IMPROVED PROCEDURES FOR ASSESSING COMPACTION IN COTTON SOILS

II. REFINEMENT OF METHODS FOR MEASURING SOIL STRENGTH AND POROSITY

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This paper discusses recent progress with the refinement of promising methods, both direct and indirect, for measuring the severity of compaction in cracking clays used for irrigated cotton. It should be read in conjunction with the companion paper by Greeenhalgh et al., in these proceedings, which summarizes the results of a preliminary evaluation of methods. Both studies are funded by CRDC as part of project DAN 50C; 'Refinement of soil physical assessment procedures'.

DIRECT MEASUREMENT OF AERATION, STRENGTH AND MACROPOROSITY

Compaction strongly affects the growth and function of cotton roots due to poorer aeration, higher strength and lower macroporosity in the soil. Methods are available to directly measure these factors although many of the procedures require complex equipment and are time consuming. Their stages of development are as follows:

(1) Aeration
* air filled porosity (a crude, but useful, first approximation)
* oxygen diffusion rate (very sensitive, and relevant to the biological processes taking place, but it is time consuming and requires expensive equipment)
* air permeability (sensitive; suitable equipment for use in the field should soon be available, but the technique is less relevant to the biological processes taking place than the oxygen diffusion procedure)

None of these methods appear to be suitable at present for routine use by advisory staff.

(2) Strength, mainly within large aggregates

* penetration resistance (using a 'Rimik' recording penetrometer, which consists of a pressure measuring device that records resistance to penetration of a sharpened steel rod as it is pushed vertically into the soil to a depth of 45 cm)
* shear strength (using a 'Geonor' shear vane; the vane is pushed into the side of a backhoe pit, then twisted with a torque measuring device until the soil fails)

These devices are easy to use although soil water content needs to be measured at the same time in clay soils to standardize the results, if between-site comparisons of the degree of compaction are required. The 'Rimik' penetrometer is able to store its data electronically, whilst everything is done manually with the shear vane.

The penetrometer and shear vane were calibrated and compared under ridges and wheeled furrows on a grey clay near Warren in 1990. This study showed that there are problems when the penetrometer is used under very wet conditions (Figure 1); compacted and uncompacted soil cannot be distinguished. However it is more effective when the soil is drier. In contrast, the shear vane clearly showed the difference between the two types of soil structure at all of the water contents under consideration. Correction of shear vane results to a reference water content therefore is straightforward (Greenhalgh et al. 1992).

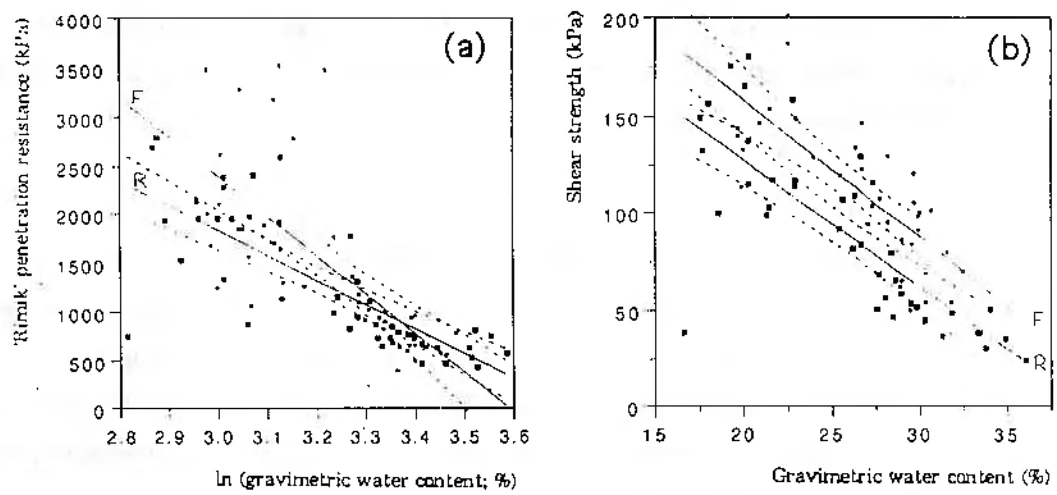

Figure 1. Influence of water content on soil strength as measured with (a) a penetrometer, and (b) a shear vane in compacted (furrow;F) and uncompacted (ridge;R) soil.

(3) **Macroporosity**

The SOLICON image analysis system (Moran et al. 1990) was developed jointly by University of Sydney and CSIRO Division of Soils about 4 years ago. It has been modified recently by Koppi and McBratney (1991) to allow large, continuous soil monoliths to be impregnated with a resin containing UV-sensitive dye, prior to video scanning. Vertical and horizontal sections of soil can be examined. Examples from under a ridge and wheeled furrow near Warren are shown in Figure 2.

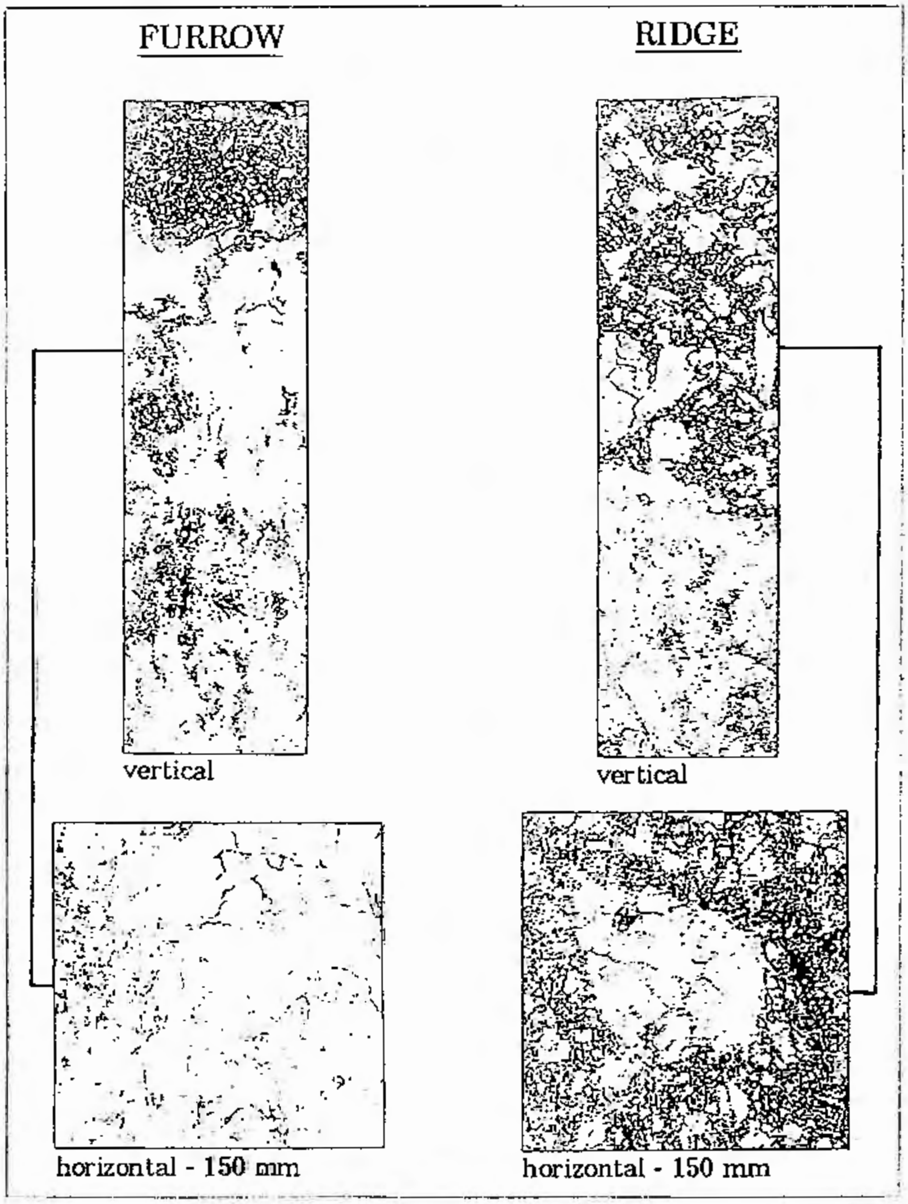

Figure 2. Vertical (400 x 100 mm) and horizontal (200 x 200 mm) images of a compacted furrow and undamaged ridge (just after listing). Dark areas indicate cavities within the soil.

The images provide a clear and permanent record of how the soil appears in the field; lines of weakness (dark areas in the images) are visible that could probably be used by roots to bypass damaged areas. They indicate which depths are most crucial for further testing, and provide a good impression of the degree of variability. The porosity can also be described numerically after scanning of the impregnated soil.

Our evaluation of image analysis systems is being carried out in two stages, one under moist conditions (field work already complete), the other when the soil is dry. Alternative procedures such as analyses of the frequency distributions of penetrometer data (Hulme et al. 1991) are also being considered.

A simpler near-surface impregnation procedure that uses Rhodamine dye infiltration patterns as an index of soil macroporosity was also investigated. Although rapid and effective, it does not perform as well as the more expensive and time consuming system of Koppi and McBratney (1991). Therefore a new series of experiments has begun to further refine image analysis procedures for use by advisory staff.

SURROGATE MEASURES OF SOIL STRUCTURAL FACTORS THAT LIMIT ROOT GROWTH

Clod shrinkage parameters have been used as standard measures of soil compaction by researchers for over 10 years. They appear to be sensitive indicators of soil physical condition, although we know little about what the parameters mean in terms of aeration, strength and macroporosity. Therefore detailed correlation studies are being carried out using data collected in 1988 from the 'Field 24' experiment. Clod parameters are being related to soil aeration, strength and resiliency, and to root growth, nitrogen uptake and lint yield. This work is being followed up by Sue Greenhalgh on a much broader range of soils.

The SOILpak score is a relatively simple measure of soil physical condition for use by advisory staff. It is described in detail in the SOILpak manual. The higher the measured values are on a scale of 0 to 2, the better the soil structure. It is anticipated that an improved version of this scheme will be available in about 2 year's time; some of the definitions at present are not always clear. However correlation studies carried out during the image analysis study (see above) showed that SOILpak scores, determined using the present system in backhoe pits, related fairly well to soil strength and aeration under moist conditions (see Figure 3).

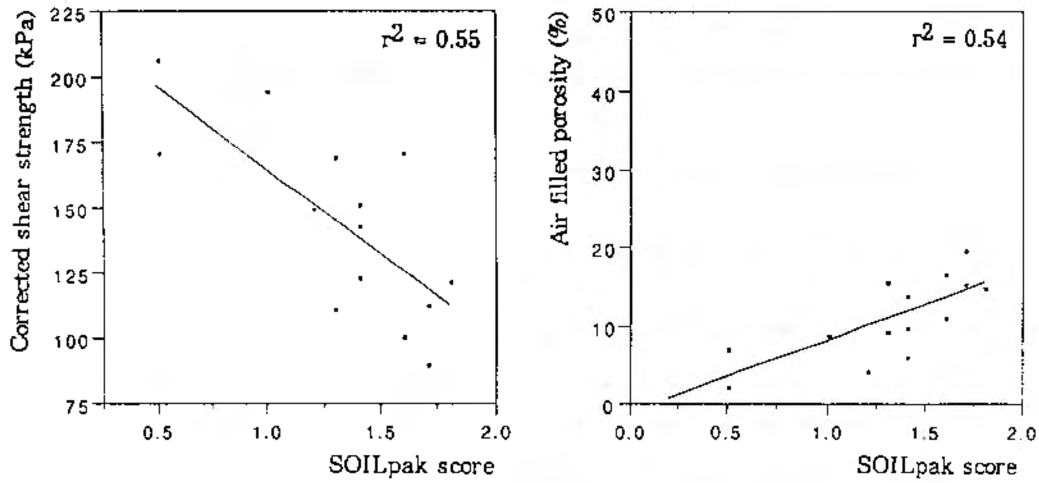

Figure 3. Relationships between the SOILpak score and direct measurements of soil strength (shear strength, corrected to a reference water content, θg = 25 %) and aeration (air filled porosity).

LOCATION AND INTENSITY OF SOIL SAMPLING

During the 1991/92 cotton season a study was carried out, at 3 sites with contrasting soil types used for irrigated cotton in the Namoi and Macquarie Valleys, to determine:

(1) Where should measurements of soil structure be located within cotton fields, and at what intensity?

(2) Can remote sensing be used to estimate soil physical condition before planting a cotton crop?

The following scans and ground truthing measurements were taken at 'Togo' (Field 86), 'Elengerah' (Field 43) and Auscott Warren (Field 24):

* bare soil photographs (normal colour)
* video scans in November and January (4 wavelengths)
* surface colour and roughness
* cotton nutrient uptake

* soil shear strength, SOILpak score and chemical properties relevant to soil structure, at depths of 0, 200 and 400 mm
* penetration resistance to a depth of 450 mm.
* ridge height

We collected soil data under ridges beside wheel rows and 'guess' rows at 9 widely dispersed reference points within each field. Cotton lint yield and root growth measurements were also taken at these locations; the information will assist with validation of the relationships derived by Greenhalgh et al.. The results are still being processed.

ROOT GROWTH CRITICAL LIMITS

In all of our 'soil condition - crop response' studies, efforts are being made to define the critical values of aeration, strength and macroporosity for cotton roots under Australian conditions. Most of the published values - particularly for soil strength - do not appear to be relevant.

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