EFFECT OF GRASSES AND SOIL AMENDMENTS ON SOIL AGGREGATES AND AGGREGATE STRENGTH

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ABSTRACT

Four solum and subsoil materials from Alberta were treated to determine if soil aggregation and aggregate strength could be increased to reduce succeptibility to soil compaction. Each soil was treated with organic amendments of manure or a control, chemical amendments of gypsum, bottom ash or a control, and cropping treatments of smooth brome grass (Bromus inermis), quack grass (Agropyron repens) or a control. Four replicates were used for each treatment. The grasses were grown in the amended soils for 23 weeks. The percentage of coarse, medium and fine aggregates in each treatment was measured, as well as the force required to crush large granular aggregates at moisture tensions of 1/3 bar, 1 bar, 3 bars and 15 bars.

All treatments favoured the development of fine aggregates at the expense of coarse aggregates. Across all moisture tensions only quack grass cropping significantly increased aggregate strength while bottom ash and manure amendments significantly decreased aggregate strength.

At 1/3 bar tension, at which aggregates have low strength and are easily crushed, all treatments significantly increased aggregate strength except the manure amendment which decreased strength. The results indicate that it may be possible to reduce the risk of soil compaction through effective land management.

INTRODUCTION

Soil compaction has become a serious concern in resource extraction industries such as coal, oil and gas exploration and logging companies. The heavy equipment used by such industries applies tremendous pressures on the soil and can result in compaction of the soil and loss of soil structure. That can lead to impeded plant root growth, greater susceptibility to drought and nutrient stress and reduced productivity.

Soil compaction is governed by the load applied to the soil and the succeptibility of the soil to compaction. The applied load is often considerable in industrial situations and in most cases this load cannot be substantially reduced. Succeptibility to compaction varies depending on soil properties. It is mainly dependent on water tension (De Kimpe et al. 1982), but also influenced by stucture (Utomo and Dexter 1981), aggregates (Douglas et al. 1986; Utomo and Dexter 1981), organic matter content (Douglas et al. 1986) and soluble salt content

(Pohjakas 1966). Modifying these properties will alter succeptibility to compaction and may provide a means of allowing heavy loads on soil without compaction.

Aggregate strength is an important factor in compaction. Soil aggregates maintain an open soil structure with large pores even in fine-textured soils. When an aggregate is crushed under a compressive load smaller aggregates and individual mineral grains are separated from larger aggregates and forced into pores. This results in loss of structure and pore space which leads to reduced infiltration, greater runoff and erosion and poor root aeration. Because aggregate strength can be manipulated it should be possible to treat the soil to increase aggregate strength, thereby allowing the soil to better resist compactive forces.

Initial formation of aggregates is enhanced by wetting and drying cycles (Russell 1971), and plant root activity (Taylor 1971). Aggregate strength is mainly due to organic matter decomposition products (Russell 1971) but calcium, aluminum and iron oxides have been shown to have considerable influence also (Giovannini and Sequi 1978).

The purpose of this paper is to investigate the effect of grass species and organic and chemical amendments on the formation and strength of aggregates in some Alberta soils. It may seldom be possible to purposely modify aggregate strength before mining or logging. However, aggregates are always being amended unintentionally by various chemical or organic amendments and different cropping practices. The results generated in this study will provide a clearer understanding of the effects of these practices on aggregate strength and aggregate formation.

MATERIALS AND METHODS

A pot experiment to investigate the effect of soil treatments on aggregate formation and strength was conducted in a greenhouse for 23 weeks from February to July, 1987. The treatments in the experiment consisted of four soils, two organic matters, three chemicals and three cropping systems. Each combination of factors was replicated four times for a total of 288 pots. The experiment was completely randomized and was designed to allow an analysis of variance.

Soils

The soils used in the experiment were a sodic minespoil from the Highvale area, a Bt horizon from an orthic Gray Luvisol (Cooking Lake area), the clay till parent material from the same orthic Gray Luvisol and the Bm horizon of an orthic Brown Chernozem (Whiedon series). No A horizon materials were included because they tend to be well aggregated and are often stripped and stockpiled before mining and therefore are not subject to compaction. Some chemical and physical data are presented in Table 1.

Four methods were used to determine chemical properties of the materials. pH was determined by glass electrode in 1:2 suspensions of soil in 0.01 M $CaCl_2$ (Sheldrick 1984). Electrical conductivity was determined by conductivity meter in saturation paste extracts (Alberta Agriculture 1988). The sodium adsorption ratio (SAR) was calculated from ion concentrations in saturation paste extracts (McKeague 1976), using atomic absorption for calcium and magnesium and atomic emmission for sodium. Texture was determined by the hydrometer method (McKeague 1976).

Table 1. Soil chemical and physical data.

soil	pH	EC (mS/cm)	SAR	Texture
minespoil	8.1	3.8	11	clay
Luvisol Bt	7.0	0.1	0	clay loam
Luvisol till	7.6	2.2	1	sandy clay loam
Chernozem B_m	8.2	0.8	0	clay loam

Treatments

The organic matter amendment consisted of mixing dry, rotted manure into half of the pots at a rate of 17.5 tonnes per hectare (8 tons/acre) and not adding manure to the other half of the pots as a control. The chemical amendments consisted of mixing into the pots powdered gypsum at a rate of 10.9 tonnes per hectare (5 tons/acre), bottom ash from the Alberta Power plant in Forestburg at a rate of 20% by volume, or no chemical amendment as a control. These chemical amendments were used because of the calcium source in gypsum and the iron and aluminum oxides in bottom ash. The cropping treatments consisted of growing smooth brome (*Bromus inermis*), quack grass (*Agropyron repens*), or not growing plants as a control. These grass species were chosen because of their dense and fibrous root systems and their ability to provide continuous growth for the duration of the experiment.

Pot Preparation

Soil materials were passed through a jaw crusher and wire sieve with one centimetre square openings to remove stones. Enough soil for all the replications of each treatment was placed in a drum mixer, the chemical and organic amendments were added, fertilizer was added at a rate of 54.5 kg N per ha (50 lb./acre), 27.3 kg P per ha (25 lb./acre) and 17.5 kg K per ha (16 lb./acre) and the amendments were thoroughly incorporated. Fertilizer was added to all pots, including controls. Fertilizer and amendment application rates were calculated on the basis of the surface area of the pots. Soil-amendment mixtures were placed in standard 14 cm plastic pots and lightly tamped. Three-month-old transplants of brome or quack grass were planted in the pots, using one plant per pot. The plants were placed in a completely randomized design in a greenhouse with supplemental fluorescent lighting.

Pots were watered twice a week; one of these waterings included dilute 20-20-20 fertilizer. Equal amounts of water were added to each pot until the planted pots began to transpire considerable moisture, as determined by rapid drying of the soil. The planted pots were then watered more heavily in an attempt to maintain the same moisture level as the unplanted controls. To stimulate growth and tillering the plants were cut to 5 cm height each time they attained an average height of 40 cm. A total of five cuts were made.

Aggregate Size Distribution

After the pots had thoroughly air-dried they were passed through a jaw-crusher and a one-centimetre sieve as described previously. Aggregates were sieved into three fractions for each pot and the weights recorded. The sizes were 4.75 to 10 mm, 2 to 4.75 mm and less than 2 mm. These sizes correspond closely to coarse (5 to 10 mm), medium (2 to 5 mm) and fine (<2 mm) granular aggregates in the Canadian system of soil classification (Canada Soil Survey Committee 1978).

Aggregate Strength Tests

One of the four replicates from each treatment of the sodic minespoil only was selected at random for aggregate strength tests. Aggregates in the 4.75 mm to 10 mm size range were chosen at random and equilibrated in pressure plate moisture extractors at 1/3 bar, 1 bar, 3 bar and 15 bar moisture tensions. Thirteen aggregates were chosen at random from each moisture tension for each treatment and crushed under a blunt rod attached to an analytical balance to determine the force needed to crush individual aggregates.

RESULTS AND DISCUSSION

Aggregate Strength

The analysis of variance indicated that for the sodic minespoil all treatments (moisture level, organic amendment, chemical amendment, cropping treatment) had a significant effect on aggregate strength at the 99% confidence level. The means of these treatments were separated by Duncan's multiple-range test. Several interactions were also significant but a discussion of these interactions is not included in this paper.

Table 2 shows the effect of moisture tension on aggregate strength. As expected, aggregates at each different moisture tension have significantly different strength, with drier aggregates having greater strength. Because low-strength aggregates are most likely to be crushed and compacted the aggregates at 1/3 bar tension are of particular interest. Therefore, an analysis of variance was also done for aggregates at 1/3 bar tension only. This showed highly significant effects due to the organic, chemical and cropping treatments, and the means of each grouping were separated by Duncan's multiple-range test (Table 3).

Across all moisture tensions the manure amendment resulted in a small (10-15%) but significant decrease in aggregate strength compared with controls. At 1/3 bar moisture tension, when aggregate strength is lowest and compaction is most likely the manure amendment resulted in a 30% decrease in aggregate strength. Organic matter is commonly believed to promote aggregation and aggregate stability; the results of this experiment suggests that it does so at the expense of aggregate strength, especially when soil is moist.

Table 2. Force required to crush aggregates (grams).

Moisture treatment	Force
1/3 bar	61 D*
1 bar	91 C
3 bar	100 B
15 bar	158 A

*Numbers followed by different letters are significantly different at the 95% confidence level.

Table 3. Force required to crush aggregates (grams).

TREATMENTS	All moisture tensions	1/3 bar tension
<u>Organic amendments</u>		
Manure	96 B*	50 B
Control	109 A	72 A
<u>Chemical amendments</u>		
Gypsum	109 A	61 B
Bottom ash	95 B	68 A
Control	103 A	54 C
<u>Cropping treatments</u>		
Brome grass	99 B	68 A
Quack grass	112 A	67 A
Control	97 B	49 B

*Numbers in the same column of each treatment grouping followed by different letters are significantly different at the 95% confidence level.

Across all moisture tensions the only chemical amendment producing significant changes in aggregate strength compared to controls was bottom ash, and this change was a 15% decrease in aggregate strength. At 1/3 bar tension the gypsum resulted in a significant 15% increase in aggregate strength and bottom ash a 30% increase. These amendments seem to produce strength increases in moist aggregates, where increased strength is especially desirable, but the effect is absent in drier aggregates.

When considering soil strength across all moisture tensions only quack grass cropping resulted in a significant (15%) increase in soil strength. The importance of this is not to imply that quack grass is a beneficial plant, but that certain plants are capable of producing more pronounced, or more rapid, changes in aggregate strength. In this instance quack grass has likely produced changes more rapidly because its dense and aggressive rooting habit ensures more root-soil interactions during the experiment. Presumably other plants could produce similar responses over longer time periods.

As indicated earlier, all of the amendments used in this experiment are thought to promote aggregate formation, stability and strength. This experiment concentrated only on examining the latter property. In this experiment organic matter appears to have different effects depending on the type present. Manure appears to decrease aggregate strength while plant roots increase strength. Both these effects are most pronounced in moist soil. The difference in effects can be attributed to different decomposition products or exudates, and perhaps some physical binding effect by plant roots. As this experiment examined aggregate strength only at the end of the experiment the possibility that manure increases aggregate strength at other stages of decomposition cannot be excluded.

Soil Aggregation

An analysis of variance was run for the percent of soil from each treatment which formed coarse, medium and fine granular aggregates. In each case the organic, chemical and cropping treatments produced significant effects at the 99% confidence level. The treatment means were separated using Duncan's multiple-range test and the results are presented in Table 4.

Larger soil aggregates more readily retain an open pore structure with good infiltration, drainage and aeration. Every treatment in this experiment resulted in significantly fewer large aggregates than the controls. All treatments except the manure also resulted in significantly fewer medium aggregates than controls. The decrease in the medium and coarse aggregates is reflected in a corresponding significant increase in fine aggregates or loose soil. (At <2 mm size the fine aggregates and unaggregated soil could not be distinguished on the basis of particle size). In most cases the decrease in the medium and coarse aggregates amounts to only a few percent of the soil mass. However, for the cropping treatments the combined loss from these two aggregate classes amounts to almost 10% of the total soil mass.

Table 4. Percent of soil forming aggregates of specified sizes.

TREATMENT	Aggregate size coarse (4.75-10mm)	medium (2-4.75mm)	fine (<2mm)
Organic amendments			
Manure	14 B*	28 A	58 A
Control	17 A	28 A	55 B
Chemical amendments			
Gypsum	14 B	28 B	58 A
Bottom ash	15 B	27 B	59 A
Control	17 A	29 A	54 B
Cropping treatments			
Brome grass	14 B	26 B	59 A
Quack grass	14 B	26 B	60 A
Control	18 A	31 A	51 B

*Percentages in the same column of each treatment grouping followed by different letters are significantly different at the 95% confidence level.

It appears that all treatments, especially the cropping treatments, promote the development of fine, rather than large, aggregates. Since all of the treatments used in this experiment are usually considered to promote soil aggregation the experimental results were unexpected. It is possible that these treatments only produce large aggregates over longer periods of time than this experiment allowed and that smaller aggregates are favoured during shorter periods of time.

CONCLUSION

The organic, chemical and cropping treatments induced significant changes in soil aggregation and aggregate strength compared with controls. All treated soils had fewer large aggregates than controls, although the differences were modest. Aggregate strength across all moisture levels was enhanced by quack grass and diminished by manure. At field capacity moisture, where soils are very susceptible to compaction, all chemical and cropping treatments increased aggregate strength while the manure treatment decreased aggregate strength compared with controls. Changes in aggregate strength did not exceed 35% of the control values.

The strength tests in this experiment were carried out for only one soil and the aggregation tests for only four soils. It is conceivable that different soils may react at different rates or have different responses, however, the soils used in this experiment should be representative of soils that are low in organic matter, high in clay content and poorly structured. The effects of the treatments were not great enough to recommend changes in soil management, but they do indicate that cropping and amendments do exert significant effects on soil aggregation and aggregate strength.

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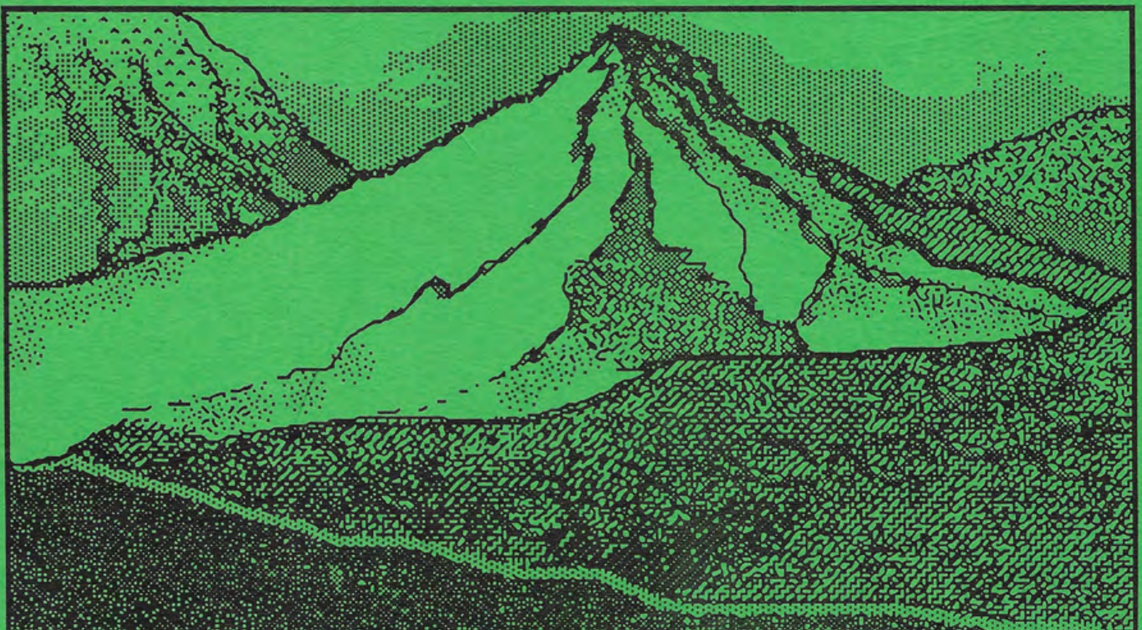

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