibly through lessening of immobilization of fertilizer N by straw. Indirect evidence suggests that placement in nests is more effective than inhibitors of nitrification in reducing losses from fall-applied N fertilizers.

The two field experiments in 1978-79, and three experiments in 1977-78 with fall-applied urea showed that band placement improved yield in comparison to incorporation, but the banding was inferior to nesting. More specifically, yields with incorporation, banding, nesting, and spring incorporation were 960, 1240, 1560, and 1830 kg/ha, respectively. In the same order, values for % uptake of fertilizer N, were 31, 38, 53, and 66%.

Taking all of the eight experiments which have been conducted with nesting during the past four years, average yield increases were 1030, 1750, and 1980 kg/ha for fall incorporation, fall nesting, and spring incorporation, respectively. This work has been restricted to northern Alberta and northern Saskatchewan, and the feasibility of practical field-scale techniques of nesting, or application of large pellets, has not yet been investigated, but nevertheless the benefit of fall nesting is large enough to suggest work on this topic by other researchers in other areas of the Prairie Provinces.

INTRODUCTION

In portions of western Canada fall-applied N fertilizer is often less effective than spring-applied N fertilizer (Ridley, 1977; Nyborg and Leitch, 1979). Limited information shows that efficiency of fall-applied N fertilizer is increased by band placement and especially by nest placement, as compared to broadcasting or incorporation (Nyborg and Malhi, 1979; and Nyborg, Malhi, Monreal, 1979). The superiority of yield and N-uptake with nesting is in part through the slowing of nitrification of the applied fertilizer, with consequent

lessening of denitrification which occurs with the spring thaw of soils (Nyborg, Malhi, and Monreal, 1979).

The technique of nest placement, or similar methods for applying nitrogen fertilizers is not new (e.g. Shiga, Ventura, and Yoshida, 1977), but this technique has not been used experimentally before in western Canada for agricultural crops. While in field experiments in northern Alberta and northern Saskatchewan the placement of fall-applied N fertilizers in nests has produced more plant-available N for the crop than has the other techniques used for fall-application of N, there have been too few field experiments on this topic to make definite and well-tested conclusions.

The purpose of this article is to report on the field and laboratory experiments conducted in 1978-79 to further compare nest placement with banding and incorporation in their effect on yields and on N-uptake, to find if nest placement functions with aqueous ammonia fertilizer as with urea, and to find any effect of nest placement on immobilization of mineral N by straw.

METHODS AND MATERIALS

Two field experiments, in a randomized complete block design in four replicates, were set out in September, 1978. There were 14 treatments. Individual sub-plots were 6.8m by 1.8m in size, and consisted of 8 rows sown to Galt barley with row-spacing of 23 cm. Fall-applied N fertilizers were added in the following ways: incorporation of dry fertilizer with a "rototiller" to a depth of about 12 cm into the soil; banding of dry fertilizer at a depth of 5 cm with a row-spacing of 45 cm; nest placement at a depth of 5 cm with one nest placed in each 45 cm by 45 cm area but the volume of the nest being less than 3 cm by 3 cm by 3 cm; banding of aqua ammonia at a depth of 10 cm with a row-spacing of 45 cm; and nest placement of aqua ammonia at a depth of 10 cm. There were only two treatments with spring applied-N, incorporated urea and banded aqua ammonia.

RESULTS AND DISCUSSION

The need for improving methods of application of fall-applied N fertilizers, at least in the north, is demonstrated by the accumulated results from six years (Table 1). The increase in yield of barley grain from urea fertilizer was twice as great from spring application as from fall application, on the average, for 31 field experiments conducted in 1973-74 to 1978-79 in northern Alberta and northern Saskatchewan. (Similar results were obtained with ammonium sulphate and with aqua ammonia.) The differences were slightly greater in N uptake by the barley grain. The dates of fall application (average of Oct. 17, within a range of Sept. 26 to Nov. 9) were early in some of the experiments, and late in other experiments, and the differences between fall and spring application usually tended to be the largest with the early fall application. Nevertheless, there were usually substantial differences between fall and spring application regardless of time of fall application. Therefore, there is a practical place for finding ways of improving the effectiveness of fertilizer N added in the fall as compared to the spring.

Table 1. Average of yield, and of N-uptake, with barley in 31 experiments comparing fall and spring application of incorporated urea at a rate of 56 kg N/ha.

Urea treatment	Yield of barley grain (100 kg/ha)	Apparent uptake of fertilizer N (%)
None	15.8	
Fall	25.4	28.1
Spring	35.0	61.6

This article gives the results in detail for the two field experiments conducted in 1978-79 with fall application of nests and bands of urea and aqua ammonia fertilizers. In addition, this article summarizes some of the results taken from the total of eight field experiments conducted with nests from 1975-76 to 1978-79. The location of the eight experiments, in this four-year period, is shown in Figure 1.

At location No. 7, on a Gray Luvisolic soil of good external drainage the yield without N fertilizer was 2650 kg/ha of barley grain, and the increase in yield from fertilizer N was, at the maximum, 1830 kg/ha (Table 2). The yield and N-uptake increases, however, varied widely with time and method of application. With mixed application of urea in late September, mid-October, early November, and on June 1, the yield increases were 310, 520, 710, and 1830 kg/ha, respectively. With application on October 13 of incorporated urea, banded urea, and nested urea yield increases were 520, 970 and 1670 kg/ha, respectively. That is, with fall application, nest placement greatly improved yield as compared to incorporation.

While nest placement of dry urea and of dry ammonium sulphate have both been used in previous field experiments (Nyborg, Malhi, and Monreal, 1979), aqua ammonia has been used in a nest placement for the first time in the present field experiments. The yield increase from fall-applied aqua ammonia was greater with nesting, as compared to banding, and this effect was somewhat greater with aqua ammonia than with urea (Table 2).

The recovery of fertilizer N in barley grain for the various treatments gave approximately the same type of results as obtained with yield increases (Table 2).

The results for the recovery of fall-applied urea N as the mineral-N found in the soil on May 24, showed values of 30, 60, and 93% for incorporation,

banding, and nesting, respectively (Table 2). That is, almost all of the nested N was found again as mineral-N but only approximately one-third of the incorporated-N is found as mineral-N. At May 24, one-half of the mineral-N still remained as ammonia-N with the nest placement. Previous results indicated that nitrification of incorporated fertilizer N was well underway by the time of spring thaw, allowing substantial denitrification, while the placed fertilizers (especially in nests) remained in the ammonium form and resistant to denitrification (Malhi and Nyborg, 1979; and Nyborg, Malhi, and Monreal, 1979; and Nyborg and Leitch, 1979).

There were treatments in the experiment at location 7 which compared use of nests with and without the application of nitrification inhibitors. The two inhibitors added to the nests had no significant effect on yields, N-uptake of barley, or the mineral-N content of soil (Table 3). Most probably, the nested urea or aqua ammonia remained in the ammonia form at the time of soil thawing (early April), and the two inhibitors therefore had no additional effect on reducing nitrification.

A similar field experiment was conducted at location 8 (Figure 1), but at this location the soil was Black and poorly drained. The yield without N fertilizer was 2150 kg/ha of barley grain, and with N fertilizer the maximum yield was 4270 kg/ha. In this experiment (Table 4), the incorporation of urea in the fall was particularly poor in increasing the yield when the application occurred late in September as opposed to mid-October (yield increases of 300 and 1020 kg/ha, respectively). The yield increases with incorporation, banding,

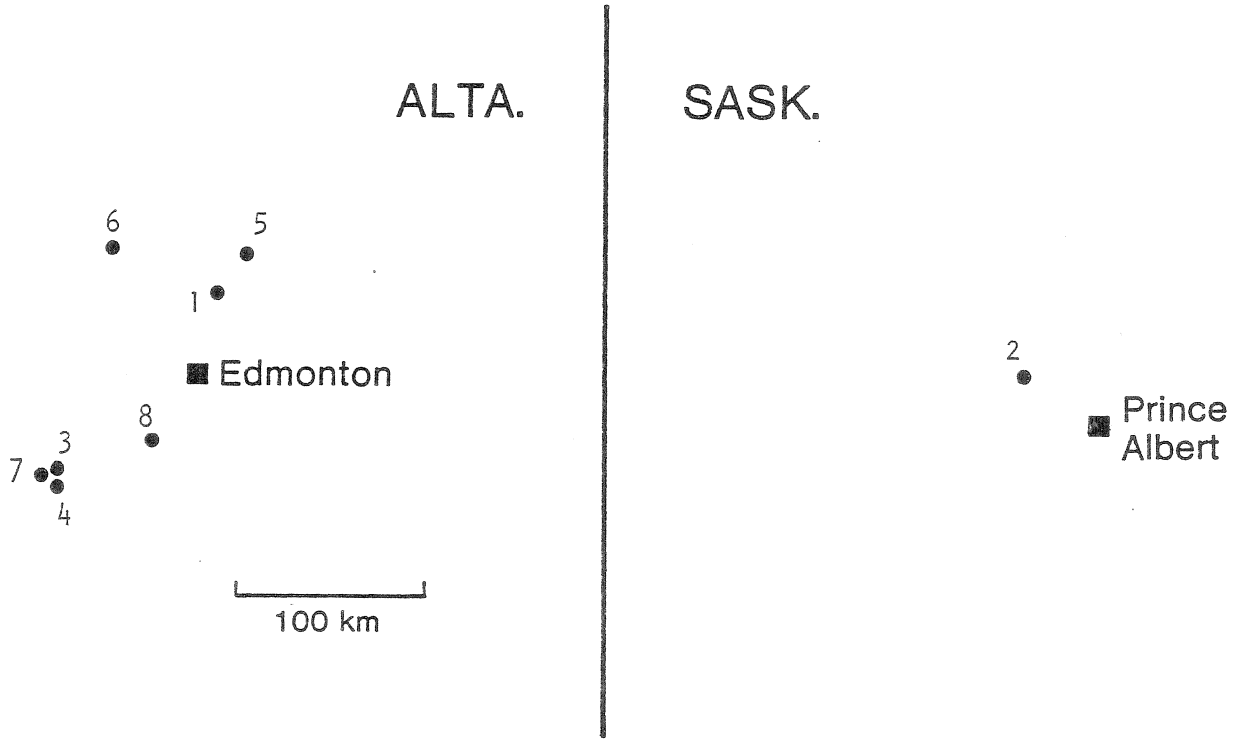

Figure 1. The location of field experiments.

Table 2. At location No. 7, the effect of kind, method and time of application of fertilizer N on the yield increase and N-uptake of barley grain, and on the soil content of mineral-N before sowing. Fertilizer N applied at the rate of 56 kg/ha.

Fertilizer	*Method	Date	Increase in yield (100 kg/ha)	% recovery of N in grain	% apparent recovery of fertilizer N in soil on May 24	
					NH_4-N	Mineral-N
$Ca(NO_3)_2$	Mixed	Oct. 13	3.5cd	9fg	0d	22d
Urea	Mixed	Sept. 26	3.1cd	13efg	1d	19d
Urea	Mixed	Oct. 13	5.2bc	15def	1d	30cd
Urea	Mixed	Nov. 2	7.1bc	27cd	1d	47bc
Urea	Banded	Oct. 13	9.7b	30c	6cd	60b
Urea	Nested	Oct. 13	16.7a	61b	50ab	93a
Urea	Mixed	June 1	18.3a	78a	**	**
NH_3	Banded	Oct. 13	7.0bc	23cde	6cd	55b
NH_3	Nested	Oct. 13	16.1a	58b	16c	94a
NH_3	Banded	June 1	16.7a	65ab	**	**

** These treatments of spring-applied fertilizers were not soil sampled because the fertilizers were applied just before sowing

* Mixed signifies the incorporation of fertilizer into the top 12 cm of soil

Note: In each column any two values are statistically different (P=0.05) when not followed by any common letter.

Table 3. At location No. 7, the effect of nitrification inhibitors applied with urea or NH_3 placed in nests on the yield increase and N-uptake by barley grain, and on the soil content of mineral-N before sowing. Fertilizer N applied at a rate of 56 kg/ha on October 13.

Fertilizer	Method	Inhibitor	Increase in yield (100 kg/ha)	% recovery of N in grain	% apparent recovery of fertilizer N in soil on May 24	
					NH_4-N	Mineral-N
Urea	Mixed	None	5.2bc	15def	1d	30cd
Urea	Nest	None	16.7a	61b	50ab	93a
Urea	Nest	*Thiourea	17.5a	65b	62a	91a
NH_3	Band	None	7.0bc	23cde	6cd	55b
NH_3	Nest	None	16.1a	58b	16c	94a
NH_3	Nest	**N-Serve (24E)	15.6a	61b	42b	87a
NH_3	Nest	*Thiourea	16.4a	65ab	39b	91a

* Rate of application of thiourea was 10 kg/ha; and the thiourea was placed in the same nests as the urea or NH_3

** Rate of application of N-Serve (24E) was 2 kg/ha; and the 24E solution was placed in the same nest as the aqua NH_3

Note: In each column, any two values are statistically different (P=0.05) when not followed by any common letter.

Table 4. At location 8, the effect of kind, method and time of application of fertilizer N on the yield increase and N-uptake of barley grain. Fertilizer N applied at the rate of 56 kg/ha.

Fertilizer	*Method	Date	Increase in yield (100 kg/ha)	% recovery of N in grain
$Ca(NO_3)_2$	Mixed	Oct. 12	5.3gh	11fgh
Urea	Mixed	Sept. 27	3.0hi	9gh
Urea	Mixed	Oct. 12	10.2ef	31e
Urea	Mixed	Nov. 2	8.7fg	23ef
Urea	Banded	Oct. 12	12.5de	34cde
Urea	Nested	Oct. 12	16.4bc	47bc
Urea	Mixed	May 31	21.2a	65a
Aqua NH_3	Banded	Oct. 12	7.4fg	22efg
Aqua NH_3	Nested	Oct. 12	15.0bcd	46cde
Aqua NH_3	Banded	May 31	19.6ab	55ab

* Mixed signifies the incorporation of fertilizer into the top 12 cm of soil

Note: In each column, any two values are statistically different (P=0.05) when not followed by any common letter.

and nesting of urea in mid-October, were 1020, 1250, and 1640 kg/ha respectively. So, while nest placement did give a significant yield increase as compared to incorporation, the nests fell 480 kg/ha short of the spring application (Table 4). With fall-application of aqua ammonia, the yield increase from nest placement was 760 kg/ha more than from banding, but was 460 kg/ha less than spring application. This experiment, at location 8, showed considerable yield increases from nest placement of urea or aqueous ammonia, but the increases were not as dramatic at location 7. It is of some interest that location 7, with a well-drained soil, had more effect from nest placement than location 8 with a poorly-drained soil.

In the experiment at location 8, N-uptake by barley grain gave a similar type of results as did the yield increases (Table 4). At location 8, as at location 7, the addition of the two inhibitors (thiourea, or N-Serve) to nested urea or aqua ammonia was of no benefit (Table 5).

Two field experiments were carried out with four different inhibitors added to fall-applied urea (Table 6). Unfortunately, these two experiments were not put out at the same locations as those experiments with nests, but the results will give a rough comparison of inhibitors and nests in their ability to increase yields from fall-applied N. The increases in yield from banded urea, from inhibitors (average of four) added with banded urea, and from spring applied urea were 960, 1480, and 2580 kg/ha of barley, respectively. While there was a fair yield increase from the inhibitors (average 520 kg/ha) with fall-applied urea, the fall-applied urea with inhibitors yielded 1100 kg/ha short of the spring-applied urea. Consequently, the results in Table 6, and possibly in Tables 3 and 5, indicate that with full-N the inhibitors do not give as large yield increases as does nest placement. Results not given in this article, show that the four inhibitors added in full were effective in slowing nitrification during the spring. This is rather puzzling.

The yield increases and increase in N-uptake of barley by nest placement is mostly caused by reducing denitrification of fall-applied N. However, the nests, as opposed to bands or especially incorporation, are less exposed to the mass of soil and perhaps the constricted nests are less subject to any net immobilization of mineral-N that proceeds in the soil. A greenhouse experiment was conducted on this subject. Two soils were sampled in the fall after harvesting of barley. The Black soil had a moderate straw cover and the Gray Wooded soil had a very light straw cover, and this straw was mixed into the soils as they were sampled. The soils were incubated in wooden boxes 30 cm square and 15 cm deep. The fertilizer-N was either mixed into the soil or there was placement of one nest per box. There were treatments with no extra straw added, and treatments with 4 tonnes per ha of finely ground straw incorporated into the soil.

When the finely ground extra straw was not added, close to 100 % of the nest placed fertilizer N was recovered at 8, 16, or 24 days, but for the Black soil the recovery of incorporated fertilizer N was only 60 to 72 % (Table 7). With the addition of the 4 tonnes/ha of finely ground extra straw, the recovery of mineral-N from the nest placement varied with time and soil ranging from 43 to 101 %, but the recovery of the incorporated fertilizer N was very low, ranging from 6 to -27 %. This laboratory experiment showed, in summary, that nest placement lessened the immobilization

Table 5. At location 8, the effect of nitrification inhibitors applied with urea or NH_3 placed in nests on the yield increases and N-uptake by barley grain. Fertilizer N applied at a rate of 56 kg/ha on October 12.

Fertilizer	Method	Inhibitor	Increase in yield (100 kg/ha)	% recovery of N in grain
Urea	Mixed	None	10.2ef	31e
Urea	Nest	None	16.4bc	47bc
Urea	Nest	*Thiourea	16.5bc	49b
NH_3	Band	None	7.4fg	22efg
NH_3	Nest	None	15.0bcd	46cde
NH_3	Nest	**N-Serve	13.0cde	33de
NH_3	Nest	*Thiourea	16.9b	50b

* Rate of application of thiourea was 10 kg/ha; and the thiourea was placed in the same nests as the urea and aqua NH_3

** Rate of application of N-Serve (24E) was 2 kg/ha; and the 24E solution was placed in the same nest as the aqua NH_3

Note: In each column, any two values are statistically different (P=0.05) when not followed by any common letter.

Table 6. Yield increases of barley grain with urea (56 kg of N/ha), and with nitrification inhibitors. Average of two experiments in 1978-79.

Method and time for urea	Inhibitor	Rate of inhibitor (kg/ha)	Yield increase (100 kg/ha)	Apparent uptake of fertilizer N(%)
Band, Oct.	None		9.6	24
Band, Oct.	CS_2	10	14.3	35
Band, Oct.	K_2CS_3	24	15.2	40
Band, Oct.	ATC	2	14.3	37
Band, Oct.	N-Serve(24E)	4	15.6	41
Mix, May	None		25.8	77

of mineral-N. However, it may be another matter to show this effect as clearly in the field.

Concerning the comparison of banding and nesting of fall N, three field experiments from 1977-78 were averaged with the two field experiments conducted in 1978-79, and the results are displayed in Table 8. Based on yield increase of barley grain, fall N gave a larger increase with banding rather than incorporation, but nest placement gave an increase slightly more than twice as much as with banding. Values for N-uptake in the grain gave wider differences between banding and nesting.

Average results for all the eight field experiments carried on in the last four years appear in Table 9. There were only three treatments common to all the experiments, and with fall application the nests produced 720 kg/ha of barley more than did incorporation, while spring application gave only 230 kg/ha more than did the fall nests. That is, on the average, fall application of nests gave much greater yield increases than did fall incorporation, and the fall application of nests gave yield increases near to those of spring-applied N. While the size of increases from fall-applied nests, as compared to fall incorporation, varied greatly from one experiment to another there were nevertheless increases in every case. The same was generally so for the three experiments in 1977-78 which contained treatments with nested ammonium sulphate and for the two experiments in 1978-79 which contained treatments with aqua ammonia.

Table 7. The recovery of mineral-N derived from urea added to soil (56 kg of N/ha). Incubation of soil at 24 C temperature and 1/3 atm. moisture content.

Soil	*Addition of straw (tonnes/ha)	**Method of adding fertilizer	% recovery of mineral-N from urea after number of days of incubation		
			8	16	24
Black	0	Mixed	70	72	60
	0	Nest	102	94	94
	4	Mixed	-27	-11	-7
	4	Nest	98	43	46
Gray Wooded	0	Mixed	83	78	82
	0	Nest	101	97	99
	4	Mixed	6	-15	-13
	4	Nest	101	99	70

* The straw was incorporated into the soil.

** The "mixed" method was incorporation of the fertilizer into the soil. The "nest" method was placing the fertilizer at a discrete point in each 30 cm by 30 cm area.

Table 8. The effect of band and nest placement on the yield increase and N uptake from urea (56 kg N/ha) for barley grain. Average of five experiments.

Method of application of urea	Time of application	Yield increase (100 kg/ha)	Apparent uptake of fertilizer N (%)
Mix	Fall	9.6	31
Band	Fall	12.4	38
Nest	Fall	15.6	53
Mix	Spring	18.3	66

Table 9. The effect of nest placement on yield increase and N uptake from urea (56 or 84 kg of N/ha) for barley grain. Averages of 8 experiments with yields and 7 experiments with N uptake.

Method of application of urea	Time of application	Yield increase (100 kg/ha)	Apparent uptake of fertilizer N (%)
Mix	Fall	10.3	25
Nest	Fall	17.5	44
Mix	Spring	19.8	56

CONCLUSIONS

1. In northern Alberta and northern Saskatchewan, fall application of incorporated urea or ammonium sulphate, or banded aqua ammonia, usually resulted in much lower yield increases than did spring application.

2. Recent results from two field experiments confirmed that fall-applied nest placement of urea produced much greater yield increase than did fall incorporation. Fall banding also produced more yield increase than fall incorporation, but the yield differences were smaller than with the nests.

3. The benefit of fall nests was found with ammonium sulphate and aqua ammonia, as well as with urea.

4. Fall nesting of N fertilizer is apparently as effective, or more effective, in increasing yields than is the addition of nitrification inhibitors. However, this observation is speculative.

5. The effect of nest placement in reducing over-winter or early spring losses of crop-available fertilizer N takes place through reduction of denitrification, and possibly also through reduction of immobilization of fertilizer N.

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