

# LONG-TERM TILLAGE, STRAW MANAGEMENT AND N FERTILIZER RATE EFFECTS ON CROP YIELD, N UPTAKE AND N BALANCE SHEET IN A BLACK CHERNOZEM

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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 Black Chernozem [Albic Agricryoll] silty clay loam soil at Ellerslie, 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<sup>-1</sup> in  $S_{Ret}$ , and only 0 kg N ha<sup>-1</sup> 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<sup>-1</sup> under both tillage systems. On the average, CT produced greater seed yield (by 332 kg ha<sup>-1</sup>), straw yield (by 323 kg ha<sup>-1</sup>) and total N uptake (by 6.3 kg N ha<sup>-1</sup>) 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<sup>-1</sup>, 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. Successful integration of tillage, crop residue and fertilizer management into cropping systems is important to determine 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 Black soil (Boroll) zone, especially when different crops are grown in a rotation. The objective of this study was to determine the long-term effects 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<sup>-1</sup> in  $S_{Ret}$ , and 0 kg N ha<sup>-1</sup> in  $S_{Rem}$  plots) on seed yield, straw yield, total N uptake in seed + straw and N balance sheet in a Black Chernozem soil at Ellerslie, Alberta, Canada.

## Materials and Methods

The field experiment was initiated in the autumn of 1979 at Ellerslie (53°25'N, 113°33'W; elevation 692 m), Alberta, Canada, on a Black Chernozem (Albic Argicryoll), with loam texture, pH of 6.0 and initial organic C concentration of 56.45 g C kg<sup>-1</sup>. This area has growing degree days (GDD) of 2419 at >0°C and GDD of 1402 at >5°C, a 120 day frost free period, and a mean daily temperature of 14°C (8°C to 21°C) in the growing season (May to August). The mean annual precipitation of this area is 450 mm, 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, with 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<sup>-1</sup>), plus two treatments receiving 56 kg N ha<sup>-1</sup> 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<sup>-1</sup>) was added to replace autumn N treatments, and the 56 kg N ha<sup>-1</sup> rate was reduced to 50 kg N ha<sup>-1</sup>. 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, one in the autumn and one in the 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 (Anonymous 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, 1995 and 2002 (with very dry conditions in 1992 and 2002, along with very dry May in 1983 and 1995). The growing season precipitation (GSP) was slightly below average in 1993, 2003, 2005, 2006 and 2007. The GSP was much higher than average (wet to very wet conditions) in 1980, 1987, 1988, 1989, 1990 and 2008. In other years, the GSP 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<sup>-1</sup> rate used during 1991 to 2008 period. On the average, CT produced greater seed and straw yield, and total N uptake than ZT in both periods, although ZT was superior to CT in only a few years. 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<sup>-1</sup> was applied in both autumn and spring, and 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<sub>Rem</sub> treatments ranged from 946 to 1851 kg N ha<sup>-1</sup> in various treatments. The amounts of N applied as inorganic fertilizer in 27 years, plus BFN (biologically fixed N) in 2 years when pea grown and N added in seed in 29 years ranged from 245 to 2452 kg N ha<sup>-1</sup>. The amounts of N that could not be accounted for ranged from -1099 to 764 kg N ha<sup>-1</sup>. The amounts of unaccounted N from applied N ranged from 845 to 1665 kg N ha<sup>-1</sup>. The amount of unaccounted N was higher in 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 possible that a portion of applied N may have leached down below the 90 cm depth sampled, as evidenced by significant amounts of nitrate-N recovered in the 30-60 and 60-90 cm soil layers in spring 2007 (data not shown). 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<sub>Ret</sub> 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.

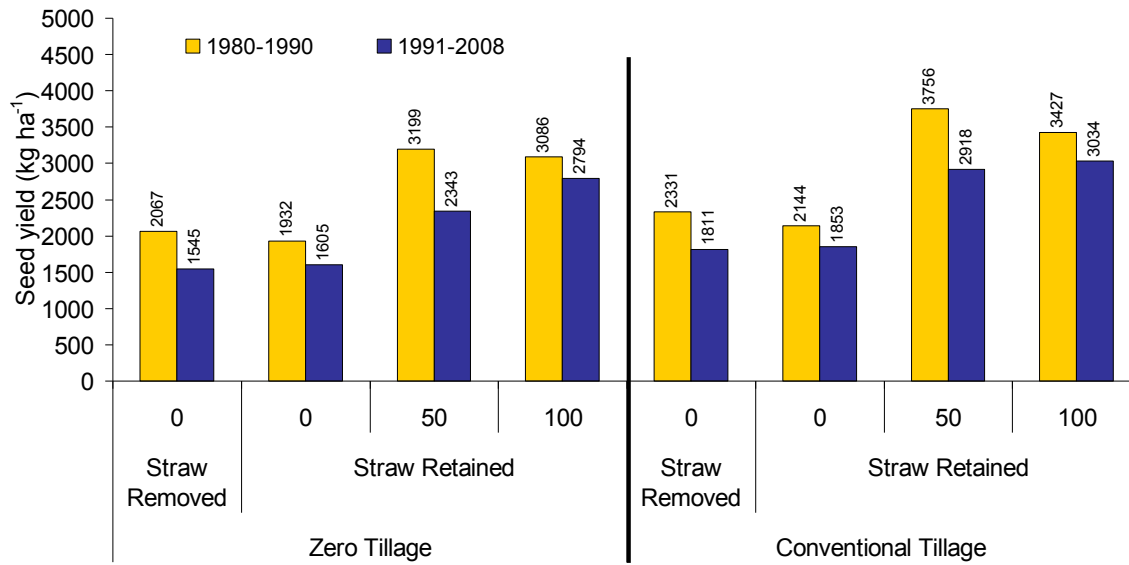
### Conclusions

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<sup>-1</sup>. Seed and straw yield, and total N uptake tended to be lower with S<sub>Ret</sub> than S<sub>Rem</sub> in initial years, but S<sub>Ret</sub> 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.

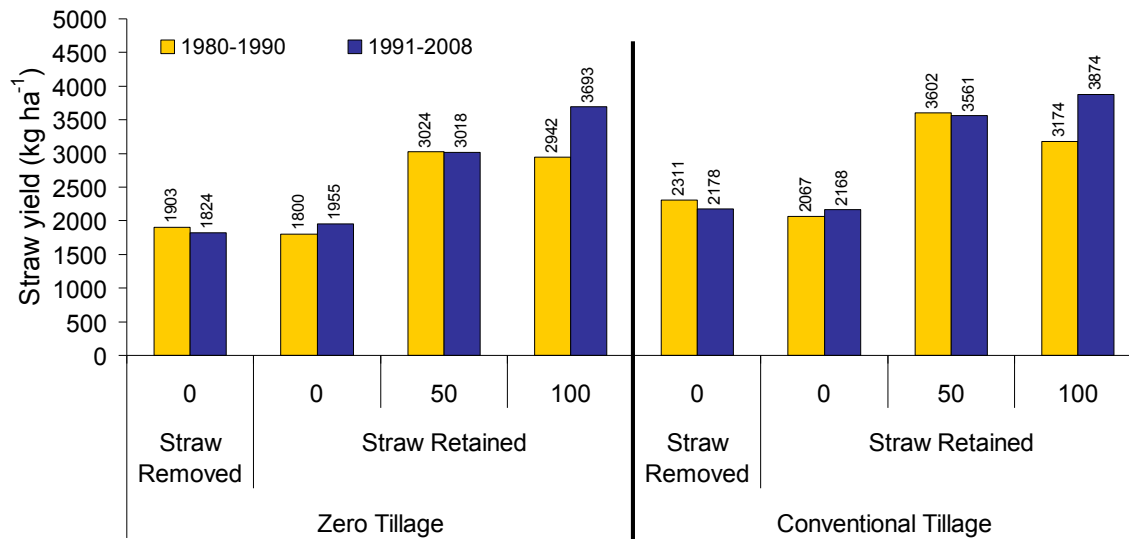
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Balance sheet of long-term tillage, straw management and N rate treatments from 1980-2008 in a field experiment established in the autumn of 1979 at Ellerslie, (Black Chernozem), Alberta, Canada

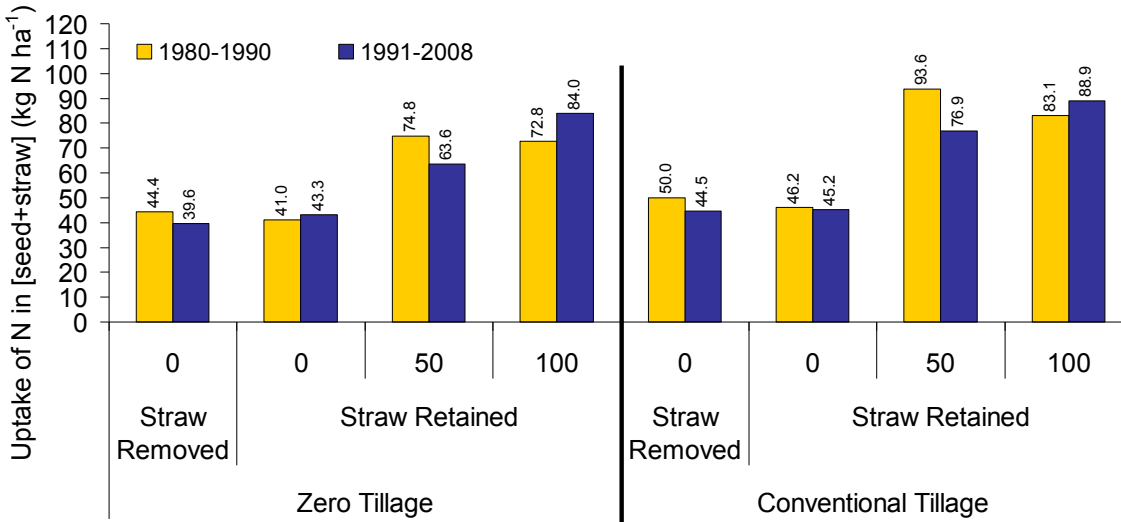
Site/parameter	ZT <sup>2</sup>				CT <sup>2</sup>			
	ZTS <sub>Rem</sub> 0	ZTS <sub>Ret</sub> 0	ZTS <sub>Ret</sub> 50	ZTS <sub>Ret</sub> 100	CTS <sub>Rem</sub> 0	CTS <sub>Ret</sub> 0	CTS <sub>Ret</sub> 50	CTS <sub>Ret</sub> 100
<b>Black Chernozem - Ellerslie</b>								
Nitrate-N recovered in soil (0-90 cm) in spring 2007 (kg N ha <sup>-1</sup> )	25	22	25	48	30	28	40	49
N removed in seed in 29 years (kg N ha <sup>-1</sup> )	886	924	1415	1617	1000	986	1783	1802
N removed in straw in S <sub>Rem</sub> treatments in 29 years (kg N ha <sup>-1</sup> )	283				317			
N removed in seed in all and in straw in S <sub>Rem</sub> treatments in 29 years (kg N ha <sup>-1</sup> )	1169	924	1415	1617	1317	986	1783	1802
N recovered in soil after 27 years + N removed seed + in straw in 29 years (kg N ha <sup>-1</sup> )	1194	946	1440	1665	1347	1014	1823	1851
Inorganic N applied in fertilizers in 27 years (kg N ha <sup>-1</sup> )	0	0	1416	2216	0	0	1416	2216
N fixed when pea was crop in 2 years in 2001 and 2005 (kg N ha <sup>-1</sup> )	204	254	176	155	190	187	190	178
Organic N added in seed in 29 years (kg N ha <sup>-1</sup> )	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 <sup>-1</sup> )	262	262	1650	2429	248	245	1654	2452
N balance (N applied/fixd/seed - N removed in seed/straw) (kg N ha <sup>-1</sup> )	-907	-662	235	812	-1069	-741	129	650
Unaccounted N (N applied/fixd/seed - N recovered in soil + seed/straw) (kg N ha <sup>-1</sup> )	-932	-684	210	764	-1099	-769	169	601
N removed in seed/straw in 29 years from applied N (kg N ha <sup>-1</sup> )			491	693			797	816
N recovered in soil after 27 years + seed/straw in 29 years from applied N (kg N ha <sup>-1</sup> )			494	719			809	837
N balance (N applied/fixd/seed - N removed in seed/straw from applied N) (kg N ha <sup>-1</sup> )			1159	1736			857	1636
Unaccounted N (N applied/fixd/seed - N recovered in soil + seed/straw from applied N) (kg N ha <sup>-1</sup> )			1156	1665			845	1615



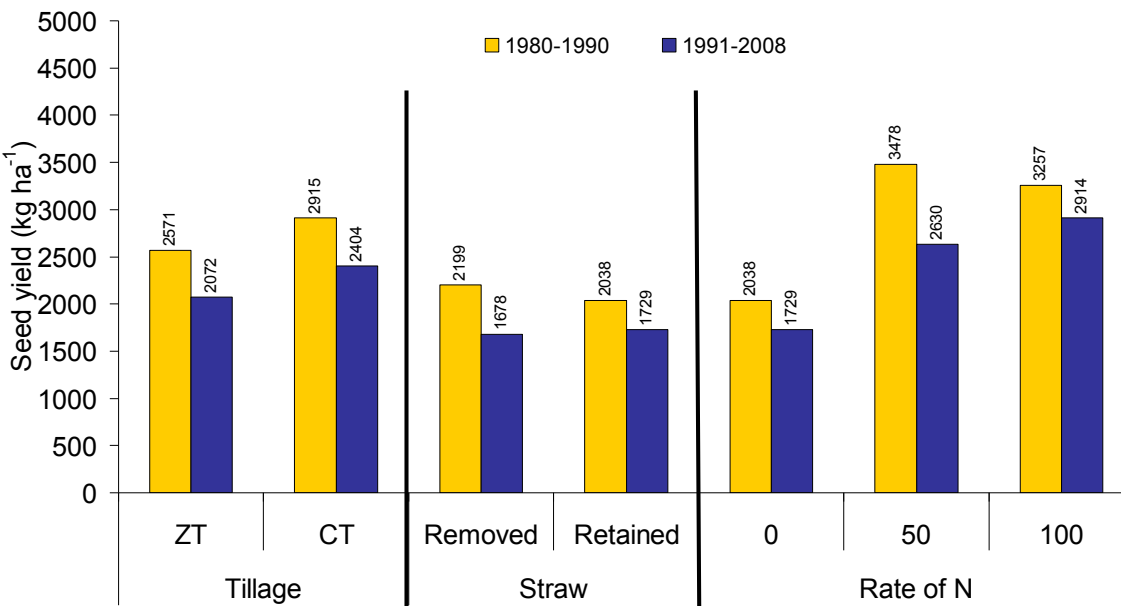
**Figure 1.** Effect of long-term tillage, straw management and N rate on mean seed yield, from 1980 to 1990 and 1991 to 2008 at Ellerslie, Alberta, Canada (Black Chernozem soil, experiment established in autumn, 1979).



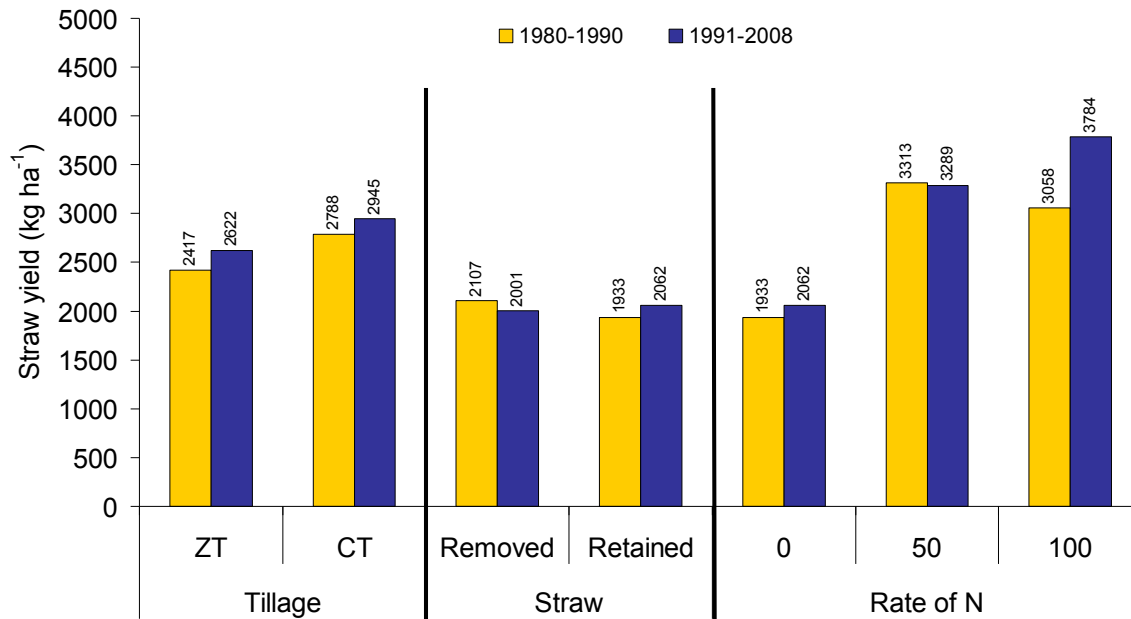
**Figure 2.** Effect of long-term tillage, straw management and N rate on mean straw yield from 1980 to 1990 and 1991 to 2008 at Ellerslie, Alberta, Canada (Black Chernozem soil, experiment established in autumn, 1979).



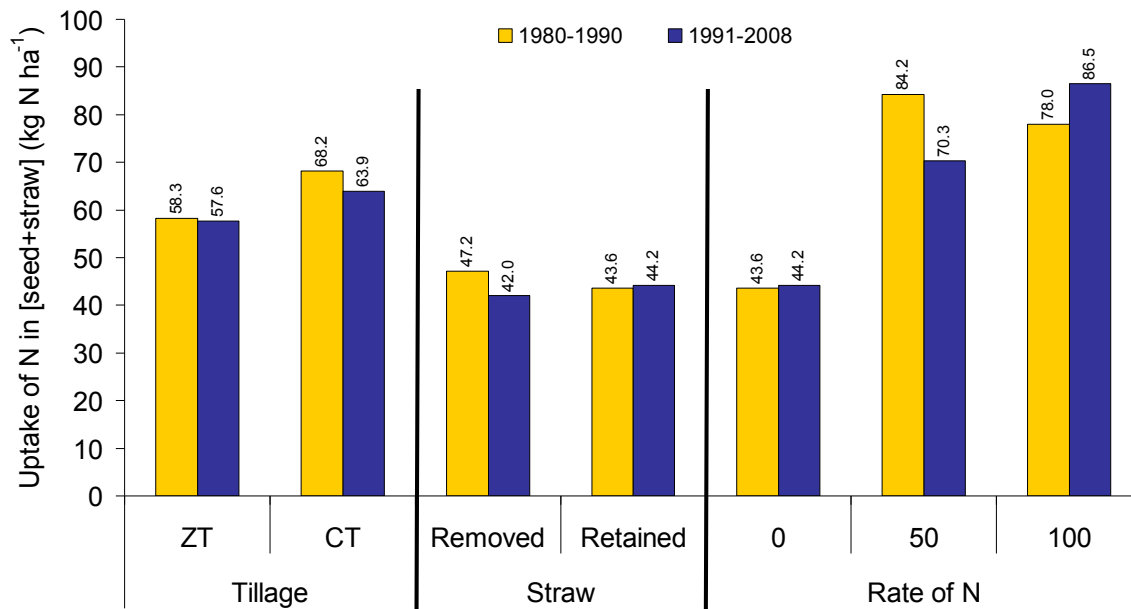
**Figure 3.** Effect of long-term tillage, straw management and N rate on mean total N uptake in seed + straw from 1980 to 1990 and 1991 to 2008 at Ellerslie, Alberta, Canada (Black Chernozem soil, experiment established in autumn, 1979).



**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 Ellerslie, Alberta, Canada (Black Chernozem 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 Ellerslie, Alberta, Canada (Black Chernozem 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 Ellerslie, Alberta, Canada (Black Chernozem soil, experiment established in autumn, 1979).