The Influence of Sampling Time on Fall Soil Nitrate Levels

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Currently the traditional and most reliable method of measuring available N for the crop is the nitrate soil test. Fall sampling is most common, and to be effective, it should reflect the amount of N available at planting time. Manitoba recommendations have traditionally been to "delay sampling until soils have cooled to 5^{o}C" so that all the N that will mineralize during the fall will be detected (1). This has historically been in early to mid October.

But earlier fall sampling may be desirable for number of reasons:

- sampling is more likely to be done
- analysis is available for fall N application
- sampling before tillage gives more consistent /reliable sample depths
- volunteer crop regrowth is less likely to hide available N from test

The following study was conducted to investigate whether soil nitrate levels from cereal fields were sufficiently stable to permit reliable early fall sampling. It more likely that soil N levels would be stable under cereal stubble than following crops with a lower straw C:N ratio (i.e. pulses, legumes or high N fertilized crops).

Materials and Methods

Four sites of varying soil texture and tillage system were soil sampled through the fall of 1999 and 2000 (Table 1). Soil texture ranged from heavy Red River clay to Reinfeld sandy loam, and production system ranged from intensively tilled soil in a potato-cereal rotation to long-term zero-till in a cereal-oilseed rotation. Sites were soil sampled every 2 weeks from early September for as long in the fall as conditions permitted and in the spring. The sample was a composite of 15 pokes taken around the perimeter and centre of a 30' diameter circle. The sampling site was marked and sequential sampling was done within 3 feet of previous cores. Samples were taken at 0-6" and 6-24"depths with a backsaver hand probe at Carman and Carberry, with a tractor mounted probe at Brandon and a truck mounted probe at St Jean. In 2 instances, spatial variability within the sampling scheme was assessed by taking adjacent samples but compositing separately.

Since timing of fall sampling is based on temperature criteria, soil temperatures at the 4"depth were recorded with 2 HOBO data loggers (ONSET computer corporation) at each site during the fall and over the winter. At the St Jean site in 1999 both HOBOs malfunctioned and did not record any data. HOBOs were retrieved in early spring in 2000 and in May in 2001.

Results

Soil Temperatures

Fall N mineralization is dependent upon many soil and environmental factor including soil temperature, moisture, aeration and mineralizable N status. Only detailed soil temperatures were measured, but fall 1999-winter 2000 could be described as dry and fall 2000 -winter 2001 as wet. Fall soil and air temperatures are presented in Figures 2-3 for the Carman site only, but other sites followed the same general cooling pattern. The following observations are apparent upon inspecting data from the Carman and other sites:

- In both falls, the decline in soil temperature was most rapid in the last week of September and first week of October (Figures 1-2). Temperatures then stabilized and did not drop below 5^{o}C until late October in 1999 and early November in 2000.

- Soil temperatures in Carman (UM) lagged about 3 days behind air temperatures.
- The dates when soils first reached a daily mean temperature of 5^{o}C or less is reported in Table 2. In 1999 the MCDC and ZT site reached the 5^{o}C temperature almost 3 weeks before Carman. In 2000, all 4 sites reached the 5^{o}C temperature within 2 days.
- The average cooling rate of soils was determined over the fall period. Mean cooling rates were 0.19 ^{o}C/day in 1999 and 0.15 ^{o}C/day in 2000 (Table 2). This is similar to values reported by Harapiak for Alberta soils (2).

Cumulative fall soil thermal units (TU)
Soil thermal units have been suggested as a method to track N mineralization rates (3). For this data, a base temperature of 5^{o}C was used since mineralization is presumed to be minimal below this temperature (Figure 3-5). Thermal units (TU) were calculated as the average daily soil temperature less 5^{o}C. Thermal units were accumulated from a common starting date in late September until all soil temperatures declined below 5^{o}C .

- At Brandon (ZT) and Carberry (MCDC) the accumulated TU's were substantially more in fall 2000 than 1999. At Carman (UM), initially TU's accumulated more rapidly in 1999, but ultimately were more in 2000.
- the greatest accumulation of TU's was in St Jean (SJ00).

Spring soil thermal units
The 2001 spring TU's are graphed in Figure 6. It is apparent that TU's accumulated rapidly through May. Mineralization would be expected to be high with moist soils and these increasing temperatures. The consequence of this heat accumulation on mineralization is considered in the next section.

Soil nitrate results
In order to determine differences due to temporal vs spatial variability, duplicate samples were taken at 2 sites in spring 2001. The range of nitrate-N in lb N/ac was 39-50 at Carman (UM00) and 59-60 at Brandon (ZT00). Based on these observations, it was presumed that values within $^+_-$10 lb N/ac were within the range of spatial or sampling error and were not different.

Soil nitrate N data is presented in Tables 3.
Based on traditional sample timing (mid October), N levels fell into the following ranges:

- 3 sites in the Low range = 20-40 lb N/ac (UM99, MCDC99 and SJ99)
- 3 sites in the Medium range = 40-60 lb N/ac (UM00, ZT00 and SJ00)
- 2 sites in the High range = 60-80 lb N/ac (MCDC00, ZT99)

When nitrate levels were averaged by date across all sites, there was little variation (Table 2) - but this ignores many of the fluctuations observed. To identify fluctuations outside of that range of spatial or sampling error, data was evaluated on the deviation from the traditional mid October sampling date, by which time soils had all approached 5^{o}C (Table 4). The readings within $^+_-$10 lb N/ac of the mid October readings (**bold** in table 4). The greatest deviations from the "traditional" date were the early September and May sampling dates.

Identified deviations from the traditional mid October readings are:

1. High early September readings (UM99, SJ99) - were unexplained - perhaps due to later microbial immobilization of N by crop residue since weed or volunteer crop growth was minimal at all sites.

2. Low early September readings (MCDC00, ZT99, and ZT00) were unexplained at ZT sites. At Carberry (MCDC00) the nitrate N level consistently increased through the fall (Figure 6). Mineralization may have been promoted through monthly tillage (aeration of soil and physical

breakdown of straw, the warm and moist soil environment in fall 2000, as well as the initial medium-high N status of the soil. Others have been observed to be greater when initial soil N levels are high (4).

3. Depressed later season N readings (UM00, SJ99) - was unexplained for the SJ site. At Carman (UM00) some 28 lb nitrate-N disappeared between early and mid November in fall 2000 (Figure 7). This is likely due to leaching of N below the 24" depth due to high rainfall on this sandy loam textured soil.

4. Greater spring readings (UM99, MCDC99, SJ99, SJ00) are probably due to early spring mineralization based on increasing soil temperatures (Figure 5). This is frequently observed and is factored into Manitoba soil test recommendations (1).

Other fluctuation of N by sampling time, particularly at the ZT sites, were not easily explained. Occasionally soil chloride levels would change similarly with nitrate levels in the subsoil portion, suggesting upward movement from deeper in the profile. Detailed explanation was beyond the scope of this study.

Summary

- Soil temperatures generally declined to the 5^{o}C target by early October. However temperatures leveled off in mid October, allowing accumulation of thermal units which may permit some mineralization and other soil N processes (nitrification, immobilization, denitrification, etc).
- Soil temperatures declined through the fall at between 0.15 and 0.2 ^{o}C per day or 1.5 to 2 ^{o}C every 10 days.
- Based on the gross mean of all sites, there appears to be little difference in nitrate-N levels among fall sampling dates. **But** there was considerable deviation (>20 lb nitrate-N/ac) with the early September sampling dates at 5 of 7 sites, indicating that sampling should be delayed until late September at the earliest. Some of this site variability in nitrate levels could be explained, but much remained beyond the scope of this study
- The consistent trend of increasing nitrate-N levels during the spring was clearly observed -except where late fall leaching reduced N levels.
- When excessive rainfall occurs after fall sampling, soils should be re-sampled since N may have been lost through leaching on sandy soils, or denitrification on saturated soils.
- This study was conducted only following cereals. One would expect fall mineralization to be greater following pulses, legumes and high N fertilized crops.

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Table 1. Descriptions of study sites.

Site	Carman UM research station	Carberry MCDC research station	Brandon Manitoba Zero Till Research Farm	St Jean R Sabourin farm
Data coding 1999 2000	**UM99** UM00	MCDC99 MCDC00	ZT99 ZT00	SJ99 SJ00
Soil type	Reinfeld sandy loam	Ramada clay loam	Newdale clay loam mid slope	Red River clay
CEC % OM	11 meq 2.9%	21 meq 5.3%	32 meq 4.9%	41 meq 4.4%
Previous crop 1999 2000	Barley Spring wheat	Barley barley	Fall rye Winter wheat	Spring wheat Spring wheat
Tillage system	No fall tillage	Tilled 2 x during fall	No fall tillage	Tilled 1 X in fall

Table 2. First date of soil temperatures below 5^{o}C and cooling rate.

Site	First Date <=5^{o}C		Cooling rate ^{o}C/day	
	1999	2000	1999	2000
Carman	**Oct 20**	Oct 6	0.20	0.13
Carberry	Oct 1	Oct 5	0.17	0.18
Brandon	Oct 2	Oct 6	0.19	0.15
St Jean	-	Oct 6	-	0.12

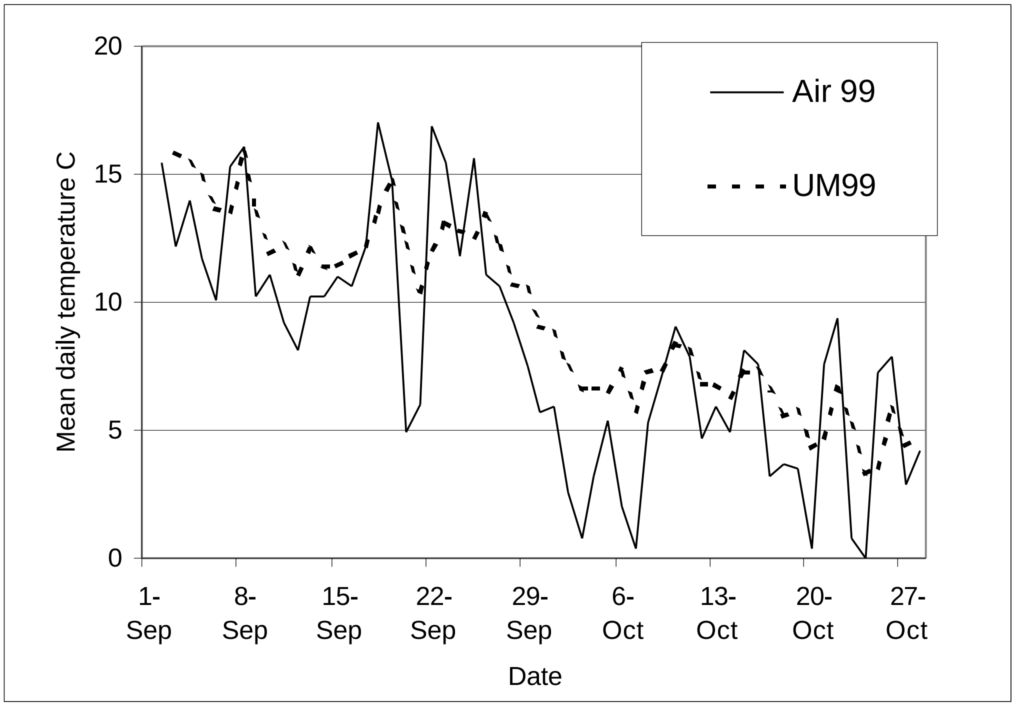


Figure 1. Mean daily air and soil temperature (4 inch depth) at the Carman sites in fall 1999.

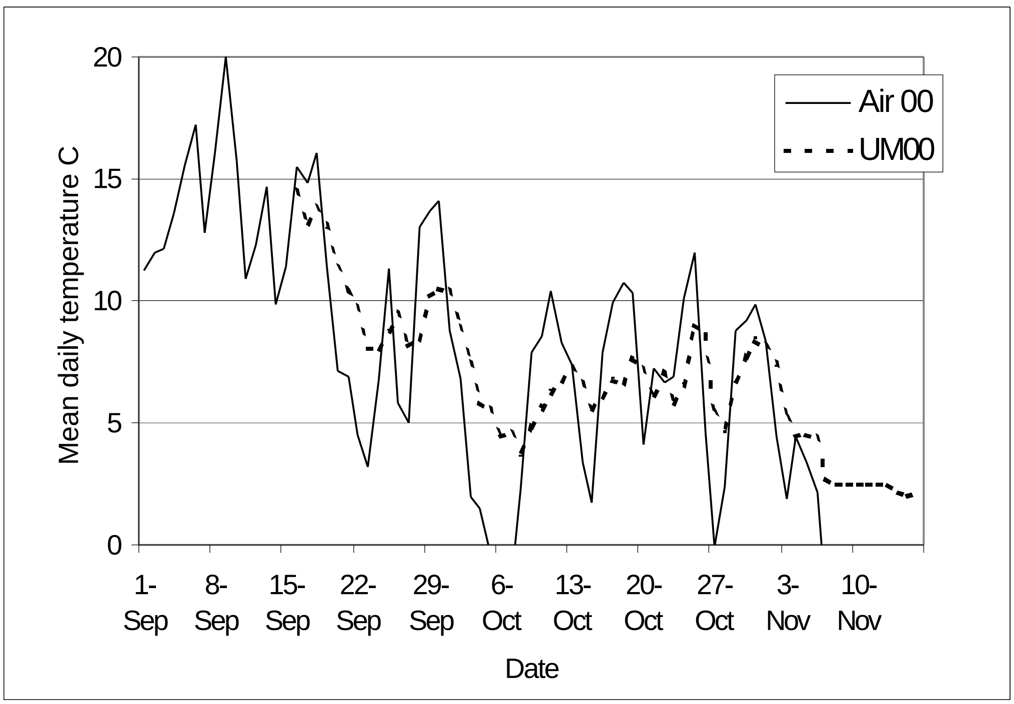
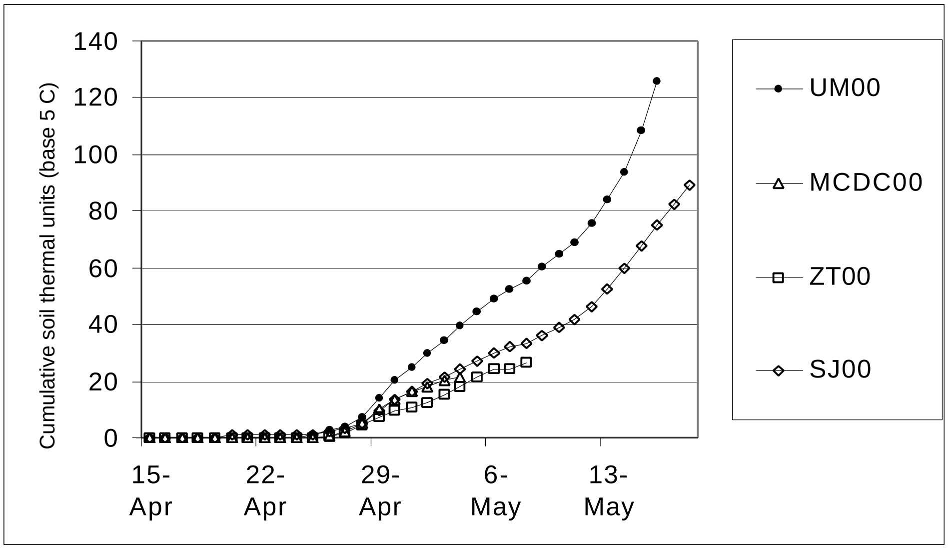
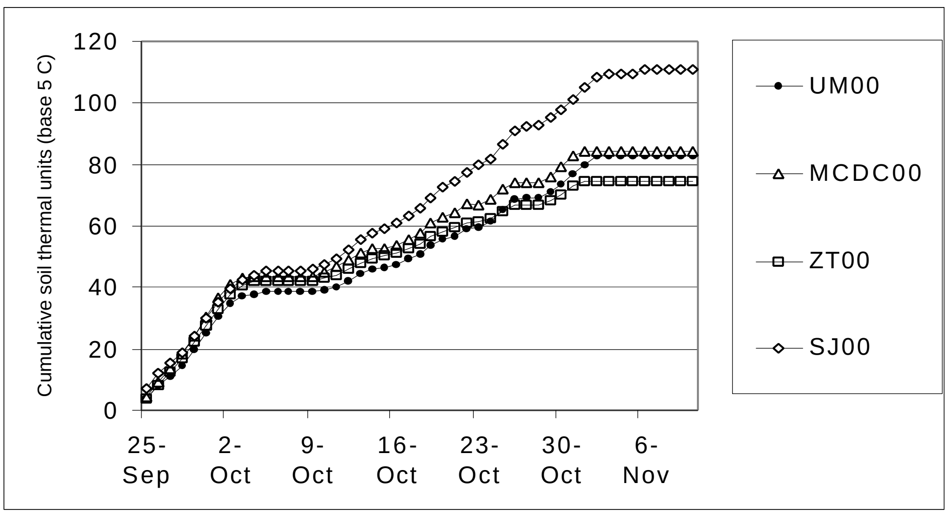
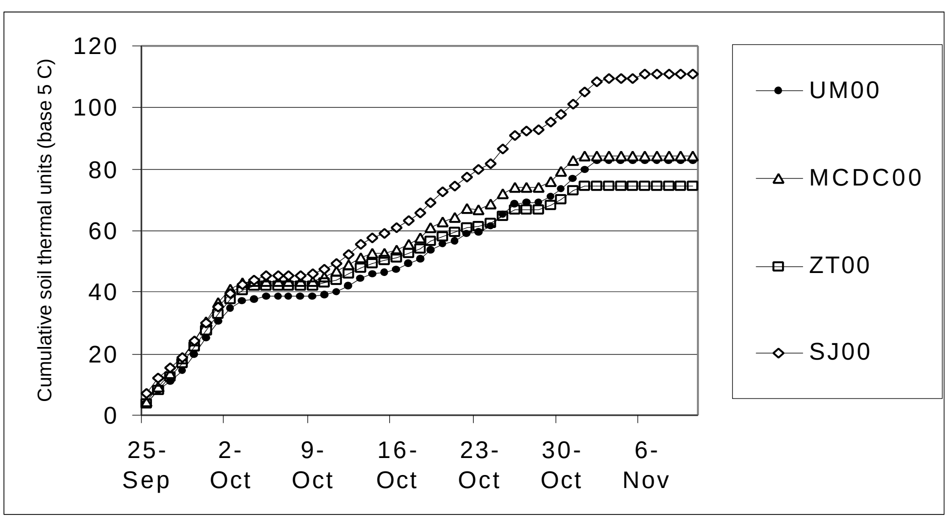


Figure 2. Mean daily air and soil temperature (4 inch depth) at the Carman sites in fall of 2000.







Figures 3-5. Soil thermal unit accumulation in fall 1999, 2000 and spring 2001.

Table 3. Soil nitrate-N levels at different sampling dates.

Sampling date	Soil nitrate-N lb N/ac in 0-24"								
	UM99	UM00	MCDC99	MCDC00	ZT99	ZT00	SJ99	SJ00	Mean
Early Sept	62	49	27	55	51	33	63		49
Mid Sept	38	58	38	63	56	76	39		53
Early Oct	42	49	31	82	47	46	32		47
Mid Oct	36	58	37	79	71	58	38	49	53
Early Nov	36	62	40		58		23		44
Mid Nov		34							
April	39	45	51		69				51
May	49	40	64	71	65	60	51	76	60

Table 4. Deviation in soil nitrate-N from the standard mid October sampling date.

Sampling date	Difference in soil nitrate-N lb N/ac in 0-24" vs. mid Oct sample date									
	UM99	UM00	MCDC99	MCDC00	ZT99	ZT00	SJ99	SJ00	Mean	Std Dev
Early Sept	26	**-9**	**-10**	-24	-20	-25	25		**-5**	22
Mid Sept	**2**	**0**	**1**	-16	-15	18	**1**		**-1**	12
Early Oct	**6**	**-9**	**-6**	**3**	-24	-12	**-6**		**-7**	10
Mid Oct	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	0
Early Nov	**0**	**4**	**3**		-13		-15		**-4**	9
Mid Nov		-24								
April	**3**	-13	14		**-2**				**1**	11
May	13	-18	27	-11	**-6**	**2**	13	27	**6**	17

Bolded numbers are not considered different than the mid October dates since they are within the presumed sampling or spatial error of $\pm$10 lb N/ac

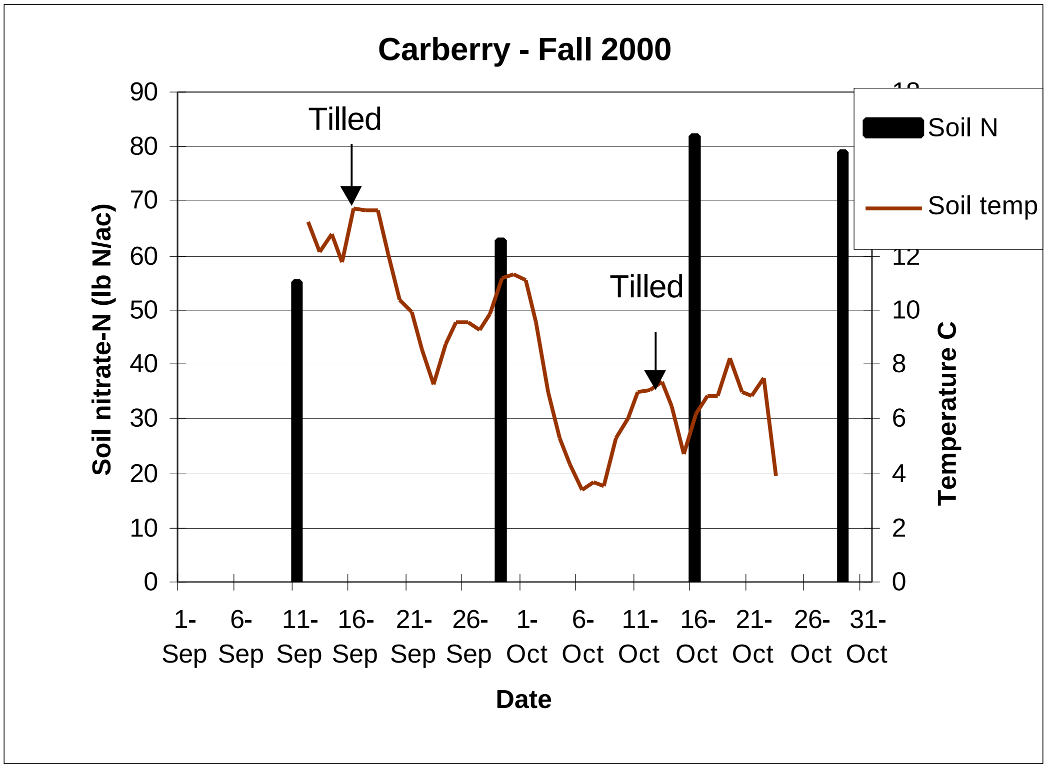


Figure 6. Soil nitrate level fluctuation at Carberry in 2000 (MCDC00)

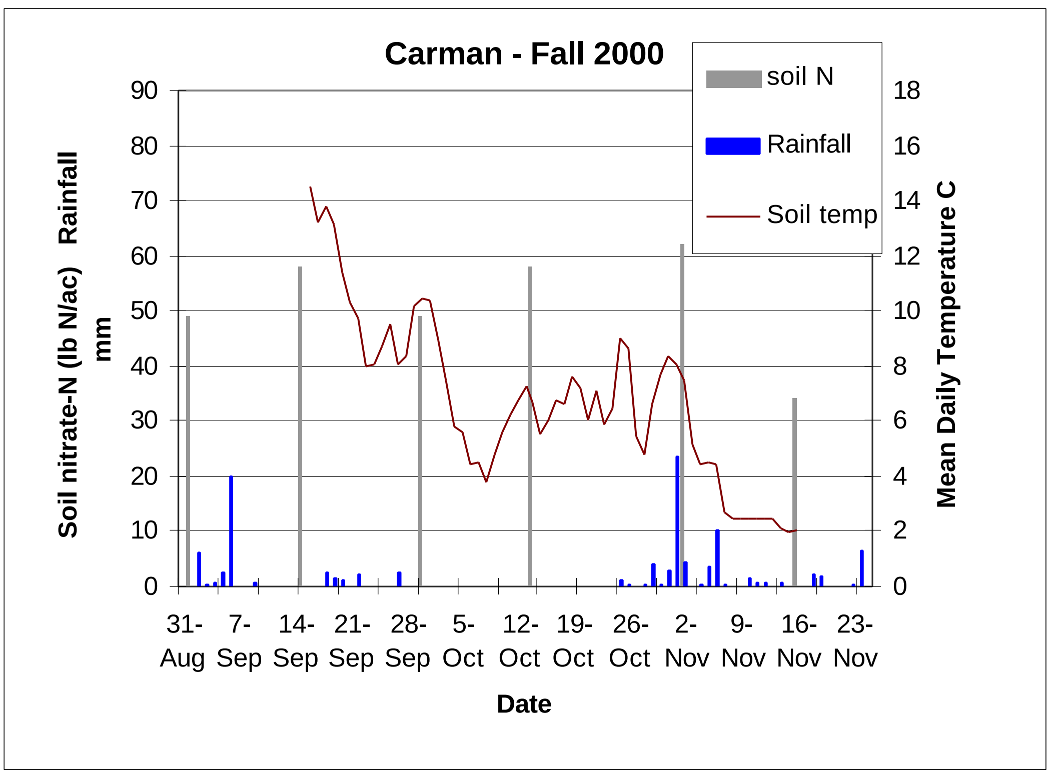


Figure 7. Fall nitrate fluctuation at Carman in 2000 (UM00).

References

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