METHODS OF REDUCING THE SOIL ACIDIFICATION CAUSED BY NITROGEN FERTILIZERS

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INTRODUCTION

The slow acidification of non-calcareous soils with the use of ammonium-based nitrogen (N) fertilizers is well known. In Alberta, this behavior has been documented with agricultural soils by several researchers (Cairns, 1971; McCoy and Webster, 1977; and Hoyt et al.; 1981).

The acidification of soils by N fertilizers essentially is caused by nitrification of the ammonium in the fertilizers. Application of anhydrous ammonia, aqueous ammonium, ammonium nitrate, or urea results in formation of nitric acid after the nitrification in the soil. Theoretically, 3.6 parts of $CaCO_3$ are needed to counteract 1 part of fertilizer N which is nitrified in the soil (Tisdale and Nelson, 1975). Application of ammonium sulphate results in formation of nitric and sulphuric acids on nitrification of the fertilizer, and the calculated value is 7.1 parts of $CaCO_3$ needed to meet the acidity produced by 1 part of N which is nitrified. In practice, the amount of acidification in cropped soils is usually much less than that requiring 3.6 or 7.1 parts of $CaCO_3$ per 1 part of fertilizer N. This is so especially when rates of N fertilizers are modest (Pearson and Adams, 1967). In northern or Central Alberta "typical" results for accumulated acidification from annual application of urea or ammonia at a rate of 100 kg per ha might be a soil pH depression of 0.05 units, annually. This estimate is given here merely as a conservative guideline.

In Alberta, approximately 40% of the cultivated soils have a soil pH of 6.5 and less. Consequently, acidification of soils by N fertilizer is a practical problem. However, liming is the obvious solution as the soils become acid.

The slowing of nitrification of fall-applied ammonium-based N fertilizers has been shown to lessen losses of the N (Nyborg, Malhi, and Monreal; 1980). In the present paper, we report results showing that techniques for slowing nitrification may have the incidental advantage of reducing soil acidification, as well as the main advantage of reducing losses of the fertilizer N.

MATERIALS AND METHODS

Field experiments were set out in randomized complete block design in four replicates. Sub-plots were 6.8m by 1.8m in size. In some experiments fertilizers were applied in the fall on certain sub-treatments and in the spring on others. In other experiments, fertilizers were applied only in the spring. All experiments were cropped to Galt barley. After harvest the soil was cultivated. On each sub-plot of each replication, the soil was sampled by compositing eight cores of the 0-15 cm depth, and the 15-30 cm depth.

Soil pH was determined by adding 50 ml of distilled water to 20 g of soil. The mixture was stirred for 30 minutes, let sit for 1 hour, the hydrogen electrode inserted into the sediment with the reference electrode in the supernatant, and the pH was read after 2 minutes.

The "titration" of soils was made with increments of dilute H_2SO_4 added to a series of containers with a 2.5:1 of water:soil mixture, and pH was determined after 3 days.

RESULTS AND DISCUSSION

Field experiments were conducted to measure the rate of acidification in 1972, 1973, and 1974 at Breton and Ellerslie and only in 1972 at Craigmyle. The soils were a Gray Luvisol (loam), Black Chernozem (silty clay loam), and a Dark Brown Solonetz (loam), respectively. There was a depression in soil pH after application of ammonium nitrate, or urea, at a rate of 67 kg N per ha yearly for three years at the Breton site (Table 1). The difference in pH of the control treatment as compared to the pH of the two treatments was statistically significant, and the differences were 0.20 and 0.32 with the ammonium nitrate and with the urea, respectively. The ammonium sulphate, at 67 kg N per ha, gave more lowering of soil pH, as would be expected. At the Craigmyle site, with only one season's results, the 67 kg N/ha rate showed a statistically significant depression of pH only on the ammonium sulphate treatment.

A rate of 202 kg N per ha of any of the three fertilizers mixed into the soil produced marked lowering of soil pH. However, for the ammonium sulphate and for the urea this high rate was also applied by placement in bands (23 cm apart) at time of seeding. The placement was made at 2.5 cm to the side of the row by 2.5 cm below the row. Application of either of the two fertilizers in bands, instead of mixing the fertilizers into the soil, resulted in much less soil pH depression.

The amounts of $CaCO_3$ required to counteract the acidity produced per unit of fertilizer N varied a good deal for the different treatments on each of the soils (Table 2). The results with mixed and banded urea, at 202 kg N per ha, showed striking differences between those two methods. With mixed urea the values of parts of $CaCO_3$ per part of fertilizer N ranged from 2.0 to 3.4 for the three soils. With banding, the values ranged from 0.1 to 2.3. Apparently, with band placement (compared to mixing) of the urea, or ammonium sulphate, there was less change in soil pH and less $CaCO_3$ needed to restore the soil to its original pH. However, these experiments were made with fertilizer applied at the time of seeding, and not with fall-applied N.

Table 1. Soil pH of the 0-15 cm depth of three soils after annual fertilization and cropping to barley.

Fertilizer	Annual rate of N (kg/ha)	Method of Application	Soil pH at three locations* Breton (3 years)	Craigmyle (1 year)	Ellerslie (3 years)
Nil	0		6.14 g	5.55 e	5.88 d
Amm. nitrate	67	Mixed	5.94 f	5.48 de	**
Amm. nitrate	202	Mixed	5.40 c	5.33 bc	5.34 b
Amm. nitrate	67	Mixed	5.58 d	5.38 cd	**
Amm. nitrate	202	Mixed	4.76 a	5.09 a	5.14 a
Amm. nitrate	202	Banded	5.38 c	5.41 cd	5.42 bc
Urea	67	Mixed	5.82 ef	5.53 e	**
Urea	202	Mixed	5.20 b	5.24 b	5.51 bc
Urea	202	Banded	5.72 de	5.53 e	5.61 c

* In each column, the values are significantly different (95% of probability) when not followed by the same letter.

** Missing values

Banding, rather than mixing, of ammonium-based fertilizers substantially delays nitrification (Malhi, 1978), and the apparent plant uptake of the ammonium-form of N before its nitrification is most probably the main reason for lessening soil acidification.

From 1974 to 1980 forty field experiments were conducted to compare fall and spring application of urea (as well as aqua ammonium and ammonium sulphate) in their effectiveness in increasing the yield and N-uptake for barley. The results, excepting those for 1980, have been summarized (Nyborg, Malhi, and Monreal, 1980), and they point out that with fall-application of N fertilizers the increase in yield and N-uptake was only about half as great as with spring application. Band application, and more so nest or pellet application, improved the performance of fall added fertilizer N. Before 1978, occasional determinations of soil pH indicated that there were reductions of pH with fall applied fertilizer mixed into the soil rather than banded or nested. Consequently, in 1979 and 1980, more intensive experiments were run.

Table 2. Kilograms of $CaCO_3$ needed per kilogram of fertilizer nitrogen to overcome the acidity generated in the top 15 cm of the soil by the fertilizers.

Fertilizer	Annual rate of N (kg/ha)	Method of Application	Kg of $CaCO_3$ per kg of N		
			Breton	Craigmyle	Ellerslie
Amm. nitrate	67	Mixed	1.2	1.2	*
Amm. nitrate	202	Mixed	1.8	1.4	5.2
Amm. sulphate	67	Mixed	3.9	3.2	*
Amm. sulphate	202	Mixed	4.6	3.3	7.1
Amm. sulphate	202	Banded	1.9	0.9	4.3
Urea	67	Mixed	1.9	0.4	*
Urea	202	Mixed	2.7	2.0	3.4
Urea	202	Banded	0.9	0.1	2.3

* Missing values

The eight experiments in 1979 and 1980 gave soil pH values which were lower with the fall applied urea mixed into the soil as compared to the nil treatment (Table 3). The differences were usually statistically significant, and average difference in pH was 0.12 units. The average difference between the spring application and the nil treatment was 0.09 pH units. These depressions in soil pH from 56 kg N per ha were unusually large, considering that the amount of $CaCO_3$ needed per part of fertilizer N was more than the theoretical requirement. (However, for two of the soils, pH was determined in 0.01 M $CaCl_2$ solution, in 1N KCl solution, and in water, and the amount of depression in soil pH values on treatments where the urea was mixed into were similar with the three methods of determination.) In this paper, let us not concern ourselves with the unusually large changes in soil pH from the fertilizer, but instead with the effect of bands and nests on soil pH.

Table 3. The soil pH of the 0-15 cm depth after harvest, with urea at 56 kg N/ha applied in the spring or previous fall.

Year	Location	Soil pH with different fertilizer treatments: Nil	Fall, Mixed	Spring, Mixed
1978-79	Buford	6.64 b	6.50 a	6.61 ab
	Thorsby	7.90 b	*7.84 a	7.92 ab
	Egremont	7.36 a	*7.27 a	7.31 a
1979-80	Breton	6.69 b	6.60 a	6.66 ab
	Hay Lakes	6.02 b	5.95 ab	5.91 a
	Viking	6.10 b	5.95 a	5.96 a
	Didsbury	7.40 b	7.24 a	7.18 a
	Olds	6.87 b	6.75 a	6.79 a
	AVERAGE	6.88	6.76	6.79

* Fertilizer was banded rather than mixed into the soil

<u>NOTE</u> In each row, values not followed by the same letter are statistically different (P = 0.05).

In four experiments, the lowering of soil pH was 0.10 units from mixing (that is, incorporation) in the fall, 0.04 units from fall banding, and 0.08 units from mixing in the spring (Table 4). In six experiments, the lowering was 0.11 units for fall mixing, 0.04 units from fall nesting, 0.10 units for spring mixing. <u>That is, fall banding or fall nesting produced less lowering of soil pH than did mixing of urea into the soil</u>. This would be a benefit from banding and nesting, in addition to their different type of benefit in increasing the crop yield and crop N-uptake.

Table 4. The soil pH of the 0-15 cm depth after harvest, with urea at 56 kg N/ha in the spring or previous fall, as influenced by band and "nest" placement and addition of nitrification inhibitors.

	No N	Fall-applied N		Spring N
		Incorporated	Bands (45 cm apart)	incorporated
Soil pH[1]	6.36	6.26	6.32	6.28

	No N	Fall-applied N		Spring N
		Incorporated	Nests	incorporated
Soil pH[2]	6.62	6.51	6.58	6.52

	No N	Fall-applied N in bands			Spring Urea
		Urea	Urea plus N-Serve*	Urea plus ATC*	incorporated
Soil pH[3]	7.66	7.56	7.68	7.68	7.62

1 Average of 4 experiments
2 Average of 6 experiments
3 Average of 2 experiments

* These are two nitrification inhibitors

In two experiments, with two nitrification inhibitors fall-applied with banded urea solution, there was no depression in soil pH. Considering the different type of benefit in increasing crop yield and N uptake, there was only modest benefit from the nitrification inhibitors (Nyborg, Malhi, and Monreal; 1980).

CONCLUSION

In one set of experiments, with only spring application of N fertilizers, banding produced less lowering of soil pH than did mixing into the soil for urea and ammonium sulphate. In another set of experiments with fall applied urea, the band and nest placement gave less soil pH depression than did mixing of the fertilizer into the soil.

While banding or nesting for fall applied urea (and for ammonium-based N fertilizers) increases crop yield and N-uptake; there is also the advantage of banding and nesting lessening soil acidification.

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