2.2 Ripping of Irrigated Solonetzic Soil to Increase Water Penetration and Crop Yield

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INTRODUCTION

Deep tillage of Solonetzic soils has resulted in increased crop production in Alberta (Toogood and Cairns, 1978). Deep plowing of Solonetzic soils results in both the disturbance of the impermeable layer, and the mixing of the Na-rich Bnt horizon with the Ca-rich C horizon. Generally, the physical and chemical properties of these deep plowed Solonetzic soils are greatly improved (Cairns and Bowser, 1977). Much of the research on deep plowing of Solonetzic soils has been done in Alberta (Cairns, 1961, 1962; Bowser and Cairns, 1967). In Saskatchewan, Ballantyne (1983) studied soil conditions and crop production following deep plowing of Solonetzic soils north of Radville (near Weyburn). He found that the improved soil chemical conditions and crop growth from deep plowing persisted at least 5 years following deep plowing

Deep ripping is considerably less expensive than deep plowing, but may cause insufficient mixing of soil layers to result in significant improvement in the productivity of Solonetzic soils (Alzubaidi and Webster, 1982). Bole (1986) found increased soil-water infiltration following deep ripping, however, the effect only lasted for 2 years. Alzubaidi and Webster (1982) found that deep ripping had resulted in increased deep leaching of salts. There has been little evidence to suggest that deep ripping results in considerable increases in crop yield of Solonetzic soils (Lavado and Cairns, 1980). Lickacz (1986) reported that deep ripping of Solonetzic soils was less beneficial in terms of increasing crop production in areas with severe moisture deficits, than in "wetter" areas. For example, he reported average wheat yield increases due to deep ripping of 130 kg/ha in the Brown soil zone compared to 400 kg/ha in the Dark Brown and Black soil zones.

This report represents a progress report on the field monitoring of soil physical properties and crop growth following deep ripping of three irrigated soils north and north-east of Glenside, Saskatchewan. The objectives of the project were to determine the effect of deep ripping on crop production and on water infiltration, and on whether deep ripping could increase the suitability of these soils for irrigation. Initial results of the work that was carried in the first year have been reported at the 1989 Soils & Crops Workshop (Grevers 1989).

MATERIALS AND METHODS

A total of 3 farm sites are included in the study, located north-east of Glenside, Saskatchewan. Legal locations of the sites are: Site DE (Dale Eliason farm) S1/2-27-29-6-W3, Site JE (Jerry Eliason farm) SW-2-30-6-W3, and Site RR (Riopka farm)N1/2-16-29-6-W3. Deep ripping was carried out in the fall of 1987, to a depth of 61 cm. The soil moisture content at the time of deep ripping varied from 11% to 23% Table 2.2.1.

Soil samples were collected at the time of deep ripping from the control strips. Samples were taken to a depth of 120 cm, in increments of 0-15, 15-30, 30-45, 45-60, 60-90 and 90-120 cm. The samples were air-dried and then analyzed for pH, conductivity, water soluble cations, sodium adsorption ratio (S.A.R.), cation exchange capacity (C.E.C.), exchangeable cations (Ca, Mg, Na, K). In the spring, additional samples were collected to a depth of 24" (60 cm) from all the tillage strips, which were analyzed for NO_3-nitrogen content.

Soil physical parameters that were measured include soil moisture, soil bulk density, saturated hydraulic conductivity (K-Sat) and soil strength. Soil water content was measured by neutron thermalization, using a DEPTHPROBE CPN 501 (Hoskins Scientific). Soil bulk density was measured by gamma backscattering using the above DEPTHPROBE CPN 501. The scanning zone of the DEPTHPROBE CPN 501 has a vertical dimension of approximately 23 cm, and is therefore not sensitive to "picking up" relatively thin dense layers in the soil. Aluminum access tubes (2 per replicated plot) had been installed to a depth of 120 cm to facilitate the measurements of the soil bulk density and of the soil moisture content in-situ, using the depth probes. During the 1988 growing season, soil moisture content was measured prior to seeding (1 to 2 weeks) and at harvest time; at Site RR, however, measurements were taken at 2 to 3 week intervals during the growing season. During the 1989 growing season, soil moisture content and precipitation (rain gauges) at all three sites were measured bi-weekly. Bulk density measurements were taken prior to seeding and at harvest. Saturated hydraulic conductivity (K-Sat) measurements were taken in the summer of 1989, by pushing soil corers into the soil; the soil cores were subsequently analyzed for K-Sat in the laboratory. Soil strength was measured with a Proctor penetrometer in the summer of 1988 at the time of harvest. This method involves pushing a probe into the soil and measuring the force required to do so. Penetrometer measurements were taken at the time of harvest at each crop sampling area.

Crop yields were determined by taking square meter samples, in a series of paired row samples, 6 pairs in each tillage strip. The samples were then transported to the University of Saskatchewan, where the samples were dried, weighed, threshed and grain weights taken.

RESULTS AND DISCUSSION

Characterization of the Soils Based on Soil Chemical Criteria

All three soils are mapped as Tuxford Soil Association, which consists of Dark Brown Solonetzic soils. Classification of Solonetzic soils in Canada is based upon the characteristic morphological features of the Solonetzic Bn or Bnt horizon and related soil chemistry. Soil chemical criteria used to differentiate Solonetzic soils from Chernozemic soils are the exchangeable Ca:Na ratio and/or the % water soluble Na. A soil is considered to be Solonetzic if the exchangeable Ca:Na ratio of the B horizon is equal to or less than 10

(Canada Soil Survey Committee, 1978). A Solonetzic soil can also be identified if the % water soluble Na in the B horizon is equal to or greater than 50% (Ballantyne and Clayton, 1962). The soil chemical characteristics for all three farm sites are shown in Table 2.2.1. The soil at the DE Site site does not meet any of the above criteria for solonetzic B horizons. The soil is also non-saline. The soil at Site RR is also non-Solonetzic in terms of soil chemical criteria. At this farm site, however, electrical conductivity levels indicate moderate salinity levels at the 30-60 cm depth , and severe salinity levels at the 60-120 cm depth. The soil at Site JE does not meet the chemical criteria for solonetzic B horizons in terms of the Ca:Na ratio ≤ 10, but does meet the criteria in terms of percentage water-soluble sodium. The soil at this site is basically non-saline.

There was considerable variability in soil chemical characteristics amongst the three replicate blocks at each Site (Fig. 2.2.1). The percentage water-soluble sodium was greater than 50% in two of the replicate blocks for Sites DE and JE, indicating that at least a part of these fields had high water-soluble sodium levels (south and north replicates at Site DE, southern 2 replicates at Site JE). At Site RR, none of the soils in the three replicate blocks had soil chemical characteristics found in Solonetzic soils.

Soil chemical criteria used for determining the irrigability of Solonetzic soils involve the sodium adsorption ratio (S.A.R.). Soils characterized by S.A.R. values greater than 12 within 1 m of ground soil surface are rated non-irrigable (Bennett, 1987). Based on the S.A.R. values, the southern 2/3 of the plot at Site JE could be considered non-irrigable. The soils at the other two Sites have S.A.R. values considerably below the critical level (S.A.R. = 12), and are therefore classified as irrigable.

Table 2.2.1. Soil chemical characteristics of the soils at the three Sites in the fall of 1987

Depth	SMC	pH	EC	SAR	WSS	ESP	Ca/Na
cm				**Dale Eliason Site**			
0-15	15.1	6.7	0.7	1.2	23.7	1.7	38.2
15-30	18.7	7.6	0.9	2.6	41.9	2.5	31.4
30-45	20.3	7.9	2.4	4.2	42.9	4.2	19.4
45-60	20.4	8.1	3.5	6.6	51.6	6.6	11.0
60-75	17.9	8.2	7.0	9.7	47.7	8.8	8.2
75-90	15.3	8.1	8.7	10.3	46.1	10.8	5.9
				Riopka Site			
0-15	16.5	7.4	0.9	1.4	26.9	1.7	42.8
15-30	18.3	7.9	1.5	3.6	39.9	3.3	21.6
30-45	21.1	8.1	4.2	5.5	43.6	5.6	11.2
45-60	20.5	8.2	5.8	7.0	42.2	7.5	7.7
60-75	17.4	8.2	7.9	8.8	42.0	8.9	7.8
75-90	15.0	8.1	9.1	9.7	42.6	7.8	9.6
				Jerry Eliason Site			
0-15	11.6	6.7	0.8	2.0	34.0	3.2	21.6
15-30	14.0	7.5	0.9	3.9	50.1	3.4	23.1
30-45	14.8	7.9	1.8	6.2	56.1	6.0	15.6
45-60	16.9	8.1	3.7	8.3	58.2	8.1	11.4
60-75	18.8	8.1	6.8	9.7	49.3	9.3	7.4
75-90	18.1	8.0	8.3	10.5	46.5	9.4	8.6

SMC= soil moisture content (% w/w), EC = Electrical Conductivity, mS/cm; SAR= Sodium Adsorption Ratio; WSS= Water Soluble Sodium, % of soluble cations; ESP = Exchangeable Sodium Percentage; Ca/Na= ratio of exchangeable Calcium to exchangeable Sodium

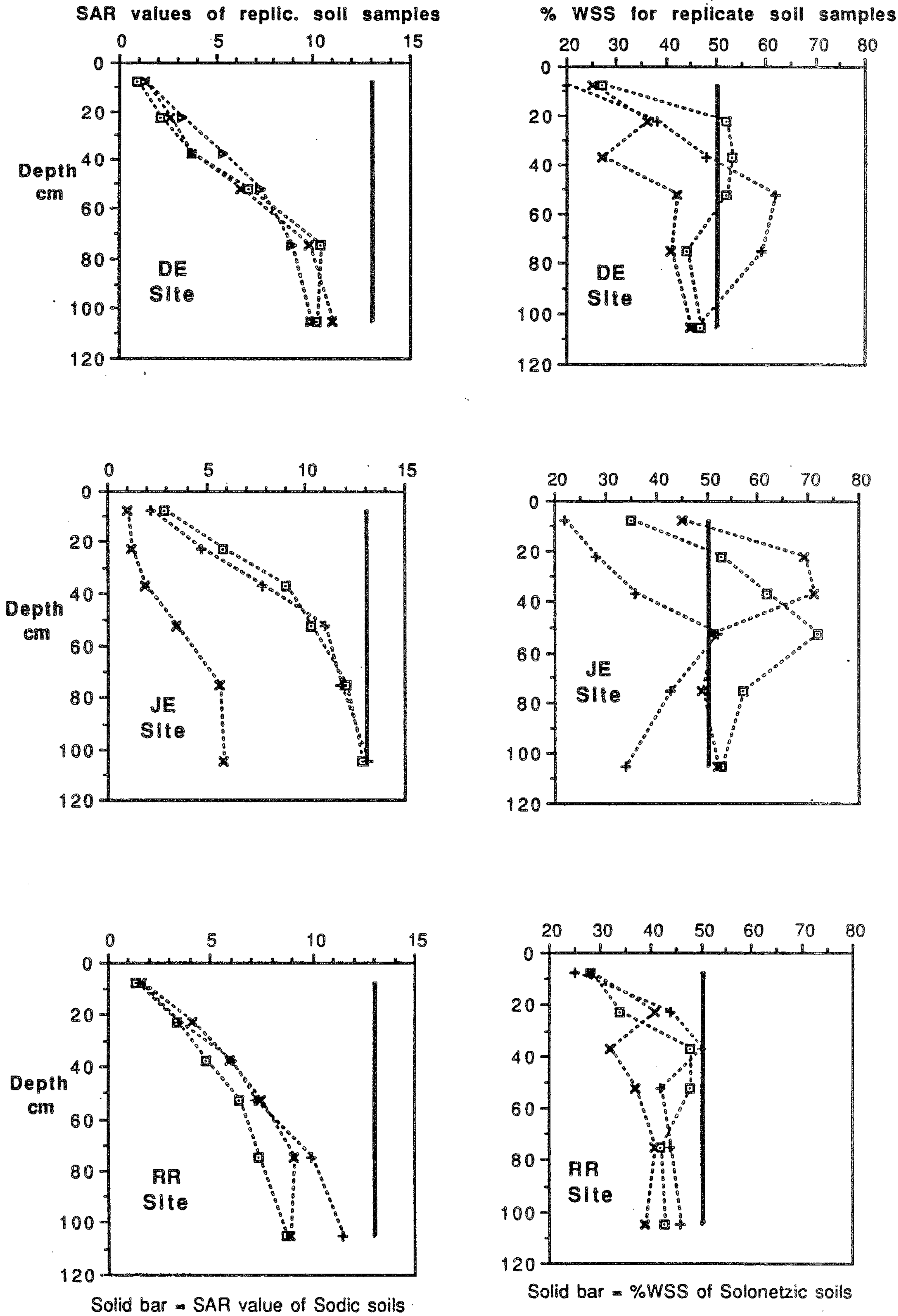

Fig. 2.2.1. Soil chemical characteristics of the individual replicate blocks for all three sites

Soil NO_3^--Nitrogen in the Spring

The soil disturbance associated with deep ripping (e.g. lower bulk density levels and increased soil porosity) could increase the rates of soil organic matter decomposition, nitrogen mineralization and nitrification. The levels of nitrate-nitrogen (NO_3^-) as measured in the spring of 1988 and 1989 are shown in Table 2.2.2. There is little difference in the nitrate levels between the deep ripped plots and the control plots, with the possible exception of Site JE for 1989. In this case the nitrate-nitrogen levels in the deep ripped plots were twice that of the control plots.

Table 2.2.2. The levels of nitrate (NO_3^-)-nitrogen of the soils in the deep ripped and in the non-ripped plots in the spring of 1988 and 1989

Depth	Spring 1988		Spring 1989	
	Ripped	Control	Ripped	Control
cm	---------- kg/ha ----------			
		DE Site		
0-15	15	12	20	16
15-30	5	3	6	5
30-60	3	6	6	9
0-60	23	21	32	30
		JE Site		
0-15	21	16	13	14
15-30	3	5	9	5
30-60	6	5	44	11
0-60	30	26	66	30
		RR Site		
0-15	25	28	11	14
15-30	7	6	4	3
30-60	9	9	3	3
0-60	41	43	18	20

Soil Strength

Measurements taken at the time of harvest in 1988, did not show any significant differences in soil strength between the deep ripped and the control plots, for any of the Sites (Table 2.2.3). Soil strength is primarily a function of soil density and soil moisture content. It is therefore quite possible that differences in soil moisture content between the deep ripped and the control plots masked possible differences in soil strength due to the soil density

Table 2.2.3. Soil strength of the soils in the deep ripped and in the non-ripped plots

Depth	Deep ripped		Control	
cm	---------- MPa ----------			
		DE Site		
10	2.33	(0.79)	2.61	(0.10)
20	4.08	(1.13)	5.06	(0.35)
30	5.75	(1.62)	6.19	(0.05)
40	6.58	(1.96)	6.53	(0.43)
		JE Site		
10	0.94	(0.19)	0.92	(0.22)
20	1.81	(0.61)	1.47	(0.38)
30	2.56	(1.05)	2.19	(0.77)
40	3.92	(1.23)	3.00	(0.79)
		RR Site		
10	1.17	(1.21)	1.46	(0.54)
20	2.01	(0.82)	2.31	(1.00)
30	2.94	(1.34)	3.60	(1.80)
40	4.25	(1.21)	4.33	(2.06)

Values in brackets are standard deviations

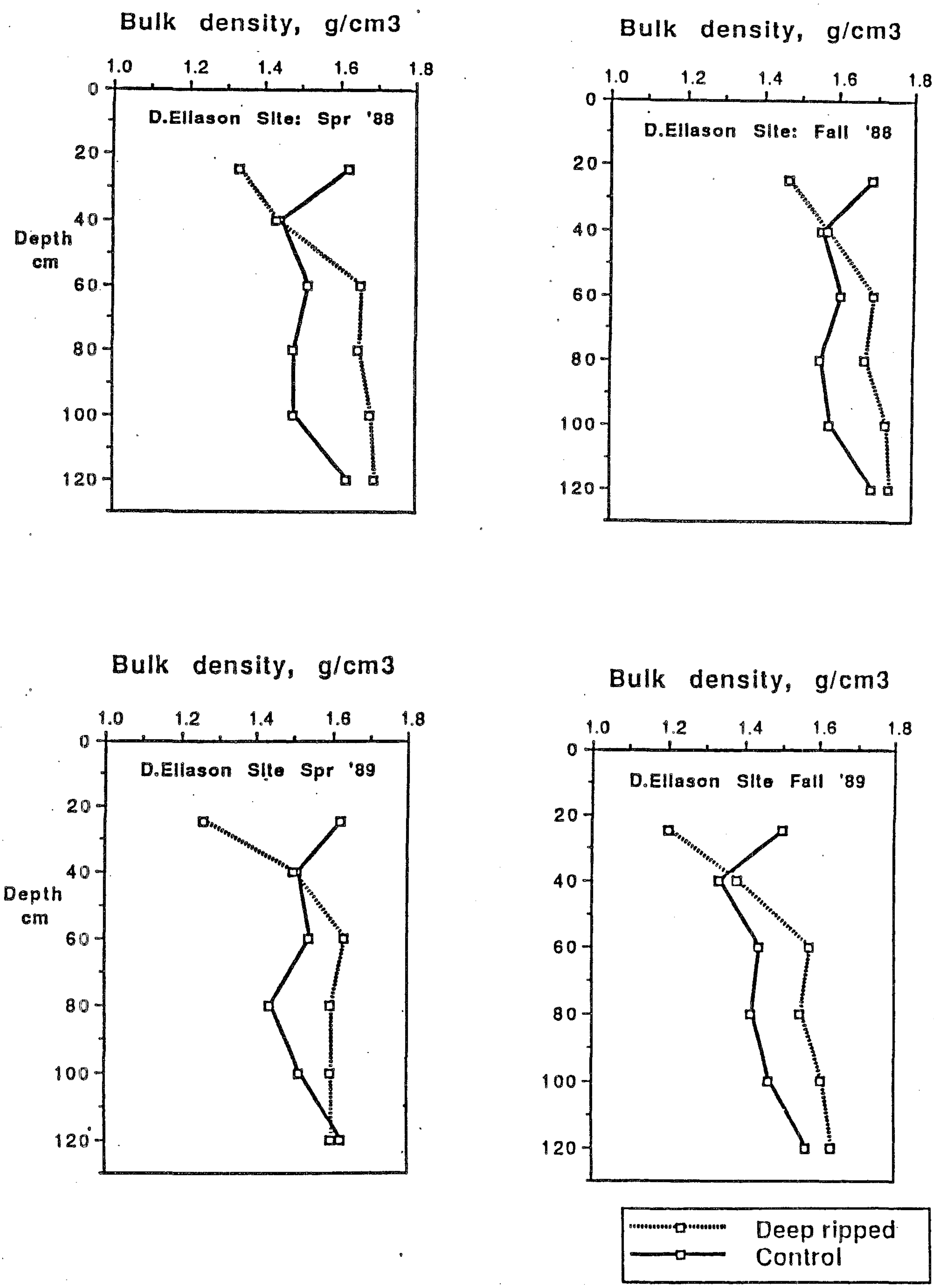

Fig. 2.2.2. Bulk density profiles of the soils at the Dale Eliason site, for 1988 and 1989.

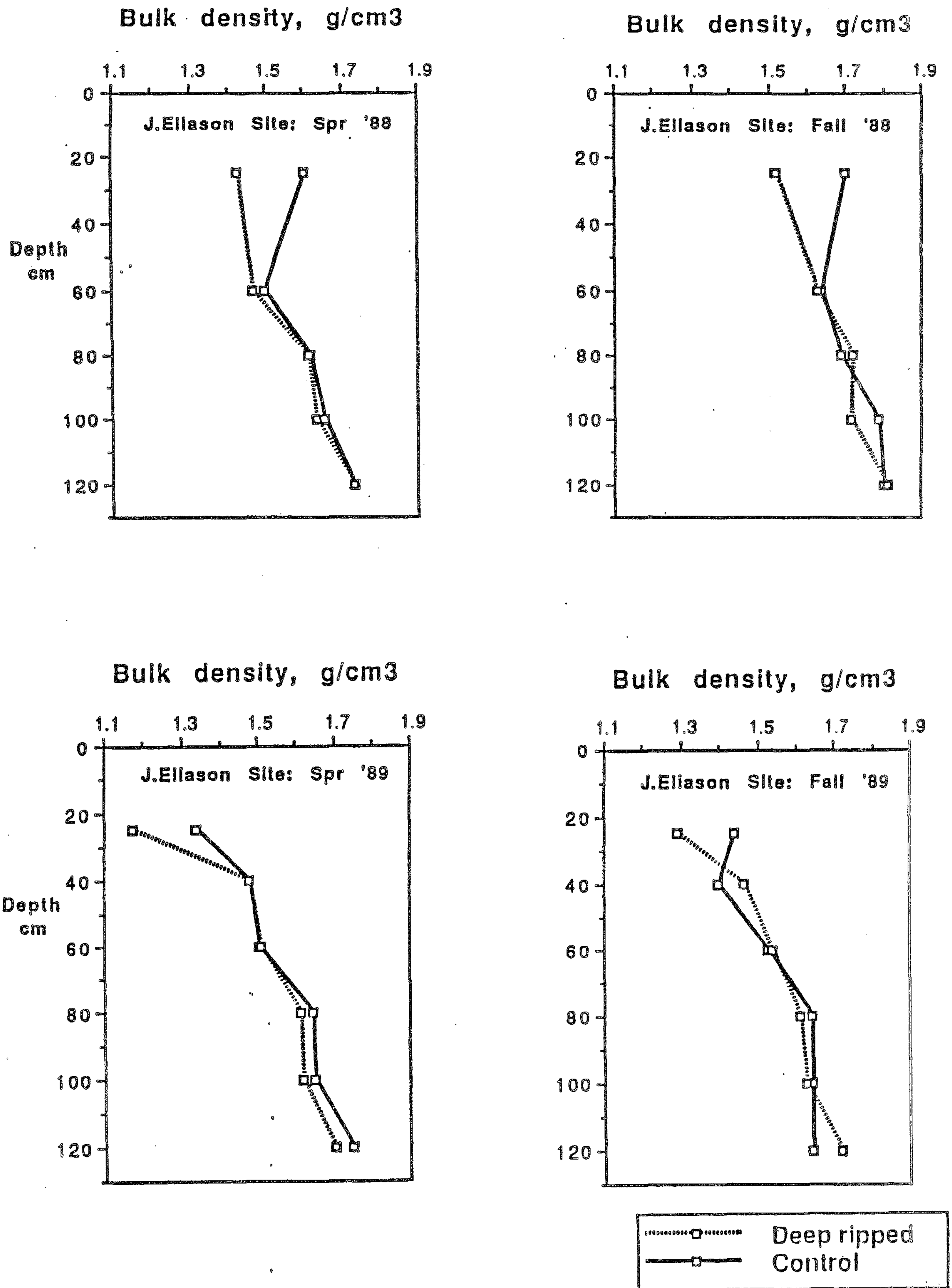

Fig. 2.2.3. Soil bulk density profiles at the Jerry Eliason (JE) Site for 1988 and 1989.

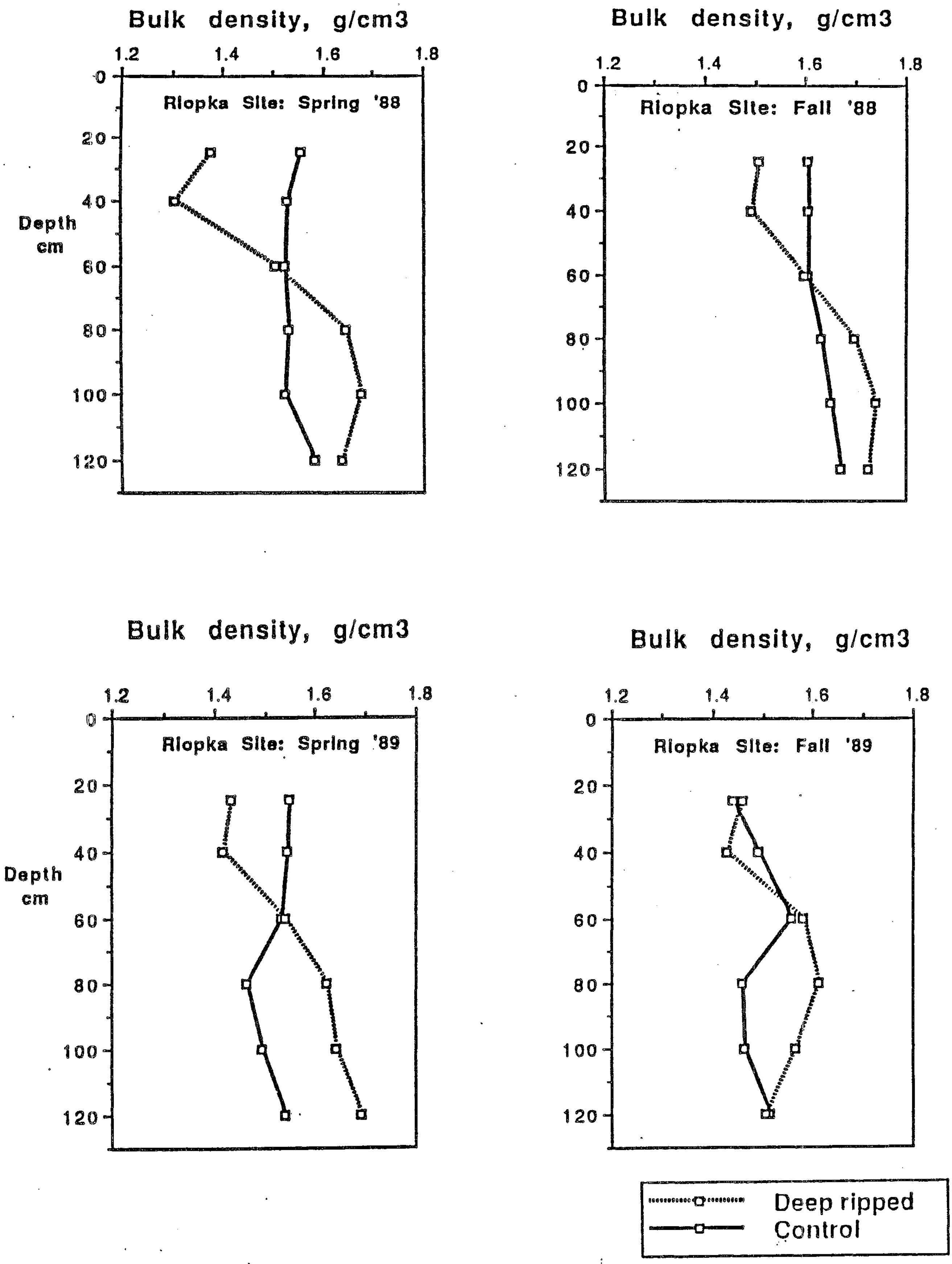

Fig. 2.2.4. Soil bulk density profiles at the Riopka (RR) Site for 1988 and 1989.

Soil Density

Measurements taken in 1988 revealed that soils at two of the sites had dense layers around the 25 cm depth, which had been loosened by deep ripping. The differences in bulk density between the deep ripped and the non-ripped (control) parts of the field became smaller as time progressed (Figs. 2.2.2, 2.2.3 and 2.2.4, Tables 2.2.4 and 2.2.5). However, by the fall of 1989, there were still considerable differences in bulk density between the deep ripped and the non-ripped soil profiles for the Dale Eliason and the Jerry Eliason Sites. Statistical analysis of the density measurements for 1989 showed significant differences at the 5% level only for the Jerry Eliason Site for the spring measurement. The rest of the differences therefore represent trends only. There are limitations with the gamma probes used for the density measurements (large sampling volume) and also with spatial variations in the field (upper lower and mid slope positions). Ideally, a large number of replicated samples should be collected to provide an adequate data base for statistical scrutiny, however, such a sampling scheme is very time consuming and costly and, therefore, beyond the means of the budget of this research project.

Soil Hydraulic Conductivity

Deep ripping has been reported to increase soil water infiltration with depth (Bole 1986; Riddell et al. 1988), especially under irrigation (Chang et al. 1986), thereby resulting in leaching of sodium salts from the Bnt horizon. Saturated hydraulic conductivity (K-Sat) was measured in the summer of 1989 at each of the sites, and results are listed in Table 2.2.6. For each of the Sites, there appears to be at least one depth increment where K-Sat was higher in the deep ripped compared to the control parts of the field. The differences, however, were not significantly different ($P < 5\%$).

Table 2.2.4. Soil bulk density in the spring and in the fall of 1988

Depth	Spring				Fall			
	Deep ripped		Control		Deep ripped		Control	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
cm	g/cm^3							
	Dale Eliason Site							
5	1.250	0.000	1.250	0.000	1.250	0.000	1.250	0.000
20	1.332	0.336	1.623	0.080	1.467	0.318	1.688	0.093
40	1.431	0.118	1.442	0.141	1.570	0.031	1.550	0.088
60	1.655	0.076	1.517	0.151	1.690	0.083	1.603	0.112
80	1.651	0.103	1.480	0.146	1.672	0.120	1.550	0.122
100	1.680	0.215	1.476	0.177	1.730	0.171	1.580	0.160
120	1.692	0.196	1.617	0.172	1.736	0.170	1.694	0.156
	Jerry Eliason Site							
5	1.250	0.000	1.250	0.000	1.250	0.000	1.250	0.000
20	1.426	0.214	1.604	0.088	1.520	0.177	1.702	0.078
40	1.398	0.098	1.295	0.071	1.525	0.075	1.449	0.061
60	1.467	0.095	1.499	0.047	1.625	0.059	1.632	0.036
80	1.616	0.070	1.620	0.076	1.717	0.046	1.683	0.082
100	1.633	0.152	1.657	0.104	1.715	0.149	1.785	0.070
120	1.736	0.121	1.736	0.037	1.803	0.126	1.812	0.035
	Riopka Site							
5	1.300	0.000	1.300	0.000	1.300	0.000	1.300	0.000
20	1.458	0.248	1.548	0.117	1.561	0.181	1.608	0.083
40	1.365	0.166	1.468	0.112	1.547	0.092	1.599	0.090
60	1.590	0.112	1.584	0.130	1.653	0.105	1.685	0.148
80	1.668	0.080	1.621	0.186	1.731	0.072	1.719	0.174
100	1.684	0.094	1.642	0.218	1.750	0.104	1.752	0.182
120	1.713	0.163	1.698	0.205	1.761	0.138	1.790	0.177

Bulk density values for the 5 cm depth are those measured in the spring of 1988, and are assumed to be similar between ripped and control throughout the duration of the experiment
S.D. = standard deviation

Table 2.2.5. Soil bulk density in the spring and in the fall of 1989

Depth	Spring				Fall			
	Deep ripped		Control		Deep ripped		Control	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
cm	g/cm³							
Dale Eliason Site								
5	1.250		1.250		1.250		1.250	
25	1.260	0.475	1.625	0.112	1.201	0.287	1.499	0.158
40	1.498	0.058	1.511	0.090	1.382	0.071	1.335	0.126
60	1.636	0.103	1.539	0.119	1.572	0.105	1.437	0.131
80	1.598	0.096	1.438	0.069	1.549	0.145	1.418	0.096
100	1.935	0.688	1.516	0.151	1.602	0.211	1.467	0.156
120	1.960	0.680	1.622	0.159	1.629	0.227	1.564	0.180
Jerry Eliason Site								
5	1.250		1.250		1.300		1.300	
25	1.171	0.290	1.338	0.517	1.289	0.221	1.442	0.167
40	1.479	0.081	1.480	0.136	1.466	0.072	1.400	0.070
60	1.512	0.073	1.507	0.029	1.541	0.057	1.530	0.039
80	1.613	0.076	1.646	0.054	1.612	0.086	1.640	0.094
100	1.618	0.137	1.649	0.138	1.628	0.149	1.936	0.624
120	1.704	0.114	1.749	0.025	1.719	0.139	2.220	0.751
Riopka Site								
5	1.300		1.300		1.300		1.300	
25	1.431	0.227	1.547	0.205	1.459	0.209	1.440	0.113
40	1.418	0.090	1.546	0.097	1.428	0.081	1.492	0.038
60	1.541	0.100	1.531	0.123	1.581	0.023	1.557	0.097
80	1.620	0.037	1.465	0.062	1.610	0.029	1.458	0.002
100	1.641	0.090	1.494	0.155	1.563	0.027	1.464	0.218
120	1.692	0.116	1.539	0.190	1.507		1.513	

Bulk density values for the 5 cm depth are those measured in the spring of 1988, and are assumed to be similar between ripped and control throughout the duration of the experiment
S.D. = standard deviation

Table 2.2.6. Saturated hydraulic conductivity of field samples

Depth	Ripped		Control	
cm	------------ cm/hour ------------			
	Dale Eliason Site			
0-15	7.04	(8.03)	1.04	(1.17)
15-30	0.02	(0.02)	0.56	(0.96)
30-45	0.15	(0.21)	0.15	(0.23)
	Jerry Eliason Site			
0-15	1.30	(0.55)	1.18	(0.80)
15-30	1.37	(1.22)	2.93	(4.85)
30-45	0.49	(0.81)	0.06	(0.07)
	Riopka Site			
0-15	17.29	(28.98)	0.09	(0.12)
15-30	0.01	(0.003)	0.01	(0.002)
30-45	0.06	(0.05)	0.01	(0.002)

Values in brackets are standard deviations from 3 replicates
None of the values for the ripped are significantly different ($P < 5\%$) from those of the control.

Soil-Water Regime

Substantial increases in soil moisture content were indicated by measurements taken with neutron probes between early May and late June of 1989. During this period there were no apparent differences in crop stand between the deep ripped and the control parts of the field. Consequently, the soil-water recharge during this period provided an opportunity to study if deep ripping would increase soil-water recharge with depth.

Soil-water recharge with depth was generally greater in the deep ripped plots compared to that in the control plots, where the recharge was more concentrated closer to the soil surface (Fig. 2.2.5) .

Soil-water depletion with depth during the growing season was not affected by deep ripping (results not shown).

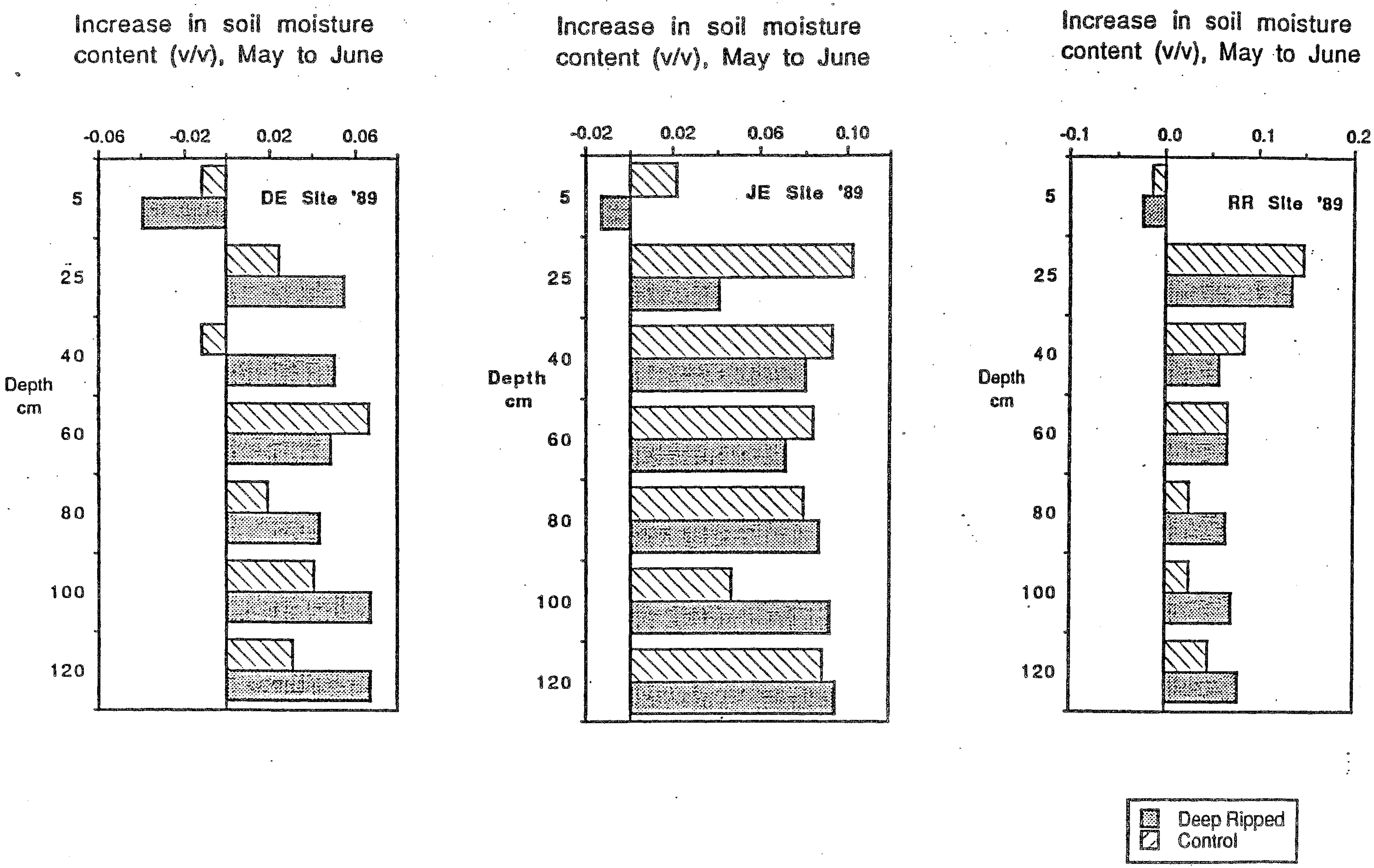

Fig. 2.2.5. Increase in soil moisture content in the deep ripped and the control plots from May 5 to June 25, 1989.

Crop Yields

Crop yields in the first year (1988) following deep ripping were significantly higher in the ripped plots compared to the control plots at the JE site, but not at the other two sites (Table 2.2.7). Crop failure at the DE site and poor weed control at the RR site prevented the crop from reaching its growth potential and possibly prevented the detection of improved soil structure effects on crop yield.

Deep ripping improved the 1989 crop yield at the DE site by 40% (Table 2.2.5). For the other sites, the differences in yield were not statistically different , except for a 35% increase in total yield at the JE site. There were some difficulties with sampling the beans (maturity date) at the JE site. For the RR site, however, it appears that deep ripping is of little value, since no significant yield increases have been found for the first two years following deep ripping. The RR site, on the other hand, did not appear to have a distinct hardpan layer, nor the soil chemical characteristics found in Solonetzic soils, as were apparent for the two other sites.

Work Activities Scheduled for 1990

The 1990 field season represents the final year of data collection for this project. Field monitoring of soil density and soil-water regimes will continue in 1990, and crop yield samples will also be taken at each of the sites. Soil samples will be collected for detailed soil chemical analysis. Questions that will be addressed include: a) whether or not deep ripping resulted in reducing the amount of sodium salts in the Bnt horizon, b) the longevity of changes to soil structure brought about by deep ripping, c) economic feasibility of deep ripping of these soils, and d) the effect of deep ripping on the suitability for irrigation of the three soils.

Table 2.2.7. Crop yields for the 1988 and 1989 growing seasons

Site	Crop	Ripped		Control	
		1988 Growing season			
		Grain yield (kg/ha)			
DE	Lentils	1135		744	
JE	Durum	3312	(1223)	2638	(865)
RR	Wheat	1452	(250)	1457	(339)
		Total yield (kg/ha)			
DE	Lentils	2089		1564	
JE	Durum	7667	(3277)	6392	(1835)
RR	Wheat	1452	(605)	3732	(750)
		1989 Growing season			
		Grain yield (kg/ha)			
DE	Durum	5028	(445)	3608	(415)
JE	Beans	2536	(656)	2201	(380)
RR	Wheat	3246	(464)	3113	(437)
		Total yield (kg/ha)			
DE	Durum	10868	(979)	7483	(802)
JE	Beans	5527	(1618)	4184	(715)
RR	Wheat	7588	(872)	7113	(662)

Values appearing in brackets are standard deviations
For the 1988 growing season at Site DE, only 1 replicate block could be sampled due to crop failure

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References:

Alzubaidi, A and G.R Webster. 1982. Effect of tillage in combination with chemical amendments on reclamation of a solonetzic soil. Can. J. Soil Sci. 62:641-649.

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.

Bowser, W.E. and R.R. Cairns. 1967. Some effects of deep plowing of a Solonetz soil. Can. J. Soil Sci. 47:239-244.

Cairns, R.R. 1961. Some chemical characteristics of a solonetzic soil sequence at Vegreville, Alberta, with regards to possible amelioration. Can. J. Soil Sci. 41:24-34.

Cairns, R.R. and W.E. Bowser. 1977. Solonetzic soils and their management. Publ. 1391. Agric. Can. 37 pp.

Canada Soil Survey Committee. 1978. The Canadian System of Soil Classification. Research Branch, Agriculture Canada. Publication 1646.

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. 1989. The effect of deep ripping and paraplowing on crop production in Saskatchewan, an up-date. Pages 47-54 *In* 1989 Soils and Crops Workshop. University of Saskatchewan, Saskatoon, Sask.

Lavado , A.S. and R.R. Cairns. 1980. Solonetzic soil properties and yields of wheat, oats and barley as affected by deep plowing and deep ripping. Soil & Tillage Res. 1:69-79.

Lickacz, J. 1986. Management of solonetzic soils. Agdex 518-8, Alta Agric., 10 pp.

Riddell, K.M., G.R. Webster and J.C. Hermans. 1988. Effects of dep ripping on chemical and physical properties of a Solonetzic soil in East-Central Alberta. Soil & Tillage Res. 12: 1-12.

Toogood, J.A. and R.R. Cairns. 1978. Solonetzic soils technology and management. Bull. B-78-1 University of Alberta. Edmonton, Alta. 105 pp.