IMPROVED PROCEDURES FOR ASSESSING COMPACTION IN COTTON SOIL

I: PRELIMINARY EVALUATION OF TECHNIQUES FOR ROUTINE USE IN THE FIELD

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Subsoil compaction and remoulding is caused mainly by the adverse effects of traffic and tillage under wet conditions. However, compaction can also result from the natural collapse and excessive swelling of aggregates that contain exchangeable sodium. Compaction and remoulding usually lead to restricted root growth due to:

1. *Poor aeration* (waterlogging) when the soil is wet;
2. *High soil strength* when the soil is dry- it appears that this particularly restricts lateral roots and root hairs that extract water and nutrients from within soil aggregates;
3. *Disruption of continuous vertical channels* (macropores) that allow roots, in particular taproots, to bypass problem areas.

Generally, poor root growth reduces the yield potential. On compacted soils, growers may be able to maintain soil water content within the narrow range that avoids serious aeration and strength problems, but the risk of yield loss is higher than for well structured soil. Often compaction increases irrigation and nitrogen costs, and may cause water subbing problems during early season irrigations.

Soil structural assessment in the field is widely used by cotton advisers. Presently, soil structural condition is assessed visually using schemes such as the SOILpak score. However, as soil management practises improve and growers become more aware of the 'compaction problem', the damage to soil is becoming more subtle and therefore more difficult to detect visually.

Hence, a project was established to find a simple, repeatable and reliable technique or series of techniques for consultants, extension personnel and managers to use to assess soil structural conditions in the field. These techniques are also being related to the more precise techniques that are used by research personnel. All of these techniques, both advisory and research, are being related to cotton root growth and yield.

EXPERIMENTAL DESIGN

The experiment was carried out on irrigated cracking grey clay soils in the Macquarie and Namoi valleys, New South Wales.

In the Macquarie valley, four sites were chosen in the 1989/90 cotton season and three sites in the 1990/91 cotton season. In the Namoi valley, two sites were selected in both the 1989/90 and 1990/91 cotton seasons. These sites represented clay soils ranging from sodic grey clays to silty grey clays.

In the 1989/90 season, smearing and compaction damage were imposed in the centre of cotton ridges at each site. However, the soil was in a relatively dry state when the 'damage' treatment was imposed, so the degree of compaction achieved was not great. The smear lines were very obvious, but regular 'tearing' of the soil meant that roots were able to bypass the damage. All soil measurements were taken from ridges next to wheeled furrows. In the 1990/91 cotton season sites were chosen that already had soil structural damage ie. fields were chosen that were partially picked prior to rain and completed when the soil was still wet. To further increase the range of soil structural conditions, measurements were taken from the centre of hills next to wheeled furrows and 'guess' furrows.

A series of soil structural and chemical measurements were carried out prior to sowing, and at the end of the cotton season to ascertain soil structural condition. This coincides with the time when commercial enterprises make soil management decisions.

SOIL STRUCTURAL MEASUREMENTS

The following techniques, listed in approximate order from the least expensive to the most expensive, were used at the experimental sites:

1. Measurements of soil condition taken prior to planting

Visual assessment- This was based on a version of Peerlkamps soil structural scheme modified for the cracking grey clay soils of NSW by Tom Batey, University of Aberdeen. Daniells and Larsen used this scheme in devising the SOILpak score. This technique was only used in the 1991 cotton season. The method is rapid and inexpensive but its accuracy to a certain extent does depend upon the experience of the assessor.

Root distribution- The pattern and distribution of roots was measured to a depth of 90 cm. This involved counting the number of roots beneath a grid. This technique is more expensive than visual assessment in terms of time taken to obtain the measurements.

Bulk-density/air-filled porosity- These were measured at 15, 25, 35, 55, 75 and 95 cm depths using soil cores. This technique is inexpensive. However, an increase in aggregate size with depth can bias the results from the subsoil (Chan, 1981). Changes in density with water content also make interpretation difficult.

Macroporosity- The cross sectional area of soil stained by Rhodamine dye was measured to provide a measure of the number of continuous vertical channels connected to the soil surface. This is a very time consuming and messy technique, and is also fairly expensive.

Soil strength- Measurements were taken using both the Rimik automatic recording penetrometer and a handheld penetrometer. The Rimik penetrometer measures soil strength vertically at 1.5 cm intervals to a depth of 45 cm. The handheld penetrometer was used horizontally down the face of a soil pit at 5 cm intervals. All penetrometer readings were taken at moisture contents just above the soil 'refill points'. The equipment is expensive to purchase, but once the initial outlay has been made the measurements are easily taken.

Clod shrinkage- Parameters recommended by McGarry and Malafant (1987) were derived using the method of Brasher et al. (1966). They were used as the standard measurement for soil structural condition when comparing alternative procedures. Clods from depths of 15cm, 35cm and 75cm were analysed. This is a sensitive measure of soil structure but it is too time consuming for routine soil assessment.

2. Information that can be obtained from previous cotton season

Yield- Lint yields for each site were measured at the end of each season. Results are inexpensive and easily collected.

Root morphological properties- Measurements of taproot morphology at 10 cm intervals were taken at the end of each season. These included taproot diameter, taproot obliquity (angle of the taproot from the vertical), number of lateral roots emanating from the taproot, and taproot flatness. The changes in these properties between depths were also recorded as ratios. Results are inexpensive and easily collected.

Water content- Soil water content was monitored throughout the cotton season with a neutron moisture meter. For this analysis the change in soil water extraction between the 20 and 40 cm depths; and 40 and 60 cm depths over one irrigation was measured. The smaller the change in water extraction between depths, the greater the rooting depth and amount of water extraction from the soil profile. The irrigation cycle chosen was where the crop vegetatively was growing rapidly, and where no rain fell. The initial equipment outlay is costly but the collection of results is rapid.

SOIL CHEMICAL MEASUREMENTS

Key soil chemical properties were measured at depths of 15, 25, 35, 55, 75 and 95 cm. These measurements included exchangeable sodium percentage, Ca/Mg ratio, percent organic matter, total nitrogen and available phosphorous in the soil.

STATISTICAL ANALYSIS

To derive the 14 structural parameters based on clod shrinkage, three joined straight lines were fitted to the data (McGarry and Malafant, 1987) using a Genstat program. Principal Component Analysis using the SAS program was used to determine the relative importance of each parameter. This was done by using the coefficients of the first principal component, which is best able to discriminate amongst the 32 different field sites. The index of soil structure was verified by ensuring that ranking of the 32 sites with the index was sensible.

The field measures of soil structural condition were examined to see which were best related to the derived index. This was done by examining the linear correlations of each field variable with the derived index. Canonical correlation was also performed to see which 'combination' of the field variables was best related to the derived index.

This analysis allows us to construct a subset of field measures which can be used in future investigations by consultants. For instance, any field measure which is poorly correlated with the derived index and has a low weighting in the canonical variable will probably not be useful in constructing a future measure of soil structure, unless it is very cheap and easy to use.

All analysis was done at the 15 cm and 35 cm depths, where the greatest degree of soil structural damage from tillage implements and wheel passes usually occurs.

RESULTS

Clod Shrinkage

The clod shrinkage parameters were used as the reference standards for soil structural condition. There were 14 parameters derived from this technique. A number of these parameters were selected for the soil structural index. These are discussed in more detail in a paper that can be obtained from Suzie Greenhalgh at this conference. A detailed explanation of this technique can also be found in the paper by McGarry and Malafant (1987).

Field Techniques

The statistical analysis allowed field techniques to be listed in order from those that have the greatest influence on the soil structural index (first principal component) to those with the least influence. At 15cm the most useful techniques, in this order according to the canonical correlation, were soil strength measurements using the Rimik automatic recording penetrometer; visual soil assessment; taproot morphological properties- the number of lateral roots emanating from the taproot and the taproot diameter; and change in water extraction between depths. At 35 cm soil strength measurements using the Rimik penetrometer had the greatest weighting in the correlation.

According to the linear correlation procedure, techniques that correlate significantly with the soil structural index at a depth of 15cm, listed in order from best to worst, are bulk density, air-filled porosity, visual soil assessment, taproot obliquity ratio and soil strength (Rimik penetrometer). At 35 cm bulk density, visual soil assessment and air-filled porosity are significantly correlated with the index.

DISCUSSION AND CONCLUSIONS

The clod shrinkage technique is a very sensitive method for establishing the structural state of the soil (McGarry and Daniells, 1987; Daniells, 1989). However, the use of clod shrinkage measurements is not feasible as a field soil structural assessment technique as it is too time consuming. Hence, this technique was used to provide a soil structural index that is a standard reference point.

Field soil structural assessment is best carried out at different depths because damage rarely occurs uniformly in the soil profile. However, assessment of soil condition at 15 and 35 cm should encompass most soil structural damage resulting from the majority of tillage operations and wheel passes.

The analysis has identified a number of techniques (described earlier) that show promise for field soil structural assessment.

Soil strength is soil moisture dependant. As the soil dries out its strength naturally increases. These measurements should be taken when all fields are at a similar soil moisture content ie. just above the soil 'refill point', as when the soil is wet and sticky compacted and uncompacted soils are difficult to distinguish (Greenhalgh et al., 1992). Therefore, measurements should not be taken immediately after rain or an irrigation. Penetrometer measurements are also readily obtained, and could be used to determine soil structural condition across a whole field.

Root morphological properties are measured at the end of the season and give an indication of any problems the roots encountered throughout the season. The changes in water extraction between depths showed that at most sites the roots were extracting a majority of the soil water from the fi[illegible] cm, thus indicating that most of the sites exhibited some plant rooting problems. However caution must be exercised when using these approaches for management of soil for the next crop, because any extra soil structural damage incurred during a 'wet' picking would not be considered in the assessment.

Visual assessment of soil pits, dug either by hand or with a backhoe, relies somewhat on the amount of experience the soil assessor has in identifying soil structural damage. However, the extent to which this cheap, widely-used approach can be complemented by the procedures outlined above will not be known until further analysis has been completed.

Other techniques that show promise are bulk density/air-filled porosity and water extraction (Neutron probe). These, and the other promising techniques, are relatively simple to use. However, both the soil strength and water extraction measurements do require relatively expensive equipment to obtain the results. Once validation trials have been completed to relate soil condition to cotton root growth, yield and profitability, a technique or combination of techniques for the routine assessment of soil structural condition will be recommended for use by advisors and managers.

In collaboration with this project is research that aims to refine promising techniques for assessing soil structure in the field and to determine the location and frequency of these measurements. Some of the results from this work are presented in a companion paper by McKenzie et al. in these proceedings.

More detailed results can be obtained from Suzie Greenhalgh at the Agricultural Research Centre, Trangie, NSW.

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