THE EFFECT OF ZERO TILLAGE UPON WATER CONTENT OF A HEAVY CLAY SOIL UNDER CROP CONDITIONS

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ABSTRACT

Recent studies on the effect of zero (ZT)- and conventional (CT) tillage systems on the soil hydraulic properties in the Canadian Prairies have focused primarily on the soil water content and storage in the entire soil profile of light and medium textured soils and not that of heavy textured soils. A study was performed at the Kemen Research Farm in the Dark Brown soil zone near Saskatoon, Saskatchewan. The soil water content in the ZT was higher than the CT within (O-l .2 m) the root zone depth, although the differences were not significant ($P=0.05$) at most times under crop conditions. The ZT had 22, 46 and 52 mm more water than the CT within the root zone depth on August 3, 1994, the end of the growing season (August 31, 1994) and at freeze up (October 19, 1994), respectively. Although there was not a significant ($P=0.05$) difference in soil water of the ZT and CT treatments within the root zone on August 3, the difference in soil water was significant ($P=0.05$) at freeze up. The ZT conserved 30 mm more water than the CT within the root zone depth. Below the root zone, there were not significant ($P=0.05$) differences in soil water of the treatments at the selected dates.

INTRODUCTION

In the semi-arid region of the Canadian Prairies, crop production normally uses all the available water from the root zone depth (1.2 m) during the growing season (McGinn et al. 1994). Water deficits range from 100 to 400 mm in this region (Grevers et al. 1986) and precipitation is seldom sufficient by itself for proper crop growth during the growing season. Hence, crop production is dependent upon the amount of water stored in the soil at seeding time. As a result, dryland farming practices depend on the soil water recharge during fall, winter and early spring.

Crop production in these regions has been successful due to the practice of summer-fallowing (Grevers et al. 1986), but the heavy reliance upon summer-fallowing as a moisture conservation technique has resulted in the decline of soil organic matter, salinization and degradation of soil structure (Jensen and Timmermans 1987). A change in the tillage management from summerfallowing to conservation tillage and thus changing tillage equipment, reducing the number of tillage operations, or the inclusion of chemicals for weed control to replace some tillage operations can help to reduce the severity of these problems and provide the potentials for increased yields (Jensen and Timmermans 1987).

Zero tillage is a form of conservation tillage. According to the 1991 Canadian Census, zero tillage accounts for 10% 5% and 3% of total farmlands in the provinces of Saskatchewan, Manitoba and Alberta, respectively (Acton and Gregorich 1995).

Higher soil water content, infiltration rates, hydraulic conductivity and organic matter content near the soil surface and reduced evaporation losses have been cited as advantages of zero tillage systems.

The objective of the research was to study the effects of zero tillage on the soil water content of a heavy clay soil under fallow and crop conditions within (0- 1.2 m) and below (1.2-1.4 m) the root zone depth in the semi-arid regions of the Canadian Prairies. The focus of this paper will be on the effects of zero tillage on the soil water content within and below the root zone depth under crop conditions.

MATERIALS AND METHODS

The study was conducted at the University of Saskatchewan Research Station, Kemen Farm, at Saskatoon, Saskatchewan (52° 8’ N, 106° 38’ W, 515 m amsl) about 2 km east of Saskatoon city limits on a 1.2 ha field during the summer and fall of 1994. The farm is situated in the Dark Brown soil zone on soils classified dominantly as Orthic Dark Brown Sutherland soils (Souster 1979). The farm landscape is characterized mainly by a level to undulating topography and a slope of about 2% from north to south with minor areas of hummocky topography (Souster 1979). The average amount of organic matter in the top 0.15 m depth of the farm is about 4.5% (Rother 1987).

The field consisted of three 10 m-wide strips oriented to the north. Each strip was 480 m in length and was divided into 16 contiguous 10 x 30 m plots. Eight plots were assigned for experimentation, two each under zero tillage fallow (ZTF), zero tillage crop (ZTC), conventional tillage fallow (CTF), and conventional tillage crop (CTC). The ZT plots had no seedbed preparation for plots under crop (only a disc drill at the seeding time), and weeds were controlled by herbicides (Bomvell; 2,4-D and Roundup). The CT consisted of two tillage operations with a cultivator (shovels and mounted harrows) after harvest in the fall of the previous year and disc drill at the seeding time and weeds were controlled by herbicides (Bomvel and 2,4-D) in plots under crop.

Sand, silt and clay contents of the soil were determined with the modified pipette method (Indorante et al. 1990) with no pretreatment for organic matter or carbonates. Measurements were performed at 0.10 m intervals from the surface to 0.30 m, and below 0.30 m, at 0.20 m intervals down to 1.4 m.

Bulk density at different depths of the soil profile was determined by hydraulically coring with a track mounted corer. Soil cores from O-0.30 m depth at 0.10 m intervals were taken by pressing a 0.30 m long metal corer with a cutting edge into the soil which consisted of three 0.10 m long and 0.084 m inside diameter plastic sleeves inside the metal corer contained the soil. Samples from the 0.20-1.40 m depth were taken at 0.20 m intervals by a cylindrical metal corer (0.084 m inside diameter) pressed into the soil. The corer was removed from the soil every 0.20 m and the samples carefully extracted.

The volumetric soil water content of the ZT and CT plots were measured by installing two PVC access tubes in each plot. the readings were made with a neutron thermalization device from 0.20 m to 1.40 m depth at 0.20 m intervals. The measurements were done weekly in the summer and every second week in the fall of 1994. The measurements began on July 27 (because of the difficulties existed in installing access tubes) and terminated on October 19 (beginning of the freeze up).

To compare the soil water contents of the ZT and CT treatments, August 3, 1994 (second measurement), end of the growing season (August 31) and beginning of freeze up (October 19) were chosen as representative dates. The first measurement (July 27, 1994) was not chosen for comparison because some errors in installation of neutron meter probe, calibration of the equipment, and readings occurred at that time. A two-way analysis of variance for any number of groups with equal and unequal subsamples (observations) was employed in the experimentation for comparison between treatments encountered (Steel and Torrie 1980).

RESULTS AND DISCUSSION

Soil physical properties

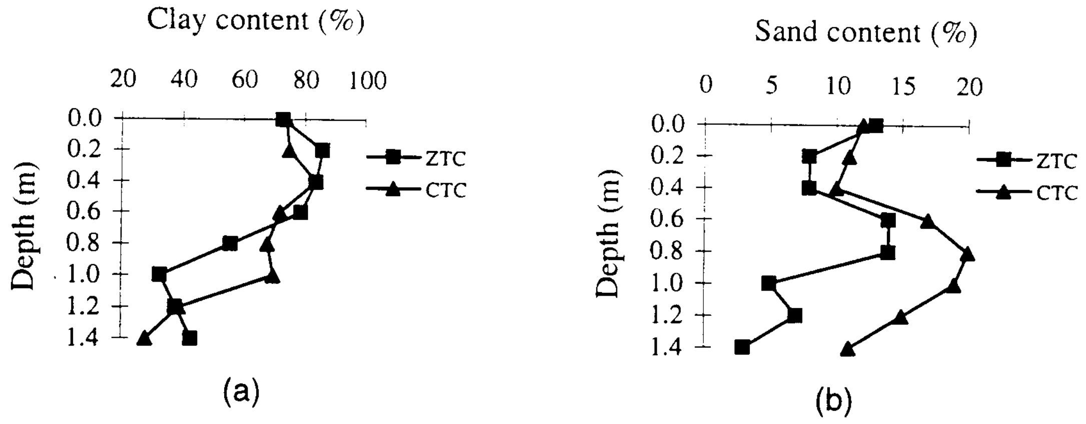
The clay content of the soil was similar in the ZT and CT treatments in the soil profile with the only significant ($P=0.05$) difference occurring at the 0.2-0.4 m layer (Fig. la). The sand contents of the ZT and CT were close together with the only significant difference occurring at the 1.0-l-2 m layer (Fig. lb). In general, the textural class of both treatments in the top 0- 1 .0 m layer was heavy clay, and in the 1 .O- 1.4 m layer was of silty clay loam to clay type.

The bulk density of the soil increased with depth in both treatments (Fig. 2). There was not a significant ($P=0.05$) difference in bulk densities of the treatments at most depths. The only significant ($P=0.05$) difference occurred at the 0.8-1.0 m layer. However, the bulk density values of the CT treatment were smaller than those of the ZT at the top O-O.4 m layer, but below 0.4 m depth, the bulk density values of the CT were greater than those of the ZT treatment.

Climate

The total precipitation for the study months for the Kemen Farm are presented in Fig. 3. The annual mean daily temperature and total precipitation for the Kemen Farm is 1.7 ℃ and 394 mm, respectively. The mean daily temperature and total precipitation for the growing season (May to September) for the Kemen farm is 10.3 ℃ and 308 mm, respectively.

Precipitation during the growing season of the study year (May to September 1994) was 53% higher than the long term average of Saskatoon Airport (309 vs. 202 mm), and the average temperature was slightly lower (15.2 vs. 15.9 ℃) than the long term average of the Saskatoon Airport. Also, precipitation during September and October of 1994 was



(a)

(b)

Fig. 1 : Clay and sand contents of the zero- and conventional tillage treatments.

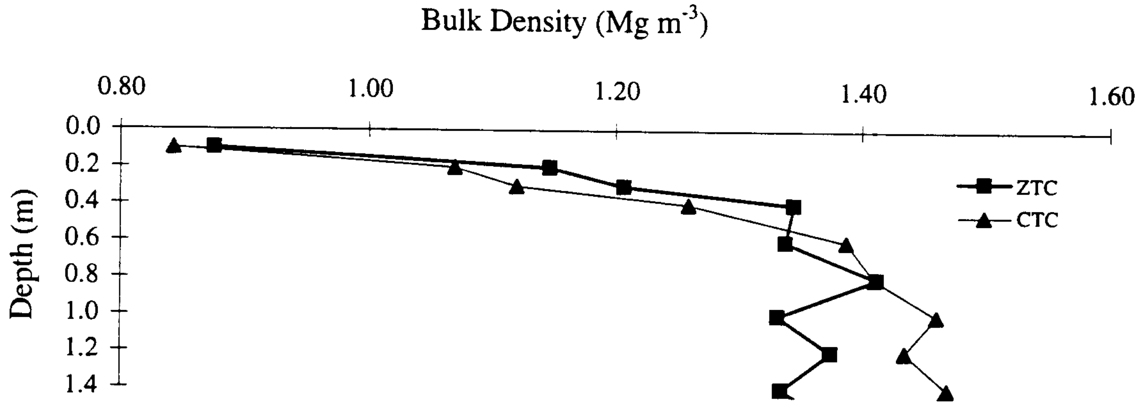


Fig. 2 : Bulk density of the zero- and conventional tillage treatments at different depths of the soil.

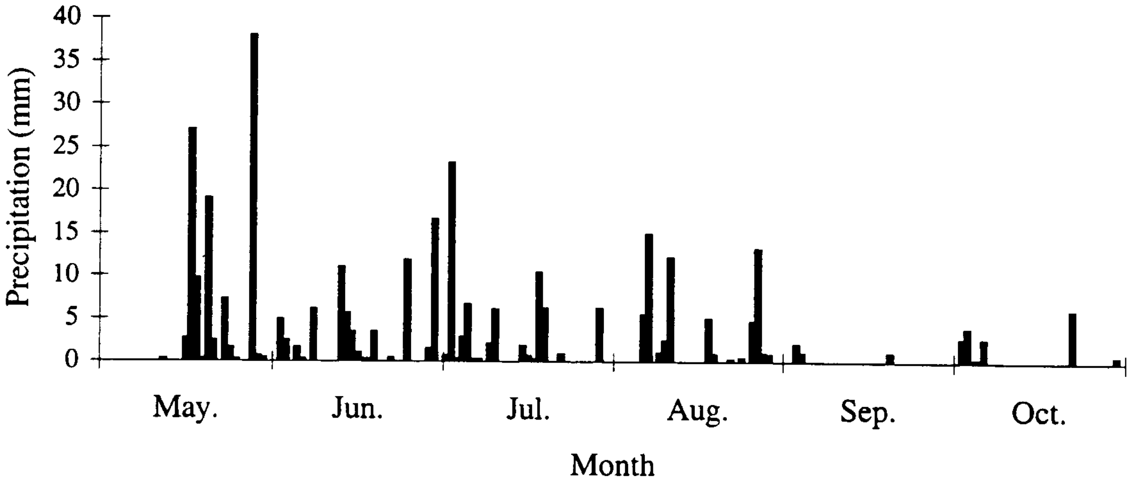


Fig. 3 : Daily precipitation for Kernen Farm from May 1 to October 30, 1994.

59% lower than the long term average (20 vs. 49 mm), and the average temperature was slightly higher than the long term average of the Saskatoon Airport (9.4 vs. 8.0 “C). Therefore, the study year has been much wetter and slightly cooler than the long term average during the growing season, and drier and slightly warmer than the long term average during September to October 1994.

Soil Water

The amounts of soil water (SW) was higher in the ZT than the CT treatment within and below the root zone depth (Table I). The ZT had 23, 46 and 52 mm more water than the CT treatment within the root zone depth at the beginning of the measurement, the end of growing season and at freeze up, respectively.

Table I. Total soil water as depth in the zero and conventional tillage treatments

Date	0- 1.2 m depth		1.2- 1.4 m depth	
	ZT	CT	ZT	CT
	.... mm		....	
August 3	386a	364a	n.a*	n.a
August 31	408a	362a	75c	72c
October 19	400a	348b	77c	69c

n.a = not available

The SW in the ZT treatment within the root zone depth increased by 22 mm from August 3 to the end of the growing season, whereas the SWs at the end of the growing season and at freeze up were similar (Table I and Fig. 4). The increase SW in the ZT treatment between August 3 and the end of the growing season is presumably due to the much rainfall (62 mm) occurred during this period (Fig. 3). Below the root zone, the SWs were similar at the end of the growing season and at freeze up (Table I and Fig. 5).

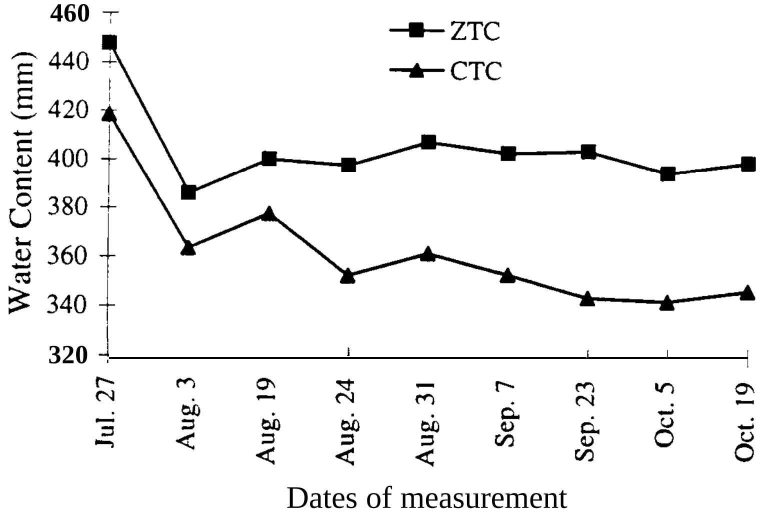


Fig. 4 : **Water content of the zero- and conventional tillage treatments at different times of measurement within the root zone depth of the soil.**

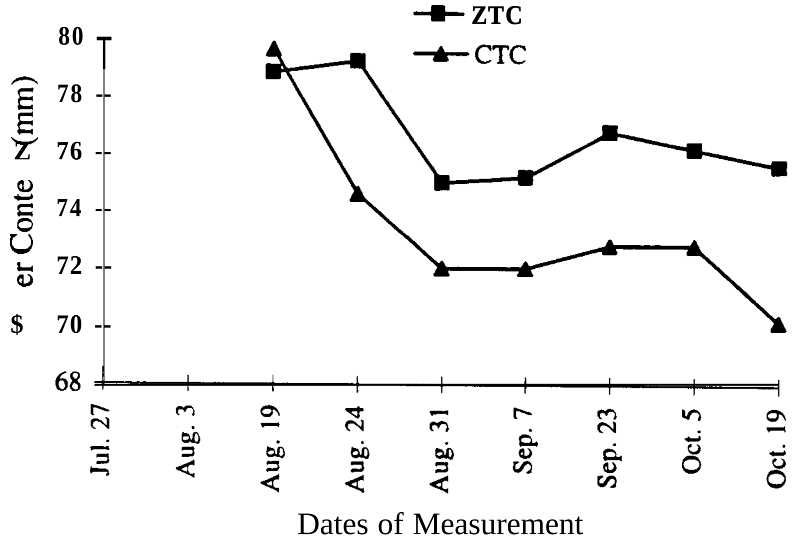


Fig. 5 : **Water content of the zero- and conventional tillage treatments at different times of measurement below the root zone depth of the soil.**

The soil water contents in the CT treatment within the root zone depth were similar on August 3 and the end of the growing season (Table I). The SW of the CT treatment decreased by 14 mm from the end of the growing season to freeze up (Table 1 and Fig. 4). The reason for the similarity in SW values in the CT on August 3 and the end of the growing season is presumably due to the much rainfall occurred in between these two dates of measurement (Fig. 3). Below the root zone depth, the SWs at the end of the growing season and at freeze up were similar in the CT treatment (Table I and Fig. 5).

There was a sharp decrease in the SW of both treatments in the soil profile from July 27 to August 3 (the first and the second measurements) (Fig. 4). This could be due to the improper calibration and installation of the neutron meter probe.

In the root zone depth, the SW of the ZT treatment increased by 22 mm from August 3 to the end of the growing season and decreased by 8 mm from the end of the growing season to freeze up (Table I and Fig. 4), whereas in the CT treatment the values of the SW were similar in the root zone depth from August 3 to the end of the growing season and decreased by 14 mm from the end of the growing season to freeze up. It appears that the ZT has gained and the CT has lost water from August 3 to freeze up, respectively.

Statistical tests showed no significant ($P=0.05$) differences in clay contents (except at 0.2-0.4 m) as well as soil bulk densities (except at 0.8-1.0 m) between the ZT and CT treatments. However, the ZT treatment had smaller bulk densities at 0.6 to 1.4 m depth (Fig. 2). Therefore, the more water in the ZT could not be attributed to the effect of texture and /or bulk density of the treatments.

In soils with low infiltration rates (heavy textured soils), infiltration rate is not affected by residue cover, but total infiltration rate may be higher in such soils where residue is present because it slows the rate of evaporation and allows infiltration to continue for a larger period of time (Taylor and Ashcroft 1972). The soils of the ZT and CT treatments in the study had a heavy texture, so due to the continuity of pores (Douglas et al. 1980; Patterson 1985) and higher recharge of meltwater (Patterson 1985) in ZT soils, one explanation for higher moisture in the ZT treatment could be that more water infiltrated in the ZT than the CT from snowmelt and from rainfall during May to July 1994 (Fig. 3).

Grain Yield

The above ground biomass mass was slightly higher in the ZT than the CT (8710 vs. 8630 kg/ ha), while the reverse was true for the grain yield, so that the grain yield of the CT was slightly higher than the ZT (2845 vs. 2735 kg/ ha). However, the grain yield of both treatments in the 1994 (study year) were above the lo-year average of the Dark Brown Soil zone (2735, 2845 and 2275 kg/ ha for the ZT, CT and the average, respectively).

CONCLUSION

The soil water within the root zone depth was affected by tillage management. Although there was not a significant (P=0.05) difference in the SW of the ZT and CT treatments at the beginning of the measurement, at freeze up the ZT had 52 mm more water than the CT and the difference was significant (P=0.05). Below the root zone, there were not significant (P=0.05) differences in the soil water of both treatments at the selected dates.

The amount of water conserved in the root zone depth was 30 mm more in the ZT than the CT treatment from August 3 to freeze up.

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