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REPORT ON PROJECT CS04C:

Soil structure and physical properties as affected by tillage operations in bed systems

Introduction

The goals of this research were:

1. measure the soil stresses and deformations due to "edge of bed" operations, and measure the changes to soil physical properties (infiltration, aeration, strength) that result. This was to be pursued in collaboration with the anticipated rotation experiments led by Cooper and the structure project led by Koppi;

2. correlate the field performance of operations with soil conditions, in order to determine optimum conditions for operations;

3. transfer the conclusions via SOILPAK, the Australian Cotton Grower and Grower Conferences.

Research programme

Field and laboratory measurements

We performed two sets of measurements of wheel/furrow interaction, both at Auscott, Narrabri. Note that we had anticipated joint work at the experiments being conducted by Copper and others, but these did not seem organised in a way useful to us at the time we undertook the fieldwork.

The first trip looked specifically at the interaction of furrow shape with tyres. The general conclusion was that in V shaped furrows the tyre would sit on either side and cause high soil stresses leading to considerable compaction at the sides. U shaped furrows suffered from this effect but to a lesser degree. Flat bottomed furrows did not suffer from this effect. After passage of the tyre all furrows ended up with a fairly flat bottom.

The second trip looked specifically at the effect of tyre width on compaction at the side of the furrow. The general conclusion was that wide tyres caused considerable compaction at the sides of the furrow, whereas narrow tyres did not. At depth, the difference in compaction between the narrow and wider tyres was small.

Stresses and compaction beneath tyres were studied in greater detail in the more controlled conditions of a soil bin, during a study visit to Silsoe UK, undertaken by Blunden and supported by the CRDC. The visit was reported in detail as a final report for CRDC grant CS06C (Report to CRDC, August 1995, B.G. Blunden, C.R. Trein and J.M. Kirby, Measurement of Stress and Strain Distributions Beneath Wheels). Briefly, the findings of this study were as follows.

1. The study provided a comprehensive data set of stresses measured in the soil, soil movement and soil mechanical properties measured before, during and after

the passage of a pulled tyre. These data enabled validation of soil mechanical models that predict the impact of traffic on the soil (see section on predicting compaction, and Kirby et al., 1997).

2. The distribution of stresses and movement of soil beneath tyres in the horizontal soil surface experiments confirmed known theory. Maximum stresses and soil movements were measured at the soil surface beneath the centre of the tyre. Smaller stresses and soil movements were recorded at increased distances from the centre line of the tyre and with increased depth.
3. The distribution of stresses and soil movement measured in the furrow experiment was different than that of the horizontal soil surface experiment. Maximum soil stresses and movements were found beneath the tyre edges, where they came into contact with the shoulders of the engineered furrow. The soil was compacted more beneath the shoulders of the furrow, possibly giving rise to reduced levels of water and air entry and increasing the density of soil within or near the root zone.
4. The study demonstrated the need for properly configured wheel furrows. If furrows are too narrow then tyres may bridge across the furrow thereby inducing considerable soil stresses and movements iuto the root zone. Furrows that enable the tyre to maintain contact with the soil on the centre line of the tyre will direct stress and soil movements directly downwards, thereby minimising compaction of the root zone in the bed

We performed a series of laboratory measurements on the influence of compaction on infiltration. As expected, infiltration was slower into compacted than uncompacted soil. This built on earlier work, reported under a previous CRDC grant, which showed that soil permeability to air was reduced, but by varying amounts, by combinations of shear and compression in soil mechanics shear boxes.

We intended to continue these tests in the field, using red soils at Auscott, Warren. However, at the time available to us (February/March 1996) the soil was dry and cracked, and the tests would not have been successful - water would simply have poured down the cracks in an uncontrolled fashion. We therefore had to abandon the plans for these tests.

Soil mechanics predictions of compaction

It is not feasible to measure compaction in the field for all combinations of soil, soil condition and vehicle. We therefore developed numerical methods as part this project to predict compaction. The methods and their validation are described in papers in the references. Compaction can be successfully predicted using these computer methods. This furthered our understanding of compaction processes.

The information from the field and the computer predictions, run on "what if" scenarios, were then used to investigate compaction management options such as: wider versus narrower tyres in furrows; different furrow shapes; influence of bed width; influence of repeated wheeling; influence of initial soil moisture content.

A comparison of the predicted impact of wide and narrow tyres showed that the narrow tyres were predicted to cause greater reductions in void ratio immediately beneath the tyre. The wide tyres were predicted to cause void ratio reductions at the side of the bed. At greater depths, however, the void ratios are predicted to be about the same for the two tyres. This illustrates two rules that govern compaction:

1. the severity of compaction near the surface of the soil is related to the stress exerted at the surface (hence the smaller void ratios beneath the higher stresses exerted by the narrow tyre);

2. the severity of compaction at depth is related to the total axle load.

These two rules have been previously reported in the comparison of dual and single tyres on flat ground (Kirby and Blunden, 1993). The wider tyre was predicted to cause greater shearing at the side of the bed. The significance of this finding is that shearing of clay soils can significantly reduce the permeability. In a furrow irrigated bed system, the shearing action of the wide tyre could reduce infiltration from the furrow into the side of the bed.

A very wide tyre will not exert a uniform pressure on the furrow bottom and side, but rather will be supported mainly at the sides and exerts high pressures at the sides of the furrow but lower pressures beneath the furrow. This supported the field stress measurement results described above, where the same effect was noted.

The predicted effect of repeated wheeling showed that, firstly, repeated wheeling result in compaction (i.e. the zone of reduced void ratio) spreading and, secondly, the spreading from the 1st to 2nd pass is about the same as that from the 2nd to 5th and 5th to 10th passes - in other words, more compaction per pass is done in the early passes. Similar results have been reported before in the literature.

Soil strength increases exponentially as soil dries. The computer studies predicted that in dry soil, in which the soil strength parameters (particularly the initial preconsolidation stress and elastic modulus) were three times greater than those used in the other solutions, there would be very little compaction in the beds or the furrow. This is consistent with commonly observed field behaviour and also published management rules about compaction damage in relation to soil moisture.

Implications for management

- Avoid using tyres that are wider than the furrow. Wide tyres disrupt the sides of the bed which may lead to reduced infiltration. They also compact the furrow and widen it. Narrow tyres do not require a wide furrow, nor widen a narrow furrow to the same extent, but they do lead to greater compaction in the base of the furrow. This may lead to reduced infiltration through the base of the furrow.
- Axle spacimgs of vehicles should be matched to furrow widths.
- The furrow should be flat at the base with steep sides (i.e. U shaped); a furrow that is not flat (i.e. V shaped) at the base will result in compaction at the sides and this will alter the shape so that it becomes flatter at the base.

Compaction at depth is little affected by tyre width, for tyres supporting the same total axle load.

- Avoid, when possible, trafficking wet soil in order to minimise compaction damage in beds. The plastic limit (an index related to soil moisture) has been shown (under a previous CRDC grant) to provide a good indication of the soil moisture content drier than which heavy clay soils may be trafficked without serious compaction by the usual range of vehicles used for cotton production. The plastic limit rule is consistent with the computer predictions.
- Promote practices that reverse the effects of compaction and avoid practices that cause the compacted zone to increase. Repeated wheeling causes compaction zones beneath the tyres to spread, but the rate of spreading decreases with increasing numbers of wheeling. It is therefore important to avoid, if possible, even one pass when the soil is wet enough for compaction to happen. However, root growth and swelling and shrinking due to wetting and drying of the soil within the bed will reverse the effects of compactiou. Thus cotton farming will result in the zone of compaction increasing and decreasing. The zone will increase with the use of heavier vehicles and/or wet soil; the zone will decrease as a result of root growth and swelling and shrinking of the soil. Rotation crops may be used to encourage this.

Attendance at industry workshops and conferences

- Cotton 2001 - Narrabri, March 1993. Blunden attended this workshop.
- CRC Cotton Soil Research Meeting - Narrabri, September 1993. Kirby attended this workshop and Kirby gave an talk about the project work.
- CRDC Cotton Soil Research Coordination Meeting - Narrabri, December 1993. Kirby and Blunden attended this workshop and Kirby gave a talk about bed systems.
- Attended the World Cotton Research Conference, Brisbane, 13-17th Feb. 1994, and presented a paper (see references).
- Attended the 7th Australian Cotton Conference, Broadbeach, Queensland, 10-12th Aug. 1994, and presented a paper (see references).
- CRDC Cotton Soil Research Coordination Meeting - Narrabri, December 1994. Kirby attended this workshop and gave a talk about bed systems, tyre pressures and numerical modelling of soil deformation.
- Participated in the Engineering and Tillage Workshops at Trangie, Narrabri and Dalby, December 1994. Gave talks and led discussion groups at the workshops and contributed to the report.

Achievement of the goals of this research

1. Soil stresses and deformations in furrows and at the edge of bed and resulting changes to strength, density, void ratio (hence aeration) were measured. Changes to infiltration properties were not measured directly in the field as the soil was unsuitable at the time chosen for this aspect of the study. The anticipated collaboration with the rotation experiments led by Cooper and the

structure project led by Koppi did not occur, as these were not organised in a way useful to us at the time we undertook the fieldwork

2. Both field and computer studies confirmed the that optimum conditions for operations are when the soil is no wetter than the plastic limit.

3. The conclusions have been transferred via the Australian Cotton Grower, Grower Conferences and other industry workshops. We anticipated a contribution to SOILPAK. It was suggested to us by David Larsen that since SOILPAK might be extensively rewritten and the format changed, we should await developments.

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