Influence of Tillage and Crop Residue Management on Seed Yield, Soil Quality and Greenhouse Gas Emissions

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Introduction

Sustainability of agriculture production has been linked to soil quality, which is in turn a function of organic matter. Crop residues provide a source of organic matter for soil and nutrients for plants. Zero tillage (no-till) with standing stubble conserves soil, organic matter and water and reduces costs of fuel and equipment (Zentner and Lindwall 1978; Philips et al. 1980). The fertilizer N equivalent credit varies with the crop. In Denmark, Thomsen and Christensen (1996) suggested a fertilizer N equivalent of 8-10 kg ha^{-1} for oilseed rape. Beckie et al. (1997) estimated a credit of 28 kg N ha^{-1} to crops that follow peas. Cereal straws, because of their wide C:N ratios, return little N to the soil.

In the Parkland region, large amounts of straw are produced by cereal crops, and too much residue left on the soil surface can be a management problem. Crop 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. Stumborg et al. (1996) estimated the value of straw to be about \$16 ha^{-1}. There may be opportunities for removing straw for alternatives uses while also maintaining optimum organic matter in soil in the Parkland zone, where large amounts of crop residues are left on soil after crop harvest and under certain situations too much crop residues may be a management problem. Before recommending straw removal, however, it is essential that the impact of straw export on crop yield sustainability and soil conservation must be assessed. Management tools such as no-tillage (Saffigna et al. 1989), choices of crops in a rotation and rotation length (Havlin et al. 1990; Soon and Arshad 1996), and adequate fertilization (Nyborg et al. 1995) can be used to enhance level of organic matter in soil. This has been shown for the Black soil zone (Nuttall et al. 1986; Campbell et al. 1991), but information is lacking for the Gray soil zone, especially in a crop rotation system.

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 seed yield, soil aggregation, and nitrous oxide (N_20) emissions in a barley-pea-wheat-canola rotation on a Gray Luvisol 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, 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, and straw removed) 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 from seedrows at a depth of 6 cm at sowing time. 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 1998, peas (*Pisum sativum* cv. Alfetta) in 1999, (Triticum aestivum cv. AC Barrie) in 2000 and canola (Brassica napus cv. 45A71) in 2001.

Seed yield was measured every year at maturity. Soil samples (0-5 cm) for dry sieved aggregates were taken at the end of 4-year rotation cycle. Nitrous oxide gas samples were taken occasionally in 2000 and 2001.

Results

Seed Yield (Figures 1, 2 and 3)

Tillage and straw treatments had no effect on seed yield in 1998, 1999 and 2000. In 2001, ZT had 389 kg ha^{-1} more seed yield of canola than CT. Retention of straw increased seed yield by 258 kg ha^{-1} compared to the straw removal. The combination of ZT with straw retention usually gave higher canola yield than the other three combinations of tillage and straw, which had similar performance.

Application of N significantly increased seed yield of crops in 1998, 2000 and 2001. In 2001, canola emergence consistently decreased with increasing rate of N due to an error in placement of the N fertilizer (urea) closer to seed and dry soil moisture conditions at sowing time which reduced yield response to rate of applied N.

Nitrous Oxide Emissions (Figure 4)

The N_20 emissions were higher in treatments receiving N fertilizer than the zero-N treatments. The emissions were substantially higher in CT plots than ZT where fertilizer N was applied.

Soil Aggregation (Figures 5, 6 and 7)

The proportion of dry sieved aggregates in the fraction with the lowest sieve opening (<0.42 mm diameter) was significantly greater in CT compared to ZT. There was a higher proportion of large aggregates (>12.7 mm) under ZT compared to CT. Addition of straw tended to increase the proportion of large aggregates and decrease the proportion of fine aggregates.

The combination of ZT with straw retention gave the lowest proportion of fine aggregates (<0.42 mm) and greatest proportion of large aggregates (>38 mm). This suggests lowest potential for soil erosion where tillage is eliminated and crop residues are returned to the soil.

Conclusion

The findings suggest that returning crop residue under ZT would improve soil quality and productivity, and may also be better for the environment.

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Figure 1. Effect of tillage on seed yield in 1998, 1999, 2000 and 2001 (averaged across four N rates and two levels of straw).

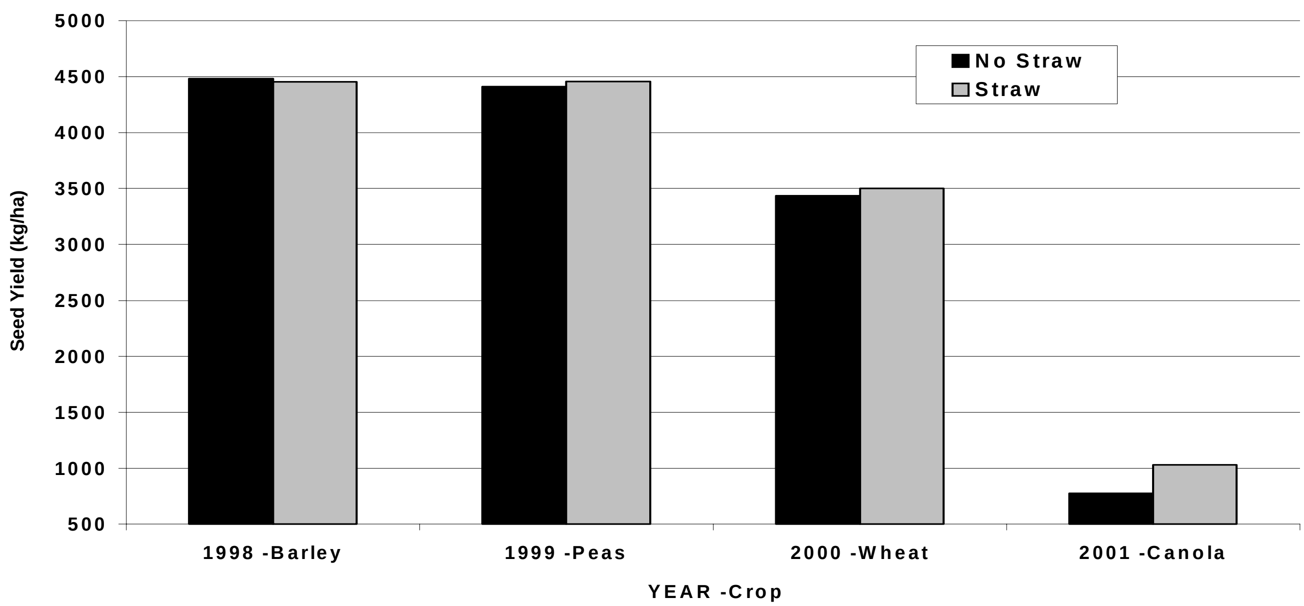

Figure 2. Effect of straw management on seed yield in 1998, 1999, 2000 and 2001 (averaged across four N rates and two tillage systems).

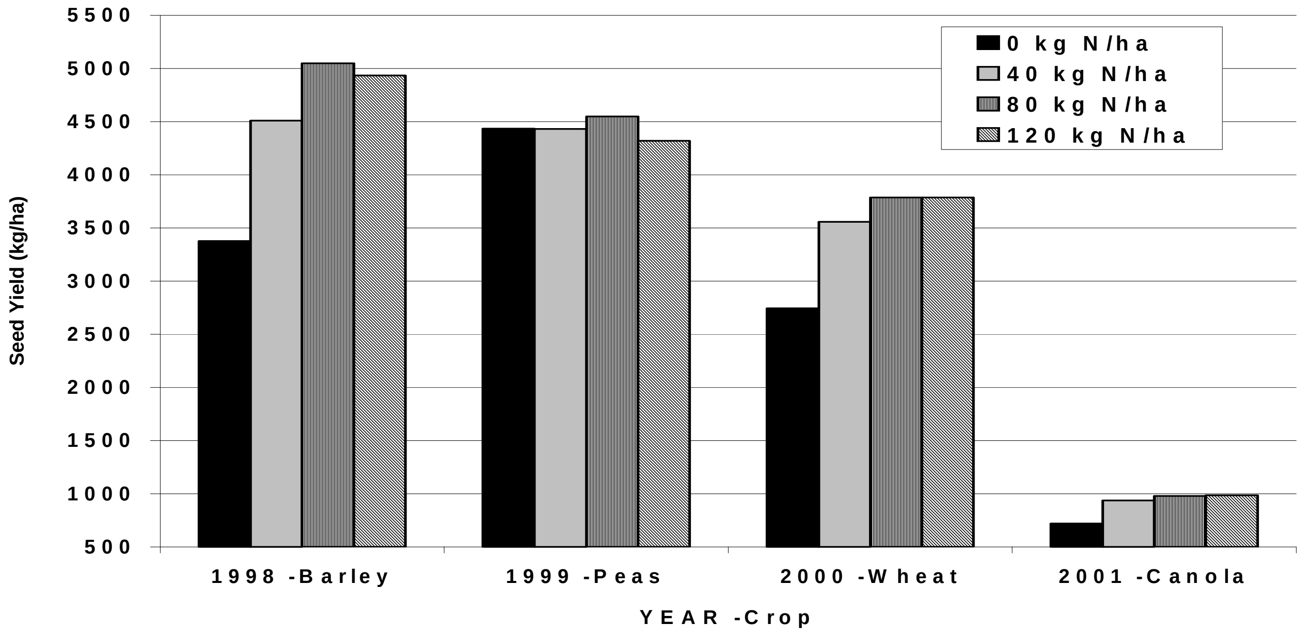

Figure 3. Effect of N rate on seed yield in 1998, 1999, 2000 and 2001 (averaged across two tillage systems and two levels of straw).

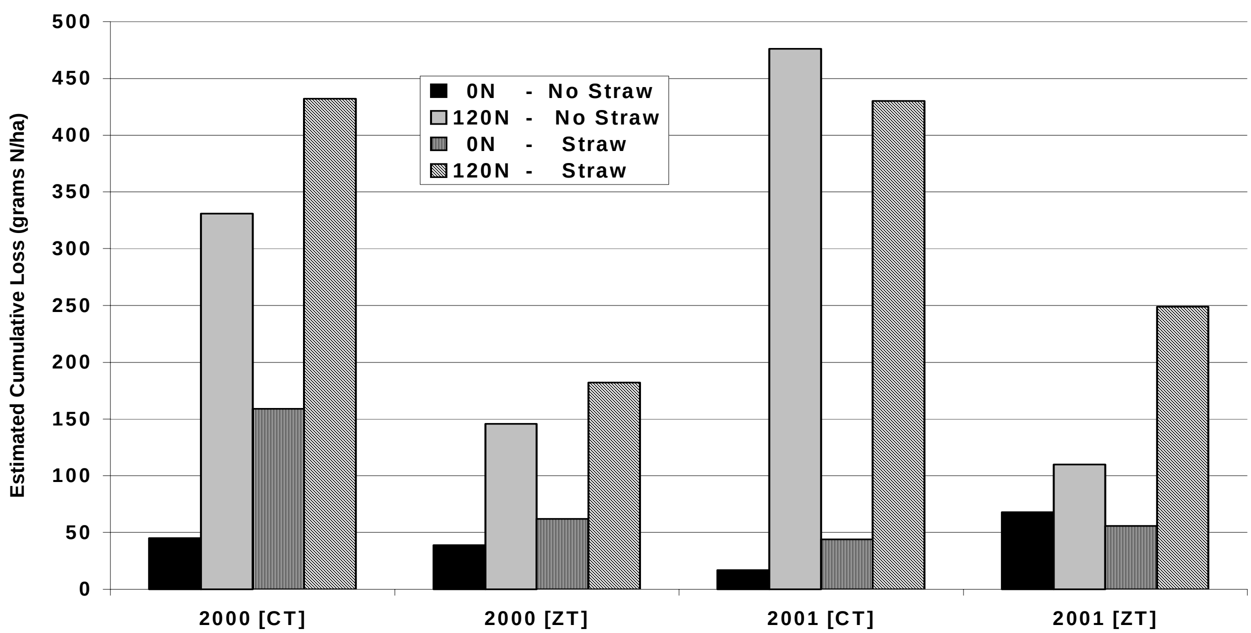

Figure 4. Estimated cumulative N_2O-N loss for various treatments at Star City during the period March 28 to June 5 2000 and April 23 to August 9 2001.

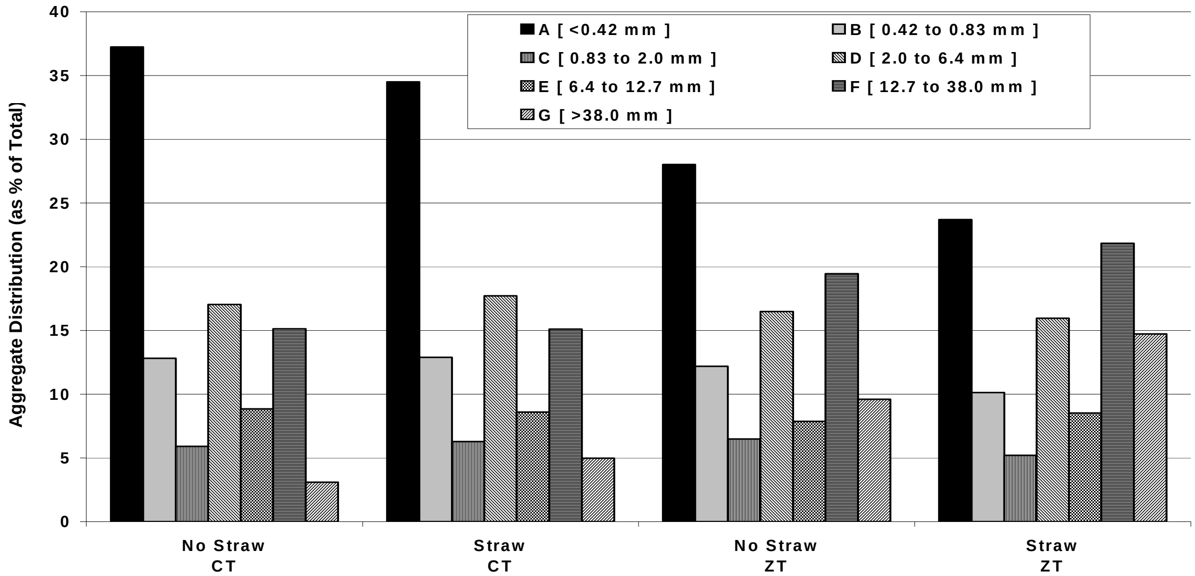

Figure 5. Effect of combination of conventional tillage [CT] and zero tillage [ZT] with straw removed and straw retained on soil aggregate distribution as a percentage of the total fractions in spring 2002.

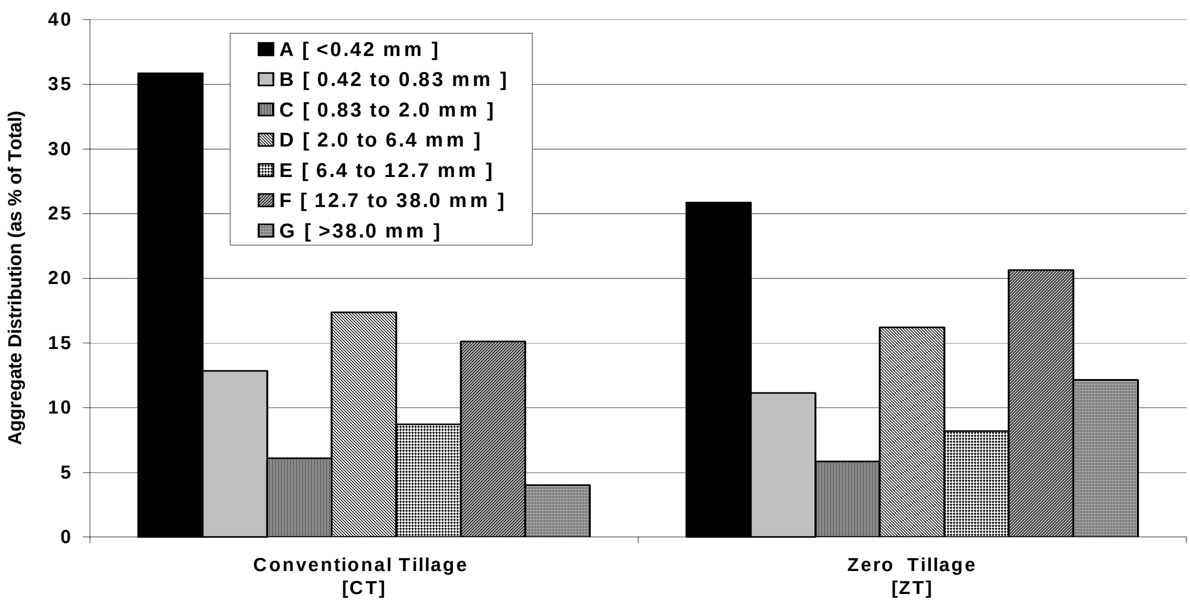

Figure 6. Effects of conventional tillage [CT] compared to zero tillage [ZT] on soil aggregate distribution as a percent of the total fractions in spring 2002.

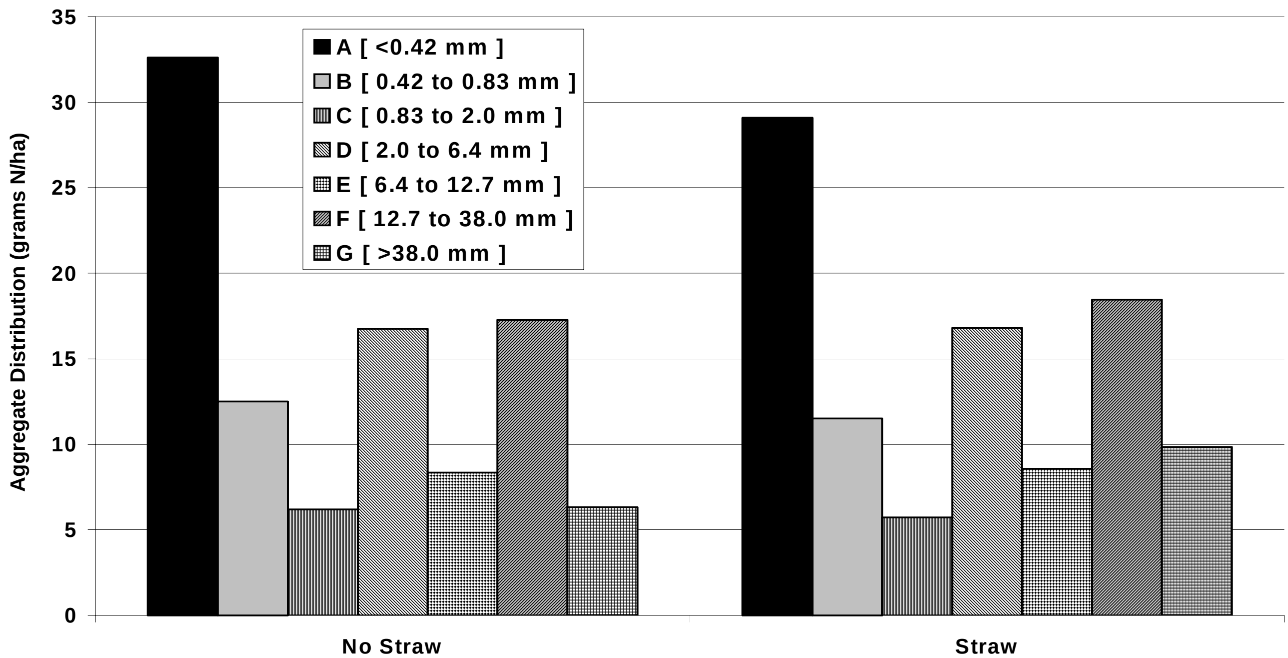

Figure 7. Effects of straw removed compared to straw retained on soil aggregate distribution as a percent of the total fractions in spring 2002.

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