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THE EFFECTS OF DEEP RIPPING AND ORGANIC MATTER AMENDMENTS ON SOILS RECONSTRUCTED AFTER COAL STRIP MINING

BY

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J. CAMERON BATEMAN

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled THE EFFECTS OF DEEP RIPPING AND ORGANIC MATTER AMENDMENTS ON SOILS RECONSTRUCTED AFTER COAL STRIP MINING submitted by J. Cameron Bateman in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN SOIL SCIENCE.

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ABSTRACT

The effects of deep ripping, with and without surface amendments of peat or manure, on soil properties were determined three years after ripping minesoils reconstructed from Solonetzic soil materials at the Highvale coal mine in central Alberta. Deep ripping increased the clay content and plasticity index of the Ap horizon. Penetration resistance (PR) and loss on ignition were reduced significantly, and mean weight diameter of air dry aggregates and exchangeable sodium percentage increased significantly in Ap horizons (0-7.5 cm) of deep-ripped soils. Manure application after ripping (R+M) resulted in a soil texture, consistence, mean weight diameter and size distribution of air-dry aggregates, exchangeable sodium content and loss on ignition of the Ap horizon which were not significantly different from those of the unripped control. In the Ap horizon, peat application after ripping (R+P) significantly increased the sand content compared to ripped only (Ripped) and control soils, and increased the plasticity index compared to control soils.

Isopleths of PR indicated a heterogeneous ripping effect and delineated the extent and distribution of within- and between-rip zones. Soil within the ripped zone at a depth of 20-27.5 cm had lower bulk density, liquid limit, plasticity index, PR, clay content, volumetric water content and lower water retention at 33 and 1500 kPa than adjacent soil in the between-rip zone at the same depth. Reduced soil pH, EC, soluble and exchangeable cations, SAR, cation exchange capacity and loss on ignition were also identified within the ripped zone and are predominantly the result of heterogeneous shattering of the subsoil and mixing with topsoil materials during the ripping operation. Significantly greater soil

water content, and lower PR, soluble sodium and potassium, SAR, exchangeable sodium and ESP were identified at 40-47.5 cm in the within-rip position than adjacent soil in the between-rip position and are likely a result of increased infiltration of water and leaching of ions.

For the soils studied, deep ripping reduced the limitations to crop growth and farming operations in the subsoil but reduced the quality of the seedbed. Special management of the seedbed, such as application of organic amendments, is required for these soils as a result of subsoiling.

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CHAPTER 1 - INTRODUCTION

1.1 Background

Dense subsoil horizons in many soils cause problems for plant growth and management. Slow transmission of water through the subsoil can lead to 'waterlogging' of the A horizon after rainfall and increased runoff causing erosion as well as reduced water availability in the subsoil. Excess water in the A horizon can reduce aeration restricting root growth and reduce soil strength, increasing the potential for rutting and other mechanical damage to the soil during farm operations (Wild, 1988). Dense clay pans can also limit root penetration into the subsoil restricting the effective rooting zone and full utilization of nutrients within the soil. Reduced infiltration and availability of water, combined with a restricted root zone can lead to severe moisture deficiency in mid-summer, especially in arid and semi-arid regions (Mech et al., 1967).

Soils with genetic clay pans, such as Solonetzic soils, also tend to exhibit considerable spatial variability in permeability and other properties resulting in uneven germination and plant growth. This patchy condition can frustrate management activities by causing differential crop response to fertilizer and differential ripening of a crop within a field (Rasmussen et al., 1972). Similar unevenness in crop growth has also been identified in soils with anthropogenic clay pans (Hastie, pers. com. 1990).

Compact subsurface horizons can be pedogenic; as in Solonetzic and some Luvisolic soils, or anthropogenic; as in traffic pans on agricultural soils or as a result of industrial activity such as pipeline construction, oil and gas leases and mining activity. In Alberta, Solonetzic soils occupy approximately 4.3 million ha or roughly 30% of all the arable land in the province. Formation of a clay pan in these soils is a result of the solodization process whereby dispersed colloids are eluviated and accumulate in the Bnt horizon resulting in a very dense and slowly permeable horizon (Pawluk, 1969). Many Luvisolic soils also have a clay pan which, in some cases, is considered a limitation to crop growth (Alberta Environment, 1977). In these soils, through lessivage, clays are peptized by organic acids, leached from a surface mineral horizon and deposited in the Bt horizon by lodgement. In many of these Luvisolic soils, mottling occurs in the Ae horizon, indicating periodic perched water conditions above the Bt horizon.

Industrial activity can also result in soils that have traffic pans which can severely limit agricultural and forestry capability. Repeated traffic during pipeline construction on rights-of-way can cause severe compaction, especially when soils are wet, resulting in a traffic pan which restricts crop growth and yields and causes the soil to behave similarly to soils with pedogenic clay pans (Nova Corporation, 1990). There are over 190,000 ha of land disturbed by oil and gas pipelines in Alberta (Ferguson, pers. com. 1992). Many of these pipelines cross arable agricultural and productive forest lands. Heavy traffic on oil and gas well leases also causes subsoil compaction. Well site activities are often conducted when the soils on the lease site are wet. In Alberta, there are over 140,000 oil and gas lease sites occupying 226,000 ha. In coal mine and tar sands development, soil materials are selectively handled by earth-moving equipment during reclamation. The materials are often handled when they are within their plastic range destroying their inherent structure. Placement of the soil on contoured, mined-out areas in lifts and grading can result in a compact, massive subsoil that restricts water movement. In Alberta, approximately 22,000 ha of land are disturbed by strip-mining activity of which approximately 6700 ha are presently reclaimed (Ferguson, pers. com. 1992.). In total, lands disturbed by pipelines, well sites, coal mines and tar sands operations in Alberta total approximately 438,000 ha with sixty percent located on agricultural lands.

Subsoiling, or deep ripping, as a means of improving soils with dense clay or traffic pans has become increasingly common in the last 10 years. Increased awareness of the impact of agricultural, forestry and other industrial activities on soil quality, and of the importance of soil quality in sustaining the productive capability of the land has increased the need for knowledge of the effects of deep ripping on different soils.

1.2 Review of Literature

The effects of subsoiling as reported in the literature are varied. This is likely due to the different types of subsoiling implements used and soil conditions studied. In the western Great Plains, the largest body of information is related to deep ripping of naturally occurring Solonetzic soils. Considerable research has also been conducted in the corn producing areas of the Atlantic Coastal Plain where tillage pans form as a result of intensive traffic (Cassel and Edwards, 1985). No reports of the effects of deep ripping on minesoils or on severely disturbed soils were found in the literature.

Trouse and Humbert (1956) studied the effects of various field patterns of subsoiling on different soils in Hawaii (Moqula silty clay loam - humic latosol; Wahiawa silty clay - low humic latosol; Hilo silty clay - hydrol humic latosol. Their subsoiler had three, 7.5-cm wide and 91-cm long shanks spaced 112 cm apart. They used the trench and pit method for determining tillage patterns, depths and mean volumes of soil affected by subsoiling. In several hundred subsoiling tests, they repeatedly found a heterogeneous subsoiling pattern with distinct within-rip and between-rip zones. Subsoiling to a depth of 51 cm resulted in a mean tillage depth of 33 cm due to the pattern of shear plane development. When shanks were spaced 112 cm apart, a 46-cm-wide area of undisturbed surface soil remained. Shattering between rips was not common until the spacing of adjacent passes was approximately 30 cm.

Below the depth of shear plane development, plastic flow shear caused the rips to be vertical having compressed walls with increased bulk density. When subsoiling to a depth of 51 cm on different soils, they found no increase in the mean depth of soil affected on soils with increasing bulk density. Also, in contrast to current popular opinion, these researchers found that the volume of soil affected by subsoiling was not appreciably affected by water contents varying between permanent wilting point and field capacity. Crisscrossing with the subsoiler at an angle of 45^{o} resulted in an additional 13 cm in the mean depth of soil affected regardless of soil density or water content. When the second pass of the subsoiler was at 90^{o} to the first, only limited additional shattering was obtained and the incremental thickness of affected soil was approximately 10 cm. When the first two passes were made at 90^{o} from each other and followed by a third pass at either 180^{o} from, or parallel to, a previous pass, an additional 5 cm in the mean thickness of soil affected could be expected as a result of the third pass. These authors suggested that for sugar cane crops, satisfactory shattering usually requires at least eight passes of the subsoiler and that under some soil conditions, many large islands of undisturbed soil remain beneath the soil surface even after as many as 18 passes. This contradicts other reports in the literature of complete and homogeneous working of the soil with a single pass.

Improvement of a Solonetzic soil (Nadurargid) by subsoiling with and without gypsum application was investigated in southwestern Oregon by Rasmussen et al. (1972). A special subsoiling machine was used with fluted, mole-like devices behind each shank. The depth of ripping was 70 cm but the shank spacing was not reported. Composite samples were taken on each plot for analysis without stratification into ripper-shank positions. No difference in water penetration between subsoiled plots and untreated check plots was observed. Also, no change in soil chemical or physical properties were identified between the subsoiled and untreated control. They reported that "the effects of subsoiling with added gypsum on soil chemical properties were erratic and could not be rationally evaluated". They further reported that "apparently the method of compositing samples from several borings masked the effect of any differential leaching over the subsoiled channels". They concluded that subsoiling in combination with gypsum is not much more effective than treatment with gypsum alone and that subsoiling alone is ineffective for improving Na-affected soils.

Cassel et al. (1978) evaluated the variability of mechanical impedance in a Norfolk sandy loam (Typic Paleudult-North Carolina) subsoiled at 91 cm intervals to a depth of 45 cm with 2.5-cm-wide shanks. The soil had a traffic pan 2 to 5 cm thick at a depth of 25 cm. Penetration resistance (PR) was measured four times during the year at seven positions, spaced 15-cm apart on a transect normal to the direction of subsoiling. A position effect was obtained on three of the four sampling dates. PR was significantly lower within the rip compared to between rips at all depths measured. These researchers suggested that lower PR values within the rip at depths of 14-28 cm stem from physical disruption of soil in and near the rip and also from partial filling of the rip with Ap horizon material. At depths of 28 to 41 cm, PR was significantly lower within the ripped zone compared to between rips although gravimetric water content was also less in the ripped zone. The authors suggested that this result indicates that drastic changes in structure have also occurred within the ripped zone at this depth interval. An important component of this study was to demonstrate a procedure that effectively and unambiguously identified statistically significant differences in soil physical properties which occur as a result of tillage treatment, position and depth. The authors concluded that future characterizations of mechanical impedance and other soil properties which are induced or modified by tillage practices which introduce nonhomogeneity of these properties include a sampling strategy which isolates not only tillage effects but also position and depth effects.

Lavado and Cairns (1980) studied the effect of deep ripping on soil properties in two different Brown Solodized Solonetzic (Natric Mollisol) soils in Alberta. At their site #3, a Bnt horizon was present at depths of 10-21 cm and a Csk horizon was present below 21 cm. At their site #4, the Bnt horizon was at depths of 19-37 cm and the Csk horizon was at depths greater than 37 cm. Large plots (30 x 800 m) were ripped on 60 cm spacing and 10 samples taken throughout the length of the plot. A Kello-bilt subsoiler designed to rip to a depth of 60 cm was used. They obtained different results on each of the sites investigated. At site #4, deep ripping resulted in an increase in the extractable sodium, gypsum requirement, clay content, soil hardness and shrinkage and a decrease in the infiltration rate of the Ap horizon. In the Bnt horizon, pH, gypsum requirement, soil hardness and shrinkage increased and extractable Ca levels decreased. No change in the infiltration rate of the Bnt horizon was observed. At site #3, the infiltration rate in the Ap horizon also decreased; however, an increase in this property occurred in the Bnt horizon. The gypsum requirement of the Bnt horizon was also increased in the deep-ripped soils. They concluded that ripping was unsuccessful at site #4 and resulted in poorer soil physical conditions and crop growth due to a Bnt horizon that was deeper than the depth of ripping, greater clay content and narrow Ca:Na ratio. A significant increase in yield was the main criterion for success at the other site.

The response from ripping on sodic, rangeland claypan soils in northwestern South Dakota was investigated at seven different sites by White et al. (1981). Ripping was conducted at spacings of 60 to 120 cm to a depth of 50 cm. The soils were sampled by position relative to the ripped zone a few days following a rainfall event. At two sites, samples were collected from only one within-rip position. At another two sites, samples were collected from only two within-rip positions. Soil water was greater within the ripped zone and the authors suggested that the water content within the ripped zone would have been even greater if a very narrow band of soil could have been sampled in which the soil was visibly very wet. This apparently was not possible with the sampling technique used; however, their comment indicates that the zone of disturbance within the soil which appeared to be affected by the ripper-shank was very narrow. Nowhere else in their study were the sizes of the within-rip zones or the volume of soil affected by the ripping operation described.

Alzubaidi and Webster (1982) studied the effects of chiseling with chemical amendments on selected soil properties of a Duagh loam (Black Solonetz) in east-central Alberta. This soil had a very hard Bnt horizon at depths of 8-25 cm and a Csk horizon at depths of 30-73 cm. Chiseling was done to a depth of 45-48 cm in one direction with a tractor-mounted cultivator equipped with narrow teeth (5 cm wide) spaced 23 cm apart. The plots were chiseled three times in an attempt to physically disturb the Bnt horizon. Plots were sampled randomly at various depths. A significant increase in the sodium adsorption ratio (SAR) and exchangeable sodium percentage occurred in the Ap horizon of the chiseled treatment over that in the control. Below the Ap horizon, differences in the exchangeable sodium percentage between chiseled and control were not significant.

Later, Webster and Nyborg (1986) reported on two sets of plots, one of which was the same as that studied by Alzubaidi and Webster (1982). Contrary to the results of the earlier work, they found that chiseling had no effect on SAR at depth intervals of 0-15 or 15-30 cm at either of the two sites nor at the 30-45 cm depth interval at one of the two sites. At the other site; however, chiseling increased the SAR from 30 to 40 at the 30-45 cm depth. No effect on cloddiness of the seedbed was identified but a greater proportion of soil aggregates less than 6-mm diameter occurred in the seedbed of the chiseled treatment at one of the sites. Chiseling also increased water stable aggregates of the seedbed at this site. Volumetric water content at a depth of 15 cm was increased in late summer as a result of chiseling at one site. Differences in water content of chiseled and normal treatments were not apparent at 15 or 30 cm depths at other times in the growing season.

Cassel and Edwards (1985) studied the effect of subsoiling to a 45-cm depth with 5-cm-wide shanks spaced 95 cm apart on a Wagram loamy sand (fine-loamy, siliceous, thermic Arenic Paleudult) in North Carolina. This soil had a tillage-induced traffic pan, 30-70 mm thick at depths of 25 to 32 cm which restricted root penetration and utilization of water and nutrients in the subsoil. They measured penetration resistance, bulk density and gravimetric water content within the ripped zone and between ripped zones. Tensiometers were used to measure soil water suction at five equally spaced positions (0.24 m apart) on a transect perpendicular to the direction of ripping. Root length and root mass were also measured at five positions on a transect across the direction of ripping. Subsoiling reduced bulk density in the ripped zone from 1.85 to 1.43 Mg m^{-3} and cone index from 6.8 to 2.0 MPa. Soil water suction was greater within the ripped zone to a depth of 60 cm indicating that roots were able to extract water approximately 0.4 m deeper in the subsoiled zone; however, root mass and length were not significantly different between the subsoiled treatment and the control. The distribution of gravimetric water and root mass and length relative to the ripped zone were not reported.

Cassel and Nelson (1985) investigated the effects of subsoiling on the spatial and temporal variability of physical properties in a Norfolk sandy loam (fine-loamy, siliceous, thermic Typic Paleudult) in North Carolina. The soil had a 7-10 cm thick traffic pan at a depth of 25 cm. The subsoiler used had shanks 3 cm wide spaced 91 cm apart and penetrated to a depth of 45 cm. They measured properties at different positions relative to the cropping row at different times in the growing season. A position effect was identified with lower bulk density and penetration resistance and greater saturated hydraulic conductivity within the rip. Bulk density decreased from approximately 1.8 to 1.5 Mg m^{-3}

within the ripped zone at a depth of 28-41 cm. Saturated hydraulic conductivity increased threefold from 2 to 6×10^{-6} m s^{-1} at this depth. These authors suggested that because bulk density varies with distance from the rip line, random measurements of bulk density are of little value. They further suggested that the root system of a plant is not controlled by the average bulk density of an entire field, but rather by the bulk density near the root tip; which varied with position as much as with depth.

Wetter et al. (1987) investigated the effects of subsoiling and lime application on soil chemical and physical properties of an association of Halkirk and Torlea soils (Dark Brown Solodized Solonetz) also in Alberta. These soils had a dense Bnt horizon at a depth of 13-26 cm and a Cca horizon at depths greater than 32 cm. Sampling was conducted three years after ripping on 61-cm centers to a 40-cm depth by collecting paired samples within the zone through which the subsoiler shank had passed and 30.5 cm to the side of the shank zone. Soil properties were not significantly different between shank and intershank zones at any of the depths sampled. However, soil pH and soluble calcium, water retention at 1500 kPa, modulus of rupture and clay content all increased in the Ap horizon as a result of ripping. Clay content increased by 11% (absolute) in the topsoil. In the Bnt and BC horizons, SAR was reduced by deep ripping and greater root penetration was observed. There was also significantly more available water at the 26-38 cm depth in subsoiled plots. The lack of a ripper-shank position effect was thought to be a result of a homogeneous working of the soil during the subsoiling operation because of very dry conditions at the time of subsoiling. These researchers found no evidence that the subsoiled treatments were reverting to their unaltered condition and suggested that subsoiling may provide a more permanent amelioration of the soils studied than was originally believed.

Oussible and Crookston (1987) studied the effects of subsoiling on compact clay loam soils in Morocco. The subsurface horizons of these soils became compacted as a result of heavy traffic on wet, irrigated areas. Ripping was conducted using a single tooth subsoiler at 40-cm spacing to a 70-cm depth. PR and water content were measured on a random sampling pattern that included points directly over, as well as between, the tooth zone of each plot without stratification into these two positions. However, samples were also collected from within the tooth path at the 35-45 cm depth interval and from the center of the "inter-tooth" zone at depth intervals of 0-15, 15-25, 25-35 and 45-60 cm for bulk density and water content determination. These researchers found that the soil bulk density and water content within the inter-tooth zone were the same as those on the check plots. However, a reduction in bulk density from 1.55 to 1.38 Mg m^{-3} was identified within the subsoiler tooth path at the 0.35-0.45 m depth. No difference in soil water content was identified between the two zones. PR was significantly lower in the subsoiled plots at depths between 20 and 35 cm compared to the control. Due to the sampling design, the authors reported "both the subsoiler tooth zone and the inter-tooth zone of subsoiled plots were thus represented in the measurements". They further suggested that "the majority of the soil volume was not directly disrupted by the ripper shank so that most of the PR data is from soil not directly disrupted by the shank". However, they were unable to delineate the proportion of the soil actually affected by deep ripping.

The effects of deep ripping on chemical and physical properties of an association of Halkirk and Torlea soils (Dark Brown Solodized Solonetz) in east central Alberta were studied by Riddell et al. (1988). These soils had a very dense Bnt horizon at a depth of 8.5-22.5 cm and a Csk horizon at a depth of 27.5-40 cm. Shank spacings of 56 and 112 cm were used, and the depth of ripping was between 35 and 45 cm. Sampling was conducted in the center of the disturbed zone created by the ripper shank and 20 cm to one side of these samples. No differences in soil chemical or physical properties were identified between the below-shank and 20-cm-over zones where 56-cm shank spacing was used. In contrast, in areas where 112-cm shank spacing was used, soil pH, electrical conductivity (EC) and clay content were significantly different between positions at various depths in the soil. Soil pH was greater in the below-shank area in the Ap horizon; however, SAR, EC and clay content were not affected. In the Bnt horizon, clay content and pH were significantly greater in the below-shank area than in the 20-cm-over zone. Clay content increased from 20% in the 20-cm-over zone to 30% in the below-shank zone. In the Csk horizon at the 27.5-40 cm depth interval, the clay content and EC of the soil were significantly lower in the below-shank area than in the 20-cm-over zone. EC was 2.8 dS m^{-1} in the below-shank zone, 5.0 dS m^{-1} in the 20-cm-over zone, and 4.0 dS m^{-1} for the corresponding depth in the control. The EC in the control was not significantly different from that in the 20-cm-over zone; however, the authors concluded that the EC increased substantially in the 20-cm-over zone at this depth. A more appropriate interpretation may be that the EC in the 20-cm-over zone was not affected by ripping but was decreased in the below-shank zone either by dilution with topsoil materials or by increased infiltration. Clay content was 5% (absolute) lower in the below-shank zone at the 27.5-40 cm depth interval supporting further the hypothesis that addition of coarser textured surface materials was the means of reducing the EC. Increased water content in the below-shank zone was also identified at depths greater than 25 cm.

1.3 Synthesis

Deep ripping has been shown to reduce the bulk density and PR of the subsoil causing an increase in root penetration, infiltration and utilization of water. In sodic soils, the EC and soluble sodium content have been shown to decrease in portions of the subsoil due to ripping. These changes to subsoil characteristics are favorable and have reduced the limitation to crop growth and management of these soils. However, it has also been shown that clay content, sodicity and crusting potential of the Ap horizon have increased as a result of deep ripping. These changes can be detrimental to the tilth of the seedbed and may require special management practices, such as additions of organic matter, to overcome in the short term.

Reports of differing effects of deep ripping on soil properties result from differing soil conditions and different ripping implements used. The sampling design used by several of the investigators has masked the treatment effect by including the variability in soil properties due to ripper-shank position. This can result in greater variability in soil properties within a deep-ripped treatment than that between a deep-ripped and control treatment. Where sampling designs included stratification of the soil into within-rip and between-rip zones, clear differences in soil properties were identified between the two positions; however, the extent and proportion of the soil represented by each of the two zones have generally not been identified. Consequently, some sampling bias has potentially been introduced. Sampling strategies used to investigate the effects of deep ripping should be designed to not only isolate tillage, position and depth effects, but also to document the areal extent of the effect around the individual shank.

1.4 General Objectives and Thesis Format

The focus of this study was on identification of the effects of subsoiling and surface organic amendments on soils reconstructed with materials from Solonetzic Gray Luvisolic and Gray Solodized Solonetzic soils after coal strip mining at the Highvale coal mine. Subsoiling has been adopted as a means of improving these compact soils, however, specific information on the effect of this practice on reconstructed soils does not exist. The purpose of the study was to identify the degree of change in soil properties that occur as a result of deep ripping and to document the spatial distribution and extent of the effect in the root zone. A third objective was to identify if a change occurs to the seedbed as a result of deep ripping and application of organic amendments and, if so, to quantify the degree of change in soil properties.

The report is divided into four chapters. In Chapter 1, pertinent literature is reviewed and the environmental conditions for the study site are described. The plot establishment technique and experimental design are also described. Chapter 2 focuses on the identification, spatial distribution and extent of changes to soil properties in relation to the original ripper-shank position on deep-ripped soils. Chapter 3 focuses on the effects of deep ripping and application of organic amendments on the seedbed for soil properties which are not affected by ripper-shank position. In this chapter, treatments are compared to a control.

General discussion and conclusions are in Chapter 4.

1.5 Study Area

The study was conducted during 1989 on plots established on reclaimed fields at the Highvale coal mine near Lake Wabamun, approximately 80 km west of Edmonton, Alberta (Sec 34 Twp 52 - Rge 5 - W5). Mean annual precipitation recorded at the Highvale Meteorological Station, 10 km east of the study site, is 540 mm with approximately 79% received in the months of April through September (Table I-1). The area has an average growing season water deficit (precipitation - potential evapotranspiration) of approximately 175 mm (AAAC 1987) characterizing the area as semiarid. Mean daily temperature from 1978 to 1989 was 3.7°C. The average frost-free period is from May 19 to September 11 (104 days) and there is an average of 1340 degree days above 5°C. Growing season precipitation in 1989 was 124% of normal, with greater than normal precipitation in the months of June, July and August.

Underlying the study area are Cretaceous bedrock deposits of the lower Paskapoo Formation. This formation consists of a sequence of continental fluvial sediments which include carbonaceous shales and interbedded argillaceous sandstones, siltstones and shales which overlie several sub bituminous coal seams (Maslowski Shutze, 1987).

Table I-1. Monthly precipitation and temperature for the Highvale Meteorological Station.

Month	Precipitation (mm) 1986	1987	1988	1989	1978-1989 Average	Mean Daily Temperature (°C) 1978-1989 Average
Jan	13	4	9	15	20	-9.8
Feb	14	6	19	12	13	-9.8
Mar	27	24	5	4	24	-2.8
Apr	41	15	11	12	23	5.1
May	44	89	32	104	59	10.9
June	59	48	117	107	82	14.7
July	219	98	127	192	134	16.8
Aug	19	119	72	122	68	15.6
Sept	95	6	41	31	59	10.6
Oct	28	5	2	44	26	6.0
Nov	22	2	7	18	14	-4.2
Dec	4	18	2	11	18	-8.4
Total	585	434	444	672	540	3.7

Source: Environment Canada, Highvale Meteorological Station.

Surficial deposits derived from the Paskapoo and Horseshoe Canyon Formations occur as discontinuous veneers and blankets of level to rolling ground moraine and glaciolacustrine and lacustrine deposits. Outcrops of sandstone, siltstone and clay shale of the Paskapoo Formation occur on steep topography. Large glacially thrusted bedrock blocks comprised of contorted coal seams, carbonaceous shales and other bedrock materials are randomly superimposed on the landscape (Tsui et al., 1989).

Dark Gray and Orthic Gray Luvisols and Gray Solodized Solonetzic soils, as well as intergrades, occur in the study area. Soils belonging to the Uncas, Modeste, Nakamun, Kawood and Wabamun Series predominate (Lindsay and Odynsky, 1968).

1.6 Plot Establishment

The study plots are located on soils reconstructed on mined-out areas in Pit 03 of the Highvale mine. The topography is level to nearly level. In 1984, subsoil materials (B and C horizons) from a soil belonging to the Nakamun Series (Solonetzic Gray Luvisol developed on fine textured till, Appendix A) were placed in lifts of approximately 20-30 cm over contoured minespoil to a total thickness of 1.5 m using large rubber tired earth scrapers (Caterpillar 637E). Topsoil materials (A horizons) were then placed with scrapers over the subsoil to a thickness of 20 cm.

The plots were established in August 1986 and are located within a 112 x 50 m area of a large reclaimed field. The treatments tested were: deep ripping (Ripped), 275 tonnes/ha (dry weight) of surface applied farmyard cattle manure following deep ripping (R+M), and 117 tonnes/ha (dry weight) of surface applied native peat following deep ripping (R+P). Application rates of manure and peat were calculated to increase the organic carbon content in the topsoil to 2.5% (Hardy BBT Ltd. 1986). An unaltered control (Unripped) was also present. Completely randomized sub-plots, 10 x 50 m, were replicated twice for each of the three treatments and the control. Ripping was conducted using a double pass of a Kello-Bilt 5000 series subsoiler powered with a 225 horse power, four wheel drive tractor. Three shanks, 4 cm wide and 152 cm long were spaced at 120 cm. Ripping was along the length of the plots and each pass was offset to result in rip spacings of about 60 cm. The depth of ripping was approximately 40-45 cm. After ripping, the surface was prepared with two passes of a Kello-Bilt Model 225 Wingfold disc. Amendments were then spread uniformly over the surface with a tractor dozer and incorporated with two passes of a John Deere Model 335 finishing double disc parallel to plot length to a depth of approximately 15 cm. The plots were harrowed prior to seeding to a grass-legume forage mixture containing (by weight) 15% alfalfa (Medicago sativa L. c.v. Rambler), 20% creeping red fescue (Festuca rubra L. c.v. Boreal), 10% Timothy (Phleum pratense c.v. Climax), 15% reed canary grass (Phalaris arundinacea L. c.v. Frontier), 25% Canada bluegrass (Poa canadensis c.v. Reubins) and 15% smooth brome (*Bromis inermis* Leyss c.v. Magma). The seed was applied using a Brillion seeder at 22 kg ha^{-1}. Fertilizer was broadcast at 43 kg N ha^{-1} and 45 kg P_2O_5 ha^{-1} shortly after seeding. In 1987 and 1988, the plots were fertilized in the spring with 58 kg N ha^{-1} and 24 kg P_2O_5 ha^{-1}. In 1989, the plots were fertilized with 87, 37, 92, 9 kg ha^{-1} of N, P_2O_5, K_2O and SO_4, respectively, in the spring and with 24 kg N ha^{-1} in the summer after the first cut of hay. The plots were generally cut twice each growing season; in late June-early July and in late August.

1.7 References

Alberta Soils Advisory Committee. 1987. Land Capability Classification for Arable Agriculture in Alberta (1987). Edited by W.W. Pettapiece. Alberta Agriculture. 103 pp, 5 maps.

Alberta Environment. 1977. Canada Land Inventory - Soil Capability for Agriculture in Alberta. Edmonton, AB. 24 pp.

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.

Cassel, D.K., H.D. Bowen, and L.A. Nelson. 1978. An evaluation of mechanical impedance for the tillage treatments on Norfolk sandy loam. Soil Sci. Soc. Am. J. 42:116-120.

Cassel, D.K. and E.C. Edwards. 1985. Effects of subsoiling and irrigation on corn production. Soil Sci. Soc. Am. J. 49:996-1001.

Cassel, D.K. and L.A. Nelson. 1985. Spatial and temporal variability of soil physical properties of Norfolk loamy sand as affected by tillage. Soil and Tillage Res. 5:5-17.

Ferguson, T. 1992. Personal communication. Soil Specialist. Land Conservation and Reclamation Council. Alberta Environment. Edmonton, AB.

Hardy BBT Ltd. 1986. Highvale soil tilth project first annual report. Prepared for TransAlta Utilities Corporation. Calgary, AB.

Hastie, W.J. 1990. Personal communication. Supervisor of reclamation and farm services. TransAlta Utilities Corporation. Calgary, AB.

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

Lindsay, J.D. and W. Odynsky. 1968. Soil survey of the Buck Lake and Wabamun Lake areas. Alberta Soil Survey Report No. 24. University of Alberta. Edmonton, AB.

Maslowski Shutze, A. 1987. Geology of the Highvale study site: Plains hydrology and reclamation project. Alberta Land Conservation and Reclamation Council #RRTAC 87-11. 77 pp. Edmonton, AB.

Mech, S.J., G.M. Horner, L.M. Cox and E.E. Cary. 19[illegible]7. Soil profile modification by backhoe mixing and deep plowing. Am. Soc. Agri. Eng. Paper No. 65-226. St. Joseph, MI.

Nova Corporation. 1990. Soil compaction and pipeline construction. A literature review. Alberta Gas Transmission Division. Environment and Quality Management. Calgary, AB.

Oussible, M. and R.K. Crookston. 1987. Effect of subsoiling a compacted clay loam soil on growth, yield and yield components of wheat. Agron. J. 79:882-886.

Pawluk, S. (ed.) 1969. Notes from the field tour held in conjunction with the symposium May 14, 1969. In: Pedology and Quaternary Research. University of Alberta. Edmonton, AB.

Rasmussen, W.W., D.P. Moore and L.A. Alban. 1972. Improvement of a Solonetzic (slick spot) soil by deep plowing, subsoiling and amendments. Soil Sci. Soc. Amer. Proc. 36:137-142.

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

Trouse, A.C. and R.P Humbert. 1959. Deep tillage in Hawaii: 1. Subsoiling. Soil Sci. 88:150-158.

Tsui, P.C., D.M. Cruden and S. Thomson. 1989. Ice-thrust terrains and glaciotectonic settings in central Alberta. Can. J. Earth Sci. 26:1308-1318.

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. 66:455-470.

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

Webb, C. 1982. The impact of linear developments, resource extraction and industry on the agricultural land base: summary. ECA82-17/IB26. Edmonton, AB. Environment Council of Alberta. 9 pp.

White, E.M., F.R. Gartner and R. Butterfield. 1981. Range claypan soil improvement. Response from furrowing and ripping in northwestern South Dakota. J. Range Manage. 34: 119-125.

Wild, A.(ed.) 1988. Russell's soil conditions and plant growth. 11th edition. Longman Group. London.

CHAPTER 2
THE EFFECT OF RIPPER-SHANK POSITION AND ORGANIC MATTER AMENDMENTS ON DEEP-RIPPED SOILS RECONSTRUCTED AFTER COAL STRIP MINING.

2.1 Objectives

The general objective of this study was to determine the effectiveness of deep ripping with and without organic matter amendments as a means of improving the quality of soils reconstructed after coal strip mining. Specific objectives were to determine the magnitude, spatial distribution and extent of the effect of these practises on soil physical and chemical characteristics within the root zone. The null hypotheses tested were:

1) The effect on soil properties at different depths from deep ripping is not a function of position in the soil relative to the ripper shank.
2) Additions of manure or peat to deep-ripped soils do not affect soil properties within the root zone.

2.2 Materials and Methods

2.2.1 Soil Sampling

Soil sampling was done in September 1989 and consisted of excavating trenches perpendicular to the direction of ripping within each subplot. Trench dimensions were approximately 4-5 m long by 1 m wide by 1.5 m deep. The face of the trench was cleaned using a knife to expose fresh soil undisturbed by excavation and was then stratified into disturbed zones created by the ripper shank (within-rip) and undisturbed zones between the ripper shank positions (between-rip). Identification of the two positions was accomplished using visual observations of color and structure supplemented with probings of the trench face with a knife. Three locations from each zone were randomly selected for sampling within each subplot. Samples were collected from each of the 0-7.5, 20-27.5 and 40-47.5 cm depth intervals from the center of each of the two ripper-shank positions. The 0-7.5 cm interval was selected to be representative of the seedbed and tillage layer of replaced Ap horizon (topsoil) materials. Soil at the 20-27.5 and 40-47.5 cm depths correspond to replaced Btnj, BC and upper Ck horizon (subsoil) materials. The 20-27.5 cm interval was selected to be representative of the subsoil directly beneath the topsoil/subsoil contact and within the depth of ripping. The 40-47.5 cm interval was selected to be representative of the subsoil directly below the depth of ripping. Samples were collected using a double cylinder Uhland core sampler 20 cm distance perpendicular from the cleaned face of the trench (Figure II-1). Samples were placed in plastic bags and sealed for transportation to the laboratory for analysis.

A Rimik cone penetrometer (30° cone, 12.83 mm diameter) was used to determine the penetration resistance (PR) adjacent to each sampling location. Three probings, recording PR at 1.5 cm depth intervals to a depth of 45 cm, were made for each of the three sample locations

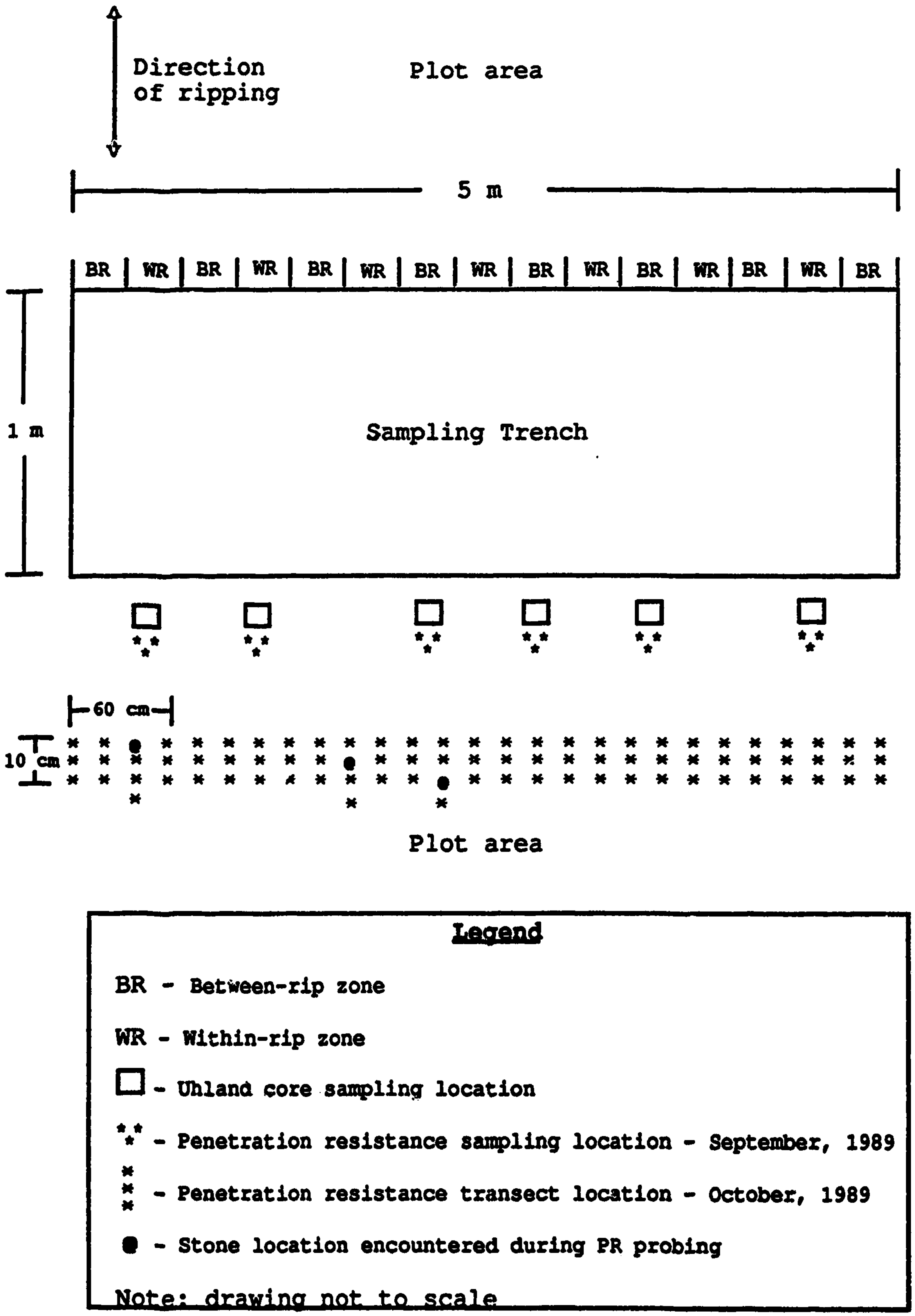


Figure II-1. Schematic diagram (top view) of sampling locations within each subplot.

for each of the two positions within each subplot. Average PR values were then determined for the corresponding Uhland core sampling depths. In October 1989, additional PR readings were taken. Three parallel transects perpendicular to the direction of ripping spaced 5 cm apart were made over the entire length of the trench 3 m away from the trench face (Figure II-1). Individual measurements within a transect were 20 cm apart giving a total of 24 sampling locations within each transect. When a stone was encountered during PR sampling, the data were discarded and an additional probing was made in the same transect position but 5 cm away from the previous probing location (Figure II-1).

2.2.2 Physical and Chemical Analysis

Fresh weights of the Uhland core samples were determined on the day of sampling prior to drying at 105°C to constant weight. After drying, the samples were reweighed and ground to pass a 2 mm round-hole sieve. Mass moisture content was determined gravimetrically. Soil bulk density was determined by dividing the dry sample weight by the volume of the Uhland core sampler. Volumetric water content was calculated using the soil bulk density, mass water content and the standard density of water. Liquid limits were determined on soil samples from the 0-7.5 cm and 20-27.5 cm depth intervals following the one point method of the American Association of State Highway and Transportation Officials (AASHTO 1988a). For accuracy equal to that obtained by the standard three point method, the accepted number of blows for groove closure was restricted to between 22 and 28 blows. At least two groove closures were observed to ensure that the accepted number of blows was truly characteristic of the sample being tested. The liquid limit was then calculated using the formula:

$$(2.1) \qquad \text{Liquid Limit} = Wn\ (N/25)^{0.121}$$

where Wn is the water content at N blows and N is the number of blows required for groove closure.

Plastic limit was determined on each sample from the 0-7.5 cm and 20-27.5 cm depth intervals using methods of AASHTO (1988b). A test sample of approximately 8 g was taken from the thoroughly wet and mixed portion of the soil prepared for the liquid limit procedure. The soil was rolled between a plexiglass sheet and fingers into a thread 3.2 mm diameter and then broken into several pieces and squeezed together. This procedure was repeated until the thread of soil failed under the pressure required for rolling. At that point, the water content was determined by oven drying and taken as the plastic limit. Plasticity index was calculated as the difference between the liquid and plastic limits.

Particle size analysis was conducted using the hydrometer method of Gee and Bauder (1986). All topsoil samples (0-

7.5 cm depth) were pre-treated for removal of organic matter with hydrogen peroxide and heat treatment (90°C). Subsoil samples were pre-treated for the removal of soluble salts and carbonates by washing with water and 1M NaOAC at pH 5.

Water retention by desorption was determined with a pressure plate apparatus for pressures of 33 and 1500 kPa. All ceramic plates were washed with acid and standardized using a control soil prior to use. Only plates that gave consistent results were used for the analysis. Plant available water was calculated as the difference between water contents at 33 and 1500 kPa. All water retention analyses were conducted on ground soil samples.

Soil pH was determined using a glass electrode pH meter in a 1:2 soil water mixture. Electrical conductivity (EC) and soluble cations (Ca, Mg, Na, and K) were determined from saturation extracts using a YSI Model 31 Conductivity Bridge and atomic absorption spectroscopy, respectively. Sodium adsorption ratio (SAR) was calculated using the formula:

$$SAR = \sqrt{\frac{Na}{\frac{Ca+Mg}{2}}} \qquad (2.2)$$

where Na, Ca and Mg are soluble ion concentrations in meq/L. Cation exchange capacity (CEC) was determined by the NH_4OAc method in which displaced NH_4 is measured at pH 7 with a colorimeter. Extractable cations (Ca, Mg, Na and

K) were determined by atomic absorption spectroscopy. Exchangeable cation concentrations were calculated following the procedure described in Handbook 60 (U.S. Dept Agriculture, 1954). Exchangeable sodium percentage (ESP) was calculated from the values of exchangeable Na^+ and divided by the CEC. Loss on ignition was determined by dry combustion in a Leco induction furnace.

2.2.3 Statistical Procedures

Soil physical and chemical data were analyzed statistically to determine ripper-shank position (within-rip, between-rip) and treatment (Ripped, R+P, R+M) effects for each sampling depth. Data from the control treatment were excluded from this statistical analysis because stratification and sampling of the two shank positions in the control was not possible. Appropriate statistical comparisons with the control are made in Chapter 3. The general linear models procedure (GLM) of the Statistical Analysis System (SAS Institute Inc., 1987) was used to perform a two-way analysis of variance (ANOVA). If F values for positions or treatments were significant ($P \leq 0.10$), comparisons of means were conducted using the least significant difference test with respective valid errors of the mean. Where the interaction between position and treatment was significant, comparisons of the two shank-position means within each treatment were conducted using the PDIFF option of LSMEANS statement in the GLM procedure (SAS

Institute Inc., 1987). In addition to the above analysis, PR data for each treatment were analyzed using a one-way analysis of variance for ripper-shank position effects for each 1.5 cm sampling interval. PR data from the three parallel transects within each subplot were also interpolated using an inverse distance squared weighted averaging technique to delineate the distribution of this property in two dimensions through the soil profile.

2.3 Results and Discussion

2.3.1 Physical Properties

In the unripped and unamended control treatment, the topsoil was a low to medium plastic clay loam and the subsoil a highly plastic clay (Table II-1). Mean soil bulk density was 1.12 Mg m^{-3} in the topsoil and increased with depth to a maximum of 1.42 Mg m^{-3} in the 40-47.5 cm depth interval. The topsoil had 39% clay content which is very close to the critical value of 40% required for a clay texture by the Agriculture Canada Expert Committee on Soil Survey (1987). Clay content in the subsoil was 46.4 and 47.0% in the 20-27.5 and 40-47.5 cm depth intervals, respectively. At the time of sampling, soil water content was approximately at the middle of the plant available range and increased with depth. Water contents at both 33 and 1500 kPa were lower for topsoil materials than for subsoil. There also was a narrower range of plant available water in topsoil than in the subsoil materials. Average PR at the time of sampling was 1861, 1531 and

Table II-1. Physical properties† of soils in the control plots (unripped, unamended) after growing hay for three years.

Depth (cm)	Bulk Density (Mg m^{-3})	Consistence: Liquid Limit (%)	Consistence: Plastic Limit (%)	Consistence: Plasticity Index (%)	Particle Size: Sand (%)	Particle Size: Silt (%)	Particle Size: Clay (%)	Texture
0 - 7.5	1.12 ± 0.07	40.8 ± 0.8	27.7 ± 0.8	13.1 ± 0.7	22.1 ± 1.1	38.8 ± 1.4	39.1 ± 1.2	CL
20 - 27.5	1.33 ± 0.13	51.1 ± 2.6	23.9 ± 1.2	27.2 ± 1.8	22.3 ± 5.6	31.3 ± 2.3	46.4 ± 3.9	C
40 - 47.7	1.42 ± 0.04				21.4 ± 2.8	31.5 ± 2.6	47.0 ± 1.7	C

Depth (cm)	Soil Water (g g^{-1} x 100)	Soil Water (cm^3 cm^{-3} x 100)	Water Retention: 33 kPa (g g^{-1} x 100)	Water Retention: 1500 kPa (g g^{-1} x 100)	Water Retention: Plant Available Water (g g^{-1} x 100)	Penetration Resistance * (kPa)	Penetration Resistance ** (kPa)
0 - 7.5	23.9 ± 1.9	26.8 ± 2.9	31.6 ± 1.9	16.8 ± 2.4	14.8 ± 1.7	1861 ± 691	919 ± 409
20 - 27.5	27.8 ± 2.0	36.9 ± 4.6	39.0 ± 3.6	19.5 ± 1.4	19.5 ± 2.8	1531 ± 371	1319 ± 446
40 - 47.7	29.2 ± 1.9	41.4 ± 3.0	40.5 ± 2.5	21.2 ± 1.4	19.3 ± 1.5	2044 ± 620	2161 ± 550

† Values are mean ± standard deviation, n=6 unless otherwise stated.
* n=60, readings taken in September, 1989, at the time of soil sampling.
** n=40, readings taken in October, 1989.

2044 kPa for the 0-7.5, 20-27.5 and 40-47.5 cm depth intervals, respectively. The higher value obtained for topsoil is likely a result of lower water content. Average PR in October was lower than that in September at the surface and at the 20-27.5 cm depth interval. Water content was not determined with the October PR readings; however, the soil water content at the surface was noticeably greater than in September.

For the initial PR sampling in September, a rapid increase from the surface to the maximum value of 2250 kPa at a depth of only 4.5 cm was obtained in the topsoil (Figure II-2a). At depths below 4.5 cm, PR values decreased slightly with increasing depth to the subsoil contact and then increased slightly at greater depths. In October, PR values were generally lower in the topsoil and in the first 15 cm of subsoil but similar to the September readings below 35 cm depth (Figure II-2b). Greater variability in PR near the topsoil-subsoil contact was evident in October.

Contour diagrams of PR from the two subplots of the control treatment show the distribution of this property through the soil profile (Figure II-3). For both subplots, PR values of 1100 kPa were common within 15 cm from the surface. PR values in the range of 1100 to 1700 kPa occurred throughout the majority of the soil profile. Isolated areas exceeding 1700 kPa also occurred.

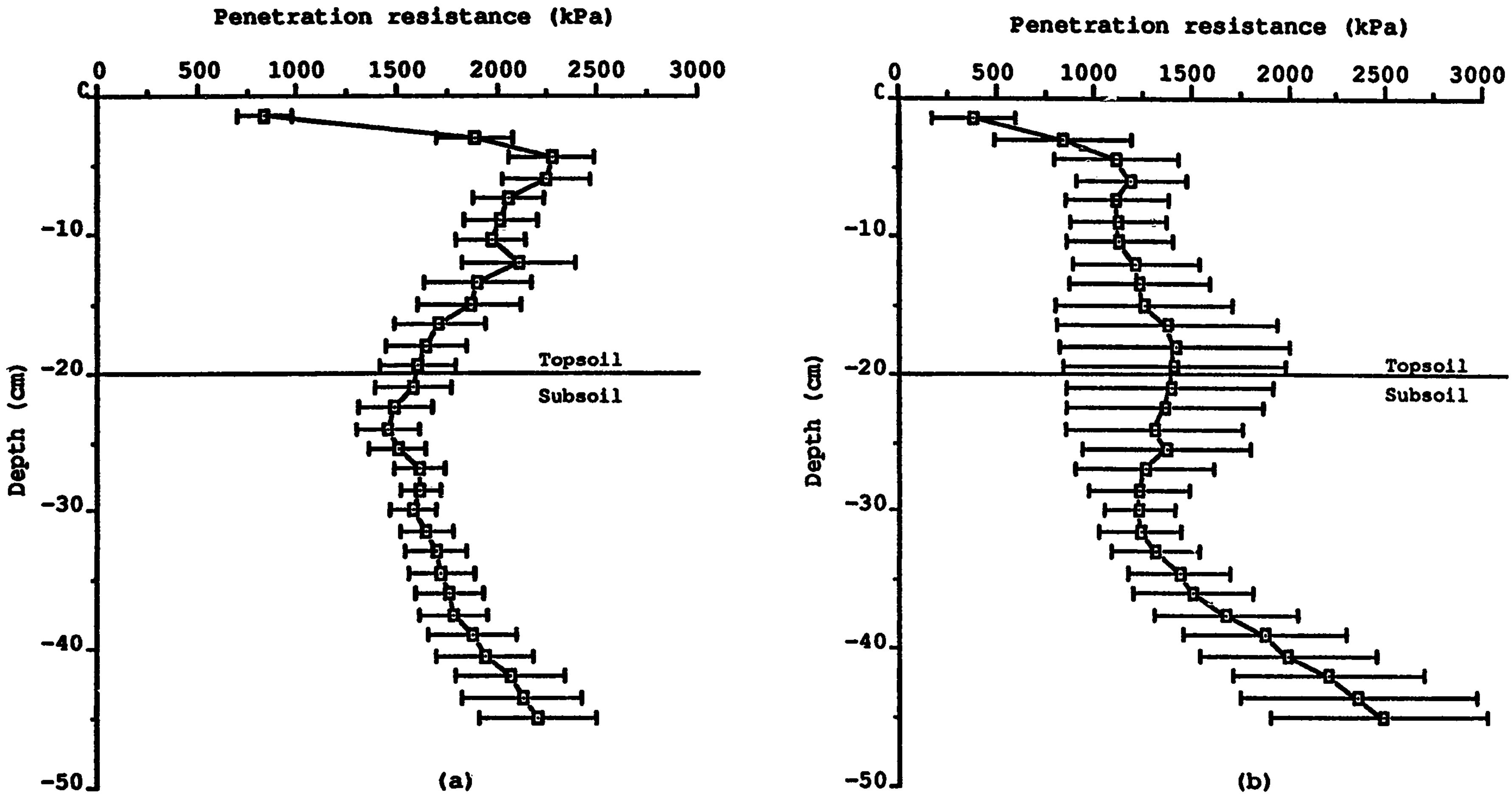


Figure II-2. Variation in penetration resistance (mean + std. dev.) for the control (unripped, unamended) treatment (a=September 1989, b=October 1989, n=6).

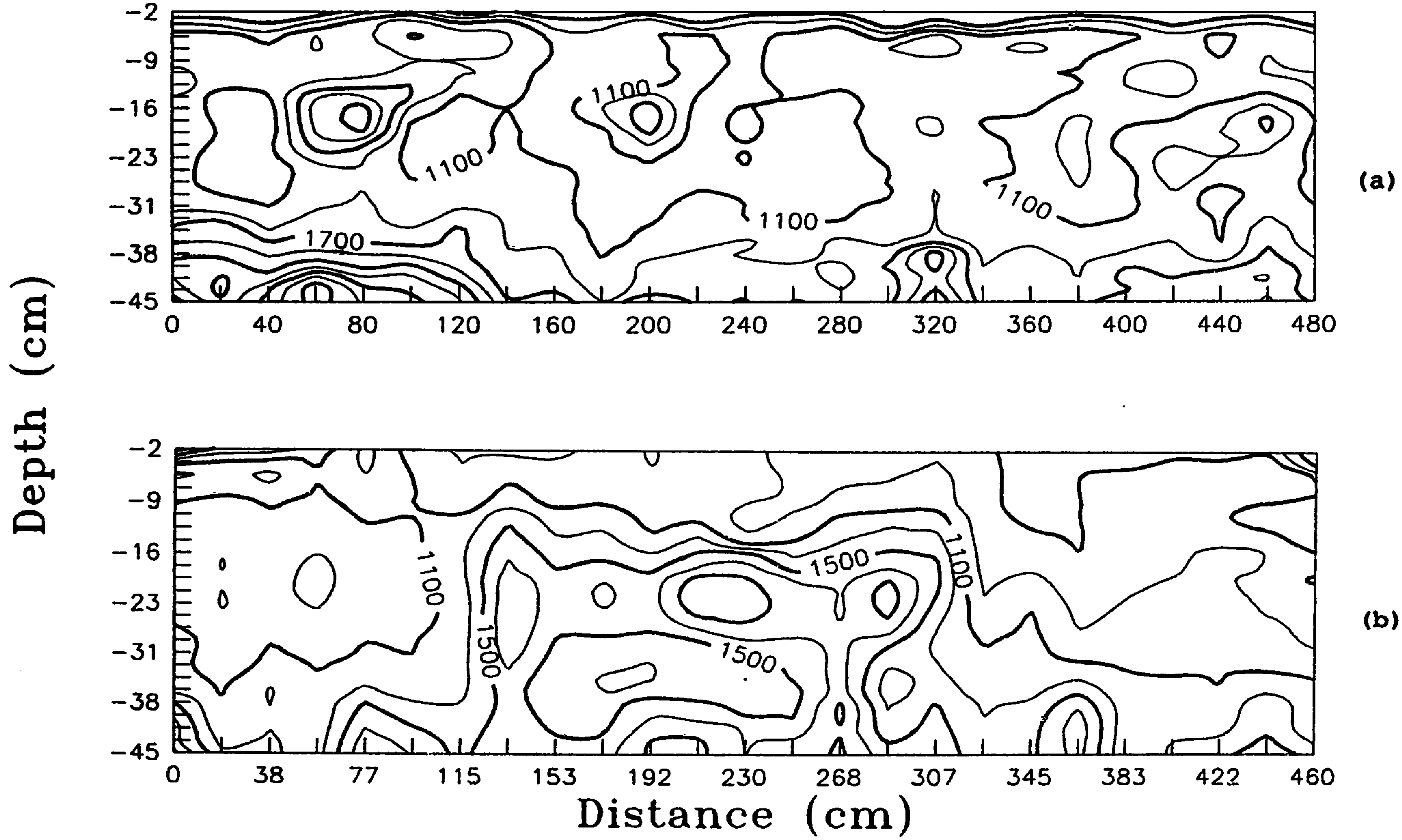


Figure II-3. Penetration resistance isolines (kPa) from the two subplots of the control treatment (n=2250 for a, 2160 for b).

In the topsoil layer, treatment effects are more prevalent than shank-position effects. Significant treatment effects were identified for plasticity index, silt and clay content and October PR values (Table II-2).

Deep ripping with manure application resulted in a lower plasticity index and a greater silt content than ripping alone or with peat. Clay content in the surface soil was significantly greater in the Ripped treatment than in either of the other treatments where an amendment was applied. PR values for the October sampling were not significantly different between the peat and manure treatments; however, ripping alone resulted in significantly lower penetration resistance in the 0-7.5 cm depth interval.

The surface soil of the R+M treatment remained in a plastic state over a narrower range of water contents than soils of the Ripped or R+P treatments as evidenced by a lower plasticity index. Lower clay contents in surface soil of the R+M and R+P treatments are likely a result of dilution of the clay content in the soil with silt and sand sized particles added to the soil with the manure and peat, respectively.

Some trends in physical properties were also evident. Soils of the R+P treatment tended to have greater sand content than the other treatments; however, the differences were not significant (Table II-2). There was

Table II-2. The effect of ripper shank position and treatment on physical properties† of replaced topsoil (0 - 7.5 cm).

Treatment	Bulk Density ($Mg\ m^{-3}$)			Liquid Limit (%)			Plastic Limit (%)			Plasticity Index (%)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	1.13	1.18	1.15	45.7	42.7	44.2	27.0	24.0	25.5	18.7	18.7	18.7a
R+M	0.87	0.94	0.90	47.4	45.6	46.5	34.9	33.0	33.9	12.5	12.6	12.6b
R+P	1.02	0.96	0.99	47.0	47.0	47.0	28.8	29.5	29.1	18.2	17.6	17.9a
Position Mean	1.00	1.03		46.7	45.1		30.2	28.8		16.5	16.3	

Treatment	Sand (%)			Silt (%)			Clay (%)			Soil Water ($g\ g^{-1}$ x 100)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	21.3	22.2	21.8	34.2	34.7	34.5 b	44.5A	43.1A	43.8 a	25.0	22.6	23.8
R+M	24.9	23.5	24.2	38.6	38.0	38.3 a	36.5B	38.5A	37.5 b	28.9	28.8	28.8
R+P	27.0	27.7	27.4	32.3	32.7	32.5 b	40.6 A	39.5A	40.1 b	32.4	32.1	32.3
Position Mean	24.4	24.5		35.0	35.2		40.6	40.4		28.8	27.8	

† Values are means, n=6 unless otherwise stated.
a, b Treatment means within columns followed by the same letter do not differ significantly (P≤0.10) as determined by ANOVA and the least significant difference test.
A,B Position and treatment x position means within rows followed by the same letter do not differ significantly (P≤0.10) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

Table II-2. Cont'd.

Treatment	Soil Water (cm^3 cm^{-3} x 100)			Soil Water @ 33kPa (g g^{-1}x100)			Soil Water @ 1500kPa (g g^{-1}x100)			Plant Available Water (g g^{-1}x100)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	28.1	26.7	27.4	31.5	30.9	31.2	16.6	15.3	16.0	14.9	15.5	15.2
R+M	24.6	26.6	25.6	34.1	32.0	33.0	16.0	15.9	16.0	18.1	16.0	17.1
R+P	32.9	30.3	31.6	33.2	31.3	32.2	17.6	16.7	17.2	15.6	14.5	15.1
Position Mean	28.5	27.9		32.9	31.4		16.7 A	16.0 B		16.2	15.4	

Treatment	Penetration Resistance (kPa)*			Penetration Resistance (kPa)**		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	1108	1467	1287	362	416	389b
R+M	1153	1295	1224	604	632	618a
R+P	1054	1143	1099	609	639	624a
Position Mean	1105	1302		525	562	

† Values are means, n=6 unless otherwise stated.
* n=60, readings taken in September 1989 at the time of soil sampling.
** n=40, readings taken in October 1989.
a, b Treatment means within columns followed by the same letter do not differ significantly ($P \leq 0.10$) as determined by ANOVA and the least significant difference test.
A,B Position and treatment x position means within rows followed by the same letter do not differ significantly ($P \leq 0.10$) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

also a tendency for the Ripped treatment to have higher bulk density than the two treatments where organic amendments were applied, however, differences between treatments were again not statistically significant. Both liquid and plastic limits in topsoil of the Ripped treatment tended to be lower than in the other two treatments, likely due to the greater clay and lower organic matter content of the topsoil in the Ripped treatment. Soil water content tended to be greater and PR (September) lower in the surface soil of the R+P treatment although not significantly.

Differences in physical properties of the surface soil relative to the ripper-shank position were not significant with the exception of soil water at 1500 kPa which was greater in the within-rip position. PR values tended to be lower in the within-rip position for both sampling periods, however, differences were not statistically significant.

The lack of difference in soil physical properties between the two ripper-shank positions in the surface soil is likely a result of tillage after deep ripping and application of amendments. Tillage of the soil with discs and harrows for seedbed preparation would re-homogenize the surface soil and mask position effects. Application and incorporation of manure and peat following ripping would also ameliorate any variation in soil characteristics due to ripper-shank position.

For the 20-27.5 cm depth interval, treatment effects were not significant for any of the soil physical properties determined except mass water content and PR in October (Table II-3). Mass water content of the R+P treatment was significantly greater than that of the R+M treatment. When expressed on a volumetric basis, however, the difference in soil water content between these two treatments was not significant. PR in October was significantly greater in the R+M treatment than in the other two treatments.

The lack of significant differences between treatments at the 20-27.5 cm depth interval is likely because manure and peat were added to the surface after deep ripping. Incorporation of the amendments and tillage would have the largest effect at the surface. Below this zone, all three of the ripped treatments were essentially similar. Variation in soil physical properties in the 20-27.5 cm depth interval is related more to ripper-shank position than to surface soil amendment.

All of the physical properties determined except plastic limit, mass water content and plant available water were affected by ripper-shank position (Table II-3). Soil bulk density and PR, in particular, were lower within the ripped zone. A significant difference in the particle size distribution was also apparent between the two

Table II-3. The effect of ripper shank position and treatment on physical properties† of replaced subsoil (20 - 27.5 cm).

Treatment	Bulk Density ($Mg\ m^{-3}$)			Liquid Limit (%)			Plastic Limit (%)			Plasticity Index (%)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	1.14	1.34	1.24	40.0	49.4	44.7	24.9	23.9	24.4	15.1	25.4	20.3
R+M	1.18	1.46	1.32	44.1	50.5	47.3	26.8	24.8	25.8	17.4	25.7	21.5
R+P	1.18	1.28	1.23	42.0	53.2	47.6	23.9	24.6	24.2	18.1	28.6	23.4
Position Mean	1.17B	1.36A		42.1 B	51.0 A		25.2	24.4		16.9 B	26.6 A	

Treatment	Sand (%)			Silt (%)			Clay (%)			Soil Water ($g\ g^{-1} \times 100$)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	29.9	21.0	25.4	40.0	34.2	37.1	30.1	44.8	37.4	29.0	27.5	28.3 ab
R+M	25.7	21.6	23.6	38.6	34.2	36.4	35.7	44.3	40.0	26.4	25.9	26.1 b
R+P	27.5	21.1	24.3	39.0	31.4	35.2	33.5	47.4	40.5	29.9	29.4	29.6 a
Position Mean	27.7 A	21.2 B		39.2 A	33.3 B		33.1 B	45.5 A		28.4	27.6	

† values are means, n=6 unless otherwise stated.
a, b Treatment means within columns followed by the same letter do not differ significantly (P>0.10) as determined by ANOVA and the least significant difference test.
A,B Position and treatment x position means within rows followed by the same letter do not differ significantly (P>0.10) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

Table II-3. Cont'd.

Treatment	Soil Water ($cm^3\ cm^{-3}$ x 100)			Soil Water @ 33kPa ($g\ g^{-1}$x100)			Soil Water @ 1500kPa ($g\ g^{-1}$x100)			Plant Available Water ($g\ g^{-1}$x100)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	32.9	36.9	34.9	30.2	35.7	33.0	14.0	18.2	16.1	16.2	17.5	16.9
R+M	31.0	37.8	34.4	34.5	37.1	35.8	16.1	18.9	17.5	18.4	18.3	18.4
R+P	35.2	37.3	36.3	32.2	38.2	35.2	15.3	19.3	17.3	16.9	18.9	17.9
Position Mean	33.0 B	37.3 A		32.3 B	37.0 A		15.1 B	18.8 A		17.2	18.2	

Treatment	Penetration Resistance (kPa)*			Penetration Resistance (kPa)**		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	[illegible]	1903	1490	526	973	750b
R+M	1321	1778	1550	868	1611	1240a
R+P	949	1085	1017	803	1006	905b
Position Mean	1115 B	1589 A		732B	1197A	

† values are means, n=6 unless otherwise stated.
* n=60, readings taken in September 1989 at the time of soil sampling.
** n=40, readings taken in October 1989.
a, b Treatment means within columns followed by the same letter do not differ significantly (P>0.10) as determined by ANOVA and the least significant difference test.
A,B Position and treatment x position means within rows followed by the same letter do not differ significantly (P>0.10) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

positions with greater sand and silt contents and lower clay contents in the within-rip position. The liquid limit and plasticity index were also both significantly lower in the within-rip position. Mass water contents were similar between the two ripper-shank positions, however, the volumetric water content was significantly greater in the between-rip position due largely to the differences in soil bulk density. Water retention at both 33 and 1500 kPa was lower in within-rip positions, although the plant available water range was similar for both positions.

Changes in soil properties in the within-rip position at this depth are likely due, in part, to mechanical mixing of topsoil and subsoil materials within the zone of disturbance. The changes identified in soil particle size, for instance, could only occur through the addition of coarser textured materials though mixing. This change in soil texture is a fundamental change in soil characteristics and can likely be considered as a permanent effect of deep ripping.

Riddell et al. (1988) also identified an effect of shank position on clay content. These researchers identified an increase in clay content within the ripper-shank zone at an 8.5-22.5 cm depth and a corresponding decrease in clay content at a depth of 27.5-40 cm. No change in clay content was identified in the 22.5-27.5 cm depth interval.

They suggested that clay was lifted from the lower position of the soil profile to the 8.5-22.5 cm depth interval thereby decreasing the clay content at depth and increasing the clay content in the 8.5-22.5 cm depth interval. However, it is unlikely that only the clay-sized particles were lifted from the 27.5-40 cm depth interval. It is more likely that decreased clay content at depth results from the addition of coarser textured surface materials from above.

In the current study, it was also evident that clay content within the ripped zone had been altered, however, it was within the 20-27.5 cm depth interval where the largest alteration of textures has occurred. At this depth, the cause is likely in-filling from above rather than lifting from below. This in-filling of topsoil from the surface may occur to some degree during both the ripping operation and subsequent discing where topsoil materials could be dragged across the opening in the soil resulting from the subsoiling operation.

Lower bulk densities and PR within the ripped zone would have a favourable effect on plant growth. Assuming a soil particle density of 2.65 Mg m^{-3}, average porosity within the ripped zone was 55.8% compared to 48.6% in the between-rip position. This increase in soil porosity within the rip would affect water and gas movement in the soil as well as pore size distribution and water retention characteristics. Lower clay content and increased sand, combined with reduced bulk density, within the rips indicate an increase in the number of larger pores within the soil. This would result in greater hydraulic conductivity when the soil is wet and improved drainage or lower water content at field capacity. This is supported by the water retention results even though disturbed samples were used. Lower water content in within-rip zones at 33 kPa indicates a greater proportion of larger pores and improved drainage after major rainfall events. The lower water contents obtained at 1500 kPa in within-rip zones indicate a smaller number of small pores where water is held more effectively at high suction impeding free drainage. The noted changes in water retention characteristics are related, to a large degree, to the soil texture and can, therefore, be considered permanent. Changes in soil structure and bulk density that occurred within the ripped zone will also affect water retention characteristics. These properties, however, are less likely to be permanent in the soil due to the potental for subsequent compaction from traffic.

The occurrence of a ripper-shank position effect on soil physical properties denotes a heterogeneous working of the soil during subsoiling. In a study by Wetter et al. (1987), differences in soil properties between shank and intershank zones were not identified. These researchers attributed this finding to a homogeneous working of the soil due to very dry conditions at the time of subsoiling and narrow shank spacings (61 cm). Riddell et al. (1988), however, identified differences in soil properties due to ripper-shank position with shank spacings of 112 cm but not with 56 cm shank spacings. In these two studies, the soils investigated were naturally occurring Dark Brown Solodized Solonetz soils with well defined, coarse, columnar structure in the Bnt horizon. Such soils would be expected to behave differently than the very weakly structured, more massive subsoil materials of the current study. The extent of shattering and mechanical disturbance would be expected to be greater in soils with strong, coarse structure in the B horizon than in soils with very weak or massive B horizon structure.

Soil water content during the subsoiling operation may also affect the degree of shattering around the ripper shank (Wild, 1988). In the study of Wetter et al. (1988), the soil water content on a dry weight basis of the Bnt horizon was 18%. The authors suggested that the lack of differences in soil properties between shank positions is due to dry soil conditions at the time of subsoiling. Riddell et al. (1988) also attributed the lack or presence of a shank-position effect to soil water content at the time of subsoiling. However, in their study, a shank-position effect was identified when soil conditions were dry during ripping and not identified when the soil was wet. This is likely because shank spacings of 112 cm were used for the dry soil which may be too wide to result in a homogenous ripping effect. In the current study, specific water contents at the time of ripping are not known, however, it is unlikely that the soil was dry due to the climatic conditions at the site, the field cropping history and soil drainage characteristics. It is interesting to note that in one of the most comprehensive published reviews on deep ripping, (Trouse and Humbert, 1956) it is reported that the volume of soil affected by subsoiling was not appreciably affected by water contents between permanant wilting point and field capacity.

Treatment effects on soil physical properties were not significant at the 40-47.5 cm depth interval, but shank-position effects were identified for mass water content and PR (Table II-4). Mass water content was significantly greater and PR significantly lower in the within-rip position. A significant treatment x shank-position interaction was identified for silt content. A greater silt content was identified in the within-rip position compared to the between-rip position for the R+M treatment. A trend was also apparent for lower bulk density, greater sand and lower clay content in the within-rip position for the R+M treatment.

Greater soil water content in the within-rip position may be a result of increased porosity and water infiltration

Table II-4. The effect of ripper shank position and treatment on physical properties† of replaced subsoil (40 - 47.5 cm).

Treatment	Bulk Density ($Mg\ m^{-3}$)			Sand (%)			Silt (%)			Clay (%)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	1.35	1.36	1.36	20.0	19.0	19.5	32.7A	34.1A	33.4	47.3	46.9	47.1
R+M	1.29	1.44	1.37	22.0	20.6	21.3	34.8A	30.4B	32.6	43.3	49.0	46.1
R+P	1.33	1.32	1.33	19.7	17.6	18.6	31.5A	31.9A	31.7	48.8	50.5	49.7
Position Mean	1.32	1.37		20.6	19.1		33.0	32.1		46.5	48.8	

Treatment	Soil Water ($g\ g^{-1}$ x 100)			Soil Water ($cm^3\ cm^{-3}$ x 100)			Soil Water @ 33kPa ($g\ g^{-1}$x100)			Soil Water @ 1500kPa ($g\ g^{-1}$x100)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip Line	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	30.2	28.3	29.2	40.7	38.4	39.5	37.7	38.1	37.9	19.3	19.6	19.4
R+M	31.0	28.6	29.8	40.0	40.9	40.5	39.8	40.4	40.1	19.6	20.7	20.1
R+P	30.9	29.7	30.3	41.1	39.1	40.1	39.4	39.4	39.4	22.0	20.4	21.2
Position Mean	30.7A	28.9B		40.6	39.5		39.0	39.3		20.3	20.2	

† values are means, n=6 unless otherwise stated.
a, b Treatment means within columns followed by the same letter do not differ significantly (P=0.10) as determined by ANOVA and the least significant difference test.
A,B Position and treatment x position means within rows followed by the same letter do not differ significantly (P=0.10) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

Table II-4. Cont'd.

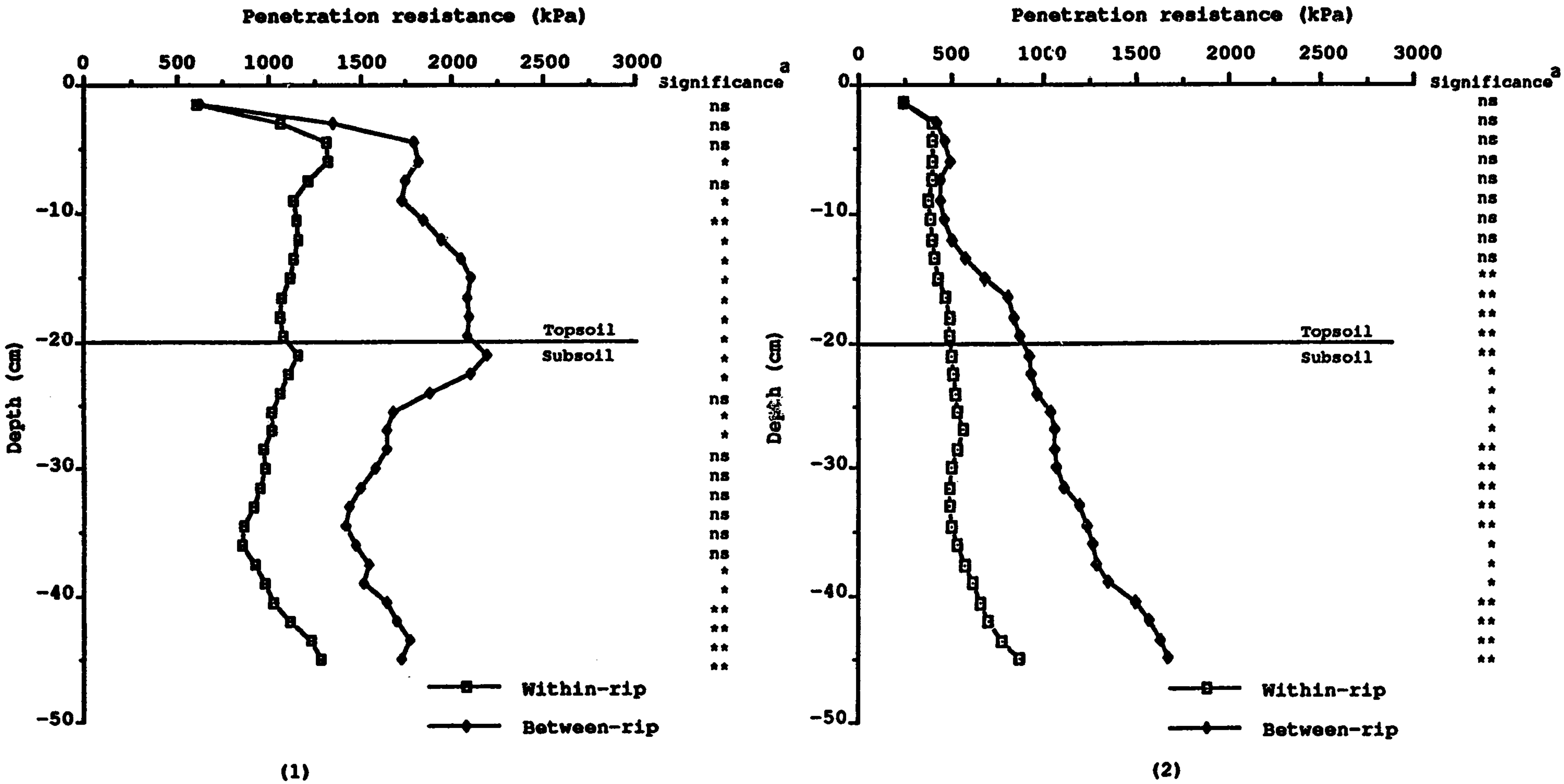
Treatment	Plant Available Water ($g\ g^{-1}x100$)			Penetration Resistance (kPa) *			Penetration Resistance (kPa)**		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	18.3	18.6	18.4	1133	1675	1404	720	1588	1154
R+M	20.3	19.7	20.0	1175	1611	1393	817	1883	1350
R+P	17.5	18.9	18.2	1257	1391	1324	873	1459	1166
Position Mean	18.7	19.1		1188 B	1559 A		803B	1643A	

† values are means, n=6 unless otherwise stated.
* n=60, readings taken in September 1989 at the time of soil sampling.
**n=40 readings taken in October 1989.
a, b Treatment means within columns followed by the same letter do not differ significantly (P=0.10) as determined by ANOVA and the least significant difference test.
A,B Position and treatment x position means within rows followed by the same letter do not differ significantly (P=0.10) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

in the ripped zone immediately above the 40-47.5 cm depth interval. Greater soil water content within the ripped zone would also result in lower PR values at this depth interval. Greater soil water content within the ripper-shank zone compared to between rips was also identified by Riddell et al. (1988). In that study, differences in soil water content between shank positions increased with depth in the soil to a maximum at the 35-40 cm depth interval. Wetter et al. (1987) found that differences in soil water content between shank and intershank zones were not significant at all depths.

Shank position effects were less prominent for the 40-47.5 cm depth interval than for the 20-27.5 cm interval, likely because the depth of ripping was generally 40 cm. For the R+M treatment, however, it was noted that two of three samples collected from one of the subplots were within the zone of ripping. In this subplot, mechanical disturbance occurred to a depth of 50 cm in some of the within-rip positions. The trends identified in texture and soil bulk density between the two positions were likely due to the greater depth of ripping in the areas sampled in this treatment than in the Ripped and R+P treatments.

In the Ripped treatment, significant differences in PR between ripper-shank positions occurred in both topsoil and subsoil for the September readings and predominantly in the subsoil for the October readings (Figure II-4). No



a- Results of Student's t comparison of means
ns - no significant difference
* - Difference between positions significant at 10% level
** - Difference between positions significant at 5% level

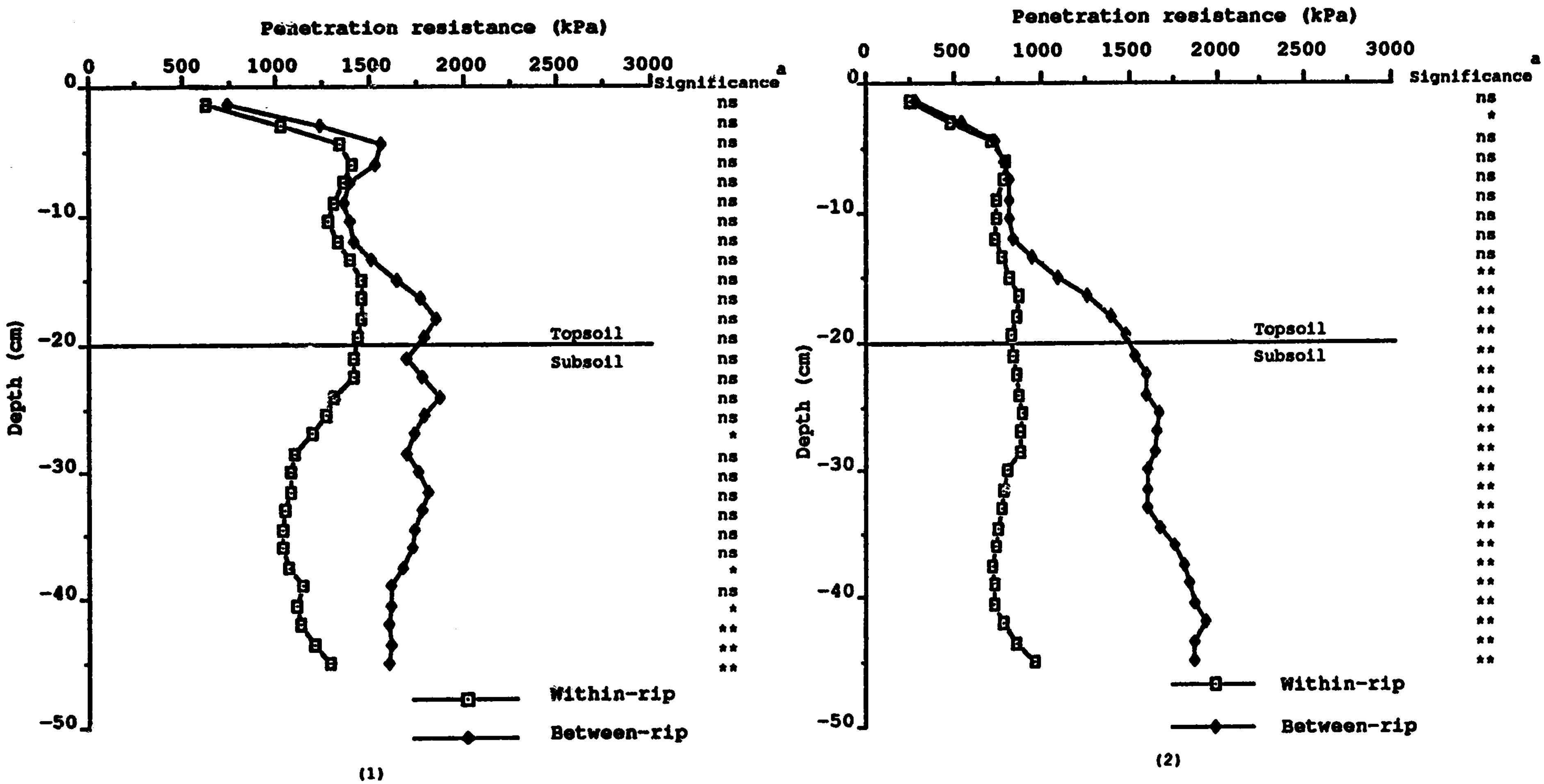
Figure II-4. Comparison of penetration resistance between ripper-shank positions for the Ripped treatment (1=September, 2=October, n=6).

significant differences were obtained between positions at depths of 30-38 cm for readings taken in September; however, there is a trend for greater values between rips.

Similar differences between ripper-shank positions are evident for the R+M treatment (Figure II-5). Significant differences between positions were obtained at more depths in October and the greatest difference between positions occurred in the subsoil.

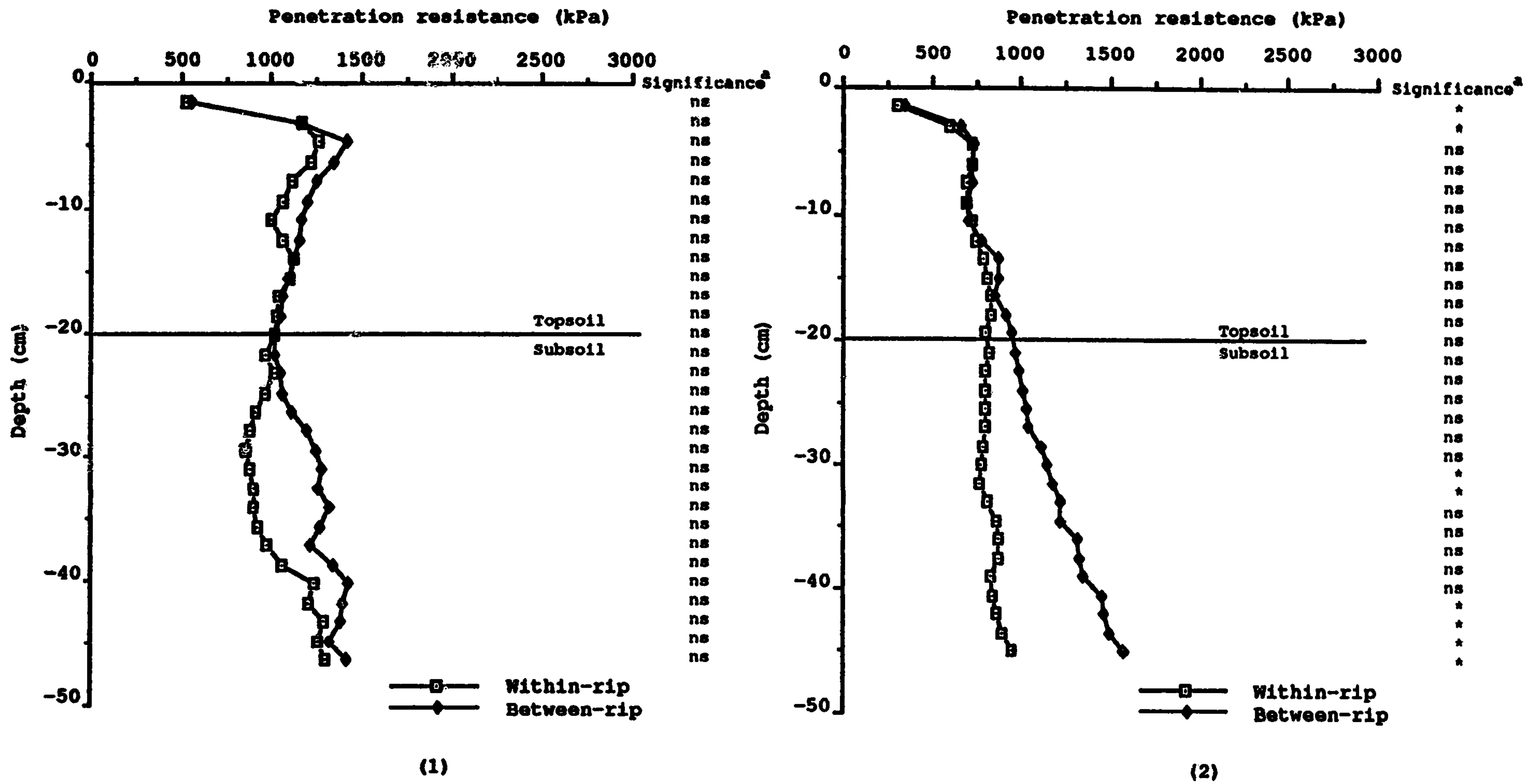
Differences in PR between the two ripper shank positions were not as evident in the R+P treatment as in either the Ripped or R+M treatment (Figure II-6). In September, significant differences between positions were not identified and occurred for only a few intervals in the subsoil in October.

Lower PR values in the within-rip position are likely a reflection of differences in bulk density and water content between the two positions. PR increases with increasing bulk density and with decreasing wetness (Mirreh and Ketcheson, 1972). Since bulk density was considerably lower in within-rip positions for the 20-27.5 cm depth interval in all treatments, PR would also be expected to be lower at similar water contents. At the 40-47.5 cm depth interval, bulk density and water content were similar for the two positions for the R+P treatment (Table II-4). This may have contributed to the lack of



a - Results of Student's t comparison of means
ns - no significant difference
* - Difference between positions significant at 10% level
** - Difference between positions significant at 5% level

Figure II-5. Comparison of penetration resistance between ripper-shank positions for the R+M treatment (1-September, 2-October, n=8).



a-Results of Student's t comparison of means
ns - no significant difference
* - Difference between positions significant at 10% level
** - Difference between positions significant at 5% level

Figure II-6. Comparison of penetration resistance between ripper-shank positions for the R+P treatment (1=September, 2=October, n=6).

significant differences in PR between positions for this treatment.

PR isopleths of each ripped subplot show a similar pattern where within-rip zones appear as valleys in the isolines and between-rip zones appear as ridges (Figures II-7, II-8 and II-9). Comparison of this pattern to that of the unripped control plots in Figure 2 indicates that a major portion of the soil profile has been affected by the subsoiling operation. These figures clearly indicate the spatial distribution and extent of within-rip and between-rip zones in the soil to a depth of 45 cm. The distribution of the two positions within the soil does not occur regularly at the shank-spacing interval of 60 cm. In one subplot of the Ripped treatment, for instance, a within-rip zone can be identified at a distance of 300 cm (Figure II-7b). Adjacent within-rip zones are apparent at distances of 220 and 440 cm. These are 80 and 140 cm, respectively, from the rip located at 300 cm.

Irregular spacing of within-rip zones may be a result of a crab and ebb effect of the subsoil implement during the second pass. The shanks of the subsoiler may realign with the rips created during the previous pass because of reduced force required for shattering when they approach a certain distance from the rips created initially. In a study by Trouse and Humbert (1959), subsoiler tines mounted with swivel tine connections to the toolbar

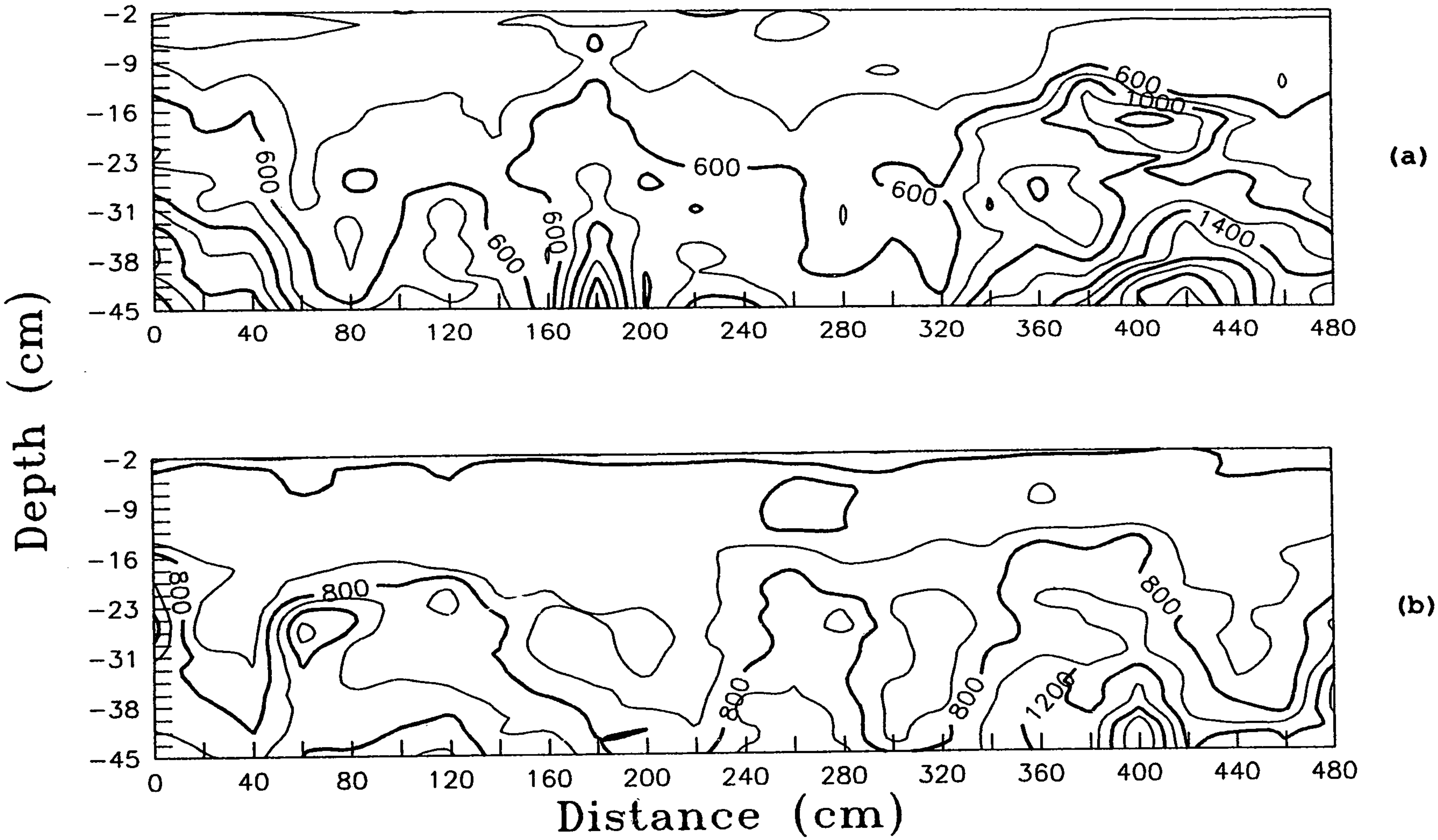


Figure II-7. Penetration resistance isolines (kPa) from the two subplots of the Ripped treatment (n=2250).

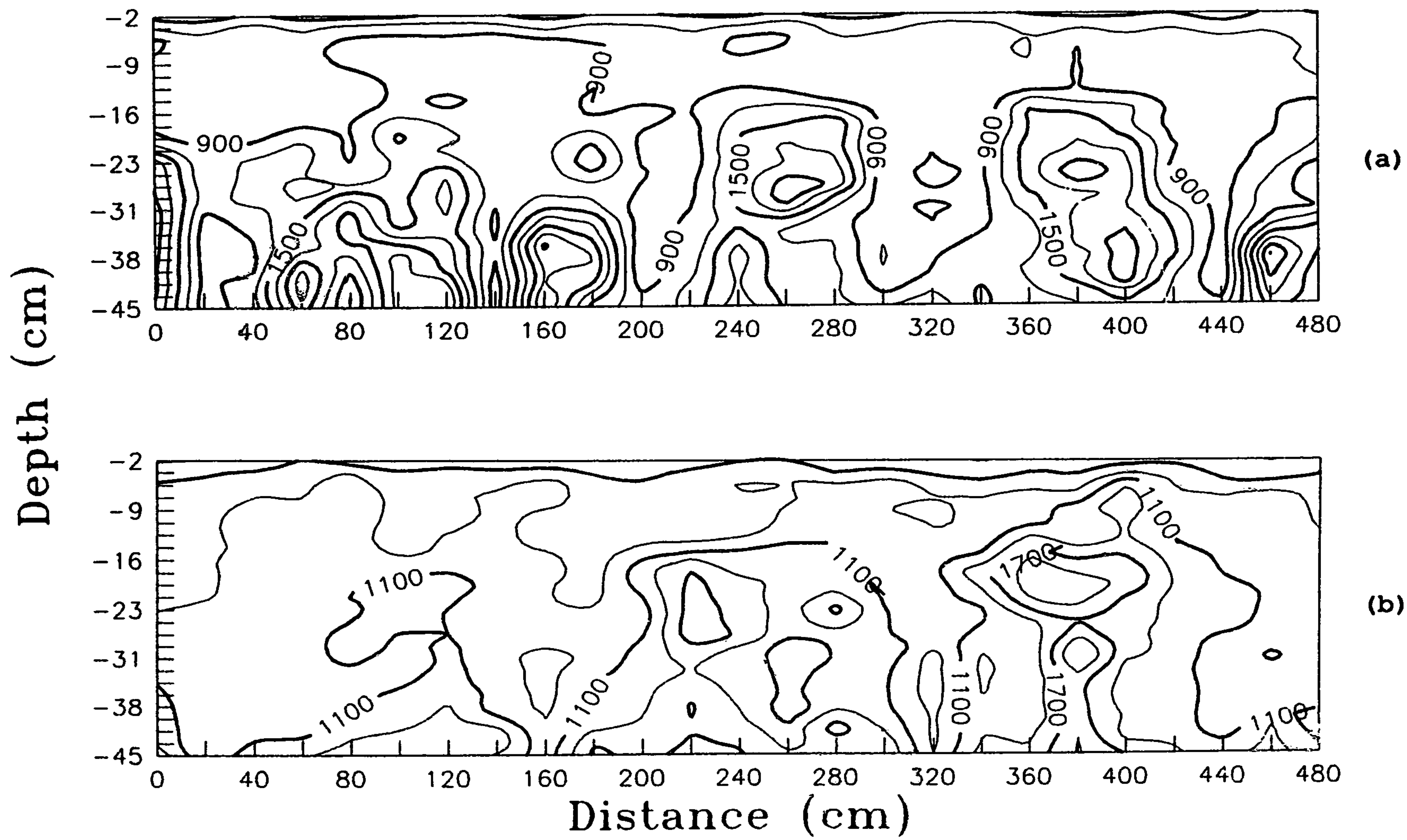


Figure II-8. Penetration resistance isolines (kPa) from the two subplots of the R+M treatment (n=2250).

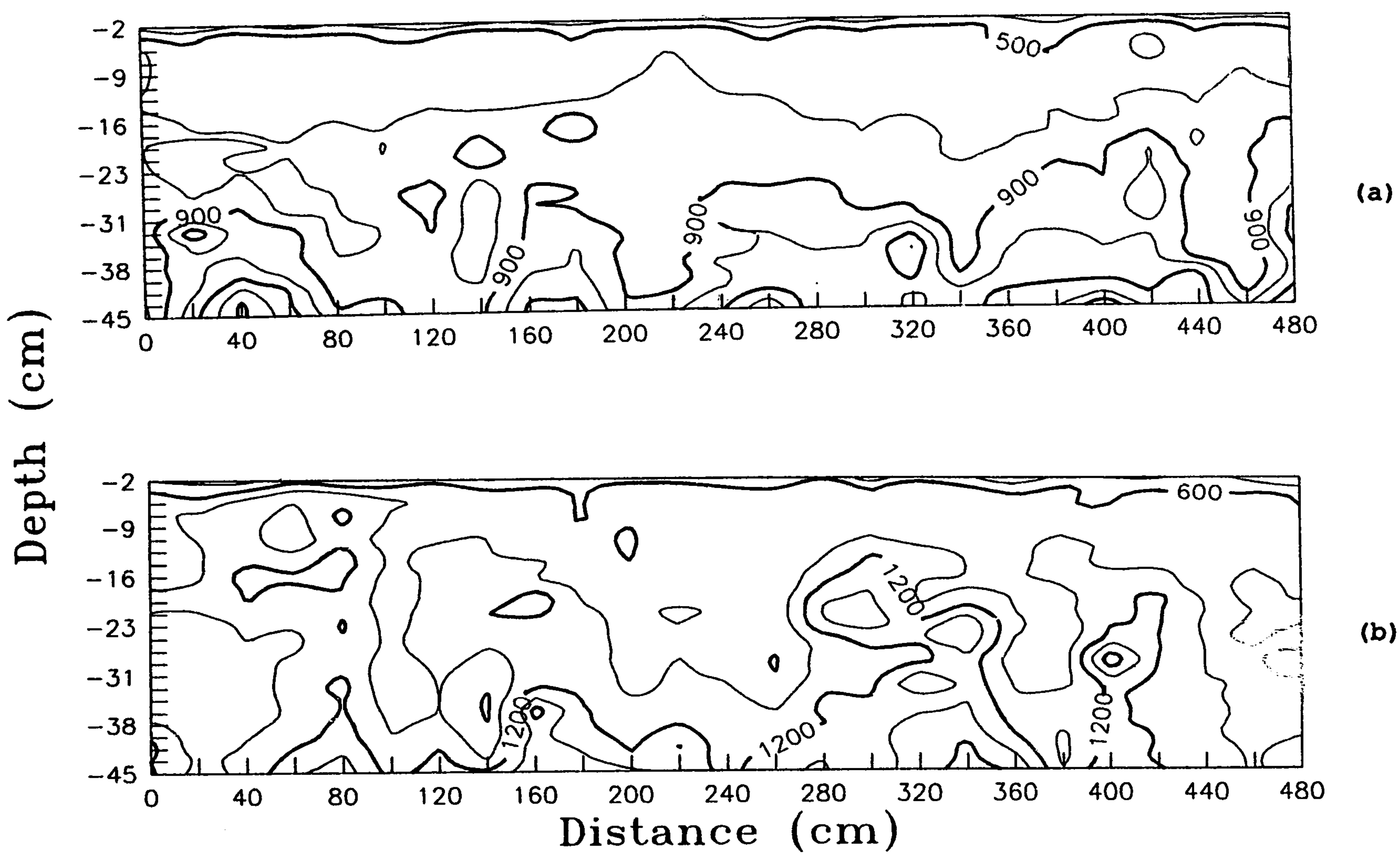


Figure II-9. Penetration resistance isolines (kPa) from the two subplots of the R+P treatment (n=2250).

realigned with the first rips over a distance of 75 to 100 feet using a D8 tractor but not when a D9 tractor was used. These authors suggested that with greater power, rip spacings remain more regular. However, it was also identified by these authors that realignment is minimized and more shattering is obtained in the subsoil if the second pass of the subsoiler is made at an angle of 45° to the initial pass.

Irregular spacing may also be related to plastic flow shear[1] within the soil and the spacing of PR sampling within the transect. In one of the R+M subplots, a ripped zone appeared as a very narrow slot approximately as wide as the shank. The soil adjacent to the slot did not appear to have been affected by the shank. The occurrence of this type of plastic flow shear would minimize the distribution of the ripper-shank effect and may not be detected using a 20-cm sampling interval.

2.3.2 Chemical Properties

Topsoil materials in the control treatment were slightly acidic and the subsoil was near neutral (Table II-5). Both topsoil and subsoil materials were generally non-saline as indicated by low EC values (EC<4 dS m^{-1}) although some salts are present in the subsoil materials (EC=1.26 dS m^{-1}). The soil solution was dominated by calcium in both topsoil and subsoil materials with

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1 Soil movement by plastic flow around the tillage implement.

Table II-5. Chemical properties[†] of replaced soils in the control plots (unripped, unamended) after growing hay for three years.

Depth (cm)	pH	Electrical Conductivity (dS/m)	Saturation Percent ($g\,g^{-1}$ x 100)	Soluble Cations				Sodium Adsorption Ratio
				Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)	Potassium (meq/L)	
0 - 7.5	6.1 ± 0.19	0.62 ± 0.05	54.8 ± 2.4	30.4 ± 2.7	12.0 ± 1.1	4.55 ± 2.0	0.6 ± 0.1	1.1 ± 0.4
20 - 27.5	7.3 ± 0.37	0.77 ± 0.37	67.0 ± 3.7	23.9 ± 13.6	7.93 ± 3.5	11.7 ± 3.4	0.5 ± 0.2	3.0 ± 0.4
40 - 47.7	7.4 ± 0.10	1.26 ± 0.27	70.3 ± 3.1	40.0 ± 14.1	12.7 ± 3.4	18.7 ± 6.1	0.7 ± 0.2	3.7 ± 1.0

Depth (cm)	Exchangeable Cations				Cation Exchange Capacity (cmol(+)/kg)	Exchangeable Sodium Percentage (%)	Exch. Ca: Exch. Na	Loss on Ignition (%)
	Calcium (cmol(+)/kg)	Magnesium (cmol(+)/kg)	Sodium (cmol(+)/kg)	Potassium (cmol(+)/kg)				
0 - 7.5	18.7 ± 1.7	5.5 ± 0.4	0.8 ± 0.2	0.9 ± 0.1	30.5 ± 4.1	2.8 ± 0.6	23.1 ± 4.0	3.3 ± 0.2
20 - 27.5	26.3 ± 1.0	6.5 ± 0.5	2.4 ± 0.7	0.8 ± 0.1	34.6 ± 2.2	7.0 ± 2.2	11.8 ± 3.6	2.0 ± 0.3
40 - 47.7	26.4 ± 2.0	6.2 ± 0.3	3.0 ± 0.3	0.9 ± 0.1	36.5 ± 2.3	8.2 ± 0.8	8.9 ± 1.2	2.4 ± 0.9

† Values are mean ± standard deviation, n=6 .

magnesium the second most abundant cation in the topsoil. Sodium, however, was more abundant than magnesium in the subsoil materials. SAR was very low for topsoil materials and less than 4.7 in the subsoil. The exchange complex was dominated with calcium and magnesium cations at all depths, however, more exchangeable sodium was present in the subsoil than in the topsoil. ESP was 2.8% for topsoil and in the range of 5-9% for subsoil materials. The average exchangeable calcium to sodium ratio in the subsoil varied around the critical value of 10 required for Solonetzic soils (Bnt) by the Agriculture Canada Expert Committee on Soil Survey (1987). Cation exchange capacity averaged 30.5 cmol(+)kg^{-1} for the topsoil and was slightly greater for subsoil materials. Loss on ignition averaged 3.3% for topsoil and was in the range of 1.7 to 3.3% for subsoil materials.

Treatment effects were identified for pH, EC, soluble calcium, magnesium and potassium, exchangeable sodium and potassium, ESP and loss on ignition for topsoil materials (Table II-6). Soil pH was significantly lower in the R+P treatment but the Ripped and R+M treatments had similar soil pH. Soil EC, soluble calcium, soluble magnesium and soluble and exchangeable potassium were significantly greater in topsoil of the R+M treatment, however, no significant differences existed between the Ripped and R+P treatments. Exchangeable sodium and ESP were significantly greater in the Ripped treatment and there

Table II-6. The effect of ripper shank position and treatment on chemical properties† of replaced topsoil (0 - 7.5 cm).

Treatment	pH			Electrical Conductivity (dS/m)			Saturation Percent ($g\ g^{-1} \times 100$)			Calcium (meq/L)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	6.6	6.5	6.5a	0.59	0.48	0.53b	58.0	55.9	56.9	28.4	24.2	26.3b
R+M	6.6	6.5	6.5a	1.29	1.02	1.15a	64.6	61.6	63.1	56.0	42.6	49.3a
R+P	6.0	5.8	5.9b	0.74	0.76	0.75b	62.0	61.8	61.9	34.7	37.4	36.1b
Position Mean	6.4	6.3		0.87A	0.75B		61.5	59.7		39.7	34.7	

Treatment	Magnesium (meq/L)			Sodium (meq/L)			Potassium (meq/L)			Sodium Adsorption Ratio		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	10.6	9.13	9.86b	7.15	5.21	6.18	0.82A	0.54A	0.68b	1.7	1.3	1.5
R+M	25.7	19.9	22.8a	5.03	4.31	4.67	8.46A	5.76B	7.11a	0.8	0.8	0.8
R+P	13.5	15.1	14.3b	7.74	7.84	7.79	0.92A	0.99A	0.96b	1.7	1.6	1.6
Position Mean	16.6	14.7		6.64	5.79		3.40A	2.43B		1.4	1.2	

† Values are means, n=6.

a, b Treatment means within columns followed by the same letter do not differ significantly ($P \leq 0.10$) as determined by ANOVA and the least significant difference test.

A,B Position and treatment x position means within rows followed by the same letter do not differ significantly ($P \leq 0.10$) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

Table II-6. Cont'd.

Treatment	Exchangeable Calcium (cmol(+)/kg)			Exchangeable Magnesium (cmol(+)/kg)			Exchangeable Sodium (cmol(+)/kg)			Exchangeable Potassium (cmol(+)/kg)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	22.9A	20.2B	21.6	5.7	5.8	5.7	1.5	1.4	1.4a	1.0	0.8	0.9b
R+M	21.3A	20.7A	21.0	5.3	5.6	5.5	0.6	1.0	0.8b	4.2	3.6	3.9a
R+P	20.2A	20.2A	20.2	5.7	5.6	5.7	1.2	0.9	1.0b	0.9	0.9	0.9b
Position Mean	21.5A	20.4B		5.6	5.7		1.1	1.1		2.0	1.8	

Treatment	Cation Exchange Capacity (cmol(+)/kg)			Exchangeable Sodium Percentage (%)			Exchangeable Ca: Exchangeable Na			Loss on Ignition (%)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	29.5	28.6	29.0	5.1	4.8	4.9a	15.9A	16.5A	16.2b	2.6	2.5	2.6b
R+M	33.3	32.8	33.0	1.9	2.9	2.4b	38.9A	26.4B	32.7a	5.7	4.8	5.3a
R+P	32.1	33.2	32.7	3.7	2.7	3.2b	18.2A	27.4A	22.8b	4.3	4.5	4.4ab
Position Mean	31.6	31.5		3.5	3.5		23.7	23.5		4.2	3.9	

† Values are means, n=6 .
a, b Treatment means within columns followed by the same letter do not differ significantly ($P \leq 0.10$) as determined by ANOVA and the least significant difference test.
A,B Position and treatment x position means within rows followed by the same letter do not differ significantly ($P \leq 0.10$) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

was no difference in the exchangeable sodium status between the R+M and R+P treatments. Loss on ignition for the 0-7.5 cm depth interval in the R+M treatment was significantly greater than in the Ripped treatment but not significantly different from the R+P treatment.

Some trends in chemical properties can also be noted although these were not identified as statistically significant in the analysis of variance and least significance difference procedure. Both saturation percent and cation exchange capacity in the 0-7.5 cm interval tended to be lower in the Ripped treatment compared to either the R+M or R+P treatments.

The treatment effects identified in the topsoil appear to be due to the chemical properties of the manure and peat used as amendments. Peat is generally acidic and manure generally has a high salt content. It would appear that calcium, magnesium and potassium salts, rather than sodium salts are contributing to increased salinity in the R+M treatment. Although salinity is elevated with the addition of manure, the EC is not sufficiently high for the soil to be considered saline nor to have an appreciable effect on plant growth (Wild, 1988).

EC, soluble potassium and exchangeable calcium in the topsoil varied significantly in relation to position in the soil relative to the ripper shank. All of these soil chemical properties were significantly greater in the within-rip position. In all cases, however, although statistically significant, these differences are not considered to have any appreciable effect on plant growth.

For the 20-27.5 cm depth interval, treatment effects for chemical properties were not significant (Table II-7). A similar result was obtained for soil physical properties. Treatment effects were less prevalent than those due to shank position at this depth interval.

Differences in soil chemical properties due to position in the soil relative to the ripper-shank were identified for soil pH, EC, saturation percent, soluble calcium, sodium and potassium, SAR, exchangeable calcium, magnesium, sodium and potassium, CEC and loss on ignition. With the exception of loss on ignition, all of these properties were significantly lower in the within-rip position. In contrast, loss on ignition was significantly greater in the within-rip position.

Differences in soil chemical properties due to shank position may be due, in part, to mixing of topsoil and subsoil materials at this depth. This is supported by the fact that for those chemical properties where differences between shank positions occurred, similar differences also occurred between topsoil and subsoil materials (Table II-5). Greater loss on ignition in the within-rip position likely reflects an increase in the organic matter content

Table II-7. The effect of ripper shank position and treatment on chemical properties of replaced subsoil (20 - 27.5 cm).

Treatment	pH			Electrical Conductivity (dS/m)			Saturation Percent ($g\,g^{-1}$ x 100)			Calcium (meq/L)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	6.2	7.1	6.7	0.65A	0.95A	0.80	51.7	63.6	57.6	26.8A	34.5A	30.6
R+M	6.3	7.2	6.7	0.75A	0.96A	0.85	56.9	65.3	61.1	28.1A	33.5A	30.8
R+P	6.7	7.3	7.0	0.57B	1.29A	0.93	55.7	67.1	61.4	24.0B	47.5A	35.7
Position Mean	6.4B	7.2A		0.66B	1.07A		54.8B	65.3A		26.3B	38.5A	

Treatment	Magnesium (meq/L)			Sodium (meq/L)			Potassium (meq/L)			Sodium Adsorption Ratio		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	9.44	10.9	10.2	12.2	16.0	14.1	0.24A	0.53A	0.38	2.9	3.5	3.2
R+M	10.2	10.2	10.2	10.3	13.5	11.9	0.60A	0.57A	0.59	2.4	3.0	2.7
R+Pt	8.15	13.2	10.7	10.4	17.5	13.9	0.39B	0.72A	0.55	2.7	3.4	3.0
Position Mean	9.24	11.4		10.9B	15.7A		0.41B	0.61A		2.7B	3.3A	

† Values are means, n=6.
a, b Treatment means within columns followed by the same letter do not differ significantly (P≤0.10) as determined by ANOVA and the least significant difference test.
A,B Position and treatment x position means within rows followed by the same letter do not differ significantly (P≤0.10) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

Table II-7. Cont'd.

Treatment	Exchangeable Calcium (cmol(+)/kg)			Exchangeable Magnesium (cmol(+)/kg)			Exchangeable Sodium (cmol(+)/kg)			Exchangeable Potassium (cmol(+)/kg)		
	Within-Rip	Between-Rip	Treatment Mean	Within-Rip	Between-Rip	Treatment Mean	Within-Rip	Between-Rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	16.8	25.9	21.3	4.7B	5.9A	5.3	2.1	2.6	2.3	0.5	0.8	0.6
R+M	20.2	25.5	22.9	5.4B	5.7A	5.6	2.4	2.7	2.5	0.9	0.9	0.9
R+P	19.7	25.4	22.5	5.0B	5.8A	5.4	1.9	2.4	2.2	0.7	0.9	0.8
Position Mean	18.9B	25.6A		5.0B	5.8A		2.1B	2.6A		0.7	0.8	

Treatment	Cation Exchange Capacity (cmol(+)/kg)			Exchangeable Sodium Percentage (%)			Exchangeable Ca: Exchangeable Na			Loss on Ignition(%)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	25.0	31.3	28.2	8.3	8.2	8.2	8.3	9.9	9.1	2.4	1.9	2.2
R+M	31.4	32.8	32.1	7.6	8.1	7.9	8.7	9.6	9.1	2.9	2.3	2.7
R+P	26.5	34.2	30.3	7.2	7.3	7.2	10.4	11.1	10.7	2.3	1.9	2.1
Position Mean	27.6B	32.8A		7.7	7.9		9.1	10.2		2.6A	2.1B	

† Values are means, n=6.
a, b Treatment means within columns followed by the same letter do not differ significantly (P≤0.10) as determined by ANOVA and the least significant difference test.
A,B Position and treatment x position means within rows followed by the same letter do not differ significantly (P≤0.10) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

as a result of the addition of topsoil materials from above. Lower EC, and soluble and exchangeable ion concentrations in the within-rip position may also be a result of topsoil additions, however, improved internal drainage in the within-rip position and leaching of ions with percolating soil water may also be contributing. Reduced bulk density, PR and coarser texture identified in the within-rip position are indicative of increased percolation of water and leaching of soil ions. Riddell et al. (1988) identified lower EC in the below-shank zone at a depth of 27.5-40 cm compared to the between-rip zone in the subsoiled treatment or a control. However, these authors concluded that EC increased in the between-rip zone rather than decreased in the below-shank zone as would appear to be the case in the current study.

Saturation percentage was the only property that was significantly different among treatments for the 40-47.5 cm depth interval (Table II-8). This property was significantly greater in the R+P treatment but no significant difference occurred between Ripped and R+M treatments.

Ripper-shank position effects at the 40-47.5 cm depth interval were identified for soluble sodium and potassium, SAR, exchangeable sodium and ESP (Table II-8). These properties were significantly lower in the within-rip position compared to the between-rip position. A trend

Table II-8. The effect of ripper shank position and treatment on chemical properties of replaced subsoil (40 - 47.5 cm).

Treatment	pH			Electrical Conductivity (dS/m)			Saturation Percent ($g\ g^{-1} \times 100$)			Calcium (meq/L)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	7.4	7.1	7.2	1.34	1.45	1.40	69.5	68.3	68.4b	43.1	59.9	51.5
R+M	7.1	7.4	7.2	0.69	1.65	1.17	65.5	71.9	68.7b	22.5	50.1	36.3
R+P	7.4	7.4	7.4	1.19	1.44	1.32	71.6	71.4	71.5a	43.7	44.9	44.3
Position Mean	7.3	7.3		1.08	1.51		68.5	70.5		36.4	51.6	

Treatment	Magnesium (meq/L)			Sodium (meq/L)			Potassium (meq/L)			Sodium Adsorption Ratio		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	13.1	18.7	15.9	17.2	25.0	21.1	0.70	0.78	0.74	3.4	4.1	3.8
R+M	7.57	14.1	10.8	13.3	20.2	16.7	0.45	0.84	0.65	3.5	3.7	3.6
R+P	13.5	14.2	13.9	20.5	21.2	20.8	0.70	0.82	0.76	3.7	3.9	3.8
Position Mean	11.4	15.7		17.0B	22.1A		0.62B	0.81A		3.5B	3.9A	

† Values are means, n=6.
a, b Treatment means within columns followed by the same letter do not differ significantly ($P \leq 0.10$) as determined by ANOVA and the least significant difference test.
A,B Position and treatment x position means within rows followed by the same letter do not differ significantly ($P \leq 0.10$) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

Table II-8. Cont'd.

Treatment	Exchangeable Calcium (cmol(+)/kg)			Exchangeable Magnesium (cmol(+)/kg)			Exchangeable Sodium (cmol(+)/kg)			Exchangeable Potassium (cmol(+)/kg)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	27.5	25.2	26.3	6.0	5.9	5.9	2.8	3.1	3.0	0.8	0.9	0.9
R+M	24.1	27.7	25.9	6.1	6.0	6.1	2.6	3.2	2.9	0.8	0.9	0.9
R+P	26.8	26.6	26.6	6.1	6.6	6.4	2.8	3.1	2.9	0.9	0.9	0.9
Position Mean	26.1	26.4		6.1	6.2		2.7B	3.1A		0.8	0.9	

Treatment	Cation Exchange Capacity (cmol(+)/kg)			Exchangeable Sodium Percentage (%)			Exchangeable Ca: Exchangeable Na			Loss on Ignition (%)		
	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean	Within-rip	Between-rip	Treatment Mean
Ripped	32.4	33.9	33.2	8.8	9.4	9.1	9.8	8.1	9.0	2.0	2.2	2.1
R+M	34.7	33.7	34.2	7.6	9.6	8.6	9.3	9.0	9.1	2.7	1.8	2.2
R+P	34.6	33.4	34.0	8.0	9.3	8.7	10.3	8.9	9.6	2.2	1.5	2.0
Position Mean	33.9	33.6		8.1B	9.4A		9.8	8.7		2.3	2.0	

† Values are means, n=6.
a, b Treatment means within columns followed by the same letter do not differ significantly (P≤0.10) as determined by ANOVA and the least significant difference test.
A,B Position and treatment x position means within rows followed by the same letter do not differ significantly (P≤0.10) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

for lower EC, soluble calcium and magnesium within the ripped zone also occurred, however, differences between positions were not statistically significant.

A position effect in the 40-47.5 cm depth interval, which is generally below the zone of physical mixing, gives further support to increased percolation within the rip as a means of reducing the EC and soluble ion concentrations as opposed to reductions in these properties by addition of topsoil materials.

2.4 Conclusions

2.4.1 Physical Properties

The spatial variation in physical soil properties of topsoil materials after deep ripping is not related to ripper-shank position but rather to cultivation and amendment following the ripping operation. The application and type of organic amendments did, however, affect physical soil properties in topsoil of deep-ripped soils.

Plasticity index, silt and clay content, and PR of topsoil were significantly different between treatments. Deep ripping with manure application resulted in greater silt content and a lower plasticity index compared to either ripping alone or with peat. Deep ripping alone resulted in greater clay content in topsoil compared to topsoil where peat or manure were added after ripping.

Surface amendment of ripped soils had no effect on soil physical properties at depths of 40-47.5 cm and only affected PR and mass water content at depths of 20-27.5 cm.

The spatial variability of soil physical properties in the subsoil after deep ripping is a function of ripper shank position, especially for the 20-27.5 cm depth interval. Soil within the ripped zone at this depth had lower bulk density, liquid limit and plasticity index, PR and clay content, volumetric water content and soil water at 33 and 1500 kPa. Many of the changes occurring in the within-rip position as a result of deep ripping such as coarser texture, lower liquid and plastic limits and lower water retention at 33 and 1500 kPa can be considered permanent. There was no apparent evidence of the ripped zones in the soil reverting to their previous condition.

At the 40-47.5 cm depth interval, gravimetric soil water content and penetration resistance were significantly lower in the within-rip position than between rips.

Differences in soil properties between the two shank positions are a result of heterogeneous shattering of the subsoil materials and mixing with topsoil during the ripping operation. The lack of a homogeneous ripping effect in the subsoil is likely due to shank spacing, the shape of shear plane development in the subsoil and crabbing of the subsoiling implement on the second pass into ripped zones created during the first pass.

2.4.2 Chemical Properties

Soil pH, EC, soluble calcium, magnesium and potassium, exchangeable sodium and potassium, ESP, exchangeable Ca:Na ratio and loss on ignition in the 0-7.5 cm depth interval of ripped soils were affected by the application and type of organic amendment. Ripping alone and with manure resulted in greater soil pH than ripping with peat. EC, soluble calcium, magnesium and potassium, exchangeable potassium and the exchangeable Ca:Na ratio were all greater in topsoil of the R+M treatment. Exchangeable sodium and ESP were lower in topsoil materials amended with either peat or manure after ripping compared to ripping alone. Loss on ignition was greater in topsoil of the R+M treatment than in the Ripped treatment. Application and type of amendment had no effect on chemical properties of ripped soils at the 20-27.5 and 40-47.5 cm depth interval.

Ripper shank position effects were generally not evident in the topsoil, however, very slight differences between shank positions were noted for EC, soluble potassium and exchangeable calcium. The detected differences were not considered great enough to significantly affect plant growth.

In the subsoil, shank-position effects were dramatic for most soil chemical parameters at the 20-27.5 cm depth except for soluble magnesium, exchangeable potassium, ESP and the exchangeable Ca:Na ratio. With the exception of loss on ignition, all other soil chemical parameters were lower in the within-rip position. Loss on ignition was greater in within-rip positions due to additions of topsoil materials containing organic matter.

At the 40-47.5 cm interval, changes in soil chemistry in the within-rip zone were related to soluble and exchangeable sodium and soluble potassium concentrations. A clear trend for reduced electrical conductivity and other soluble ion concentrations in this depth interval suggests that enhanced leaching from increased percolation of water within ripped zones may be the reason for differences between ripper-shank positions.

2.5 References

AASHTO. 1988a. Standard method of test for determining the liquid limit for soils. AASHTO Designation: T89-86B p.159-167. In: Asphalt Institute Soils manual for the design of asphalt pavement structures. Manual Series No. 10. College Park, MD.

AASHTO. 1988b. Standard method for determining the plastic limit and plasticity index of soils. AASHTO Designation: T90-86. In: Asphalt Institute Soils manual for the design of asphalt pavement structures. Manual Series No. 10. College Park, MD.

Agriculture Canada Expert Committee on Soil Survey. 1987. The Canadian system of soil classification. Second edition. Agriculture Canada; Publication 1646. 164 pp.

Gee G.W. and J.W. Bauder. 1986. Particle-size analyses. In: Klute et al (ed). 1986. Methods of soil analysis, Part 1. Physical and mineralogical methods. Second Edition. Agronomy Monogragh 9. Soil Sci. Soc. of Am. Madison, WI. pp. 383-409.

Mirreh, H.F. and J.W. Ketcheson. 1972. Influence of soil bulk density and matric pressure on soil resistance to penetration. Can. J. Soil Sci. 52:477-483.

Page, A.L., R.H. Miller and D.R. Keeney (eds). 1982. Methods of soil analysis. Part 2. Chemical and microbiological properties. Agronomy Monogragh 9. Soil Sci. Soc. Am. Madison, Wisconsin.

Riddell, K.M., G.R. Webster and J.C. Hermans. 1988. Effects of deep ripping on chemical and physical properties of a Solonetzic soil in east-central Alberta. Soil and Till. Res. 12:1-12.

SAS Institute Inc. 1987. SAS/STAT Guide for personnal computers, Version 6 Edition. Cary N.C. 1028 pp.

Trouse, A.C. and R.P Humbert. 1959. Deep tillage in Hawaii: 1. Subsoiling. Soil Sci. 88:150-158.

U.S. Department of Agriculture. 1954. Diagnosis and improvement of saline and alkali soils. Handbook 60. Government Printing Office, Washington, D.C. 160 pp.

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

Wild, A.(ed.) 1988. Russell's soil conditions and plant growth. 11th edition. Longman Group. London.

CHAPTER 3
THE EFFECT OF DEEP RIPPING AND ORGANIC MATTER AMENDMENTS ON AP HORIZONS OF SOIL RECONSTRUCTED AFTER COAL STRIP-MINING.

3.1 Introduction

Deep ripping is a subsoil management technique primarily for improvement of sodic clay-pan soils with dense subsurface horizons which limit infiltration of water and penetration of roots. This technique is also routinely used at the Highvale mine in the management of compact minesoils reconstructed with large earth moving machinery. However, several investigations have indicated that in certain situations, subsoiling may affect surface soil quality leading to greater crusting potential, increased surface runoff and poor soil structure (Wetter et al., 1987; Webster and Nyborg, 1986). Negative seedbed effects must be recognized and balanced against the off-setting improvement to subsoil quality. Also, the permanence of the seedbed effect and how management practises such as addition of amendments ameliorate any negative impact from deep ripping must be defined and optimized if deep ripping is to be transformed from a hit and miss art to a scientifically based, dependable and sustainable means of improving soil quality.

3.2 Objectives

Deep ripping is a means of improving the physical characteristics of subsoil in reconstructed minesoils; however, the effect on surface soil characteristics is not well documented. The objectives of this study were to evaluate the effect of deep ripping with and without the use of organic matter amendments on the tilth of Ap horizons of reconstructed minesoils. The specific null hypotheses tested in this experiment were:

1) Deep ripping does not affect the tilth of the Ap horizon.
2) Addition of organic matter amendments to ripped soils does not alter the tilth of Ap horizons.

3.2 Materials and Methods

Data for soil properties measured and reported in Chapter 2 were also used for this analysis if the specific soil property was not affected by position in the soil relative to the ripper shank. Sampling procedures and analysis, therefore, follow those described in Chapter 2 with the exception of those discussed below.

3.2.1 Soil Sampling and Analysis

Samples were taken when the soil was reasonably dry in late August, 1989 for aggregate distribution analysis and modulus of rupture determination. Five randomly located sites within each subplot were sampled by carefully removing a 40 x 25 cm piece of soil with a spade. Samples were trimmed to a thickness of 15 cm and placed intact into a paper bag for air dying on the floor of an open shed prior to processing. After air drying, the samples were gently broken up by hand into aggregates. All roots and plant matter were removed.

Dry sieving analysis was performed on a 500 g (approximately) subsample from the bulk soil sample. Each sample was shaken for 2 minutes on a nest of sieves containing a sequence of mesh openings of 16, 8, 4, 2, 1, 0.5, 0.25 mm and a pan using a Roto-tap shaking machine. The soil collected on each sieve was weighed and expressed as a percentage of the total weight of the sample.

Wet sieving analysis was performed to determine the distribution of water-stable soil aggregates after agitation in water. Approximately 500 g of the air dried soil was first passed through an 8-mm sieve. Three subsamples of approximately 50 g were taken and placed on a nest of sieves containing a sequence of mesh openings of 4, 2, 1, 0.5, 0.25, and 0.125 mm. The sieves were agitated in tap water at room temperature for 30 minutes at 30 oscillations per minute through a 4-cm stroke. The soil on each sieve was collected, weighed after oven drying and expressed as a percentage of the total oven dry weight of the sample. The water was kept at room temperature and renewed after sieving three samples.

Mean weight diameter and geometric mean diameter were calculated for both wet and dry sieving data. Mean weight diameter (MWD) was calculated using the formula (Kemper and Rosenau, 1986):

$$\text{MWD} = \sum_{i=1}^{n} x_i \cdot w_i \qquad (3.1)$$

where x_i is the mean diameter of each size fraction, w_i is the proportion of the total sample weight occurring in the corresponding size fraction and n is the number of size fractions. The geometric mean diameter (GMD) was calculated by the equation (Kemper and Rosenau, 1986):

$$\text{GMD}=\exp\left[\sum_{i=1}^{n} w_i \log x_i / \sum_{i=1}^{n} w_i\right] \qquad (3.2)$$

where w_i is the weight of aggregates in a size class with an average diameter x_i and $\sum^{n}{}_{i=1} w_i$ is the total weight of the sample.

Modulus of rupture was used as an index of the crusting potential of the soil. Soil from the bulk sample was passed though a 2 mm round-hole sieve. Six briquets with dimensions 0.9 x 3.4 x 7.0 cm were made from each sample. The inside of the mold was protected with a thin layer of petroleum jelly to prevent the soil from sticking. Molds were placed on photographic blotting paper and filled with soil using a tremie. The surface of the mold was smoothed, without compaction, with a steel 'T' tool. The molds were then placed in a tray and distilled water added until level with the surface of soil. The molds were soaked for 1 h, drained for 20 minutes and dried to constant weight at 50°C. The force required to break the briquet was determined using the apparatus described by Richards (1953). The modulus of rupture was calculated with the formula:

$$s = (3FL/2000\ bd^2) \quad (3.3)$$

where s is the modulus of rupture in millibars; F is the breaking force in dynes (breaking force in grams weight x 980); L is the distance between briquet supports; and b and d are the width and thickness (cm) of the briquet, respectively, determined after drying.

3.2.2 Statistical Procedures

Soil physical and chemical data from Ap horizons were analysed statistically to determine the effect of each treatment. The treatments being evaluated are Ripped, ripped with surface applied manure (R+M) and ripped with surface applied peat (R+P). Each of these are compared to an unripped, unamended control. The general linear models (GLM) procedure of the Statistical Analysis System (SAS Institute Inc., 1987) was used to perform a one-way analysis of variance. If F values for treatments were significant ($P \leq 0.10$) comparisons of means were conducted using the least significant difference test.

3.3 Results and Discussion

Plasticity index, particle size distribution and penetration resistance (PR) in October, 1989 were the physical soil properties in the Ap horizon where a treatment effect was identified (Table III-1). Plasticity index was significantly greater in the Ripped and R+P treatments than in either the control or the R+M treatment. Sand content in the Ap horizon

Table III-1. Effect of deep ripping and organic amendments on physical properties of Ap horizons†.

Treatment	Bulk Density ($Mg\ m^{-3}$)	Consistence: Liquid Limit (%)	Consistence: Plastic Limit (%)	Consistence: Plasticity Index (%)	Particle Size: Sand (%)	Particle Size: Silt (%)	Particle Size: Clay (%)
R+M	0.90	46.5	33.9	12.6 b	24.2 ab	38.3 a	37.5 b
R +P	0.99	47.0	29.2	17.9 a	27.4 a	32.5 b	40.1 b
Ripped	1.15	44.2	25.5	18.7 a	21.8 b	35.4 b	43.8 a
Unripped††	1.12	40.8	27.7	13.1 b	22.1 b	38.8 a	39.1 b
Pr > F	0.1385	0.5394	0.1330	0.0636	0.0722	0.0132	0.0332

Treatment	Soil Water ($g\ g^{-1}$x100)	Soil Water ($cm^3\ cm^{-3}$x100)	Water Retention: 33 kPa ($g\ g^{-1}$ x 100)	Water Retention: Plant Available Water ($g\ g^{-1}$ x 100)	Modulus of Rupture (millibars)	Penetration Resistance: September (kPa)	Penetration Resistance: October (kPa)
R+M	28.8	25.6	33.0	17.1	65	1224	618 b
R+P	32.3	31.6	32.2	15.1	59	1099	624 b
Ripped	23.8	27.4	31.2	15.2	265	1287	389 c
Unripped††	23.9	26.9	31.6	14.8	116	1861	919 a
Pr > F	0.2915	0.4525	0.8358	0.2570	0.2304	0.2599	0.0264

† Values are means, n = 12 unless otherwise stated.
†† n=6.
a, b Treatment means within columns followed by the same letter do not differ significantly ($P \leq 0.10$) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

was not significantly different among the Ripped and R+M treatments and the control; however, the R+P treatment had a greater sand content than either the Ripped or Unripped treatments. There was significantly more silt in the Ap horizon of the R+M treatment and the control than in either the R+P or Ripped treatments. Clay content was significantly greater in the Ripped treatment than in the control, R+P and R+M treatments. PR of the Ap horizon in October was greater in the control than in any of the treatments that were ripped and ripping without amendments resulted in a significantly lower PR than in either of the treatments where an amendment was applied.

No significant effect on bulk density, liquid or plastic limits, modulus of rupture, water retention characteristics or the soil water content at the time of sampling was identified. However, a trend for greater modulus of rupture was noted in the Ap horizon of the Ripped treatment compared to unripped or amended soils. Modulus of rupture also tended to be lower in the amended soils than in the control. Bulk density was generally lower, and mass water content greater, in the R+M and R+P treatments than in either the Ripped treatment or the control. Plant available water was greatest in the R+M treatment and lowest in the control. The plastic limit tended to be greatest in the R+M and lowest in the Ripped treatment.

The changes to texture and consistence in the Ap horizon as a result of deep ripping are expected to alter the behavior of the soil. Clay content of the surface soil was increased by approximately 5% (absolute) with ripping changing the texture from a clay loam to a clay. Since the subsoil is approximately 47% clay, an increase of 5% clay would require dilution by approximately 10% with subsoil. This addition of subsoil to the surface may alter the movement of water and gas within the soil. Soils with more clay generally have a smaller pore size distribution than coarser textured soils, which will result in slower water and gas movement. Clay particles also tend to hydrate causing the soil to swell upon wetting and shrink upon drying (Hillel, 1982). Therefore, increasing the clay content of the Ap horizon will increase the shrink-swell capacity of the soil. Hillel (1982) suggested that increasing the clay content makes the soil plastic and sticky when wet, as well as tight and cohesive when dry, both of which make the soil more difficult to cultivate.

In another study, Riddell et al. (1988) found that deep ripping had no effect on clay content in the Ap horizon, even though a similar deep ripper was used. Wetter et al. (1987), however, identified an increase in clay content in the Ap horizon of ripped soils. Lavado and Cairns (1980) also identified increased clay content (approximately 7%) at the surface due to ripping.

The greater clay content of the Ap horizon in the Ripped treatment was ameliorated by the addition of either manure or peat in the R+M and R+P treatments, respectively. With the addition of manure to the soil after ripping, the particle size distribution was very similar to that which existed prior to ripping, indicating that silt- and sand-sized mineral materials were present in the manure. In contrast, addition of peat resulted in a similar clay content to that of the control but lowered the silt and increased the sand content. This indicates that predominantly sand-sized mineral materials were present in the peat. The organic matter content of the manure and peat at the outset of the experiment was 32 and 77%, respectively, indicating that 68 and 23% of the amendments were mineral material (Hardy BBT Limited, 1987).

Deep ripping resulted in an increase of approximately 6% (absolute) in the plasticity index due primarily to an increase in the liquid limit. With the addition of manure or peat to deep-ripped soils, the liquid and plastic limits also tended to increase. The increase in plastic limit was greatest for the R+M treatment, resulting in a significantly lower plasticity index for this treatment than that of the R+P treatment.

These changes in soil consistence are likely related to differences in the clay content, organic matter content and quality and the exchangeable cations. Organic matter and clay provide reactive surfaces in the soil, and water molecules are adsorbed to these surfaces. The dipole nature of water molecules results in the positive end directed towards the negatively charged sites on the clay or organic matter surface to form bonds similar to ion-dipole bonds (Sowers, 1965). Additional layers of water become bonded to the first layer by dipole-dipole bonds or by longer range van der Waals forces. The viscosity of adsorbed water decreases with greater distances from the mineral surface until it equals that of 'free' pore water (Sowers, 1965). When the layers of water around the mineral surface are thick, the outermost layers have normal viscosity and interparticle forces are negligible causing the soil to become liquid. Since more clay is present in Ripped soils, more water is required to achieve the same adsorbed water thickness and viscosity to cause the soil to flow. In the case of the amended soils, increased organic matter content increases the amount of water that must be adsorbed to cause the soil to flow.

Manure appears to be better than peat as a means of improving soil consistence as indicated by significantly greater plasticity index and higher plastic limit. This may have occurred because a greater proportion of the peat was present as undecomposed fibers and not as decomposed organic matter as in the manure treatment. The peat may, therefore, behave as porous grains and absorb water as opposed to providing a reactive surface for water adsorption.

Significant relationships exist between liquid limit and cation exchange capacity (Figure III-1), plastic limit and loss on ignition (Figure III-2) and plasticity index and clay content (Figure III-3). Approximately one half of the variance in liquid limit and plasticity index can be explained by CEC and clay content, respectively. Approximately 73% of the variation in plastic limit can be explained by loss on ignition.

Highly dissociated cations such as sodium also increase the liquid limit (Sowers, 1965). Greater liquid limit in Ripped soils may also be related to increased exchangeable sodium content.

The increase in the plasticity index resulting from ripping indicates that the Ap horizons of Ripped soils will remain in a plastic and sticky state over a greater range of wetness than unripped soils. Application of a mechanical force to the soil when it is within its plastic range will deform and mold the soil, smearing the original soil structure. The Ap horizons of deep-ripped soils, therefore, have a greater potential for deformation and smearing of soil structure when cultivated within water contents between 25 and 30% than the control soils. Tillage of deep-ripped soils should be conducted at lower water contents to prevent soil puddling.

In contrast, addition of manure to deep-ripped soils results in a plasticity index similar to the control due to an increase in both the liquid and plastic limits. This soil is

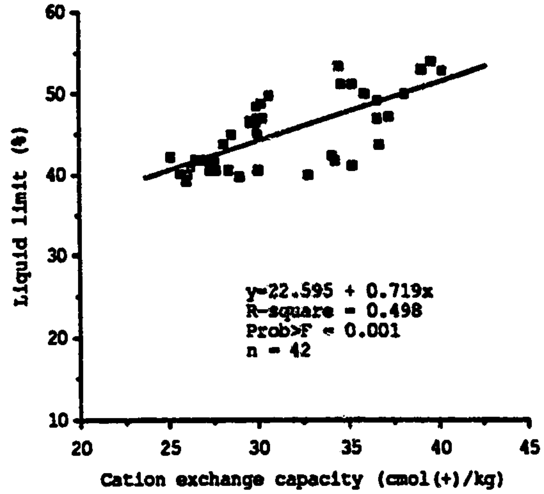

Figure III-1. Relationship between liquid limit and cation exchange capacity.

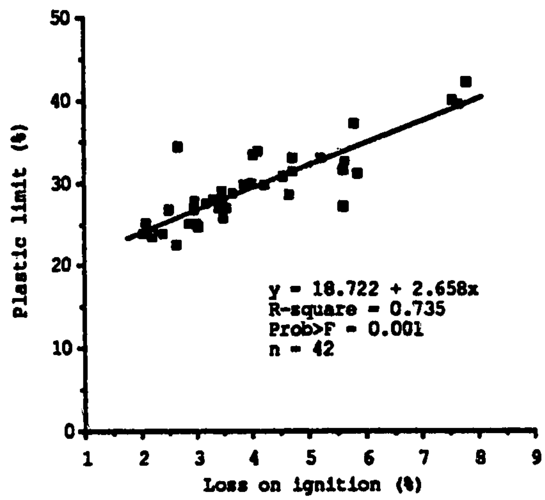

Figure III-2. Relationship between plastic limit and loss on ignition.

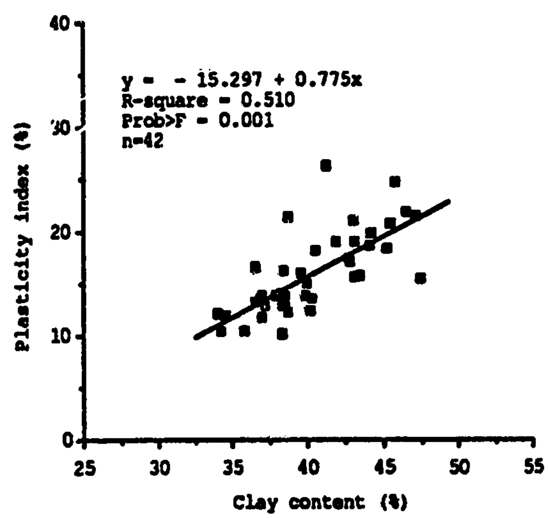

Figure III-3. Relationship between plasticity index and clay content.

plastic over a narrower range of wetness compared to the R+P and Ripped soils. This suggests that the soil will be in a friable condition at greater water contents allowing tillage without adversely affecting soil structure.

The tendency for a greater modulus of rupture in the Ap horizon of deep-ripped soils indicates that the soil has a greater potential for crusting than soil in the Unripped treatment. Surface crusts impede infiltration of water and exchange of gases between the soil and atmosphere (Hillel, 1982) and may also inhibit seedling emergence if the crust strength is great enough. Richards (1953) found that emergence of bean seedlings decreased from 100 to 0% when modulus of rupture increased from 108 to 273 mb. It would appear that the mean value of 265 mb obtained in the Ripped treatment would be sufficiently high to inhibit seedling emergence, especially for small seeded species such as alfalfa and some grasses. However, actual formation and strength of a naturally occurring crust will depend on factors such as rainfall intensity, duration and the rate of drying. A high modulus of rupture value only indicates that the potential for crusting is high and does not necessarily indicate that seedling emergence will be affected. Measurement of naturally formed crusts would be a better indication of a limitation to seedling emergence.

The increase in crusting potential due to ripping is likely related to increased clay content in the Ap horizon.

Stauffer (1927) concluded that the relationship between mechanical composition of soil and its modulus of rupture appeared to be linear. Later, Carnes (1934) found that modulus of rupture was proportional to the surface area of the fine particles in contact within the soil. Chepil (1955) showed that modulus of rupture varies inversely with particle size. Lemos and Lutz (1957) identified an increase in modulus of rupture from 143 to 589 mbars with an increase in clay content of 20.6% (absolute). They also report that montmorillinite clays have a greater effect on increasing crust strength than kaolinitic clays and that soils with high organic matter content had lower modulus of rupture. Lower crust strengths in the R+P and R+M treatments are most probably related to greater organic matter content.

Application of manure or peat to the Ap horizon of ripped soils resulted in a decrease in mean soil bulk density of 22 and 14%, respectively, compared to the Ripped treatment. This is likely partly due to the fact that the organic matter in the peat and manure added to the soil has a specific gravity less than that of the soil particles. Organic matter will also have an effect on the structure of the soil by increasing soil aggregation.

A significant relationship exists between bulk density of the Ap horizon and loss on ignition (Figure III-4). Approximately 88% of the variation in bulk density can be explained by this relationship.

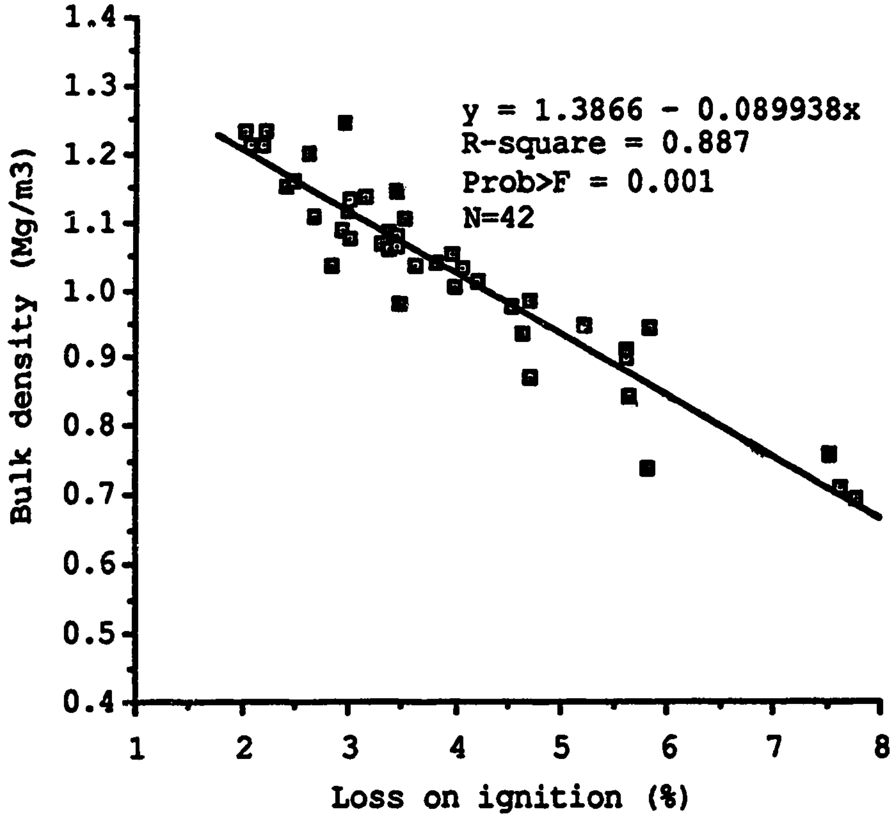

Figure III-4. Relationship between bulk density and loss on ignition in Ap horizons.

Aggregate distribution analysis by dry sieving indicates significant changes to this property have also occurred after ripping (Table III-2). The Ap horizon of ripped soils had a significantly greater proportion of large (>16 and 8-16 mm) aggregates and a lesser proportion of aggregates less than 1.0 mm compared to the control. It is generally accepted that an aggregate size range of 1 to 5 mm is required for the seedbed (Russell, 1961). Aggregates larger than 8 mm accounted for 42% of the Ap horizon in the Ripped treatment and less than 20% in the control. Mean weight diameter increased from 4.4 to 7.6 mm with deep ripping indicating a cloddy seedbed. The large soil aggregates in the Ripped treatment were extremely firm when dry. Some of the clods remaining on the 16-mm sieve were as large as 50 mm in diameter. An increase in the cloddiness of the soil at the expense of aggregates <2.0 mm diameter is more likely to result in poor seed-to-soil contact and poor germination (Wild, 1988).

Increased cloddiness after ripping is likely related to the addition of subsoil materials to the surface. This material is usually brought to the surface in large clods by the action of the ripper shanks and will require considerable time to break down and become totally incorporated with the topsoil.

Distribution of aggregate sizes in the R+M treatment was very similar to the control except for the 0.25-0.5 mm diameter

Table III-2. Effect of deep ripping and organic amendments on aggregate size distribution of Ap horizons.

Aggregate Size (mm)	Percent of Sample Retained†				Pr > F
	R +M	R+P	Ripped	Unripped	
>16	6.2 B	8.7 AB	13.7 A	4.0 B	0.0898
8-16	20.3 BC	22.4 B	28.6 A	15.5 C	0.0220
4-8	19.3	18.2	18.4	15.6	0.2382
[illegible]	16.8	16.1	13.5	16.4	0.1360
1-2	14.0 A	11.2 B	9.9 B	15.3 A	0.0356
0.5-1	11.0 AB	9.6 BC	7.3 C	13.5 A	0.0307
0.25-0.5	6.2 B	6.5 B	3.9 C	8.6 A	0.0333
<0.25	6.3 A	7.3 B	4.7 B	11.0 A	0.0320
Mean weight diameter (mm)	5.5 BC	6.1 B	7.6 A	4.4 C	0.0323
Geometric mean diameter (mm)	1.6 B	1.6 B	1.9 A	1.3 C	0.0314

† n = 10.
A,B Treatment means within rows followed by the same letter do not differ significantly ($P \leq 0.10$) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

size class which was significantly greater in the control. The geometric mean diameter of aggregates from the R+M treatment was also significantly greater than that of the control.

Only slight differences in the aggregate size distribution were observed between the R+M and R+P treatments. Significantly more aggregates <0.25 mm diameter and significantly fewer aggregates in the 1-2 mm size class were present in the R+P treatment than in the R+M treatment. However, no significant differences were identified in the mean weight diameter or the geometric mean diameter between these two treatments although the R+P treatment tended to have a greater mean weight diameter than the R+M treatment due to slightly greater proportions of aggregates greater than 8 mm in diameter.

Of most importance is the difference between the two amended treatments and the Ripped treatment. The mean weight diameter and geometric mean diameter were significantly lower in the R+M and R+P treatments than in the cloddy seedbed characteristic of the Ripped treatment. A significant reduction in the proportion of soil in the 8-16 mm size class and a significant increase in the 0.25-0.5 mm size class occurred in the peat and manure amended treatments compared to the Ripped treatment. A larger increase in the 1-2 mm size class occurred between the R+M treatment and the Ripped treatment than between the R+P treatment and the Ripped treatment. Also, significantly more aggregates were present in the 0.5-1 mm size class of the R+M treatment than in the Ripped treatment whereas no significant difference was identified between the R+P and Ripped treatments for this size class. Similarly, significantly fewer aggregates >16 mm were present in the R+M treatment than in the Ripped treatment whereas no significant difference occurred between the R+P and Ripped treatments for this size class. Thus, manure was more effective than peat at reducing the cloddy condition of the seedbed caused by ripping and increasing aggregation in the 0.5 through 2 mm size classes. This is likely due to the differences in decomposition rates between these two amendments and the effect that the amendments have on plant growth. Allison (1968) suggested that peat acts to reduce the formation of larger aggregates by keeping smaller aggregates physically separated and acting strictly as a diluent. The author suggested that there is little effect in binding soil particles into aggregates. In the case with manure, a readily decomposed organic material, more products of decomposition are present to aid in aggregation. Microbial gums and polysaccharides serve to stabilize aggregates formed by forces within the soil. Plant roots are also an important factor in formation of soil aggregates. Crop yield measurements on these plots over the three year period since their establishment indicate that the R+M treatment yielded an average of 200% more above-ground biomass than the average of the other three treatments and that the species composition was predominantly grasses (Chanasyk and Naeth, 1990). Over the three year period, this would amount to considerably greater total root production within the soil. This increased root production may be partly responsible for the reduction in the cloddy seedbed condition of the R+M treatment.

The distribution of water stable aggregates (WSA) in the Ripped treatment was not significantly different than the control (Table III-3). WSA distribution in the R+P and R+M treatments were similar and were significantly different from both the Ripped treatment and the control. In the two amended treatments, a larger proportion of the soil was present in the 2.0-4.0 mm aggregate size class and less in the 0.125-0.25 mm size class than in the unamended treatments. The R+P treatment had a significantly greater proportion of WSA in the >4.0 mm size class than both the Ripped treatment and the control, whereas the R+M treatment has a similar proportion of WSA in this size class to that in the Ripped treatment but significantly more than that in the Unripped treatment. The proportion of WSA in the R+M treatment in the 0.5-1.0 mm size class was significantly greater than in both the Ripped and Unripped treatments whereas the proportion of WSA in the R+P treatment in this size class was not significantly different from that in the Unripped treatment but was significantly greater than that of the Ripped treatment.

Table III-3. Effect of deep ripping and organic amendments on water stable aggregate size distribution of Ap horizons.

	Percent of Sample Retained†				
Aggregate Size (mm)	R+M	R+P	Ripped	Unripped	Pr > F
> 4.0	24.6 AB	28.4 A	21.7 BC	19.5 C	0.0395
2.0-4.0	14.0 A	14.0 A	12.0 B	12.5 B	0.0558
1.0-2.0	14.1	14.0	11.3	11.8	0.1247
0.5-1.0	17.5 A	16.0 AB	13.7 C	15.3 BC	0.0761
0.25-0.5	13.7	13.0	15.3	15.1	0.3583
0.125-0.25	7.6 B	7.1 B	12.7 A	11.0 A	0.0340
Mean weight diameter (mm)	2.3 A	2.5 A	2.0 B	1.9 B	0.0195
Geometric mean diameter (mm)	1.0 A	1.1 A	0.9 B	0.9 B	0.0251
Δ in MWD from air dry state	- 3.2	- 3.6	- 5.6	- 2.5	
Δ in GMD from air dry state	- 0.6	- 0.5	- 1.0	- 0.4	

† n = 30

A,B Treatment means within rows followed by the same letter do not differ significantly ($P \leq 0.10$) as determined by ANOVA and the least significant difference test. If means do not differ significantly letters have been omitted.

The large increase in WSA >4.0 mm for the R+P teatment compared to the Ripped treatment is actually due to the presence of peat aggregates of this size class and not of aggregated mineral soil. As the dry weight of these aggregates was relatively low, the volume contribution of pure peat peds in this size class was considerable. It is important to recognize that although these peat aggregates are water stable, they are not contributing to the stability of the mineral aggregates. Mean weight diameter and geometric mean diameter calculations for this treatment, therefore, include a considerable bias from non-mineral aggregates in the >4.0 mm size class. Thus, mean weight diameter and geometric mean diameter of mineral material are actually lower than the values reported in Table III-3 for the R+P treatment.

The magnitude of change in the mean weight diameter from the air-dry condition to the wet condition can be used as a index of aggregate stability (Table III-3). A small change indicates stable aggregates. The Ripped treatment had the greatest change in mean weight diameter and the control had the least. Values for the R+P and R+M treatment were similar. Thus, the greater proportion of larger aggregates and clods identified in the Ripped treatment by dry sieving were not water stable and broke down into smaller sizes in water. In contrast, aggregates in the Ap horizon of the control slaked less in water resulting in a less dramatic change in size distribution between air dry and wet sieving.

The reduced stability in water of soil from the Ripped treatment is likely due to a reduction in the organic matter content and changes in soil chemistry due to addition of subsoil materials to the Ap horizon.

Changes in chemical characteristics of the Ap horizon that occurred with deep ripping are related to exchangeable sodium and loss on ignition (Table III-4). Exchangeable sodium levels were elevated in the Ripped treatment resulting in a significantly greater ESP. The ripped treatment also tended to have a lower exchangeable calcium to sodium ratio than the control. Increased exchangeable sodium in the Ap horizon is likely due to the addition of subsoil to the surface. The subsoil materials used in soil reconsruction originated from B and C horizons of a member of the Nakamun soil series (Solonetzic Gray Luvisol on fine textured till) and have an ESP of approximately 7-8 and an exchangeable calcium to sodium ratio of between 9 and 12. The increase in the ESP from 2.8 to 4.9 as a result of deep ripping is not large enough to cause serious sodium related dispersion problems. An ESP of 15 is normally used as a critical figure; above which the soil structure will become unstable (Wild, 1988). Bohn et al. (1985) reported that when exchangeable sodium exceeds 5 to 15% of the cation exchange capacity, water movement into and through the soil is inhibited and that lower values apply to fine textured soils, especially those containing high contents of swelling clays. It is, therefore, important to recognize that there is no universal

Table III-4. Effect of deep ripping and organic amendments on chemical properties† of Ap horizons.

Treatment	pH	Saturation Percent ($g\ g^{-1}$ x 100)	Soluble Cations: Calcium (meq/L)	Soluble Cations: Magnesium (meq/L)	Soluble Cations: Sodium (meq/L)	Sodium Adsorption Ratio	Cation Exchange Capacity ($cmol(+)kg^{-1}$)
R+M	6.5 a	63.1	49.3 a	22.8 a	4.67	0.8	33.0
R+P	5.9 b	61.9	36.1 b	14.3 b	7.79	1.6	32.7
Ripped	6.5 a	56.9	26.3 c	9.86 c	6.18	1.5	29.0
Unripped††	6.1 a	54.8	30.4 bc	12.0 bc	4.95	1.1	30.5
Pr > F	0.0707	0.3413	0.0244	0.0092	0.3987	0.3357	0.7797

Treatment	Exchangeable Cations: Magnesium ($cmol(+)kg^{-1}$)	Exchangeable Cations: Sodium ($cmol(+)kg^{-1}$)	Exchangeable Cations: Potassium ($cmol(+)kg^{-1}$)	Exchangeable Sodium Percent (%)	Exch. Ca: Exch. Na	Loss on Ignition (%)
R+M	5.5	0.8 b	3.9 a	2.4 b	37.3 a	5.3 a
R+P	5.7	1.0 b	0.9 b	3.2 b	22.8 b	4.4 a
Ripped	5.8	1.4 a	0.9 b	4.9 a	16.2 b	2.6 b
Unripped††	5.5	0.8 b	0.9 b	2.8 b	23.1 b	3.3 a
Pr > F	0.9150	0.0385	0.0202	0.0170	0.0207	0.0823

† Values are means, n = 12 unless otherwise stated.

†† n=6.

a, b Treatment means within columns followed by the same letter do not differ significantly ($P \leq 0.10$) as determined by ANOVA and the least significant difference test. If means do not differ significantly, letters have been omitted.

value for the minimum ESP a soil must possess for its structure and permeability to be affected. Any increase in sodium will increase the potential for swelling of clay, especially smectite. In the presence of mechanical forces from raindrop impact, lower ESP values become more critical and can lead to structural breakdown and puddling of soil crumbs. The lower stability of WSA in the Ripped treatment discussed above is likely partly related to the increase in sodium status of the Ap horizon. The elevated sodium levels may also contribute to greater modulus of rupture. Reeve et al. (1954) found a positive and linear relationship between exchangeable sodium content and modulus of rupture.

Loss on ignition was significantly lower in the Ap horizon of the Ripped treatment compared to the control and is likely due to dilution of the topsoil with subsoil materials.

Additions of peat or manure to deep-ripped soils resulted in significant changes to soil chemistry. Soil pH of the Ap horizon in the R+M treatment was not significantly different from the control or the Ripped treatment; however, pH in the R+P treatment was significantly lower. Soluble calcium and magnesium were significantly greater in the R+M treatment than in the other treatments and the control. In the R+P treatment, soluble calcium and magnesium were not significantly different from the control but were significantly greater than in the Ripped treatment. Exchangeable sodium and ESP in both the R+M and R+P treatments were not significantly different from the control. However, the exchangeable calcium to sodium ratio of the R+M treatment was significantly greater than that of both the R+P treatment and the control. The exchangeable potassium concentration was significantly greater in the R+M treatment than in the other treatments and the control. Both the saturation percent and the CEC tended to be greater in the R+P and R+M treatments than in either the control or the Ripped treatment; these trends are likely related to increased organic matter content.

3.4 Conclusions

The tilth of the Ap horizon was affected by deep ripping. Changes occurring to the physical properties of the topsoil were related to particle size distribution, plasticity, penetration resistance, aggregate size distribution and stability of aggregates in water. The 5% increase in clay was related to an increase in the plasticity index causing the soil to be plastic and sticky over a greater range of wetness than in unripped soils. Penetration resistance in the Ap horizon decreased with deep ripping. The mean weight diameter of aggregates increased by 73% as a result of deep ripping due to an increase in the proportion of aggregates greater than 8 mm in diameter and a corresponding decrease in aggregates less than 2 mm in diameter. This increase in the cloddiness of the seedbed will result in poor seed-to-soil contact and result in lower germination rates. The stability of aggregates of the Ap horizon in water was reduced as a result of deep ripping. This reduction in stability is thought to arise from a decrease in the organic matter content and an increase in the clay content and sodium status of the Ap horizon.

The changes occurring to the Ap horizon as a result of deep ripping are due to additions of subsoil to the surface and are expected to make the seedbed more difficult to cultivate and manage on a sustained basis unless specific management practises are adopted to overcome the changes in soil tilth that have occurred.

Additions of manure or peat to deep-ripped soils altered the tilth of the Ap horizon. Manure application decreased the clay content and the plasticity index compared to Ripped soils and also tended to raise the liquid and plastic limits causing the soil to be more friable than Ripped soils at similar water contents. Crusting potential also tended to be lower after manure application. Application of manure after deep ripping resulted in a lower mean weight diameter of aggregates compared to Ripped soils due to a reduction in the proportion of aggregates greater than 8 mm in diameter and an increase in the proportion of aggregates less than 2 mm in diameter. These changes to structure are thought to be caused by both a direct effect of the manure and by an indirect effect of increased plant and root production on manure amended plots. Addition of manure to ripped soils also increased the stability of aggregates in water.

Application of peat to deep-ripped soils increased the sand and silt content compared to the Ripped treatment but had no effect on soil consistence. Crusting potential tended to be reduced by peat application to deep-ripped soils.

3.5 References

Allison, F.E. 1968. Soil aggregation - some facts and fallacies as seen by a microbiologist. Soil Sci. 106:136-143.

Bohn, H.L., B.L. McNeal and G.A. O'Conner. 1985. Soil Chemistry. Second edition. John Wiley and Sons. New York. 341 pp.

Carnes, A. 1934. Soil Crusts. Agr. Eng. 15:167-169.

Chanasyk, D.S. and M.A. Naeth. 1990. Highvale soil tilth project fourth annual report 1989. Prepared for TransAlta Utilities Corporation, Calgary, AB.

Chepil, W.S. 1955. Factors that influence clod structure and erodibility of soil by wind:IV. Sand silt and clay. Soil Sci. 74:155-162.

Hardy BBT Ltd. 1987. Highvale soil tilth project first annual report. Prepared for TransAlta Utilities Corporation. Calgary, AB.

Hillel, D. 1982. Introduction to soil physics. Academic Press. Toronto, ON. 364 pp.

Kemper W.D. and R.C. Rosenau. 1986. Aggregate stability and size distribution. In: Klute et al. (ed.) 1986. Methods of soil analysis, Part 1. Physical and mineralogical methods. Second Edition. Agronomy Monogragh 9. Soil Sci. Soc. Am. Madison, WI. pp. 425-442.

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

Lemos, P. and Lutz, J.F. 1967. Soil crusting and some factors affecting it. Soil Sci. Soc. Am. Proc. 21:485-491.

Reeve, R.C., C.A. Bowen, Brooks, R.H., and F.B. Gschwend, 1954. A comparison of the effects of exchangeable sodium and potassium upon the physical condition of soils. Soil Sci. Soc. Amer. Proc. 18:130-132.

Richards, L.A. 1953. Modulus of rupture of soils as an index of crusting of soil. Soil Sci. Soc. Am. Proc. 17:321-323.

Riddell, K.M., G.R. Webster and J.C. Hermans. 1988. Effects of deep ripping on chemical and physical properties of a

Solonetzic soil in east-central Alberta. Soil and Till. Res. 12:1-2

Russell, E.W. 1961. Soil conditions and plant growth. Longmans, Green and Co. Ltd. London, England.

SAS Institute Inc. 1987. SAS/STAT Guide for personnal computers, Version 6 Edition. Cary, NC 1028 pp.

Sowers, G.F. 1965. Soil Consistence. In: Black et al. (ed.) 1965. Methods of soil analysis. Part 1, physical and mineralogical properties. Soil Sci. Soc. Am. Madison WI. pp 391-399.

Stauffer, 1927. Soil Sci. 24:373

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. 66:455-470.

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

Wild, A.(ed.) 1988. Russell's soil conditions and plant growth. 11th edition. Longman Group. London England. 991 pp.

CHAPTER 4 - SYNTHESIS

Deep ripping is an important tool for reducing the severity of limitations to crop growth and management in soils which have had subsoil structure altered by compaction or for soils with dense subsurface horizons from pedogenic processes. For the reconstructed soils investigated in this study, field management had been severely hampered due to excesses of water and 'soft' field conditions. Crop growth was uneven as a result of poor internal drainage. Harvesting operations were difficult and rutting and other mechanical damage to the soil was common.

Changes in physical properties within the subsoil as a result of deep ripping should allow greater infiltration of water and depth of rooting, increasing both the amount of water stored and utilization of the stored water by the crop. Increased water storage in the subsoil will reduce runoff and erosion. These changes to the soil should also improve the ease of management by allowing farm operations to proceed sooner following rainfall than would have been the case otherwise. The risk of losing a crop because fields are non-trafficable in the fall has also been reduced as a result of deep ripping.

Concern has been expressed regarding the loss of topsoil due to deep ripping. In this study, mixing of topsoil and subsoil materials was identified and infilling of topsoil into the rip was observed. Redistribution of topsoil materials into the disturbed zone of the subsoil, however, can not be considered a loss. In this study, the depth of ripping was generally 40 cm with a maximum depth of approximately 50 cm. This depth is still within the root zone. Nutrients available in the topsoil should still be available for crop use at this depth. The presence of topsoil materials in the disturbed zones of deep-ripped soils ensures that benefits obtained in improved infiltration and internal drainage will be long lasting. In this study, additions of topsoil materials into the subsoil were less of a concern than the additions of subsoil materials to the topsoil.

For the soils investigated, improvement to physical properties of the subsoil were offset by negative impacts to the Ap horizon. Increased clay, plasticity and cloddiness and decreased organic matter content will make cultivation and seedbed preparation more difficult. The trend for increased modulus of rupture also increases the potential for poor seedling emergence. These negative affects are due largely to the physical and chemical characteristics of the subsoil materials, which in this case originated from Solonetzic Gray Luvisolic and Gray Solodized Solonetzic soils and were highly plastic clays with a low exchangeable Ca:Na cation ratio.

Soil reconstruction techniques at other mines in the province and elsewhere in western Canada and the United States and for pipeline rights-of-way are similar to those used at the Highvale mine and result in soils with similar limitations to crop growth and management. However, it is important to recognize that the effects of deep ripping on the Ap horizon are related to the chemical and physical characteristics of the topsoil and subsoil materials so that different results will likely be obtained on different soils. In soils with highly sodic subsoil materials, the magnitude of the effect of subsoil additions to the topsoil would likely be greater. Conversely, for non-sodic soils, the magnitude of the effect in the topsoil may be significantly less. For soils where the texture of the topsoil and subsoil materials are similar, or for soils with very coarse textured topsoil overlying finer textured subsoil materials, the effects of subsoil additions to the topsoil may be minimal or even beneficial. Soils inherently high in organic matter in the topsoil also would not likely experience as significant an effect from subsoil additions due to deep ripping as the soils studied at Highvale. The effect to the topsoil and the need for subsequent special management practices resulting from deep ripping is, therefore, related to the characteristics of both subsoil and topsoil materials. The information obtained in this study can be used for the prediction of changes to soil characteristics due to deep ripping and the need for subsequent management for a variety of different soils.

This study has shown that for the soils investigated, manure and peat amendments improved the quality of the seedbed after deep ripping by decreasing cloddiness and potential for crusting and increasing the stability of aggregates in water compared to unamended ripped soils. Manure application also improved the consistence of the topsoil. All of these soil properties had been negatively affected by deep ripping. It is the author's opinion that for the soils studied, the negative effects to the seedbed are severe enough to warrant some special management practices, especially if an annual cropping system is adopted where the soil is cultivated several times each year for preparation of the seedbed. The rates of application of manure and peat used in this study are relatively high and are greater than rates of manure normally applied to agricultural fields. Lower annual rates applied over a longer term or other methods of increasing the organic matter content such as cropping to forages or seeding to pasture species may also be beneficial albeit requiring a longer term. In the setting of strip mining, where large volumes of materials are regularly handled and where organic deposits exist in advance of the mine, high initial amendment rates may be more appropriate.

The magnitude of the effect and the net benefits of manure or peat addition to the Ap horizon of deep-ripped soils would also likely be different under differing soil conditions. Where highly sodic soils are deep ripped, additions of subsoil to the surface will increase the negative effect in the topsoil compared to that identified in this study. Organic amendments will likely result in a greater benefit to these soils than to soils where the negative effects to the topsoil are not as serious. Soils with inherently low organic matter content in the topsoil, or soils where the topsoil materials are mixed with Ae, AB or Bnt horizons as a result of soil handling procedures on pipeline rights-of-way, well leases or mine sites, are more likely to have the greatest response to organic matter amendment after deep ripping.

This study has focused strictly on the effects of deep ripping and organic matter amendments to soil properties. A detailed economic analysis and risk assessment was beyond the scope of this study, however, the costs associated with deep ripping and application of amendments need to be evaluated against the risks of crop loss or lower long term crop yields. For the agricultural producer, it is important to know if the magnitude of the reduction in seedbed tilth is large enough to warrant the cost of manure application. Also, what incremental costs will be incurred as a result of reduced seedbed quality and what is the effect on crop yields? This has to be weighed against the costs of amendment, the risks of not subsoiling and the potential for crop loss. For industries that have an impact on soils, such as the oil and gas and coal mining industries, the economic analysis is of less significance and knowledge of the direct effects of these management procedures on the soil are more important. These industries have the responsibility and obligation to return all disturbed areas to equivalent capability for either agricultural or forestry use to that which existed prior to disturbance. In situations where limitations to production or management are recognized due to soil compaction occurring as a result of industrial activity, results of this study can be useful in identifying the effects and changes to soil quality that can be anticipated from deep ripping and organic amendments of deep-ripped soils.

The use of deep ripping as a soil management tool is likely to increase in the future as awareness on the effects of industrial, agricultural and forestry activities on soils increases. To further develop and refine this management tool, some important aspects of deep ripping require further investigation. Further research is required to address the extent of the effect of subsoiling in the subsoil and the magnitude of the effect on the topsoil as a function of soil water content at the time of ripping. This information will aid in optimizing the beneficial effects of this important management tool. The longevity of changes to soil bulk density and structure in the subsoil as a result of deep ripping also needs further investigation. This study and others have shown that effects are prevalent in the soil after three years and that the effects on some soil properties are likely permanent. Documentation of the duration of the effects will improve soil management decisions on the periodicity of deep ripping over the long term. This study has shown that organic amendments are required for some soils to reduce the negative effects to the Ap horizon from deep ripping. Information on other offsetting management practices such as long term hay or pasture crops or application of other surface amendments need to be evaluated in order to optimize the beneficial effects of deep ripping at the lowest cost.

This study has shown that the distribution of effects to properties in the soil is heterogeneous and related to position in the soil relative to the original ripper shank position as well as to depth. Failure to include the effect of position and to include the position effect in the data analysis will limit the usefulness of the data. Future studies dealing with soil property measurements influenced by deep ripping must be designed to include both position and depth effects. To better understand the extent and distribution of deep ripping effects in the subsoil thus allowing optimization of this technique, intensive sampling on a transect or complete excavation is recommended.

APPENDIX A
SOIL DESCRIPTIONS

Pedon Description
Nakamun Map Unit (Nk1)

SITE LOCATION: SW 27-52-5-W5

CLASSIFICATION: Solonetzic Gray Luvisol; fine clayey, montmorillinitic?, alkaline, cold semiarid

PARENT MATERIAL: Till derived from Mudstone - Paskapoo Formation

LANDFORM: Morainal

SLOPES: Gentle Slopes (4%)

DRAINAGE: Moderately well drained

SURFACE STONINESS: Non stoney to slightly stony

ROOTS: 150cm

PROFILE DESCRIPTION

Horizon	Average Depth (cm)	Color	Texture	Structure	Consistence
Ap	0-19	black	sil-l	2mgr	mfr, wss, wpo-wsp
Aegj	19-29	grayish brown	sil	1mpl	mfr, wss, wpo
Btnj	29-45	very dark gray	c - sic	2-3vcpr	mvfi, wvs, wvp
Btnj	45-75	very dark gray	c	3vcpr	mvfi, wvs, wvp
C	75-150	black	c	2vcpr	mefi, wvs, wvp
IIC	150-170	olive brown	fsl	rocklike	mfi

SITE LOCATION: SW 27-52-5-W5

CLASSIFICATION: Solonetzic Gray Luvisol: fine clayey, montmorillinitic?, alkaline, cold semiarid?

PARENT MATERIAL: Till derived from Mudstone - Paskapoo Formation

MAP UNIT: Nakamun - Nk1

LABORATORY ANALYSIS - Nakamun (Nk1)

Horizon	Average Depth (cm)	pH (Sat. paste)	Elect. Conduc. (ms/cm)	Saturation %	Soluble Cations (meq/l) Ca	Mg	Na	K	Sodium Absorption Ratio	Extractable Cations (meq/100g) Ca	Mg	Na	K	CEC (meq/100g)
Ap	0-19	6.4	0.18	48.5	0.92	0.27	0.84	0.03	1.1	14	3.2	0.5	0.2	34
Btnj1	29-45	7.6	0.09	60.2	0.16	0.05	0.77	0.03	2.4					
Btnj2	45-75	7.9	0.34	71.3	0.79	0.37	2.64	0.03	3.5	37	11.5	2	0.5	50
C	75-150	8.1	0.41	58.7	0.97	0.44	3.24	0.08	3.9					

Horizon	Average Depth (cm)	Sand (%)	Texture Silt (%)	Clay (%)	Texture Class	Organic Carbon (%)
Ap	0-19	25	50	25	sil	2.9
Btnj1	29-45	9	40	51	c	
Btnj2	45-75	23	23	54	c	
C	75-150	33	21	46	c	

APPENDIX B
SUMMARY STATISTICS - CHAPTER 2

Table B1. Summary Statistics - Soil Physical Properties

TREAT=Ripped POS=Inrip DEPTH=0

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.125	0.004	0.061	0.025
	MMOIST	24.977	4.944	2.224	0.908
	VMOIST	28.112	8.341	2.888	1.179
	FLDCAP	31.543	11.528	3.395	1.386
	PWP	16.620	2.439	1.562	0.638
	AWHC	14.925	6.127	2.475	1.011
	LIQLIM	45.707	13.815	3.717	1.517
	PLASLIM	27.003	14.401	3.795	1.549
	PLASINDX	18.703	16.399	4.050	1.653
	SAND	21.283	1.994	1.412	0.577
	SILT	34.192	8.392	2.897	1.183
	CLAY	44.528	7.297	2.701	1.103
	TOTCARB	2.586	0.105	0.325	0.133

TREAT=Ripped POS=Inrip DEPTH=20

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.142	0.009	0.097	0.040
	MMOIST	29.020	13.972	3.738	1.526
	VMOIST	32.911	7.777	2.789	1.138
	FLDCAP	30.235	13.684	3.699	1.510
	PWP	14.010	2.579	1.606	0.656
	AWHC	16.223	6.122	2.474	1.010
	LIQLIM	40.043	5.236	2.288	0.934
	PLASLIM	24.897	7.065	2.658	1.085
	PLASINDX	15.147	13.145	3.626	1.480
	SAND	29.907	17.497	4.183	1.708
	SILT	39.975	11.810	3.437	1.403
	CLAY	30.113	10.758	3.280	1.339
	TOTCARB	2.432	0.489	0.699	0.285

TREAT=Ripped POS=Inrip DEPTH=40

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.350	0.013	0.113	0.046
	MMOIST	30.234	3.994	1.998	0.816
	VMOIST	40.663	2.971	1.724	0.704
	FLDCAP	37.652	5.864	2.422	0.989
	PWP	19.343	2.471	1.572	0.642
	AWHC	18.308	1.624	1.274	0.520
	SAND	20.045	2.549	1.597	0.652
	SILT	32.667	5.900	2.429	0.992
	CLAY	47.290	5.598	2.366	0.966
	TOTCARB	1.959	0.340	0.583	0.238

TREAT=Ripped POS=Between rip DEPTH=0

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.179	0.004	0.065	[illegible]
	MMOIST	22.578	9.253	3.042	1.242
	VMOIST	26.652	16.967	4.119	1.682
	FLDCAP	30.855	5.617	2.370	0.968
	PWP	15.345	0.707	0.841	0.343
	AWHC	15.507	2.539	1.593	0.651
	LIQLIM	42.665	2.243	1.498	0.611
	PLASLIM	23.993	0.796	0.892	0.364
	PLASINDX	18.672	5.017	2.240	0.914
	SAND	22.227	8.562	2.926	1.195
	SILT	34.717	3.521	1.876	0.766
	CLAY	43.057	7.908	2.812	1.148
	TOTCARB	2.530	0.190	0.436	0.178

TREAT=Ripped POS=Between rip DEPTH=20

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.339	0.010	0.102	0.041
	MMOIST	27.533	8.560	2.926	1.194
	VMOIST	36.853	21.477	4.634	1.892
	FLDCAP	35.730	31.366	5.601	2.286
	PWP	18.212	13.205	3.634	1.484
	AWHC	17.522	5.628	2.372	0.969
	LIQLIM	49.383	73.267	8.560	3.494
	PLASLIM	23.940	0.780	0.883	0.361
	PLASINDX	25.443	71.742	8.470	3.458
	SAND	20.992	56.048	7.487	3.056
	SILT	34.247	12.594	3.549	1.449
	CLAY	44.763	98.988	9.949	4.062
	TOTCARB	1.925	0.100	0.317	0.129

TREAT=Ripped POS=Between rip DEPTH=40

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.363	0.017	0.129	0.053
	MMOIST	28.250	3.061	1.750	0.714
	VMOIST	38.399	10.093	3.177	1.297
	FLDCAP	38.115	2.243	1.498	0.611
	PWP	19.550	1.873	1.369	0.559
	AWHC	18.565	0.453	0.673	0.275
	SAND	19.012	18.827	4.339	1.771
	SILT	34.103	7.095	2.664	1.087
	CLAY	46.885	15.410	3.926	1.603
	TOTCARB	2.195	2.261	1.504	0.614

Table B1. Cont'd. Summary Statistics - Soil Physical Properties

TREAT=Rip+Manure POS=Inrip DEPTH=0

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	0.868	0.023	0.152	0.062
	MMOIST	28.861	12.954	3.599	1.469
	VMOIST	24.644	3.771	1.942	0.793
	FLDCAP	34.103	8.270	2.876	1.174
	PWP	16.035	2.641	1.625	0.663
	AWHC	18.068	1.907	1.381	0.564
	LIQLIM	47.397	30.288	5.503	2.247
	PLASLIM	34.857	21.480	4.635	1.892
	PLASINDX	12.540	1.432	1.197	0.489
	SAND	24.913	8.406	2.899	1.184
	SILT	38.580	2.948	1.717	0.701
	CLAY	36.507	3.374	1.837	0.750
	TOTCARB	5.743	2.491	1.578	0.644

TREAT=Rip+Manure POS=Inrip DEPTH=20

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.176	0.006	0.076	0.031
	MMOIST	26.364	3.928	1.982	0.809
	VMOIST	31.008	9.555	3.091	1.262
	FLDCAP	34.498	12.286	3.505	1.431
	PWP	16.087	6.583	2.566	1.047
	AWHC	18.413	1.090	1.044	0.426
	LIQLIM	44.143	39.668	6.298	2.571
	PLASLIM	26.790	9.015	3.002	1.226
	PLASINDX	17.353	21.894	4.679	1.910
	SAND	25.710	17.244	4.153	1.695
	SILT	38.620	3.724	1.930	0.788
	CLAY	35.677	26.127	5.111	2.087
	TOTCARB	2.983	0.690	0.831	0.339

TREAT=Rip+Manure POS=Inrip DEPTH=40

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.289	0.003	0.058	0.024
	MMOIST	31.[illegible]35	3.938	1.984	0.810
	VMOIST	40.[illegible]4	8.879	2.980	1.217
	FLDCAP	39.[illegible]47	1.387	1.178	0.481
	PWP	19.570	3.214	1.793	0.732
	AWHC	20.272	1.000	1.000	0.408
	SAND	21.978	0.658	0.811	0.331
	SILT	34.768	18.268	4.274	1.745
	CLAY	43.252	20.514	4.529	1.849
	TOTCARB	2.668	0.472	0.687	0.280

Table B1. Cont'd. Summary Statistics - Soil Physical Properties

TREAT=Rip+Manure POS=Between rip DEPTH=0

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	0.937	0.018	0.134	0.055
	MMOIST	28.787	20.312	4.507	1.840
	VMOIST	26.634	12.486	3.533	1.443
	FLDCAP	31.955	4.829	2.197	0.897
	PWP	15.915	3.643	1.909	0.779
	AWHC	16.038	2.639	1.625	0.663
	LIQLIM	45.632	32.212	5.676	2.317
	PLASLIM	33.028	23.562	4.854	1.982
	PLASINDX	12.603	4.939	2.222	0.907
	SAND	23.452	6.259	2.502	1.021
	SILT	38.025	2.928	1.711	0.699
	CLAY	38.522	6.853	2.618	1.069
	TOTCARB	4.787	2.359	1.536	0.627

TREAT=Rip+Manure POS=Between rip DEPTH=20

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.460	0.000	0.022	0.009
	MMOIST	25.897	5.032	2.243	0.916
	VMOIST	37.782	8.349	2.889	1.180
	FLDCAP	37.138	3.709	1.926	0.786
	PWP	18.850	5.360	2.315	0.945
	AWHC	18.287	0.352	0.593	0.242
	LIQLIM	50.468	17.948	4.236	1.730
	PLASLIM	24.793	0.623	0.789	0.322
	PLASINDX	25.675	16.652	4.081	1.666
	SAND	21.352	15.716	3.964	1.618
	SILT	34.1[illegible]	5.799	2.408	0.983
	CLAY	44.290	35.492	5.958	2.432
	TOTCARB	2.336	0.179	0.423	0.173

TREAT=Rip+Manure POS=Between rip DEPTH=40

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.443	0.027	0.165	0.067
	MMOIST	28.636	10.896	3.301	1.348
	VMOIST	40.907	6.586	2.566	1.048
	FLDCAP	40.447	4.344	2.084	0.851
	PWP	20.702	1.215	1.102	0.450
	AWHC	19.745	1.892	1.376	0.562
	SAND	20.640	7.923	2.815	1.149
	SILT	30.362	7.337	2.709	1.106
	CLAY	49.000	1.220	1.105	0.451
	TOTCARB	1.825	0.059	0.242	0.099

Table B1. Cont'd. Summary Statistics - Soil Physical Properties

TREAT=Unripped POS=Between rip DEPTH=0

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.121	0.005	0.070	0.028
	MMOIST	23.941	3.576	1.891	0.772
	VMOIST	26.849	8.539	2.922	1.193
	FLDCAP	31.558	3.732	1.932	0.789
	PWP	16.753	5.524	2.350	0.960
	AWHC	14.810	2.887	1.699	0.694
	LIQLIM	40.802	0.659	0.812	0.331
	PLASLIM	27.713	0.627	0.792	0.323
	PLASINDX	13.088	0.511	0.715	0.292
	SAND	22.085	1.242	1.114	0.455
	SILT	38.792	1.902	1.379	0.563
	CLAY	39.127	1.505	1.227	0.501
	TOTCARB	3.306	0.036	0.189	0.077

TREAT=Unripped POS=Between rip DEPTH=20

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.327	0.016	0.126	0.051
	MMOIST	27.795	3.905	1.976	0.807
	VMOIST	36.902	21.557	4.643	1.895
	FLDCAP	38.995	12.973	3.602	1.470
	PWP	19.502	1.917	1.384	0.565
	AWHC	19.490	7.937	2.817	1.150
	LIQLIM	51.127	6.828	2.613	1.067
	PLASLIM	23.912	1.537	1.240	0.506
	PLASINDX	27.215	3.401	1.844	0.753
	SAND	22.260	31.423	5.606	2.288
	SILT	31.335	5.218	2.284	0.933
	CLAY	46.407	15.358	3.919	1.600
	TOTCARB	2.028	0.085	0.292	0.119

TREAT=Unripped POS=Between rip DEPTH=40

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.419	0.002	0.040	0.016
	MMOIST	29.178	3.663	1.914	0.781
	VMOIST	41.405	8.843	2.974	1.214
	FLDCAP	40.468	6.184	2.487	1.015
	PWP	21.175	1.870	1.367	0.558
	AWHC	19.295	2.259	1.503	0.614
	SAND	21.440	7.641	2.764	1.128
	SILT	31.533	6.578	2.565	1.047
	CLAY	47.028	2.771	1.664	0.680
	TOTCARB	2.427	0.798	0.893	0.365

Table B1. Cont'd. Summary Statistics - Soil Physical Properties

TREAT=Rip+Peat POS=Inrip DEPTH=0

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.019	0.007	0.081	0.033
	MMOIST	32.429	45.394	6.738	2.751
	VMOIST	32.874	43.967	6.631	2.707
	FLDCAP	33.167	12.992	3.604	1.471
	PWP	17.575	5.497	2.345	0.957
	AWHC	15.592	3.289	1.813	0.740
	LIQLIM	46.993	30.229	5.498	2.245
	PLASLIM	28.837	8.207	2.865	1.170
	PLASINDX	18.157	22.152	4.707	1.921
	SAND	27.035	3.875	1.968	0.804
	SILT	32.330	3.061	1.750	0.714
	CLAY	40.635	6.939	2.634	1.075
	TOTCARB	4.333	1.243	1.115	0.455

TREAT=Rip+Peat POS=Inrip DEPTH=20

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.177	0.010	0.098	0.040
	MMOIST	29.902	7.945	2.819	1.151
	VMOIST	35.190	19.209	4.383	1.789
	FLDCAP	32.158	8.488	2.913	1.189
	PWP	15.270	3.833	1.958	0.799
	AWHC	16.890	1.925	1.387	0.566
	LIQLIM	42.018	27.306	5.226	2.133
	PLASLIM	23.922	2.901	1.703	0.695
	PLASINDX	18.097	34.531	5.876	2.399
	SAND	27.480	29.085	5.393	2.202
	SILT	38.993	0.852	0.923	0.377
	CLAY	33.528	37.100	6.091	2.487
	TOTCARB	2.253	0.209	0.457	0.187

TREAT=Rip+Peat POS=Inrip DEPTH=40

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.332	0.005	0.074	0.030
	MMOIST	30.892	0.896	0.947	0.386
	VMOIST	41.119	5.547	2.355	0.962
	FLDCAP	39.447	1.403	1.184	0.484
	PWP	21.988	1.743	1.320	0.539
	AWHC	17.458	0.507	0.712	0.291
	SAND	19.698	7.961	2.822	1.152
	SILT	31.470	4.303	2.074	0.847
	CLAY	48.833	8.875	2.979	1.216
	TOTCARB	2.235	0.555	0.745	0.304

Table B1. Cont'd. Summary Statistics - Soil Physical Properties

TREAT=Rip+Peat POS=Between rip DEPTH=0

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	0.959	0.008	0.091	0.037
	MMOIST	32.137	62.990	7.937	3.240
	VMOIST	30.304	25.071	5.007	2.044
	FLDCAP	31.250	4.999	2.236	0.913
	PWP	16.740	2.225	1.492	0.609
	AWHC	14.510	1.318	1.148	0.469
	LIQLIM	47.022	6.842	2.616	1.068
	PLASLIM	29.458	6.739	2.596	1.060
	PLASINDX	17.563	11.649	3.413	1.393
	SAND	27.722	16.509	4.063	1.659
	SILT	32.733	1.153	1.074	0.438
	CLAY	39.548	19.314	4.395	1.794
	TOTCARB	4.494	1.182	1.087	0.444

TREAT=Rip+Peat POS=Between rip DEPTH=20

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.280	0.035	0.188	0.077
	MMOIST	29.381	3.668	1.915	0.782
	VMOIST	37.338	14.277	3.778	1.543
	FLDCAP	38.240	1.799	1.341	0.548
	PWP	19.338	1.616	1.271	0.519
	AWHC	18.902	0.439	0.662	0.270
	LIQLIM	53.180	1.695	1.302	0.531
	PLASLIM	24.577	0.385	0.620	0.253
	PLASINDX	28.603	2.344	1.531	0.625
	SAND	21.137	7.392	2.719	1.110
	SILT	31.430	1.740	1.319	0.539
	CLAY	47.433	12.981	3.603	1.471
	TOTCARB	1.945	0.181	0.426	0.174

TREAT=Rip+Peat POS=Between rip DEPTH=40

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.319	0.023	0.151	0.062
	MMOIST	29.692	1.033	1.016	0.415
	VMOIST	39.078	15.140	3.891	1.588
	FLDCAP	39.363	6.184	2.487	1.015
	PWP	20.427	0.786	0.887	0.362
	AWHC	18.935	2.788	1.670	0.682
	SAND	17.588	11.375	3.373	1.377
	SILT	31.933	9.521	3.086	1.260
	CLAY	50.478	1.258	1.122	0.458
	TOTCARB	1.846	0.276	0.525	0.214

Table B2. Summary Statistics - Soil Chemical Properties

TREAT=Ripped POS=Inrip DEPTH=0

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	6.55	0.16	0.40	0.16
	EC	0.59	0.01	0.11	0.04
	SAT	57.98	11.00	3.32	1.35
	CAMEQ	28.39	36.12	6.01	2.45
	MGMEQ	10.59	5.10	2.26	0.92
	NAMEQ	7.15	6.53	2.56	1.04
	KMEQ	0.82	0.04	0.20	0.08
	SAR	1.65	0.43	0.66	0.27
	CEC	29.49	1.71	1.31	0.53
	CAX	22.94	13.00	3.61	1.47
	MGX	5.74	0.85	0.92	0.38
	NAX	1.49	0.08	0.28	0.11
	KX	1.00	0.01	0.12	0.05
	ESP	5.08	1.00	1.00	0.41
	CANA	15.93	20.18	4.49	1.83

TREAT=Ripped POS=Inrip DEPTH=20

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	6.19	0.50	0.71	0.29
	EC	0.65	0.01	0.09	0.04
	SAT	51.67	6.39	2.53	1.03
	CAMEQ	26.78	22.74	4.77	1.95
	MGMEQ	9.44	2.53	1.59	0.65
	NAMEQ	12.20	1.38	1.17	0.48
	KMEQ	0.24	0.01	0.07	0.03
	SAR	2.90	0.18	0.43	0.17
	CEC	25.04	3.49	1.87	0.76
	CAX	16.83	10.32	3.21	1.31
	MGX	4.71	0.57	0.75	0.31
	NAX	2.07	0.27	0.52	0.21
	KX	0.47	0.01	0.07	0.03
	ESP	8.25	3.34	1.83	0.75
	CANA	8.30	1.93	1.39	0.57

Table B2 Cont'd. Summary Statistics - Soil Chemical Properties

TREAT=Ripped POS=Inrip DEPTH=40

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	7.35	0.05	0.22	0.09
	EC	1.34	0.37	0.61	0.25
	SAT	68.49	26.30	5.13	2.09
	CAMEQ	43.06	562.56	23.72	9.68
	MGMEQ	13.11	42.14	6.49	2.65
	NAMEQ	17.20	26.67	5.16	2.11
	KMEQ	0.70	0.04	0.20	0.08
	SAR	3.42	0.62	0.79	0.32
	CEC	32.42	11.51	3.39	1.39
	CAX	27.48	2.94	1.72	0.70
	MGX	5.99	0.48	0.70	0.28
	NAX	2.84	0.15	0.38	0.16
	KX	0.83	0.00	0.06	0.02
	ESP	8.76	0.69	0.83	0.34
	CANA	9.82	2.07	1.44	0.59

TREAT=Ripped POS=Between Rip DEPTH=0

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	6.54	0.07	0.26	0.11
	EC	0.48	0.00	0.07	0.03
	SAT	55.87	3.01	1.74	0.71
	CAMEQ	24.20	9.90	3.15	1.28
	MGMEQ	9.13	1.51	1.23	0.50
	NAMEQ	5.21	6.15	2.48	1.01
	KMEQ	0.54	0.02	0.14	0.06
	SAR	1.29	0.35	0.59	0.24
	CEC	28.56	10.28	3.21	1.31
	CAX	20.19	2.73	1.65	0.67
	MGX	5.76	0.13	0.36	0.15
	NAX	1.36	0.21	0.46	0.19
	KX	0.82	0.02	0.12	0.05
	ESP	4.75	2.24	1.50	0.61
	CANA	16.55	43.64	6.61	2.70

Table B2 Cont'd. Summary Statistics - Soil Chemical Properties

------------------------------ TREAT=Rip+Manure POS=Inrip DEPTH=0 ------------------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	6.58	0.03	0.17	0.07
	EC	1.29	0.08	0.27	0.11
	SAT	64.56	62.13	7.88	3.22
	CAMEQ	56.05	98.97	9.95	4.06
	MGMEQ	25.71	11.35	3.37	1.38
	NAMEQ	5.03	9.44	3.07	1.25
	KMEQ	8.46	9.33	3.06	1.25
	SAR	0.79	0.24	0.49	0.20
	CEC	33.26	44.84	6.70	2.73
	CAX	21.30	23.17	4.81	1.96
	MGX	5.28	0.43	0.66	0.27
	NAX	0.62	0.27	0.52	0.21
	KX	4.17	1.68	1.30	0.53
	ESP	1.87	2.25	1.50	0.61
	CANA	81.48	10828.67	104.06	42.48

------------------------------ TREAT=Rip+Manure POS=Inrip DEPTH=20 ------------------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	6.30	0.26	0.51	0.21
	EC	0.75	0.07	0.26	0.10
	SAT	56.93	60.13	7.75	3.17
	CAMEQ	28.14	83.00	9.11	3.72
	MGMEQ	10.15	8.59	2.93	1.20
	NAMEQ	10.26	11.44	3.38	1.38
	KMEQ	0.60	0.47	0.68	0.28
	SAR	2.39	0.58	0.76	0.31
	CEC	31.36	35.73	5.98	2.44
	CAX	20.22	21.15	4.60	1.88
	MGX	5.36	0.51	0.72	0.29
	NAX	2.36	0.19	0.44	0.18
	KX	0.90	0.29	0.54	0.22
	ESP	7.61	1.73	1.32	0.54
	CANA	8.68	3.05	1.75	0.71

Table B2 Cont'd. Summary Statistics - Soil Chemical Properties

-------------------- TREAT=Ripped POS=Between Rip DEPTH=20 -------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	7.13	0.88	0.94	0.38
	EC	0.95	0.16	0.40	0.16
	SAT	63.55	113.54	10.66	4.35
	CAMEQ	34.50	568.84	23.85	9.74
	MGMEQ	10.90	44.19	6.65	2.71
	NAMEQ	16.03	40.04	6.33	2.58
	KMEQ	0.53	0.06	0.24	0.10
	SAR	3.54	0.65	0.80	0.33
	CEC	31.32	38.92	6.24	2.55
	CAX	25.85	71.91	8.48	3.46
	MGX	5.87	1.58	1.26	0.51
	NAX	2.57	0.48	0.70	0.28
	KX	0.78	0.03	0.18	0.07
	ESP	8.19	2.03	1.43	0.58
	CANA	9.90	3.10	1.76	0.72

-------------------- TREAT=Ripped POS=Between Rip DEPTH=40 -------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	7.09	0.20	0.45	0.18
	EC	1.45	0.08	0.28	0.11
	SAT	68.34	10.48	3.24	1.32
	CAMEQ	59.91	276.25	16.62	6.79
	MGMEQ	18.69	21.66	4.65	1.90
	NAMEQ	24.99	26.14	5.11	2.09
	KMEQ	0.78	0.05	0.22	0.09
	SAR	4.10	1.19	1.09	0.44
	CEC	33.90	41.06	6.41	2.62
	CAX	25.19	9.39	3.06	1.25
	MGX	5.88	0.25	0.50	0.20
	NAX	3.12	0.08	0.28	0.12
	KX	0.89	0.00	0.07	0.03
	ESP	9.42	2.73	1.65	0.67
	CANA	8.10	0.95	0.97	0.40

Table B2 Cont'd. Summary Statistics - Soil Chemical Properties

-------------------- TREAT=Rip+Manure POS=Inrip DEPTH=40 --------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	7.06	0.14	0.37	0.15
	EC	0.69	0.01	0.08	0.03
	SAT	65.50	28.39	5.33	2.18
	CAMEQ	22.47	62.34	7.90	3.22
	MGMEQ	7.57	6.82	2.61	1.07
	NAMEQ	13.30	0.46	0.68	0.28
	KMEQ	0.45	0.01	0.12	0.05
	SAR	3.53	0.19	0.43	0.18
	CEC	34.71	5.27	2.30	0.94
	CAX	24.12	5.11	2.26	0.92
	MGX	6.10	0.15	0.39	0.16
	NAX	2.63	0.10	0.32	0.13
	KX	0.83	0.00	0.07	0.03
	ESP	7.57	0.67	0.82	0.34
	CANA	9.27	1.50	1.23	0.50

------------------ TREAT=Rip+Manure POS=Between Rip DEPTH=0 ------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	6.47	0.08	0.28	0.11
	EC	1.02	0.07	0.27	0.11
	SAT	61.56	30.36	5.51	2.25
	CAMEQ	42.62	57.09	7.56	3.08
	MGMEQ	19.89	28.71	5.36	2.19
	NAMEQ	4.31	1.41	1.19	0.49
	KMEQ	5.76	9.54	3.09	1.26
	SAR	0.78	0.05	0.22	0.09
	CEC	32.78	31.05	5.57	2.27
	CAX	20.74	21.39	4.63	1.89
	MGX	5.63	0.35	0.60	0.24
	NAX	0.96	0.17	0.42	0.17
	KX	3.64	1.43	1.20	0.49
	ESP	2.93	1.62	1.27	0.52
	CANA	26.40	204.09	14.29	5.83

Table B2 Cont'd. Summary Statistics - Soil Chemical Properties

------------------ TREAT=Rip+Manure POS=Between Rip DEPTH=20 -----------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	7.15	0.10	0.31	0.13
	EC	0.96	0.19	0.43	0.18
	SAT	65.27	48.72	6.98	2.85
	CAMEQ	33.52	530.79	23.04	9.41
	MGMEQ	10.17	27.59	5.25	2.14
	NAMEQ	13.47	8.55	2.92	1.19
	KMEQ	0.57	0.07	0.27	0.11
	SAR	3.03	0.06	0.24	0.10
	CEC	32.81	21.24	4.61	1.88
	CAX	25.52	26.26	5.12	2.09
	MGX	5.75	0.60	0.77	0.32
	NAX	2.69	0.36	0.60	0.25
	KX	0.85	0.00	0.06	0.02
	ESP	8.14	0.79	0.89	0.36
	CANA	9.56	1.32	1.15	0.47

------------------ TREAT=Rip+Manure POS=Between Rip DEPTH=40 -----------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	7.31	0.04	0.20	0.08
	EC	1.65	1.03	1.01	0.41
	SAT	71.88	11.20	3.35	1.37
	CAMEQ	50.11	1017.94	31.91	13.03
	MGMEQ	14.12	45.28	6.73	2.75
	NAMEQ	20.19	47.22	6.87	2.81
	KMEQ	0.84	0.09	0.30	0.12
	SAR	3.65	0.14	0.37	0.15
	CEC	33.65	2.03	1.42	0.58
	CAX	27.67	2.25	1.50	0.61
	MGX	6.00	1.68	1.29	0.53
	NAX	3.21	0.70	0.84	0.34
	KX	0.91	0.00	0.06	0.02
	ESP	9.55	5.88	2.43	0.99
	CANA	9.03	3.88	1.97	0.80

Table B2 Cont'd. Summary Statistics - Soil Chemical Properties

------------------- TREAT=Unripped POS=Between Rip DEPTH=0 ------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	6.08	0.03	0.19	0.08
	EC	0.62	0.00	0.05	0.02
	SAT	54.80	5.56	2.36	0.96
	CAMEQ	30.36	7.06	2.66	1.08
	MGMEQ	12.02	1.16	1.08	0.44
	NAMEQ	4.95	3.94	1.99	0.81
	KMEQ	0.61	0.02	0.13	0.05
	SAR	1.08	0.20	0.44	0.18
	CEC	30.46	16.94	4.12	1.68
	CAX	18.73	2.84	1.68	0.69
	MGX	5.46	0.12	0.35	0.14
	NAX	0.84	0.05	0.22	0.09
	KX	0.90	0.02	0.12	0.05
	ESP	2.77	0.36	0.60	0.24
	CANA	23.07	16.11	4.01	1.64

------------------- TREAT=Unripped POS=Between Rip DEPTH=20 ------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	7.32	0.14	0.37	0.15
	EC	0.77	0.13	0.37	0.15
	SAT	67.01	13.46	3.67	1.50
	CAMEQ	23.89	186.03	13.64	5.57
	MGMEQ	7.93	11.99	3.46	1.41
	NAMEQ	11.74	11.50	3.39	1.38
	KMEQ	0.47	0.03	0.17	0.07
	SAR	3.03	0.12	0.35	0.14
	CEC	34.57	4.63	2.15	0.88
	CAX	26.28	1.02	1.01	0.41
	MGX	6.50	0.22	0.47	0.19
	NAX	2.40	0.49	0.70	0.29
	KX	0.83	0.00	0.07	0.03
	ESP	6.99	4.64	2.15	0.88
	CANA	11.79	13.00	3.61	1.47

Table B2 Cont'd. Summary Statistics - Soil Chemical Properties

------------------ TREAT=Unripped POS=Between Rip DEPTH=40 ------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	7.36	0.01	0.10	0.04
	EC	1.26	0.07	0.27	0.11
	SAT	70.30	9.33	3.05	1.25
	CAMEQ	40.02	198.13	14.08	5.75
	MGMEQ	12.68	11.82	3.44	1.40
	NAMEQ	18.69	36.92	6.08	2.48
	KMEQ	0.65	0.02	0.16	0.06
	SAR	3.69	1.02	1.01	0.41
	CEC	36.50	5.26	2.29	0.94
	CAX	26.37	3.84	1.96	0.80
	MGX	6.22	0.09	0.29	0.12
	NAX	2.99	0.11	0.33	0.14
	KX	0.86	0.00	0.07	0.03
	ESP	8.21	0.64	0.80	0.33
	CANA	8.90	1.44	1.20	0.49

------------------ TREAT=Rip+Peat POS=Inrip DEPTH=0 ------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	6.00	0.06	0.25	0.10
	EC	0.74	0.03	0.18	0.07
	SAT	61.96	28.42	5.33	2.18
	CAMEQ	34.70	86.78	9.32	3.80
	MGMEQ	13.54	13.22	3.64	1.48
	NAMEQ	7.74	9.67	3.11	1.27
	KMEQ	0.92	0.08	0.28	0.11
	SAR	1.68	0.81	0.90	0.37
	CEC	32.12	11.51	3.39	1.39
	CAX	20.24	5.54	2.35	0.96
	MGX	5.74	0.10	0.31	0.13
	NAX	1.19	0.12	0.35	0.14
	KX	0.94	0.02	0.12	0.05
	ESP	3.69	0.99	0.99	0.41
	CANA	18.20	27.46	5.24	2.14

Table B2 Cont'd. Summary Statistics - Soil Chemical Properties

--------------------- TREAT=Rip+Peat POS=Inrip DEPTH=20 --------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	6.65	0.32	0.57	0.23
	EC	0.57	0.01	0.11	0.05
	SAT	55.72	29.79	5.46	2.23
	CAMEQ	23.96	61.99	7.87	3.21
	MGMEQ	8.15	9.38	3.06	1.25
	NAMEQ	10.38	1.68	1.30	0.53
	KMEQ	0.39	0.01	0.08	0.03
	SAR	2.73	0.61	0.78	0.32
	CEC	26.46	10.25	3.20	1.31
	CAX	19.65	8.18	2.86	1.17
	MGX	4.98	0.27	0.52	0.21
	NAX	1.90	0.08	0.29	0.12
	KX	0.65	0.01	0.11	0.04
	ESP	7.17	0.39	0.62	0.25
	CANA	10.41	1.86	1.36	0.56

--------------------- TREAT=Rip+Peat POS=Inrip DEPTH=40 --------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	7.39	0.04	0.19	0.08
	EC	1.19	0.24	0.49	0.20
	SAT	71.60	3.75	1.94	0.79
	CAMEQ	43.73	544.15	23.33	9.52
	MGMEQ	13.51	40.17	6.34	2.59
	NAMEQ	20.51	148.92	12.20	4.98
	KMEQ	0.70	0.06	0.25	0.10
	SAR	3.69	1.88	1.37	0.56
	CEC	34.55	1.19	1.09	0.45
	CAX	26.82	6.64	2.58	1.05
	MGX	6.12	0.50	0.71	0.29
	NAX	2.77	0.67	0.82	0.33
	KX	0.88	0.00	0.02	0.01
	ESP	8.05	6.29	2.51	1.02
	CANA	10.30	6.33	2.52	1.03

Table B2 Cont'd. Summary Statistics - Soil Chemical Properties

-------------------- TREAT=Rip+Peat POS=Between Rip DEPTH=0 ------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	5.75	0.11	0.33	0.13
	EC	0.76	0.02	0.13	0.05
	SAT	61.75	33.10	5.75	2.35
	CAMEQ	37.41	45.85	6.77	2.76
	MGMEQ	15.07	10.98	3.31	1.35
	NAMEQ	7.84	7.67	2.77	1.13
	KMEQ	0.99	0.09	0.30	0.12
	SAR	1.56	0.36	0.60	0.24
	CEC	33.24	12.85	3.58	1.46
	CAX	20.17	5.95	2.44	1.00
	MGX	5.63	0.34	0.59	0.24
	NAX	0.87	0.13	0.35	0.14
	KX	0.94	0.02	0.14	0.06
	ESP	2.70	1.61	1.27	0.52
	CANA	27.42	168.93	13.00	5.31

------------------- TREAT=Rip+Peat POS=Between Rip DEPTH=20 ------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	7.29	0.06	0.24	0.10
	EC	1.29	0.69	0.83	0.34
	SAT	67.10	15.04	3.88	1.58
	CAMEQ	47.45	903.01	30.05	12.27
	MGMEQ	13.19	43.72	6.61	2.70
	NAMEQ	17.49	72.32	8.50	3.47
	KMEQ	0.72	0.08	0.27	0.11
	SAR	3.36	1.47	1.21	0.49
	CEC	34.19	30.04	5.48	2.24
	CAX	25.44	14.01	3.74	1.53
	MGX	5.77	0.20	0.44	0.18
	NAX	2.44	0.42	0.65	0.26
	KX	0.86	0.00	0.07	0.03
	ESP	7.26	5.24	2.29	0.93
	CANA	11.06	9.72	3.12	1.27

Table B2 Cont'd. Summary Statistics - Soil Chemical Properties

------------------- TREAT=Rip+Peat POS=Between Rip DEPTH=40 ------------------

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	7.37	0.00	0.05	0.02
	EC	1.44	0.09	0.30	0.12
	SAT	71.36	3.66	1.91	0.78
	CAMEQ	44.93	267.91	16.37	6.68
	MGMEQ	14.23	23.78	4.88	1.99
	NAMEQ	21.15	68.33	8.27	3.37
	KMEQ	0.82	0.03	0.16	0.07
	SAR	3.92	1.76	1.33	0.54
	CEC	33.36	4.61	2.15	0.88
	CAX	26.44	7.30	2.70	1.10
	MGX	6.63	0.77	0.88	0.36
	NAX	3.09	0.36	0.60	0.25
	KX	0.88	0.00	0.04	0.02
	ESP	9.30	3.36	1.83	0.75
	CANA	8.94	7.18	2.68	1.09

Table 83. General Linear Models Procedure

Dependent Variable: BULK DENSITY 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.38635817	0.19317908	3.25	0.1777
REP(TREAT)	3	0.17851375	0.05950458		
POS	1	0.00390625	0.00390625	1.21	0.3520
TREAT*POS	2	0.02959017	0.01479508	4.58	0.1227
REP*POS(TREAT)	3	0.00970042	0.00323347		
Error	24	0.12988800	0.00541200		
Corrected Total	35	0.73795675			

Dependent Variable: MASS MOISTURE 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	439.15041206	219.57520603	1.63	0.3314
REP(TREAT)	3	403.59008717	134.53002906		
POS	1	7.64338178	7.64338178	0.91	0.4108
TREAT*POS	2	9.89218672	4.94609336	0.59	0.6089
REP*POS(TREAT)	3	25.23956950	8.41318983		
Error	24	350.40764133	14.60031839		
Corrected Total	35	1235.92327856			

Dependent Variable: VOLUMETRIC MOISTURE 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	224.51532372	112.25766186	1.17	0.4217
REP(TREAT)	3	288.53169450	96.17723150		
POS	1	4.16432044	4.16432044	0.49	0.5357
TREAT*POS	2	33.93120039	16.96560019	1.98	0.2828
REP*POS(TREAT)	3	25.68248617	8.56082872		
Error	24	238.79362933	9.94973456		
Corrected Total	35	815.61865456			

Dependent Variable: FIELD CAPACITY (1/3 BAR) 0-7.5 cm

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
TREAT	2	20.16433889	10.08216944	0.29	0.7643
REP(TREAT)	3	102.76441667	34.25480556		
POS	1	22.59417778	22.59417778	4.99	0.1116
TREAT*POS	2	3.69407222	1.84703611	0.41	0.6970
REP*POS(TREAT)	3	13.58041667	4.52680556		
Error	24	124.82686667	5.20111944		
Corrected Total	35	287.62428889			

Dependent Variable: PERMANENT WILTING POINT (15 BAR) 0-7.5 cm

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
TREAT	2	11.11595000	5.55797500	0.41	0.6985
REP(TREAT)	3	41.12711667	13.70903889		
POS	1	4.97290000	4.97290000	7.43	0.0722
TREAT*POS	2	2.03885000	1.01942500	1.52	0.3494
REP*POS(TREAT)	3	2.00695000	0.66898333		
Error	24	42.62573333	1.77607222		
Corrected Total	35	103.88750000			

Dependent Variable: AVAILABLE WATER HOLDING CAPACITY 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	29.65455000	14.82727500	2.03	0.2770
REP(TREAT)	3	21.90811667	7.30270556		
POS	1	6.40090000	6.40090000	2.05	0.2475
TREAT*POS	2	10.48681667	5.24340833	1.68	0.3240
REP*POS(TREAT)	3	9.36381667	3.12127222		
Error	24	57.82300000	2.40929167		
Corrected Total	35	135.63720000			

Dependent Variable: LIQUID LIMIT 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	54.50526667	27.25263333	0.27	0.7782
REP(TREAT)	3	299.50129167	99.83376389		
POS	1	22.83246944	22.83246944	2.71	0.1984
TREAT*POS	2	14.27082222	7.13541111	0.85	0.5112
REP*POS(TREAT)	3	25.29382500	8.43127500		
Error	24	253.35160000	10.55631667		
Corrected Total	35	669.75527500			

Dependent Variable: PLASTIC LIMIT 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	430.44957222	215.22478611	3.73	0.1535
REP(TREAT)	3	173.04405000	57.68135000		
POS	1	17.78027778	17.78027778	4.76	0.1172
TREAT*POS	2	20.58783889	10.29391944	2.75	0.2093
REP*POS(TREAT)	3	11.21145000	3.73715000		
Error	24	191.67560000	7.98648333		
Corrected Total	35	844.74878889			

Dependent Variable: PLASTICITY INDEX 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	264.21857222	132.10928611	5.33	0.1030
REP(TREAT)	3	74.40014167	24.80004722		
POS	1	0.31546944	0.31546944	0.02	0.9042
TREAT*POS	2	0.75570556	0.37785278	0.02	0.9799
REP*POS(TREAT)	3	55.34787500	18.44929167		
Error	24	178.19000000	7.42458333		
Corrected Total	35	573.22776389			

Dependent Variable: SAND 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	190.91193889	95.45596944	5.13	0.1077
REP(TREAT)	3	55.87024167	18.62341389		
POS	1	0.02833611	0.02833611	0.01	0.9460
TREAT*POS	2	10.46523889	5.23261944	1.00	0.4652
REP*POS(TREAT)	3	15.72440833	5.24146944		
Error	24	156.43146667	6.51797778		
Corrected Total	35	429.43163056			

Dependent Variable: SILT 0-7.5 cm

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
TREAT	2	207.23277222	103.61638611	12.56	0.0349
REP(TREAT)	3	24.75101667	8.25033889		
POS	1	0.13937778	0.13937778	0.04	0.8511
TREAT*POS	2	2.09960556	1.04980278	0.31	0.7515
REP*POS(TREAT)	3	10.00915000	3.33638333		
Error	24	75.25993333	3.13583056		
Corrected Total	35	319.49185556			

Dependent Variable: CLAY 0-7.5 cm

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
TREAT	2	239.02857222	119.51428611	9.73	0.0488
REP(TREAT)	3	36.84111667	12.28037222		
POS	1	0.29521111	0.29521111	0.18	0.6964
TREAT*POS	2	21.92540556	10.96270278	6.86	0.0761
REP*POS(TREAT)	3	4.79681667	1.59893889		
Error	24	216.78273333	9.03261389		
Corrected Total	35	519.66985556			

Dependent Variable: LOSS ON IGNITION 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	45.98750672	22.99375336	5.05	0.1095
REP(TREAT)	3	13.65155750	4.55051917		
POS	1	0.72250000	0.72250000	1.55	0.3011
TREAT*POS	2	2.10322817	1.05161408	2.26	0.2519
REP*POS(TREAT)	3	1.39539317	0.46513106		
Error	24	22.80678067	0.95028253		
Corrected Total	35	86.66696622			

Dependent Variable: BULK DENSITY 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.05675872	0.02837936	0.91	0.4900
REP(TREAT)	3	0.09321850	0.03107283		
POS	1	0.33988900	0.33988900	13.60	0.0346
TREAT*POS	2	0.04944150	0.02472075	0.99	0.4677
REP*POS(TREAT)	3	0.07495817	0.02498606		
Error	24	0.18653267	0.00777219		
Corrected Total	35	0.80079856			

Dependent Variable: MASS MOISTURE 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	75.17029372	37.58514686	7.32	0.0701
REP(TREAT)	3	15.40039883	5.13346628		
POS	1	6.12397511	6.12397511	0.38	0.5823
TREAT*POS	2	1.97407506	0.98703753	0.06	0.9421
REP*POS(TREAT)	3	48.64653517	16.21551172		
Error	24	151.47986333	6.31166097		
Corrected Total	35	298.79514122			

Dependent Variable: VOLUMETRIC MOISTURE 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	22.57028317	11.28514158	1.08	0.4443
REP(TREAT)	3	31.46166542	10.48722181		
POS	1	165.51251336	165.51251336	9.71	0.0526
TREAT*POS	2	32.63819006	16.31909503	0.96	0.4769
REP*POS(TREAT)	3	51.13705742	17.04568581		
Error	24	320.62387933	13.35932831		
Corrected Total	35	623.94358875			

Dependent Variable: FIELD CAPACITY 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	53.35571667	26.67785833	0.78	0.5331
REP(TREAT)	3	102.40491667	34.13497222		
POS	1	202.11361111	202.11361111	43.81	0.0070
TREAT*POS	2	20.34027222	10.17013611	2.20	0.2577
REP*POS(TREAT)	3	13.83995000	4.61331667		
Error	24	240.41513333	10.01729722		
Corrected Total	35	632.46960000			

Dependent Variable: PERMANENT WILTING POINT 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	13.17520556	6.58760278	0.25	0.7918
REP(TREAT)	3	78.24328333	26.08109444		
POS	1	121.73444444	121.73444444	65.15	0.0040
TREAT*POS	2	3.78960556	1.89480278	1.01	0.4608
REP*POS(TREAT)	3	5.60528333	1.86842778		
Error	24	82.02873333	3.41786389		
Corrected Total	35	304.57655556			

Dependent Variable: AVAILABLE WATER HOLDING CAPACITY 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	13.74593889	6.87296944	3.60	0.1593
REP(TREAT)	3	5.72021667	1.90673889		
POS	1	10.13361111	10.13361111	5.47	0.1012
TREAT*POS	2	7.11193889	3.55596944	1.92	0.2903
REP*POS(TREAT)	3	5.55321667	1.85107222		
Error	24	66.50673333	2.77111389		
Corrected Total	35	108.77165556			

Dependent Variable: LIQUID LIMIT 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	60.54053889	30.27026944	0.29	0.7662
REP(TREAT)	3	311.65201667	103.88400556		
POS	1	719.67004444	719.67004444	36.84	0.0090
TREAT*POS	2	35.80203889	17.90101944	0.92	0.4891
REP*POS(TREAT)	3	58.60841667	19.53613889		
Error	24	455.33373333	18.97223889		
Corrected Total	35	1641.60678889			

Dependent Variable: PLASTIC LIMIT 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	17.17587222	8.58793611	0.75	0.5432
REP(TREAT)	3	34.21447500	11.40482500		
POS	1	5.28233611	5.28233611	0.52	0.5247
TREAT*POS	2	10.71040556	5.35520278	0.52	0.6387
REP*POS(TREAT)	3	30.74634167	10.24878056		
Error	24	38.88166667	1.62006944		
Corrected Total	35	137.01109722			

Dependent Variable: PLASTICITY INDEX 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	56.75870556	28.37935278	0.29	0.7666
REP(TREAT)	3	292.71600833	97.57200278		
POS	1	848.26562500	848.26562500	71.97	0.0034
TREAT*POS	2	8.71895000	4.35947500	0.37	0.7185
REP*POS(TREAT)	3	35.36074167	11.78691389		
Error	24	473.45686667	19.72736944		
Corrected Total	35	1715.27689722			

Dependent Variable: SAND 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	20.26737222	10.13368611	0.13	0.8815
REP(TREAT)	3	230.94358333	76.98119444		
POS	1	377.00694444	377.00694444	14.94	0.0306
TREAT*POS	2	34.01357222	17.00678611	0.67	0.5731
REP*POS(TREAT)	3	75.68078333	25.22692778		
Error	24	408.28706667	17.01196111		
Corrected Total	35	1146.19932222			

Dependent Variable: SILT 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	22.05657222	11.02828611	0.80	0.5254
REP(TREAT)	3	41.16601667	13.72200556		
POS	1	315.18084444	315.18084444	200.19	0.0008
TREAT*POS	2	14.59200556	7.29600278	4.63	0.1209
REP*POS(TREAT)	3	4.72321667	1.57440556		
Error	24	136.70426667	5.69601111		
Corrected Total	35	534.42292222			

Dependent Variable: CLAY 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	63.92535000	31.96267500	0.23	0.8057
REP(TREAT)	3	412.51674167	137.50558056		
POS	1	1381.48500278	1381.48500278	91.64	0.0024
TREAT*POS	2	64.99810556	32.49905278	2.16	0.2628
REP*POS(TREAT)	3	45.22447500	15.07482500		
Error	24	649.49020000	27.06209167		
Corrected Total	35	2617.63987500			

Dependent Variable: LOSS ON IGNITION 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	2.20843756	1.10421878	1.03	0.4561
REP(TREAT)	3	3.21158292	1.07052764		
POS	1	2.13793136	2.13793136	5.67	0.0975
TREAT*POS	2	0.17352422	0.08676211	0.23	0.8072
REP*POS(TREAT)	3	1.13070892	0.37690297		
Error	24	4.90144000	0.20422667		
Corrected Total	35	13.76362497			

Dependent Variable: BULK DENSITY 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.01087606	0.00543803	0.31	0.7569
REP(TREAT)	3	0.05330475	0.01776825		
POS	1	0.02335803	0.02335803	0.93	0.4057
TREAT*POS	2	0.04815106	0.02407553	0.96	0.4762
REP*POS(TREAT)	3	0.07525108	0.02508369		
Error	24	0.31281333	0.01303389		
Corrected Total	35	0.52375431			

Dependent Variable: MASS MOISTURE 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	6.65390839	3.32695419	1.58	0.3405
REP(TREAT)	3	6.33276117	2.11092039		
POS	1	31.15872400	31.15872400	112.14	0.0018
TREAT*POS	2	2.22886517	1.11443258	4.01	0.1420
REP*POS(TREAT)	3	0.83358950	0.27786317		
Error	24	111.91884933	4.66328539		
Corrected Total	35	159.12669756			

Dependent Variable: VOLUMETRIC MOISTURE 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	5.21809772	2.60904886	0.28	0.7757
REP(TREAT)	3	28.28047117	9.42682372		
POS	1	11.57814044	11.57814044	0.60	0.4941
TREAT*POS	2	18.74199672	9.37099836	0.49	0.6555
REP*POS(TREAT)	3	57.62629717	19.20876572		
Error	24	160.17264600	6.67386025		
Corrected Total	35	281.61764922			

Dependent Variable: FIELD CAPACITY 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	31.95286667	15.97643333	1.85	0.2995
REP(TREAT)	3	25.89350000	8.63116667		
POS	1	0.96040000	0.96040000	0.44	0.5533
TREAT*POS	2	0.78446667	0.39223333	0.18	0.8430
REP*POS(TREAT)	3	6.50326667	2.16775556		
Error	24	74.72920000	3.11371667		
Corrected Total	35	140.82370000			

Dependent Variable: PERMANENT WILTING POINT 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	18.89581667	9.44790833	1.84	0.3011
REP(TREAT)	3	15.41438333	5.13812778		
POS	1	0.04987778	0.04987778	0.03	0.8658
TREAT*POS	2	11.23667222	5.61833611	3.81	0.1501
REP*POS(TREAT)	3	4.42411667	1.47470556		
Error	24	36.67273333	1.52803056		
Corrected Total	35	86.69360000			

Dependent Variable: AVAILABLE WATER HOLDING CAPACITY 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	23.23948889	11.61974444	2.62	0.2194
REP(TREAT)	3	13.28966667	4.42988889		
POS	1	1.45604444	1.45604444	0.58	0.5032
TREAT*POS	2	6.11535556	3.05767778	1.21	0.4121
REP*POS(TREAT)	3	7.59056667	2.53018889		
Error	24	20.44146667	0.85172778		
Corrected Total	35	72.13258889			

Dependent Variable: SAND 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	44.24503889	22.12251944	1.80	0.3064
REP(TREAT)	3	36.85850833	12.28616944		
POS	1	20.08533611	20.08533611	1.24	0.3462
TREAT*POS	2	1.84770556	0.92385278	0.06	0.9454
REP*POS(TREAT)	3	48.48144167	16.16048056		
Error	24	161.12513333	6.71354722		
Corrected Total	35	312.64316389			

Dependent Variable: SILT 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	17.00542222	8.50271111	0.26	0.7867
REP(TREAT)	3	98.07166667	32.69055556		
POS	1	6.28337778	6.28337778	3.28	0.1677
TREAT*POS	2	58.80882222	29.40441111	15.36	0.0265
REP*POS(TREAT)	3	5.74336667	1.91445556		
Error	24	158.30593333	6.59608056		
Corrected Total	35	344.21858889			

Dependent Variable: CLAY 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	79.92815556	39.96407778	1.18	0.4193
REP(TREAT)	3	101.81469167	33.93823056		
POS	1	48.83680278	48.83680278	2.69	0.1992
TREAT*POS	2	58.90335556	29.45167778	1.62	0.3326
REP*POS(TREAT)	3	54.37555833	18.12518611		
Error	24	108.18480000	4.50770000		
Corrected Total	35	452.04336389			

Dependent Variable: LOSS ON IGNITION 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.29024439	0.14512219	0.09	0.9121
REP(TREAT)	3	4.58719208	1.52906403		
POS	1	0.99234803	0.99234803	5.36	0.1035
TREAT*POS	2	1.75899572	0.87949786	4.75	0.1176
REP*POS(TREAT)	3	0.55538075	0.18512692		
Error	24	14.67089467	0.61128728		
Corrected Total	35	22.85505564			

Dependent Variable: pH 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	3.45208889	1.72604444	5.99	0.0897
REP(TREAT)	3	0.86490000	0.28830000	4.47	0.0124
POS	1	0.13444444	0.13444444	3.89	0.1431
TREAT*POS	2	0.08002222	0.04001111	1.16	0.4239
REP*POS(TREAT)	3	0.10363333	0.03454444	0.54	0.6620
Error	24	1.54640000	0.06443333		
Corrected Total	35	6.18148889			

Dependent Variable: EC 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	2.38043889	1.19021944	7.29	0.0705
REP(TREAT)	3	0.48985000	0.16328333	7.29	0.0012
POS	1	0.13201111	0.13201111	8.71	0.0600
TREAT*POS	2	0.12257222	0.06128611	4.04	0.1408
REP*POS(TREAT)	3	0.04548333	0.01516111	0.68	0.5749
Error	24	0.53786667	0.02241111		
Corrected Total	35	3.70822222			

Dependent Variable: Saturation Percent 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	253.3580722	126.6790361	1.04	0.4535
REP(TREAT)	3	365.0199500	121.6733167	6.62	0.0020
POS	1	28.19610000	28.19610000	2.47	0.2141
TREAT*POS	2	12.15831667	6.07915833	0.53	0.6340
REP*POS(TREAT)	3	34.2425500	11.4141833	0.62	0.6081
Error	24	440.9115333	18.3713139		
Corrected Total	35	1133.8865222			

Dependent Variable: Soluble Calcium 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	3209.049867	1604.524933	10.58	0.0437
REP(TREAT)	3	454.817700	151.605900	3.46	0.0320
POS	1	222.5069444	222.5069444	3.98	0.1401
TREAT*POS	2	393.8256889	196.9128444	3.52	0.1634
REP*POS(TREAT)	3	167.858767	55.952922	1.28	0.3045
Error	24	1050.967733	43.790322		
Corrected Total	35	5499.026700			

Dependent Variable: Soluble Magnesium 0-7.5cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	1037.003089	518.501544	18.58	0.0204
REP(TREAT)	3	83.725767	27.908589	2.75	0.0649
POS	1	33.13921111	33.13921111	3.69	0.1504
TREAT*POS	2	81.83442222	40.91721111	4.56	0.1232
REP*POS(TREAT)	3	26.920567	8.973522	0.88	0.4635
Error	24	243.689600	10.153733		
Corrected Total	35	1506.312656			

Dependent Variable: Soluble Sodium 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	58.51777222	29.25888611	1.55	0.3451
REP(TREAT)	3	56.[illegible]160833	18.89053611	3.42	0.0334
POS	1	6.51100278	6.51100278	1.30	0.3372
TREAT*POS	2	6.32107222	3.16053611	0.63	0.5908
REP*POS(TREAT)	3	15.04090833	5.01363611	0.91	0.4522
Error	24	132.6354000	5.5264750		
Corrected Total	35	275.6977639			

Dependent Variable: Soluble Potassium 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	317.2629056	158.6314528	14.06	0.0299
REP(TREAT)	3	33.8366833	11.2788944	4.56	0.0116
POS	1	8.41000000	8.41000000	11.21	0.0441
TREAT*POS	2	13.67255000	6.83627500	9.11	0.0531
REP*POS(TREAT)	3	2.2508500	0.7502833	0.30	0.8229
Error	24	59.4159333	2.4756639		
Corrected Total	35	434.8489222			

Dependent Variable: SAR 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	4.76237222	2.38118611	1.93	0.2891
REP(TREAT)	3	3.69974167	1.23324722	4.38	0.0136
POS	1	0.25502500	0.25502500	1.02	0.3878
TREAT*POS	2	0.19355000	0.09677500	0.39	0.7096
REP*POS(TREAT)	3	0.75334167	0.25111389	0.89	0.4597
Error	24	6.76013333	0.28167222		
Corrected Total	35	16.42416389			

Dependent Variable: CAX 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	11.29428889	5.64714444	0.11	0.9011
REP(TREAT)	3	157.0636667	52.3545556	6.31	0.0026
POS	1	11.40187778	11.40187778	12.40	0.0389
TREAT*POS	2	12.13268889	6.06634444	6.60	0.0797
REP*POS(TREAT)	3	2.7576000	0.9192000	0.11	0.9530
Error	24	199.1028667	8.2959528		
Corrected Total	35	393.7529889			

Dependent Variable: MGX 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.56708889	0.28354444	0.16	0.8615
REP(TREAT)	3	5.42910000	1.80970000	9.06	0.0003
POS	1	0.06760000	0.06760000	0.26	0.6432
TREAT*POS	2	0.32826667	0.16413333	0.64	0.5870
REP*POS(TREAT)	3	0.76990000	0.25663333	1.29	0.3020
Error	24	4.79140000	0.19964167		
Corrected Total	35	11.95335556			

Dependent Variable: NAX 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	2.47162222	1.23581111	9.41	0.0510
REP(TREAT)	3	0.39409167	0.13136389	0.74	0.5396
POS	1	0.01400278	0.01400278	0.21	0.6785
TREAT*POS	2	0.68508889	0.34254444	5.12	0.1079
REP*POS(TREAT)	3	0.20082500	0.06694167	0.38	0.7710
Error	24	4.27093333	0.17795556		
Corrected Total	35	8.03656389			

Dependent Variable: KX 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	71.02843889	35.51421944	11.86	0.0376
REP(TREAT)	3	8.98414167	2.99471389	11.06	0.0001
POS	1	0.51600278	0.51600278	3.94	0.1413
TREAT*POS	2	0.41217222	0.20608611	1.57	0.3408
REP*POS(TREAT)	3	0.39274167	0.13091389	0.48	0.6969
Error	24	6.49913333	0.27079722		
Corrected Total	35	87.83263056			

Dependent Variable: CEC 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	117.8203722	58.9101861	0.48	0.6580
REP(TREAT)	3	366.0937083	122.0312361	16.76	0.0001
POS	1	0.08313611	0.08313611	0.01	0.9189
TREAT*POS	2	6.97487222	3.48743611	0.51	0.6428
REP*POS(TREAT)	3	20.3559417	6.7853139	0.93	0.4405
Error	24	174.7338667	7.2805778		
Corrected Total	35	686.0618972			

Dependent Variable: ESP 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	39.60000556	19.80000278	13.17	0.0327
REP(TREAT)	3	4.51170833	1.50390278	0.87	0.4724
POS	1	0.06846944	0.06846944	0.09	0.7874
TREAT*POS	2	6.48440556	3.24220278	4.11	0.1381
REP*POS(TREAT)	3	2.36470833	0.78823611	0.45	0.7170
Error	24	41.68846667	1.73701944		
Corrected Total	35	94.71776389			

Dependent Variable: CA:NA Ratio 0-7.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	9734.357872	4867.178936	3.02	0.1914
REP(TREAT)	3	4839.483742	1613.161247	0.82	0.4967
POS	1	2047.411669	2047.411669	1.43	0.3176
TREAT*POS	2	7310.925106	3655.462553	2.55	0.2250
REP*POS(TREAT)	3	4293.166442	1431.055481	0.73	0.5467
Error	24	47332.15407	1972.17309		
Corrected Total	35	75557.49890			

Dependent Variable: PH 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.65126667	0.32563333	0.23	0.8104
REP(TREAT)	3	4.32809167	1.44269722	5.87	0.0037
POS	1	5.92922500	5.92922500	49.54	0.0059
TREAT*POS	2	0.13806667	0.06903333	0.58	0.6139
REP*POS(TREAT)	3	0.35909167	0.11969722	0.49	0.6945
Error	24	5.89853333	0.24577222		
Corrected Total	35	17.30427500			

Dependent Variable: EC 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.10667222	0.05333611	0.23	0.8101
REP(TREAT)	3	0.70754167	0.23584722	1.29	0.3013
POS	1	1.53346944	1.53346944	8.54	0.0614
TREAT*POS	2	0.43320556	0.21660278	1.21	0.4126
REP*POS(TREAT)	3	0.53867500	0.17955833	0.98	0.4185
Error	24	4.39540000	0.18314167		
Corrected Total	35	7.71496389			

Dependent Variable: SAT 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	106.8374056	53.4187028	0.35	0.7283
REP(TREAT)	3	453.8376500	151.2792167	4.28	0.0149
POS	1	998.7706778	998.7706778	45.66	0.0066
TREAT*POS	2	22.20753889	11.10376944	0.51	0.6458
REP*POS(TREAT)	3	65.6236500	21.8745500	0.62	0.6097
Error	24	848.561067	35.356711		
Corrected Total	35	2495.837989			

Dependent Variable: CAMEQ 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	198.1590889	99.0795444	0.36	0.7270
REP(TREAT)	3	836.678600	278.892867	0.72	0.5496
POS	1	1338.584178	1338.584178	5.56	0.0997
TREAT*POS	2	582.3238889	291.1619444	1.21	0.4122
REP*POS(TREAT)	3	722.885133	240.961711	0.62	0.6074
Error	24	9292.298133	387.179089		
Corrected Total	35	12970.929022			

Dependent Variable: MGMEQ 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	2.04046667	1.02023333	0.05	0.9513
REP(TREAT)	3	60.32776667	20.10925556	0.86	0.4762
POS	1	42.38010000	42.38010000	2.22	0.2330
TREAT*POS	2	40.11926667	20.05963333	1.05	0.4509
REP*POS(TREAT)	3	57.26230000	19.08743333	0.81	0.4984
Error	24	562.402[illegible]	23.4334333		
Corrected Total	35	764.5323000			

Dependent Variable: NAMEQ 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	37.53540556	18.76770278	0.25	0.7928
REP(TREAT)	3	224.2506417	74.7502139	4.94	0.0082
POS	1	200.4584028	200.4584028	6.72	0.0809
TREAT*POS	2	26.37410556	13.18705278	0.44	0.6788
REP*POS(TREAT)	3	89.4896750	29.8298917	1.97	0.1453
Error	24	363.3038000	15.1376583		
Corrected Total	35	941.4120306			

Dependent Variable: KMEQ 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.28137222	0.14068611	0.51	0.6429
REP(TREAT)	3	0.82148333	0.27382778	2.67	0.0704
POS	1	0.35601111	0.35601111	7.45	0.0720
TREAT*POS	2	0.22860556	0.11430278	2.39	0.2393
REP*POS(TREAT)	3	0.14335000	0.04778333	0.47	0.7089
Error	24	2.46260000	0.10260833		
Corrected Total	35	4.29342222			

Dependent Variable: SAR 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	1.60486667	0.80243333	0.23	0.8106
REP(TREAT)	3	10.68222500	3.56074167	14.77	0.0001
POS	1	3.68000278	3.68000278	8.67	0.0603
TREAT*POS	2	0.00035556	0.00017778	0.00	0.9996
REP*POS(TREAT)	3	1.27262500	0.42420833	1.76	0.1818
Error	24	5.78600000	0.24108333		
Corrected Total	35	23.02607500			

Dependent Variable: CAX 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	15.58771667	7.79385833	0.08	0.9273
REP(TREAT)	3	302.0293417	100.6764472	5.62	0.0046
POS	1	404.2110250	404.2110250	44.42	0.0069
TREAT*POS	2	24.52625000	12.26312500	1.35	0.3823
REP*POS(TREAT)	3	27.2975417	9.0991806	0.51	0.6804
Error	24	429.7926000	17.9080250		
Corrected Total	35	1203.4444750			

Dependent Variable: MGX 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.42428889	0.21214444	0.12	0.8911
REP(TREAT)	3	5.31106667	1.77035556	3.25	0.0395
POS	1	5.46001111	5.46001111	70.89	0.0035
TREAT*POS	2	0.89762222	0.44881111	5.83	0.0926
REP*POS(TREAT)	3	0.23106667	0.07702222	0.14	0.9343
Error	24	13.08806667	0.54533611		
Corrected Total	35	25.41212222			

Dependent Variable: NAX 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.75177222	0.37588611	0.28	0.7732
REP(TREAT)	3	4.01907500	1.33969167	7.13	0.0014
POS	1	1.88146944	1.88146944	10.78	0.0463
TREAT*POS	2	0.07757222	0.03878611	0.22	0.8128
REP*POS(TREAT)	3	0.52360833	0.17453611	0.93	0.4418
Error	24	4.50793333	0.18783056		
Corrected Total	35	11.76143056			

Dependent Variable: KX 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.39310556	0.19655278	1.69	0.3226
REP(TREAT)	3	0.34915000	0.11638333	2.53	0.0815
POS	1	0.22090000	0.22090000	2.25	0.2308
TREAT*POS	2	0.20311667	0.10155833	1.03	0.4556
REP*POS(TREAT)	3	0.29488333	0.09829444	2.13	0.1224
Error	24	1.10580000	0.04607500		
Corrected Total	35	2.56695556			

Dependent Variable: CEC 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	91.76321667	45.88160833	0.48	0.6606
REP(TREAT)	3	288.2491500	96.0830500	6.25	0.0027
POS	1	238.5995111	238.5995111	17.39	0.0251
TREAT*POS	2	64.86183889	32.43091944	2.36	0.2419
REP*POS(TREAT)	3	41.1556833	13.7185611	0.89	0.4593
Model	11	724.6294000	65.8754000	4.29	0.0014
Error	24	368.9294000	15.3720583		

Dependent Variable: ESP 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	6.23590556	3.11795278	0.70	0.5640
REP(TREAT)	3	13.41044167	4.47014722	2.46	0.0876
POS	1	0.30802500	0.30802500	0.09	0.7862
TREAT*POS	2	0.55401667	0.27700833	0.08	0.9259
REP*POS(TREAT)	3	10.51324167	3.50441389	1.93	0.1524
Error	24	43.68360000	1.82015000		
Corrected Total	35	74.70523056			

Dependent Variable: CANA 20-27.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	21.08370556	10.54185278	1.33	0.3864
REP(TREAT)	3	23.82004167	7.94001389	3.25	0.0394
POS	1	9.80733611	9.80733611	1.31	0.3357
TREAT*POS	2	1.49360556	0.74680278	0.10	0.9080
REP*POS(TREAT)	3	22.48594167	7.49531389	3.07	0.0471
Error	24	58.61566667	2.44231944		
Corrected Total	35	137.30629722			

Dependent Variable: pH 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.17377222	0.08688611	1.68	0.3233
REP(TREAT)	3	0.15475000	0.05158333	0.71	0.5577
POS	1	0.00444444	0.00444444	0.03	0.8716
TREAT*POS	2	0.55643889	0.27821944	1.94	0.2884
REP*POS(TREAT)	3	0.43098333	0.14366111	1.97	0.1459
Error	24	1.75320000	0.07305000		
Corrected Total	35	3.07358889			

Dependent Variable: EC 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.31340556	0.15670278	0.26	0.7871
REP(TREAT)	3	1.81104167	0.60368056	2.41	0.0917
POS	1	1.72922500	1.72922500	4.25	0.1314
TREAT*POS	2	1.21951667	0.60975833	1.50	0.3541
REP*POS(TREAT)	3	1.22197500	0.40732500	1.63	0.2094
Error	24	6.00913333	0.25038056		
Corrected Total	35	12.30429722			

Dependent Variable: SAT 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	68.92653889	34.46326944	6.15	0.0868
REP(TREAT)	3	16.80131667	5.60043889	0.43	0.7310
POS	1	36.08004444	36.08004444	1.18	0.3575
TREAT*POS	2	86.45017222	43.22508611	1.41	0.3702
REP*POS(TREAT)	3	92.01081667	30.67027222	2.37	0.0953
Error	24	310.1158667	12.9214944		
Corrected Total	35	610.3847556			

Dependent Variable: CAMEQ 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	1387.204422	693.602211	0.98	0.4693
REP(TREAT)	3	2115.256333	705.085444	1.77	0.1791
POS	1	2087.271511	2087.271511	3.13	0.1749
TREAT*POS	2	1060.603756	530.301878	0.80	0.5281
REP*POS(TREAT)	3	1998.639400	666.213133	1.68	0.1988
Error	24	9541.828267	397.576178		
Corrected Total	35	18190.803689			

Dependent Variable: MGMEQ 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	155.3531556	77.6765778	1.79	0.3075
REP(TREAT)	3	129.9794667	43.3264889	1.61	0.2123
POS	1	165.0368444	165.0368444	3.96	0.1409
TREAT*POS	2	58.50408889	29.25204444	0.70	0.5626
REP*POS(TREAT)	3	125.1842667	41.7280889	1.55	0.2262
Error	24	644.1309333	26.8387889		
Corrected Total	35	1278.1887556			

Dependent Variable: NAMEQ 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	142.8577722	71.4288861	0.19	0.8396
REP(TREAT)	3	1155.594050	385.198017	29.07	0.0001
POS	1	235.213344	235.213344	17.75	0.0003
TREAT*POS	2	90.93240556	45.46620278	1.18	0.4176
REP*POS(TREAT)	3	115.112683	38.370894	2.90	0.0560
Error	24	317.990467	13.249603		
Corrected Total	35	2057.700722			

Dependent Variable: KMEQ 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.08871667	0.04435833	0.34	0.7380
REP(TREAT)	3	0.39514167	0.13171389	3.35	0.0358
POS	1	0.34222500	0.34222500	13.93	0.0335
TREAT*POS	2	0.17921667	0.08960833	3.65	0.1573
REP*POS(TREAT)	3	0.07370833	0.02456944	0.62	0.6061
Error	24	0.94406667	0.03933611		
Corrected Total	35	2.02307500			

Dependent Variable: SAR 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.31810556	0.15905278	0.02	0.9817
REP(TREAT)	3	25.63968333	8.54656111	68.05	0.0001
POS	1	1.06777778	1.06777778	13.85	0.0338
TREAT*POS	2	0.54517222	0.27258611	3.54	0.1626
REP*POS(TREAT)	3	0.23128333	0.07709444	0.61	0.6126
Error	24	3.01400000	0.12558333		
Corrected Total	35	30.81602222			

Dependent Variable: CAX 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	3.25602222	1.62801111	0.41	0.6975
REP(TREAT)	3	11.99583333	3.99861111	0.68	0.5733
POS	1	0.78027778	0.78027778	0.16	0.7183
TREAT*POS	2	53.30442222	26.65221111	5.37	0.1021
REP*POS(TREAT)	3	14.89283333	4.96427778	0.84	0.4836
Error	24	141.26773333	5.88615556		
Corrected Total	35	225.49712222			

Dependent Variable: MGX 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	1.26373889	0.63186944	1.27	0.3986
REP(TREAT)	3	1.49341667	0.49780556	0.96	0.4274
POS	1	0.08604444	0.08604444	0.05	0.8380
TREAT*POS	2	0.74657222	0.37328611	0.22	0.8178
REP*POS(TREAT)	3	5.20311667	1.73437222	3.35	0.0358
Error	24	12.43746667	0.51822778		
Corrected Total	35	21.23035556			

Dependent Variable: NAX 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.02507222	0.01253611	0.02	0.9829
REP(TREAT)	3	2.17204167	0.72401389	2.20	0.1142
POS	1	1.43600278	1.43600278	17.18	0.0255
TREAT*POS	2	0.15993889	0.07996944	0.96	0.4770
REP*POS(TREAT)	3	0.25070833	0.08356944	0.25	0.8577
Error	24	7.89820000	0.32909167		
Corrected Total	35	11.94196389			

Dependent Variable: KX 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	0.00373889	0.00186944	0.62	0.5972
REP(TREAT)	3	0.00911667	0.00303889	1.07	0.3789
POS	1	0.01777778	0.01777778	4.27	0.1306
TREAT*POS	2	0.01150556	0.00575278	1.38	0.3754
REP*POS(TREAT)	3	0.01248333	0.00416111	1.47	0.2477
Error	24	0.06793333	0.00283056		
Corrected Total	35	0.12255556			

Dependent Variable: CEC 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	6.86802222	3.43401111	0.20	0.8298
REP(TREAT)	3	51.85169167	17.28389722	1.57	0.2232
POS	1	0.60062500	0.60062500	0.15	0.7230
TREAT*POS	2	13.59740000	6.79870000	1.72	0.3185
REP*POS(TREAT)	3	11.88255833	3.96085278	0.36	0.7830
Error	24	264.63193333	11.02633056		
Corrected Total	35	349.43223056			

Dependent Variable: ESP 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	1.88840556	0.94420278	0.13	0.8807
REP(TREAT)	3	21.36010833	7.12003611	2.37	0.0956
POS	1	15.06733611	15.06733611	9.64	0.0531
TREAT*POS	2	2.60250556	1.30125278	0.83	0.5158
REP*POS(TREAT)	3	4.69140833	1.56380278	0.52	0.6721
Error	24	72.08406667	3.00350278		
Corrected Total	35	117.69383056			

Dependent Variable: CANA 40-47.5 cm

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	2.75721667	1.37860833	0.17	0.8497
REP(TREAT)	3	24.03690833	8.01230278	2.45	0.0883
POS	1	10.98922500	10.98922500	4.73	0.1179
TREAT*POS	2	3.58535000	1.79267500	0.77	0.5365
REP*POS(TREAT)	3	6.96884167	2.32294722	0.71	0.5557
Error	24	78.55193333	3.27299722		
Corrected Total	35	126.88947500			

APPENDIX C
SUMMARY STATISTICS - CHAPTER 3

Table C1. Summary Statistics - Soil Physical Properties

TREAT=Ripped DEPTH=0-7.5 cm

N Obs	Variable	Mean	Variance	Std Dev	Std Error
12	BDENS	1.152	0.004	0.065	0.019
	MMOIST	23.777	8.023	2.832	0.818
	VMOIST	27.383	12.085	3.476	1.004
	FLDCAP	31.199	7.922	2.815	0.813
	PWP	15.983	1.873	1.369	0.395
	AWHC	15.216	4.031	2.008	0.580
	LIQLIM	44.186	9.822	3.134	0.905
	PLASLIM	25.498	9.379	3.063	0.884
	PLASINDX	18.687	9.735	3.120	0.901
	SAND	21.755	5.041	2.245	0.648
	SILT	34.454	5.490	2.343	0.676
	CLAY	43.792	7.502	2.739	0.791
	TOTCARB	2.558	0.135	0.367	0.106

TREAT=Rip+Manure DEPTH=0-7.5 cm

N Obs	Variable	Mean	Variance	Std Dev	Std Error
12	BDENS	0.902	0.020	0.141	0.041
	MMOIST	28.824	15.122	3.889	1.123
	VMOIST	25.639	8.469	2.910	0.840
	FLDCAP	33.029	7.213	2.686	0.775
	PWP	15.975	2.860	1.691	0.488
	AWHC	17.053	3.190	1.786	0.516
	LIQLIM	46.514	29.259	5.409	1.561
	PLASLIM	33.943	21.385	4.624	1.335
	PLASINDX	12.572	2.897	1.702	0.491
	SAND	24.182	7.248	2.692	0.777
	SILT	38.303	2.755	1.660	0.479
	CLAY	37.514	5.756	2.399	0.693
	TOTCARB	5.265	2.454	1.566	0.452

Table C1. Cont'd - Summary Statistics - Soil Physical Properties

TREAT=Unripped DEPTH=0-7.5 cm

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	BDENS	1.121	0.005	0.070	0.028
	MMOIST	23.941	3.576	1.891	0.772
	VMOIST	26.849	8.539	2.922	1.193
	FLDCAP	31.558	3.732	1.932	0.789
	PWP	16.753	5.524	2.350	0.960
	AWHC	14.810	2.887	1.699	0.694
	LIQLIM	40.802	0.659	0.812	0.331
	PLASLIM	27.713	0.627	0.792	0.323
	PLASINDX	13.088	0.511	0.715	0.292
	SAND	22.085	1.242	1.114	0.455
	SILT	38.792	1.902	1.379	0.563
	CLAY	39.127	1.505	1.227	0.501
	TOTCARB	3.306	0.036	0.189	0.077

TREAT=Rip+Peat DEPTH=0-7.5 cm

N Obs	Variable	Mean	Variance	Std Dev	Std Error
12	BDENS	0.989	0.008	0.088	0.025
	MMOIST	32.283	49.289	7.021	2.027
	VMOIST	31.589	33.183	5.760	1.663
	FLDCAP	32.208	9.179	3.030	0.875
	PWP	17.157	3.700	1.924	0.555
	AWHC	15.051	2.413	1.553	0.448
	LIQLIM	47.007	16.851	4.105	1.185
	PLASLIM	29.148	6.899	2.627	0.758
	PLASINDX	17.860	15.460	3.932	1.135
	SAND	27.378	9.394	3.065	0.885
	SILT	32.532	1.960	1.400	0.404
	CLAY	40.092	12.255	3.501	1.011
	TOTCARB	4.414	1.109	1.053	0.304

Table C2. Summary Statistics - Aggregate Size Distribution (Air Dry)

TREAT=Ripped

N Obs	Variable	Mean	Variance	Std Dev	Std Error
10	0-0.25 mm	4.7	1.0	1.0	0.3
	0.25-0.5 mm	3.9	0.3	0.6	0.2
	0.5-1 mm	7.3	1.9	1.4	0.4
	1-2 mm	9.9	3.3	1.8	0.6
	2-4 mm	13.5	3.5	1.9	0.6
	4-8 mm	18.4	3.0	1.7	0.6
	8-16 mm	28.6	8.0	2.8	0.9
	>16 mm	13.7	25.5	5.1	1.6
	DMWD	7.6	0.8	0.9	0.3
	DGMD	1.9	0.0	0.1	0.0

TREAT=Rip+Manure

N Obs	Variable	Mean	Variance	Std Dev	Std Error
10	0-0.25 mm	6.3	3.6	1.9	0.6
	0.25-0.5 mm	6.2	2.5	1.6	0.5
	0.5-1 mm	11.0	5.2	2.3	0.7
	1-2 mm	14.0	3.1	1.8	0.6
	2-4 mm	16.8	0.9	0.9	0.3
	4-8 mm	19.3	7.2	2.7	0.8
	8-16 mm	20.3	15.0	3.9	1.2
	>16 mm	6.2	7.8	2.8	0.9
	DMWD	5.5	0.7	0.9	0.3
	DGMD	1.6	0.0	0.2	0.0

Table C2. Cont'd. Summary Statistics - Aggregate Size Distribution (Air Dry)

TREAT=Unripped

N Obs	Variable	Mean	Variance	Std Dev	Std Error
10	0-0.25 mm	11.0	5.0	2.2	0.7
	0.25-0.5 mm	8.6	4.1	2.0	0.6
	0.5-1 mm	13.5	7.1	2.7	0.8
	1-2 mm	15.3	2.3	1.5	0.5
	2-4 mm	16.4	1.0	1.0	0.3
	4-8 mm	15.6	2.4	1.5	0.5
	8-16 mm	15.5	14.5	3.8	1.2
	>16 mm	4.0	4.6	2.1	0.7
	DMWD	4.4	0.7	0.9	0.3
	DGMD	1.3	0.0	0.1	0.0

TREAT=Rip+Peat

N Obs	Variable	Mean	Variance	Std Dev	Std Error
10	0-0.25 mm	7.3	2.9	1.7	0.5
	0.25-0.5 mm	6.5	2.0	1.4	0.4
	0.5-1 mm	9.6	2.8	1.7	0.5
	1-2 mm	11.2	2.2	1.5	0.5
	2-4 mm	16.1	18.9	4.3	1.4
	4-8 mm	18.2	4.9	2.2	0.7
	8-16 mm	22.4	22.3	4.7	1.5
	>16 mm	8.7	6.8	2.6	0.8
	DMWD	6.1	0.9	0.9	0.3
	DGMD	1.6	0.0	0.2	0.0

Table C3. Summary of Water Stable Aggregate Distribution

TREAT=Ripped

N Obs	Variable	Mean	Variance	Std Dev	Std Error
30	0.125-0.25 mm	12.689	73.706	8.585	1.567
	0.25-0.5 mm	15.254	4.836	2.199	0.402
	0.5-1.0 mm	13.678	2.938	1.714	0.313
	1.0-2.0 mm	11.307	3.456	1.859	0.339
	2.0-4.0 mm	12.046	2.033	1.426	0.260
	>4.0 mm	21.669	24.617	4.962	0.906
	WMWD	2.021	0.077	0.278	0.051
	WGMD	0.901	0.006	0.076	0.014

TREAT=Rip+Manure

N Obs	Variable	Mean	Variance	Std Dev	Std Error
30	0.125-0.25 mm	7.628	1.566	1.252	0.229
	0.25-0.5 mm	13.695	3.260	1.806	0.330
	0.5-1.0 mm	17.523	4.902	2.214	0.404
	1.0-2.0 mm	14.085	2.395	1.548	0.283
	2.0-4.0 mm	14.021	2.180	1.477	0.270
	>4.0 mm	24.551	21.300	4.615	0.843
	WMWD	2.307	0.070	0.265	0.048
	WGMD	1.048	0.005	0.072	0.013

TREAT=Unripped

N Obs	Variable	Mean	Variance	Std Dev	Std Error
30	0.125-0.25 mm	10.960	3.365	1.834	0.335
	0.25-0.5 mm	15.113	9.792	3.129	0.571
	0.5-1.0 mm	15.285	7.114	2.667	0.487
	1.0-2.0 mm	11.806	3.027	1.740	0.318
	2.0-4.0 mm	12.544	2.844	1.686	0.308
	>4.0 mm	19.539	40.378	6.354	1.160
	WMWD	1.927	0.132	0.364	0.066
	WGMD	0.901	0.007	0.084	0.015

TREAT=Rip+Peat

N Obs	Variable	Mean	Variance	Std Dev	Std Error
30	0.125-0.25 mm	7.102	2.852	1.689	0.314
	0.25-0.5 mm	12.973	3.914	1.978	0.367
	0.5-1.0 mm	15.958	7.888	2.809	0.522
	1.0-2.0 mm	14.002	22.562	4.750	0.867
	2.0-4.0 mm	14.039	3.315	1.821	0.332
	>4.0 mm	28.368	16.224	4.028	0.735
	WMWD	2.515	0.052	0.228	0.042
	WGMD	1.076	0.021	0.145	0.026

Table C4. Summary Statistics - Soil Chemical Properties

TREAT=Ripped DEPTH=0-7.5 cm

N Obs	Variable	Mean	Variance	Std Dev	Std Error
12	PH	6.54	0.10	0.32	0.09
	EC	0.53	0.01	0.10	0.03
	SAT	56.93	7.58	2.75	0.79
	CAMEQ	26.30	25.71	5.07	1.46
	MGMEQ	9.86	3.59	1.89	0.55
	NAMEQ	6.18	6.79	2.61	0.75
	KMEQ	0.68	0.05	0.22	0.06
	SAR	1.47	0.39	0.63	0.18
	CEC	29.02	5.68	2.38	0.69
	CAX	21.57	9.20	3.03	0.88
	MGX	5.75	0.44	0.67	0.19
	NAX	1.43	0.13	0.37	0.11
	KX	0.91	0.02	0.15	0.04
	ESP	4.91	1.50	1.23	0.35
	CANA	16.24	29.11	5.40	1.56

TREAT=Rip+Manure DEPTH=0-7.5 cm

N Obs	Variable	Mean	Variance	Std Dev	Std Error
12	PH	6.52	0.05	0.23	0.07
	EC	1.15	0.09	0.30	0.09
	SAT	63.06	44.49	6.67	1.93
	CAMEQ	49.34	120.18	10.96	3.16
	MGMEQ	22.80	27.45	5.24	1.51
	NAMEQ	4.67	5.07	2.25	0.65
	KMEQ	7.11	10.57	3.25	0.94
	SAR	0.79	0.13	0.36	0.10
	CEC	33.02	34.56	5.88	1.70
	CAX	21.02	20.34	4.51	1.30
	MGX	5.45	0.39	0.62	0.18
	NAX	0.79	0.23	0.48	0.14
	KX	3.90	1.49	1.22	0.35
	ESP	2.40	2.06	1.44	0.41
	CANA	37.27	591.66	24.32	7.02

Table C4. Summary Statistics - Soil Chemical Properties

TREAT=Unripped DEPTH=0-7.5 cm

N Obs	Variable	Mean	Variance	Std Dev	Std Error
6	PH	6.08	0.03	0.19	0.08
	EC	0.62	0.00	0.05	0.02
	SAT	54.80	5.56	2.36	0.96
	CAMEQ	30.36	7.06	2.66	1.08
	MGMEQ	12.02	1.16	1.08	0.44
	NAMEQ	4.95	3.94	1.99	0.81
	KMEQ	0.61	0.02	0.13	0.05
	SAR	1.08	0.20	0.44	0.18
	CEC	30.46	16.94	4.12	1.68
	CAX	18.73	2.84	1.68	0.69
	MGX	5.46	0.12	0.35	0.14
	NAX	0.84	0.05	0.22	0.09
	KX	0.90	0.02	0.12	0.05
	ESP	2.77	0.36	0.60	0.24
	CANA	23.07	16.11	4.01	1.64

TREAT=Rip+Peat DEPTH=0-7.5 cm

N Obs	Variable	Mean	Variance	Std Dev	Std Error
12	PH	5.88	0.09	0.30	0.09
	EC	0.75	0.02	0.15	0.04
	SAT	61.85	27.98	5.29	1.53
	CAMEQ	36.05	62.29	7.89	2.28
	MGMEQ	14.31	11.63	3.41	0.98
	NAMEQ	7.79	7.88	2.81	0.81
	KMEQ	0.96	0.08	0.28	0.08
	SAR	1.62	0.54	0.73	0.21
	CEC	32.68	11.42	3.38	0.98
	CAX	20.20	5.22	2.29	0.66
	MGX	5.68	0.20	0.45	0.13
	NAX	1.03	0.14	0.38	0.11
	KX	0.94	0.02	0.13	0.04
	ESP	3.20	1.44	1.20	0.35
	CANA	22.81	112.42	10.60	3.06

Table C5. General Linear Models Procedure

Dependent Variable: BULK DENSITY

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	0.44423420	0.14807807	3.32	0.1385
REP(TREAT)	4	0.17851642	0.04462910		
Error	34	0.19738950	0.00580557		
Corrected Total	41	0.82014012			

Dependent Variable: MASS MOISTURE

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	536.64269207	178.88089736	1.77	0.2915
REP(TREAT)	4	404.00404983	101.00101246		
Error	34	410.64970600	12.07793253		
Corrected Total	41	1351.29644790			

Dependent Variable: VOLUMETRIC MOISTURE

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	233.95231879	77.98410626	1.08	0.4528
REP(TREAT)	4	289.06213717	72.26553429		
Error	34	344.73781567	10.13934752		
Corrected Total	41	867.75227162			

Dependent Variable: FIELD CAPACITY (1/3 BAR)

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	21.93775000	7.31258333	0.28	0.8358
REP(TREAT)	4	103.18576667	25.79644167		
Error	34	182.93506667	5.38044314		
Corrected Total	41	308.05858333			

Dependent Variable: PERMANENT WILTING POINT (15 BAR)

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	11.86510714	3.95503571	0.36	0.7867
REP(TREAT)	4	44.03918333	11.00979583		
Error	34	76.35450000	2.24572059		
Corrected Total	41	132.25879048			

Dependent Variable: AVAILABLE WATER HOLDING CAPACITY

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	34.42717857	11.47572619	2.00	0.2570
REP(TREAT)	4	23.00038333	5.75009583		
Error	34	97.41786667	2.86523137		
Corrected Total	41	154.84542857			

Dependent Variable: LIQUID LIMIT

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	188.31469881	62.77156627	0.84	0.5394
REP(TREAT)	4	299.58530833	74.89632708		
Error	34	318.96138333	9.38121716		
Corrected Total	41	806.86139048			

Dependent Variable: PLASTIC LIMIT

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	447.41205000	149.13735000	3.42	0.1330
REP(TREAT)	4	174.50431667	43.62607917		
Error	34	242.92843333	7.14495392		
Corrected Total	41	864.84480000			

Dependent Variable: PLASTICITY INDEX

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	319.70691548	106.56897183	5.67	0.0636
REP(TREAT)	4	75.24389167	18.81097292		
Error	34	236.32158333	6.95063480		
Corrected Total	41	631.27239048			

Dependent Variable: SAND CONTENT

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	219.40072024	73.13357341	5.22	0.0722
REP(TREAT)	4	56.09065833	14.02266458		
Error	34	188.63918333	5.54821127		
Corrected Total	41	464.13056190			

Dependent Variable: SILT CONTENT

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	277.46944524	92.48981508	14.30	0.0132
REP(TREAT)	4	25.86903333	6.46725833		
Error	34	95.89933333	2.82056863		
Corrected Total	41	399.23781190			

Dependent Variable: CLAY CONTENT

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	248.25543095	82.75181032	8.46	0.0332
REP(TREAT)	4	39.14751667	9.78687917		
Error	34	249.02070000	7.32413824		
Corrected Total	41	536.42364762			

Dependent Variable: LOSS ON IGNITION

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	49.06007131	16.35335710	4.78	0.0823
REP(TREAT)	4	13.67729900	3.41932475		
Error	34	27.18094333	0.79943951		
Corrected Total	41	89.91831364			

Dependent Variable: pH

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	3.74694762	1.24898254	5.29	0.0707
REP(TREAT)	4	0.94425000	0.23606250		
Error	34	1.95770000	0.05757941		
Corrected Total	41	6.64889762			

Dependent Variable: ELECTRICAL CONDUCTIVITY

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	2.57377381	0.85792460	6.97	0.0457
REP(TREAT)	4	0.49266667	0.12316667		
Error	34	0.84540000	0.02486471		
Corrected Total	41	3.91184048			

Dependent Variable: SATURATION PERCENT

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	427.12691190	142.37563730	1.51	0.3413
REP(TREAT)	4	377.80955000	94.45238750		
Error	34	530.54010000	15.60412059		
Corrected Total	41	1335.47656190			

Dependent Variable: SOLUBLE CALCIUM

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	3451.89456667	1150.63152222	10.11	0.0244
REP(TREAT)	4	455.09936667	113.77484167		
Error	34	1870.18580000	55.00546471		
Corrected Total	41	5777.17973333			

Dependent Variable: SOLUBLE MAGNESIUM

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	1105.12309048	368.37436349	17.50	0.0092
REP(TREAT)	4	84.18503333	21.04625833		
Error	34	390.93286667	11.49802549		
Corrected Total	41	1580.24099048			

Dependent Variable: SOLUBLE SODIUM

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	66.72222024	22.24074008	1.27	0.3987
REP(TREAT)	4	70.29187500	17.57296875		
Error	34	166.59051667	4.89972108		
Corrected Total	41	303.60461190			

Dependent Variable: SOLUBLE POTASSIUM

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	344.60020714	114.86673571	13.57	0.0145
REP(TREAT)	4	33.85483333	8.46370833		
Error	34	83.81466667	2.46513725		
Corrected Total	41	462.26970714			

Dependent Variable: SAR

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	4.99339167	1.66446389	1.53	0.3357
REP(TREAT)	4	4.34000833	1.08500208		
Error	34	8.30278333	0.24419951		
Corrected Total	41	17.63618333			

Dependent Variable: CEC

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	124.17910595	41.39303532	0.37	0.7797
REP(TREAT)	4	447.05397500	111.76349375		
Error	34	205.87488333	6.05514363		
Corrected Total	41	777.10796429			

Dependent Variable: EXCHANGEABLE CALCIUM

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	36.09779524	12.03259841	0.29	0.8313
REP(TREAT)	4	165.84826667	41.46206667		
Error	34	230.79176667	6.78799314		
Corrected Total	41	432.73782857			

Dependent Variable: EXCHANGEABLE MAGNESIUM

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	0.70804762	0.23601587	0.16	0.9150
REP(TREAT)	4	5.73736667	1.43434167		
Error	34	6.25383333	0.18393627		
Corrected Total	41	12.69924762			

Dependent Variable: EXCHANGEABLE SODIUM

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	2.77128929	0.92376310	7.73	0.0385
REP(TREAT)	4	0.47810833	0.11952708		
Error	34	5.33471667	0.15690343		
Corrected Total	41	8.58411429			

Dependent Variable: EXCHANGEABLE POTASSIUM

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	76.31224881	25.43741627	11.28	0.0202
REP(TREAT)	4	9.02095833	2.25523958		
Error	34	7.85878333	0.23114069		
Corrected Total	41	93.19199048			

Dependent Variable: ESP

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	42.40145357	14.13381786	12.45	0.0170
REP(TREAT)	4	4.53972500	1.13493125		
Error	34	52.36398333	1.54011716		
Corrected Total	41	99.30516190			

Dependent Variable: EXCHANGEABLE CALCIUM:SODIUM RATIO

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	2808.23801548	936.07933849	11.11	0.0207
REP(TREAT)	4	336.88667500	84.22166875		
Error	34	7808.78595000	229.67017500		
Corrected Total	41	10953.91064048			

Dependent Variable: MEAN WEIGHT DIAMETER (WET AGGREGATES)

Source	DF	Type III SS	Mean Square	F Value	Pr> F
TREAT	3	6.51519909	2.17173303	11.51	0.0195
REP(TREAT)	4	0.75446583	0.18861646		
Error	112	8.87886600	0.07927559		
Corrected Total	119	16.14853092			

Dependent Variable: GEOMETRIC MEAN DIAMETER (WET AGGREGATES)

Source	DF	Type III SS	Mean Square	F Value	Pr> F
TREAT	3	0.78780236	0.26260079	9.97	0.0251
REP(TREAT)	4	0.10538390	0.02634597		
Error	112	1.02211067	0.00912599		
Corrected Total	119	1.91529693			

Dependent Variable: 0.125-0.25 MM - WET

Source	DF	Type III SS	Mean Square	F Value	Pr> F
TREAT	3	639.47794444	213.15931481	8.33	0.0340
REP(TREAT)	4	102.38634993	25.59658748		
Error	111	2257.95516413	20.34193842		
Corrected Total	118	2999.78221587			

Dependent Variable: 0.25-0.5 mm - WET

Source	DF	Type III SS	Mean Square	F Value	Pr> F
TREAT	3	106.51931568	35.50643856	1.43	0.3583
REP(TREAT)	4	99.32586360	24.83146590		
Error	111	529.01265267	4.76587975		
Corrected Total	118	737.44516346			

Dependent Variable: 0.5-1.0 mm - WET

Source	DF	Type III SS	Mean Square	F Value	Pr> F
TREAT	3	228.77985596	76.25995199	5.04	0.0761
REP(TREAT)	4	60.50882831	15.12720708		
Error	111	594.02848346	5.35160796		
Corrected Total	118	883.03174198			

Dependent Variable: 1.0-2.0 mm - WET

Source	DF	Type III SS	Mean Square	F Value	Pr> F
TREAT	3	189.41007630	63.13669210	3.58	0.1247
REP(TREAT)	4	70.48413980	17.62103495		
Error	112	841.27710187	7.51140270		
Corrected Total	119	1101.17131797			

Dependent Variable: 2.0-4.0 mm - WET

Source	DF	Type III SS	Mean Square	F Value	Pr> F
TREAT	3	94.04723089	31.34907696	6.15	0.0558
REP(TREAT)	4	20.38504637	5.09626159		
Error	112	280.41530373	2.50370807		
Corrected Total	119	394.84758099			

Dependent Variable: >4.0 mm - WET

Source	DF	Type III SS	Mean Square	F Value	Pr> F
TREAT	3	1315.08094687	438.36031562	7.62	0.0395
REP(TREAT)	4	230.12567873	57.53141968		
Error	112	2742.93002627	24.49044666		
Corrected Total	119	4288.13665187			

Dependent Variable: 0-0.125 mm - AIR DRY

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	218.7264719	72.9088240	8.63	0.0320
REP(TREAT)	4	33.7855416	8.4463854		
Error	32	78.6737597	2.4585550		
Corrected Total	39	331.1857733			

Dependent Variable: 0.25-0.5 mm - AIR DRY

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	110.7725154	36.9241718	8.43	0.0333
REP(TREAT)	4	17.5241339	4.3810335		
Error	32	63.2707714	1.9772116		
Corrected Total	39	191.5674207			

Dependent Variable: 0.5-1.0 mm - AIR DRY

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	203.3543458	67.7847819	8.85	0.0307
REP(TREAT)	4	30.6362614	7.6590653		
Error	32	122.6826498	3.8338328		
Corrected Total	39	356.6732570			

Dependent Variable: 1-2 mm - AIR DRY

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	187.7684268	[illegible]	8.10	0.0356
REP(TREAT)	4	30.9089955	7.7272489		
Error	32	66.5596676	2.0799896		
Corrected Total	39	285.2370898			

Dependent Variable: 2-4 mm - AIR DRY

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	65.68353919	21.89451306	3.36	0.1360
REP(TREAT)	4	26.04399111	6.51099778		
Error	32	192.88805405	6.02775169		
Corrected Total	39	284.61558435			

Dependent Variable: 4-8 mm - AIR DRY

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	73.95167506	24.65055835	2.14	0.2382
REP(TREAT)	4	46.11867401	11.52966850		
Error	32	111.5155292	3.4848603		
Corrected Total	39	231.5858783			

Dependent Variable: 8-16 mm -AIR DRY

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	893.3996266	297.7998755	10.75	0.0220
REP(TREAT)	4	110.8329670	27.7082417		
Error	32	427.935125	13.372973		
Corrected Total	39	1432.167719			

Dependent Variable: >16 mm - AIR DRY

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	517.2646163	172.4215388	4.51	0.0898
REP(TREAT)	4	152.8191150	38.2047787		
Error	32	250.2902238	7.8215695		
Corrected Total	39	920.3739551			

Dependent Variable: MEAN WEIGHT DIAMETER - AIR DRY

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	53.01268750	17.67089583	8.58	0.0323
REP(TREAT)	4	8.23339000	2.05834750		
Error	32	20.18160000	0.63067500		
Corrected Total	39	81.42767750			

Dependent Variable: GEOMETRIC MEAN DIAMETER - AIR DRY

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	1.52112705	0.50704235	8.73	0.0314
REP(TREAT)	4	0.23227085	0.05806771		
Error	32	0.51438482	0.01607453		
Corrected Total	39	2.26778272			