Nitrate leaching after 17 years in no-tilled crop rotations in southwestern Saskatchewan

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Keywords: Nitrate leaching, fallowing frequency, wheat, legume green manure, crested wheatgrass

Introduction

- High nitrate concentration in drinking water can be a health hazard, particularly for infants, causing methemoglobinemia (Keeney and Follett 1991), or blue baby syndrome.
- Nitrate lost below the root system is also an economic loss to producers.
- Much of the nitrate in soils is attributed to use of N fertilizers.
- Although the climate in much of the Canadian prairies is semiarid, there is still opportunity for nitrate leaching.
- Soil and crop management practices that may increase the risk of nitrate leaching include (Campbell et al. 1984):
  - Improper fertilization rates and application practices.
  - Use of legumes in crop rotations, especially when used as green manure.
  - High incidence of summerfallow.

Objective

To study wheat (W) based cropping sequences in order to determine the influence of fallow (F) frequency, use of annual legumes as green manure (LGM), and use of perennial grass on soil nitrate leached over 17 years in an Orthic Brown Chernozem in southwestern Saskatchewan.

Materials and Methods

- Data were obtained from an on-going crop rotation experiment initiated in 1987 at Swift Current, SK (Zentner et al. 1996).
- The soil had been under F-W cropping for the previous 80 years.
- Crops were fertilized with N and P according to soil test criteria. Crested Wheatgrass (CWG) was fertilized with N and P based on crop removal.
- We sampled selected wheat based crop rotations, and a CWG hay system (Table 1).
- The soil was cored to 2.4 m depth in pathways between treatments in each replicate in 1987, and in the selected treatments in fall 2003 (2 cores per plot) (Fig. 1).
  - Segmented cores into 30 cm depth intervals.
  - Determined core density and NO_3-N concentration.
  - Calculated amount of NO_3-N per depth increment using concentration and core bulk densities.

- Aggregated mass of NO_3-N for the rooting depth of wheat (0 to 1.2 m) and below the rooting depth (1.2 to 2.4 m).
- NO_3-N distribution with depth in 2003 for each treatment was analyzed as a split-plot with crop rotations as main effect and depth as sub-plot (Steel and Torrie 1980).
- Differences in NO_3-N content between 1987 and 2003 were analyzed as a split-plot with crop rotations as main effect and depth as sub-plot, and 95% confidence intervals for the mean differences were calculated to determine rotation effects (Steel and Torrie 1980).

Table 1. Description of rotations sampled in the study.

Rotation description	**Phase sampled**	**Fertilization regime**	**Abbreviation**
Fallow-spring wheat-spring wheat	Wheat after fallow	N and P based on soil test	F-W-W
Continuous wheat	Wheat	N and P based on soil test	Cont W
Annual legume green manure-spring wheat-spring wheat	Wheat after legume	N and P based on soil test with allowance for legume-derived N	LGM-W-W
Continuous crested wheatgrass hay	Hay	N and P based on crop removal	CWG

Results

Nitrate Distribution

- The amount of NO_3-N in the 0- to 2.4-m depth in 1987 totaled 149 kg ha^{-1}, with 60 kg in the rooting depth and 89 kg below the reach of crop roots (Fig. 2).
- Under CWG we found the least amount of NO_3-N, reflecting the fact that this perennial grass required and used more N than was supplied as fertilizer and by mineralization, and that it used all the available water during the growing season (Fig. 2).
- NO_3-N in the soil profile in fall 2003 was greater for LGM-W-W than in any other cropping system, and most of the nitrate in this system was below the rooting depth (1.2 m) (Fig. 2)

Changes in nitrate distribution

- Complete profile (0- to -2.4 m)
  - CWG hay reduced the amount of NO_3-N in the entire profile ($P \leq 0.05$) by 104 kg ha^{-1}, and F-W-W produced a drop of 49 kg ha^{-1} ($P \leq 0.05$) (Table 2).
  - No other rotation reduced the amount of NO_3-N in the profile ($P > 0.05$).
- Rooting depth (0- to -1.2 m)

- All rotations, except LGM-W-W produced a significant decrease ($P \leq 0.05$) in soil NO_3-N within the rooting depth; the largest decrease was produced by CWG ($P \leq 0.009$) (Table 2).
- Most of this drop in soil NO_3-N was observed between the 0.3- and -0.9 m depth, reflecting the removal of N through crop uptake (Fig2).

- While LGM-W-W shows a significant decrease in NO_3-N in the 0-.3 to -0.6 m depth, it showed no changes at any other depth segment within the rooting zone (Fig. 2).

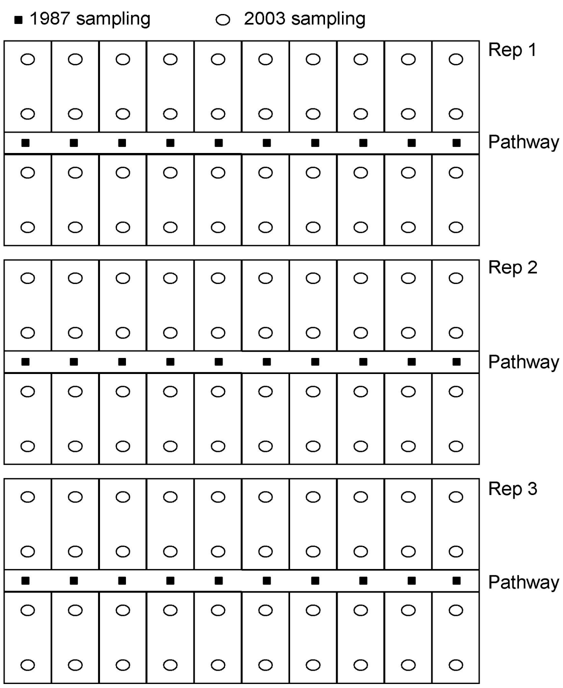

Figure 1. Sample locations for the initial (1987) and 2003 sampling periods.

<u>Below rooting depth (1.2- to -2.4 m)</u>

- Only CWG hay produced a reduction in NO_3-N ($P \leq 0.05$) below the rooting depth of the crop (Table 2).
- LGM-W-W produced a significant increase in the amount of NO_3-N in the soil below the rooting depth, revealing that the contribution of symbiotically fixed N_2 together with the partial-fallow period that follows green manure termination can produce substantial amounts of mineral N which are out of synchrony with the needs of the succeeding wheat crop.

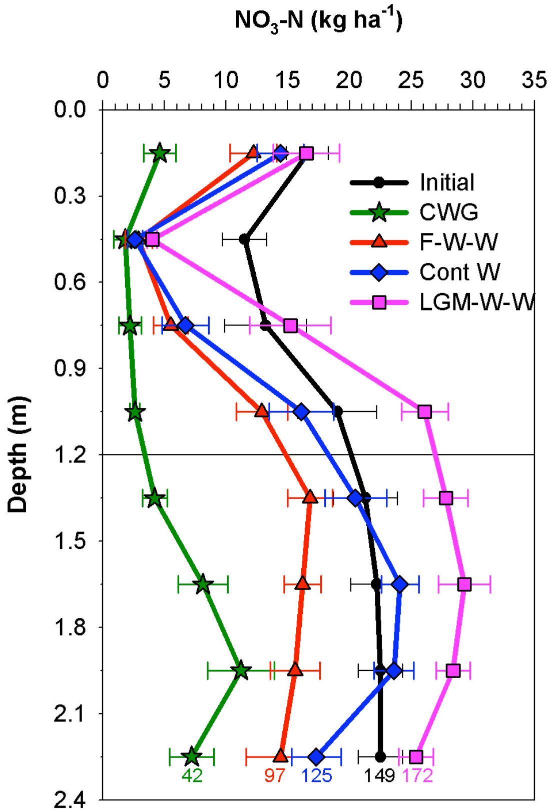

Figure 2. Soil nitrate profiles in 2003 for the rotations studied and the 1987 (initial)sampling. Error bars are $LSD_{0.05}$ for rotation x depth interaction. Figures at bottom of profiles indicate total NO_3-N in the 0-2.4 m depth.

Discussion

- The large decrease in soil NO_3-N throughout the depth of sampling in the CWG hay system reveals that:
  - The crop remains physiologically active throughout the growing season, using all the moisture accumulated during the winter months and precipitation received during the growing season, leaving no excess water that may percolate deeper into the soil.
  - The rooting zone of CWG is much deeper than that of wheat, as evidenced by the large decrease in NO_3-N in the lower layers of the profile.
  - The amount of nutrients, especially N, supplied to CWG as fertilizer based on crop removal may not have been adequate to meet this crop's requirements, as suggested by the decreasing hay yields experienced after the 5th harvest (data not shown).
- The increase in NO_3-N in the profile under LGM-W-W indicates that:
  - LGM has increased the N supplying capacity of the soil.
  - The 9- to -10 month partial-fallow period that follows LGM termination enhances soil water storage and stimulates decomposition and mineralization of symbiotically fixed legume-N.

- The increase in NO_3-N below the rooting depth suggests that:
    - The allowances made by soil testing laboratories for the legume-derived N may be too conservative.
    - There is a lack of synchrony between N mineralization under the LGM system and periods of maximum N demand by the succeeding wheat crop.
- The superior economic of LGM-W-W over F-W-W rotations noted in other studies needs to be weighed against the increased risk of NO_3-N leaching and possible contamination of ground water.

- Lack of change in NO_3-N under the other fallow containing rotations fertilized based on soil test indicates that there has been no NO_3-N leaching below the rooting zone, indicating a proper balance between N inputs and outputs.
- Cont W leached significant amount of NO_3-N ($P<0.09$). Although it was not expected, this may reflect that:
    - Cont W received more fertilizer-N than the F-W-W rotation in the 17-year period (280 kg N ha^{-1} more).
    - Crop growth is more dependent on growing season precipitation than in the F-W-W rotation. In years of poor crop growth because of reduced precipitation, fertilizer derived N would not be fully used by the crop. If dry years are then followed by fall, winter, or spring periods with above normal precipitation, the risk of NO_3-N leaching would increase substantially.

Table 2. Changes in NO_3-N content from 1987 to 2003 within and below the rooting depth of wheat

Rotation	Rooting Depth (0-1.2m)	Below Rooting Depth (1.2-2.4 m)	Total Depth (0-2.4 m)
F-W-W	-27	-22	-49
Cont W	-21	10	-11
LGM-W-W	1	26	27
CWG	-50	-54	-104
95% Conf. Interval	± 16	± 30	± 36

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