Deep Tillage for improving the irrigability of Saskatchewan Soils

M.C. J. Grevers
Saskatchewan Centre for Soil Research

A substantial acreage of dryland soils has been put into irrigation near the Luck Lake region and some of the land involves fine-textured or Solonetzic-type soils. These soils have a low to poor suitability for irrigation mainly because of low soil permeability to water, which can result in a high evaporative loss of water and problems with water run-off and soil-water erosion.

Subsoiling of Solonetzic soils has been shown to increase the irrigability of these soils (Bole 1986; Chang et al. 1986; Grevers 1991a) and their productivity (Ballantyne 1983; Grevers 1991a; Wetter et al. 1987). Grevers and Boehm (1992) showed that deep tillage improves soil productivity on Solonetzic soils for 2 to 4 years under irrigation, and for up to 5 years under dryland farming. conditions. The longevity of soil loosening by deep tillage diminishes with time, because of natural soil settling and due to compaction by farm equipment.

The soil disturbance created by deep tillage could be enhanced and its longevity increased by modifying the deep tillage implement and/or by incorporating soil amendments. Soil disturbance of inigated Solonetzic soils by modified deep rippers could result in the dramatic soil loosening found in deep ripped dryland Solonetzic soils, where significant differences in soil structure have persisted into the third year (Grevers 1991b) and increases in crop production have lasted for up to 12 years (Lickacz 1991). Soil amendments such as gypsum and lime, have been used successfully to improve the productivity of Solonetzic soils (Webster and Nyborg 1986), especially under irrigated conditions (Carter et al. 1986). The application of soil amendments in conjunction with deep tillage operations should increase the ameliorative effect of deep tillage.

The objective of this research project is to evaluate the effectiveness and longevity of subsoiling and of deep ripping on soil-water penetration, soil-water storage, and crop production.

Materials and Methods

Four field plots were selected in consultation with extension personnel and farm co-operators; the sites are all in the vicinity of Luck Lake. They are:

Site #l Roy King farm: Sceptre heavy clay
Site #2 Bob Tulles farm: Fox Valley/Kelstern clay to clay loam
Site #3 Leonard Ward farm: Kelstern/Till loam to clay loam
Site #4 Elmer Ward farm: Kelstem very fine sandv loam

The soils at sites 3 and 4 had Solonetzic characteristics as evidenced by the structure of the B horizon. Sites 1 and 2 were non-Solonetzic; their high clay contents, however, made subsoiling an option for improving water penetration. The texture of the soils varied from Heavy Clay to Clay for sites 1 and 2, to Loam to Clay Loam for sites 3 and 4 (Table 1). The soils were slightly acidic to slightly basic, with soil pH values ranging from 6.2 to 8.1 (Table 1). Soil salinity levels were low (≤ 2 dS/m), indicating non-saline soil conditions for at least the top 20 cm of the soil profile. The SAR values suggest non-sodic conditions

The dimensions of the field plots are 150 x 300 ft (1.0 acre), and were located between two pivot tracks. The experimental design is a replicated block design. The deep tillage treatments consist of subsoiling, deep ripping and a control. Subsoiling was done in the fall of 1993 to a depth of 60 cm using a straight vertical shank subsoiler, with it's shanks **112** cm apart. Deep ripping was done to a depth of 60 cm using a parabolic shank subsoiler, with shanks 55 cm apart.

The soil disturbance patterns were considerably different between the subsoiled and the deep tilled soils (Fig. 1). The soil disturbance by the subsoiler was quite localized in a narrow zone and resembled a mole-plow trench. The deep ripped soil profiles did not show an open slot; however, the entire soil surface was lifted up by -10 cm leaving no area of soil surface undisturbed. Soil loosening was apparent in the top 50 cm below the shank and in the top 15 cm in between the shanks.

Soil samples were collected in the spring of 1994 and analyzed for pH, soil salinity (EC), Sodium Absorption Ratio (SAR), soil fertility (NO_3-Nitrogen), and the percentage of sand, silt and clay. Soil-water content was determined by neutron thermalization and soil density by gamma radiation attenuation, using aluminum access tubes installed in the spring to a depth of 1.2 m. Critical limts for bulk densities are 1.4 g/cm^3 for fine-textured soils and 1.6 g/cm^3 for coarse-textured soils (Jones, 1983). Soil strength was determined in the field using a depth penetrometer. This unit consists of a narrow cone which is pushed into the soil, and the soil resistance is recorded by means of a chart and pen assembly. The maximum depth that can be sampled is 1 m; however, often the maximum strength that the unit can measure is exceeded before the maximum depth is attained. Soil strength values exceeding 2 MPa (200 N cm-*) are considered root limiting (Taylor et al. 1966).

Saturated hydraulic conductivity (K-sat) was determined from field soil cores (7.5 cm x 7.5 cm), which were transported to the laboratory. K-Sat was determined by the constant head method (Klute, 1965). K-Sat values of <3 cm/day are considered very slow, values between 48 and 150 cm/day moderate, and >600 cm/day very rapid.

The rate of soil-water infiltration was determined in May and June of 1995 using the double ring infiltrometer method (Bertrand, 1976). Two cylindrical metal rings, the inner ring with a diameter of 30 cm and the outer ring with a diameter of 50 cm were inserted into the soil to a depth of 5 cm. A 15 cm head of water was applied to both rings to a depth of 15 cm and the soil was allowed to drain for a 24 hour period. The rings were once again filled with water, and the rate of water infiltration in the inner rings was measured by lowering a ruler into the ring at intervals of 0, 1,3,5, 10,20,30,45,60,90, and 120 minutes. Two sets of readings were taken in each of the treatments in each of the three replicate blocks. The water used in the infiltration experiment was obtained locally and had a pH of 8.5, an EC of 0.4 dS/m, and SAR of 0.8; the water contained 21 PPM of Na+, 46 PPM of Ca++, and 18 PPM of Mg++.

Crop production was estimated by harvesting square meter yields (3 tillage x 3 block x 6 replicates) prior to the crop being swathed by the cooperators. The plant samples were transported to the University of Saskatchewan, where they were dried, weighed, threshed and weighed for grain content.

Site #3 was tilled to a depths up to 30 cm in field preparation for a potatoe crop grown in the spring of 1994. This tillage operation, which included the entire research plot area, essentially masked any treatment effects. The results for site #3 are therefore not presented in this paper.

3.2 Soil Strength and soil density

Deep tillage reduced soil strength at all three sites (data not shown). For site 1, soil loosening was apparent below a depth of 15 cm, and site 4 soil loosening was apparent below 30 cm depth. Both deep tillage treatments reduced the bulk density of the soils (Fig. 2). The differences persisted into the second year (1995), but by the third year the differences were no longer significant. The data for soil strength and for soil density was not conclusive as to which deep tillage treatment resulted in the greatest amount of soil loosening. A substantial degree of spatial variability in soil loosening achieved by deep tillage equipment (Fig. 1) and subsequent sampling would therefore be subject to considerable “hit and miss” of the loosened area.

3.3 Soil-Water Infiltration

Saturated soil hydraulic conductivity was measured in the spring of 1994 (data not shown). there were no significant differences in K-Sat; there was a high of a degree of variation between replicates. The rate of soil-water infiltration at the four sites as measured in the spring of 1995 is shown in Table 2. When the data for all the sites are analyzed by a single analysis of variance, it shows that subsoiling increased soil-water infiltmtion compared to the control, with deep ripping at intermediate levels. In this case subsoiling improved soil-water infiltration by 88%, and deep ripping by 44%, or by 1.3 mm and 6 mm per hour. When the data was analyzed on a per farm basis, it shows that subsoiling consistently improved soil-water infiltration; however, deep ripping resulted in variable results ranging from small increases to small decreases in soil-water infiltration.

The soil-water infiltration results appear consistent with the other soil physical parameters indicating loosened soil conditions following deep tillage. However, the results are inconsistent regarding which deep tillage operation was more effective.

Table 2. Rate of soil-water infiltration at the Birsay sites, measured in May 1995

Site	Subsoiled	Control	Ripped
	---------------------------- cm/hour ----------------------------		
All sites combined	2.82 b	1.50 a	2.16 ab
Site #1: King Farm	1.48 b	0.33 a	0.61 ab
Site #2: Tulles farm	1.11 b	0.68 ab	0.28 a
Site #3: Elmer Ward farm	2.60	1.64	3.24

Means followed by the same letter are not statistically different (P 0.05)

The effect of deep tillage on crop production

There were significant effects of deep tillage on total dry matter yields and on grain yields (Table 3). This represents a third year effect from deep tillage. The individual analysis for each of sites show a significant treatment by site interaction in the third year (19%). Deep ripping improved crop production at Site 2 and at Site 4; whereas subsoiling only affected crop production at the Site 4. Subsoiling out yielded deep ripping at Site 4. At Site 1 there was no effect of either deep ripping or subsoiling on crop production. I offer the following possible explanations:

- Site 1 has a high clay contents and the shrink-swell behaviour of these heavy soils more than likely negated the effect of soil loosening over time (3 years to date). The soil at Site 2 does not show the extensive shrink-swell behaviour than is evident at the Site 1.
- Soil loosening by deep ripping was more uniform and more extensive than subsoiling at Site 2.
- The lighter textured soil at the Site 4 was substantially loosened by both deep ripping and subsoiling. However, the vertical slot created by the subsoiler was much more apparent at this site compared to the other sites, which have finer-textured soils. The loosening action of the subsoiler is concentrated in a narrow soil zone, which maximizes the effect and soil loosening. On the other hand, the deep ripping effect was across the entire soil surface of the plots. Settling and compacting of the soil following deep tillage at this site may proceed faster following deep ripping than following subsiding for the above reasons.

Conclusions

- Soil loosening by deep tillage equipment varied substantially between the subsoiler and the deep ripper. Subsoiling resulted in a high degree of disturbance but was limited to a cone-shaped soil disturbance pattern centered around a vertical slot. Deep ripping resulted in a more uniform soil disturbance pattern which extended across the entire width of the deep ripped area.
- Soil loosening by the deep tillage operations persisted into the second year after the soils were either deep ripped or subsoiled.
- Deep tillage increased soil-water infiltration by up to 8 mm per hour
- Deep tillage increased crop production by 6%, l0%, and 12%, in the first, second and in the third year since deep tillage, respectively. Deep ripping was more successful than subsoiling in terms of increasing crop production on the clay- and heavy clay-textured soils. On the other hand, subsoiling was at least as successful as deep ripping on the Solonetzic loam-textured soil.
- Deep tillage was more effective in terms of improving crop production for a Solonetzic soil, less effective for a Chemozemic soil, and least effective for a heavy clay-textured Chemozemic soil.

References

Ballantyne, A.K. 1983. Five years of soil analyses and yield data on deep-plowed Solonetzic soil. Can. J. Soil Sci. 63: 191-197.

Bole, J.B. 1986. Amelioration of a calcareous Solonetzic soil by irrigation, deep ripping, and acidification with elemental sulfur. Can. J. Soil Sci. 66: 347-356.

Carter, M.R., J.R. Pearen, P.G. Karkanis, R.R. Cairns, and D. W. McAndrew 1986. Improvement of soil properties and plant growth on a Brown Solonetzic soil using irrigation, calcium amendments and nitrogen. Can. J. Soil Sci. 66: 581-589.

Chang, C., T.G. Sommerfeldt, G.B. Schaalje and C.J. Palmer. 1986 Effect of subsoiling on wheat yield and salt distribution of a Solonetzic soil. Can. J. Soil Sci. 66: 437-443.

Grevers, M.C.J. 1991a. Ripping of irrigated Solonetzic soils to increase water penetration and crop yield. Final report # SP-88CA-21. Sask. Water Corp., Outlook, Sask.

Grevers, M.C.J. 1991b. Deep tillage of Solonetzic and non-Solonetzic soils in Saskatchewan. Proc. 1991 Soils & Crops Workshop, Univ. of Sask., Saskatoon. Sask. (In press).

Grevers, M.C.J. and M.M. Boehm. 1992. Field monitoring and economic assessment of deep plowing and of deep ripping in Saskatchewan. Final Report on ADF project SOA-R-0152. Agriculture Development Fund, Saskatchewan Agriculture, Regina, Sk.

Lickacz, J. 1991. Deep tillage of Solonetzic soils: the Alberta experience. Proc. 1991 Soils & Crops Workshop, Univ. of Sask., Saskatoon. Sask. (In press).

Webster, G.R. and M. Nyborg. 1986. Effects of tillage and amendments on yields and selected soil properties of two Solonetzic soils. Can. J.Soil Sci. 66: 455470.

Wetter, L.G., G.R. Webster, and J. Lickacz. 1987. Amelioration of Solonetzic soil by subsoiling and liming 1987. Can. J. Soil Sci. 67: 919-930.

Working Group on Irrigation Suitability Classification. 1985. Irrigation suitability classification system for the Canadian Prairies. Preliminary Draft of Workshop Rpt., Prairie Region.

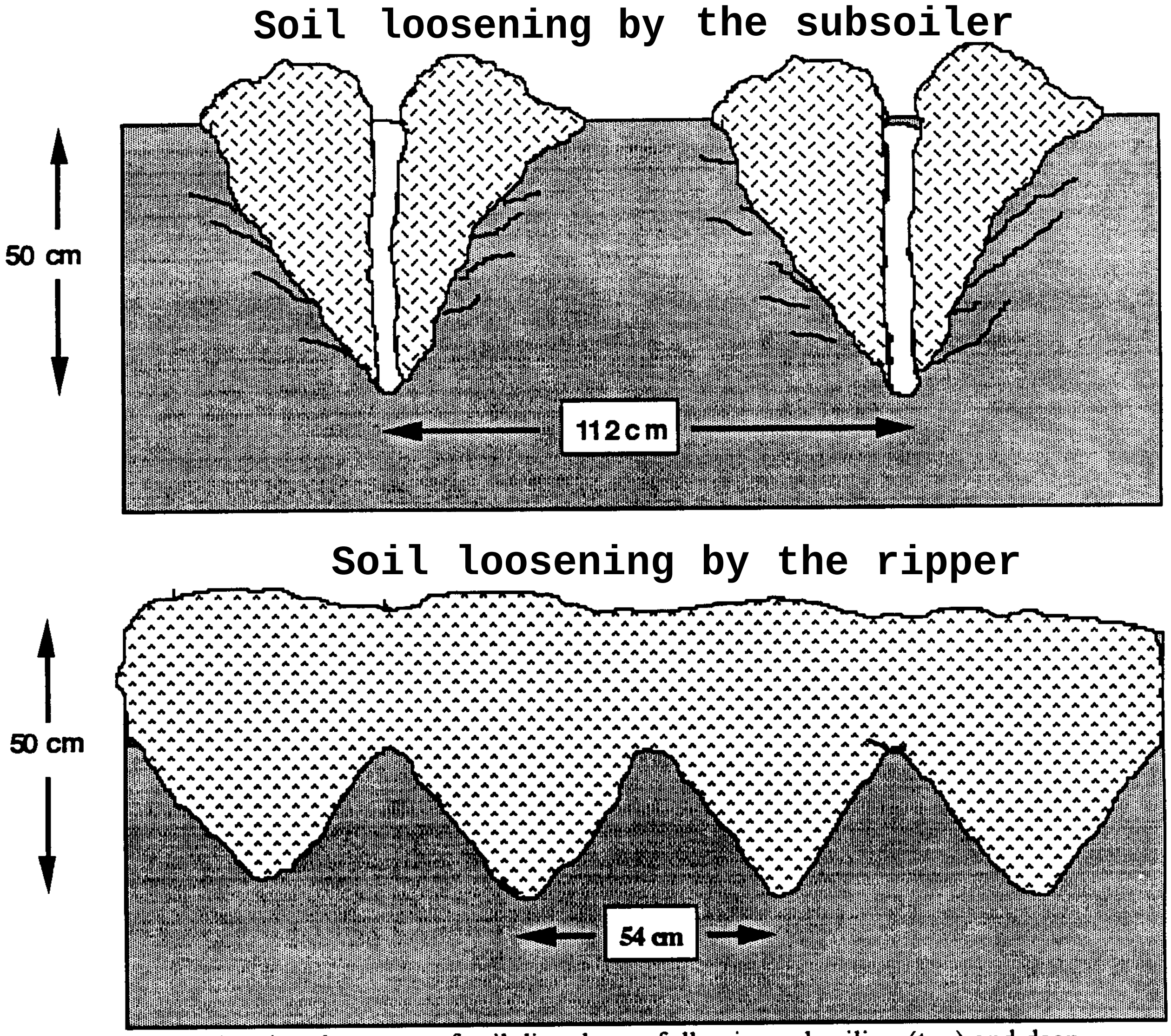

Fig. 1. Diagram showing the extent of soil disturbance following subsoiling (top) and deep ripping (bottom) The light shaded area indicates loosened soil.

Table 1. Soil chemical and mechanical characteristics for sites 1,2,3 and 4

Depth	pH	EC	SAR	NO_3-N	Sand	Silt	Clay	Texture
(cm)		dS/m		kg/ha		(%)		
					Site #1			
o-15	7.1	0.8	1.1	33.9	9.0	36.6	54.4	C
15-30	7.5	0.6	1.9	5.6	7.9	35.9	56.2	C
30-60	7.2	2.7		2.7	6.1	33.4	60.4	HC
					Site #2			
o-15	6.7	0.6	1.0	26.8	16.0	43.2	40.8	SiC
15-30	7.4	0.7	1.4	9.2	14.2	37.8	48.0	C
30-60	7.7	2.5		4.8	14.4	32.4	53.2	C
					Site #3			
o-15	6.6	0.6	0.8	68.8	34.2	40.4	25.4	L
15-30	7.0	0.3	1.6	9.6	27.7	40.4	31.9	CL
30-60	7.6	0.5		21.6	31.	34.7	33.5	CL
					Site #4			
o-15	7.5	0.4	1.1	18.7	41.0	22.0	37.0	CL
15-30	7.3	0.4	1.2	6.5	34.6	23.9	41.5	c
30-60	8.0	0.6		6.4	31.4	30.2	38.4	CL

Above measurements taken in the summer of 1994.
Values in brackets are standard errors.

Table 3. Crop production in the subsoiled, in the control and in the ripped plots.

Site	Subsoiled	Control	Ripped
1994 Growing season			
	Grain Yield (tonnes/ha)		
Site #1: Roy King	5.8b	5.1a	5.5ab
Site #2: Bob Tulles	2.5a	2.8b	2.5a
Site #4: E. Ward	1.3a	1.2a	1.5b
	Dry Matter Yield (tonnes/ha)		
Site #1: Roy King	11.2a	10.2a	10.7a
Site #2: Bob Tulles	5.7a	5.8a	6.2b
Site #4: E. Ward	5.3a	5.0a	6.2b
1995 Growing season			
	Grain Yield (tonnes/ha)		
Site #1: Roy King	8.0a	8.0a	8.7b
Site #2: Bob Tulles	4.7a	5.0a	6.0b
Site #4: E. Ward	8.4	7.9	8.4
	Dry Matter Yield (tonnes/ha)		
Site #1: Roy King	1.7a	1.8a	2.0b
Site #2: Bob Tulles	2.3a	2.4a	3.1b
Site #4: E. Ward	3.6b	3.2a	3.6b
1996 Growing season			
	Grain Yield (tonnes/ha)		
Site #1: Roy King	5.8	5.6	5.6
Site #2: Bob Tulles	4.5a	4.8ab	5.3b
Site #4: E. Ward	3.8c	2.6a	3.1b
	Dry Matter Yield (tonnes/ha)		
Site #1: Roy King	10.7	10.5	10.5
Site #2: Bob Tulles	9.2a	9.5a	10.7b
Site #4: E. Ward	7.6b	5.7a	7.1b

Means followed by the same letter are not statistically different (*P* 0.05)