# EFFECT OF CULTIVATION AND SOIL TEXTURE ON SUBSOIL NITRATE

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Wheat is produced in Southwestern Saskatchewan mainly on summerfallow in a 2-year rotation. A number of soil scientists in the Province have suggested recently that this rotation results in large losses of soil nitrogen. They have advocated that more cropping and less summerfallowing be included in the rotation.

When prairie soils are broken, rapid decomposition of organic matter takes place (Caldwell, Wyatt and Newton, 1939; Doughty, Cook and Warder, 1954). This will result in rapid buildup of larger concentrations of nitrate in the profile than the crops can use in a short time. Excess nitrates may be lost via denitrification or leached beyond the root zone and into the subsoil. Only limited information is available on how much nitrate is present in subsoils below the root zone. Doughty et al (1954) have shown that there was a significant concentration of nitrate present between the 1.2-3.0 m depth in three Brown soils cultivated for fourteen years.

The objectives of this study were to determine the effects of length of cultivation and soil texture on the distribution of nitrates in the subsoil of four Brown soils.

## MATERIALS AND METHODS

Soil samples were taken to the greatest depth possible by means of a Giddings model G soil coring device mounted on a truck. The basic sampling unit was modified by constructing extension tubes which were readily coupled. The depths of sampling varied depending on when impermeable layers due to stones and gravel were reached. Samples from two geological survey sites in the Swift Current area were made available by Dr. E. A. Christiansen of the Saskatchewan Research Council. These samples were taken to a depth of 9 m with a side hole coring device after a borehole was made with a Sterling drill.

Soil samples were taken in 1974 from soils which were broken in 1939 and sampled in 1939 and 1953 by Doughty et al (1954), also from soils located at these same sites but which were broken in 1956, and from virgin soils. The samples were taken from three Brown Chernozems, namely, a Wood Mountain loam, a Sceptre heavy clay, and a Hatton fine sandy loam (the latter was not reported on in the 1954 paper) and from a Dark Brown Chernozem which was a Cypress loam (Mitchell, Moss, Clayton and Edmunds, 1944). Duplicate samples were taken at each site. Nitrates at all depths and total N at some depths were determined.

# RESULTS AND DISCUSSION

## Redistribution of Nitrate in Subsoil as Influenced by Length of Cultivation and Soil Texture

Generally, the total N in the top 0.3 m of soil (where mineralization-nitrification would be most active) was greatest under virgin conditions and decreased with increasing duration of cultivation (Table 1). This is in keeping with the findings of other workers (Caldwell et al., 1939) and explains the source of mineralizable organic substrate which results in nitrate production in cropped soils.

EFFECT OF WHEAT-FALLOW CROPPING ON PERCENT N

| DEPTH (m) | SAMPLED 1953 | | SAMPLED 1974 | | SAMPLED 1953 | | SAMPLED 1974 | |
|---|---|---|---|---|---|---|---|---|
| | Virgin | Broken 1939 | Broken 1956 | Broken 1939 | Virgin | Broken 1939 | Virgin | Broken 1939 |
| | WOOD MOUNTAIN LOAM | | | | CYPRESS LOAM | | | |
| 0.0-0.3 | 0.20 | 0.14 | 0.21 | 0.11 | 0.17 | 0.15 | 0.17 | 0.10 |
| | SCEPTRE HEAVY CLAY | | | | HATTON FINE SANDY LOAM | | | |
| 0.0-0.3 | 0.19 | 0.12 | 0.22 | 0.17 | NA | NA | 0.12 | 0.06 |

NA - Data not Available

Table 1

Soil nitrate concentrations in virgin soils were generally very low and uniformly distributed through all depths (Figures 1-4). This was because the supply of readily mineralizable organic residues was limited, especially since there was predominantly living tissue located in the surface horizons where mineralization would be most active.

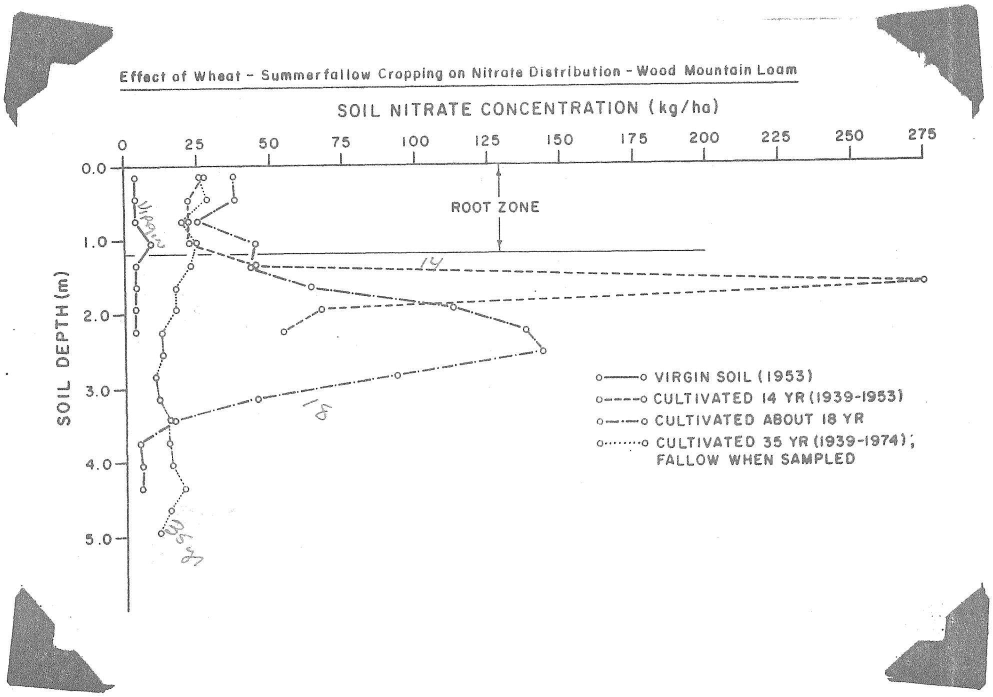


Figure 1

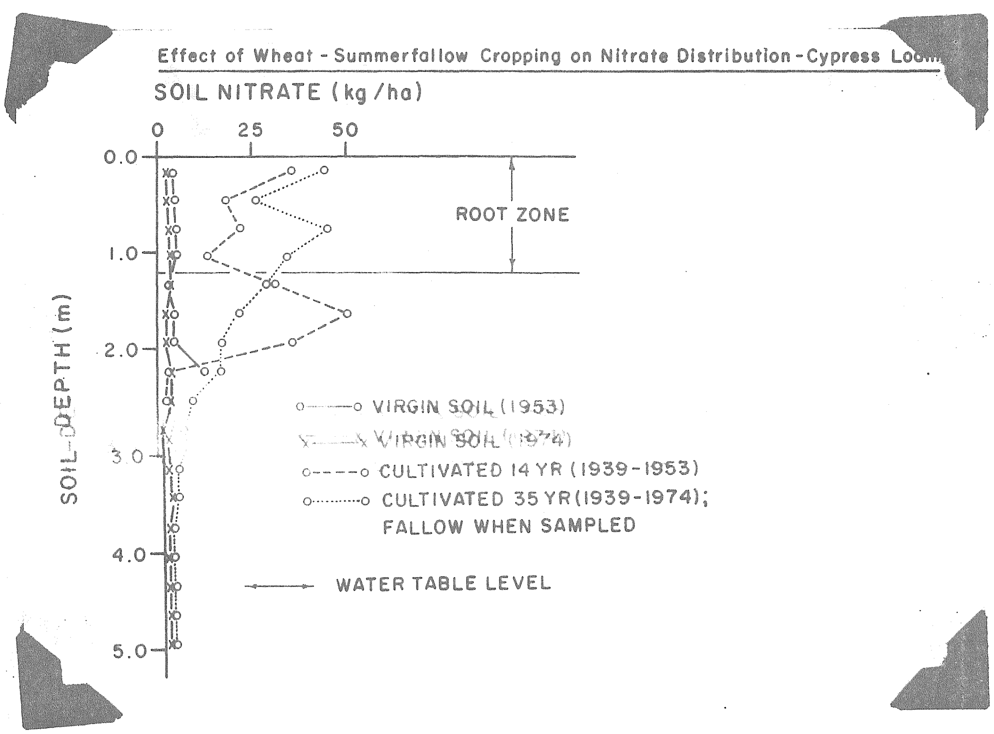


Figure 2

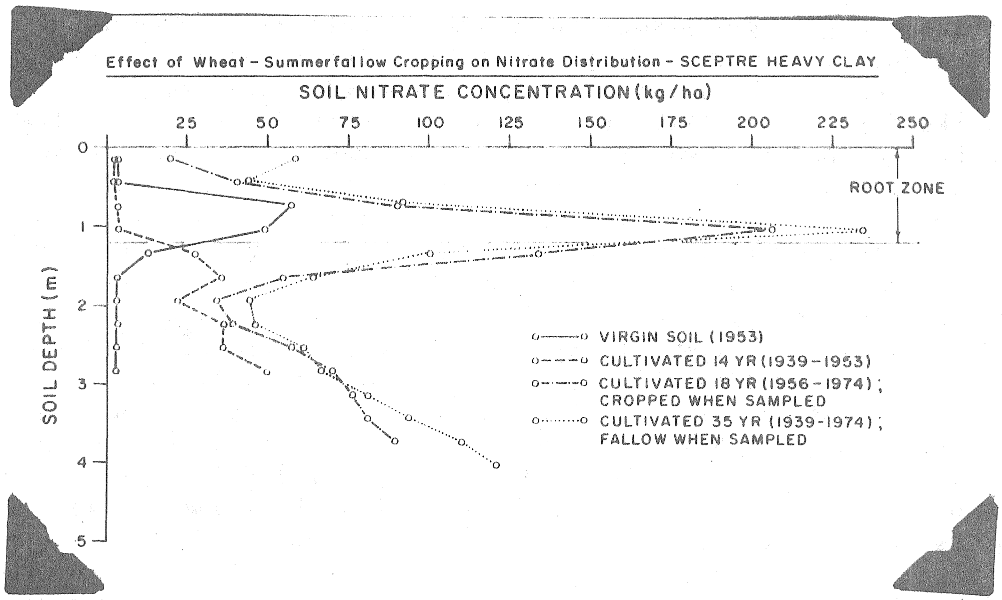


Figure 3

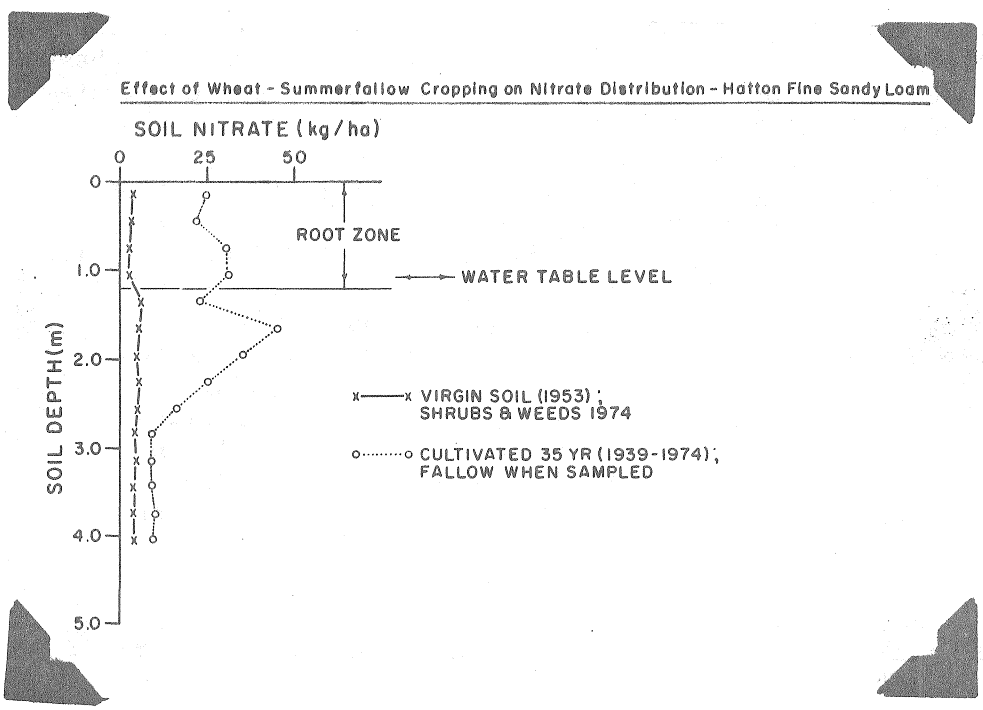


Figure 4

After the soil was broken the organic residues were rapidly mineralized and nitrified. Cropping the soil to cereals, especially in a 2-year wheat-fallow rotation, did not provide sufficient plant-uptake-potential, consequently, large quantities of excess nitrate were leached beyond the root zone. Thus, in the first 15 to 20 years after breaking there was a distinct nitrate 'front' or bulge which generally occurred just below the root zone (Figures 1 and 2). The location of this 'front' would likely depend on the amount and rate of precipitation as well as the soil texture. The coarser the soil texture the deeper would the 'front' be expected to be located (Figures 1 & 2 vs 3). However, some distance below the 'front' one would still expect to find the low concentration and uniform distribution of nitrate which was characteristic of the virgin soil (Figures 1, 2 and 3). This would be especially true since precipitation in the Swift Current area of Saskatchewan is generally low (36 cm per annum) and moisture movement in the subsoil would be primarily by slow capillarity rather than rapid gravitational movement.

After cropping the Wood Mountain loam to a wheat-fallow system for 35 years, the nitrate 'front' disappeared and the distribution of subsoil nitrate became more uniform (Figure 1) but at a higher concentration than in the virgin soil. This seems to suggest that the nitrate has been moved back and forth throughout the profile from time to time; i.e., downwards by leaching and upwards as a result of (i) evaporation (Campbell et al., 1973; Wetselaar, 1961), and (ii) temperature gradients combined with freezing near the soil surface (Campbell et al., 1970), so that eventually there remains no visible nitrate 'fronts'. If only leaching was occurring there would have been at least one 'front' discernible in the subsoil where no water table was near the surface.

In the medium- and coarse-textured soils which have a water table near the surface (Figures 2 and 4) the 'front' had disappeared after 35 years of cropping and the nitrate concentrations below the 2.4 m depth were lower than in the Wood Mountain. The latter can be explained as the result of periodic leaching causing losses into the water table. In the fine-textured soil with a deep water table, the 'front' has persisted even after 35 years of cropping and the subsoil nitrate levels appeared to have actually increased with time (Figure 3). This type of distribution in the clay soil can be explained on the basis that precipitation would mainly leach down the cracks and channels and would therefore tend to miss the nitrates which are mainly formed in micropores (Wild 1972).

## Significance of Soil Nitrogen Changes Resulting from Wheat-Fallow Cropping System

It is possible to estimate a balance sheet of the disposition of N in soil after 14 and 35 years of cropping to a 2-year wheat-fallow rotation. This is demonstrated using the Wood Mountain loam's data as an example.

**Balance Sheet of N Disposition in Wood Mountain Loam after 14 and 35 yr Cropping to 2 yr Wheat-Fallow Rotation**

| | | |
|---|---|---|
| Years cropped to wheat-fallow | 14 | 35 yr |
| Organic N lost from top 0.3 meters (as per table 1) | 2670 | 4000 kg/ha |
| N removed in grain; assuming 22 bu/ac and 60 lb/bu, and 2.5% N in grain | 260 | 630 kg/ha |
| % of the N lost which was removed by grain (Viets Jr. report similar values) | 10% | 16% |
| Nitrified N remaining in top 2.5 m (14 yr), top 5 m (35 yr) | 486 | 215 kg/ha |
| $NO_3$-N remaining in profile as % of N lost from 0.3 m | 18% | 5% |
| N unaccounted for and assumed denitrified | 72% | 79% |

Table 2

After 14 years cultivation the loss of N from the system as a result of denitrification and grain removal was 82% of the organic matter N which was decomposed; after 35 years it was 95%. This is equivalent to 5.8% loss/year in the first 14 years and 0.65% loss/year over the following 21 years of cropping. So the rate of loss in the last 21 years of cultivation has decreased considerably although losses do continue to occur.

Only 43% of the nitrates which were present in the soil after 14 years cultivation were still present after 35 years (Table 2). But 90% of the present after 14 years was located in the subsoil (Figure 1). Therefore, some of this subsoil nitrate must have been recycled into the root zone where it was used by the crop or denitrified. Denitrification in the subsoil itself would have been very small because of the very low levels of soluble carbon (Viets, Jr., 1971).

## CONCLUSIONS

1. It is during the first few years of cropping that the major losses of N occur. After 15 to 20 years or so of cropping, the wheat-fallow system contributes relatively little to further losses of N. This would seem to indicate that recently broken land should be continuously cropped (moisture and weeds permitting) for several years so as to make maximum use of the large amounts of N mineralized.

2. Although some nitrate is leached well beyond the root zone and becomes temporarily unavailable to the crop, not all subsoil nitrate remains unavailable.

3. It appears that unless there is a water table near the soil surface, nitrate pollution from leaching will be quite small especially in fine textured soils.

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