FATE OF FERTILIZER N AND ITS REACTION PRODUCTS WHEN APPLIED TO FORAGE IN WINTER

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INTRODUCTION

Many producers in western Canada prefer to fertilize in the fall in order to distribute their workload more evenly throughout the year. It is believed that by late fall to early winter soil temperatures are cold enough so that microbial N transformations would be minimal.

Several studies have shown that crop responses to fertilizer N depend on the time of fertilization. (Malhi and Nyborg 1979; Selles et al. 1986). In a study of N fertilization of forage grasses on a Brown and a Dark Brown soil in Saskatchewan, yield increases were the highest when fertilization was carried out in mid April; when fertilization was done in mid October, mid November, and mid March, yield increases became progressively lower (Campbell et al. 1986).

This study was designed to determine the fate of 34-0-0 and 46-0-0 applied to grass plots in the winter.

MATERIALS AND METHODS

Blocks of soil 10 cm deep were excavated from an old crested wheat grass field in a Swinton silty loam soil at Swift Current before freeze up. The blocks were placed in wooden flats and put back in the holes where the blocks had been taken. One half of the flats were covered with a plastic sheet until after the first snowfall when the plastic covers were removed and either reagent grade urea (UR) or ammonium nitrate (AN) was applied to the surface of the bare flats or onto the snow of the snow-covered flats at a rate equivalent to 100 kg N/ha. The experiment was carried out during the 1981-82 and 1985-86 winters. The size of the flats was reduced from 39.4 x 34.4 cm in 1981 to 23 x 7.6 cm in 1985 to facilitate the removal from the frozen soil. The flats were sampled 4 times during each winter and the content of NH_4-, NO_2-, NO_3-, and urea-N were determined in the snow, the grass thatch the first 2.5 cm of soil, and the bottom 7.5 cm of soil.

RESULTS AND DISCUSSION

The recovery of mineral N in spring was different during the two winters studied (Fig. 1 a and b). During 1981 one week after fertilization (T1) 76 to 88 % of the applied nitrogen was recovered from the 46-0-0 (UR) and 34-0-0 (AN) bare plots, respectively, whereas in early spring (T4), recovery was around 40 and 50% for the UR and AN plots, respectively. In the AN snow-covered plots, recoveries were similar to those found in the bare

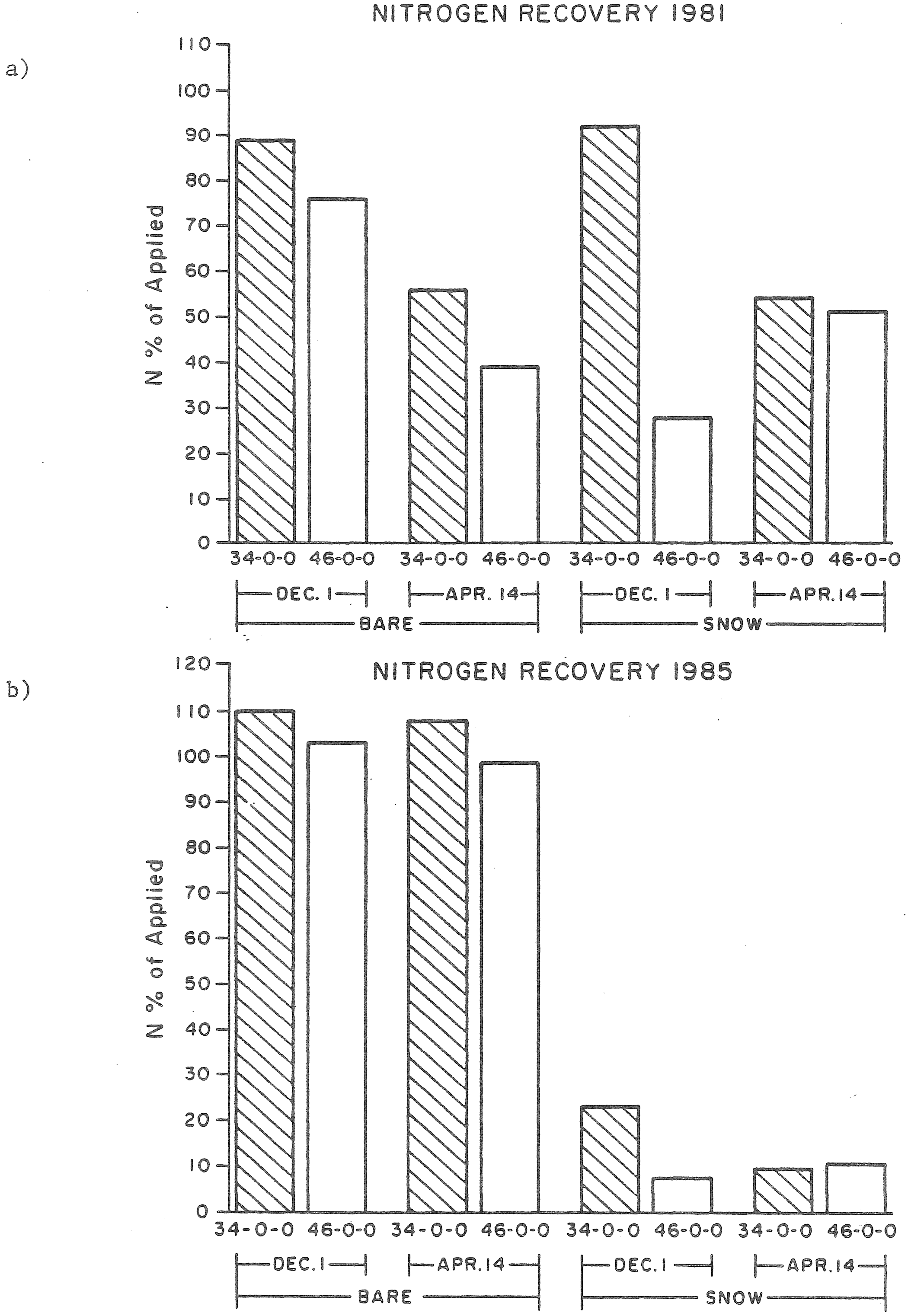

Figure 1. Recovery of mineral N in fall and spring:
a) 1981
b) 1985

plots, whereas it was lower lower in the UR plots. The lower recovery shown for the UR plots at the first sampling (Fig. 1a) was due to losses of NH_4-N during concentration of the snow extract in the lab, as some hydrolysis of urea had taken place in the field. During 1985, in the bare plots N recoveries 12 days after fertilization (T1) were 100% regardless of N source, and there was no reduction in recovery at the spring sampling. Recovery in the snow-covered plots, however, was extremely low as most of the fertilizer was blown off the fields with the drifting snow a couple of days after fertilization.

The large differences in N recovery at the spring sampling between the two years are no doubt due to different weather conditions during each winter, which may have affected the N transformation processes in the soil.

Recovery in 1981-82.

During the winter of 1981-82 the soil was slightly above $0^{o}C$ from the time of fertilization to the first sampling on December 1 (T1) (Fig. 2). Between T1 and the second sampling on January 4 (T2) soil temperatures dropped fast and remained well below zero until a few days before the third sampling on February 22 (T3). From T3 to the last sampling on April 14 (T4), the soil warmed up and temperatures reached the 10°C mark. During this winter the soil remained covered with snow for 117 days (Fig. 2). There was a fast melt just prior to T3, as a result of the high temperatures observed during those days but the soil remained snow covered.

All the plots during 1981 showed a constant decline of mineral N content through the winter (Figs. 3a, 3b, 4a, and 4b), and consistently lower mineral N recoveries in the UR plots than in the AN plots. At T1 in the AN bare plots, about 1/3 of the N was found in the thatch, about 1/2 in the first 2.5 cm of soil, and the remainder in the bottom 7.5 cm, while in the snow covered plots (Fig. 3b) 2/3 of the N was found in the snow and 1/5 in the 0-2.5 cm depth. Throughout the winter there was a marked tendency for N in the AN plots to move downward in the soil, thus, by T2, the thatch had nearly no mineral N; it had moved into the soil immediately below and some had even reached the bottom 7.5 cm. By T3 there was further evidence of this downward movement as the upper 2.5 cm soil layer had lost N compared to T2, and the bottom layer had a net gain. This was possibly the result of snow melt water entering the soil just prior to the T3 sampling. By T4, there is a further reduction in the mineral N recovered. At this time, however, there was a net increase of mineral N in the first 2.5 cm and a net loss from the lower 7.5 cm, probably reflecting mineralization on the surface of the soil,and gaseous losses in the deeper portion. The surface soil dried sooner while the lower layer remained waterlogged for a longer period of time. At all the samplings, the mineral N in the AN plots was found in equal amounts of NH_4 and NO_3, indicating that very little N transformations had occurred during the 1981 winter.

The N recovered from the UR plots showed that N tended to remain in the surface 2.5 cm (Fig 4) layer, which is consistent with the fact that with the exception of the T1 sampling more than 90% of the mineral N in these plots was found as NH_4-N. At T1 the UR bare plots had over 80% of their N in the first 2.5 cm of soil; of this roughly 30% was in the urea form. The snow

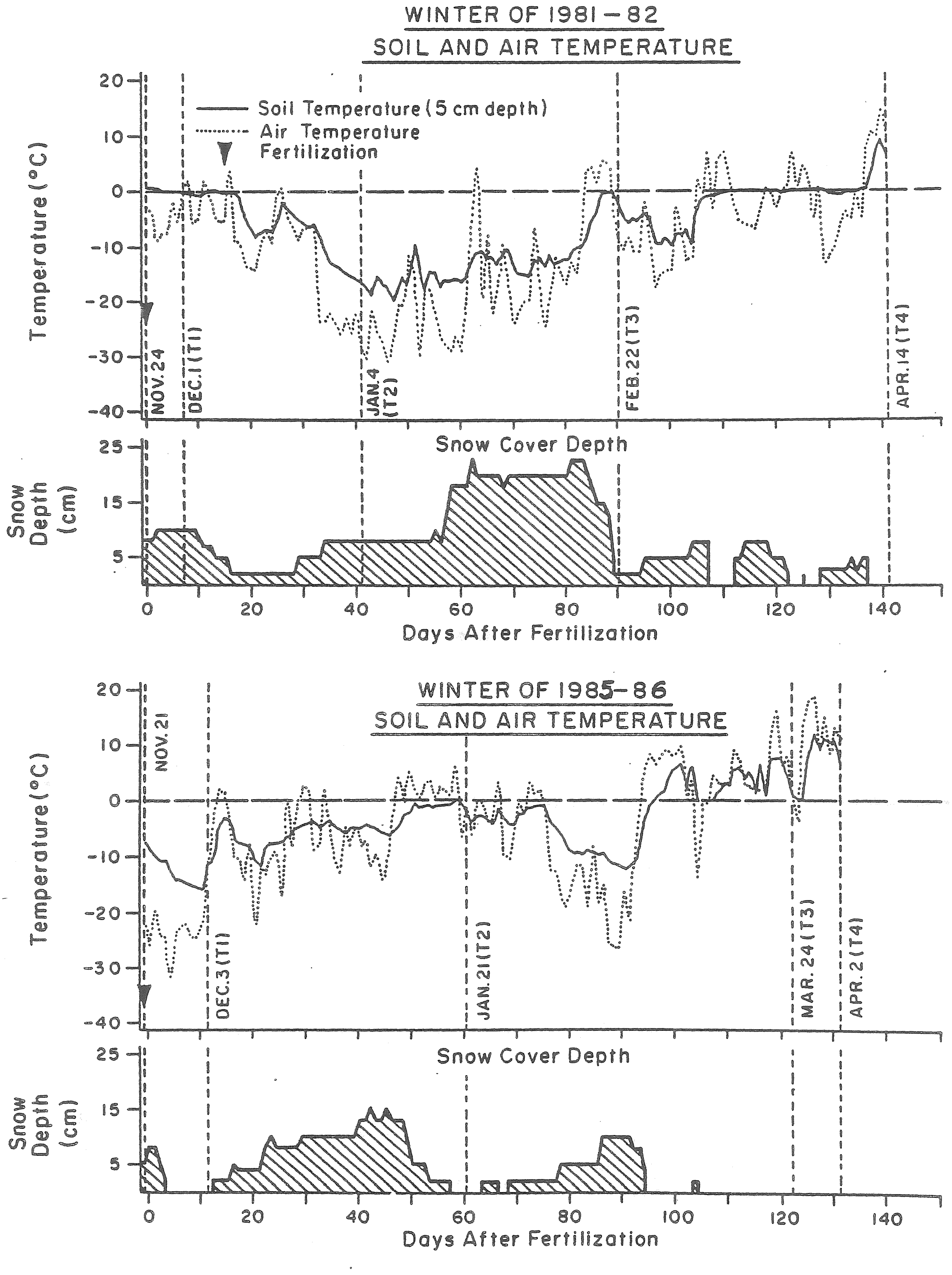

Figure 2. Soil, air temperature, and snow cover depth during the experiments.

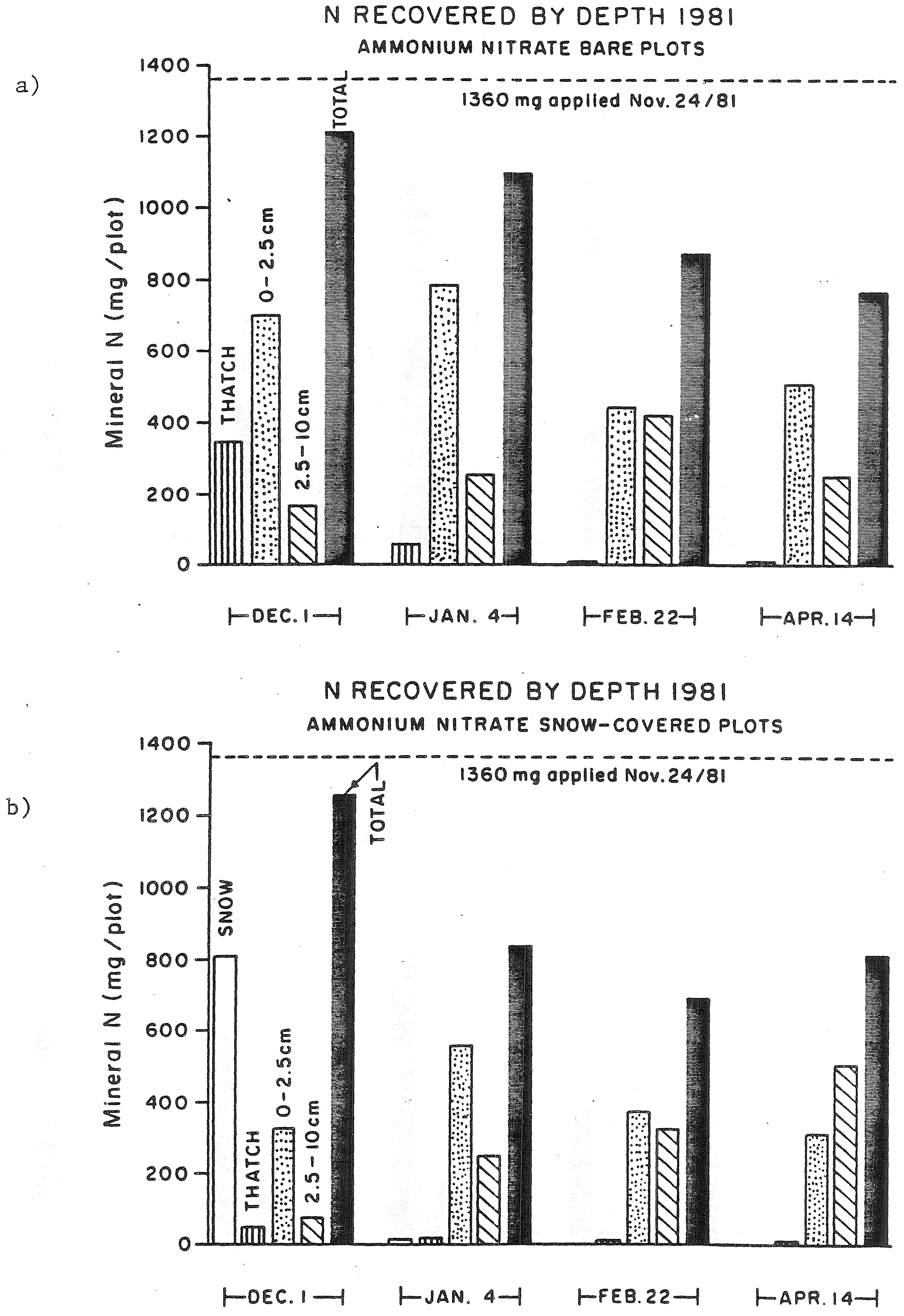

Figure 3. Recovery of mineral N throughout the winter from the ammonium nitrate fertilized plots:
a) bare plots,
b) snow-covered plots.

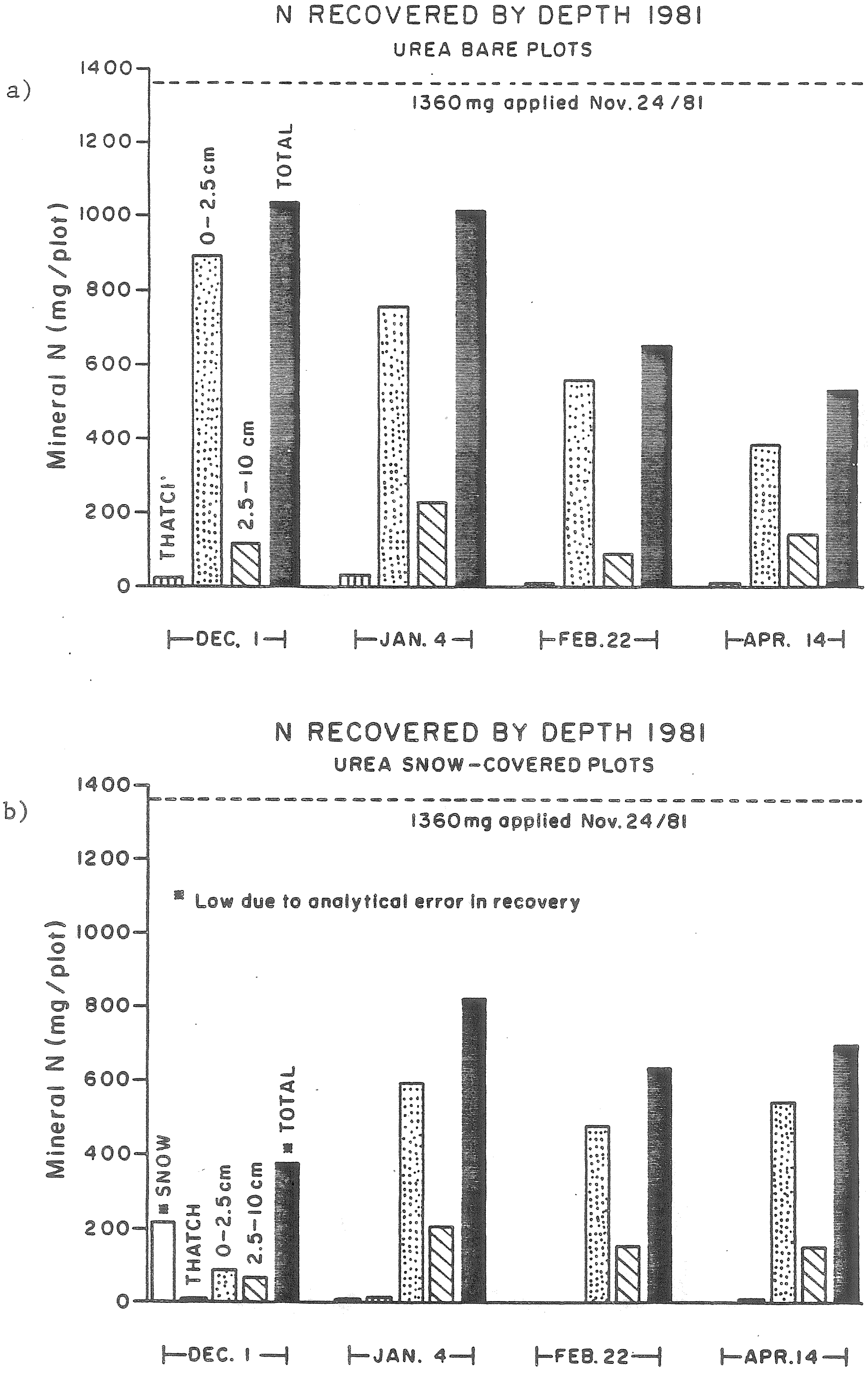

Figure 4. Recovery of mineral N throughout the winter from the urea fertilized plots:
a) bare plots,
b) snow-covered plots.

covered plots had most of the N in the snow layer and of this 50% was in the urea form. In these plots the mineral N contained only 30 and 50% of the N as urea in the bare and snow-covered plots. This indicates that urea hydrolysis can proceed in the field at low temperatures, and further, that hydrolysis in the snow is much slower than in the soil.

Recovery in 1985-86.

The winter of 1985 was characterized by a cold fall and mild winter. From fertilization (November 21) to the fist sampling on December 3 (T1), the soil was frozen and temperatures were near -10°C (Fig. 2). After T1 soil temperatures increased and the soil experienced several freeze-thaw cycles just before the second sampling on January 21 (T2) while the air temperatures oscillated between 0 and +5°C for about 12 days. These mild temperatures continued for 2 weeks after T2. By the third sampling on March 24 (T3) soil temperatures had increased and fluctuated between 0 and +7°C for several weeks. After T3 soil temperatures increased further and by the last sampling on April 2 (T4) the soil was at 10°C. Snow cover during this winter was thin and frequently disappeared either because of strong winds or melting. Four days after fertilization strong winds blew the snow off the plots carrying the fertilizer with it; consequently, the snow-covered plots for 1985 are not discussed.

The cold temperatures observed between fertilization and T1 prevented any transformation or movement of N in the AN bare plots (Fig 5a). Over 90% of the N in the AN bare plots was recovered from the thatch in equal amounts of NH_4- and NO_3-N. In the UR bare plots (Fig. 5b) N recovery was very similar to the AN plots but urea- and NH_4-N comprised 40 and 60% of the recovered N, respectively. This indicates once more the capacity of the soil system to hydrolyze urea even at very low temperatures.

At T2, the mineral N in the AN and UR plots was more than 3 times the amount of N applied. In the UR plots over 90% of the mineral was in the NH_4 form, while in the AN plots 70% was NH_4-N and 30% was NO_3-N. Malhi and Nyborg (1986) have observed overwinter increases in mineral N content of soil, but the increases they found were smaller than these. We believe that the repeated freeze-thaw cycles experienced prior to this sampling were partially responsible for this increase in mineral N. In addition, previous studies (Laura 1974) have indicated that changes in the dissociation of water due to salt effects results in a protolytic mineralization of soil organic matter, creating an apparent priming effect. One could speculate that the combined effect of freeze-thaw cycles and the salt effect of the fertilizer are the main factors affecting the release of mineral N from soils in winter. Some nitrification, however cannot be ruled out as there was a 100 mg increase in the NO_3-N content of the AN plots between T1 and T2.

At T3 and T4 the AN and UR plots showed large losses of mineral N, which were similar to those observed in the 1981 experiment. Malhi and Nyborg (1986) have attributed similar losses to denitification as the soils warm up and become waterlogged in early spring for quite some time, however some immobilization cannot be ruled out, especially in this soil that has accumulated a large amount of wide C/N ratio materials.

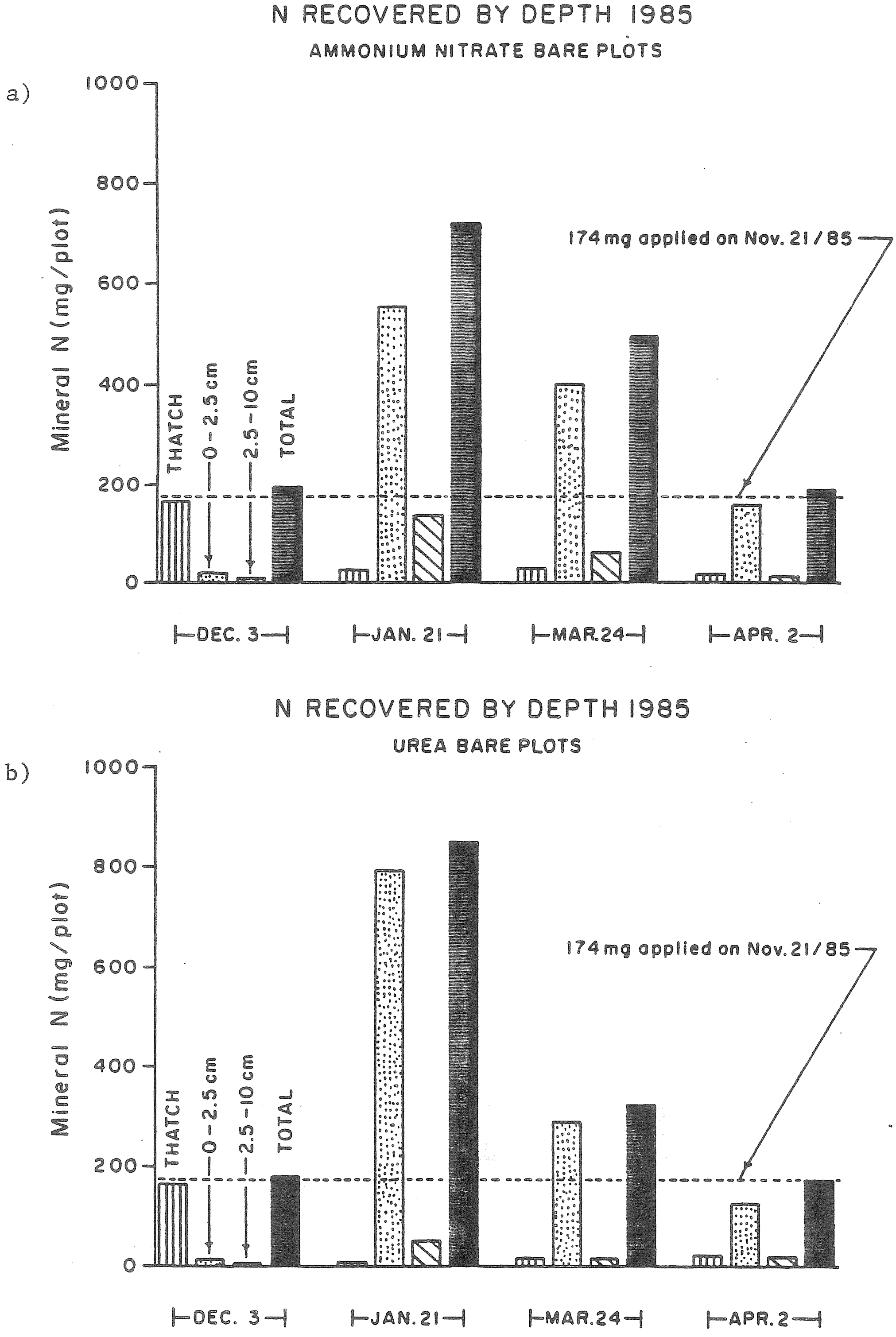

Figure 5. Recovery of mineral N throughout the winter from the bare plots in 1985:
a) ammonium nitrate fertilized plots,
b) urea fertilized plots.

SUMMARY AND CONCLUSIONS

The results of this study indicate that while winter temperatures remain well below $0^{\circ}C$ neither 34-0-0 nor 46-0-0 applied onto the snow will penetrate the snow pack, thus, they may remain susceptible to losses due to snow drifting. Further, under these conditions N transformations of 34-0-0 will be minimal, but urea will be hydrolyzed, even in the snow with the urease carried by wind-blown soil; the NH_3 produced could be lost by volatilization. Applications of 34-0-0 or 46-0-0 directly onto grasses in late fall will tend to reduce the losses ecountered when fertilizing through the snow; however, both fertilizers will hardly penetrate into the soil and could be lost during the spring melt, unless there are warm periods in the winter, when fertilizer N will move into the soil with the snowmelt water, and will be less susceptible to loss.

When winter temperatures fluctuate close to the freezing point, there could be a sizeable increase of mineral N, however the processes leading to this increase are not well understood and more research is required to identify the processes and to quantify their importance.

Regardless of the winter temperatures, there was a large decrease of mineral N in early spring which we attributed mainly to denitrifation but also some immobilization may have occurred.

Although from the producers perspective application of fertilizer N in late fall or winter may be desirable to distribute the workload more evenly, application of N fertilizer to grass stands through the snow are considered inadvisable in areas where snow drifting is a common occurrence. Application of fertilizer N onto bare grass stands reduces the potential losses due to snow drifting. In areas where chinooks often blow, fertilizer will enter the soil. The decision of whether to fertilize in late fall or winter depends on pure economic considerations as discussed previously by Campbell et al. (1986).

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