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THE EFFECTS OF SUBSOILING COMPACTED SOILS UNDER GRASS — A PROGRESS REPORT

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ABSTRACT

The relationship between penetrometer resistance, root growth and pasture production have not been satisfactorily defined under field conditions.

It is often difficult to identify those layers of soil which have sufficiently high mechanical impedence to limit root growth. The object of our research has been to establish a relationship between the physical properties of the soil and pasture production. The Gallagher subsoiler shattered the soil with little damage to the pasture.

Replicated trials were laid down during late Spring 1986 and Autumn 1987, at six sites. The soil types included a Whatawhata clay loam, a Te Kowhai silt loam, a Horotiu sandy loam and a Hamilton clay loam.

Subsoiling reduced the resistance of the soil to a penetrometer and decreased the bulk density and hence increased the porosity of the soil. After subsoiling a Whatawhata clay loam the root length of prairie grass plants increased. Pasture production is being monitored using a pasture probe.

Additional Key Words: bulk density, penetrometer, porosity, tillage, soil strength.

INTRODUCTION

Soil physical properties influence the growth of roots (Nye and Tinker, 1977). Soil horizons that have a high resistance to a penetrometer often have a high bulk density, and a low percentage of large continuous pores (Russell, 1977). These horizons may occur naturally in the soil as fragipans or duripans from soil forming processes, or they may result from livestock trampling, use of heavy machinery, on in the case of sports fields, heavy use at high moisture levels. Such horizons can be broken up by subsoiling – a form of deep tillage. In New Zealand subsoiling pasture land every 2-3 years, to depth of 45 cm, has not been a recognised form of sub-tillage because of the damage to pasture inflicted by traditional arable subsoilers.

The objective of this study is to monitor the effect of subsoiling on grass growth in pastoral farming and at a stadium used for sport. The machinery used in this study prevents surface scuffing. It slices through the turf in front of the subsoiler shanks and two rollers at the back of the machine partly press the uplifted soil, thus conserving soil moisture.

Location

Six sites in the Waikato where soil compaction appeared to limit pasture production were chosen but results from only three sites are reported here. Table 1 gives the location, soil types, pasture species and date of subsoiling.

Experimental design

In each trial a modified block design with four or five replicates was used. Plots varied in size from 100 – 400 m^2 and were either subsoiled (treated) or nonsubsoiled (control) to depths of up to 45 cm using a *Gallagher Grassland Subsoiler, with shank spacing set at 100 cm. Data was analysed using GENSTAT.

Field measurements

Soil strength was measured at ten sites within each plot using a *Bush recording cone penetrometer (Anderson, *et al.*, 1980). Readings were taken at increments of 3.5 cm, with the force applied per unit area expressed as a cone index (MPa).

Bulk density was measured at two locations per plot using a *Ronly, hand-held gamma-ray probe. Measurements down the profile were taken at 5 cm intervals. Auger samples were taken and gravimetric measurements of soil water were made at corresponding depths.

Table 1: Location, subsoiling date, soil type and pasture type.

Location	Subsoiling Date	Soil Type	Pasture Species
Rugby Park Hamilton	7.10.86	artifically constructed	Perennial ryegrass
Ohaupo	20.11.86	Horotiu sandy loam	Perennial ryegrass
Whatawhata	5.12.86	Whatawhata clay loam	Praire grass

Table 2: Soil porosity (%) at Whatawhata

		Depth (cm)							
Treatments	Porosity	5	10	15	20	25	30	35	40
Subsoiled	total	64	63	62	62	58	57	57	62
Control	total	56	55	53	49	45	44	43	50
Subsoiled	air-filled	46	44	38	31	23	18	17	22
Control	air-filled	38	34	23	17	7	4	4	10

* *Mention of trade names does not imply endorsement by Waikato University to the exclusion of other products that may be suitable.*

Table 3: Maximum root depths of 40 cores taken at Whatwhata

	Subsoiled	Nonsubsoiled	SED	Signif.
Maximum root depth (cm)	28.5	23.5	6.56	***

Table 4: Pasture production at two sites from 15 May to 7 July 1987

Location	Treatment	Kg ha^{-1}	% increase yield	SED	Signif.	n
Ohaupo	Subsoiled	2740	12			
	Control	2447		17.28	***	200
Whata-whata	Subsoiled	2330	15			
	Control	2021		14.76	***	200

Moisture tension was assessed using a *Quickdraw tensiometer at depths of 10, 30 and 45 cm. Measurements were made in July 1987 and were taken within 10 cm of the slits made by the subsoiler.

Pasture production and root depth

Pasture production was quantified using a pasture probe (*Design Electronics, Palmerston North). The instrument is a portable microprocessor controlled capacitance meter, which measures and records pasture mass as kilograms of dry matter per hectare.

Small monoliths taken from the pasture with a spade were used to measure root depth. These soil blocks were gently shaken to expose the root system.

RESULTS

Maximum penetrometer readings were obtained in the control plots at Whatawhata at 25 cm depth and at Rugby Park at 10 cm depth (Figure 1).

When plots were subsoiled at these sites penetrometer readings were reduced and maximum readings were obtained at 45 and 40 cm depth respectively. Subsoiling shattered the soil laterally 50 cm either side of the shanks (Figure 2.)

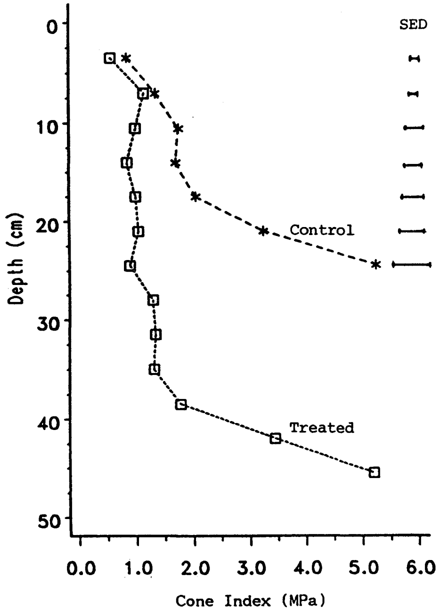


Figure 1: Variations in cone index in a soil profile from Whatawhata clay loam. Mean of 40 measurements. Significance * (10-40 cm depth)**

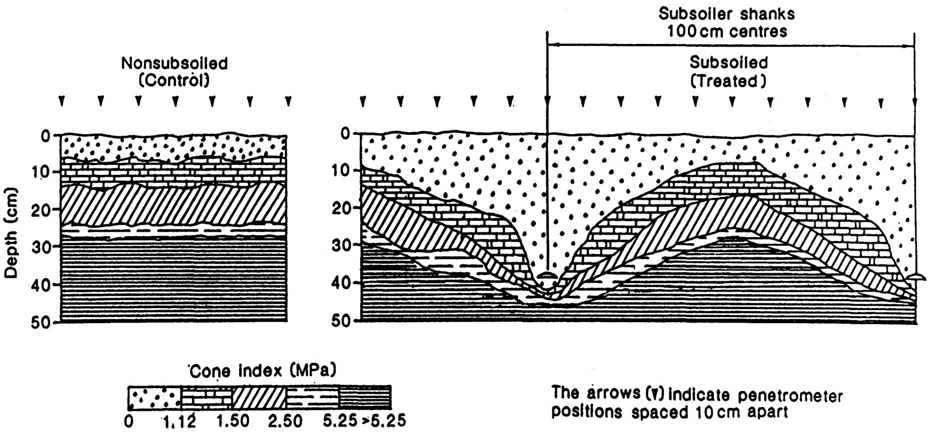
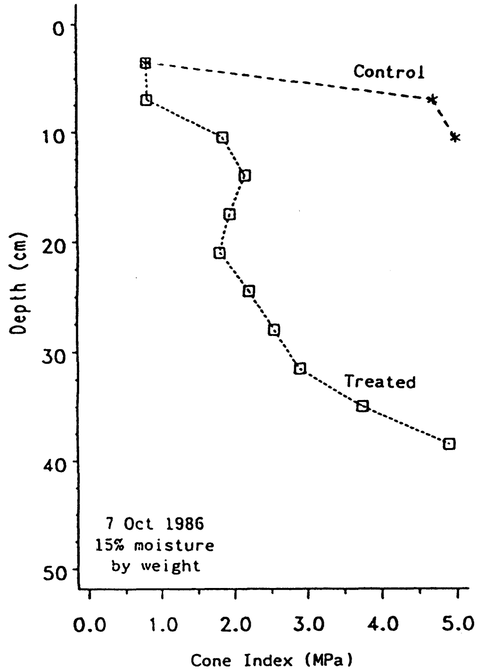


Figure 2: Variation in cone index (CI) with depth on a Whatawhata clay loam.



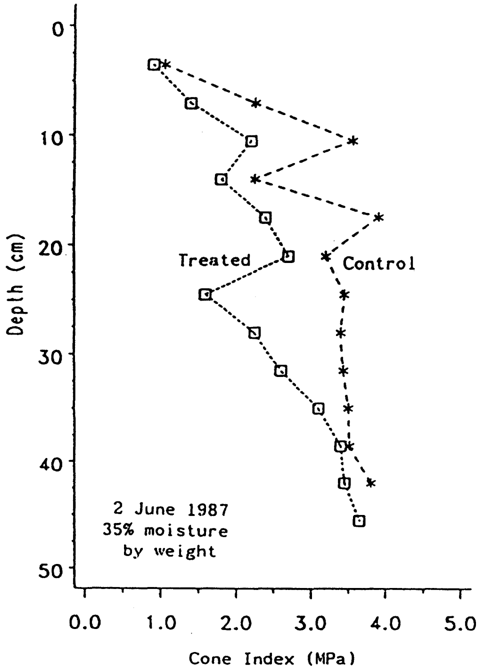


Figure 3: The influence of soil moisture on a cone index in an artifically constructed soil at Rugby Park.

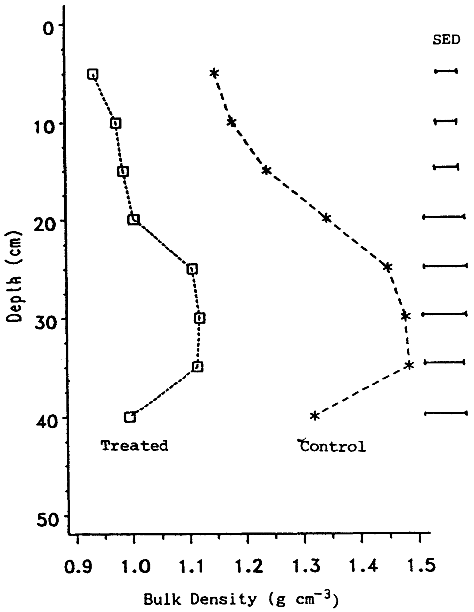


Figure 4: Bulk density within the profile of a Whatawhata clay loam.

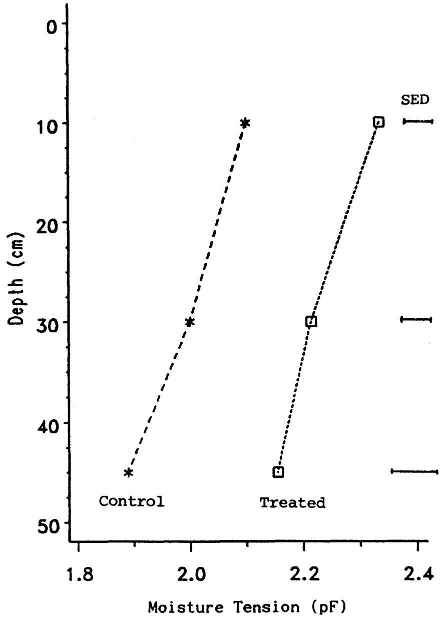


Figure 5: Variation in soil moisture tension in the profile of a Whatawhata clay loam.

Soil strength fell significantly at moisture contents of 35% (Figure 3.).

Total porosity and air-filled porosity were calculated from bulk density and were greater in the subsoiled plots throughout the profile, even though the measurements were carried out 200 days after subsoiling occurred (Table 2).

Eight months after subsoiling, moisture tension was significantly greater in the subsoiled plots than in the control plots, which suggests that the soil in the treated plots was drier (Figure 5).

At the Whatawhata site, the depth of plant roots growing within a 10 cm band either side of the subsoiler slits were deeper than roots in the nonsubsoiled plots (Table 3).

Early winter pasture production was measured with a pasture probe and showed a significant increase in yield due to subsoiling of 12-15% (Table 4).

In some cases severe wilting occured when pastures were subsoiled during mid-summer, due to root pruning and/or soil moisture loss. However this was not a problem at other times of the year.

DISCUSSION

At all sites significant changes to the physical condition of the soil were achieved by using the Gallagher subsoiler. These changes were not transitory but lasted for at least nine months. The destruction of a compacted layer within the soil profile lowered the bulk density and raised the porosity of the soil and reduced the penetrometer cone index readings.

Root growth has been shown to be severely restricted by high soil strength (Taylor and Ratliff, 1969). A subsoiler can modify soil structure, thus enabling grass roots to grow better (Table 3), fill a larger volume, and hence produce more leaves (Table 4).

Subsoiling increased the number of larger pores in the soil profile giving better aeration of the top 25 cm. Circulating air may evaporate water and remove it from the soil, resulting in the higher moisture tensions shown in Figure 5 which may bring the soil nearer to the moisture content optimum for plant growth.

In the control plots the number of air-filled pores in the layer of soil between 20 and 35 cm deep was very low and it is possible that plant growth could be limited by poor aeration. However in the subsoiled treatments the number of air-filled pores was satisfactory (Table 2). The increase in total porosity shown in this table may be assumed to be due to an increase in macropores, which are most affected by cultivations (Nye and Tinker, 1977) or compaction (Allbrook, 1986).

More work on root volume and root depth is required, and we hope to gain from our micromorphological studies information on why compacted soils provide unsuitable conditions for root growth and how these soils may be improved. Monitoring of soil moisture throughout the year will show whether moisture conditions near optimum for plant growth have been achieved. In the case of the sports stadium, maintenance of a freely drained soil should allow the turf to recover after its surface has been severely compacted during rugby matches in winter.

REFERENCES

Allbrook, R.F., 1986: Effect of skid trail compaction on a volcanic soil in Central Oregon. *Soil Science Amercian Journal 50*: 1344-1346.

Anderson, G., Pidgeon, J.D., Spencer, H.B., Parks, R., 1980: A new hand-held recording penetrometer for soil studies. *Journal of Soil Science 31*: 279-297.

Gorbing, J., 1948: Simple Spade Methods. *In* W. Bohm, "Methods of Studying Root Systems". Springer-Verlag, Berlin 20-21.

Nye, P.H., Tinker, P.B., 1977: Solute Movement in the Soil – Root system. Vol. 4. Blackwell Scientific Publications, Oxford.

Russell, R.S. 1977: Plant root systems. McGraw-Hill Book Co. Ltd., London.

Taylor, H.M. Ratliff, L.F., 1969: Root elongation rates of cotton and peanuts as a function of soil strength and soil water content. *Journal of Soil Science 108*: 113-119.