Response of Soil Physical Properties to Tillage and Straw Management on Two Contrasting Soils in the Parkland Region of Western Canada

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Abstract

Field experiments were conducted to evaluate the effects of 5 years of tillage-straw practices on bulk density, penetration resistance, aggregation and infiltration rate of a Black Chernozemic soil at Innisfail (loam, 65 g kg^{-1} organic matter, Udic Boroll) and a Gray Luvisol soil at Rimbey (loam, 31 g kg^{-1} organic matter, Boralf) cropped to spring barley in a cool temperate climate in Alberta, Canada. The treatments comprised combinations of two tillage methods: no tillage (NT) and conventional tillage (T), and two straw levels: straw removed (-S), and straw retained on the surface (+S). Each year, the T plots were rototilled three times to about 10 cm depth. All the plots were seeded using 2 cm wide disc type openers on drill. Bulk density (Db) of the 0-7.5 and 7.5-15 cm depths was significantly greater in NT plots (between 1.13 and 1.58 Mg m^{-3}) than in T plots (between 0.99 and 1.41 Mg m^{-3}) in both soils, irrespective of straw management. In Black Chernozemic soil, NT treatment had significantly greater penetration resistance (PR) than T treatment up to 15 cm depth. Straw retention significantly reduced PR of the 0-10 cm soil in NT plots but such effect in T plots was small. In the 0-5 cm depth of Black Chernozemic soil, the >2 mm fraction of dry aggregates was highest in the NT+S treatment (72%), followed by NT-S (66%), T+S (56%) and T-S (50%). The wind-erodible fraction (aggregates <1 mm size) was smallest (18%) in NT+S and largest (39%) in T-S treatment. Such values for NT-S and T+S were 23 and 33%. Soil aggregation benefited more from a reduction in tillage than from straw retention. Proportion of wind-erodible aggregates was generally greater in Gray Luvisol soil than in Black Chernozemic soil. In Black Chernozemic soil, average steady-state infiltration rate (IR) was significantly smaller (33%) in NT plots than in T plots. Straw retention improved IR in both NT and T treatments. In Gray Luvisol soil, IR was not significantly affected by the treatments. In summary, elimination of tillage and straw retention generally improved aggregation and infiltration while bulk density and penetration resistance were within desirable range for plant growth.

Background

Soil bulk density and porosity greatly influence air-water relations and potential productivity of a soil. Similarly, soil strength or mechanical impedance has been reported to influence crop root growth and subsequent yield. These soil properties, among others, are normally altered by tillage (or lack thereof) and mode of crop residue disposal, but the magnitude of change can be quite variable among different soil and agro-environment conditions. In view of their soil and water conservation effects and economic benefits (less fuel, equipment and labor requirements), reduced tillage or no-tillage systems are becoming very popular in the Prairie Provinces of Canada. Information on the long-term effects of different tillage-straw systems on soil physical properties, however, is not adequate for this region. The objective of this study was to quantify the effects of four tillage-straw management systems on soil physical behavior of two contrasting soils under barley after 5 years of imposing treatments in a subhumid temperate environment in western Canada.

Materials and Methods

Tillage:

NT: no tillage (direct seeding)
T: conventional tillage (rototilled to 10 cm depth, once in autumn and twice in spring)

Straw management:

-S: straw-off (straw removed)
+S: straw-on (chopped straw retained)

Black Chernozemic soil:

Udic boroll at Innisfail, Alberta
65 g kg^{-1} organic matter, loam, pH 7.0
Average growing season precipitation: 247 mm

Gray Luvisol soil:

Boralf, at Rimbey, Alberta
31 g kg^{-1} organic matter, loam, pH 7.0
Average growing season precipitation: 220 mm

Crop:

Spring barley (May-August)

Results

Soil Bulk Density (Figure 1)

Bulk density (Db) of the 0-7.5 and 7.5-15 cm depths was significantly greater in NT plots (between 1.13 and 1.58 Mg m^{-3}) than in T plots (between 0.99 and 1.41 Mg m^{-3}) in both soils, irrespective of straw management.

Penetration Resistance (Figures 2 and 3)

In Black Chernozemic soil, NT had significantly greater penetration resistance (PR) than T up to 15 cm depth, irrespective of whether straw was off or on. Straw retention significantly reduced PR of 0-10 cm soil in NT but such effect in T was small.

In Gray Luvisol soil, treatment effects on PR were generally similar to those in Black Chernozemic soil up to about 13-15 cm depth.

Soil Aggregation (Figures 4, 5, 6 and 7)

In Black Chernozemic soil, the 0-5 cm depth of NT with straw treatment had maximum (72%) dry aggregates >2 mm size, followed by NT without straw (66%), T with straw (56%) and T without straw (50%).

Further the wind-erodible fraction of aggregates (<I mm size) was smallest (18%) in NT with straw and largest (39%) in T without straw treatment. Such values for NT without straw and T with straw were 23 and 33%, respectively.

Treatment effects on aggregation in Gray Luvisol soil were similar with generally greater proportion of aggregates in wind-erodible range than in Black Chernozemic soil. Beneficial effects of NT and straw retention were also reflected in mean weight diameter values.

Water Infiltration (Figures 8 and 9)

Average infiltration rate (1R) was 2.6 times greater in Black Chernozemic soil than in Gray Luvisol soil. In Black Chernozemic soil, IR was much higher in T, and straw improved IR in both NT and T. In Gray Luvisol soil, IR was not significantly affected by tillage-straw treatments.

Conclusions

No tillage increased bulk density and penetration resistance of soil. The changed values seemed to be within desirable limits for crop growth.

Aggregation was increased with no tillage, and was further increased with straw retention.

Straw retention increased infiltration rate of soil, but the infiltration rate decreased with no tillage.

In summary, soil physical conditions generally improved with elimination of tillage and straw retention.

Overall, Boroll (Black Chernozemic soil) was better than Boralf (Gray Luvisol soil) from a soil conservation perspective.

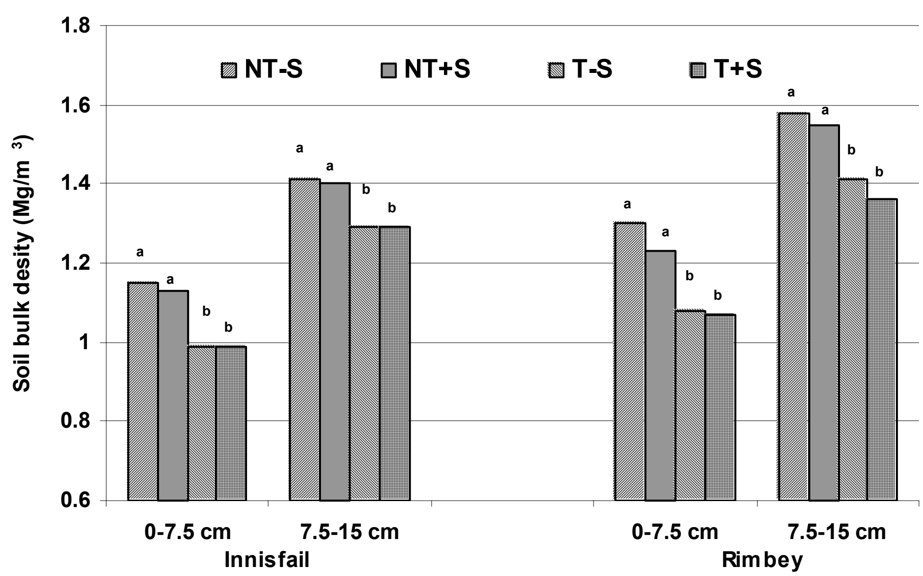

Figure 1. Effect of tillage and straw treatments on bulk density of soil at Innisfail (Black Chernozemic soil) and Rimbey (Gray Luvisol soil) in Alberta.

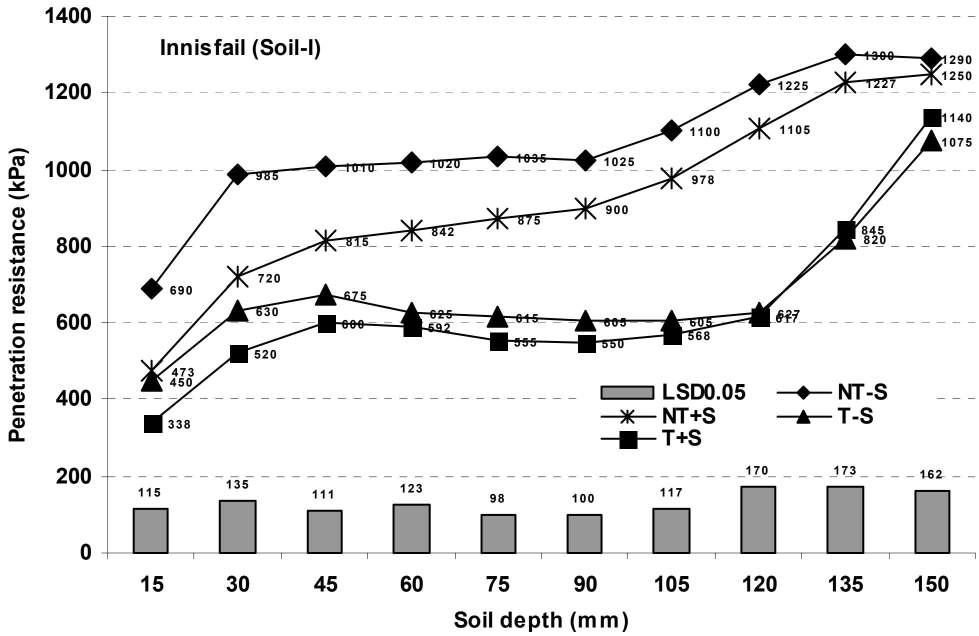

Figure 2. Effect of tillage and straw treatments on penetration resistance of Black Chernozemic soil at Innisfail, Alberta (bars on x-axis refer to $LSD_{0.05}$ values at soil depths).

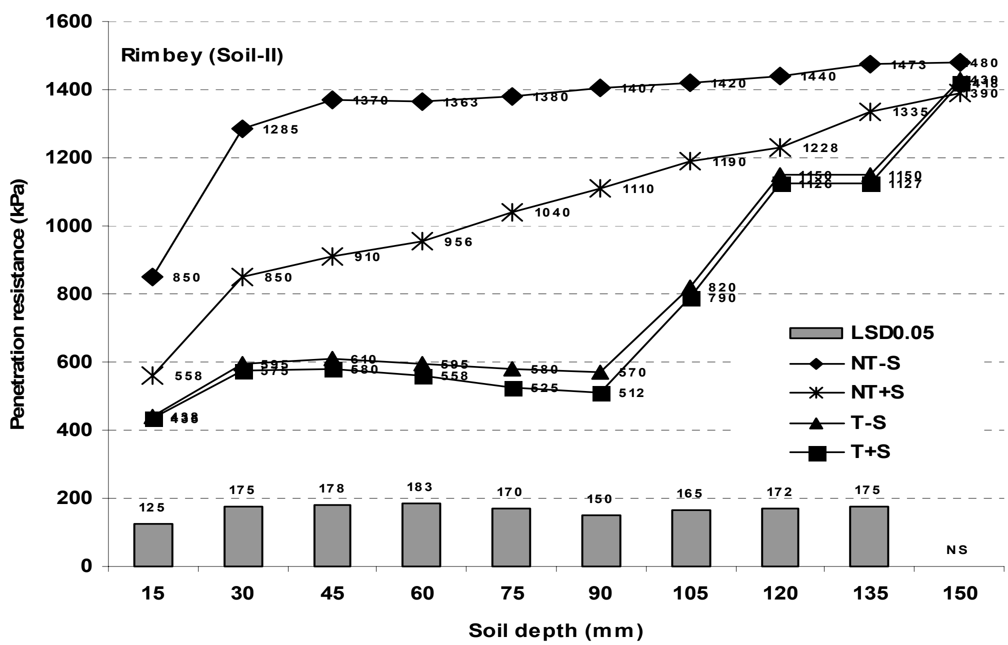

Figure 3. Effect of tillage and straw treatments on penetration resistance of Gray Luvisol soil at Rimbey, Alberta (bars on x-axis refer to $LSD_{0.05}$ values at soil depths).

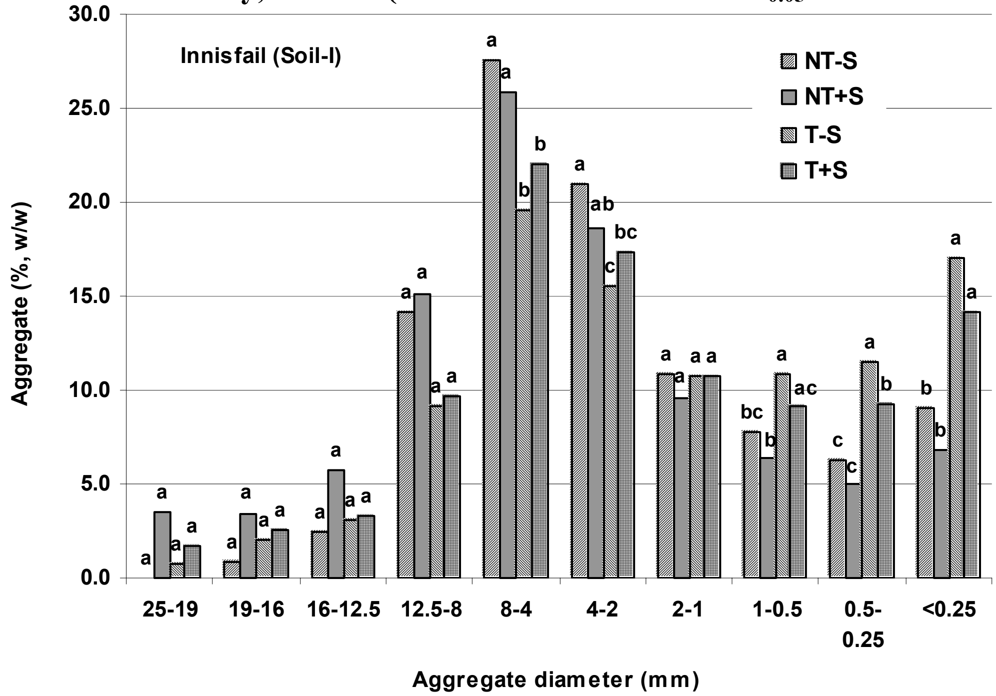

Figure 4. Size distribution of dry aggregates in Black Chernozemic soil at Innisfail, Alberta.

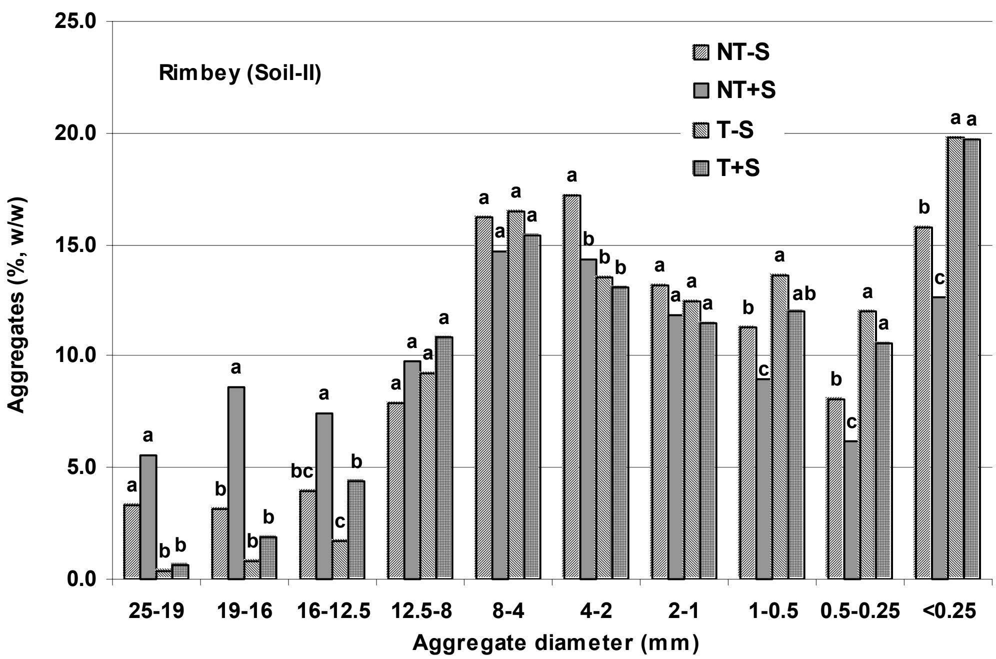

Figure 5. Size distribution of dry aggregates in Gray Luvisol soil at Rimbey, Alberta.

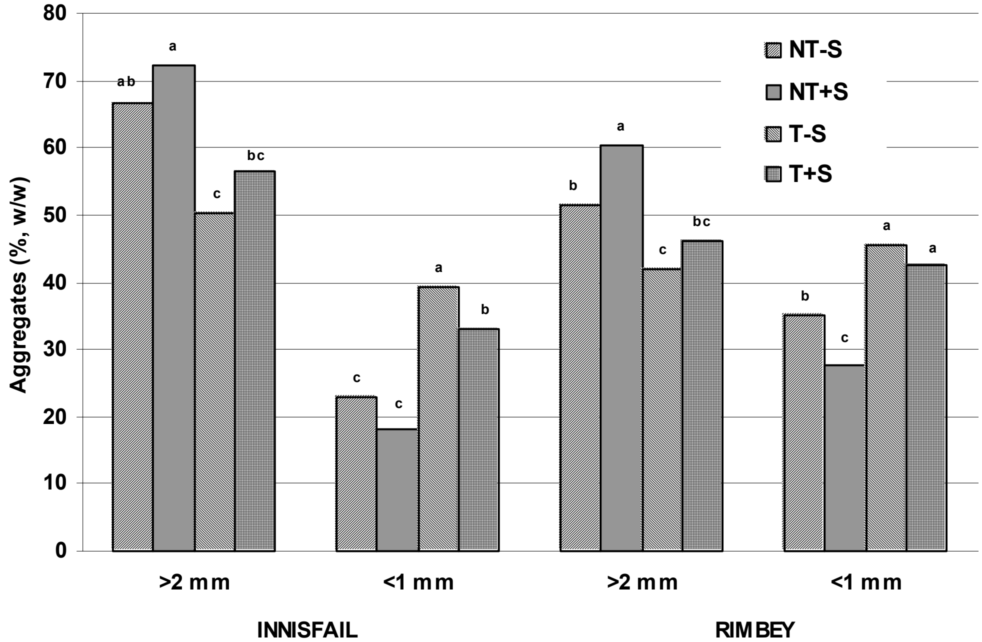

Figure 6. Distribution of wind-erodible aggregates (<1 mm) and aggregates not affected by the wind (>2 mm) in soil at Innisfail (Black Chernozemic soil) and Rimbey (Gray Luvisol soil) in Alberta.

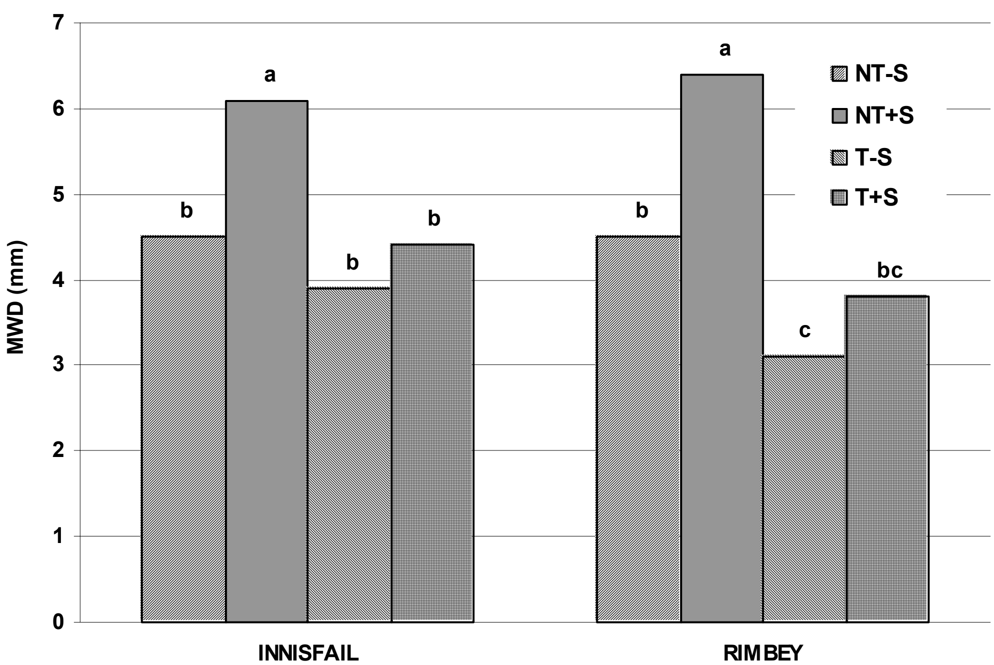

Figure 7. Mean weight diameter (MWD) of dry aggregates in soil at Innisfail (Black Ch

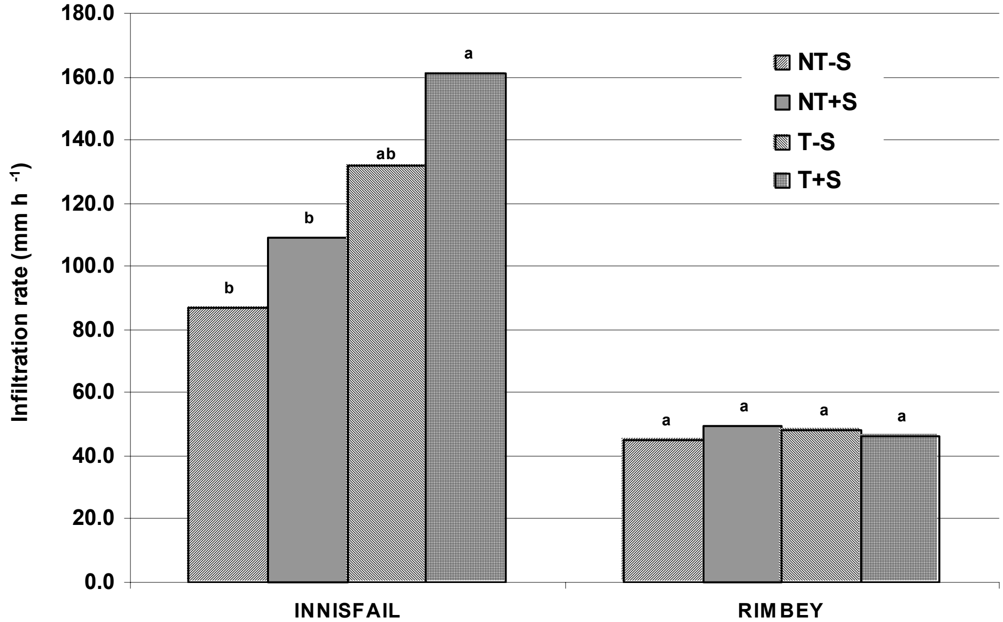

Figure 8. Infiltration rate of soil at Innisfail (Black Chernozemic soil) and Rimbey (Gray Luvisol soil) in Alberta.

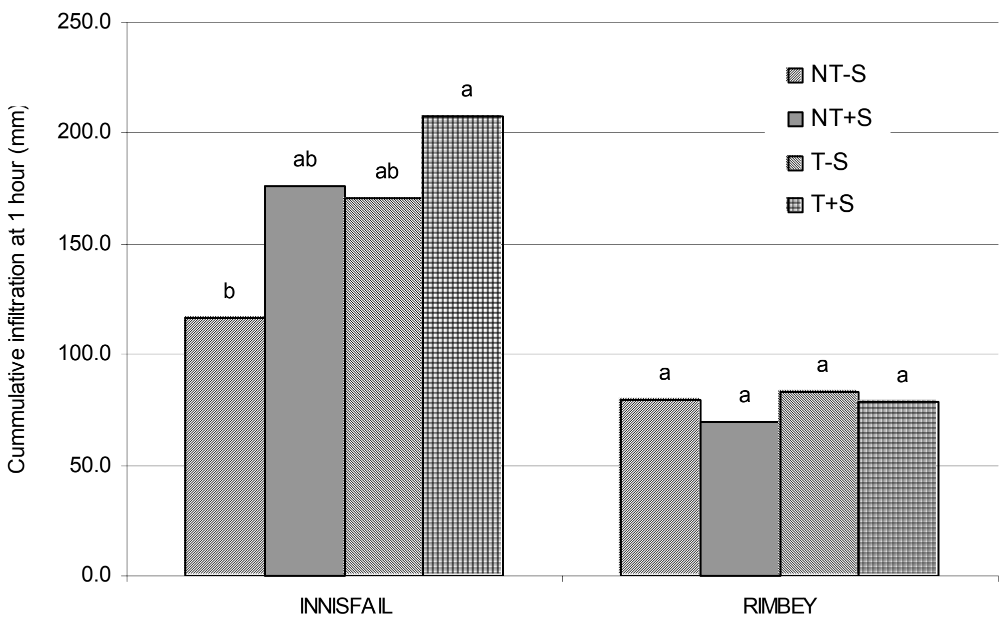

Figure 9. Cummulative infiltration rate at 1 hour of soil at Innisfail (Black Chernozemic soil) and Rimbey (Gray Luvisol soil) in Alberta.