LONG-TERM STRAW MANAGEMENT AND N FERTILIZER RATE EFFECTS ON CROP YIELD, N UPTAKE AND N BALANCE SHEET IN A GRAY LUVISOL

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Abstract

A field experiment with barley monoculture (1983-1996), and wheat/barley-canola-triticale-pea rotation (1997-2009) was conducted on a Gray Luvisol [Typic Haplocryalf] loam soil at Breton, Alberta, to assess the influence of straw management (straw removed [S_{Rem}] and straw retained [S_{Ret}]), N fertilizer rate (0, 25, 50 and 75 kg N ha^{-1}) and N source (urea and polymer-coated urea [called ESN]) under conventional tillage on seed yield, straw yield, total N uptake in seed + straw and N balance sheet. On the average, S_{Ret} produced greater seed yield (by 102 kg ha^{-1}), straw yield (by 196 kg ha^{-1}) and total N uptake (by 3.7 kg N ha^{-1}) in the 1997-2009 period for both N sources. There was a considerable increase in yield and total N uptake up to 75 kg N ha^{-1} rate. The ESN was superior to urea in increasing seed yield (by 109 kg ha^{-1}), straw yield (by 80 kg ha^{-1}) and total N uptake (by 2.4 kg N ha^{-1}) in the 1983-1996 period (mainly at the 25 and 50 kg N ha^{-1} rates). The N balance sheets over the 1983-2009 study duration indicated large amounts of applied N unaccounted for, ranging from 740 to 1518 kg N ha^{-1}, suggesting a great potential for N loss from the soil-plant system through denitrification and/or nitrate leaching, and from the soil mineral N pool by N immobilization. In conclusion, the findings suggest that long-term retention of crop residue may gradually improve soil productivity.

Rationale and Objective

Crop residues are a source of soil organic matter, which is the primary source of plant nutrients and an energy source for soil micro-organisms. Long-term use of continuous cropping, retaining crop residues and improved fertilization can improve soil quality/fertility and sustain productivity. There is limited information on the long-term effects of crop residue management and N fertilizer rate on crop production and nutrient uptake. The objective of this study was to determine the long-term influence of straw management, N fertilizer rate and N source on seed yield, straw yield, total N uptake in seed + straw and N balance sheet over 27 years (from 1983 to 2009) on a Gray Luvisol soil under conventional tillage.

Materials and Methods

Field experiment was conducted from 1983 to 2009 at Breton, Alberta, Canada, on an Orthic Gray Luvisol (Typic Haplocryalf), with loam texture, pH of 6.6 and initial total C concentration of 13.75 g C kg^{-1}. This area has 2356 growing degree days (GDD) at >0°C and 1335 GDD at >5°C, 118 days frost free period, mean growing season precipitation 335 mm (range of 182 to 514 mm) and a growing season mean temperature of 14°C (7°C to 20°C). The growing season is from May to August, and approximately 60% of the total precipitation occurs in the growing season. The mean annual precipitation is 475 mm. The experiment was initiated in the autumn of 1982.

The treatments included: two straw managements (straw removed [S_{Rem}] and straw retained [S_{Ret}]), four N rates (0, 25, 50 and 75 kg N ha^{-1}) and two N sources (urea and polymer-coated urea [called ESN]) under conventional tillage in a randomized complete block design in four replications. All plots were tilled twice, once in autumn and once in spring, with a chisel cultivator followed by a coil packer. The plots were planted to barley (*Hordeum vulgare* L.) monoculture from 1983 to 1996 (Solberg et al. 1997). However, after 1996, barley (2002, 2009) was rotated with other crops to include spring wheat (*Triticum aestivum* L.; 1997, 1998, 2006), canola (*Brassica napus* L.; 1999, 2003, 2007), triticale (X *Triticosecale*, Wittmack; 2000, 2004, 2008), or pea (*Pisum sativum* L.; 2001, 2005). Data were collected on seed and straw yield, and total N uptake. For N balance sheet, N fixed by pea was estimated based on the published information in the region (Annonymous 2005), with slight modifications after taking into account for variations in crop yield.

Summary of Results

Growing conditions

Precipitation during the growing season (May, June, July and August) was substantially below the long-term average in 8 years (1984, 1985, 1992, 2002, 2003, 2005, 2006 and 2009) and above average in 4 years (1986, 1988, 1989 and 2007). In other years, the GSP was either slightly below average or slightly above average.

Seed and straw yield, and total N uptake (Figures 1 to 6)

On the average of 1983 to 1996, seed and straw yield increased up to 75 kg N^{-1} rate. Seed and straw yields and their responses to applied N were essentially similar for S_{Ret} and S_{Rem}. Seed and straw yields were greater with ESN than urea, under both S_{Ret} and S_{Rem} treatments, mainly at 25 and 50 kg N ha^{-1} rates. Response trends of N uptake in seed + straw to treatments were usually similar to seed and straw yield. Responses of yield and total N uptake to straw management, N rate and N source during the period from 1997 to 2009, were generally similar to that during 1983 to 1996, with only few exceptions. For example, seed and straw yield and total N uptake tended to be greater with SRet than SRem during the 1997 to 2009 period.

Nitrogen balance sheet (Table 1)

The estimated amounts of nitrate-N recovered in soil + N removed in seed in all treatments and in straw in SRem treatments ranged from 666 to 1645 kg N ha^{-1} in various treatments (Table 1). The estimated amounts of N applied as inorganic fertilizer in 24 years, plus BFN (biologically fixed N) in 3 years when pea was grown + N added in seed in 27 years ranged from and 394 to 2305 kg N ha^{-1}. The amounts of N that could not be accounted for ranged from -336 to 848 kg N ha^{-1}. The amounts of unaccounted N from N applied/fixed/added ranged from 740-1518. It is unlikely that a portion of applied N was leached down below 90 cm soil depth, as evidenced by the little nitrate-N recovered in deeper layers in autumn 2009 when soil was sampled to a depth of 90 cm. Our results suggest no over-application of N compared to crop requirement for this region where soil moisture usually is not a limiting factor for normal crop growth. It is possible that a portion of the applied N in N treatments may have been immobilized in soil organic N, as evidenced by higher amount of soil N in LFON especially in SRet than SRem plots (Malhi et al. 2011). In addition, it is also possible that a small portion of the applied N may have been lost from the soil-plant system through denitrification (e.g., nitrous oxide and other N gases) due to wet soil conditions which temporarily exist in the present study in some years in early spring after snow melt or after occasional heavy rainfall during summer and/or autumn.

Conclusions

There was a considerable increase in yield and N uptake with N application up to 75 kg N ha^{-1} rate for both N sources in both periods. On average, S_{Ret} produced greater seed yield (by 102 kg ha^{-1}), straw yield (by 196 kg ha^{-1}) and total N uptake in seed + straw (by 3.7 kg N ha^{-1}) than S_{Rem} for both N sources in the 1997 to 2009 period. ESN was superior to urea in increasing seed yield (by 109 kg ha^{-1}), straw yield (by 80 kg ha^{-1}) and total N uptake in seed + straw (by 2.4 kg N ha^{-1}) in the 1983 to 1996 period, mainly at 25 and 50 kg N ha^{-1} rates.

Acknowledgements

The authors thank Z. Zhang , D. Leach and K. Strukoff for technical help

Balance sheets of long-term straw management and N rate treatments from 1983-2009 in field experiments established in the autumn of 1982 at Breton (Gray Luvisol), Alberta, Canada.

	Treatments							
Site/parameter Gray Luvisol - Breton	$^{z}S_{Rem}$25-U	S_{Ret}25-U	S_{Rem}50-U	S_{Ret}50-U	S_{Rem}75-U	S_{Ret}75-U	S_{Rem}0	S_{Ret}0
Nitrate-N recovered in soil (0-90 cm) in autumn 2009 (kg N ha^{-1})	6	6	13	6	4	4	10	23
N removed in seed in 27 years (kg N ha^{-1})	911	982	1134	1217	1414	1453	650	643
N removed in straw in S_{Rem} treatments in 27 years (kg N ha^{-1})	126	0	168	0	227	0	92	0
N removed in seed in all treatments and in straw in S_{Rem} treatments in 27 years (kg N ha^{-1})	1037	982	1302	1217	1641	1453	742	643
N recovered in soil after 27 years + N removed in seed + in straw in 27 years (kg N ha^{-1})	1043	988	1315	1223	1645	1457	752	666
Inorganic N applied in fertilizers in 24 years (kg N ha^{-1})	600	600	1200	1200	1800	1800	0	0
Organic N fixed when pea was crop in 3 years in 2001, 2005 and 2009 (kg N ha^{-1})	371	441	365	393	428	445	356	334
Organic N added in seed in 27 years (kg N ha^{-1})	60	60	60	60	60	60	60	60
N applied in 24 years + N fixed in 3 years + N added in seed in 27 years (kg N ha^{-1})	1031	1101	1625	1653	2288	2305	416	394
N balance (N applied/fixed/seed – N removed in seed/straw) (kg N ha^{-1})	-6	119	323	436	647	852	-326	-249
Unaccounted N (N applied/fixed/seed – N recovered in soil + seed/straw) (kg N ha^{-1})	-12	113	310	430	643	848	-336	-2732
N removed in seed/straw in 27 years from applied N (kg N ha^{-1})	295	339	560	574	899	810		
N recovered in soil after 27 years + seed/straw in 27 years from applied N (kg N ha^{-1})	291	322	563	557	893	787		
N balance (N applied/fixed/seed – N removed in seed/straw from applied N) (kg N ha^{-1})	736	762	1065	1079	1389	1495		
Unaccounted N (N applied/fixed/seed – N recovered in soil + seed/straw from applied N) (kg N ha^{-1})	740	779	1062	1096	1395	1518		
Recovery of applied N in seed over 27 years (%)	43.5	56.5	40.3	47.8	42.8	45.0		

$^{z}S_{Rem}$ = Straw removed; S_{Ret} = Straw retained; 0, 25, 50 and 75 kg N ha^{-1}. U = urea.

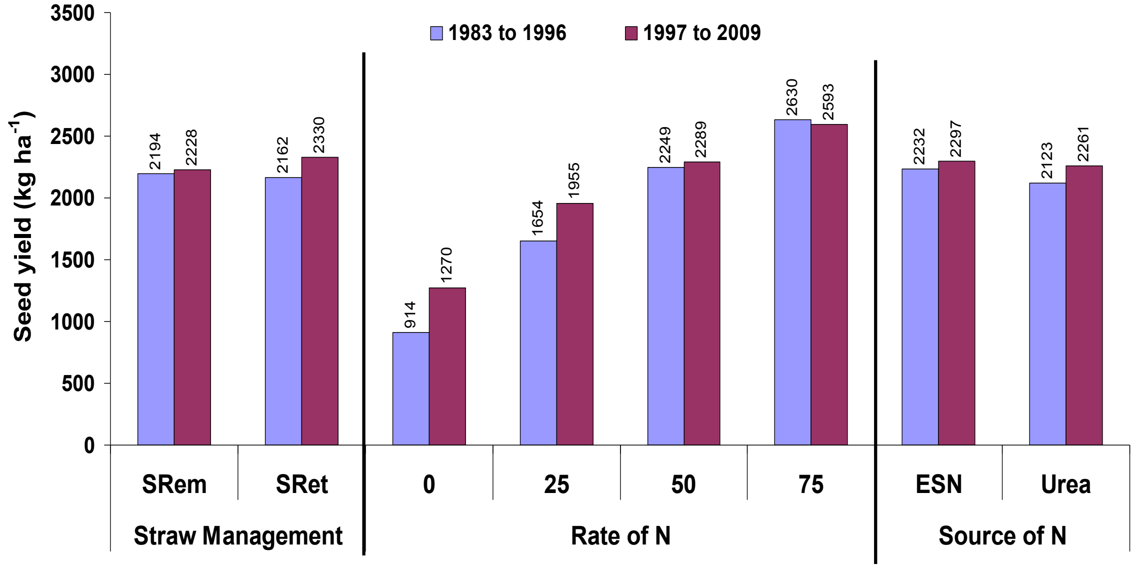

Figure 1. Effect of long-term straw management, N source and N rate on mean seed yield, from 1983 to 1996 and 1997 to 2009 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn, 1982).

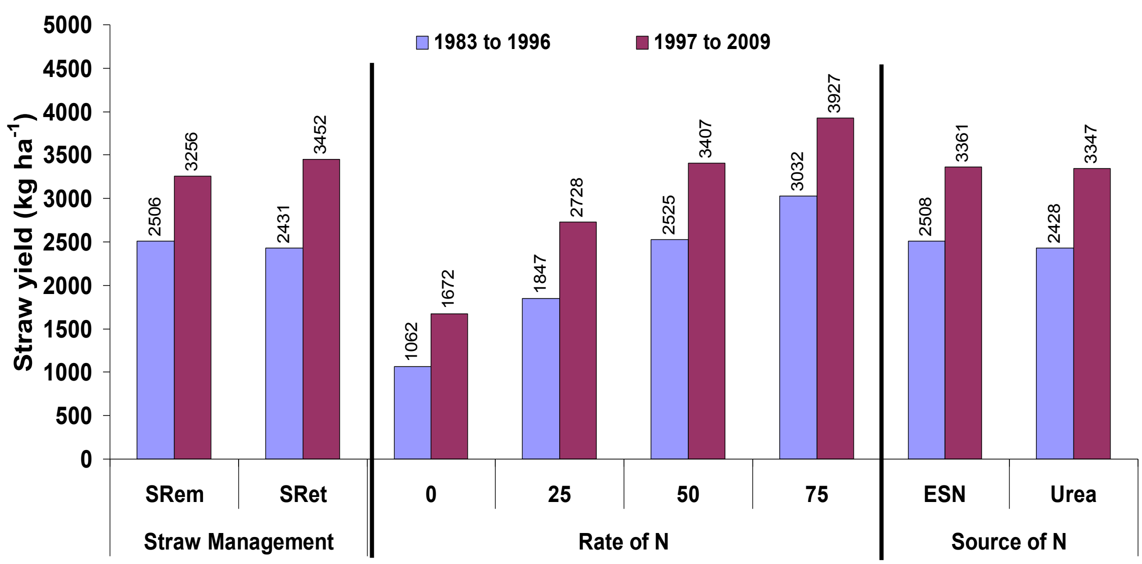

Figure 2. Effect of long-term straw management, N source and N rate on mean straw yield from 1983 to 1996 and 1997 to 2009 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn, 1982).

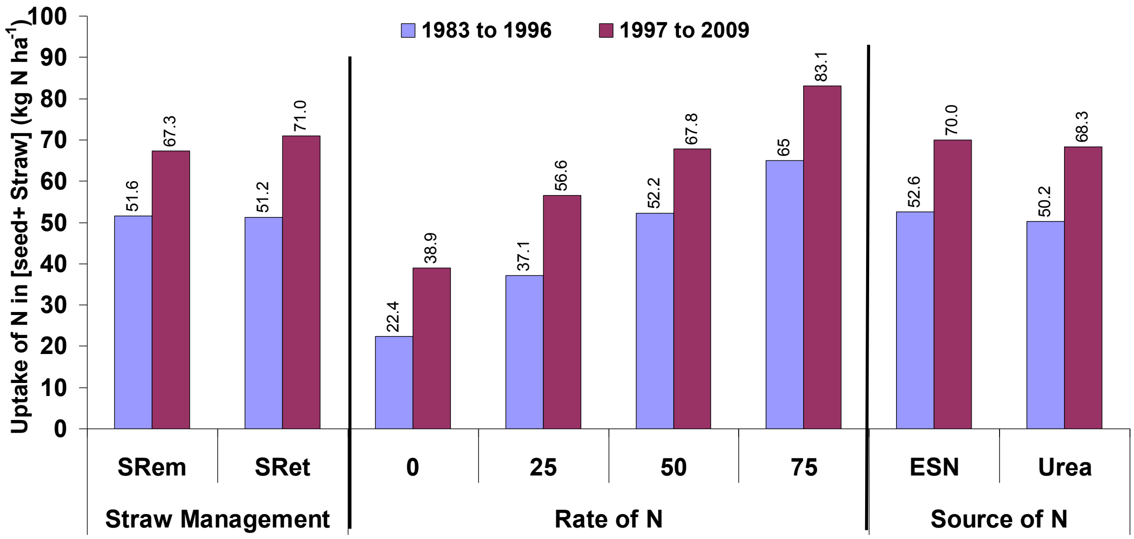

Figure 3. Effect of long-term straw management, N source and N rate on mean total N uptake in seed + straw from 1983 to 1996 and 1997 to 2009 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn, 1982).

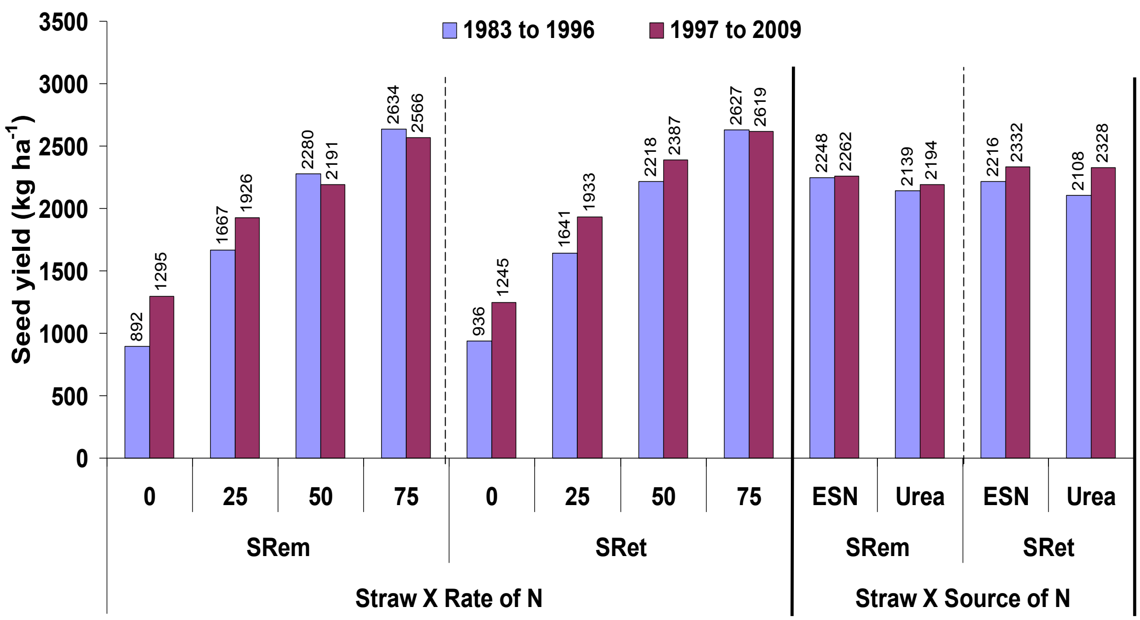

Figure 4. Effect of long-term straw management, N source and N rate interactions on mean seed yield from 1983 to 1996 and 1997 to 2009 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn, 1982).

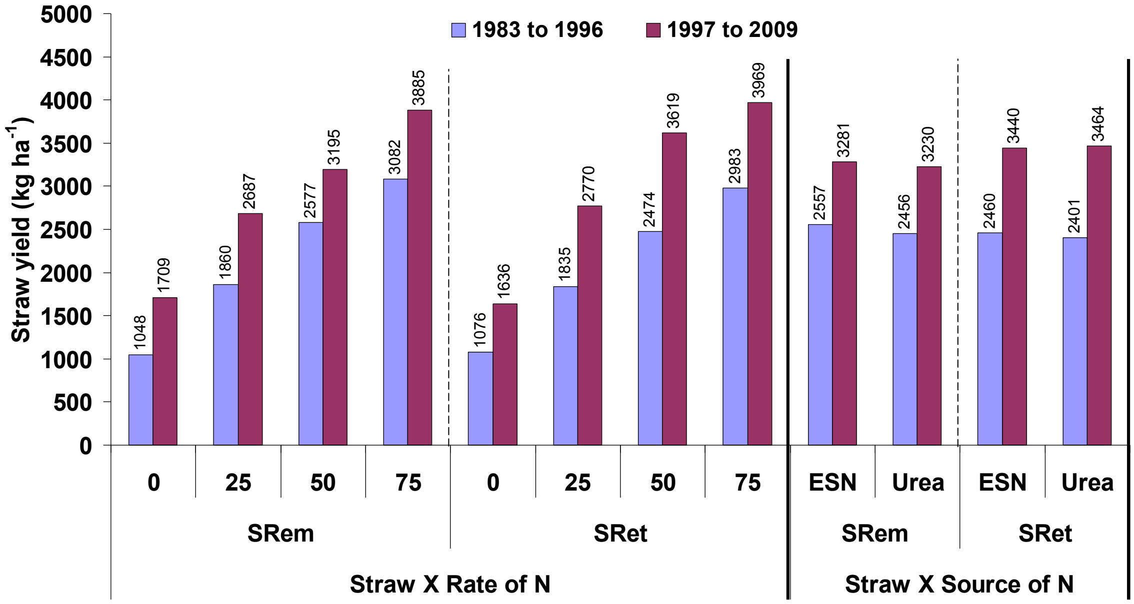

Figure 5. Effect of long-term straw management, N source and N rate interactions on mean straw yield from 1983 to 1996 and 1997 to 2009 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn, 1982).

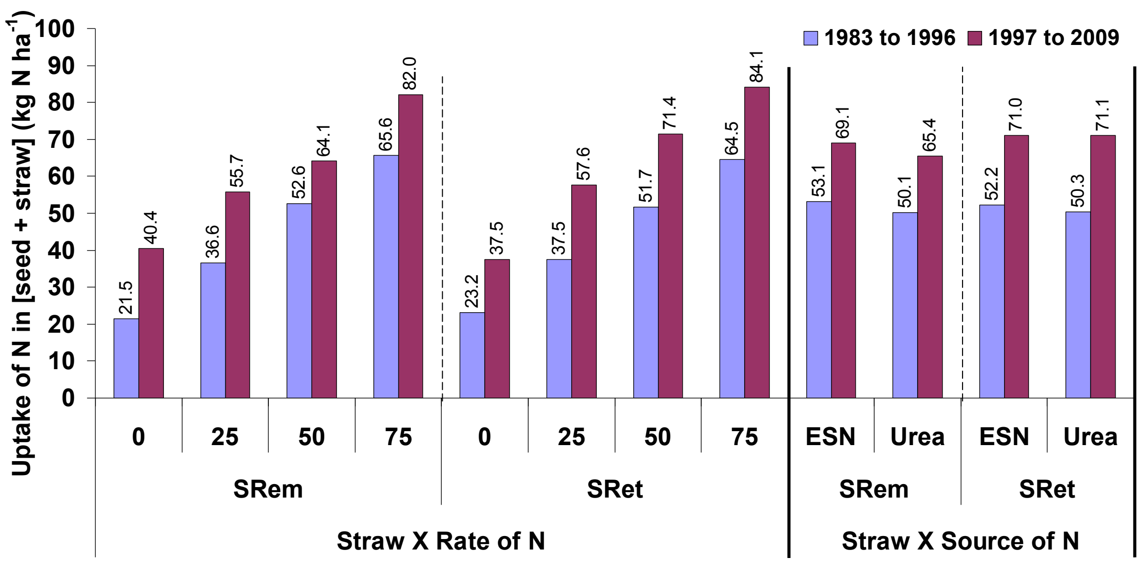

Figure 6. Effect of long-term straw management, N source and N rate interactions on mean total N uptake in seed + straw from 1983 to 1996 and 1997 to 2009 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn, 1982).