Urea-based fertilizer assessment in forage grass production in eastern Canada

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Abstract
Nitrogen fertilization is essential for forage grass production but little information exists on the efficiency of different mineral N fertilizers available in eastern Canada. We assessed the benefits of using different urea-based fertilizers in timothy (*Phleum pratense* L.), the main forage grass species used in eastern Canada. We compared, during two growing seasons (2014-2015), polymer-coated controlled release urea (PCU), blend of 50% PCU:50% urea, and urea treated with an inhibitor of urease (Urea + NBPT) broadcast at early spring to calcium ammonium nitrate (CAN) broadcast at early spring (60%) and after the first cut (40%). Each N fertilizer was added at rates of 50, 100, 150 and 200 kg N ha^{-1}. A control with no applied N was included. The three enhanced-efficiency N fertilizers produced similar annual forage yields than CAN in both years. Yield distribution by cut, however, was significantly affected by the fertilizers. The highest yield was achieved with the blend PCU:Urea and Urea + NBPT at the first cut, and with PCU at the second cut. The soil nitrate content after the first cut was highest with PCU:Urea and Urea + NBPT, but in the fall it was low and not affected by fertilizers. Forage total N and nitrate concentrations were also highest in the first cut with the application of Urea + NBPT whereas PCU mostly increased forage N in the second cut. Urea management options are recommended as alternative to CAN under the climatic conditions of eastern Canada.

Key Words
Nitrogen fertilizers, urea, controlled-release, NBPT, forage grass, forage nitrate

Introduction
Urea is currently the most widely used N fertilizer in crop production because of its high N content (460 g kg^{-1}), its low price compared to other fertilizers, and its convenience for transport, storage and spreading (Soares et al. 2012). However, urea has the disadvantage to lose considerable amounts of N via NH_3 volatilization, especially when not incorporated into the soil. When applied to forage crops, those losses may range from 5 to 40% depending on environmental conditions (UNECE 2015) and consequently reduce its efficiency.

One available option to better manage urea include urease inhibitors, such as NBPT (Agrotain™) which delays urea hydrolysis (Trenkel 2010), hence providing more time for adequate rainfall to move the surface-applied urea into the soil with a resulting enhanced retention of the released ammonia (Dawar et al. 2011). A meta-analysis indicated that using NBPT in the field resulted in an average 10% yield increase with larger responses in forage crops likely due to higher fertilizer N rate and aboveground biomass harvested (Abalos et al. 2014). Another option is polymer coated urea (PCU) which releases N as a function of soil temperature once granules are moistened (Trenkel 2010). The new micro-thin PCU generation (ESN™; Agrium Inc. 2014) costs less while working more consistently offering opportunity to farmers to use them in large scale production with one pass. Connell et al. (2011) reported that using PCU alone in forage grass gave a poor dry matter (DM) yield performance in the first cut. However, by blending PCU in an equal proportion with urea, improvement in forage yield and quality can be expected (Payne and Hancock 2013).

Urea-based fertilizers have been widely assessed on annual row crops but much less on perennial forage crops, particularly in the cool and humid climate conditions of eastern Canada. Therefore, the objectives of this study were to evaluate the effects of three enhanced-efficiency N fertilizers applied at different rates on forage DM yield, N concentration, and nitrate concentration, and on soil NO_3-N content.

Methods
Experimental site
A field experiment was carried out in 2014 and 2015 near Quebec City, QC, Canada (46°47′ N, 71°08′ W) on an established forage field dominated by timothy (*Phleum pratense* L.) on a clay soil with a pH of 5.8, 32 g total C kg^{-1} dry soil, and 550 g clay kg^{-1} dry soil. To avoid any effect of residual N, a new experimental site was selected at a different location within the same field each year.

Field experiment

Treatments consisted of: (i) a control (0 kg N ha^{-1}), (ii) a reference treatment (CAN) at 50, 100, 150, and 200 kg N ha^{-1} with 60% applied at early spring (mid-May) and 40% applied after the first cut (mid-June), and (iii) three enhanced-efficiency N fertilizers at rates of 50, 100, 150, and 200 kg N ha^{-1} all applied at early spring. The enhanced-efficiency fertilizer treatments were: PCU, blend of PCU and urea (50:50 on DM basis) and urea + NBPT. All fertilizers were broadcast. Other nutrients such as P and K were added based on local soil test recommendations. The plots (1.5 × 5 m) were laid out in a randomized complete block design with a total of 17 treatments (4 N sources × 4 N rates + unfertilized control) and four replicates.

The plots were harvested twice each year using a flail-type forage harvester (section of 0.91 m × 5 m) at the early heading stage of timothy in mid-June and mid-August. The plant samples were weighed in the field, and a representative (300-500 g) subsample was dried at 55°C in a forced-draft oven to constant weight for dry matter (DM) determination. Due to unexpected growth of red clover following the first cut in June 2014 in plots receiving the smallest or no N fertilization, the field received an application of mecocrop-P/2,4-D/ dicamba in October to control broadleaf weeds.

Plant and soil analysis

Forage N concentrations of dried ground samples were determined by H_2SO_4-H_2SeO_3 digestion (Isaac and Johnson 1976). Nitrates in plant tissue were determined by extraction in 2% acetic acid solution (Miller 1998). Soil NO_3-N content was determined at the 0-15 cm depth after the first cut in mid-June and at the end of September using 1 M KCl extraction (Maynard et al. 2007). Concentrations of both elements were measured with an automated continuous-flow injection colorimeter.

Results

First cut and annual forage DM yield increased with increasing N rates when averaged across two years (Fig. 1 and 3). Annual forage DM yield averaged across fertilizers and years increased from 6.4 Mg DM ha^{-1} in the unfertilized control to 9.8 Mg DM ha^{-1} with 200 kg N ha^{-1}. This response to N rates was similar in both years as indicated by the non-significant interaction between years and N rates. Furthermore, this response was quadratic at the first cut but linear for the annual forage DM yield. The response to N rates at the second cut was different in the two years (Fig. 2) and this was due to unexpected regrowth in red clover, notably in the unfertilized control.

The N source did not affect annual forage DM yield but it affected the yield distribution between the two cuts. PCU applied alone produced a lower first cut forage DM yield at rates ≤ 150 kg N ha^{-1} than other N fertilizers (Fig. 1). At the second cut, Urea + NBPT tended to produce a lower forage DM yield at rates ≤ 150 kg N ha^{-1} than the other fertilizers (Fig. 2). These results indicated that the release of N from PCU when applied at early spring was too slow under the climatic conditions of this study (cool temperatures in May, 10-12°C) to be effective on the first cut. Blending some PCU with untreated urea may provide sufficient N for early timothy growth while still maintaining the benefits of the slow N release. Additionally, this will result in a lower cost for the controlled release PCU.

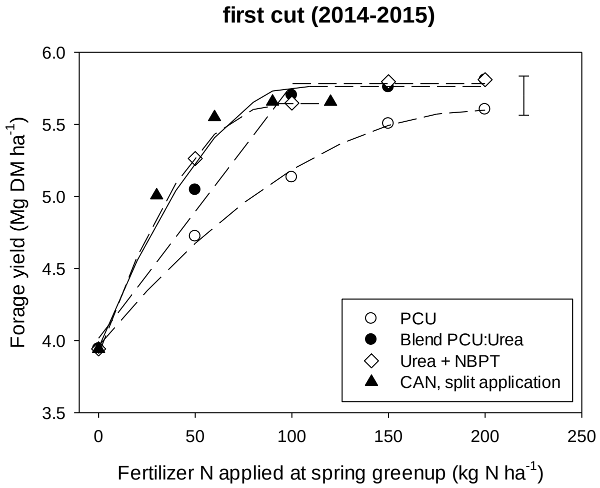

Figure 1. Effect of N source and rate on first cut forage DM yield averaged across years.

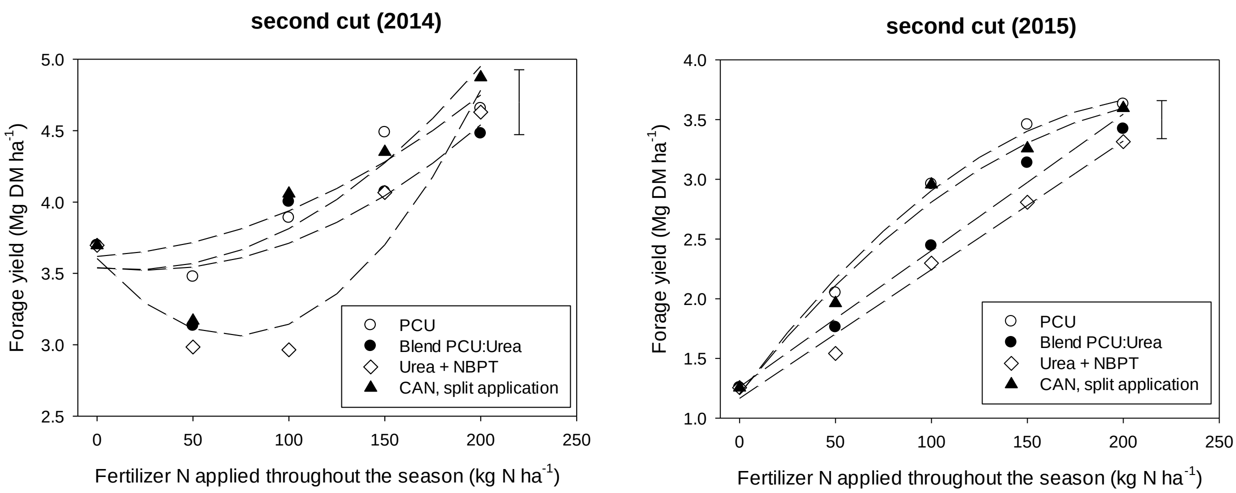

Figure 2. Effect of N source and rate on second cut forage DM yield.

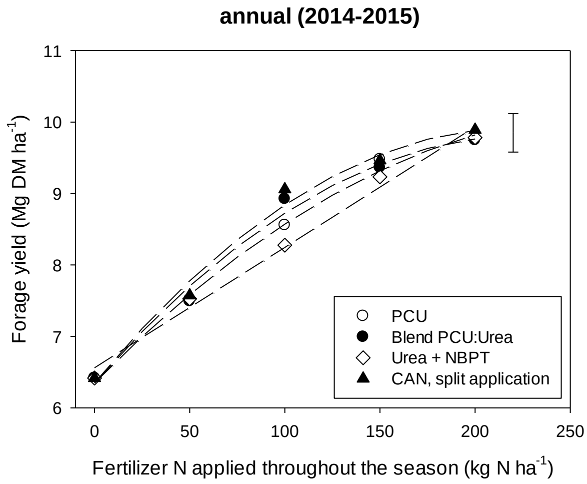

Figure 3. Effect of N source and rate on annual forage DM yield averaged across years.

Urea + NBPT applied at 150 kg N ha^{-1} resulted in greater forage N and NO_3-N concentrations at the first cut than other fertilizers (Table 1). Forage NO_3-N concentrations greater than 1000 m kg^{-1} DM present a risk to cattle health, especially with pregnant animals (Rusche et al. 2012). The soil NO_3-N content in the 0- to 15-cm layer at the first cut was greater with the blend PCU:Urea and Urea + NBPT than with CAN (Table 1). At 200 kg N ha^{-1}, the soil NO_3-N content with those two N sources (24 mg NO_3-N kg^{-1}) was twice that found with CAN (12 mg NO_3-N kg^{-1}).

Table 1. Effect of N source applied at 150 kg N ha^{-1} on forage N and NO_3-N concentrations, and soil (0-15 cm) NO_3-N content at the first cut averaged across two years. Log_{10} transformed data are in parenthesis.

Parameters	0 N	PCU	PCU:Urea	Urea + NBPT	CAN	LSD(P=0.05)
Forage N (g kg^{-1} DM)	19.1 c	24.4 b	25.6 b	28.1 a	24.1 b	1.5
Forage NO_3-N (mg kg^{-1} DM)	5 d	241 c	420 b	1001 a	186 c	
	(0.734)	(2.382)	(2.623)	(3.001)	(2.269)	(0.233)
Soil NO_3-N (mg kg^{-1})	5.5 c	14.9 ab	15.5 a	17.6 a	10.9 b	
	(0.744)	(1.174)	(1.192)	(1.246)	(1.036)	(0.139)

Different letters in a row indicate significant differences at P = 0.05.
Statistical analysis for forage and soil NO_3-N was done on $\log_{10}$ transformed data (values in parenthesis) due to heterogeneity of variance.

At the second cut, forage N concentrations were greater with PCU and CAN than with PCU:Urea and Urea + NBPT (Table 2). The forage N concentration was similar between cuts for PCU, CAN, and the unfertilized control but was largely reduced with the blend PCU:Urea and Urea + NBPT at the second cut, suggesting a reduced N availability for these treatments. Forage NO_3-N concentration was much lower in the second cut than in the first cut and it was not affected by N source. Finally, the soil NO_3-N content in the fall was low even at the highest N rate, averaging 3 mg NO_3-N kg^{-1} more than in the unfertilized control, and was not affected by the fertilizer source.

Table 2. Effect of N source applied at 150 kg N ha^{-1} on the second cut forage N and NO_3-N concentrations in 2015, and on the soil (0-15 cm) NO_3-N content in the fall averaged across two years. Log_{10} transformed data are in parenthesis.

Parameters	0 N	PCU	PCU:Urea	Urea + NBPT	CAN	LSD(P=0.05)
Forage N (g kg^{-1} DM)	20.0 b	24.6 a	20.8 b	21.2 b	24.1 a	1.8
Forage NO_3-N (mg kg^{-1} DM)	8 b	52 a	36 a	31 ab	34 a	
	(0.916)	(1.715)	(1.555)	(1.484)	(1.526)	(0.604)
Soil NO_3-N (mg kg^{-1})	7.1 b	9.9 a	9.6 a	9.6 a	9.6 a	1.6

Different letters in a row indicate significant differences at P = 0.05.
Statistical analysis for forage NO_3-N was done on log_{10} transformed data (values in parenthesis) due to heterogeneity of variance.

Conclusion

The fertilizer N source did not affect annual forage DM yield but it affected the yield distribution between the two cuts. PCU applied alone produced a lower first cut forage DM yield than other N fertilizers, while Urea + NBPT tended to produce a lower forage DM yield at the second cut. Urea-based N fertilizers regardless of their forms appear to be an interesting alternative to CAN in eastern Canada but further research is needed to assess their economic benefits.

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