Influence of Tillage and Crop Residue Management on Crop Yield, Soil Properties and Greenhouse Gas Emissions in the Second 4-Year Rotation Cycle

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BACKGROUND

- Crop residues play an important role in maintaining soil productivity and quality by providing a source of organic matter for soil and nutrients for plants.
- In the Parkland region, however, large amounts of straw are produced by cereal crops, and too much residue left on the soil surface can be a management problem.
- Also, residues which are not conserved as organic matter in soil can be an economic loss to the producers as straw can be a valuable resource for on-farm (animal feed, e.g., pea straw) and off-farm (fuel and paper products, e.g., cereal straw) uses.
- Successful integration of crop residue management strategies into sustainable cropping systems requires an understanding of how crop residues influence cycling of nutrients from soil and fertilizers, and soil chemical, physical and biological properties.
- Information is needed to evaluate the availability of nutrients from crop residues to plants and their effects on fertilizer requirements for optimum crop production, and to determine if crop residues can be removed from cropping systems for alternative uses without detrimental impact on soil quality and productivity.

OBJECTIVE

- To determine the influence of tillage, crop residue and N rate on crop yield, soil aggregation, soil organic C and N, soil mineral N and nitrous oxide (N_20) emissions in the second 4-year rotation cycle on a Dark Gray soil near Star City, Saskatchewan, Canada.

MATERIALS AND METHODS

- Field experiment (four replications in a randomized complete block design) was established in 1998 on a Gray Luvisol soil (sandy clay loam texture, 5 % organic matter and 7.1 pH) with a 4-year barley-pea-wheat-canola rotation under two tillage systems (zero tillage, ZT and conventional tillage, CT), two levels of straw (straw retained, S and straw removed NS) and four levels of N fertilizer (0, 40, 80 and 120 kg N ha^{-1}, except no N to pea).
- In the autumn of every year, straw was removed from the NS plots. The plots under CT were tilled once in autumn and once in spring. The ZT plots were sprayed with glyphosate herbicide for weed control.
- Nitrogen fertilizer (urea) was side-banded 2.5 cm away and about 5 cm below the seedrow at sowing time, as per treatments. Blanket annual applications of P (30 kg P ha^{-1}), K (42 kg K ha^{-1}) and S (17 kg S ha^{-1}) fertilizers were applied to all plots in spring prior to and/or at sowing.
- The test crops were barley (*Hordeum vulgare* cv. AC Lacombe) in 2002, peas (*Pisum sativum* cv. Alfetta) in 2003, wheat (*Triticum aestivum* cv. AC Barrie) in 2004 and canola (*Brassica napus* cv. 45A71) in 2005.
- Seed yield was measured every year at maturity. Soil samples for dry sieved aggregates (0-5 cm), organic C and N (0-5, 5-10 and 10-15 cm), and nitrate-N and ammonium-N (0-15, 15-30 and 30-60 cm) were taken in the autumn of 2005 at the end of second 4-year rotation cycle. Nitrous oxide gas samples were taken from early spring to late autumn of every year in 2002, 2003, 2004 and 2005.

RESULTS

Crop Yield:

- ZT produced significantly greater seed (by 344 kg ha^{-1}), straw (by 261 kg ha^{-1}) and chaff yield (by 53 kg ha^{-1}), and root mass (by 45 kg ha^{-1}) than CT for barley in 2002. Retention of straw increased seed, straw and chaff yield and root mass for barley in 2002, pea in 2003 and wheat in 2004. For barley in 2002, straw retention increased seed yield by 400 kg ha^{-1}, straw yield by 449 kg ha^{-1}, chaff yield by 49 kg ha^{-1}) and root mass by 80 kg ha^{-1} compared to straw removal.

- The combination of ZT with straw retention gave the highest canola seed yield (1306 kg ha^{-1}) and CT with straw removal gave the lowest seed yield (562 kg ha^{-1}).
- Application of N significantly increased seed yield of bar**ley in 2002, wheat in** 2004 and canola in 2005.

Nitrous Oxide Emissions:

- The N_20 emissions were significantly higher in treatments receiving N fertilizer than the zero-N treatments in all 4 years.
- In N-fertilized plots, emissions were significantly higher in CT than ZT in 2004, but tended to be higher in ZT than CT in 2005.

Soil Aggregation:

- The proportion of dry sieved aggregates in the fine fraction (<0.42 mm diameter) was significantly greater in NS than S treatment. There was a higher proportion of large aggregates (>12.7 mm) in S than NS treatment.
- There was no improvement in aggregation with elimination of tillage.
- The combination of ZT with straw retention gave lowest proportion of fine aggregates (<0.42 mm) and greatest proportion of large aggregates (>38 mm). This suggests lowest potential for soil erosion when tillage is eliminated and residues are returned to the soil.

Soil Organic C and N:

- Straw management had no significant effect on TOC and TN in 0-15 cm soil, but mass of LFOM (by 3.42 Mg OM ha^{-1}), LFOC (by 1.275 Mg C ha^{-1}) and LFN (by 0.031 Mg N ha^{-1}) was greater when straw was returned than when straw was removed.
- Tillage also had no significant effect on TOC and TN, but LFOM, LFOC and LFN mass was greater or tended to be greater under ZT than CT.
- Rate of N fertilizer had no significant effect on TOC and TN, but mass of LFOM, LFOC and LFN was significantly greater 80 kg N ha^{-1} rate compared to zero-N control.

Soil Mineral N:

- Concentration of nitrate-N in soil increased significantly (but increases were small) with increasing N rate.
- There was no effect of tillage, but S tended to have greater nitrate-N than NS.

- For ammonium-N concentration in soil, there was no effect of tillage, straw management or N rate.

CONCLUSION

- The findings suggest that returning crop residue under ZT would improve some soil properties and may also be better for the environment and the sustainability of high crop production.

ACKNOWLEDGEMENTS

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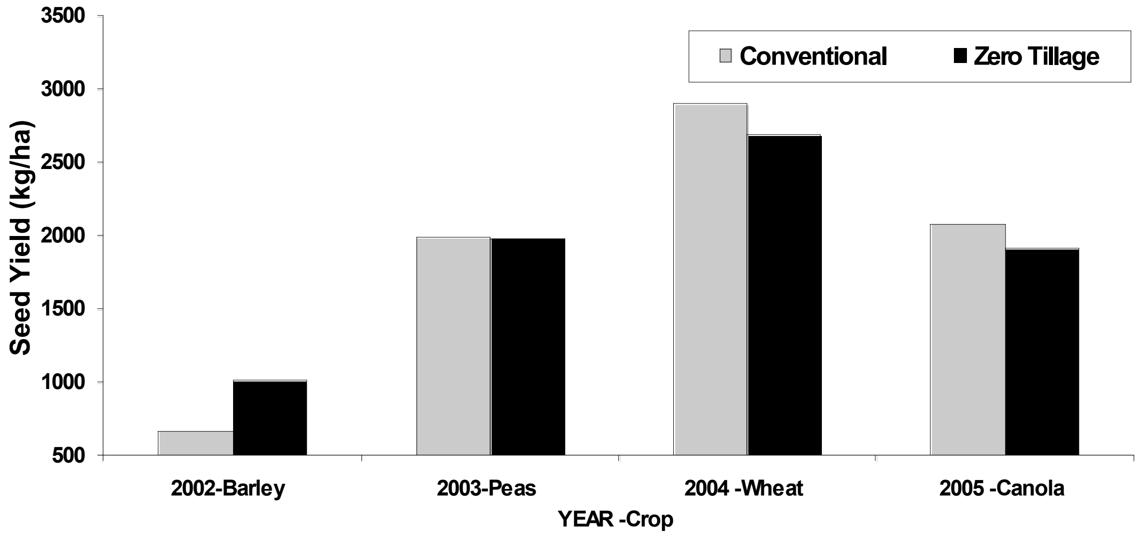

Figure 1. Effect of tillage on seed yield in 2002, 2003, 2004 and 2005 (averaged across four N rates and two levels of straw).

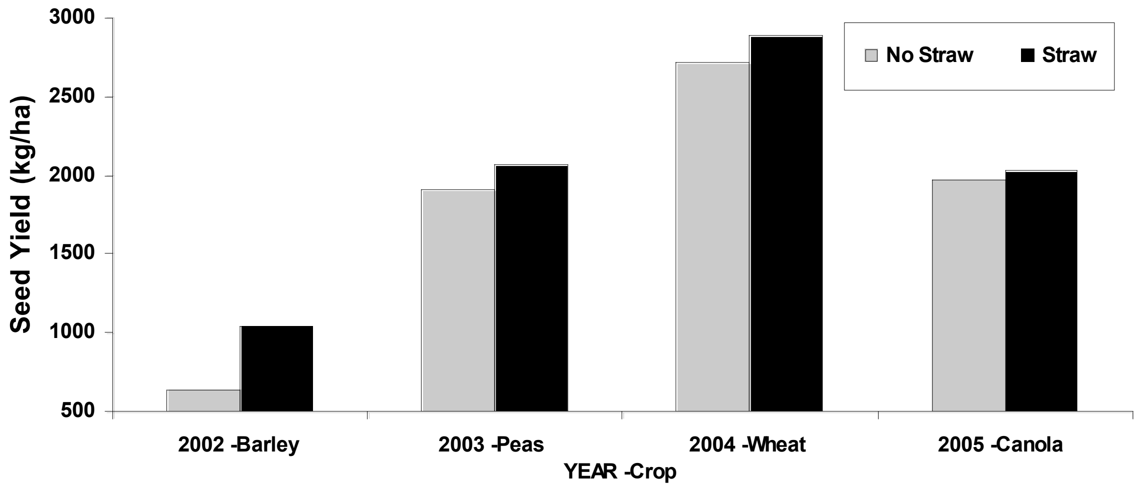

Figure 2. Effect of straw management on seed yield in 2002, 2003, 2004 and 2005 (averaged across four N rates and two tillage systems).

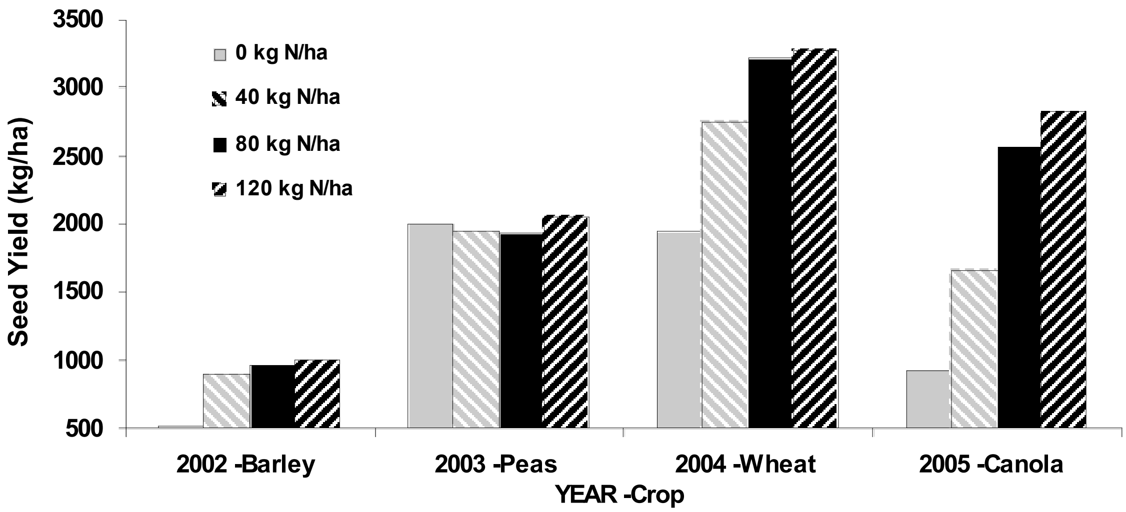

Figure 3. Effect of N rate on seed yield in 2002, 2003, 2004 and 2005 (averaged across two tillage systems and two levels of straw).

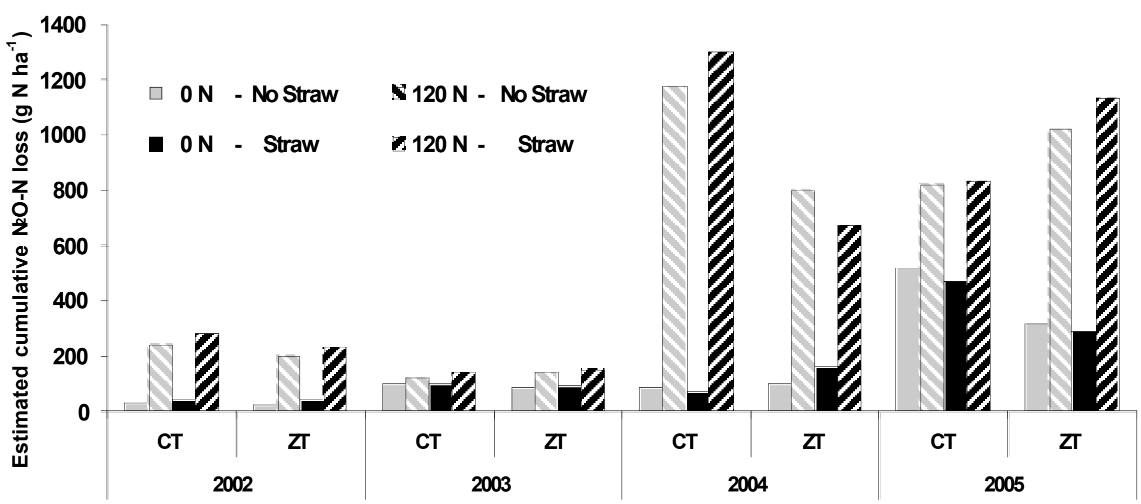

Figure 4. Estimated cumulative N_2O-N loss for various treatments during the period from early spring to late autumn in 2002, 2003, 2004 and 2005 .

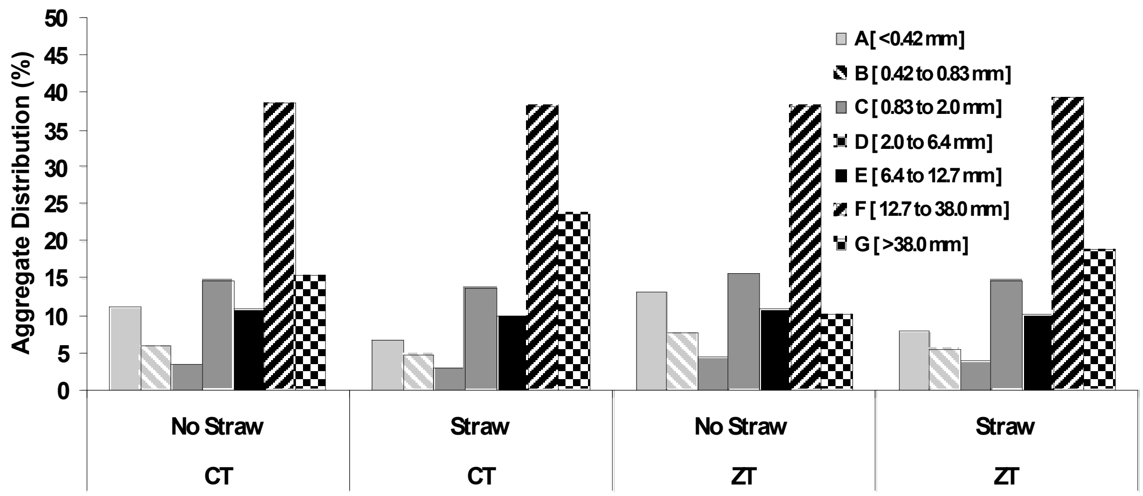

Figure 5. Effect of combination of conventional tillage [CT] and zero tillage [ZT] with straw removed and straw retained on soil aggregate distribution as a percentage of the total fractions in autumn 2005.

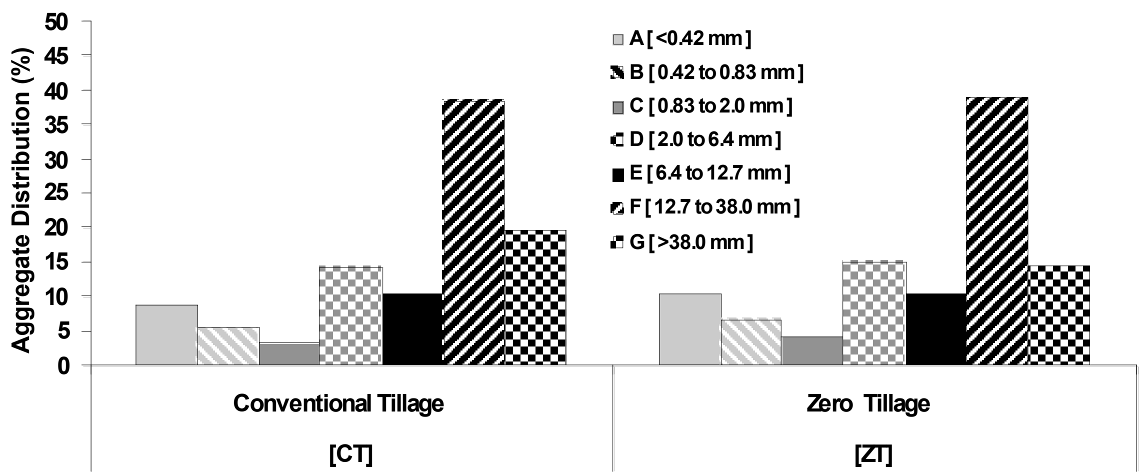

Figure 6. Effects of conventional tillage [CT] compared to zero tillage [ZT] on soil aggregate distribution as a percent of the total fractions in autumn 2005.

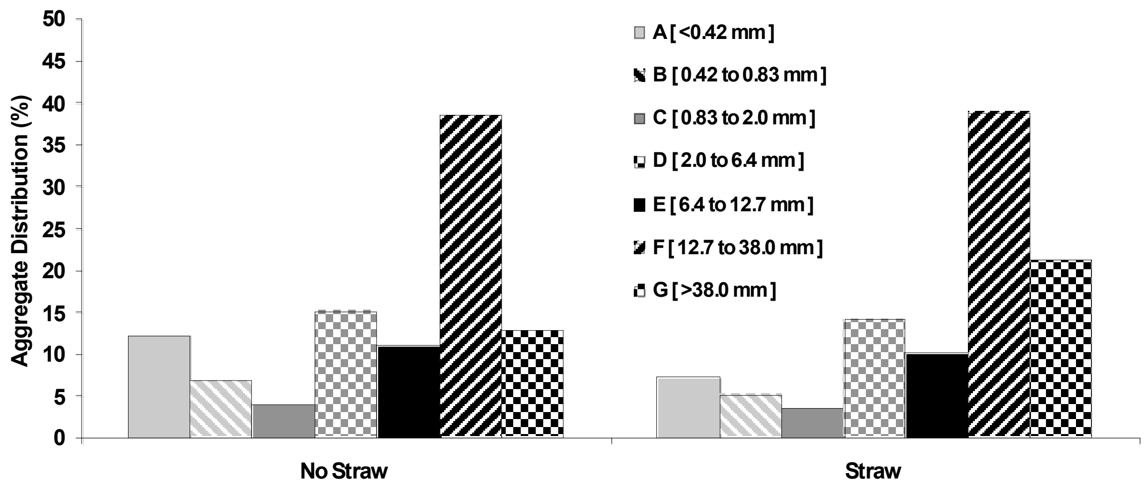

Figure 7. Effects of straw removed compared to straw retained on soil aggregate distribution as a percent of the total fractions in autumn 2005.

Table 1. Effect of tillage, straw management and N rate on total organic C (TOC) and N (TN), light fraction organic matter (LFOM), C (LFOC) and N (LFN), and NO3-N in 0-15 cm soil after second 4-year crop rotation cycle in autumn 2005.

	Tillage		Straw	
	CT	NT	NS	S
Mass of TOC (Mg C ha^{-1})	61.87	61.70	62.98	60.59
Mass of TN (Mg N ha^{-1})	5.21	5.32	5.38	5.14
Mass of LFOM (Mg OM ha^{-1})	28.29	30.86	27.87	31.29
Mass of LFOC (Mg C ha^{-1})	5.706	6.269	5.350	6.625
Mass of LFN (Mg N ha^{-1})	0.312	0.356	0.319	0.350
Concentration of NO_3-N (mg N kg^{-1})	4.8	4.6	4.2	5.2
	N Rate (kg N ha^{-1})			
	0	40	80	120
Concentration of NO_3-N (mg N kg^{-1})	3.3	3.8	4.7	5.8