NITROGEN AND PHOSPHORUS LOSS IN SNOWMELT RUN-OFF FROM AN IN-FIELD CATTLE OVERWINTERING SITE NEAR LANIGAN, SASKATCHEWAN

A. Smith¹, J. Schoenau¹, H.A. Lardner²,³, J. Elliott⁴

¹Dept. Soil Science, University of Saskatchewan, Saskatoon, SK, S7N 5A8
(E-mail: abs163@mail.usask.ca; jjs372@mail.usask.ca)
³Western Beef Development Centre, Humboldt, SK, S0K 2A0
²Dept. of Animal & Poultry Science, University of Saskatchewan, Saskatoon, SK, S7N 5A8
(E-mail: blardner.wbdc@pami.ca)
⁴National Hydrology Research Center, Environment Canada, 11 Innovation Blvd., Saskatoon, SK, S7N 3H5
(E-mail: Jane.Elliott@EC.GC.CA)

KEY POINTS

1. Wintering cattle directly in the field creates concerns with increased nutrients being deposited where they may be susceptible to movement with snowmelt run-off.

2. Nutrients in the urine and fecal material will influence the nutrient content in soil, runoff water and ground water.

3. Nitrate-N concentrations in snowmelt run-off water were similar in the control and winter-fed areas. This is explained by lack of sufficient time and temperature for organic N, urea and ammonium in the urine and fecal matter to convert to nitrate.

4. Orthophosphate-P and ammonium-N concentrations were significantly elevated in run-off from the winter feed treatment basins compared to the controls.

5. Caution should be used when utilizing an in-field winter feeding system and selecting appropriate sites so the runoff water does not reach sensitive water bodies.

INTRODUCTION

On the Canadian prairies, many cow-calf producers are adopting an in-field overwintering system. The in-field system can potentially lower cost of production due to reduced yardage and manure hauling costs. The in-field overwintering system was shown in previous research to increase retention and recycling of nutrients contained in feed (Jungnitsch, 2008) as the nutrients are applied directly to the field instead of being lost in the pen before being transferred to the field. Increased return of nutrients to the soil and potential loading with high stocking rates in the field raises concern with prospective nutrient transport in runoff.

Phosphorus, usually in the form of orthophosphate, is a nutrient that is of concern in runoff water from prairie agricultural landscapes. Eutrophication is primarily caused by elevated...
concentration of phosphorus in the water (Singh et al., 2008). Glozier et al. (2006) proposed a guideline that runoff water should not exceed 0.255 mg total P L⁻¹.

Runoff water with elevated nitrogen concentrations is undesirable and total nitrogen concentrations should not exceed 1.1610 mg L⁻¹ to ensure a healthy watershed (Glozier et al., 2006). When nitrogen is applied in excess, ammonium-N and nitrate-N can be lost through surface or subsurface flow (Forman, 1995; Larney and Hao, 2007; Freney, 2005). Glozier et al. (2006) proposed a guideline for maximum levels of nitrite, nitrate and ammonium in runoff water at 0.280 mg L⁻¹ for NO₂⁻-N/NO₃⁻-N and 0.119 mg L⁻¹ for NH₄⁺-N. Above 10 mg L⁻¹ NO₃⁻-N, the nitrate-N can become harmful to human health (Forman, 1995; Stumborg et al., 2007).

The objective of the study reported in this paper is to determine the effect of imposing a cattle in-field winterfeeding system on the nutrients in snowmelt runoff water. Surface and subsurface water samples were collected from catchment basins in paired winterfeeding versus control (no winterfeeding) watershed basins at a location in a pasture field near Lanigan, Saskatchewan. The water samples were analysed for forms and concentrations of nitrogen and phosphorus. The effect of winterfeeding versus no winterfeeding on the labile, exchangeable levels of nitrogen and phosphorus in the soil surface (0-10 cm) layer in the spring were also assessed.

**MATERIALS AND METHODS**

**Site.** The study was conducted on a Russian wild ryegrass pasture at the Western Beef Development Center's Termuende Research Ranch located near Lanigan in east-central Saskatchewan. The pasture site had no cattle present or fertilizer applied in the past five years. The terrain in the field is hummocky, creating ephemeral wetlands for the runoff water to collect.

**Paddock/catchment layout.** In the fall of 2008, the pasture was divided into a control area containing 4 basins and a cattle winterfeeding area with 4 basins. The control area was 6 ha and the winterfeeding site was 3 ha in size. Approximately 100 beef cows were baled grazed during the winter of 2008-2009 at a stocking rate of 2218 cow-days ha⁻¹ for 87 d in the winterfeeding area of the pasture. The cattle were managed within the bale fed area using portable electric fence to control animal access to feed and minimize feed wasting. Farm yard had two basins that snowmelt runoff drained into that were monitored during the spring snowmelt during the spring of 2009.

**Water Measurements.** Wells and piezometers were installed in all 8 basins. Data loggers were installed in two of the winterfeeding basins and two of the control basins to monitor the melt. After the cows were removed from the pasture a snow survey was completed.

**Nutrient Losses.** On 31 March 2009 runoff water collection started and continued daily until the spring melt was complete on 19 April 2009. Piezometer samples were collected weekly starting 2 April 2009 and continued until 30 June 2009.

Water samples were frozen at -20 °C until they were thawed and filtered through a through a 0.45 micron mixed cellulose ester gridded filter paper using a Millipore glass apparatus. The
filtered samples were stored in 50 mL vials and analyzed using a Technicon Autoanalyzer II (Keeney and Nelson, 1982) for orthophosphate-P (PO₄-P), nitrate-N (NO₃-N) and ammonium-N (NH₄-N).

Soil. Soil was sampled using hand augers to 0-10 cm depth. A sampling grid was utilized during the soil collection. In the fall of 2008 prior to in-field feeding, a total of 50 soil samples were collected across the control and winterfeeding watershed locations. After the spring melt in May 2009 a total of 150 soil samples were collected from grids across the control and winterfeeding site. Soil samples were spread out and air dried for 7 days. The samples were then ground to pass through 2 mm sieve and stored at room temperature in vials until analyzed.

Nitrate-N analysis was completed using the 2M KCl method in which 5 g of soil was extracted with 50 mL of 2M KCl followed by filtration using a Whatman® #454 filter paper and colorimetric analysis (Keeney and Nelson, 1982). Water extractable labile P analysis was completed following the procedure outlined in Schoenau and Huang (1991). The extracted solution was analyzed colorimetrically for orthophosphate-P using the Murphy and Riley (1962) method.

Statistical Analysis. Soil and water nutrients were transformed using log and square root and then tested for normality using the Shapiro test (Crawley, 2007). Water and soil samples were statistically analyzed using the Mixed Model using the coding lme from the statistical program R (Crawley, 2007). Results of the model were summarized by running an ANOVA (Crawley, 2007). The model was set to focus on significant difference between control and winterfeeding water and soil samples, and if time influenced the results. Differences were considered significant when P < 0.05.

RESULTS AND DISCUSSION

Water
Concentrations of orthophosphate-P collected in the snowmelt runoff water from the in-field overwintering sites were significantly elevated compared to water from the control watersheds (Figure 1 and Table 1). Ammonium-N in runoff water was also significantly elevated compared to the control water (Figure 2 and Table 1). There was no significant difference in nitrate-N concentrations in water from the overwintering sites versus the control (Figure 3 and Table 1). The lack of effect on nitrate is attributed to dominance of organic N and ammonium in dung and urine deposited, with cold temperatures limiting conversion of ammonium to nitrate. Piezometer well samples also showed some elevation of ammonium-N and orthophosphate-P in the overwintering sites that may have originated from the catchment basins.
### Table 1. ANOVA results for water ammonium-N (NH$_4$-N), nitrate-N (NO$_3$-N) and orthophosphate-P (PO$_4$-P) from control areas versus the winterfeed areas and the influence of time.

<table>
<thead>
<tr>
<th>Fixed Factor</th>
<th>numDF$^a$</th>
<th>denDF$^b$</th>
<th>NH$_4$-N</th>
<th>NO$_3$-N</th>
<th>PO$_4$-P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F-value</td>
<td>P-value$^c$</td>
<td>F-value</td>
<td>P-value$^c$</td>
<td>F-value</td>
</tr>
<tr>
<td>Plot$^d$</td>
<td>1</td>
<td>6</td>
<td>157.28</td>
<td>&lt;.0001</td>
<td>3.824</td>
</tr>
<tr>
<td>Time</td>
<td>1</td>
<td>106</td>
<td>12.556</td>
<td>0.0006</td>
<td>33.157</td>
</tr>
<tr>
<td>Plot*Time</td>
<td>1</td>
<td>106</td>
<td>7.7461</td>
<td>0.0064</td>
<td>0.0911</td>
</tr>
</tbody>
</table>

$^a$ Degrees of Freedom Numerator  
$^b$ Degrees of Freedom Denominator  
$^c$ Exact P-value  
$^d$ Control versus Winterfeeding site Plot

![Figure 1. Average orthophosphate-P (SRP) concentration from surface runoff water collected 31 March to April 2009.](image)

The bars denote standard deviation:  
- Control  
- Farm  
- Treatment (Winterfeed)

$x$ control  
$y$ farmyard  
$z$ treatment
**Figure 2.** Average ammonium-N (NH$_4$-N) concentration from surface runoff water from 31 March to 19 April 2009.

The bars denote standard deviation

- Control
- Farm
- Treatment (Winterfeed)

**Figure 3.** Average nitrate-N (NO$_3$-N) concentration from surface runoff water from 31 March to 19 April 2009.

The bars denote standard deviation

- Control
- Farm
- Treatment (Winterfeed)
Soil

There was no significant difference in water extractable phosphorus in the soil samples taken from winterfeeding and control grids set up across the watersheds in May (Figure 4 and Table 2). Water extractable phosphorus in the surface layer (0-10cm) of the soil was lower in the spring of 2009 than in the fall of 2008 for both control and winterfeeding treatments. This likely reflects the rapid uptake of residual phosphate by the pasture grass and soil microbial populations in the spring. Soil nitrate-N concentrations were similar between fall and spring sampling and were also not significantly different between the control and winterfeeding sites (Figure 5 and Table 2).

Table 2. ANOVA results for soil nitrate-N (NO$_3$-N) and water extractable phosphorus (PO$_4$-P) from control areas versus the winterfeed areas and the influence of season.

<table>
<thead>
<tr>
<th>Fixed Factor</th>
<th>numDF$^a$</th>
<th>denDF$^b$</th>
<th>Nitrate (NO$_3$-N)</th>
<th>Water Extractable Phosphorus (PO$_4$-P)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>F-value</td>
<td>P-value$^c$</td>
</tr>
<tr>
<td>Plot$^d$</td>
<td>1</td>
<td>45</td>
<td>0.4511</td>
<td>0.5052</td>
</tr>
<tr>
<td>Season</td>
<td>1</td>
<td>47</td>
<td>0.0244</td>
<td>0.8765</td>
</tr>
<tr>
<td>Plot*Season</td>
<td>1</td>
<td>47</td>
<td>5.6218</td>
<td>0.0219</td>
</tr>
</tbody>
</table>

$^a$ Degrees of Freedom Numerator  
$^b$ Degrees of Freedom Denominator  
$^c$ Exact P-value  
$^d$ Control versus Winterfeeding site Plot

Figure 4. Average water extractable phosphorus (PO$_4$-P) concentrations (μg g$^{-1}$ of soil) in soil samples collected from large treatment and control grid in fall 2008 and spring 2009.  
$^w$ The bars denote standard deviation
CONCLUSION

Elevation of orthophosphate-P and ammonium-N concentrations in snowmelt runoff water from winter feeding sites indicates that these sites should be located in the landscape to avoid runoff water entering into sensitive surface and subsurface water bodies. Similar nitrate-N concentrations in snowmelt runoff water from control and winterfeeding sites in the first year of establishment may be explained by cool temperatures limiting microbial conversion of ammonium to nitrate. Lower water soluble soil phosphate in spring compared to fall is attributed to rapid plant and microbial uptake of phosphate in spring as the soil warmed and the pasture began early season growth.

ACKNOWLEDGEMENT

Funding support for this research is from the Saskatchewan Agriculture Development Fund.

REFERENCES


