TRAFFIC LOADINGS AND SOIL COMPACTION

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INTRODUCTION

Compaction causes poor drainage and aeration and increased soil strength which leads to restricted root growth, which may lead to yield declines. The poor drainage can lead to problems over timing of operations.

Compaction by tyres or tracks results when the vehicle ground pressure is greater than the pressure the soil can bear. The strength of cracking clay soils, and hence their capacity to bear vehicle traffic without damage to the soil structure (i.e. compaction), is clearly very dependent on soil moisture content. Very wet soils are weak and cannot bear the pressure exerted by vehicles, while very dry soils can be strong and hard enough to show little imprint even from the grousers of a vehicle such as a D8.

Obviously, avoiding trafficking wet soil is one means of avoiding soil structural damage. Another is to use a vehicle with lower ground pressure, by using dual tyres, wide tracks, etc. But which is more important - soil moisture or vehicle ground pressure? What are the trade offs? This article seeks to explore these questions.

SOIL STRENGTH AT A RANGE OF MOISTURE CONTENTS

We have previously measured (Kirby 1990, 1991) the variation of soil strength with moisture content for a rane of cracking clay soils used in the cotton industry. The form of the relationship between strength and moisture content is shown in Fig. 1. Also shown on the figure is the plastic limit (PL), wilting point (WP) and field capacity (FC). The plastic limit is readily measured.

Different soil have different plastic limits - heavy clays have greater plastic limits than light clays. However, the strength of different clays is about the same when the moisture content is at the plastic limit. Therefore the principles of Fig. 1 apply to all cracking clays used for cotton, but with different actual moisture contents on the X axis.

Figure 1 confirms that the soils are weak when wet and strong when dry. It can be seen that the strength of the soils varies by a factor of about a hundred whenthe moisture content varies from wilting point to field capacity.

VEHICLE PRESSURES

We have measured the pressures that some vehicles exert on the soil at a depth of 10 cm (Kirby, Blunden and McLachlan, 1991). The results are shown in Figs. 2 to 5 and summarised in Table 1. Table 1 also shows ground pressures based on estimates. Surface pressures are estimated as being approximately equal to tyre inflation pressures. For tracked vehicles, the vehicle weight divided by the track area is used to estimate ground pressure but this gives the average pressure which is probably an underestimate of the peak pressure (as shown by Figs 3 and 4; see also Kirby, Blunden and McLachlan, 1991). It may be safer to double the average pressure to estimate the peak pressure, which is what is done in the table.

It can be seen that the pressures vary by a factor of about five times in the measured data, or 6 to 7 times in the estimates. It should be noted that the information in this table is based on measurements and estimates for only a limited range of vehicles and operating conditions. Tractors with different tyres, for example, almost certainly exert pressures outside the range shown here; in particular, low ground pressure tyres would lead to lower ground pressures. The table indicates that tracked vehicles generally have lower ground pressures than tractors and pickers.

COMPARING SOIL STRENGTH AND VEHICLE GROUND PRESSURE

The first point to note is that soil strength varies by a factor of about 100 whereas vehicle ground pressure varies by about 5-7 times. Therefore, it is more important to get the soil dry than it is to choose another vehicle or wider tyres.

The strength required to support the range of vehicle pressures has been superimposed on Fig. 1. From the figure, soil that is a little drier than the plastic limit should be able to bear the pressure of most vehicles without great compaction.

MINIMISING TRAFFIC COMPACTION

Based on the above information, several approaches to minimising compaction by tyres or tracks can be identified, and involve paying attention to both the vehicle and the soil.

Avoid trafficking wet soil
It is obvious that soil moisture content is crucial in determining whether the soil cn bear traffic without damage. Soil at about the plastic limit is strong enough to bear pressures in the middle of the range imposed by vehicles used for cotton production. Vehicles with higher pressures (e.g. pickers) will require slightly drier soil, whereas vehicles with lower pressures (e.g. most tracked vehicles) can traffic soil marginally wetter than the plastic limit.

Therefore the single most important step in minimising compaction is to avoid trafficking wet soil whenever possible.

Minimising wheelslip
Wheelslip smears the soil which aggravates compaction problems. Minimising wheelslip, by operating at higher forward speeds, helps minimise compaction (Spoor, 1987).

Using lower ground pressures by fitting wider tyres or tracks
Fitting a vehicle with wider tyres or tracks reduces the pressure it exerts on the soil. Some reduction can also be achieved by using the minimum permissible tyre pressures for the load carried (Spoor, 1987; Inns and Kilgour, 1978). This in turn means that it is possible to drive on soil a little bit wetter than can be done with normal tyres or tracks without causing compaction.

However, it is important to realise that lower ground pressures merely increase the moisture content range that may be trafficked without damage. This can be seen in Fig. 1, where, compared to higher pressures, the lower range of vehicle pressures are shown to be acceptable in slightly wetter soil, but not in soil as wet as field capacity, for example. The increase in the moisture content range is about 4-5% for every halving of the ground pressure (Kirby and Blunden, 1992). An attempt to traffic the soil when wetter than this increased range will cause damage over a wider area, due to the use of wider tyres. This reinforces the point that there are more gains to be made by avoiding wet soil.

The trend over the last few decades of using heavier tractors has been accompanied by the use of wider tyres or tracks, primarly to aid traction. Ground pressures have therefore not changed much with increasing weight of vehicle. However, compaction when it occurs affects soil to a depth on the same order as the tyre or track width. Consequently, the trend to heavier vehicles has been accompanied by a trend to deeper compaction damage. Deeper compaction is harder and more costly to fix by tillage, if indeed it is within the reach of tillage implements.

Therefore, wider tyres or tracks should be used with caution.

Using lower ground pressures by using a lighter vehicle
This has the same effect as above; it increases the range of moisture content that may be trafficked without undue compaction damage. Lighter vehicles may have lower productivity and so appear less attractive but in conjunction with bed systems (see below) this may not be so. Some reduction in weight is also achieved by using the minimum tyre ballast compatible with low wheelslip (Spoor, 1987; Inns and Kilgour, 1978).

Using bed systems
In a bed system the traffic is separated from the plant lines. This can be achieved to an extent by keeping cotton hills in the same place from one year to the next, but a bed system is usually understood to mean something more permanent. Even in a bed system the considerations outlined above still hold. Therefore the soil should still be dry enough to bear the traffic without compaction. Of secondary importance, the vehicle pressures may be considered.

In a bed system, compaction is allowed in the traffic lane thus giving the vehicle a firmer and better roadway. This results in better traction and lower energy losses due to rolling resistance of the tyre. On the other hand, the bed is never trafficked and the soil remains loose which results in lower energy requirements for tillage. Thus there is a double saving in the energy requirements of operations. This means both that a lighter tractor may be used and that fuel costs are lower. The savings may be considerable

In the cotton industry there remain some unresolved practical problems about using beds. These include the spreading of wheeltrack compaction undr the beds, the damage to the sides of beds by various implements (such as gas knives) or tyres/tracks, and infiltration ("subbing") problems. These problems are the focus of a new research effort.

Bed systems offer an all round approach to minimising compaction damage, but some effort is required to identify best practices.

WHAT IF THE SOIL HAS BEEN COMPACTED?

What to do with compacted soil depends on what crop it is desired to plant next, how dry the soil is and how deep and severe the damage is. The depth and severity of compaction are best identified by making a soil pit and having a look (as explained in SOILPAK), though some idea can be gained if it is known what operation (particularly vehicle ground pressures and tyre/track width; for tillage operations, depth and type of tillage) caused the compaction and the moisture content of the soil at the time of the operation.

Once these factors are decided, a range of tillage and crop rotation options are available, as outlined in SOILPAK.

CONCLUSIONS

1. It is more important to get the soil dry than to choose another vehicle or wider tyres.

2. Low ground pressure tyres or tracks do not prevent compaction. Compared to normal tyres or tracks, they do allow slightly wetter soil to be trafficked with minimal compaction.

3. If low ground pressure tyres or tracks are used, it is more important to avoid soil that is too wet because any compaction damage caused will be spread over a wider area and hence will also go deeper into the soil.

REFERENCES

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Spoor, G., 1987. Keeping out of the harvest rut. Power Farming, November 1987, 38-40.

Table 1 Maximum pressures under selected vehicles

Vehicle	Pressure (kPa) Measured at 10 cm depth	Pressure (kPa) Estimated at surface
Tractor JD 4650 (front tyre)	250	180
Picker 2 row (rear tyre)		330
Picker 4 row (front tyre)	175	275
D8 with ammonia tanks etc for listing operation		75-150 *
D8 for chiselling etc		45-90 *
rig up	160	
rig down (engaged)	145	
Caterpillar Challenger 65		
no rig	50	40-75 *
rig up	95	50-100 *
rig down (engaged)	55	
Scraper / tractor (Case 9170)	75	140
(scraper blade)	(30)	
Toyota Landcruiser	125	250

* The lower figure is the estimated average ground pressure; the upper figure is the probable peak pressure.

Table 2 Minimising soil phsyical degradation - a summary

avoid wet soil (wetter than about the plastic limit)
minimise wheelslip
use lower ground pressures
use lighter vehicles
restrict area of wheeling
use bed systems

Figure 1 Soil strength as a function of moisture content (schematic)

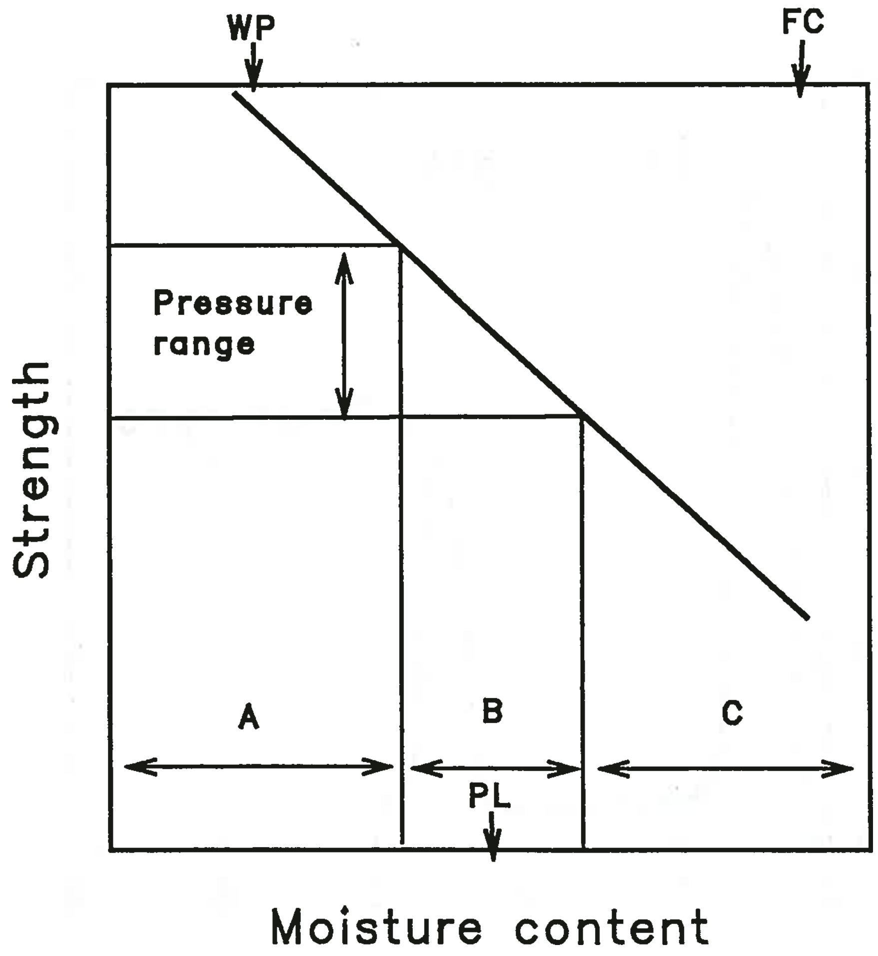

Fig. 2 Stresses beneath an empty two-wheel drive picker.

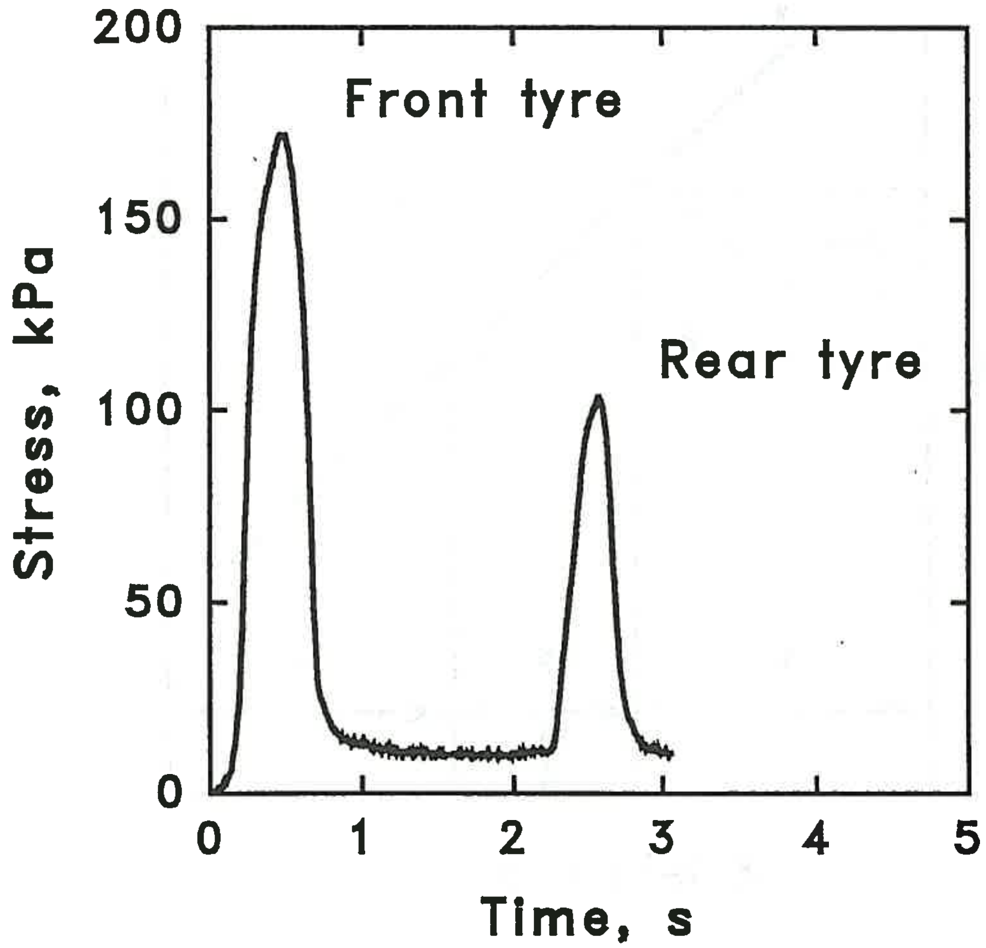

Fig. 3 Stresses beneath Cat Challenger 65, with no cultivator, and Cotcul 24 row cultivator up or down (engaged).

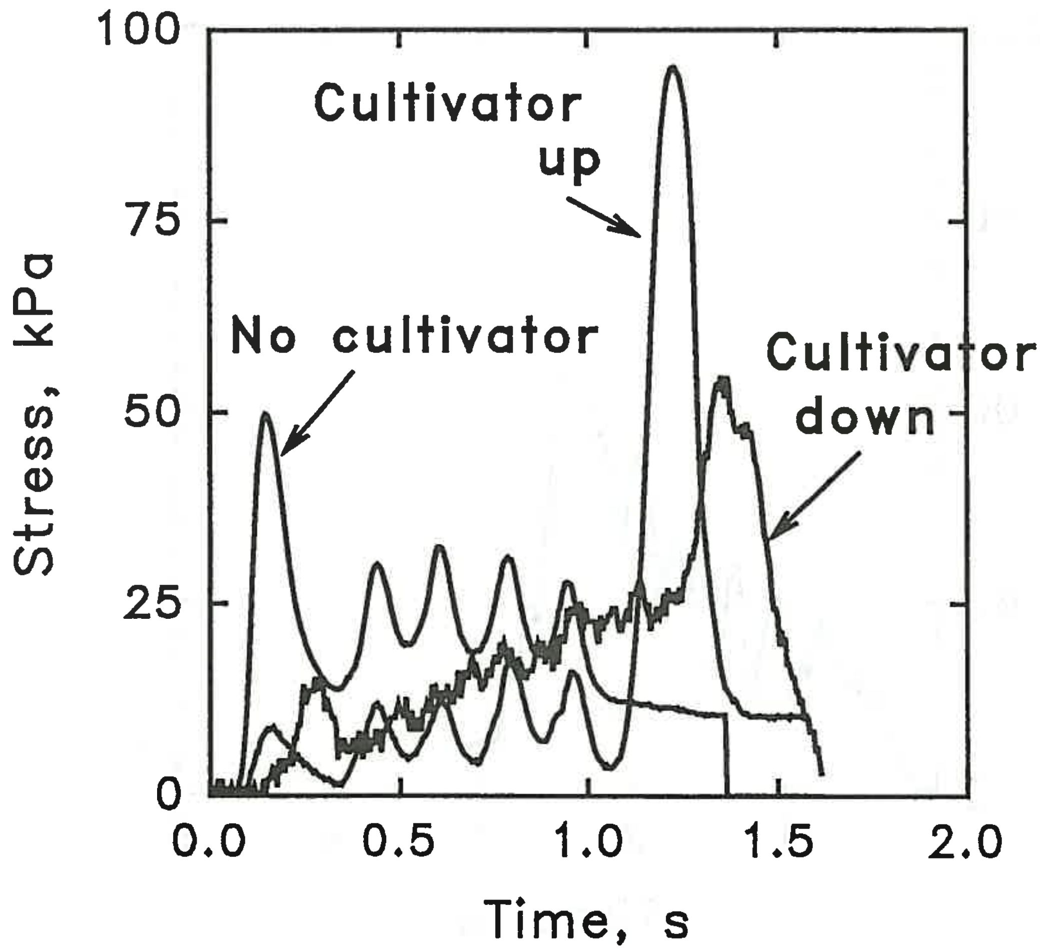

Fig. 4 Stresses beneath D8.

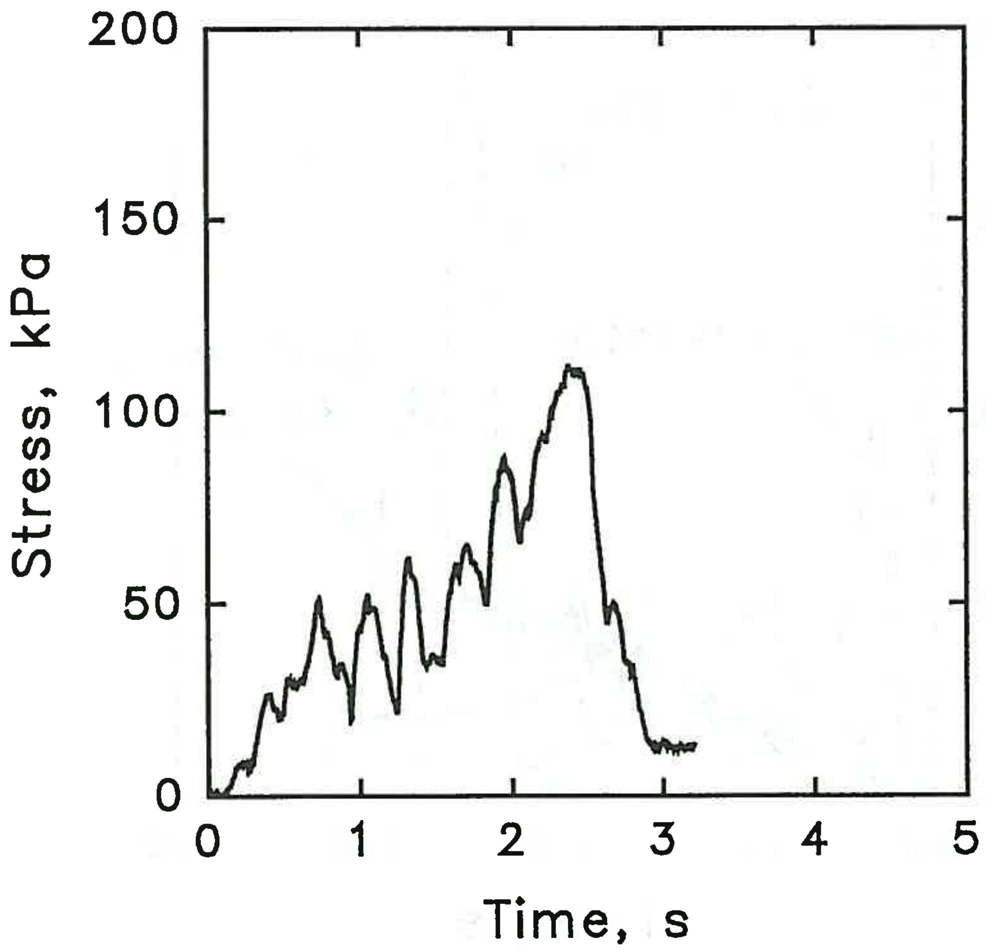

Fig. 5 Stresses beneath Case 9170 and scraper.