Snowmelt Simulations to Determine the Source of Nutrients in Snowmelt Runoff.

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Abstract

Agriculture has been identified as a contributor of nutrients to surface waters. However, most sources of agricultural nutrients are diffuse and have not been clearly identified. A potential source that has been largely overlooked is nutrient release from senesced plant material. The release of nutrients from plant material during snowmelt and the subsequent transport of these nutrients in surface runoff could contribute to the eutrophication of downstream receiving waters.

A snowmelt simulation study was designed to assess nutrient release from different plant residues during snowmelt in controlled conditions. Frozen residues were covered with a layer of snow that was typical of over-winter snow-cover and subjected to a number of thaw-freeze cycles. The resulting melt-water was analyzed for dissolved N, P and C content to assess the nutrient release potential of each residue. A range of plant residues, including cereals, pulse crops, oilseeds and native vegetation, were collected for testing. In addition, paired samples of residue and surface soil were collected and nutrient release during simulated snowmelt was measured for the soils and residues alone and in combination.

The potential for residues to contribute nutrients to snowmelt was comparable to that for soils and varied with the nutrient content and freshness of the residue. Some interesting interactions between soils and residues were observed in the combined experiment. These results are particularly relevant to the development of beneficial agricultural management practices for the protection of water quality.

Introduction

Eutrophication and nutrient loading problems in surface waters on the Canadian prairies are increasing. Algal blooms on Lake Winnipeg have attracted the attention of the national media and have stimulated much discussion on the causes and solutions to the problem (Lake Winnipeg Stewardship Board, 2006). Agriculture has been identified as a source of nutrients to surface water to surface waters on the prairies (Chambers et al., 2001) and considerable effort is being put into the adoption of beneficial management practices (BMPs) for the protection of surface waters.

Many of the BMPs proposed for the prairies were developed in warm, humid climates on steeply sloping landscapes where soil erosion is a major contributor to water quality problems. They may not be so effective in the prairie landscape where more than 80 %

of surface water recharge results from snowmelt (Nicholaichuk, 1967). The snowmelt runoff process is not as well understood as rainfall runoff and there are key differences in the energy of the water and in the interaction with soil. Unlike rainfall-generated runoff, dissolved rather than particulate nutrients are the main form of nutrients present in snowmelt runoff (Glozier et al., 2006). In addition to soil as a source of nutrients to snowmelt, plant residues may also play an important role if freeze-thaw cycles result in the release of nutrients from plant material (Bechmann et al., 2005). If this is the case, BMPs that employ vegetation to trap particulate material may not be very effective under snowmelt conditions.

The overall goal of this study is to aid in the development of effective BMPs to protect surface water quality during snowmelt. The specific objectives addressed here were to identify the potential for different crop and plant residues to contribute nutrients to snowmelt and to identify interactions between soil, plant and snow nutrients during snowmelt.

Materials and Methods

In late October, 2006, a range of crop and plant residues were collected from 12 different fields in the Outlook-Rosetown area of Saskatchewan (Dark Brown Soil Zone). In each field, residue samples were collected from three 0.09m^2 plots by clipping all the above ground material. After the residue had been collected a 0-15 cm soil sample was collected from the centre of each plot and both the residue and soil samples were stored at -15°C until analysis. The residues studied were: winter wheat (2006 crop), canola, flax, peas, lentils, barley, winter wheat (2007 crop), aged alfalfa stand, riparian vegetation and 3 fields of spring wheat. The spring wheat samples were used for the residue-soil interaction study and at these sites the shallow surface soil (0-5 cm) below the residue cover in the 0.09m2 plots was also collected. Recently-fallen snow was collected from an open field near NHRC in Saskatoon and placed in storage at -15°C. Since the snow contained significant amounts of dissolved organic C (DOC: 0.7 mg L^{-1}) and total N (TN: 0.4 mg L^{-1}) snow blanks were included in each experimental run and the contribution from snow was subtracted from concentration in the runoff.

The residue and shallow surface soil samples were laid out in a coldroom and carefully divided into sub-samples for snowmelt simulation, nutrient analysis and moisture content. The samples used for snowmelt simulation were 44.4% of the total sample mass and corresponded to an area of 0.04 m^2. These samples were placed in plastic pails and overlain with snow corresponding to 20 cm depth (2 cm snow water equivalent) which was typical for the collection area. For the interaction study with the wheat samples 3 separate pails were assembled for each sample. One contained residue + snow, another soil + snow and the third had a layer of soil overlain with residue overlain with snow (soil + residue + snow). Weighing and sample preparation were carried out in a -5°C cold room and the samples were returned to -15°C for storage.

The snowmelt scenario was based on a typical snowmelt event and the temperatures in the coldroom were programmed to follow 3 diurnal cycles from -5°C overnight, rising to a high of +9°C in late afternoon before dropping back to -5°C (Figure 1). On the fourth day the temperature was increased to +5°C and the samples were allowed to melt for the next 2 days. Visually the snowmelt in the pails was similar to what is usually observed in the field. When melt was complete, the meltwater was poured off and analysed for total dissolved N (TDN), nitrate (NO3), ammonia (NH3), total P (TP), total dissolved P (TDP), ortho P (OP) and DOC.

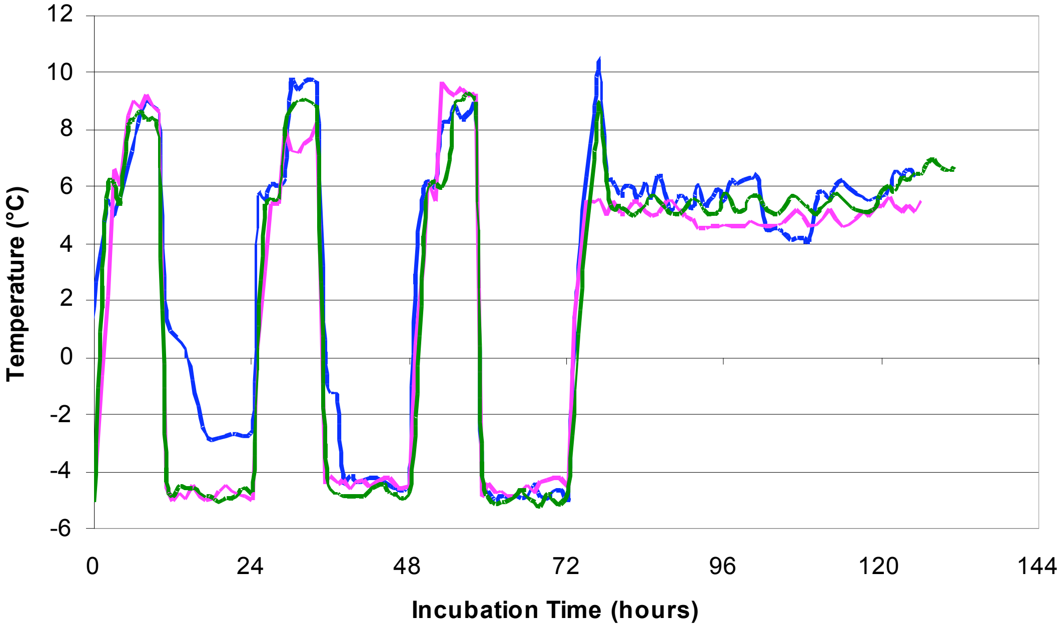

Figure 1. Temperature cycle followed for snowmelt simulation. The different colours represent different experimental batches.

Results and Discussion

For most nutrients the greatest potential contribution from residues came from the 2007 crop winter wheat followed by alfalfa and riparian vegetation. The contribution from lentils appeared to be a little higher than from the other crop residues but this difference was never significant. The pattern shown in Figure 2 for TDN was also observed for TP, OP, TDN and DOC. For all nutrients the contributions from the 2007 crop winter wheat were significantly greater than those from any other residue type. In the case of TDP (Figure 2) and DOC, the contributions from the riparian vegetation and alfalfa while significantly less than those from the 2007 crop winter wheat, were significantly greater than those from the other residues.

Different residue contribution patterns were observed for NH3 and NO3. For NH3 the same basic pattern held but there was no significant difference between the 2007 crop winter wheat, the alfalfa and the riparian vegetation and the potential contribution from these vegetations types was significantly greater than from the others. Canola stubble was the only residue to contribute significant NO3 to the snowmelt and its contribution was highly variable between replicates.

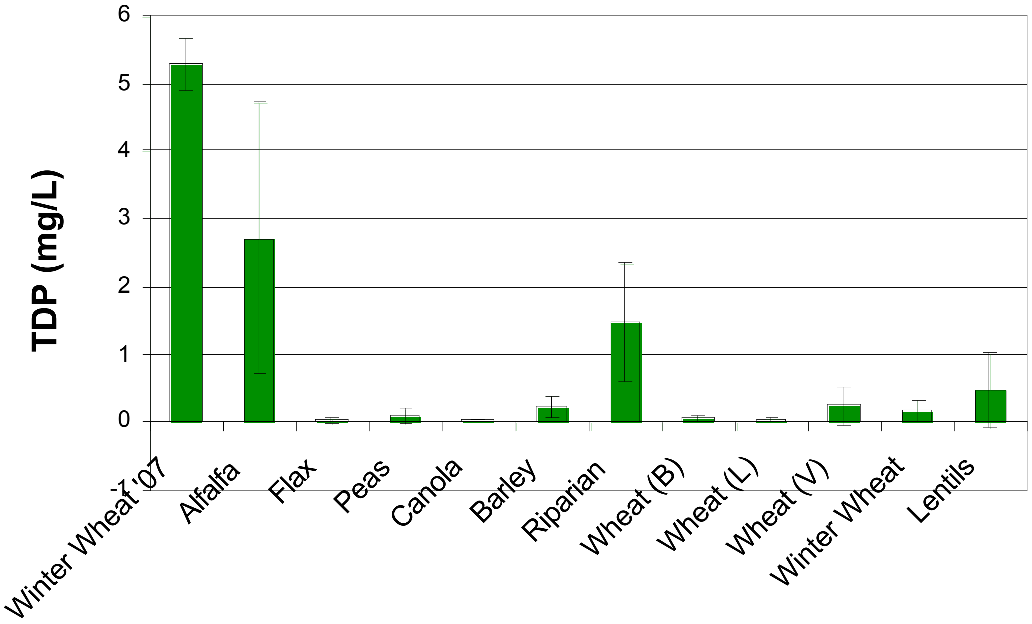

Figure 2. Total dissolved P concentrations in the melted snow after the snowmelt simulations.

Most residue samples appeared to remove NO3 from the melting snow as the concentrations in the snow that melted in the presence of residues were lower than the concentrations present in the snow. Some residues also appeared to remove NH3 from melting snow.

The relative contribution of soil and residues to snowmelt runoff was investigated using wheat residues only (Figure 3).

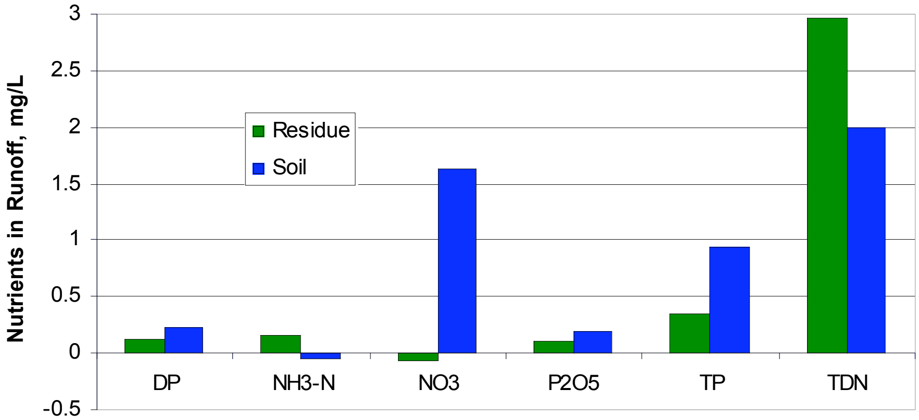

Figure 3. Nutrient concentrations in melted snow after snowmelt simulations with residues and soils.

On average the potential nutrient contribution from soil was approximately twice that from wheat residue for TP, TDP and OP. However, although the NO3 contribution from soil was much greater than from wheat (average net loss), the TDN contribution from residues was greater than that from soil.

Interactions occurred when the snow was melted over the soil and residue together. Figure 4 gives an example of DOC. Concentrations of DOC in meltwater from residues alone were significantly greater than those in meltwater from soils. However when snow was melted over the soil and residue together, the DOC content in the melted snow was less than in the meltwater from the residues. If there was no interaction between soil, residue and snow, the concentrations in meltwater from residue and snow should have been equal to the sum of the two sources. The results suggest that the soil was able to remove some of the DOC released by the residue.

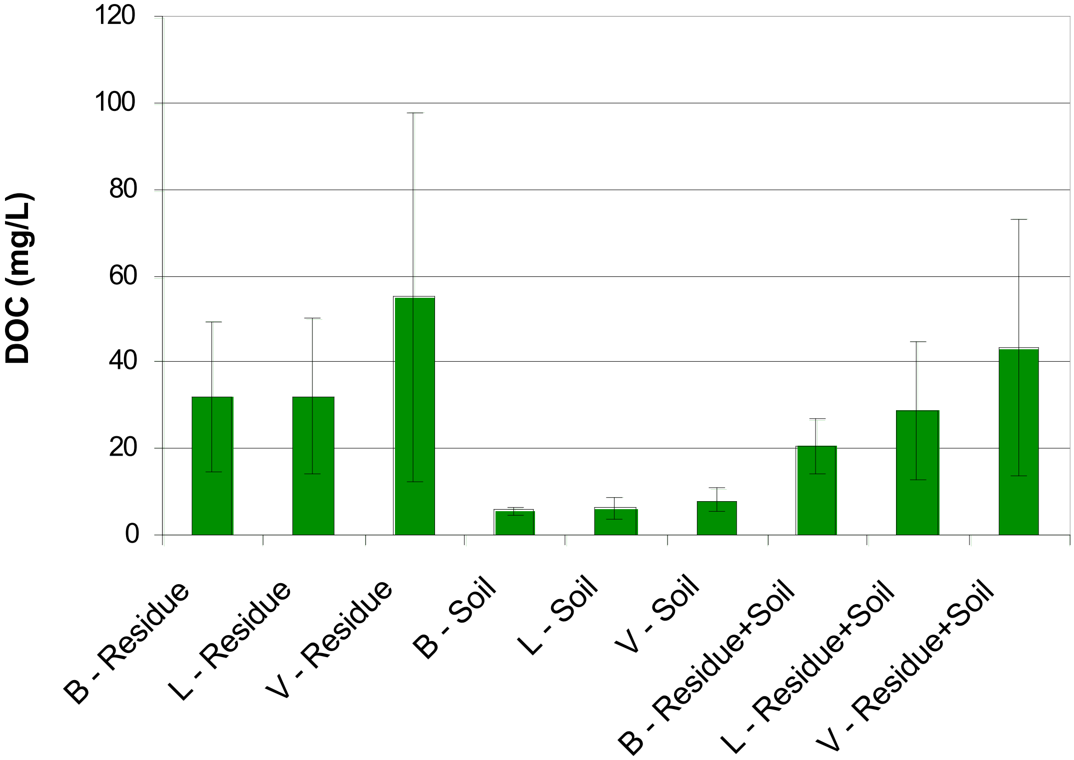

Figure 4. Nutrient release to snowmelt from wheat residue and soil, alone and in combination. B,L and V refer to the fields from which the samples were taken.

Conclusions

The potential for plant residues to contribute nutrients to snowmelt runoff is high and depends on the freshness of the residue and on its N and P content. Residues and soil likely make comparable nutrient contributions to snowmelt runoff on average but the relative contribution varies between nutrients. In this study, most of the nitrate in snowmelt originated from soil while most of the TDN came from residues. Interactions were observed to occur between snow, soil and plant residues. Residues appeared to uptake nitrate from snow and soil, while the presence of soil reduced the NH3 contribution from residues. Consideration of residues as source of nutrients in snowmelt runoff has implications for BMPs that use plants to reduce the movement of particulates.

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