Effect of Short-Term Disturbance on Soil Properties after Long-Term Zero Tillage

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Impact
High intensity disturbance following long-term zero-tillage affected aggregate-size distribution but few other soil physical and fertility properties in the short term.

Objective
The objective of this research was to measure soil physical properties, soil carbon and quality, soil moisture and temperature under low and high disturbance tillage following 9 years of zero tillage.

This research was conducted as part of a study designed to determine the impact of tillage in a long term zero tillage system on crop yields, weed numbers, foliar disease nutrient uptake and soil properties.

Methods
This research was conducted from 1999 to 2002 at a site located approximately 25 km north of Brandon, Manitoba, Canada. The site was previously in zero tillage for 9 years, and was cropped to grains and oilseeds. Soils at the study site, are moderately to strongly calcareous and clay loam in texture (Newdale association).

The trial was a 4 replicate randomized complete block with 2 rotations canola, wheat, flax and canola, wheat pea. While all phases of the crop rotation were present in each growing season it was not until 2002 that tillage occurred in the current season, 1 year previous to the current season or 2 years prior to the current season. Plots were 4 m wide and 15 m long and crops were planted and managed using “normal” seeding and fertility rates and herbicides applied according to farm recommendations.

The tillage systems were:
- Continuous low disturbance seeding (LD),
- Strategic tillage where a heavy duty cultivator was used to eliminate weeds just prior to planting in one year of a 3 year cropping system (HDx),
- Continuous low disturbance seeding but with heavy harrowing in the fall prior to planting (HH).

In treatments (LD, HH, HD2), volumetric soil moisture was measured 0 to 15 cm depth with time domain reflectrometry (TDR) sensors (E.S.I. Environmental Sensors Inc., Victoria, British Columbia) logged at 1 hour intervals for the period from after seeding (June 1, 2001) to prior to harvest (August 17, 2001). Soil temperature was measured at a 2.5 cm depth with thermistors (Onset Computer Corporation, Bourne, Massachusetts) logged at 1 hour intervals for the period from after seeding to prior to harvest.

In September 2002, soil was sampled in canola, pea and flax residue following wheat phases of the rotations for the low (LD) and high (HD2, HD3) disturbance tillage treatments. Bulk density was measured (0-10 cm, 10-20 cm, 20-30 cm) using the core method with 3 samples per plot. Soil samples weighing approximately 2.5 kg were sampled (0-5 cm) in at 3 locations in each plot and dry sieved with a rotary sieve (>68.8 mm, 68.8 to 38 mm, 38 to 12.7 mm, 12.7 to 7.2 mm, 7.2 to 2.0 mm, 2.0 to 1.3 mm, 1.3 to 0.5 mm, < 0.5 mm). The 1.2-2.0 mm fraction was tested for stability by slaking sieving aggregates samples with a wet sieving apparatus (Kemper et al., 1986), Nimmo et al., 2002). Crop residue cover (%) was measured in a 144 point grid in a 1 m^2 area from digital images of each plot. Penetration resistance (k Pa, 0 – 50 cm, 5 cm increments) was measured at 5 locations in each plot with a compaction meter (Spectrum Technologies, Inc, Plainfield, Illinois).

Selected treatments were sampled for organic carbon and nitrogen content of soil (0-10, 10-20 cm, 20-30 cm depths), soil aggregates (1.3-2.0 mm diameter in 0-5 cm depth) in three locations per plot, and flax residues. Organic carbon and total nitrogen were measured with a Carlo Erba 2500 elemental analyser (Thermo Electron Corporation, Milan, Italy).

Three soil samples were collected in each plot for 0-10, 10-20 cm, and 20-30 cm depths, after harvest during September, 2002 in canola, flax and pea crops seeded in wheat stubble for low and high disturbance treatments. Soil nitrate nitrogen (2 M KCl extract), phosphate phosphorus (0.5 M $NaHCO_3$ extract) and sulphate sulphur (.001M $CaCl_2$ extract) were determined by colorimetric methods using a Technicon auto-analyzer with procedures described by McKeague (1981). Selected treatments were sampled (0-10, 10-20 cm, 20-30 cm depths) in September 2002 for mineralizable nitrogen measured using the amino sugar test Khan et al., (2001). Laboratory analyses of the amino sugar test were conducted by Agvise Labs (Northwood, North Dakota).

Statistical analysis was conducted in JMP software version 5.01a (SAS Institute Inc. 2002). Analysis of variance, based on a factorial design with 4 replicates, was used to analyze the effects of tillage (high and low disturbance) and crops (flax peas and canola on wheat stubble). Means were compared with orthogonal contrasts and Tukey's honestly significant difference for effects with a probability less the 5%. Plot averages of bulk density, aggregate size fractions, wet stable aggregates and penetration resistance were transformed (log base 10) to normalize the distribution of the data.

Results and Discussion

No significant difference of high and low disturbance seeding on soil temperature or moisture from June 1 to July 8, 2001. These results contrast with those of Gauer et al., (1982), and Malhi et al., (1990) who reported lower soil temperature and higher soil moisture under zero tillage compared to conventional tillage. This difference is attributed to short term of the period during which the tillage systems were established in this study. Arshad et al. (1995) reported soil moisture was lower in conventional tillage during dry periods. Gravimetric soil moisture measured in fall 2002 (Figure 1) was higher in low compared to high disturbance ($p = 0.0088$).

Low, relative to high, intensity tillage following zero tillage in the short term had no effect on bulk density, penetration resistance, and wet stable aggregates. Arshad et al., (1999) found an increase in water stable aggregates and soil organic carbon after long term zero and conventional tillage. Significant differences in soil test nitrate-N and sulphate-S between crops are attributed to residual fertilizer applied to canola in the growing season. Mineralizable nitrogen was not affected by tillage management or crop. Total organic carbon and nitrogen were also not affected, which is attributed to the short period when high disturbance tillage was imposed. The difference in experimental results between this study and those reported in the literature are attributed to the short-term nature of this experiment.

The proportion of large soil aggregates (38 – 68.8 mm diameter) increased significantly ($p = 0.0041$) with decreased tillage intensity (Figure 2) while the proportion of small aggregates (diameter < 0.5 mm) decreased. Large proportions of small aggregates reflect poor soil structure and will increase potential for wind erosion in the absence of significant crop residue.

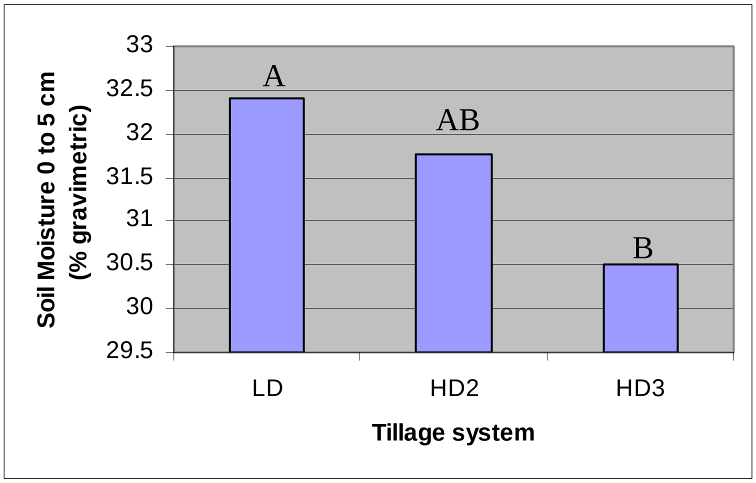

Figure 1. Soil moisture 0 to 5 cm fall 2002.
LD – Low disturbance direct seeding
HD2 – High disturbance in year 2 of rotation
HD3 – High disturbance in year 3 of rotation
A, AB, B denote significant differences between means with the Tukey honestly significant difference at p=0.05

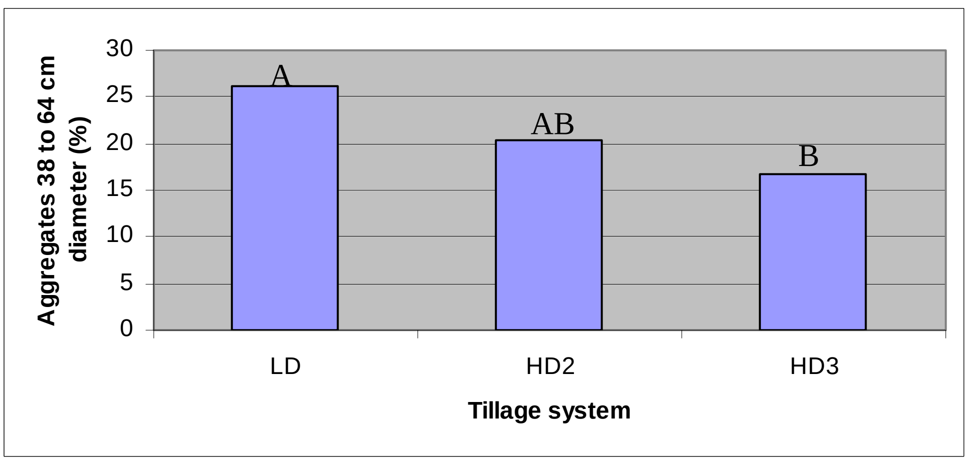

Figure 2. Proportion of dry sieved aggregates (38-68.8 mm) in tillage systems.
LD – Low disturbance direct seeding
HD2 – High disturbance in year 2 of rotation
HD3 – High disturbance in year 3 of rotation
A, AB, B denote significant differences between means with the Tukey honestly significant difference at p=0.05

Stability of wet-sieved aggregates increased with organic carbon content as observed by Angers et al. (1993). However in this study tillage and crop management had no significant effect on organic carbon content or stability of wet-sieved aggregates.

Conclusions

The effect of high and low intensity tillage, after a long period in zero tillage, on soil organic carbon, physical properties and fertility is not significant over one or two years with the exception of aggregate size distribution. It is expected that in the long term high intensity tillage following a long period of zero tillage will significantly affect soil organic matter, soil physical properties and fertility. However, the duration and temporal impact of this process requires further research.

Acknowledgements

The authors wish to acknowledge the technical support of Grant Gillis and Greg Logan.

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