An analysis of different permanent bed and wheel track configurations in cotton growing.

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Introduction

Permanent bed or controlled traffic systems have been widely adopted by the cotton industry as a soil management system. It minimises the occurrence of soil structural degradation, particularly after wet winters, by limiting the amount and the working depth of tillage operations. It particularly gained momentum after the wet harvests and winters in the late eighties. Reductions in tillage costs which includes less wear and tear of equipment and fuel consumption through a reduction in the number of tillage operations without affecting the yield is seen as great benefit. In addition, the permanent bed systems have improved the timeliness of the farming operations.

Several observations reported in literature (Thompson and Cull, 1989) and verbally by people in the industry would suggest that soil structural degradation can still be an issue in permanent beds, particularly in the rows adjacent to the wheel tracks. This is visible in the field as wave patterns in the height of the crop as well as irregularities in crop development. An improvement in the wheel tracks with the aim to minimise the effect of traffic on the crop would therefore have the potential to benefit the cotton industry.

Several experiences have been recorded where the special attention has been paid to the wheel tracks within the context of controlled traffic. Burt (1984) found in a soil bin that elevated lane ways had superior traction performance compared to level or recessed laneways. Darcey et al (1984) experimented with elevated lane ways in cotton, growing in a clay loam. A 2.5 m strip was sacrificed to construct two elevated traffic lanes which were positioned on top of two hills which normally would have had cotton. No advantage was found over the conventional system in terms of soil compaction and yield. Spoor et al (1988) investigated different shaped recessed wheel tracks aiming to improve the internal drainage. Although some improvement was made, none of the solutions was lasting. Monroe and Taylor (1989) trialed elevated laneways in the field to carry the weight of a 26 Ton gantry system. Significant differences were found between elevated and level and recessed laneways in terms of timeliness. However in order to build the elevated laneways they went to the extent of actually building a road. Closer to home Tullberg and Lahey (1990) reported on two different configurations wheel tracks, recessed and level, used in controlled traffic experiments in Gatton, Queensland. They concluded that the recessed wheel track performed best.

From the above it is evident that some benefit can be derived from elevated laneways but the experience is very limited. The main advantage of the concept of elevated or raised laneways in controlled traffic was seen to improve drainage. In an irrigated row crop such as cotton, the use of a raised wheel track would exclude the irrigation water from the wheel track and therefore improve traction, timeliness and reduce soil compaction compared to recessed wheel tracks which are being used simultaneously as irrigation furrows.

The concept of raised wheel tracks in cotton growing was investigated in the 91'-92' growing season on a commercial property on the Darling Downs. The elevated laneways were installed with a custom made laneway builder which produced the laneways in the required shape. This experiment has been discussed by Bakker and Harris (1992). Difficulties in the establishment of the crop in the elevated sections and limited height of the beds and wheel tracks did not lead to significant differences between treatments. The experiment was continued for two more seasons in another field and a comparison between the conventional 1m and the 2m bed configuration and the raised wheel track was made. This paper discusses the continued experiment, the observations and the results.

Experiment

The trial was conducted in the '92'-93 and the '93-'94 growing season on a commercial property on the Darling Downs, Queensland. The soil was a self-mulching heavy clay soil, classified as an Black Earth. Three blocks of one treatment each were installed consisting of 32 rows each. This was the equivalent of four passes with a tractor and implement which had a standardised width of 8 rows. The row spacing was 1 m while the length of the blocks was 750 m. Three bed/wheel track configurations were: 1m beds, 2m bed and the raised wheel track (RWT). The 1m bed configuration was the standard on the farm while the 2m bed was a configuration which has several advantages (Lucy, 1993) but has not yet been completely adopted by the growers. The RWT configuration consisted of an elevated wheel track, almost level with the top of the bed. Fig. 1 illustrates the three treatments.

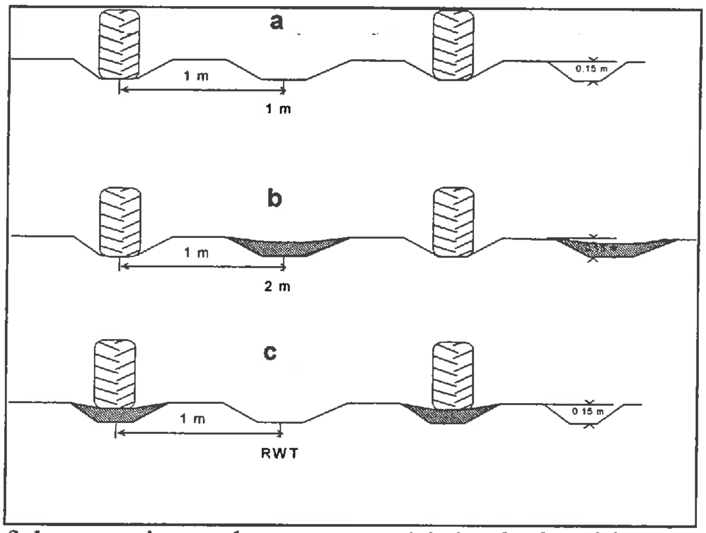

Figure 1 Cross sections of the experimental treatments. (**a**) 1m beds with recessed wheel tracks, (**b**) 2m beds, recessed wheel tracks and (**c**) raised wheel tracks. The hatched areas indicate the volume of soil added during the installation of the experiment, starting from a 1m situation.

Observations made during the '92-'93 season included: soil moisture content of the wheel tracks, crop water extraction (neutron probe), crop development and yield assessment, root mass, soil deformation following traffic, soil structure assessment of the hills and the wheel tracks using shrinkage curves. The observations carried out during the '93-'94 season included: rainfall simulator tests, soil moisture content and root mass, crop development and yield and soil structure assessment using resin impregnated blocks of soil.

Results and Discussion

Season, '92-'93

Soil Moisture Content.

The soil moisture content in the various positions have been summarised in Table 1. Large differences existed between the wheel tracks of the treatments shortly after an irrigation and a rainfall event. However these disappeared after several days. The recessed wheel tracks function as irrigation furrow during irrigation or as drain after substantial rainfall. On those occasions they carry a substantial amount of silt which is left behind as a slurry which increases the moisture content. This is does not occur in the raised wheel tracks and would therefore be beneficial when traffic has to occur under conditions similar to those found in this experiment shortly after irrigation or rainfall (eg. wet pick). Under drier conditions the raised wheel tracks do not have a lower moisture content.

Table 1. Soil moisture content at different dates, locations. For the top 0-10cm only. Value between brackets is the standard deviation. wt = wheel track, hill = plant row.

Occasions and specifications	depth, cm	1M, hill	1M, wt	2M, hill	2M, wt	RWT, hill	RWT, wt
22/09/93 Pre-installation	0-5	30.6					
average of head & tail	5-10	41.5					
03/10/93, 2 days after irrigation	0-5	51 (1.70)			57.6 (1.35)		50.9
11/10/93, 9 days after irrigation	0-20	48.7	46.3				
20/10/93, 22 days after irrigation	0-7	36.8 (2.2)	36.7 (1.00)	32.9 (2.1)	32.4 (1.5)	36.5 (2.5)	41.5 (2.7)
25/11/93, 51 days after irrigation,	0-10	31.8		29.5		32.0	
18/01/93,	0-5			39.2	38.5	38.5	28.7
five days after 100 mm rain	7-12			45.7	47.0	46.4	45.6
22/01/1993, nine days after 100 mm of rain	0-5				37.4 (2.4)		33.7 (2.1)
10/02/1993	0-5		52.5 (3.0)		47.1 (1.1)		41.5 (2.2)
10/02/93 (3 samples) five days after irrigation,	0-5		51.2 (1.5)		50.3 (0.9)		46.1 (1.1)
bd rings	07-12		49.9 (0.2)		48.5 (0.6)		46.8 (0.5)
17/09/93, two days after irrigation	0-5				65.1		52.5

Crop water extraction

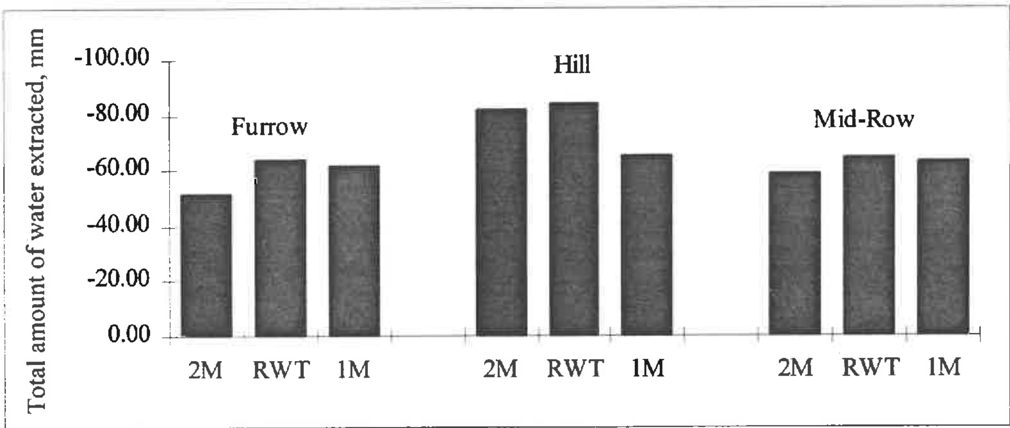

Figure 2 Crop water extraction patterns for various positions relative to the plant row and treatments

The crop in the RWT treatment extracted the highest amount of water with little difference between the furrow (wheel track) and Mid-row (non-wheel track) which indicated similar root activity in both locations. The higher amount of extracted water in the RWT was reflected in the development of the crop which is illustrated in Fig. 3.

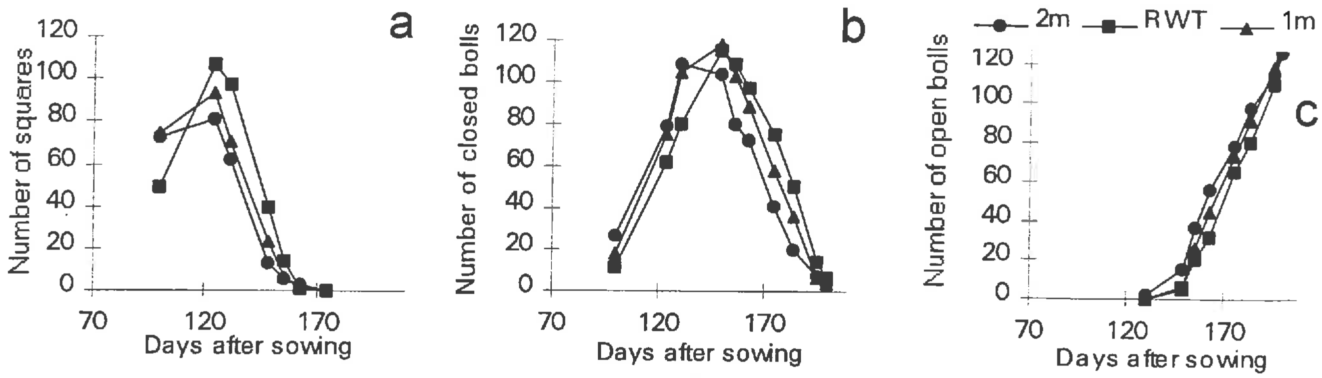

Figure 3 Crop development in days after sowing. (a) Number of squares, (b) Number of closed bolls and (c) Number of open bolls.

The RWT crop had a late start in terms of number of squares which further affected the timing of the peak in the closed bolls and initiation of boll opening, The difference in the number of open bolls was clearly visible in the field. Yield data also reflected the trends in the crop development with the treatments yielding: 3.40, 3.17 and 3.49 b/ha^{-1} for the 1m, 2m and the RWT treatment respectively. The yield in the 2m treatment was significantly less than the other two treatments.

The delay in squaring and the subsequent larger number of bolls in the RWT could have been due to the compensation phenomenon (Constable, 1995, pers. comm.). The RWT and 2m beds were established from well prepared seed beds. The top soil had been removed and deposited in a different position either in the mid-row or in the wheel track. Alterations in the immediate top soil of the seed bed affecting eg. VAM or micro-elements could have caused an initial stress to the crop which compensated for this at a later stage. However, it should be pointed out that only the RWT treatment reacted in a manner, similar to the compensation effect while the 2m beds and the RWT treatment had a similar history.

Root sampling in the various wheel tracks, indicated a significant higher amount of root mass in the raised wheel track compared to the recessed wheel tracks.

Soil Deformation

The effect of wheel track geometry on the soil deformation was assessed with the pin displacement method (Bakker and Davis, 1995). Space constrains do not allow a full discussion of the method but in short a soil pit is dug perpendicular to the direction of travel. Pins are placed in a grid pattern in both longitudinal walls of the pit. After back filling, a vehicle is driven over the soil pit and displaces the pins. After re-excavating the soil pit, the position of the pins is determined. The deformation of the grid pattern is then used to calculated changes in bulk density. Fig. 4 and fig 5, displaced grid points and changes in bulk density respectively, illustrate some of the results of this technique.

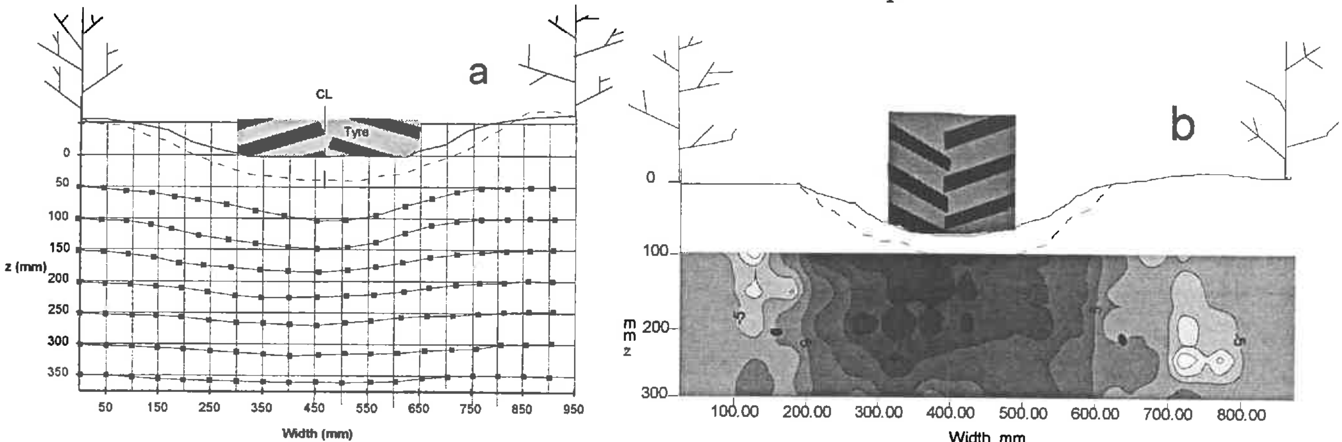

Figure 4 (a) Example of a displaced grid of pins and (b) changes in bulk density, calculated from the displaced pins.

The displacements of the pins can be separated into horizontal and vertical displacements. For every depth these displacements in both directions can be added up. Little difference in vertical displacement between the raised and the recessed wheel tracks was found but the sum of the horizontal displacements in the RWT treatment was significantly less than the recessed wheel tracks. This was contributed to the different shape of the wheel tracks. In recessed furrows, the tyres are more likely to run slightly on the shoulders of the beds which increases the horizontal displacements compared to the reasonable level surface of the RWT.

McGarry and Daniells (1987) used shrinkage curves of natural aggregates as an indicator for the soil structure. On regular occasions, four clods were collected from the wheel tracks and the adjacent hills. A 'Two-Line' model was fitted through the data and the several parameters of the model were calculated for the various data sets. From the statistical analysis of the parameters it was found that after one year of operation the RWT's had a better soil structure than the recessed wheel tracks.

Season '93-'94

This season was severely affected by lack of rainfall and limited irrigation water allocation. During this season, rainfall simulator tests were carried out, crop development observation and soil structure determination using resin impregnated blocks of soil.

Rain fall simulator tests.

These tests were carried out with the QDPI (Dalby) simulator covering an area of $2m^2$ during two different stages: a bare soil, just prior to sowing and in January (1994) when the canopy of crop was nearly closed. On neither of the occasions was there any difference between the timing of initial run off or the total amount of run off. It is often attributed to 2m bed system (Lucy, 1992) that short sharp storms are better utilised (ie. less run off), this was not confirmed during the simulator tests. The bare soil slaked rapidly, creating an impermeable surface which led to significant run off regardless the internal soil structure. On the second occasion the field had dried out substantially and large cracks appeared at the surface which captured any run off. Interestingly, 24 hours after the second test was carried out , a storm of similar intensity ($100mm.hr^{-1}$) fell on the experimental area without generating any run off in the treatments thus confirming the results of the second test.

Crop Development, Yield and Root Mass

The development of the crop was severely affected by the lack of soil moisture with no significant differences between the treatments. The RWT treatment was again behind in number of squares but remained behind in number of open bolls per metre. Internode length was also shorter for the RWT treatment. The crop developed fastest in the 1m treatment. This was reflected in the yield of 2.10, 1.86 and 2.00 $ba.ha^{-1}$ for 1m, 2m and RWT treatment respectively. Compared to the yield of the previous season this was extremely low.

Root mass was sampled in the wheel tracks and the inter-row space (non-wheel track) but unlike the previous season no significant difference was found between treatments nor positions.

Soil Structure Assessment

One large block of soil (90 x 20 x 40 cm: width x thickness x height respectively), which included a part of the wheel track, the entire width of the hill and a part of the non-wheel track was sampled in every treatment and impregnated with epoxy resin, mixed with a fluorescent dye. The blocks were positioned on the side and the surface leveled using a router, equipped with a diamond plated grinding bit. This was repeatedly done with increments of 2.5 mm. The exposed surfaces were illuminated with UV light and the image of fluorescent voids and cracks captured on slide. The slides were digitised, producing a binary image of the soil structure. Every image was partitioned into three sections, the wheel track, the hill and the non-wheel track. See Fig. 5 for an example of a cross section of the 2m bed.

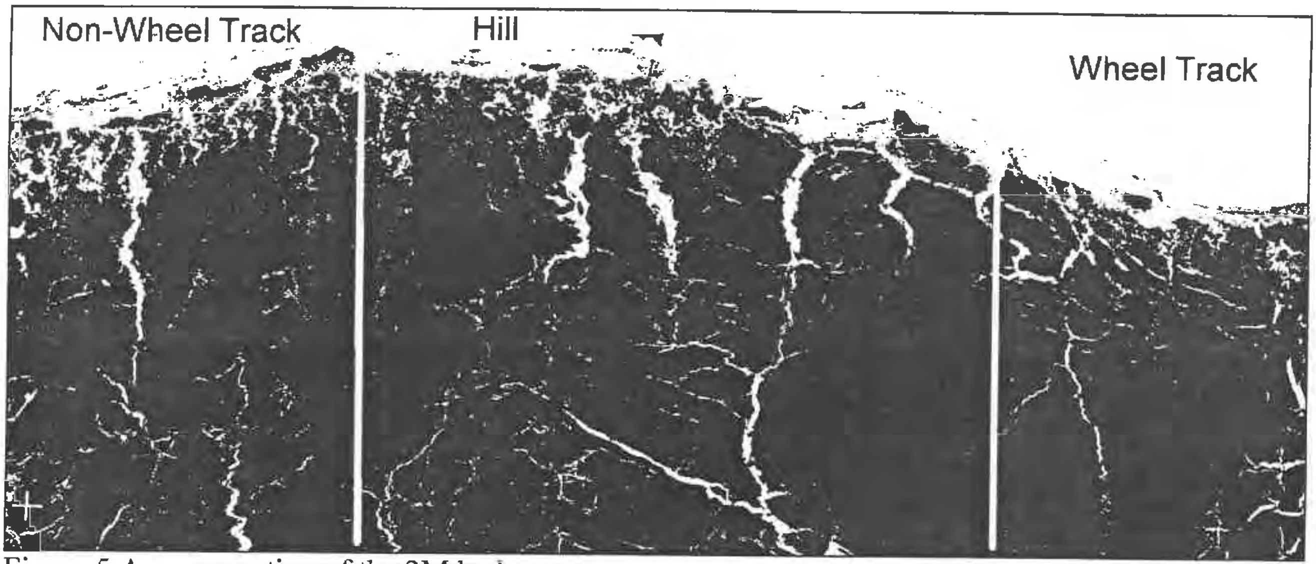

Figure 5 A cross section of the 2M bed

A program, STRUCTURA, (Moran and McBratney, 1991) which was modified to accept sloping surfaces was used to calculate several soil structural attributes for all three sections in every image. Statistical analysis of the attributes and visual observations revealed that the RWT had a significant poorer soil structure in the top 15 cm of the soil profile in the hill and the wheel track, compared to the other treatments. The hill of the RWT however had a higher moisture content which might explain some of the differences. The wheel tracks had a similar moisture content.

Conclusions

From the above it can be concluded that the raised wheel tracks (RWT) did offer some advantages in terms of reduced moisture content immediately after irrigation, better soil deformation patterns (less horizontal deformation) and crop performance (first season only). It was surprising that in the dry second season neither the 2m nor the RWT treatment seemed to have any advantage above the 1m bed, despite the larger soil mass available for root growth and moisture storage. The RWT's did have a better soil structure according to the clod shrinkage data at the beginning of the second season but this had disappeared and the soil structure was slightly more deteriorated compared to the recessed wheel tracks at the end of that season, according to observations on resin impregnated blocks.

The tractor operator did not experience problems travelling over the raised wheel tracks but was not particularly impressed since more concentration was needed to stay on track. An tractor guidance system would be beneficial under such conditions. In summary, differences between treatments were observed and were translated into yield differences but they were not sufficient and consistent enough for the grower to change his practices which were based on 1m beds with recessed wheel tracks.

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