

# INFLUENCE OF FORAGE FERTILIZATION ON SOIL NUTRIENT DISTRIBUTION<sup>1</sup>

J.T. Harapiak and N. Flore<sup>2</sup>

Few of the field experiments that are carried out in Western Canada are designed to test the cumulative impact of annual fertilizer treatments on the soil to which they applied. It is unfortunate that this phase of research is ignored since the application of fertilizer can have a significant influence on soil quality. The potential of nitrogen to displace cations such as calcium and magnesium is one of the common concerns related to fertilizer application. Concerns about the potential of nitrogen fertilizers contributing to contamination of groundwater supplies has also become a major issue in recent years.

## Experimental Sites

Some of the field research trials conducted by WESTCO agronomists have been deliberately maintained for extended periods of time so that the effect of successive fertilizer applications could be assessed. A series of long-term, replicated, randomized block design forage (bromegrass) trials established in the thin black soil zone (Carstairs, Alberta) on a resorted glacial till loam soil provided an opportunity to measure the impact of a wide range of nitrogen rates and sources on soil acidity. The first trial (experiment #8) comparing rates of ammonium nitrate ranging from 0-300 lbs N/acre established in 1968 was subjected to intensive soil sampling after sixteen years of fertilizer application (i.e. 1983). The second trial at this location (experiment #145) was established in 1974 to compare urea and ammonium nitrate applied at a rate of 100 lbs N/acre at four different times of application (i.e. early fall, late fall, early spring and late spring). This site was sampled after eleven years (i.e. 1984). The final study (i.e. experiment #186) was established in 1979 to compare four nitrogen sources (i.e. ammonium nitrate, urea, calcium nitrate and ammonium sulphate applied at relatively high rates of fertilization (i.e. 150 and 300 lbs N/acre). This trial was soil sampled after only five years (i.e. 1983) of fertilizer applications.

## Soil Sampling Technique

Each of the treatments was replicated six times and each of the replicates were sampled individually. A separate series of shallow and deep samples were collected. The shallow sampling consisted of three depths (i.e. 0-2", 2-4" and 4-6"). The deep samples were more typical of the types of samples that would normally be collected if a field were to be routinely soil tested (i.e. 0-6", 6-12", 12-24") plus two additional depths (i.e. 24-36" and 36-48"). These samples were submitted to the Alberta Soils and Nutrition Laboratory

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  2. Westco Fertilizers, P.O. Box 2500, Calgary, Alberta, T2P 2N1

(formerly ASFTL) for routine soil analysis (Lavery and Bollo-Kamara, 1988).

### Average Yield Data

The main emphasis of this paper will be on the data collected from the nitrogen rate study (i.e. experiment #8) for which the average yield data is presented in Figure 1. It should be pointed out that the majority of the yield increase was accounted for by a rate of 100 lbs/N acre. Most producers would apply considerably less nitrogen to their hay fields. As will be seen later in this paper, the application of excessive amounts of nitrogen (i.e. exceeding 100 lbs N/acre) resulted in much more rapid changes in the soil than did the lower rates that were more typical of rates currently being applied by prairie farmers.

### Rate of Acidification

The impact of sixteen years of applying various rates of nitrogen on the pH as determined on a soil:water (1:2) mixture (Lavery and Bollo-Kamara, 1988) of the deeper sampling depths is illustrated in Figure 2. It is obvious that the soil pH values were highly influenced by rate of N application in the 0-6" layer. The rate of acidification of the 0-6" layer appeared to differ at rates above and below 100 lbs N/ac. Calculated regression lines indicated that over a sixteen year period, for rates of N up to 100 lbs/ac applied annually, the drop in pH amounted to 0.004 units per lb of N. At rates between 100-300 lbs N, the drop in pH over the same period amounted to 0.008 units per lbs of N. This suggests that for the 0-6" layer, the rate of soil acidification at excessive rates of N application was doubled.

After sixteen years of ammonium nitrate application at the rate of 100 lbs N/ac, the actual pH of the surface soil (i.e. 0-6") had only declined by 0.3 units (i.e. 7.3 vs 7.0). Similar or larger declines in the pH values of the 0-6" layer have been recorded for comparable periods of application, but at much lower rates of nitrogen for annual crop production (Campbell and Zentner, 1984; Janzen, 1986). It is possible that the annual mixing of the plow layer by cultivation may predispose the soil to more rapid acidification. Since it was only the uppermost portion of the soil (i.e. 0-2") that came into intimate contact with the fertilizer, this portion was most vulnerable to acidification. Limiting the amount of soil coming in direct contact with the fertilizer to the extreme surface as would be the case in forage stands, rather than mixing it into direct contact with more of the soil as a result of tillage as occurs in annually cultivated soils, may have helped to buffer against the full expression of the potential acidifying power of the volume of nitrogen fertilizer that was applied.

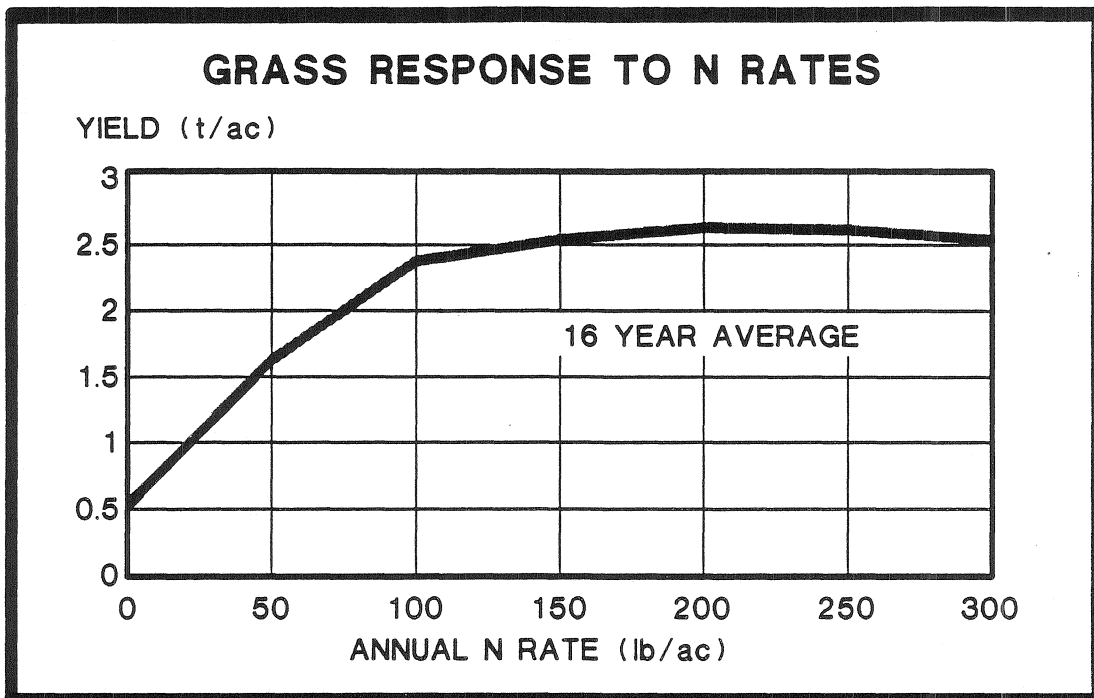


Fig. 1. Average response of bromegrass to increasing rates of sixteen successive annual applications of ammonium nitrate in the thin black soil zone of central Alberta.

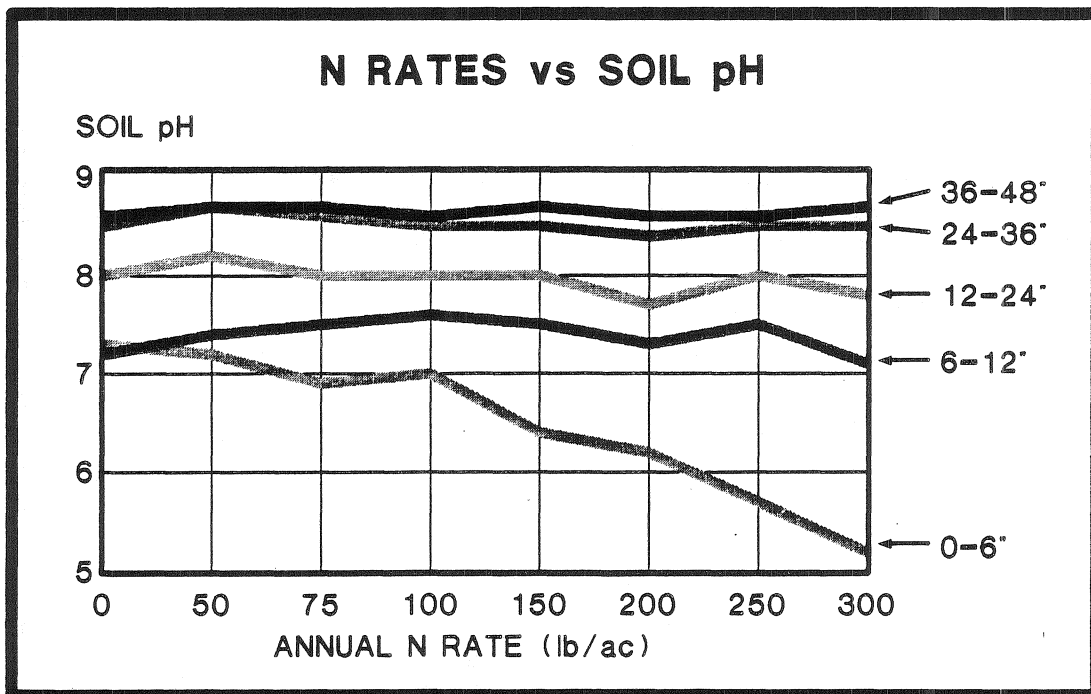


Fig. 2. Soil pH of five consecutive soil depths (i.e. 0-6", 6-12", 12-24", 24-36" and 36-48") as influenced by sixteen successive years of ammonium nitrate application.

At lower rates of N application, it appeared that the pH of the 6-12" layer was actually increasing. Higher rates of fertilizer application (i.e. 100-300 lbs N/ac), resulted in a gradual acidification of the 6-12" layer. It appeared that the rate of nitrogen application did not have any consistent influence on the soil pH values that were measured below the 6-12" layer.

#### Urea vs Ammonium Nitrate

Comments in the literature (Tisdale, et al, 1985; van Lierop and Tran, 1979; Bordeleau, 1979) suggest that ammoniacal sources of nitrogen are more acidifying than non-ammoniacal sources of nitrogen. On this basis, it would be assumed that urea would be more acidifying than ammonium nitrate. Data collected in this study indicated that after eleven years of N application at the rate of 100 lbs N/ac, ammonium nitrate was actually more acidifying on the 0-6" layer than was urea (7.0 vs 7.3). In these trials, on average, urea was only 75% as effective as ammonium nitrate in terms of increasing the yield of grass forage. This reduced efficiency of urea was attributed to the fact that it was more vulnerable to atmospheric volatilization losses of ammonia. It would therefore appear that urea was less acidifying than ammonium nitrate because less of the N fertilizer that was applied as urea actually entered the soil system. Similar trends were observed in the shallower samples with the bulk of the acidification occurring in the 0-2" layer.

#### Four Nitrogen Sources

The relative impact of four nitrogen sources (ammonium nitrate, urea, calcium nitrate and ammonium sulphate) over a relatively short period of time (i.e. 5 years) applied at relatively high rates of N (i.e. 150 and 300 lbs/ac) was also evaluated in this study. Ammonium sulphate was the most acidifying of the four nitrogen sources while calcium nitrate increased the pH slightly. Urea was less acidifying than ammonium nitrate. The bulk of the pH modification was accounted for in the 0-6" layer.

For a more detailed report on the rate of soil acidification, the reader is referred to a companion paper that was presented at the Manitoba Soil Science Meeting (Harapiak and Flore, 1988).

#### Soil Phosphorus

The application of nitrogen alone appeared to have an impact on soil available P levels. As indicated in Figure 3, the application of 50-75 lbs N/ac resulted in a decline in soil P levels in the 0-6" layer due to "soil-mining". At higher rates of N application, soil P levels increased due to soil acidification. The greatest impact of N fertilization on soil available P levels occurred in the 0-2" layer.

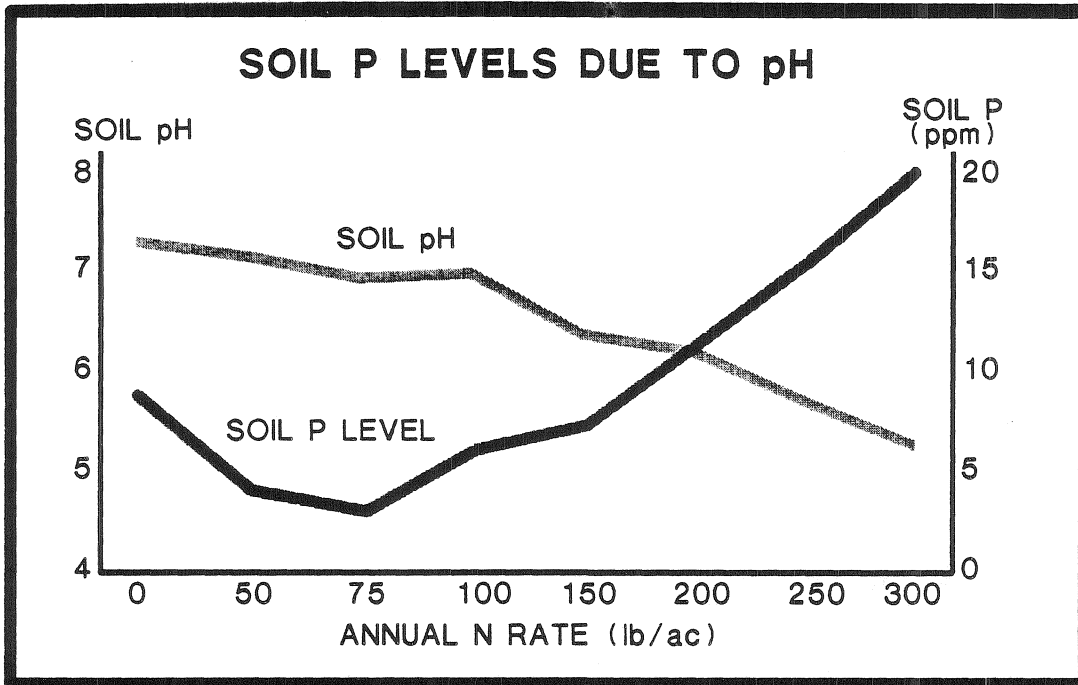


Fig. 3. Relationship of soil pH as influenced by sixteen successive years of increasing rates of annually applied nitrogen fertilizer to the available soil phosphorus levels in the 0-6" soil layer.

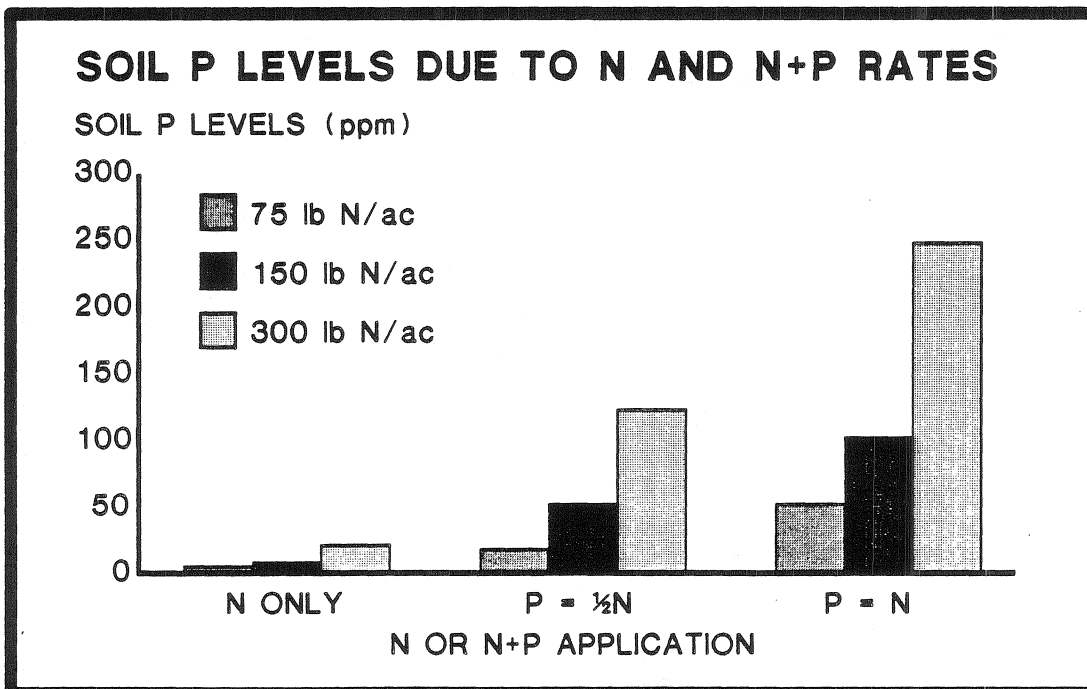


Fig. 4. Influence of rates of N and P fertilizer on available soil phosphorus levels in the 0-6" soil layer. Rates of P varied with N rate ( $P = \frac{1}{2}N$  indicates a 2:1 ratio of  $N:P_2O_5$  while  $P = N$  indicates a 1:1 ratio of  $N:P_2O_5$ ). Phosphate applied for first 10 years only (i.e. 1968-77).

In the main study, two rates of P were applied over a wide range of N rates (i.e. 75, 150, 250 and 300 lbs N/ac). The rates of P were either 1/2 the rate of N (i.e. 2:1 ratio of N:P<sub>2</sub>O<sub>5</sub>) or equal to the rate of N (i.e. 1:1 ratio of N:P<sub>2</sub>O<sub>5</sub>). The response of the bromegrass to P was not significant despite the relatively low levels of soil P present in the soil (i.e. less than 10 lbs of available P in the 0-6"). Because of the relatively high rates of fertilizer used in this study, the application of phosphorus was discontinued after a period of ten years (i.e. 1968-77).

The impact of fertilizer N and P<sub>2</sub>O<sub>5</sub> applications on the soil P levels that were recorded after sixteen years is illustrated in Figure 4. It is obvious that the level of available soil P measured in the 0-6" layer was related to the amount of P<sub>2</sub>O<sub>5</sub> that was applied. The influence of fertilizer on the levels of available P in the 6-12" layer was insignificant. The data graphed in Figure 5 indicates that based on the shallow soil samples that were collected, the influence of P application on the levels of available P was highest near the surface (i.e. 0-2" depth) confirming that downward movement of P was quite restricted.

#### Soil Potassium

The application of increasing rates of nitrogen resulted in a decline in available soil K levels in the 0-6" and 6-12" depths (see Figure 6). Although the data is not included in this report, the greatest rate of decline in K levels occurred in the 0-2" depth. At rates exceeding 200 lbs N/ac, the K levels of the 0-2" layer appeared to increase. It is likely that the increased acidification of this layer resulting from N fertilizer application was a factor in the increased levels of available K that were observed. Acidification probably created an environment that favoured more rapid weathering of minerals which would contribute to higher soil available K levels.

It should also be pointed out that the application of some phosphate fertilizer resulted in a more rapid depletion of soil K levels. This suggests that even though the application of P had minimal influence on yield, it may have influenced nutrient uptake from the soil. The drop in soil K levels as influenced by P application appeared to be confined to the 0-2" layer.

#### Calcium and Magnesium

In most situations, a drop in soil pH was accompanied by a drop in calcium and magnesium levels as determined in an ammonium acetate (1:5) extract. It appeared that magnesium may have been more readily mobilized by regular nitrogen fertilizer application than was calcium. This observation may have important implications for pasture fertilization in situations where cattle are vulnerable to magnesium deficiencies (i.e. "grass tetany").

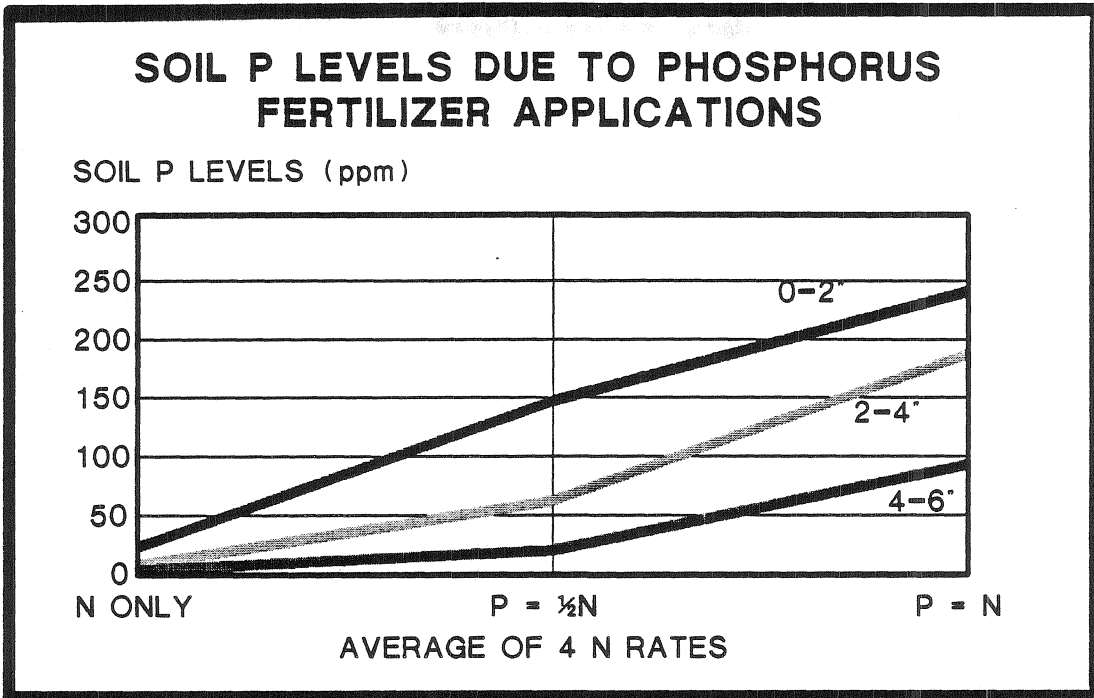


Fig. 5. Distribution of available soil phosphorus in the shallow soil samples as influenced by rates of N and P application (Note that P = 1/2N indicates 2:1 ratio of N:P<sub>2</sub>O<sub>5</sub> while P = N indicates a 1:1 ratio of N:P<sub>2</sub>O<sub>5</sub>).

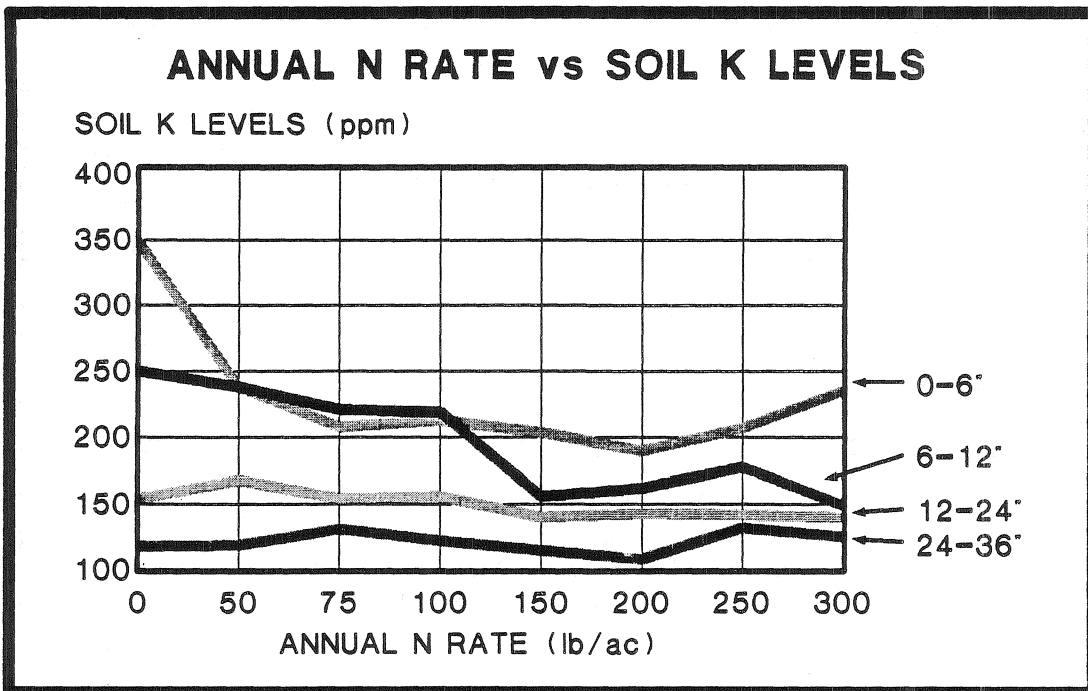


Fig. 6. Influence of sixteen successive years of increasing rates of annually applied N (ammonium nitrate) on available soil potassium levels in the 0-6", 6-12", 12-24" and 24-36" depths of soil.

The influence of increasing rates of annual N application on soil calcium levels is illustrated in Figure 7. It is apparent that at rates exceeding 100 lbs N/ac, levels of calcium were steadily declining in response to increasing rates of annual N application. However, there appeared to be a corresponding build-up of calcium in the 6-12" layer and possibly in the 12-24" layer as well. The levels of soil magnesium in the 0-6" layer appeared to decline more rapidly in response to increasing N rates than in the case of calcium. The decline in calcium and magnesium levels appeared to be most dramatic in the 0-2" layer.

Application of ammonium nitrate resulted in a more rapid decline in calcium and magnesium levels of the 0-2" layer than did urea. The influence of the four nitrogen sources applied for 5 years on the distribution of magnesium in the surface layers is summarized in Figure 8. Most of the changes appeared to be confined to the 0-2" layer except for the treatments involving calcium nitrate and ammonium sulphate in which case changes in magnesium levels appeared to occur in both the 2-4" and 4-6" layers.

#### Ammonium Nitrogen

The build-up in  $\text{NH}_4^+$ -N levels (i.e. 2N KCl extractable) appeared to be minimal at rates of up to 100 lbs N/ac applied as ammonium nitrate. As illustrated in Figure 9, the bulge in  $\text{NH}_4^+$ -N at excessive rates of application was concentrated in the 0-2" layer. At rates exceeding 250 lbs N/ac, an increase in  $\text{NH}_4^+$ -N was detected at the 2-4" level. The application of some phosphate fertilizer appeared to reduce the accumulation of  $\text{NH}_4^+$ -N in the surface layer. The application of ammonium nitrate increased the level of  $\text{NH}_4^+$ -N in the surface layers significantly more than urea. After 5 years of application, the influence of ammonium sulphate on  $\text{NH}_4^+$ -N levels in the 0-2" layer was greater (i.e. approximately double) than was ammonium nitrate. Calcium nitrate and urea had minimal influence on  $\text{NH}_4^+$ -N levels. At the higher rate of application (i.e. 300 lb N/ac), it appeared that ammonium nitrate and ammonium sulphate also increased the levels of  $\text{NH}_4^+$ -N in the 2-4" and 4-6" layers. The application of phosphate fertilizer tended to reduce the amount of  $\text{NH}_4^+$ -N that accumulated.

#### Nitrate Nitrogen

The build-up in  $\text{NO}_3^-$ -N (i.e. 2N KCl extractable) in the soil was considered to be minimal at rates of ammonium nitrate up to 100 lbs N/ac. In the surface layer (0-6"), the highest levels of  $\text{NO}_3^-$ -N occurred in the 4-6" depth. As indicated in Figure 10, the bulge in  $\text{NO}_3^-$ -N at higher rates of N application occurred in the 6-12" and 12-24" layers. It appears that at realistic rates of N fertilization, the accumulation of nitrate-nitrogen at the 36-48"



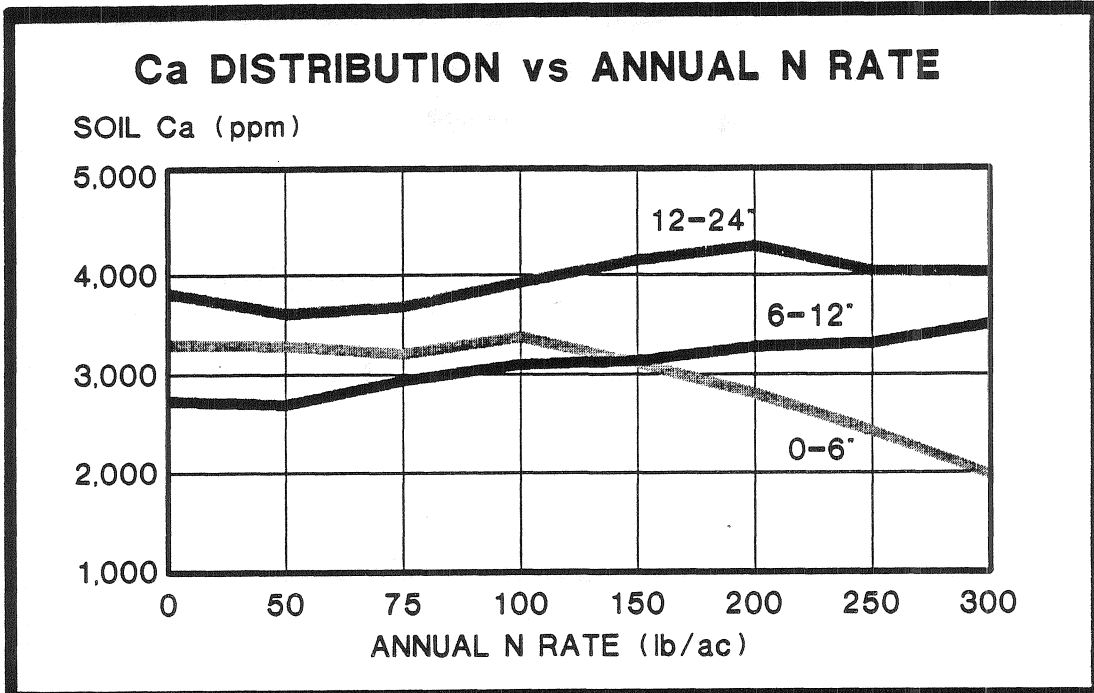


Fig. 7. Soil calcium distribution as influenced by sixteen successive years of increasing rates of N application (ammonium nitrate) to a grass forage stand.

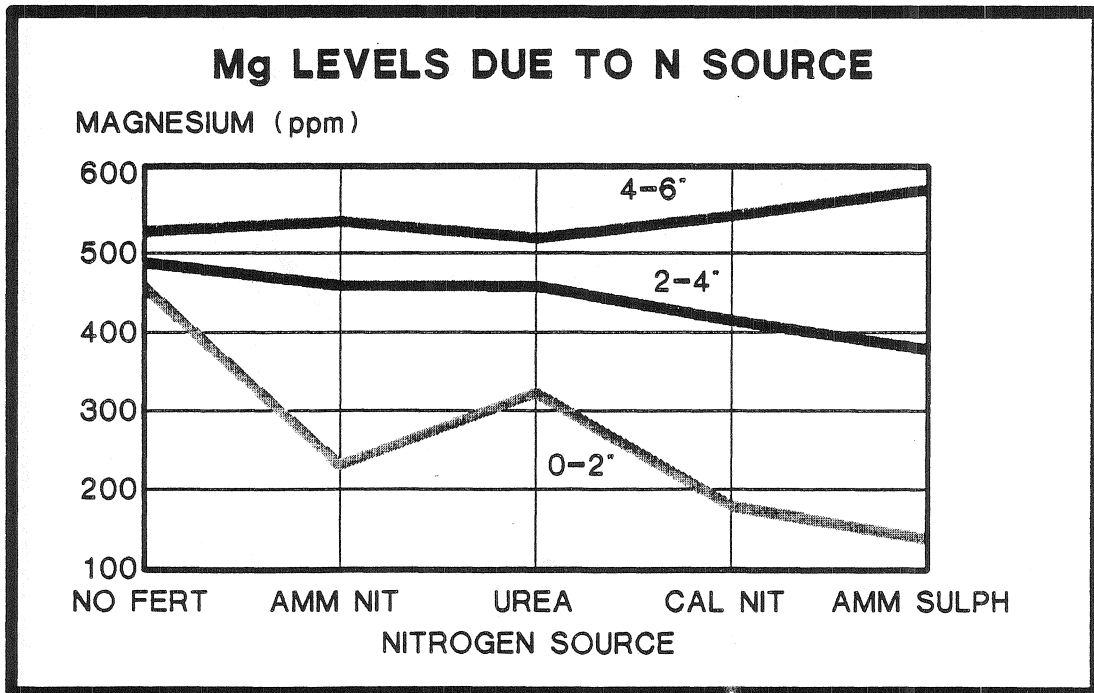


Fig. 8. Soil magnesium distribution as influenced by five successive years of ammonium nitrate, urea, calcium nitrate and ammonium sulphate application.

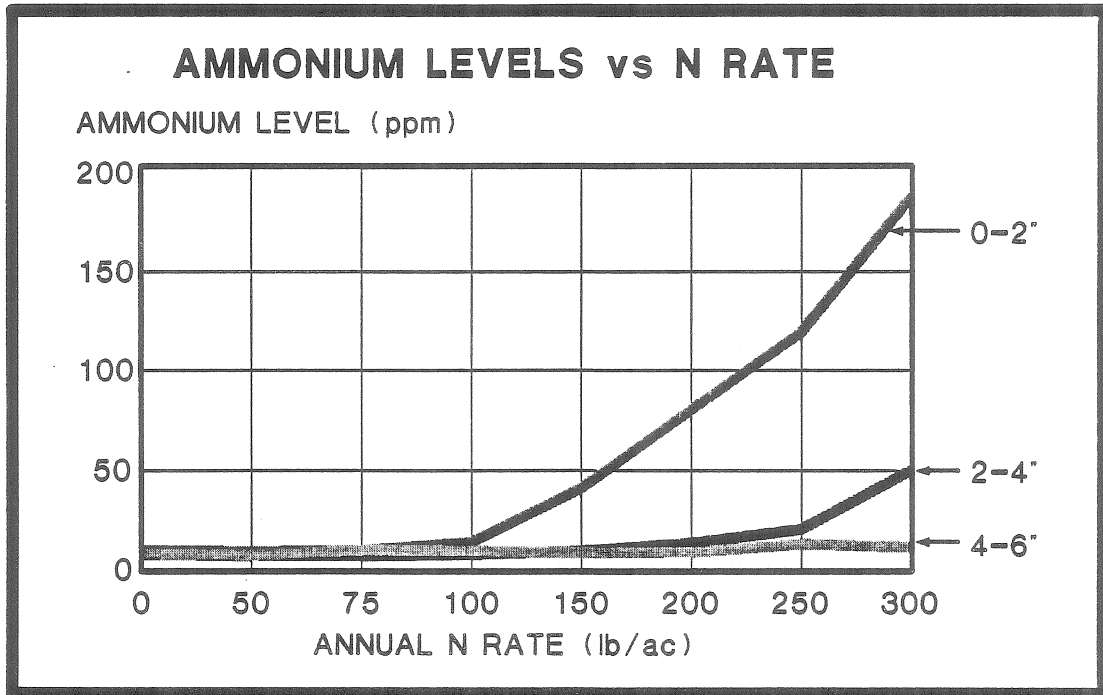


Fig. 9. Impact of sixteen successive years of increasing rates of ammonium nitrate applications on the ammonium-nitrogen content of several soil surface layers.

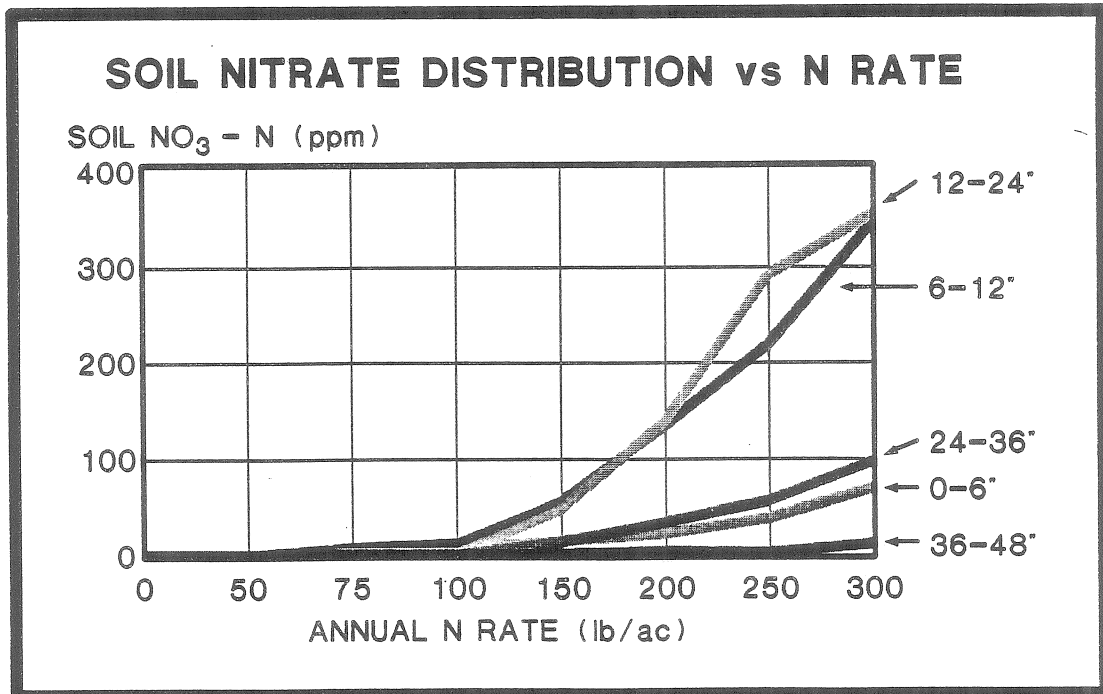


Fig. 10 Influence of sixteen successive years of increasing rates of ammonium nitrate application on the distribution of nitrate-nitrogen in the various soil layers.

depth of soil will be minimal. Significant accumulations of nitrate-nitrogen occur within the soil if rates of N fertilization exceed those normally required for adequate grass forage production (refer to Figure 11). The application of phosphate fertilizer appeared to reduce the accumulation of  $\text{NO}_3^-$ -N in the surface layers.

The following are the regression equations that describe the level the of  $\text{NO}_3^-$ -N accumulation in response to annual applications of fertilizer nitrogen ranging from 100-300 lbs N/ac for the various soil depths that were sampled:

$$\underline{0-6''} \quad \text{NO}_3^- \text{-N (ppm)} = (0.295 \times \text{N rate}) - 27 \quad R^2 = 0.90$$

$$\underline{6-12''} \quad \text{NO}_3^- \text{-N (ppm)} = (1.67 \times \text{N rate}) - 179 \quad R^2 = 0.97$$

$$\underline{12-24''} \quad \text{NO}_3^- \text{-N (ppm)} = (1.90 \times \text{N rate}) - 212 \quad R^2 = 0.97$$

$$\underline{24-36''} \quad \text{NO}_3^- \text{-N (ppm)} = (0.48 \times \text{N rate}) - 54 \quad R^2 = 0.96$$

$$\underline{36-48''} \quad \text{NO}_3^- \text{-N (ppm)} = (0.05 \times \text{N rate}) - 5 \quad R^2 = 0.73$$

$$\underline{0-48''^*} \quad \text{NO}_3^- \text{-N (lb/ac)} = (13.6 \times \text{N rate}) - 1495 \quad R^2 = 0.98$$

\*Based on assumption of uniform soil density for all of the depths of soil sampling.

In the trial that involved dates of application of two nitrogen sources for a period of eleven years, it appeared that the late fall application of ammonium nitrate significantly boosted the levels of  $\text{NO}_3^-$ -N in the 6-12" and 12-24" layers compared to the other treatments. In the study involving the four different nitrogen sources, at the higher rate of application (i.e. 300 lb N/ac for 5 years), ammonium nitrate increased  $\text{NO}_3^-$ -N levels in the 0-6" layer significantly more than any of the other three sources. However, at greater depths of sampling (i.e. 12-24" and 24-36") calcium nitrate increased the level of  $\text{NO}_3^-$ -N significantly above the other nitrogen sources.

#### Total N

Increasing rates of N application resulted in a steady build-up in total N content (as determined by the Kjeldhal method) of the 0-6" layer. The increase in total N content of the 6-12" layer was more erratic but was still considered to be significant. In the case of the trial comparing urea and

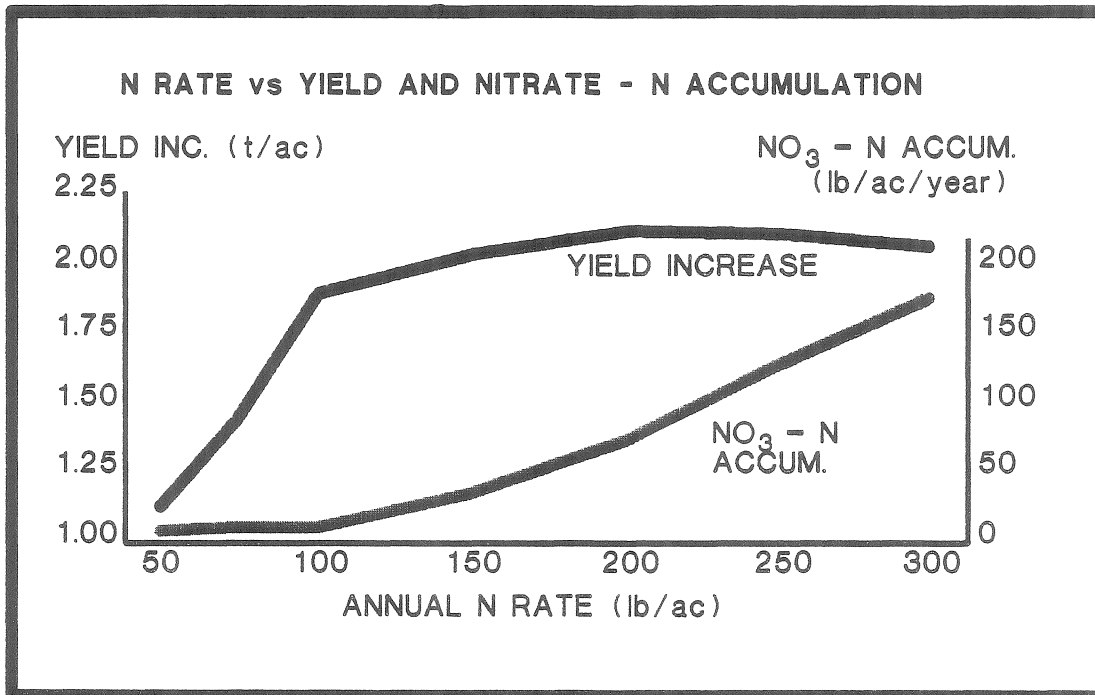


Fig. 11. Relationship of yield response of bromegrass and average annual contribution to soil content of nitrate-nitrogen in the 0-48" layer as influenced by increasing rates of annually applied N fertilizer (Note: based on assumption of equal soil density with depth).

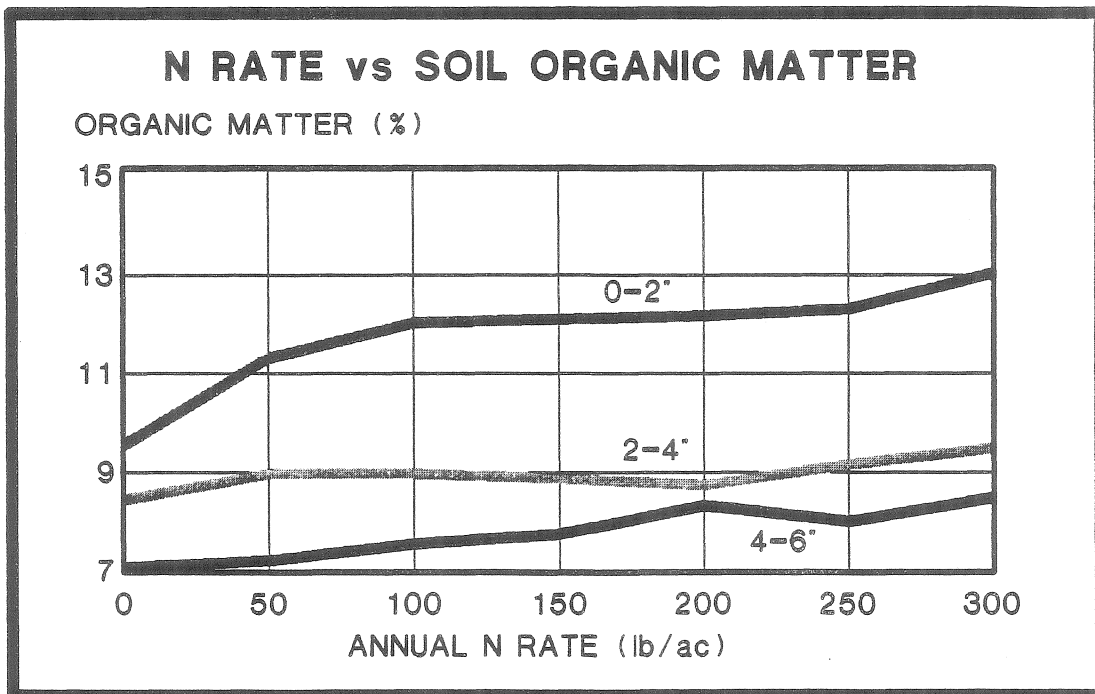


Fig. 12. Organic matter content (%) of three consecutive surface layers as influenced by sixteen successive years of ammonium-nitrate application to a grass forage stand.

ammonium nitrate applications, it was found that the total N content of the 0-6" layer was similar for both sources. There was however, a tendency for these values to be slightly higher for urea in the 6-12" layer. As well, the values for both sources (i.e. urea and ammonia nitrate) were slightly lower for the last application date (i.e. late spring). For the study involving four different sources of N, the highest total N values for the 0-6" layer were recorded for the highest rate of ammonium sulphate application.

### Organic Matter Content

Annual applications of increasing amounts of N resulted in a significant increase in the organic matter content (as determined by the ignition method) of the surface layers. The largest increase occurred in the 0-2" layer (i.e. increased from 9.5% to 13.0% organic matter). It should be noted that it was recently reported (Goh et al, 1987) that significant accumulations of soil organic matter can occur in response to N fertilization of grass forage stands over relatively short periods of time.

As illustrated in Figure 12, the greatest proportion of the increase in organic matter content was accounted for by the annual application of rates of 50 to 100 lb N/ac. In the comparisons involving urea and ammonium nitrate as sources of nitrogen for forage fertilization, there was a tendency for the organic matter to be higher at the surface (i.e. 0-2") for the ammonium nitrate treatments and higher for the urea treatments at the next two sampling depths (i.e. 2-4" & 4-6"). In the short-term study involving four nitrogen sources, there was a tendency for slightly higher organic matter levels in the calcium nitrate treatments.

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