THE RECOVERY AND RELATIVE EFFICIENCY OF UREA AND AMMONIUM NITRATE FERTILIZER SOURCES APPLIED ONTO SNOW COVERED FORAGE CROPS

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INTRODUCTION

Spring is the time of greatest activity for most producers. Many activities have to be compressed into a narrow time span. In contrast, fall activities tend to be fewer and less urgent. Consequently, it has often been advocated that some spring activities, such as broadcasting fertilizer onto grasslands for hay or pasture production, could be switched to the fall, thus reducing the producer's spring workload. Unfortunately, many studies have shown that fall applied fertilizer nitrogen, particularly when broadcast as would be the case with perennial forage crops, is less effective than spring applied nitrogen due to overwinter losses from denitrification, volatilization, and leaching. On the other hand, the reduced efficiency of the fertilizer application may presumably be offset by the lower cost of fertilizer purchased in the fall.

Recently, it was suggested that late fall fertilizer applications, including applications onto snow cover, could reduce these losses and thus make fall applications more efficient and profitable. As a result, research was started at Swift Current to look at the behaviour of nitrogen fertilizers at low temperatures and on snow. Studies presently underway include examination in the laboratory of the effect of temperature and fertilizer source on N movement through snow; recovery of N applied in the field under controlled conditions to snow covered forage and cereal stubble using ^{15}N; and the effect of simulated 'Chinooks' on snow applied fertilizer N.

The study reported on here was set up to determine whether fall applications can be made more efficient through timing applications on the basis of weather conditions and whether the nitrogen source was important. A parallel study is also being run at Scott for the Dark Brown soil zone. This paper will report on the first two years of the study and concentrate on the relative efficiency of the nitrogen sources as influenced by the time of application. Some preliminary economic comments will also be presented. A full report on yields, efficiencies, and economics will be presented with recommendations after a few more years data are gathered.

MATERIALS AND METHODS

In 1980-81 and again in 1981-82, urea or ammonium nitrate fertilizers were applied to the same established stands of six grasses (Russian wild ryegrass, Intermediate wheatgrass, bromegrass, green needlegrass, and two types of crested wheatgrass) located at Swift Current on a Haverhill loam soil. Fertilizer was applied at a rate of 50 kg N/ha at one of three times in the late fall (October, November or December) or in the early spring (April). One set of plots was left unfertilized as a control. There were three replicates. The intent of the timing of application was that fertilizer be applied to cold unfrozen soil; frozen but snow free soil; frozen snow covered soil; and to unfrozen soil in the spring.

Plots were cut twice each year; first cut was in mid-June and second cut in mid-August. Dry matter and N content were determined. Soil samples were taken to 100 cm in spring and in fall and analysed for urea, ammonium, and nitrate ions.

A similar experiment was initiated on bromegrass grown on a Scott loam soil. This experiment was replicated four times. Only yield data are presently available.

As well as the usual statistical analysis of the results, the total yields for each year and location were subjected to a preliminary economic analysis. Several assumptions were made for these analyses: hay price - \$70/tonne; ammonium nitrate cost - \$0.73/kg; urea cost - \$0.66/kg; opportunity cost of labour - \$12/hr; application cost - \$4.32/ha; and labour required - 0.124 hr/ha.

Because of the differing times of application the data were reanalyzed after seasonal adjustment assuming fertilizer costs 20% less in the fall and labour opportunity costs for fall and winter were 50% of spring costs.

RESULTS

1980

1. WEATHER CONDITIONS

Although the fall of 1980 was cool, the winter and spring of 1980-81 was one of the warmest on record (Table 1). Fertilizer was first applied on October 23rd, a cool cloudy day with temperatures about +2C. The soil was very wet underfoot as a result of heavy fall rains. The soil was sampled prior to fertilization. The soil was still very wet although frozen to a depth of 20 cm on November 25th when the next set of plots were fertilized. The day was cloudy and cold (-2C) with a slight "skiff" of snow covering about 50% of the basal area. Soil samples were taken again. About 10 cm of snow was on the ground on December 8th when the third set of plots were fertilized. Although there had been a week of temperatures around -20°C the day was cloudy, no wind with a temperature of -2C and the snow was soft. No soil samples could be taken. On April 3, 1981, the spring plots were fertilized onto a dry soil surface. Temperature was +8C.

Table 1. Average monthly temperatures (°C)

Month	1980-81 Max.	1980-81 Min.	1981-82 Max.	1981-82 Min.	Long-term avg. Max.	Long-term avg. Min.
Nov.	4.4	-4.8	5.6	-3.9	1.6	-8.6
Dec.	-6.4	-16.1	-6.1	-13.9	-4.7	-14.5
Jan.	0.0	-8.1	-16.4	-27.6	-8.6	-18.9
Feb.	-2.5	-10.8	-8.1	-17.6	-6.3	-16.6
Mar.	7.1	-4.8	-2.1	-10.4	0.1	-10.4
Apr.	13.4	-1.1	7.6	-4.1	11.0	-1.8

SOIL NITROGEN

Long periods of above-zero weather in mid-winter caused significant thawing of the soil. Consequently, we were able to take soil samples even in January. On January 22, 1981, we recovered over 80% of the applied fertilizer N in the top 15 cm (Fig. 1). However,

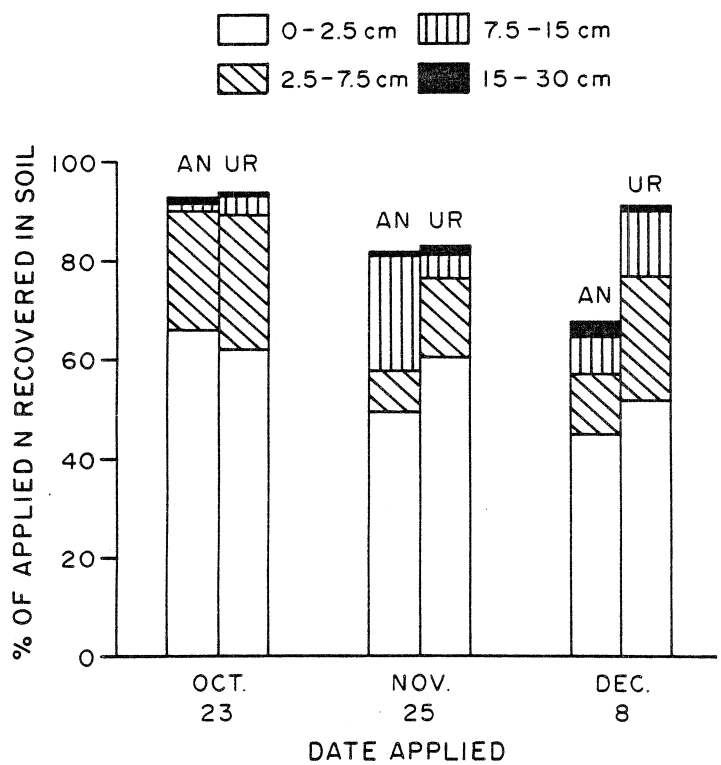

Fig. 1. Recovery of applied fertilizer N from the soil on January 22, 1981

March 17, 1981, recovery in the soil had dropped to between 12.6 and 29% of the applied N (Table 2). It is assumed that most of the N had been lost from the system already. This conclusion was substantiated by the N recovery in the plant (Fig. 4). There was no residual N found in the soil after two cuts were taken.

Table 2. Effect of date of application+ on proportion (%) of applied N recovered+ in soil on Mar. 17/81

	Time of Application (1980)		
Depth (cm)	Oct. 23	Nov. 25	Dec. 8
0-2.5	22.8	9.7	17.9
2.5-7.5	4.5	2.5	2.4
7.5-15	1.6	0.4	0.9
Total	28.9	12.6	21.2

+Average of urea and AN treatments on six grasses with three reps; source of N was not significant

3. YIELDS AND N RECOVERY

In 1981 the plots were cut twice. The spring of 1981 was

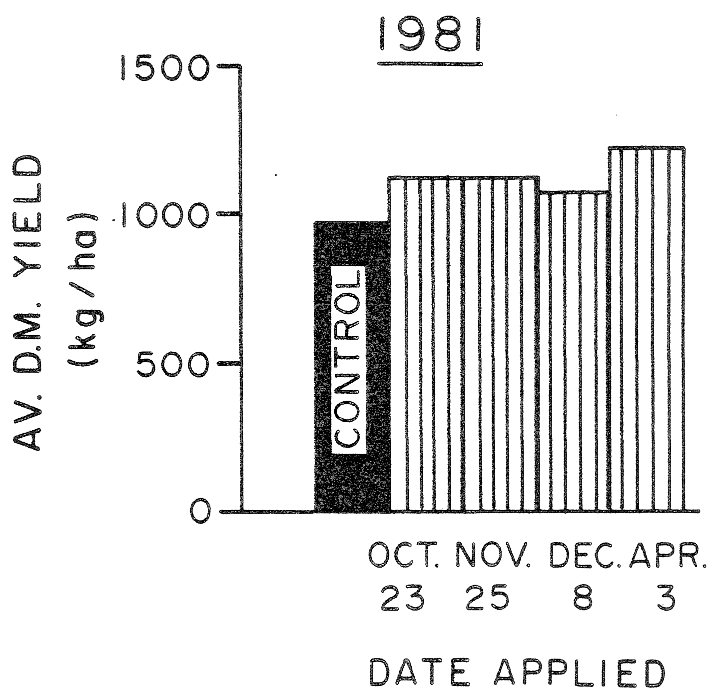

Fig. 2. Total dry matter yield in 1981 averaged over 6 grasses and 2 fertilizer sources

extremely dry and first cut growth was poor. Cut 1 yields were low (overall mean 385 kg D.M./ha) and neither type of fertilizer nor date of application had significant effects on yields. Increased precipitation prior to cut 2 resulted in higher yields (overall mean 720 kg/ha) and the appearance of treatment effects. There were no differences between the responses to fall applications
although the application of 50 kg N/ha increased yields by 24%. Spring applications produced significantly higher yields (39% greater than the check). The type of fertilizer used did not significantly result in yield differences. The total dry matter yield for the two cuts, averaged over the six grasses in the study, is shown in Figure 2. Over the season, the addition of 50 kg N/ha only increased yield by 18% and time of application was not significant at the 5% level of probability. However, the trends seen in Cut 2 are clearly seen (Fig. 2).

Although cut 1 yields were unaffected by the fertilizer treatments, addition of 50 kg N/ha significantly increased the % N in cut 1 with the spring application resulting in higher % N than the fall application. Nitrates in plants were also highest in treatments receiving the spring application. Ammonium nitrate produced a small but significantly greater increase in % N than urea. In cut 2 the picture changed. The greater growth response resulted in a dilution of nitrogen taken up so that the unfertilized plots with the lowest yields had the highest % N (2.54%) and the fall plots (which had less nitrogen available to be taken up after overwinter losses) were all similar with lower percentages of nitrogen. Spring-treated plots were intermediate. There was no difference between the two fertilizer types in their effect on % N in cut 2.

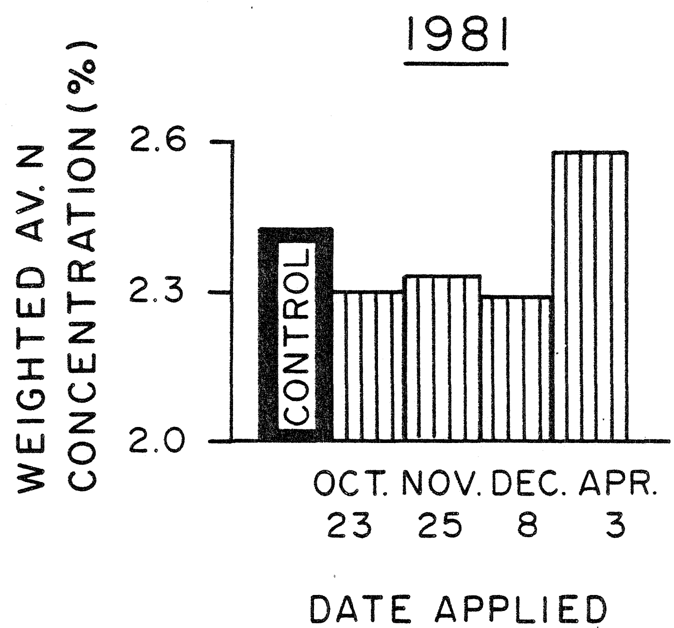

Fig. 3. Effect of time of fertilizer application on N concentration in forage (results averaged over 6 grasses, 2 cuts and 2 fertilizer sources)

Because of the higher yields in cut 2, the weighted average % N in the grasses over the two cuts was greatest for the spring applied N (2.58%) and least for the three fall treatments (Fig. 3). The three fall treatments also had lower N concentrations than the unfertilized controls as a result of N dilution as noted above.

There was no effect of grass species or source of N on N recovery in the plant; time of treatment was significant at P 0.05. Recovery of N for the three fall treatments averaged 12.9% of the applied N (based on two cuts) while recovery was 22.4% for the spring applied N (Fig. 4). In the spring applied N there appeared to be a slightly better recovery of the ammonium nitrate source compared to the urea source but this difference was not significant. These low recoveries confirm the N recovery data obtained in the soil in March (Table 2) and also reflect the relatively dry growing season in 1981.

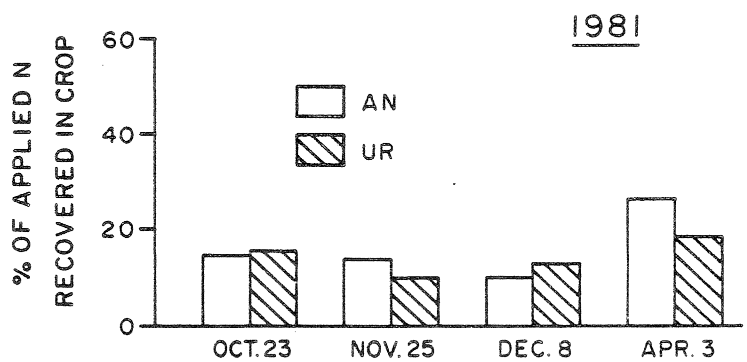

Fig. 4. N recovery from grasses fertilized in fall and spring averaged over grasses and fertilizer sources

4. ECONOMICS

The pattern of economic returns from fertilizer applications was similar to that for crop yields. As might be expected, the drought conditions, by affecting crop growth and response to nitrogen, made any application of fertilizer non-profitable. The poorest economic returns were from the December application onto snow (Fig. 5). After seasonal adjustment, however, the economic returns from fall applications improved relative to spring application because of lower fertilizer and opportunity labour costs. In 1981 there were no real or consistent differences in economic returns due to the form of nitrogen applied.

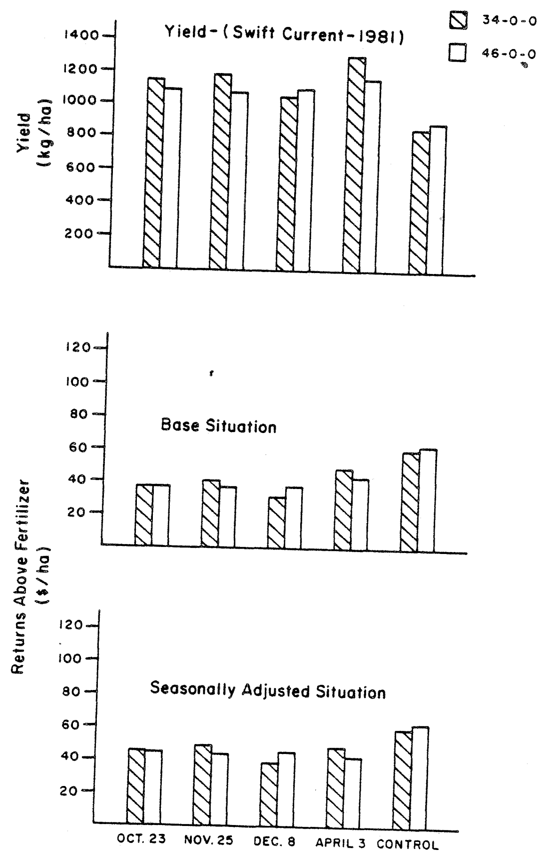

Fig. 5. Preliminary economic assessment of 1981 forage yields at Swift Current

1981-82

1. WEATHER CONDITIONS

The fall and winter of 1981-82 was much colder than that of 1980-81 (Table 1). When the fertilizer was applied on October 26th, the soil had been frozen on the surface earlier in the month but had thawed out again. The soil was moist and it was a calm overcast day with temperatures around 3°C. On November 23rd when the second application was made, the soil was frozen to 10 cm, there was about 4 cm of snow on the ground, the temperature was about 3°C and the day was bright and sunny. On December 14th the temperature was -14°C, the ground was snow covered and the day was calm and sunny. On April 16th the temperature was 4°C, the soil was damp but not wet, the wind was brisk and it was partly cloudy.

2. SOIL NITROGEN

More N was recovered from the soil when it was sampled in April 1982 than in March 1981 (Fig 6. and Table 2). This was particularly true for the spring applied N where over 70% of the N was recovered in the top 30 cm. As in 1980-81, most of the mineral N was at this time located in the top 2.5 cm of the soil. The average recovery of N in the soil in the case of the fall applied N was about 40%, with the recovery being consistently and significantly greater from the ammonium nitrate source (Fig. 6). The overall averagerecovery of ammonium nitrate-N at this stage was 59% and of urea-N 36%. The greater loss of urea-N can be explained by its tendency to increase soil pH, thus driving off NH_4 as NH_3 by volatilization. In contrast, NH_4NO_3 tends to reduce pH. The greater recovery of the fall applied N in 1982 compared to 1981 was due to the colder conditions in 1982 slowing the reaction rates. Denitrification losses would also be lower under colder conditions.

Nitrate-N levels were greater in ammonium nitrate treated soils than in urea treated soils (as expected); the same was generally true for NH_4N in ammonium nitrate treated soils (Table 3). By April the NO_3 concentration was much greater and NH_4 much lower in the October treatment than in the other fall treatments, indicating that

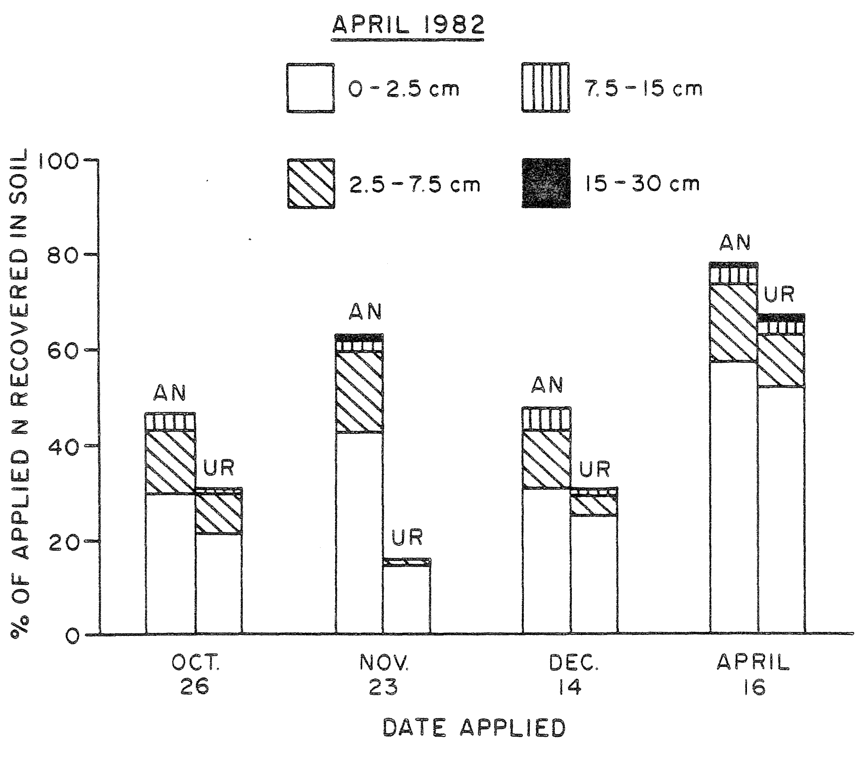

Fig. 6. Effect of source of N and date of application on recovery of N in the soil in April 1982

nitrification in the October treatment probably occurred in the fall. Most of the recovered N was located in the top 7.5 cm of the soil.

3. YIELDS AND RECOVERY

In 1982, which was a much wetter year than 1981, the average yield of the control plots at Swift Current (two cuts) was 1105 kg/ha. The increase in yield due to 50 kg N/ha of fertilizer was 61% on the average. Furthermore, both time of application and source of N (in contrast to 1981) significantly affected yield and interacted in their effect (Fig. 7). Yields were generally greater when ammonium nitrate was applied than when urea was applied. This reflected the fertilizer recovery from the two sources mentioned earlier. The best yield response to fertilizer was obtained from spring applied N but this was only slightly better than N applied in late October (if better at all). The lowest yield response to fertilizer was obtained where the fertilizer was applied on frozen soil that had some snow cover. There was a 24% yield advantage when the fertilizer was applied in October or April compared to November or December.

The study carried out at Scott in the Dark Brown soil zone showed similar yield trends although the level of response was much greater (Table 4). Application of 50 kg N/ha almost tripled the yield and both time of application and source of N significantly affected yield. As in Swift Current, ammonium nitrate produced higher yields than urea; however, in contrast to Swift Current, highest yields were obtained from fertilizer applied in mid-November or mid-December. The lowest yield response to fertilizer occurred where fertilizer was applied in March, well before grass growth started. At this location, application onto snow cover appeared to have an advantage. However, proper interpretation of these data awaits more detailed information on the meteorological and soil conditions at time of fertilizer application.

The excellent rainfall obtained in 1982 (about 30% greater than the long-term average for April to August inclusive) resulted in good yield response to the fertilizer treatments and the relative response between 1981 and 1982 at Swift Current shows the importance of applying fertilizer so as to make efficient use of rainfall.

At Swift Current, except for the cold, unfrozen soil treatment (October)in which there was no effect of N source, treatments receiving ammonium nitrate generally had greater % N in first-cut forage than treatments receiving urea (Fig. 8). By the second cut all the applied N was probably lost or used up by the crop, thus there was no effect of time of application or source of N on N concentration.

N recovery reflected N concentration response of first cut forage (Fig. 8, top). Because the year was wet and good growth was obtained, most of the applied N that remained in the soil until spring was recovered by the plant (mainly in the first cut) (compare Fig. 6 & 8). Furthermore, in the case of the October treatment, all the N that was present in the soil in the spring appeared to have been recovered

Table 3. Effect of date of application and N source on mineral N located in various soil segments on April 21, 1982

Fertilizer	Depth (cm)	Date applied (1981-82) Oct. 26	Nov. 23	Dec. 14	Apr. 16	Control	Mean
		- - NO_3-N (kg/ha) - -					
Am.Nitrate	0-2.5	9.9	10.2	10.0	16.0	3.2	9.8
	2.5-7.5	8.7	8.7	5.7	6.3	2.3	6.3
	7.5-15.0	3.2	1.7	2.1	2.0	0.9	2.0
	15.0-30.0	1.0	0.9	1.0	1.2	0.8	1.0
	Total	22.8	21.5	18.8	25.5	7.2	19.2
Urea	0-2.5	9.9	5.2	9.1	4.8	2.8	6.3
	2.5-7.5	6.4	2.3	3.4	2.2	1.7	3.2
	7.5-15.0	1.7	0.8	1.3	0.9	0.8	1.1
	15.0-30.0	1.3	0.8	1.2	1.0	0.8	1.0
	Total	19.3	9.1	14.9	8.9	6.1	11.6
		- - NH_4 (kg/ha) - -					
Am.Nitrate	0-2.5	13.4	19.9	13.8	19.3	5.6	14.4
	2.5-7.5	5.5	7.0	8.2	9.3	6.0	7.2
	7.5-15.0	4.6	5.1	5.7	5.1	4.9	5.1
	15.0-30.0	4.6	5.2	4.4	5.3	4.9	4.9
	Total	28.1	37.2	32.1	39.0	21.4	31.6
Urea	0-2.5	9.3	10.5	12.2	29.7	5.2	13.4
	2.5-7.5	5.2	5.9	6.1	10.9	5.2	6.6
	7.5-15.0	4.4	4.6	4.8	5.9	4.7	4.9
	15.0-30.0	4.3	4.6	4.2	5.5	5.1	4.7
	Total	23.2	25.7	27.2	52.0	20.2	30.0

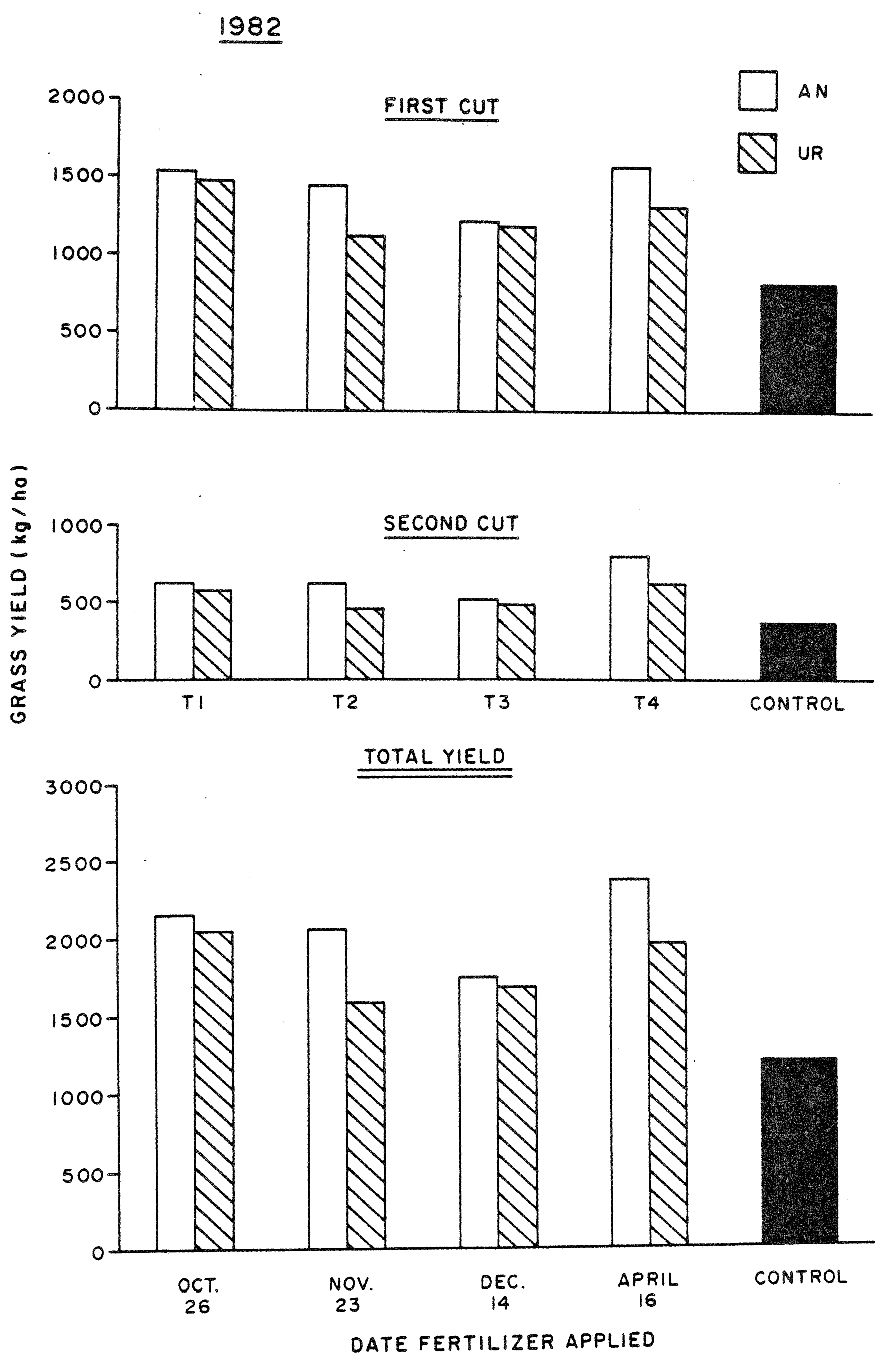

Fig. 7. Effect of N source and date of application on 1982 yields (kg DM/ha) at Swift Current (mean of 6 grasses)

Table 4. Effect of time of broadcasting N on 1982 bromegrass yields (kg DM/ha) at Scott

N source	Time applied				
	Oct.	Nov.	Dec.	March	April
Urea	1459	1838	1717	1228	1680
Ammonium nitrate	1656	2081	1910	1456	1752
Check	664	-	-	-	-
LSD 5%	514				
1%	692				
CV	22.46				

by the crop (Fig. 6 & 8). The latter is significant because it suggests that there may be a time or a condition under which urea fertilizer can be just as effective as ammonium nitrate when they are applied in the fall. Another interesting observation was that recovery of urea applied in October was as good as that applied in spring, and the total dry matter yields (Fig. 7) were also similar. If this could be established consistently, it would mean a great saving to the producer to apply the fertilizer in the fall since urea might be the only reasonable source of N available to him in the future. The Scott data (Table 4) tends to corroborate this conclusion.

4. ECONOMICS

As in 1981, the pattern of economic returns in 1982 followed closely the pattern of yields at both Swift Current and Scott.

At Swift Current, applying N fertilizer was profitable when applied in October or April, but was not profitable or only marginally profitable when applied in December. It was not profitable to apply urea in November (Fig. 9). Spring application generally gave the greatest economic returns, but when costs were seasonally adjusted, the returns from the October application were as good as, or better than spring applications, particularly for urea.

At Scott, applying fertilizer was generally profitable (Fig. 10). Highest returns were obtained from the November application and lowest from the March application. Seasonal adjustment did not change the picture except to make fall application even more profitable.

CONCLUSIONS

As stated in the introduction, this is an interim report. The two years for which we have data so far were somewhat abnormal with one being very dry and one very wet. However, a few tentative conclusions

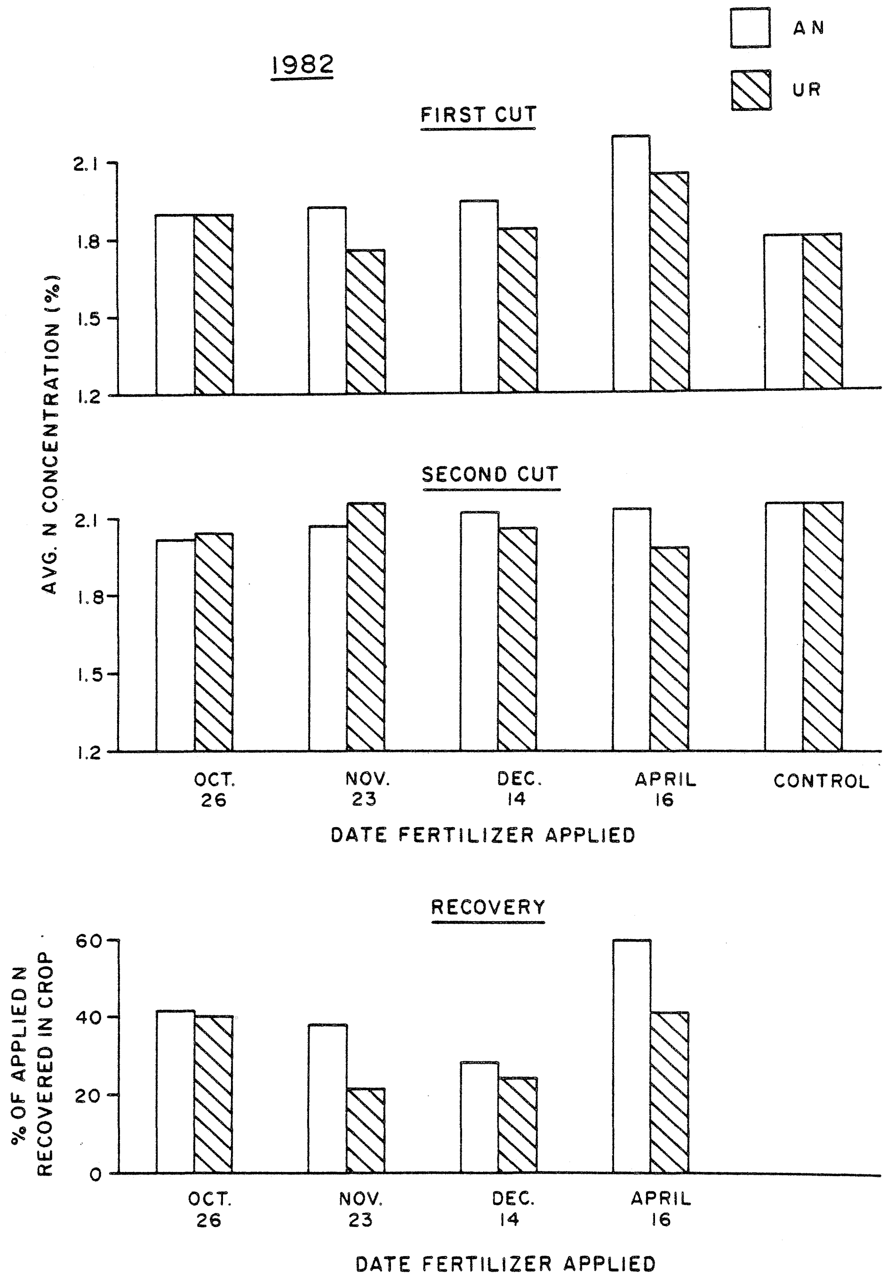

Fig. 8. Effect of time of N application and fertilizer source on N concentration in forage and N recovery at Swift Current

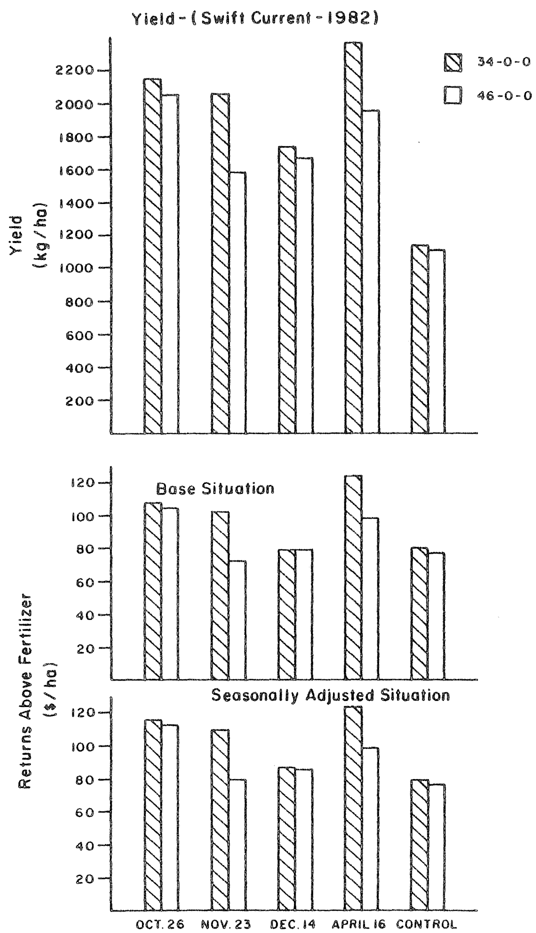

Fig. 9. Preliminary economic assessment of 1982 forage yields at Swift Current as affected by time of application and source of fertilizer N

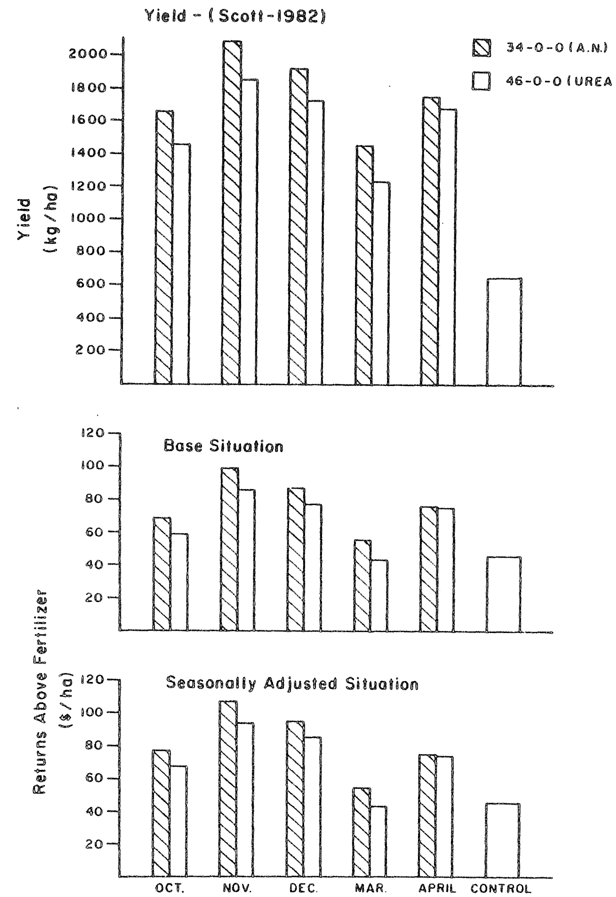

Fig. 10. Preliminary economic assessment of 1982 bromegrass yields at Scott as affected by time of application and source of fertilizer N

may be drawn so far:

1. N recovery and yield response varies considerably with soil and weather conditions in the fall to spring period as well as with the growing season weather.

2. N recovery and yield response was generally superior for ammonium nitrate than for urea.

3. Recovery and yield were generally higher for spring applied N compared to fall applied N.

4. There might be soil and weather conditions under which fall applied N will result in as good a yield response as spring applied N.

5. Results to date indicate some promise from an economic standpoint for N applied to cold unfrozen soil.

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