COTTON PRODUCTION WITHOUT DEEP TILLAGE IS VIABLE IN THE ABSENCE OF STRUCTURAL DEGRADATION

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The presence of right-angle bending in cotton tap roots clearly shows the restrictions which degradation of soil structure imposes on cotton growth. The obvious solution to this problem is to break up degraded layers by deep tillage. This solution has readily been taken up by cotton growers to the extent that deep tillage is routinely used by some growers.

Concerns have been expressed about the cost of, and time involved in, preparing a cotton seedbed by knocking down hills and rebuilding them. These concerns led to the establishment of an experiment in which cotton production on beds left in the same place (permanent beds) was compared with production on areas which were deep tilled prior to each cotton crop. The main aim of this experiment was to assess whether high cotton production could be maintained on cotton beds kept in the same place for a number of years.

In addition, the effect of deep tillage on soil structure during the cotton season was monitored. This was undertaken to improve our understanding of how deep tillage affected crop growth and subsequent yields. Subsidiary studies were undertaken to determine which practices are most likely to lead to structural degradation in a permanent bed system of cotton production.

FIELD EXPERIMENT

A field experiment was established on a grey clay near Warren. Three tillage treatments were imposed in May, 1984 following cotton in the 1983/84 season: (i) beds reformed with no subsurface cultivation (permanent beds); (ii) ripping to 0.4 m; (iii) chiselling to 0.25 m. Cotton was grown in the 1984/85 season followed by wheat in 1985, and reimposition of subsurface tillage treatments in April, 1986. Cotton growth and soil physical properties (water content, penetration resistance, air filled porosity and oxygen flux density) were measured throughout the 1984/85 and 1986/87 seasons. The permanent beds had been in place for four years at the end of the 1986/87 season.

Under the management system used for the project, cotton lint yield was highest for the permanent beds and lowest for the ripping treatment (Table 1).

The physical properties measured gave differing indications of the benefits of the treatments for cotton growth. Penetration resistance profiles reflected the depth of tillage, with penetration resistance (a measure of soil strength) being lower in the ripped than permanent bed soil to 0.4 m (Fig. 1). There was no difference between treatments in soil water content for depths shallower than 0.4 m. Soil water content at depths below 0.6 m was greatest in the ripped soil and lowest in the permanent bed soil.

Table 1. Per hectare partial budget of tillage treatments based on yields and machinery operation rates for Field 30, Auscott Warren, 1984 to 1987. (DL: direct list).

		DL	Rip	Chisel
Gross production				
Lint 1984/85 (kg ha^{-1})		1493	1466	1417
Lint 1986/87 (kg ha^{-1})		1451	1255	1414
Average lint (kg ha^{-1})		1472	1361	1416
Income		$	$	$
Value of lint @ \$250 $bale^{-1}$	(A)	1636	1512	1573
@ \$400 $bale^{-1}$	(B)	2617	2420	2517
Less storage and transport costs				
Module building and tarpaulins @ \$2.93 $bale^{-1}$		18	17	17
Transport to gin @ \$3.15 $bale^{-1}$		20	19	20
Value net of storage and transport	(A)	1597	1476	1536
	(B)	2578	2384	2480
Varying cash costs				
Ripping 1.22 hr ha^{-1} @ \$110 hr^{-1} *			135	
Chiselling 0.53 hr ha^{-1} @\$106 hr^{-1} *				56
Discing 0.31 hr ha^{-1} @106 hr^{-1}			36	36
Listing *		47	42	42
Total varying costs		47	212	134
Margin between varying cash costs and returns	(A)	1550	1264	1402
	(B)	2531	2172	2346

* Contract rate, April, 1987.

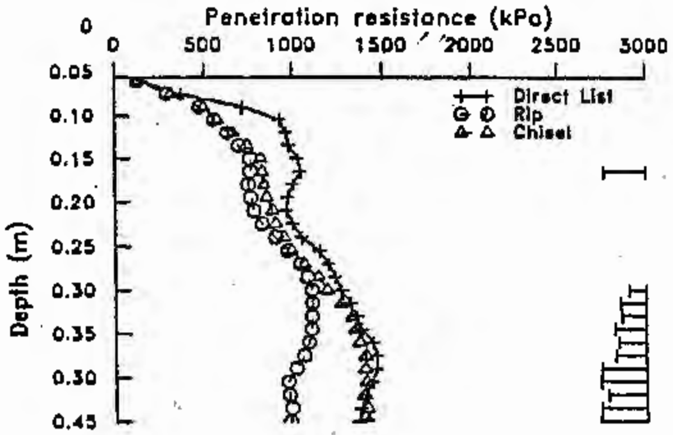

FIGURE 1. Resistance to cone penetration in the centre of cotton hills one month after planting. Each point represents the average of 72 readings taken at Field 30, Auscott, Warren on 10/11/86. Bars represent 5% LSD for depths for which differences in cone index were statistically significant.

Measures of aeration indicated poorer conditions in the ripped soil than permanent beds. Air filled porosity at 0.2 m rose to the critical value of 0.13 m3 m-3, above which adequate oxygen flow for cotton growth was predicted to occur, sooner after irrigation in the permanent beds than in the ripped soil. The yield data indicate that, under the management to which the experiment was subjected, the influence of poorer aeration in the ripped soil overrode the potential advantage of higher plant available water.

ECONOMIC ANALYSIS

Lower costs contributed more to the improved profitability of permanent beds than higher yields. The cost of preparing permanent beds formed by direct listing was one quarter of the cost of preparing beds formed after ripping, and one third of the cost of preparing beds formed after chiselling (Table 1). The small yield increase (<10%) from the direct list compared to the ripped treatment led to increased returns from direct listing of \$124 ha^{-1} at cotton prices of \$250 $bale^{-1}$, and \$197 ha^{-1} at \$400 $bale^{-1}$. The net benefit of direct listing compared to ripping, the poorest economic performer, is equivalent to 1.15 bales ha^{-1} for cotton prices of \$250 $bale^{-1}$, and 0.90 bales ha^{-1} lint for \$400 $bale^{-1}$.

Ripping and chiselling will only be profitable if application of the tillage treatments leads to significant yield improvement. Deep tillage did not improve cotton yields in the current project, nor have cotton yield improvements consistently been demonstrated in tillage experiments on structurally degraded vertisols in central and southern NSW as the benefits of deep tillage are short lived. There is clearly a need to predict whether responses to expensive tillage operations can be expected in a given situation. This topic is addressed below.

GENERAL DISCUSSION

Experimental factors

The physical measures best correlated with plant growth were indicators of waterlogging soon after irrigation. As waterlogging limits plant growth largely by restricting oxygen supply to plant roots, indicators of waterlogging used were oxygen flow in the soil and air filled porosity.

Cone penetrometer resistance was successfully used in this project to differentiate between soil conditions created by tillage treatments (Hulme et al., 1986; Fig. 1), and to show the extent of structural degradation after machinery wheeling. Soil water content has a large influence on penetration resistance, and consequently must be taken into account when interpreting penetration resistance profiles. These profiles are a quick, simple means of estimating the forces roots must exert to grow through the soil. Differences in penetration resistance profiles were not reflected by differences in plant growth in this project, as waterlogging rather than penetration resistance was the main limitation to growth.

The practice adopted in this project of irrigating all tillage treatments at the same time appeared to favour treatments with low plant available water capacity. The ripped soil had consistently higher water content and lower penetration resistance toward the end of drying cycles than both the chiselled and direct listed soils. Cotton growers have observed that permanent beds require one more irrigation during the cotton season than cotton grown on similar soils which have been deep tilled. Improved conditions in the ripped soil were not utilized because all treatments were irrigated whenever the first signs of plant stress were observed in the other treatments.

Implications for management

The absence of measured structural degradation of the permanent beds during the project, combined with the greater cotton production of the permanent beds compared to the deep tilled treatment, has shown that permanent beds are a viable means of cotton production. However, in view of the well documented depression of cotton yield in degraded soils (McGarry and Chan, 1984; McGarry, 1987), care must be taken to avoid structural degradation if the productivity of permanent beds is to be maintained.

The most important factor in avoiding structural degradation is to avoid traffic on wet soil. Structural degradation in response to picker and header traffic over wet soil was measured in this project, while Kirby (1988) has shown that shear rather than density increase is the main mechanism of structural degradation in similar clay soils.

Reducing traffic on wet soil involves much more than a day-to-day decision on whether the soil is too wet to be trafficked. Rather, irrigated cotton growing has to be planned to reduce the need to drive on wet soil. Because of the decline in cotton quality with delay in harvesting, cotton picking is the trafficking operation least likely to be delayed to accommodate the aim of maintaining good soil structure. Although the cotton grower has no control over rainfall and evaporation, advantage can be taken of seasonal trends to reduce the likelihood of soil damage. As evaporation declines towards the end of the cotton season, the likelihood of wet soil at picking can be minimized by managing the crop so that it yields well, yet matures as early as possible, and timing the final crop irrigation so that the cotton crop can dry the soil before it is defoliated. Successful weed control using cultural and chemical tools to their best advantage reduces the need to carry out interrow cultivation when the soil is wet. Similarly, adoption of a permanent bed tillage system reduces the number of passes over cotton fields by heavy machinery, and reduces the need to traffic wet soil during seedbed preparation when growing back-to-back cotton.

Formation of shrinkage cracks in the soil when it is dried by plants can ameliorate structural damage in vertisols, the soils most commonly used for irrigated cotton growing in Australia, and improve the effectiveness of subsequent deep tillage (Beale, 1982). Stress suffered by plants in penetrating degraded soil precludes the use of high value crops to ameliorate structural degradation. This has led to the use of wheat and safflower to dry and crack the soil, combined with deep tillage to further loosen the soil.

Although deep tillage can also be used to ameliorate structural degradation, it does not invariably increase cotton production of irrigated vertisols (McKenzie et al., 1988). The challenge now is to identify soil conditions and management practices which will lead to positive yield responses to deep ripping.

Evidence from the current study and other experiments indicates that several conditions need to be satisfied if deep ripping of vertisols is to lead to yield improvement. First, the soil must contain a barrier to air and water permeability and root penetration, which is shallower than tillage depth. As the cost of tillage increases rapidly with tillage depth, tillage should be just deep enough to penetrate the impermeable barrier. The more favourable for root growth is the soil below this barrier, the more beneficial is deep tillage likely to be. If the subsoil is sodic, the longevity of deep tillage benefits can be increased by addition of gypsum, but gypsum application to ameliorate subsoil sodicity is often unprofitable in the short term.

Second, deep tillage should be carried out at optimum soil water contents. Research carried out at Myall Vale has demonstrated structural degradation and cotton yield depression in response to deep tillage of soil wetter than the lower plastic limit (LPL) in comparison to deep tillage when the soil was drier than the LPL (Daniells, 1984; McGarry, 1987). Tillage is most effective when the soil is slightly drier than the LPL as the soil can be tilled with less effort than at lower water contents, and the risk of structural damage is minimal. The LPL is a soil property which can be determined in the field with no equipment, so can be used by cotton growers to provide an indication of whether or not deep tillage will cause structural damage. The critical depth of tillage, above which soil moves forward, sideways, and upwards when tilled, thus causing decompaction, and below which the soil only flows forward and sideways, causing compaction, is also affected by soil water content. Critical depths become shallower as the soil becomes more plastic or when surface layers are exceptionally dry and cemented, with moist layers below.

Third, recompaction of the soil by passage of machinery over deep tilled soil should be avoided. One wheel pass over deep tilled soil can cause substantial recompaction.

Fourth, crops grown after deep tillage need to be managed to utilize the improved porosity created by deep tillage. This is important when soil conditions are suboptimal for root growth for extended periods, exemplified by the waterlogging measured in ripped plots in this experiment in the 1986/87 season.

CONCLUSIONS

Permanent beds were a viable means of cotton production for at least four years under the management regime imposed on the field experiment. Productivity of the permanent beds will probably be maintained until structure is degraded by an event like wet conditions during cotton harvest.

Although deep tillage did not improve cotton production in this project, it is beneficial provided several conditions are satisfied. Deep tillage will be beneficial if the soil is degraded, the tillage is carried out at optimum water contents, recompaction is avoided, and advantage is taken of the improved physical conditions in the deep tilled soil.

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