LONG-TERM TILLAGE, 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 (established in autumn 1979, with monoculture barley [1980-1990] and barley/wheat-canola-triticale-pea rotation [1991-2008] was conducted on a Gray Luvisol [Typic Haplocryalf] loam soil at Breton, Alberta, to determine the influence of tillage (zero tillage [ZT] and conventional tillage [CT]), straw management (straw removed [S_{Rem}] and straw retained [S_{Ret}]) and N fertilizer rate (0, 50 and 100 kg N ha^{-1} in S_{Ret}, and only 0 kg N ha^{-1} in S_{Rem} plots) on seed yield, straw yield, total N uptake in seed + straw (1991-2008), and N balance sheet (1980-2008). The N fertilizer urea was midrow-banded under both tillage systems in the 1991-2008 period. There was a considerable increase in yield and total N uptake up to 100 kg N ha^{-1} under both tillage systems. On the average, CT produced greater seed yield (by 223 kg ha^{-1}), straw yield (by 177 kg ha^{-1}) and total N uptake (by 5.6 kg N ha^{-1}) than ZT. Compared to S_{Rem} treatment, seed yield, straw yield and total N uptake tended to be greater with S_{Ret} at the zero-N rate used in the study. The amounts of applied N unaccounted for over the 1980-2008 period ranged from 845 to 1665 kg N ha^{-1}, suggesting a great potential for N loss from the soil-plant system through denitrification, and N immobilization from the soil mineral N pool. In conclusion, crop yield and N uptake were lower under ZT than CT, and long-term retention of straw suggests some gradual improvement in soil productivity.

Rationale and Objective

Zero-tillage (ZT, no-tillage – NT, or direct seeding) with standing stubble prevents soil erosion, and conserves soil organic matter and moisture, and generally increases crop production and economic returns. Straw is a valuable resource for on-farm animal feed and off-farm fuel and paper products. In the Parkland region of western Canada, large quantities of cereal straw are produced, which if left on soil surface can sometimes pose a management problem related to seeding. In these areas, there may be opportunities for removing straw for alternative uses, while maintaining optimum soil organic matter and crop yield. Before recommending straw removal, however, the impact of this practice must be assessed on crop yield on a long-term basis. Management options such as NT, choice of crops in a rotation or residue management, and adequate fertilization can be used to increase organic matter in soil, which might offset the potentially negative impact of residue removal on soil moisture and crop yield. Integration of tillage, crop residue management and proper fertilization is important to determine the influence of crop residues on cycling of nutrients from soil and fertilizers, and their effects on the sustainability of crop production. Information is needed as to find whether crop residues can be removed from field for alternative uses without any detrimental impact on crop productivity, but long-term information is lacking for the Gray soil (Cryalf) zone, especially when different crops are grown in a rotation. The objective of this study was to determine the influence of tillage (zero tillage [ZT] and conventional tillage [CT]), straw management (straw removed [S_{Rem}] and straw retained [S_{Ret}]) and N fertilizer rate (0, 50 and 100 kg N ha^{-1} in S_{Ret}, and 0 kg N ha^{-1} in S_{Rem} plots) on seed yield, straw yield, total N uptake in seed + straw and N balance sheet in a Gray Luvisol soil at Breton, Alberta, Canada.

Materials and Methods

The field experiment was initiated in the autumn of 1979 at Breton, Alberta, Canada. The soil is 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, and a growing season (May to August) mean temperature of 14°C (7°C to 20°C). The mean annual precipitation is 475 mm for this area, and approximately 60% of the total precipitation occurs in the growing season. The treatments were arranged in a RCBD in four replications.

In 1980 to 1990, The plots were seeded to a barley (*Hordeum vulgare* L.) monoculture. Two tillages (conventional tillage [CT] and zero tillage [ZT]), Two straw managements (straw removed [S_{Rem}] and straw retained [S_{Ret}]), and Two N rates in spring (0 and 56 kg N ha^{-1}), plus two treatments receiving 56 kg N ha^{-1} in autumn under ZT and CT. The N fertilizer urea was surface broadcast under ZT, and broadcast/incorporated into soil under CT.

In 1991 to 2008, Another N rate (100 kg N ha^{-1}) was added to replace autumn N treatments, and the 56 kg N ha^{-1} rate was reduced to 50 kg N ha^{-1}. Urea was midrow-banded under both tillage systems. At the same time, monoculture barley was changed to spring wheat (*Triticum aestivum* L.)/barley-canola (*Brassica napus* L.)-triticale (X *Tricosecale, Wittmack*)-pea (*Pisum sativum* L.).

Plots under CT were tilled twice, once in autumn and then in spring, with a seep-chisel cultivator followed by a coil packer. The ZT plots did not undergo any disturbance, except for seeding drill. Data were collected annually from 1980 to 2008 on seed and straw yield at maturity, and total N uptake in seed and straw. For N balance sheet, N fixed by pea was estimated based on published information in the region (Annonymous 2005), with slight modifications after taking into account for the 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 1984, 1985, 1992, 2002, 2003, 2005 and 2006 (with very dry conditions in 1992 and 2002, along with very dry May in 1983, 1995 and 2008). The growing season precipitation (GSP) was slightly below average in 1993, 1995 and 1997. The GSP was much higher than average (wet to very wet conditions) in 1980, 1986, 1988, 1989 and 2007. In other years, the GPS was near or slightly above average.

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

There was a considerable increase in seed and straw yield, and total N uptake in seed + straw with N application up to the 100 kg N ha^{-1} rate used during 1991 to 2008 period. On the average, CT produced greater seed and straw yield, and total N uptake than ZT, although ZT was superior to CT in only a few years, usually GSP only slightly below average. Seed and straw yield, and total N uptake tended to be lower in 1980 to 1990, but tended to be higher in 1991 to 2008 with S_{Ret} than S_{Rem}. In the 1980 to 1990 period where urea at 56 kg N ha^{-1} was applied in both autumn and spring, autumn-applied N was inferior to spring applied N in improving yield and N uptake.

Nitrogen balance sheet from 1980 to 2008 (Table 1)

The estimated amounts of nitrate-N recovered in soil + N removed in seed in all treatments and in straw in S_{Rem} treatments ranged from 421 to 1273 kg N ha^{-1} in various treatments. The values of N applied as inorganic fertilizer 27 years, plus BFN (biologically fixed N) in 2 years when pea was grown and N added in seed in 29 years ranged from 239 to 2519 kg N ha^{-1}. The amounts of N that could not be accounted for ranged from -395 to 1425 kg N ha^{-1}. The amounts of unaccounted N from applied N ranged from 1114 to 1846 kg N ha^{-1}. The amounts of unaccounted N were higher for treatments receiving N fertilizer compared to zero-N. This suggested that a large proportion of the applied N did not become available to the crops. It is unlikely that a portion of applied N leached down below 120 cm, because there was little nitrate-N recovered in deeper soil layers when soil was sampled to 120 cm depth in spring 2007. It is possible that a portion of the applied N may have been immobilized in soil organic N, as evidenced by higher amount of soil N in LFON especially in S_{Ret} than S_{Rem} plots (data not shown). In addition, it is also possible that a 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 area in most years in early spring after snow melt, or after occasional heavy rainfall during summer and/or autumn.

Conclusions

There was a considerable increase in seed and straw yield, and total N uptake in seed + straw with N application up to 100 kg N ha^{-1}. Seed and straw yield, and total N uptake tended to be lower with S_{Ret} than S_{Rem} in initial years, but S_{Ret} improved yield and N uptake with duration/time. CT produced greater seed and straw yield, and total N uptake than ZT, although ZT was superior to CT in only few years. Autumn-applied N was inferior to spring-applied N, used in the 1980 to 1990 period.

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Balance sheet of long-term tillage, straw management and N rate treatments from 1980-2008 in a field experiment established in the autumn of 1979 at Breton (Gray Luvisol), Alberta, Canada

Site/parameter	ZT[z]				CT[z]			
	$ZTS_{Rem}0$	$ZTS_{Ret}0$	$ZTS_{Ret}50$	$ZTS_{Ret}100$	$CTS_{Rem}0$	$CTS_{Ret}0$	$CTS_{Ret}50$	$CTS_{Ret}100$
Gray Luvisol - Breton								
Nitrate-N recovered in soil (0-120 cm) in spring 2007 (kg N ha^{-1})	17	20	31	21	19	19	22	28
N removed in seed in 29 years (kg N ha^{-1})	380	401	963	1038	464	498	1059	1245
N removed in straw in S_{Rem} treatments in 29 years (kg N ha^{-1})	165	0	0	0	184	0	0	0
N removed in seed in all and in straw in S_{Rem} treatments in 29 years (kg N ha^{-1})	545	401	963	1038	648	498	1059	1245
N recovered in soil after 27 years + N removed seed + in straw in 29 years (kg N ha^{-1})	562	421	994	1059	667	517	1081	1273
Inorganic N applied in fertilizers in 27 years (kg N ha^{-1})	0	0	1416	2216	0	0	1416	2216
N fixed when pea was crop in 2 years in 2001 and 2005 (kg N ha^{-1})	181	181	213	210	214	211	227	245
Organic N added in seed in 29 years (kg N ha^{-1})	58	58	58	58	58	58	58	58
N applied in 27 years + N fixed in 2 years + N added in seed in 29 years (kg N ha^{-1})	239	239	1687	2484	272	269	1701	2519
N balance (N applied/fixed/seed – N removed in seed/straw) (kg N ha^{-1})	-306	-162	724	1446	-376	-229	642	1274
Unaccounted N (N applied/fixed/seed – N recovered in soil + seed/straw) (kg N ha^{-1})	-323	-182	693	1425	-395	-248	620	1246
N removed in seed/straw in 29 years from applied N (kg N ha^{-1})			562	637			561	747
N recovered in soil after 27 years + seed/straw in 29 years from applied N (kg N ha^{-1})			573	638			564	756
N balance (N applied/fixed/seed – N removed in seed/straw from applied N) (kg N ha^{-1})			1125	1847			1140	1772
Unaccounted N (N applied/fixed/seed – N recovered in soil + seed/straw from applied N) (kg N ha^{-1})			1114	1846			1137	1763

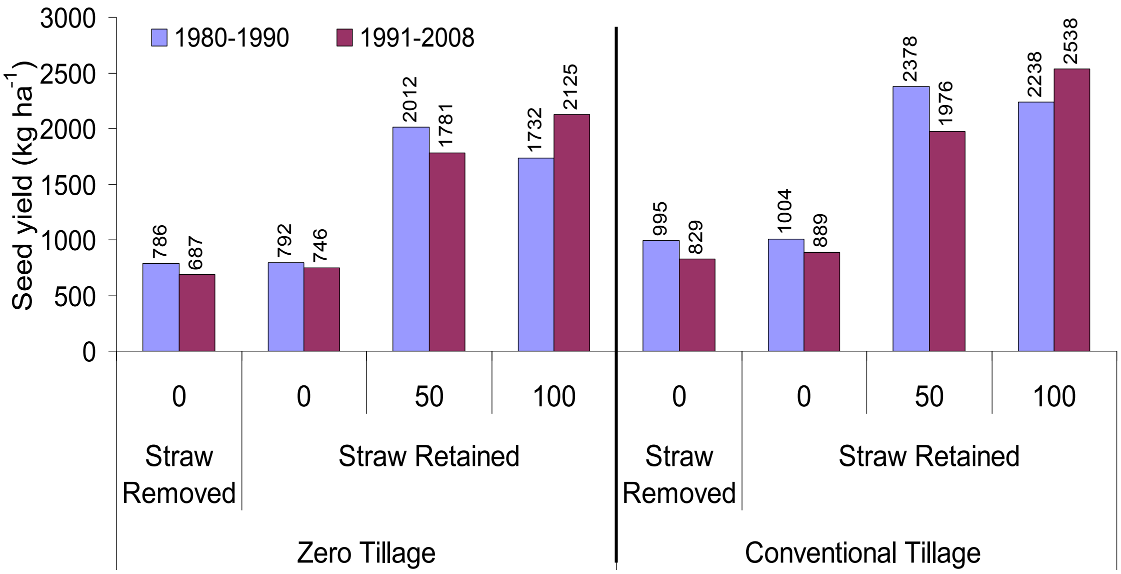

Figure 1. Effect of long-term tillage, straw management and N rate on mean seed yield, from 1980 to 1990 and 1991 to 2008 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn, 1979).

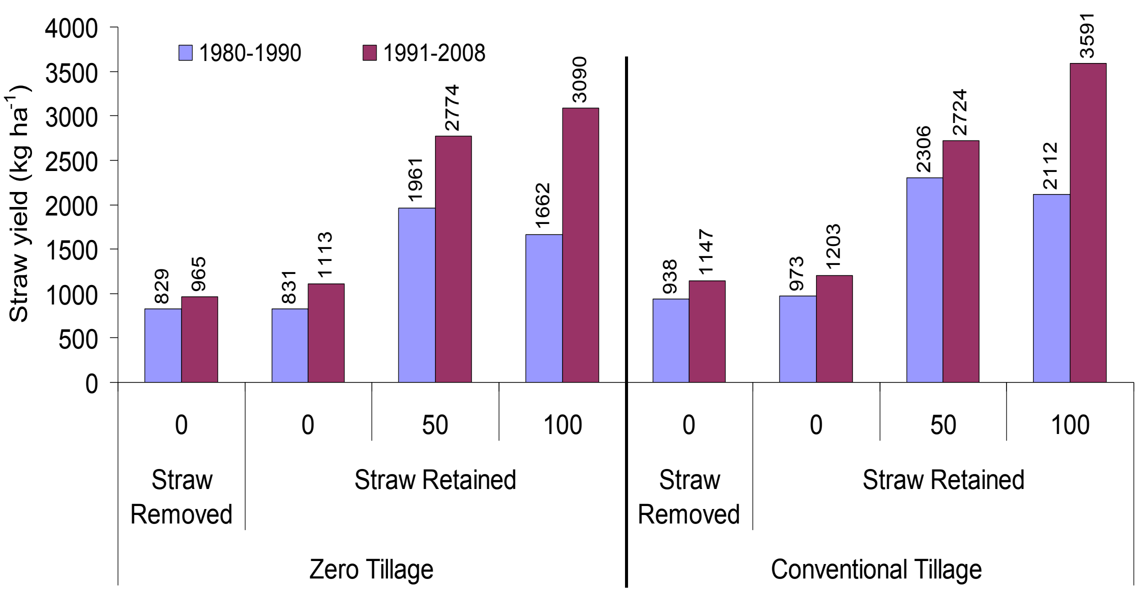

Figure 2. Effect of long-term tillage, straw management and N rate on mean straw yield from 1980 to 1990 and 1991 to 2008 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn, 1979).

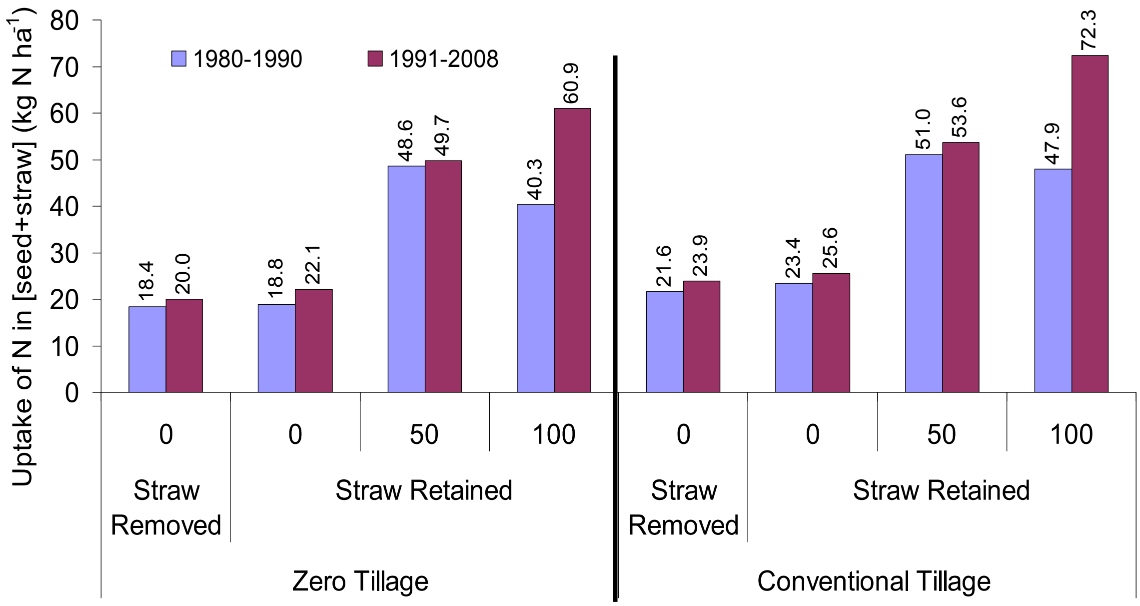

Figure 3. Effect of long-term tillage, straw management and N rate on mean total N uptake in seed + straw from 1980 to 1990 and 1991 to 2008 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn, 1979).

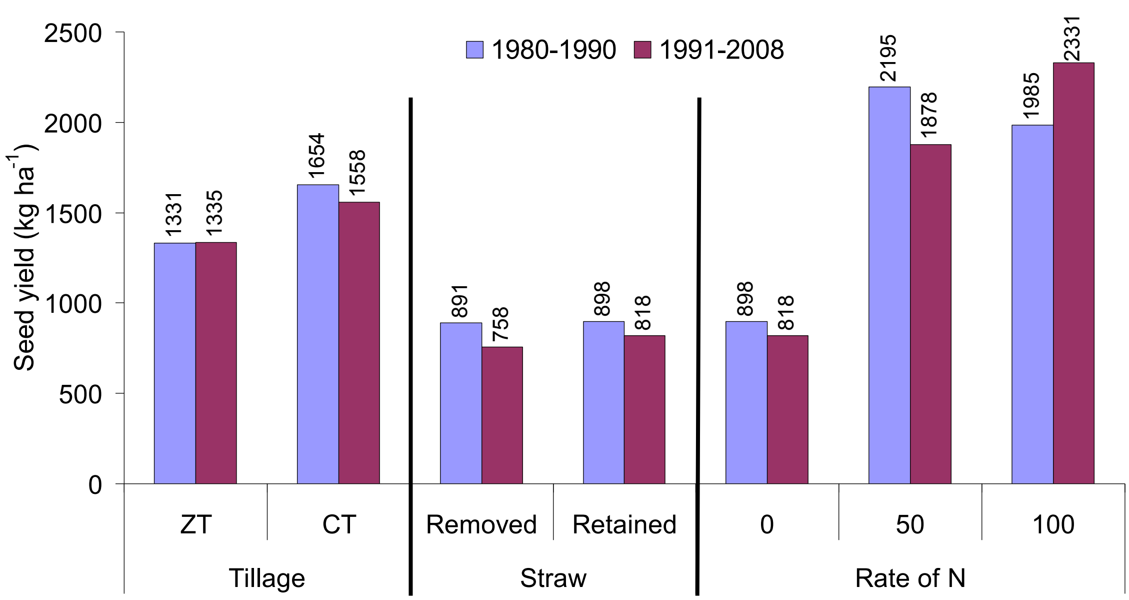

Figure 4. Effect of long-term tillage, straw management and N rate interactions on mean seed yield from 1980 to 1990 and 1991 to 2008 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn, 1979).

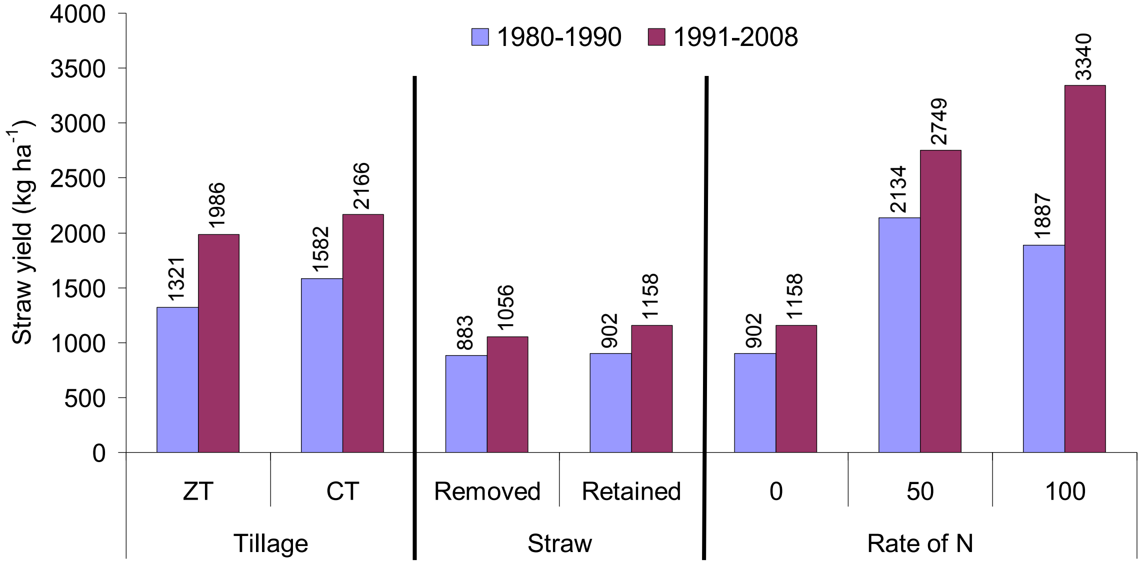

Figure 5. Effect of long-term tillage, straw management and N rate interactions on mean straw yield from 1980 to 1990 and 1991 to 2008 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn, 1979).

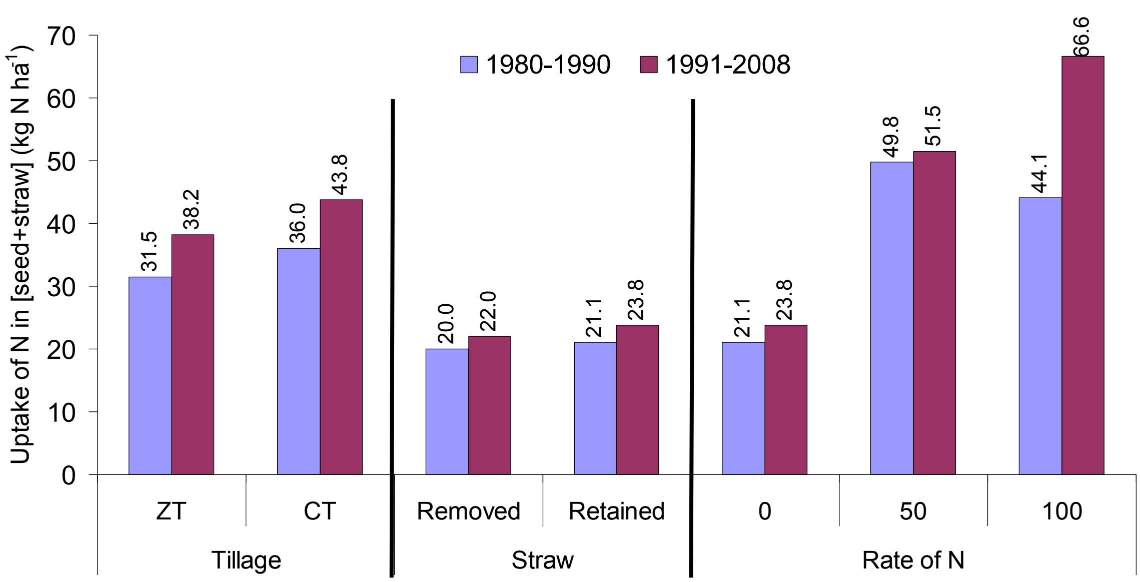

Figure 6. Effect of long-term tillage, straw management and N rate interactions on mean total N uptake in seed + straw from 1980 to 1990 and 1991 to 2008 at Breton, Alberta, Canada (Gray Luvisol soil, experiment established in autumn, 1979).