Managing N-Fertilizer to Protect Groundwater Beneath Irrigated Potato Production

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Abstract

Four fertilizer management systems for irrigated potatoes were compared in terms of their effects on yield, shallow groundwater and soil nitrate-N (NO_3). Preliminary results from the first two years of a four year study are reported here. The high N treatment (**300**) did not increase yield relative to the three other treatments. These treatments applied the recommended rate as a single application (**200**), a split application (**SPLIT**) and a split application with supplementary N supplied through fertigation (**FERT**). The water table under all treatments rose while potatoes were growing and the NO_3 content of shallow groundwater also increased. Under the **300** treatment, NO_3 in shallow groundwater continued to increase in the year following potato production when canola was grown. Nitrate accumulated in the soil profile in all plots during potato production but profile NO_3 decreased under canola.

Introduction

Irrigated potato production is a high risk environmental scenario with respect to leaching to groundwater because of the large inputs of fertilizers, pesticides and water required; the lack of an economic disincentive for over-fertilization; and the relatively inefficient root system of the potato plant. In western Canada the acreage of irrigated potato production is rapidly expanding but there is limited information on leaching of agrochemicals and groundwater quality when potatoes are grown under irrigation. This study was initiated to assist in the development of environmentally sustainable best management practices for potatoes. Four fertilizer management scenarios that are currently being used in Saskatchewan were compared by monitoring NO_3 in soil and shallow groundwater before, during and after potato production.

Methodology

Site Description and Agronomic Information

The experiment was conducted on two fields at the Canada/Saskatchewan Irrigation Diversification Centre (CSIDC) near Outlook, Saskatchewan with centre pivot, sprinkler irrigation. Soils at the study site are mapped as Dark Brown Chernozems of the Bradwell Association and range from fine sandy loams to silt loams in both fields. In the first year of the study (1998), seed potatoes (*cv* Penta) were grown on the South field and in 1999 canola was grown on the South field and seed potatoes were grown on the North field. Both fields were divided into quadrants identified by their compass directions (ie, NE, NW, SW and SE), with each quadrant being randomly allocated a fertilizer treatment in the potato year (Table 1). The same allocation of treatments was used in both the North and South fields. Urea (46-0-0) was used for all applications except fertigation where urea-ammonium nitrate solution (28-0-0) was used. P and K were applied to meet crop requirements at the same rate on each plot (90 kg P_2O_5 ha^{-1} as 12-51-0 and 56 kg K_2O ha^{-1} as 0-0-60). They were the same for all treatments. The canola crop was fertilized at an average rate for the field (50 kgN ha^{-1} broadcast as 46-0-0 and 20 kg P_2O_5 ha^{-1} seed-placed as 12-51-0).

Table 1. Fertilizer treatments on the seed potato fields in 1998 and 1999.

Plot	Incorporated prior to Seeding	Broadcast prior to Hilling	Applied as Fertigation
		kgN ha^{-1}	
300	300	0	0
200	200	0	0
FERT	100	100	56 (1998) 34 (1999)
SPLIT	100	0	0

Soil, Water and Crop Sampling

Soil samples were taken at 0.3 m increments to 1.8 m from 6 locations in each treatment prior to the pre-planting fertilizer application and after harvest. The samples were analysed at Enviro-Test laboratories in Saskatoon for soil NO_3-N. Nitrate-N extractable by 0.001 M $CaCl_2$ was determined colorimetrically. Additional soil samples were taken at 0-0.3 and 0.3-0.6 m depths from the same locations in all plots in early June and early August and from the **SPLIT** and **FERT** treatments in early July (after hilling).

Piezometers were installed centrally in each quadrant to a depth of 4.5 m on the South field and 5.5 m on the North field. After seeding the buried piezometers were excavated and pumped several times daily until there was no further sediment in the water column. Water samples were taken and water levels recorded every week from May to September (less frequently in the fall and winter). The water samples were analyzed for NO_3 using the standard colorimetric method (automated cadmium reduction on filtered samples). Samples for NO_3 analysis were stored overnight at 4^oC and were submitted on the day following collection.

Potato yield and size grade were measured on samples from 6 locations in each treatment at harvest.

Results

In 1998 there was no significant effect of fertilizer treatment on tuber yield or size grade but in 1999 total yields and yields of tubers >45 mm were significantly lower on the **300** treatment (Table 2). Canola yields in 1999 were unaffected by residual nutrients from the 1998 treatments. Yields of potatoes in 1999 were considerably lower than in 1998 because of a cool, wet, growing season. Cool, moist conditions slowed crop development and resulted in conditions favourable for diseases and pests. The crop was harvested while the tubers were still relatively small to reduce the risk of a loss in potato quality.

Table 2. Fertilizer application effects on yield of Penta potato in 1998 and 1999 and canola in 1999.

Treatment	Tuber Yield, Mg ha^{-1} 1998	Tuber Yield, Mg ha^{-1} 1999	Canola Yield, kg ha^{-1} 1999
300	33.9	14.0	1335
200	31.6	16.9	1631
FERT	34.9	19.4	1566
SPLIT	33.2	18.8	1396
Significance	ns	0.05	ns
Least Significant Difference (0.05)	-	4.1	-
Coefficient of Variation (%)	10.5	19.5	13.5

The depth to the water table on the South Field in 1998 and 1999 is shown in Figure 1. The water table rose under all treatments in 1998 when potatoes were grown and fell the following year when canola was grown. The rise in water table was greatest on the **300** and **SPLIT** plots where water use efficiency was also less. In 1999 the water table rose under the North Field while potatoes were grown. The high water requirement and inefficient root system of potatoes has resulted in water moving down through the soil profile.

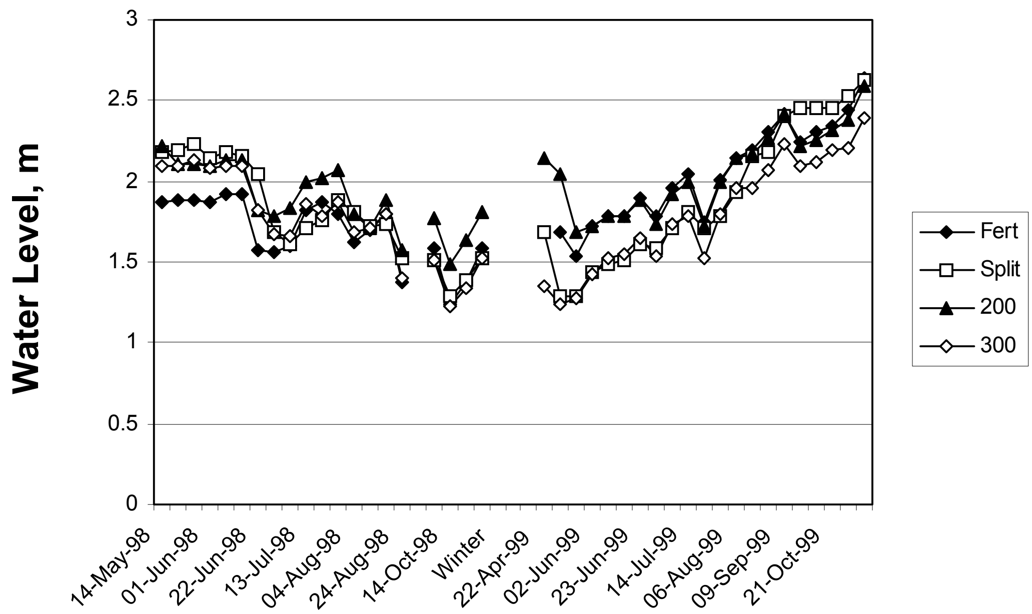

Figure 1. Water levels in the piezometers on the South Field in 1998 and 1999.

There was considerable variation between treatments in initial concentrations of NO_3-N in the shallow groundwater but concentrations increased beneath all treatments during the 1998 growing season (Figure 2). Initial concentrations beneath the **200** and **SPLIT** treatments were around 2 mgN L^{-1} while those beneath the **300** and **FERT** treatments were around 11 mgN L^{-1}. Beneath the **300** treatment there was a steady increase in NO_3 concentration from spring till fall. Concentrations of NO_3 below the **200, SPLIT** and **FERT** treatments also increased from spring till fall but changes on the **SPLIT** and **FERT** plots were more erratic than those on the **300** and **200** plots. On the **FERT** plot, NO_3 initially decreased in shallow groundwater but there was a sharp increase in groundwater NO_3 at the time of fertigation. In 1999, under the canola crop, NO_3 in shallow groundwater beneath the **300** plot continued to increase despite a falling water table. On the other canola plots, NO_3 concentrations in groundwater decreased during the 1999 season. No data is shown for the **FERT** plot on the South Field in 1999 as this piezometer was contaminated by surface soil during the winter. On the North Field, NO_3 increased in the shallow groundwater under all plots as the potato crop grew in 1999.

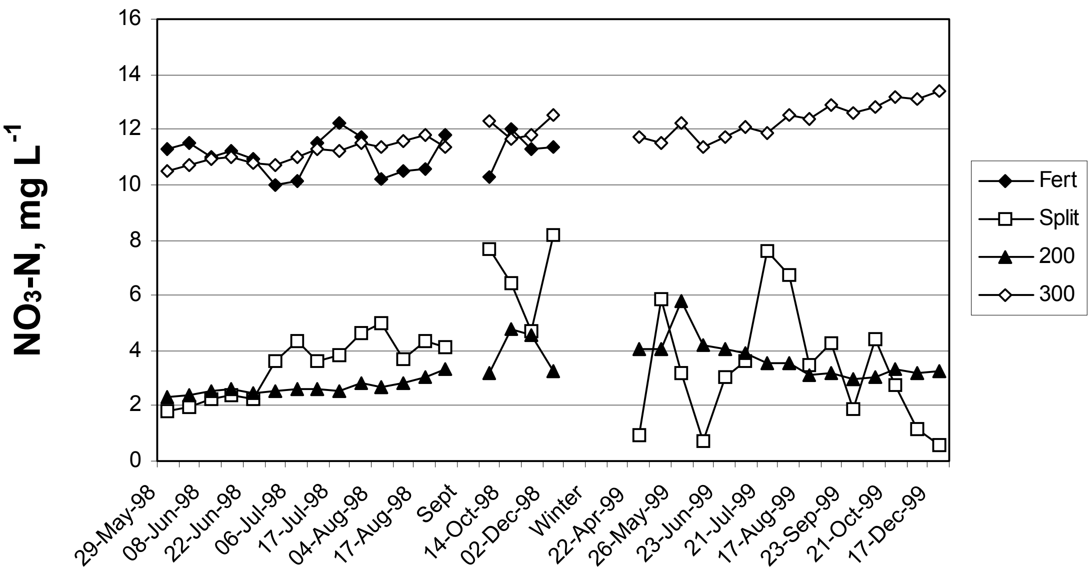

Figure 2. Nitrate-N concentrations in the piezometers on the South Field in 1998 and 1999.

Soil NO_3 at the start of the experiment (Spring 1998 for the South Field and Spring 1999 for the North Field) varied significantly between quadrants. As a result the data presented in Figures 3, 4 and 5 represent the changes in profile NO_3 during the growing seasons. During the 1998 growing season all plots accumulated NO_3 in the surface layer and the **300** and **FERT** plots accumulated NO_3 throughout the profile (Figure 3). Nitrate-N accumulated in the profile of the **300** plot was significantly greater than that on the **SPLIT** or **200** plots and NO_3 accumulated in the 0.3 - 0.6 m layer of the **300** plot was significantly greater than that on any other plot. Under canola in 1999, NO_3 was lost from the profile of all treatments (Figure 4) but there were no significant differences between treatments in the amount of NO_3 lost.

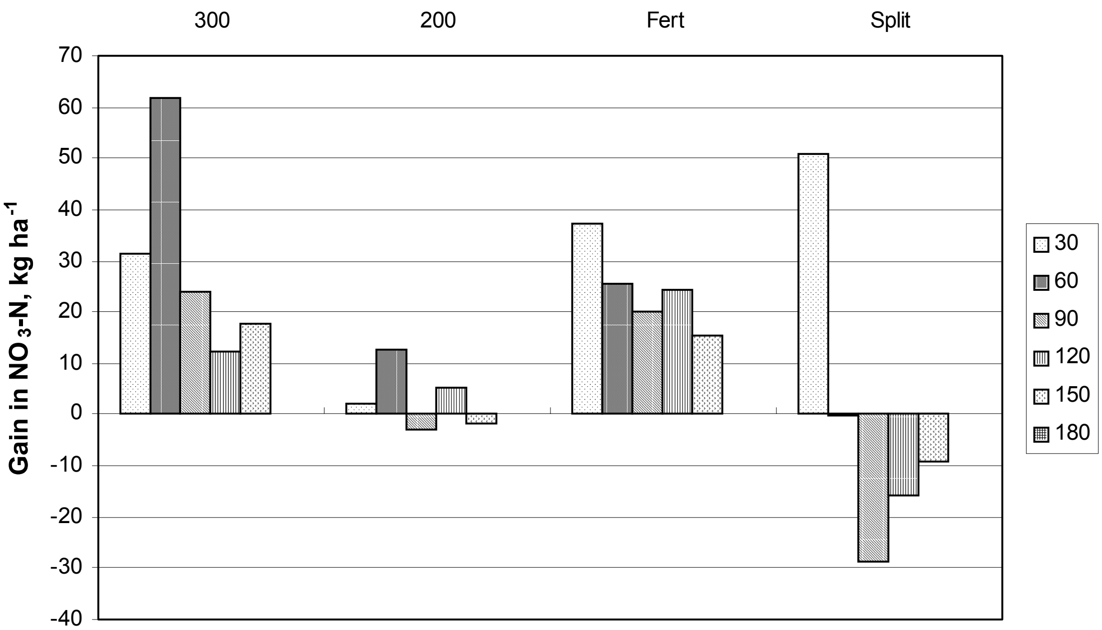

Figure 3. Gain in soil NO_3-N during the potato growing season in 1998 on the South Field.

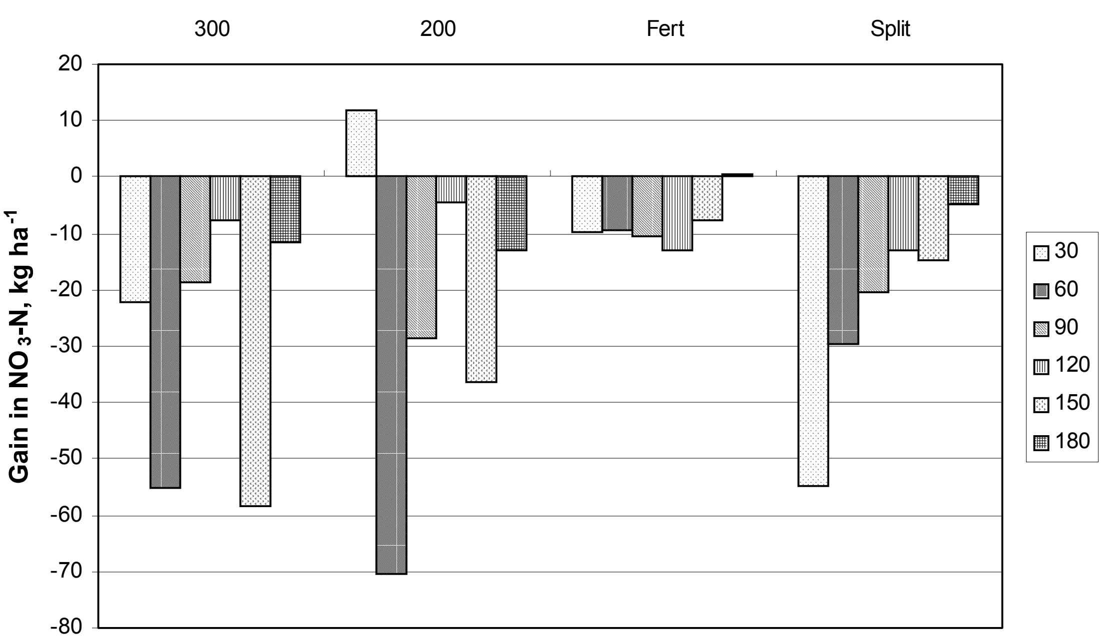

Figure 4. Gain in soil NO_3-N during the canola growing season in 1999 on the South Field.

Under the potato crop in 1999, NO_3 was gained in the soil profile of all treatments (Figure 5). The only significant difference between treatments was that the **300** and **200** plots gained more NO_3 in the surface layer than the other plots. Substantial NO_3 gains made at depth on the **SPLIT** plot appear to have resulted from the leaching of large amounts of NO_3 present in the profile of this plot in the spring prior to fertilization.

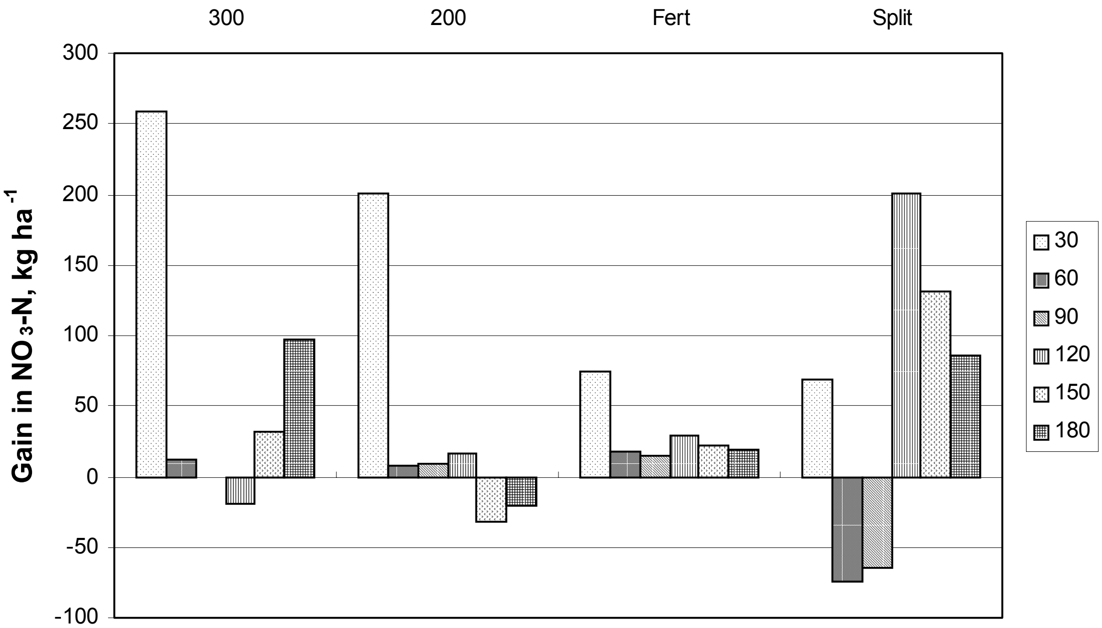

Figure 5. Gain in soil NO_3-N during the potato growing season in 1999 on the North Field.

Conclusions

Yield or size grade of potatoes did not increase with the increase in N applied to the **300** plot but the gain in NO_3 in the soil profile did increase. There were no significant differences in yield or gain in NO_3 in shallow groundwater between the **200**, **SPLIT** or **FERT** treatments but in both years less N was applied to the fertigated plot. The water table rose and NO_3 concentration in shallow groundwater increased under all potato plots.

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