Effect of Cropping Frequency, Crop Type, and Fertilization on Nitrate Leaching in a Semiarid Environment

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Introduction

- Protecting groundwater quality from nitrate accumulation is an environmental and health priority.
- Nitrate leached below the rooting zone of crops also represents an economic loss to the producers.
- Much of the soil N found at depth is attributed to use of N fertilizers.
- Although the climate of southwestern Saskatchewan is semiarid, there is still opportunity for nitrate leaching.
- Soil and crop management practices that increase the risk of nitrate leaching include (Campbell et al. 1984):
    - Improper fertilization.
    - Inclusion of legumes in the rotation.
    - Frequent summerfallowing.

Objective

To determine the influence of cropping frequency, fertilizer application, and type of crop on soil NO_3-N leached below the rooting depth of wheat (1.2 m) over 37 years in a loam soil in southwestern Saskatchewan.

Materials and Methods

- Data were obtained from an on-going crop rotation experiment initiated in 1967 at the Semiarid Prairie Agricultural Research Centre at Swift Current, SK (Campbell et al. 2004). The soil had been under F-W cropping for the previous 70 years.
- We sampled selected wheat phases of 9 crop rotation systems (Table 1).
- Cropping systems were fertilized with recommended rates of N and P, N only, or P only, based on soil test criteria. Wheat on fallow designated to receive N had 8 kg N ha^{-1} applied up to 1991 and about 41 kg N ha^{-1} thereafter, while wheat grown on stubble received 10-32 kg N ha^{-1} and about 50 kg N ha^{-1} in these same periods. Plots designated to receive P fertilizer had 9.6 kg P ha^{-1} applied with the seed.
- All systems were managed using conventional tillage practices, with recommended methods and rates of pesticides applied.

- The N was broadcast applied and soil incorporated with tillage during seedbed preparation.
- The soil was sampled in fall 2003 to a depth of 4.5 m in 30 cm increments.
    - We used a soil corer to sample to a depth of 2.4 m, and then an auger to sample below 2.4 m.
    - We determined core densities (0 - 2.4 m) and NO_3-N concentrations (Hamm et al. 1970).
    - Calculated amounts of NO_3-N per depth increment using the concentration and measured core densities; below 2.4 m we used a constant core density of 1.71 Mg m^{-3}.
    - No deep cores (i.e., below 1.2 m) were taken at the start of the experiment in 1967.
- NO_3-N distribution with depth in 2003 for each treatment, and differences in NO_3-N between 1967 and 2003, were analyzed as a split-plot with crop rotation as main plot and depth as sub-plot (SAS Institute, Inc. 1985).

Table 1. Crop rotations and wheat phase sampled (shown in brackets).

Rotation description	Fertilizer regime	Abbreviation
Fallow-(Wheat)	N and P	F-W (N,P)
Fallow-(Wheat)-Wheat	N and P	F-W-W (N,P)
Fallow-(Wheat)-Wheat	N only	F-W-W (N)
Fallow-(Wheat)-Wheat	P only	F-W-W (P)
Fallow-Flax-(Wheat)	N and P	F-Flx-W (N,P)
Fallow-Fall Rye-(Wheat)	N and P	F-Rye-W (N,P)
Continuous (Wheat)	N and P	Cont W (N,P)
Continuous (Wheat)	P only	Cont W (P)
(Wheat)-Lentil	N and P	W-Lent (N,P)

Results and Discussion

Effect of Cropping Frequency (N and P fertilized systems)

- The amount of NO_3-N in the 0 to 1.2 m depth in 1967 averaged 112 kg N ha^{-1} (Fig. 1) ; we estimated the amount of NO_3-N in the 1.2 to 4.5 m depth in 1967 to be 221 kg ha^{-1}.
- All cropping systems allowed NO_3-N to leach below the root zone of wheat, with the amount of NO_3-N leached over the 37 years being greater and deeper as fallow frequency increased (Fig 1).
- The amount of NO_3-N leached under F-W (N,P) (180 kg ha^{-1}) was almost 3 times that leached under F-W-W (N,P) (65 kg ha^{-1}), and 4 times that leached under Cont W (N,P) (47 kg ha^{-1}).
- The differences in NO_3-N leaching were directly proportional to amount of N mineralized in the systems [F-W > F-W-W > Cont W] and to the excess water stored in these systems, and not directly related to differences in N applied, nor to N removed in harvest.

- The NO_3-N was leached deepest under F-W with a sharp peak at 2.4 – 2.7 m; the next deepest, but broader peak was under F-W-W (2.1 – 2.4 m), and the shallowest peak (1.5 – 1.8 m) and most dispersed distribution was under Cont W.

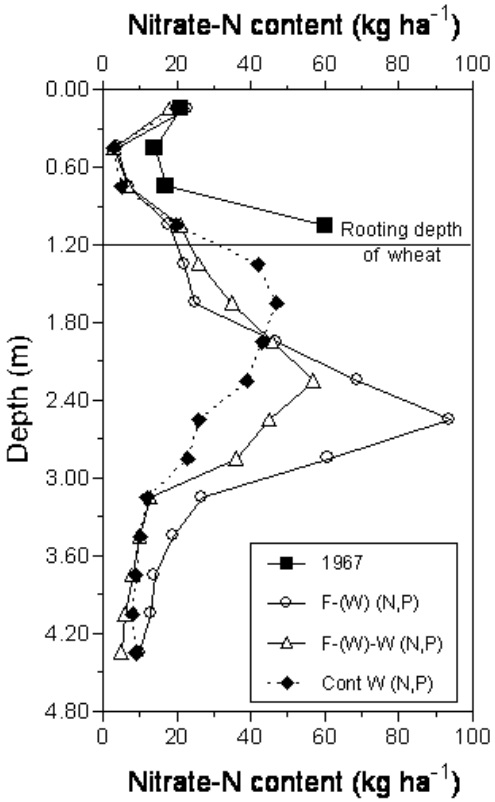

Figure 1. Effect of cropping frequency (N and P fertilizer applied) on NO_3-N leached over 37 years.

Effect of Fertilizer

- Withholding N or P fertilizer resulted in greater NO_3-N being leached beyond the root zone compared to when N and P were applied based on soil tests (Fig. 2). Inadequate N or P fertilization reduces crop growth and N uptake which permits greater leaching of the NO_3-N produced in the fallow period.
- The two less well-fertilized F-W-W systems had about 80 kg ha^{-1} more NO_3-N leached than F-W-W (N,P) over the 37 years.
- In contrast, Cont W (N,P) had 47 kg ha^{-1} more NO_3-N leached below the root zone (mainly into the 1.2 - 1.8 m depth) than did Cont W (P) (Fig 3). This reflects the 1073 kg ha^{-1} more fertilizer N that was applied to Cont W (N,P) compared to Cont W (P) over the study period. Although there was about 518 kg ha^{-1} more N harvested in Cont W (N,P) than in Cont W (P), there is greater likelihood of extra mineral N being left in the soil under the N,P treatments and this would be susceptible to leaching when drought conditions were followed by wet fall to early spring periods.

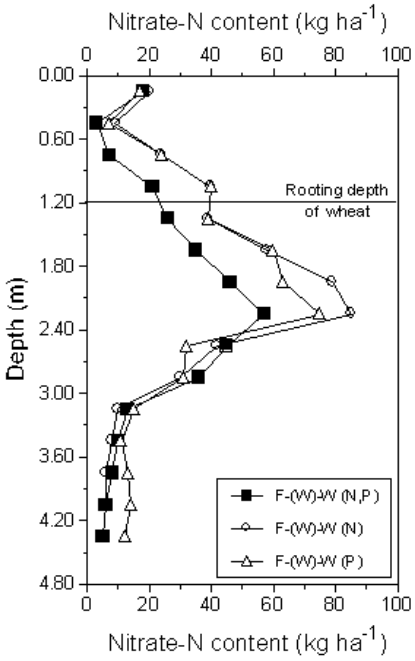

Figure 2. Effect of N and P fertilizer on NO_3-N leached in a F-W-W system over 37 years.

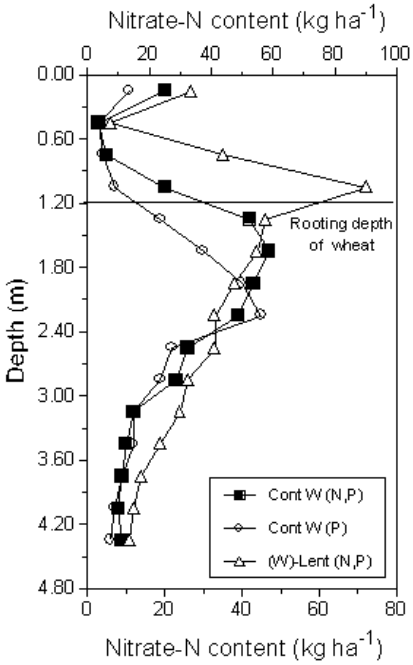

Figure 3. Effect of N fertilizer and inclusion of a pulse crop on NO_3-N leached in continuously cropped systems over 37 years.

Effect of Crop Type

- Including flax in the rotation [F-Flx-W (N,P)] increased the amount of NO_3-N leached below the 1.2 m depth by 90 kg ha^{-1} compared to F-W-W (N,P) (Fig 4). The greater N leaching under the flax system is partly because of its shallower rooting pattern than for wheat, and partly because flax produces less plant biomass and the rotation removes less N in the grain, even though it also receives less fertilizer N.
- Including a fall-seeded crop in the rotation [F-Rye-W (N,P)] reduced NO_3-N leaching to less than even under Cont W (N,P) (Fig. 4). This reflects the shorter fallow period (12 months for rye vs 20 months for spring wheat) for the fall seeded system and the fact that the rye grows in fall and then starts its growth again in early spring (when spring seeded crops are not yet planted) taking up much of the excess NO_3-N and using stored soil water, thereby reducing the opportunity for leaching in wet springs.
- Including a grain legume in the rotation with wheat did not increase the total amount of NO_3-N leached compared to Cont W (N,P), but more of the NO_3-N was located in the 0.6 to 1.2 m depth under the W-Lent (N,P) system (Fig 3). This mainly reflects the contribution of symbiotically fixed N_2 and the greater N mineralization associated with the increased N supplying capacity of the soil under the legume system.

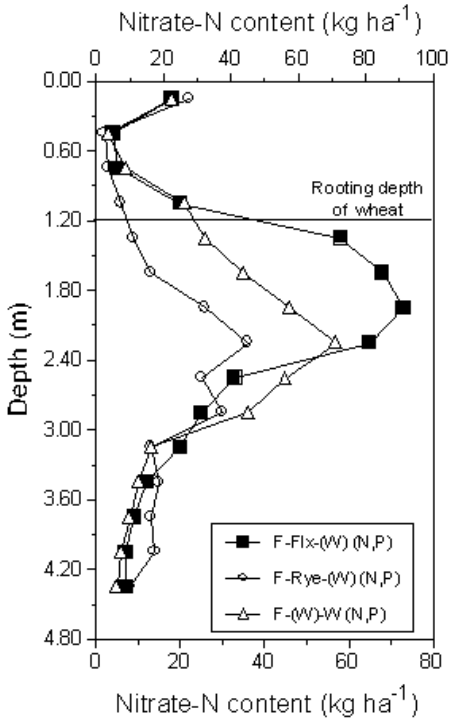

Figure 4. Effect of including flax and fall rye in the rotation on NO_3-N leached over 37 years.

Conclusions

- Nitrate leached was greater and deeper as fallow frequency increased (F-W > F-W-W > Cont W).
- In fallow-based cropping systems, use of proper N and P fertilizer rates based on soil tests is imperative to minimize NO_3-N leaching [F-W-W (N,P) < F-W-W (N) = F-W-W (P)].
- In continuously cropping systems, NO_3-N leaching was directly proportional to N input [W-Lent (N,P) = Cont W (N,P) > Cont W (P)].
- Replacing spring wheat with a shallow rooted, less robust flax crop increased NO_3-N leaching, while replacing spring wheat with a fall-seeded cereal minimized NO_3-N leaching losses.

References

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