Effect of Rotation and Short-Term Tillage on Soil Quality after Long-Term Zero Tillage

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Abstract

A field study was established in 2000, near Brandon Manitoba, to determine the effect of tillage and crop on soil physical and biological properties. Most soil physical and biological properties were not affected by tillage system or current year crop when sampled in the fall after harvest. The proportion of large (38 to 68.8 mm diameter) dry sieved aggregates increased under low compared to high intensities of tillage. Aggregate stability increased with increasing concentration of organic carbon. The effect of high and low intensity tillage over one or two years, after 9 years in zero tillage, on soil organic carbon, physical properties and fertility was not significant.

Introduction

Although the effects of no tillage and direct seeding on bulk density, aggregate size distribution, and soil organic carbon have been reported (Layton et al 1993, Liang et al 2003), there is little published information on the effect of cultivation and crop following long-term zero tillage. The objective of this research was to measure soil physical properties and soil quality due to short-term tillage and crop following 9 years of zero tillage.

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 continuously 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 randomized complete block design with 4 replicates and 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 seeding in one year of a 3 year cropping system (Hdx). Two treatments were established. Two tillage operations were applied with a heavy duty cultivator in the second year of the study, spring 2001 (HD2). Two tillage operations were applied with a heavy duty cultivator in the third year of the study, spring of 2002 (HD3).

Continuous low disturbance seeding but with heavy harrowing in the fall prior to planting (HH).

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 1.3-2.0 mm fraction was tested for stability by slaking aggregate samples with a wet sieving apparatus (Kemper et al., 1986), Nimmo et al., 2002). 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), mineralizable nitrogen, soil aggregates (1.3-2.0 mm diameter in 0-5 cm depth) in three locations per plot. Organic carbon and total nitrogen were measured in soil and aggregates with a Carlo Erba 2500 elemental analyser (Thermo Electron Corporation, Milan, Italy). Mineralizable nitrogen was measured using the amino sugar test

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 analyse 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 than 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

Soil Physical Properties

The proportion of large soil aggregates (38 to 68.8 mm diameter) decreased significantly (P = 0.0041) as tillage intensity increased from LD to HD3 (Figure 1), while the proportion of small aggregates (diameter < 0.5 mm) increased (Figure 2). Large proportions of small aggregates reflect poor soil structure and will increase potential for wind erosion in the absence of significant crop residue.

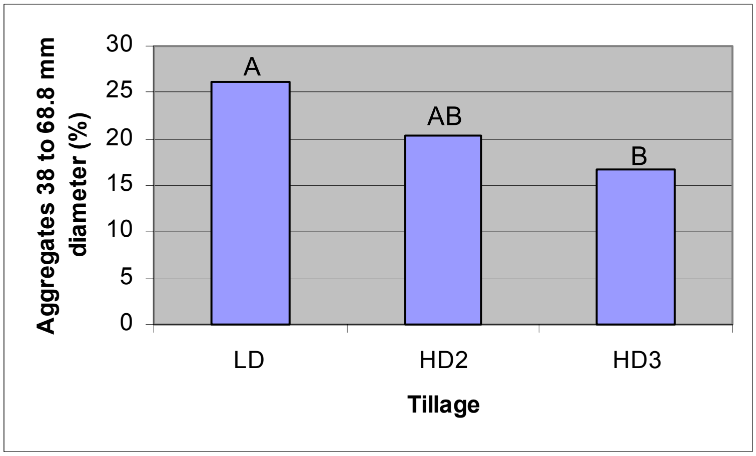

Fig. 1 Proportion of large soil aggregates (38 to 68.8 mm) as affected by tillage intensity. A and B represent Tukey's honestly significant differences between tillage treatments (P = 0.05).

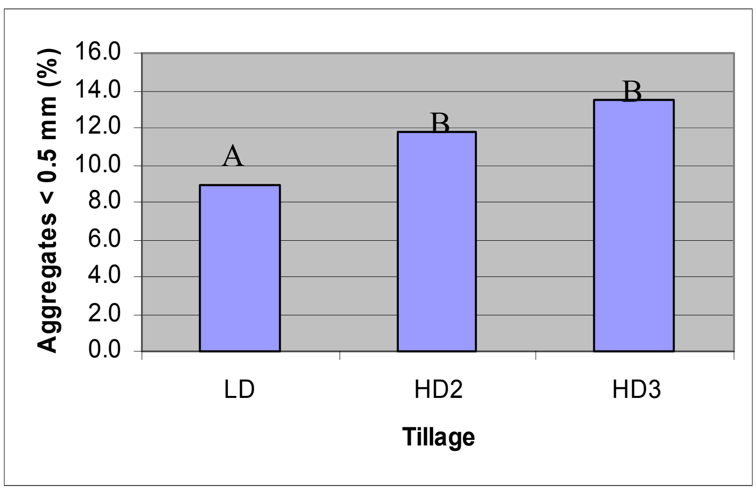

Fig. 2 Proportion of small soil aggregates (< 0.5 mm) as affected by tillage intensity. A and B represent Tukey's honestly significant differences between tillage treatments (P = 0.05).

Low, relative to high, intensity tillage had no effect on wet stable aggregates. In contrast, Arshad et al., (1999) found an increase in water stable aggregates and soil organic carbon after long term zero and conventional tillage. Stability of wet-sieved aggregates increased ($P = 0.001$, $r^2 = 0.40$) with organic carbon content (Figure 3) as observed by Angers et al. (1993). No significant difference was observed in organic carbon and nitrogen of soil aggregates due to tillage or crop.

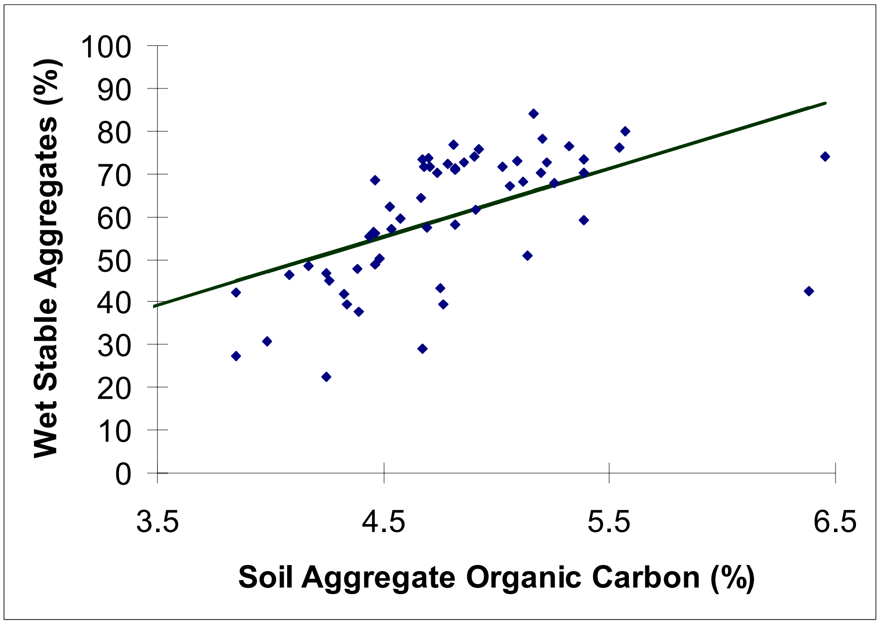

Fig. 3. Relationship of wet stable aggregates to soil aggregate organic carbon.

Penetration resistance (kPa) was similar in high and low intensity tillage at 0-5 cm and 5-10 cm). No significant differences were observed between types of crop stubble. Bulk density (0-5 cm) was not affected by tillage or crop.

Soil Organic Carbon and Fertility

Tillage and preceding crop had no significant effect on soil organic carbon (%) and total nitrogen (%). Tillage intensity (high and low levels) and preceding crops (peas or canola) had no significant effect on phosphate phosphorus (0-10 cm). However nitrate nitrogen (0-10 cm) was higher in high disturbance tillage and following canola. High levels of nitrate nitrogen and ammonium are attributed to residual nitrogen fertilizer.

Tillage intensity (high and low levels) and preceding crop (peas, flax or canola) had no significant effect on mineralizable nitrogen measured with the amino sugar test. All levels of mineralizable nitrogen in the soil were above 300 mg kg^{-1}, deemed sufficient for plant growth without additional nitrogen fertilizer.

Conclusions

The effect of high and low intensity tillage, after 9 years in zero tillage, on soil organic carbon, physical properties and fertility is not significant over one or two years. 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.

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