TEMPORAL VARIABILITY IN SOIL-WATER CONSERVATION UNDER REDUCED AND CONVENTIONAL TILLAGE SYSTEMS DURING MAY TO SEPTEMBER

M.C.J. Grevers and R.K. Foster

(This project was supported by a grant from the Saskatchewan Agriculture Development Fund)

Introduction

Water is the main factor limiting plant growth in the semi-arid regions of this country. The amount of water that can possibly be lost from the soil due to evaporation and crop water use normally exceeds the amount of growing season precipitation. Consequently, a severe water shortage for plants can develop unless a reserve of available soil water is stored before planting. Tillage, or the lack of tillage can affect each of these losses and therefore affects precipitation storage efficiency. In addition, tillage may alter several soil physical and chemical properties that may affect crop production and water use efficiency. Long-term research has indicated that the addition of only 1 cm of available water in the spring can translate into yield increases of up to 200 kg of grain per hectare. Increasing the efficiency of soil moisture conservation by practices such as residue management can therefore result in substantial yield increases.

Summerfallow was universally adopted in the prairies following the 1930's to accumulate sufficient soil water to reduce the risk of failure when the crop was planted. The main reasons for summerfallow are to conserve moisture and to control weeds and diseases. In the long-term, summerfallow has been found to result in reduced levels of soil organic matter and increased soil erosion by wind and water.

The efficiency of soil-water conservation (gain in soil water content relative to the total amount of precipitation) under summerfallow is low, ranging from less than 10% in the Dark Gray and Gray soil zones to around 25% in the Brown and Dark Brown soil zones. Considerable amounts of soil moisture are lost during the winter and summer periods in the 21-month summerfallow cycle (de Jong and Steppuhn 1983). Soil-water conservation on fallow during the summer and fall periods is also quite low. For example, soil-water conservation in the Dark Brown soil zone during fallow from May-October was calculated by de Jong and Steppuhn (1983) to be only 1.1 cm, which for the Saskatoon area would translate into a soil-water conservation efficiency of only 4%.

Herbicides such as 2,4-D and Banvel have made chemical weed control on stubble fields a viable alternative to fall tillage operations. Data on soil moisture conservation from the Innovative Acres Program (Dept. Soil Science, Univ. of Sask), indicate that stubble fields gained an average of 3.4 cm more soil moisture from fall rains and winter snowfall than summerfallowed fields. Summerfallowed fields can actually lose considerable amounts of soil moisture during the late winter to early spring period in years of little snow cover (Grevers et al. 1986).

Minimum tillage (1 to 3 operations) and zero tillage (direct seeding) may improve moisture storage efficiency some 5 to 10%, bringing the overall average efficiency up to 26 to 28% as compared to 25% for conventional fallow (R.K. Foster, personal communication). Occasionally, greater improvements may be experienced in seasons having heavy wet snowfalls in late spring. The significant benefits of "reduced" tillage systems are better control of erosion by wind and water, and possibly reduced loss of moisture by evaporation after seeding if zero-till seeding is practiced.

The objective of this project was to determine soil-water conservation under reduced tillage, using microlysimeters. It was thought that microlysimeters would provide for a more accurate determination of changes in soil moisture content of the soil surface, as compared to gravimetric analysis or by means of neutron tubes. The experiment concentrated on changes in soil moisture content of the soil surface because the effect of reduced tillage on soil-water conservation is likely most pronounced in the soil surface layer.

Materials and Methods

The plots were located at the Kernen farm (NE8-37-4-W3) on a Sutherland clay-clay loam (Ortic Dark Brown Chernozem) and consisted of replicate blocks of tillage plots: cultivated and zero till plots, which were split into Haybuster-seeded and discer-seeded sub-plots. The plots were part of a long-term study on reduced tillage systems and crop production by R.K. Foster. This report involves soil moisture monitoring in test plots that were in the fallow part of the crop rotation for 1991 and for 1992.

Microlysimeters were pushed into the soil using the hydraulic system of a punch truck. They consisted of 20-cm length sections of 15-cm (i.d.) PVC pipe (0.5 cm thick). In each of the split tillage plots, 2 reps of lysimeters were used. The (soil-filled) lysimeters were removed from the soil surface and inserted into a large plastic bag (the open end of the plastic bag was rolled back and folded over the outside perimeter of the lysimeter), in order to prevent soil loss. The hole left by the excavated lysimeter was enlarged in order for a inverted pipe-end (cap) to be placed in the hole. The plastic bag was not used in 1992, instead the cap was used to prevent soil loss, by securing it to the bottom of the lysimeter by means of a section of inner tube. The lysimeter with soil was weighed and placed back in the excavated hole on top of the pipe-end. Measurements were taken daily, except for week-ends by removing the lysimeters and weighing them using a field balance. Gravimetric soil samples for soil moisture content were collected at the start of the experiments from soil adjacent to the lysimeters. During the 1992 field season, the lysimeters were repeatedly emptied and refilled, or irrigated when the soil moisture contents in the lysimeters fell to below the wilting point.

Soil water content was measured by neutron thermalization, using a DEPTH MOISTURE GAUGE CPN 503. Aluminum access tubes (2 per tillage plot) had been installed to a depth of 120 cm to facilitate the measurements of the soil moisture content in-situ. Surface (0-10 cm) soil water content was determined by gravimetric analysis.

Air (2m height), soil surface and 8-cm depth soil temperature was measured on an hourly basis in 1992, using thermocouples and a datalogger.

Results and Discussion

Soil-water recharge to a depth of 110 cm during the 1991 and 1992 field seasons is shown in Table 1. The zero till plots outgained the cultivated plots during the two-month period from May-July in 1991 by 2 cm H_2O, which represents an increase in water conservation efficiency of 15% (Table 1). The soil-water conservation during the same period in 1992 showed a similar trend; however, the difference was not significant. During the two-month period from July-September, there were no differences in soil-water conservation in 1991 or in 1992. The last two-months of the summer period were also dryer than the first two months, receiving on average only 6 cm of precipitation compared to 14 cm precipitation. Soil water conservation during the four-month period from May-September in 1991 was greater in the zero till plots; the zero till soils gained 2.8 cm more soil moisture than the cultivated soils, which represents an increase of 13% in the efficiency of soil-water conservation. There were no differences in soil-water conservation between zero- and conventional tilled soils from May to September in 1992.

The soil and air temperature regimes from July to September in 1992 are shown in Table 2. The mean soil temperatures of the soil surface were higher than that of the air temperature (@ 2m height). The mean temperature of the surface of the cultivated soils was between 0.6 and 3.7 C higher than that of the zero till soils. The maximum temperature of the surface of the cultivated soils was between 0.8 and 15 C higher than that of the zero till soils. The mean and maximum temperatures of the zero- and conventional tilled soils at 8-cm depth were similar.

The temporal variability in soil-water content of the top 10-cm of the soil (in the lysimeters) during the 1991 and 1992 field seasons are shown in Table 3. Soil-water conservation in 1991 showed a trend, suggesting greater soil-water recharge following rainfall events in the zero tilled soils compared to the cultivated soils, lower soil-water evaporation rates immediately after rainfall and greater soil-water evaporation rates several days after rainfall. The significant differences in the data for 1992 confirm the trend observed in 1991. The greater amount of soil-water recharge in the zero tilled soils is probably because of the effect of trash cover and/or because of greater soil-pore continuity (Grevers et al. 1986). The lower soil-water evaporation rates in the zero tilled soils immediately following rainfall are probably the result of the surface residue effect and also because of the lower temperatures of the soil surface shown earlier. The greater soil-water evaporation rates several days after rainfall are likely the result of limiting hydraulic conductivity. The cultivated soils, which lose soil-water more rapidly immediately after rainfall also dry out faster, which dramatically lowers the hydraulic conductivity thereby reducing soil-water evaporation rates. The zero tilled soils lose soil-water more slowly and the impact on the soil hydraulic conductivity is therefore less dramatic.

Soil-water conservation during the summer months may be improved by reduced tillage, depending on the type of summer. The above data shows that the potential for improving soil-water conservation by reduced tillage does exist. In theory, the differences surface residue cover and the differences in the soil-pore system should improve soil-water conservation under reduced tillage compared to under conventional tillage. However, over extended dry periods, the above factors are less important in terms of soil-water conservation than the hydraulic conductivity of the soil. The surface of the zero tilled soils and that of the conventionally tilled soils both dry out during long dry periods; the conventionally tilled soils may initially dry out faster, but at the end of the dry period both soils reach the same end point. The data suggests that during relatively "wet" periods of the summer (e.g. May-July of 1991), the differences between the two tillage systems are maximized, resulting in significant increases in soil-water conservation.

Conclusions

A field study was carried to determine the temporal variability in soil-water conservation during the summer months under zero- and conventional tilled fallow. During a relatively "wet" period during the summer, the zero-tilled soils conserved more soil moisture than the conventionally tilled soils. The differences in soil-water conservation were the result of greater soil-water recharge following rainfall and reduced soil-water evaporation rates immediately following rainfall. The surface of the conventionally tilled soils was warmer than that of the zero tilled soils, thereby enhancing water evaporation from the soil surface. During a relatively long and dry period, there were no differences in soil-water conservation between zero- and conventional tillage. Water conservation from the soil surface in extended dry periods was not affected by the physical differences in the zero- and conventional tilled soils.

Acknowledgements

The authors wish to recognize the hard work provided by Jerry Stuber (technician) and Lee Poppy (summer student) during the installation of the microlysimeters and during the data collecting part of the study.

References

De Jong, E., and H. Steppuhn. 1983. Water conservation: Canadian Prairies. In: H.E. Dregne and W.O. Willis (Editors). Dryland Agriculture. A.S.A. Monograph No.23. Am. Soc. Agron. Madison, WI. pp: 89-104.

Grevers, M.C., Kirkland, J.A., de Jong, E. and Rennie, D.A. 1986. Soil water conservation under zero- and conventional tillage systems on the Canadian prairies. Soil Tillage Res., **8**: 265-276.

Table 1. Precipitation, soil-water recharge and efficiency in the tillage plots during the 1991 and 1992 field seasons

Period¥	Precip.	Soil-water recharge†		Efficiency	
		Zero Till	Cultiv.	Zero Till	Cultiv.
	(cm)	------- (cm) -------		------- (%) -------	
		1991 Field season			
May-July	17.4	2.64*	0.60	15.2*	3.4
Jul-Sep	3.9	-0.81	-1.53	-20.8	-39.2
May-Sep	21.3	1.83*	-0.93	8.6*	-4.4
		1992 Field season			
May-July	10.8	1.04	-0.43	9.6	-4.0
Jul-Sep	8.5	0.33	2.50	3.9	29.4
May-Sep	19.3	1.38	2.08	7.2	10.8

¥ May 29, July 25, and Sep 19, 1991, and May 19, July 27, September 28, 1992.
† Soil-water recharge to a depth of 110 cm

Table 2. Air temperatures and mean and maximum soil temperatures in the tillage plots during the 1992 field season.

Period	Air*	Soil surface		8 cm depth	
		Zero Till	Cultiv.	Zero Till	Cultiv.
		Mean temperatures (C)			
Jul 21-Jul 27	17.9	19.1	20.8	18.2	18.4
Jul 28 - Aug 3	16.8	18.7	20.8	18.3	18.6
Aug 4 - Aug 10	18.2	19.2	22.2	18.8	19.3
Aug 11 - Aug 17	18.3	19.2	22.9	18.3	18.9
Aug 18 - Aug 24	12.9	15.2	16.5	16.2	16.5
Aug 25 - Aug 31	10.9	11.8	12.6	12.7	12.9
Sep 1 - Sep 7	9.2	10.3	10.9	11.4	11.5
Sep 8 - Sep 14	9.3	8.9	9.8	9.8	10.1
		Maximum temperatures (C)			
Jul 21-Jul 27	26.4	28.3	43.4	21.3	21.1
Jul 28 - Aug 3	26.6	26.5	34.9	20.6	21.1
Aug 4 - Aug 10	28.8	27.5	37.4	21.4	21.6
Aug 11 - Aug 17	32.4	30.2	41.4	21.8	22.2
Aug 18 - Aug 24	32.5	29.3	37.3	21.2	21.5
Aug 25 - Aug 31	20.4	20.2	21.0	15.5	15.8
Sep 1 - Sep 7	18.5	18.4	19.9	14.5	15.2
Sep 8 - Sep 14	22.2	15.5	19.1	12.1	13.2

* Taken at 2m height

Table 3. Daily change in surface soil-water content during the 1991 and 1992 seasons.

Period	Precipitation	Tillage effect		Seeder effect	
		Zero Till	Cultiv.	Haybuster	Discer
	(mm/period)	(mm/day)			
		1991 Field season			
*S.M.C. (Aug 21)**		*20.9*	*20.6*	*22.7*	*19.0*
Aug 21-Aug 22	1.8	0.68	0.52	0.63	0.57
Aug 22-Aug 23	0.0	-1.25	-1.69	-1.62	-1.32
Aug 23-Aug 24	4.0	1.92	1.78	2.42	1.28
Aug 24-Aug 26	0.0	-0.65	-0.71	-0.71	-0.64
Aug 26-Aug 29	1.0	-0.77	-0.67	-0.72	-0.71
Aug 29-Sep 1	0.0	-0.76	-0.54	-0.67	-0.63
Sep 1-Sep 3	0.0	-0.61	-0.38	-0.53	-0.46
Sep 3-Sep 5	5.8	2.51	2.27	2.56	2.23
Sep 5-Sep 7	0.0	-1.26	-1.54	-1.31	-1.50
Sep 7-Sep 9	0.0	-0.30	-0.20	-0.26	-0.24
Sep 9-Sep 16	2.0	-0.21	-0.19	-0.19	-0.21
Sep 16-Oct 8	8.0	-0.09	-0.10	-0.08	-0.12
		1992 Field season			
*S.M.C. (Jun 11)**		*34.3*	*32.7*	*33.6*	*33.3*
Jun 11-Jun 16	0.0	-0.87	-0.87	-0.89	-0.85
Jun 16-Jun 19	7.0	2.50*a*	1.94*b*	1.94*a*	2.46*b*
Jun 19-Jun 22	0.0	-1.62*a*	-1.87*b*	-1.71	-1.78
Jun 22-Jun 29	0.0	-0.82	-0.79	-0.82	-0.79
Jun 29-Jul 13	38.0	0.68*a*	0.50*b*	0.46*a*	0.70*b*
*S.M.C. (Jul 14)**		*34.3*	*32.7*	*33.6*	*33.3*
Jul 14-Jul 23	28.1	-0.58	-0.73	-0.81*a*	-0.50*b*
Jul 23-Jul 27	10.0	0.98*a*	0.69*b*	0.78	0.88
*S.M.C. (Aug 3)**		*34.3*	*32.7*	*33.6*	*33.3*
Aug 3-Aug 8	2.5	-0.57	-0.51	-0.54	-0.44
Aug 8-Aug 18	0.0	-0.66	-0.63	-0.61	-0.68
*S.M.C. (Aug 20)**		*38.9*	*39.0*	*38.9*	*39.0*
Aug 20-Aug 21	0.0	-3.54*a*	-5.54*b*	-4.76	-4.31
Aug 21-Aug 24	8.0	1.50	1.20	1.23	1.46
Aug 24-Aug 26	0.0	-1.63	-1.22	-1.40	-1.45
Aug 26-Aug 28	0.0	-1.36*a*	-1.10*b*	-1.18	-1.27
Aug 28-Aug 31	31.0	6.68*a*	7.68*b*	6.93	7.43
Aug 31-Sep 1	0.0	-3.83*a*	-5.27*b*	-4.68	-4.42

* Moisture content of soil in the lysimeter (v/v)
Values in columns followed by a different letter are significantly different (P<5%)