THE EFFECTS OF SOIL COMPACTION DUE TO INFIELD TRANSPORT ON RATOON CANE YIELDS AND SOIL PHYSICAL CHARACTERISTICS

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Abstract

The results of a soil compaction trial conducted on a Longlands form soil at La Mercy are reported. The treatments included moderate (3,7 ton loads) and severe (5,7 ton loads) compaction of the interrow only and of the cane row plus the interrow. The results from two ratoon crops both of which were compacted, showed that both moderate and severe compaction over the cane row and the interrow caused a marked reduction in cane yield. Compaction of the interrow only resulted in a less severe reduction in yield. Increases in cane yield resulted from ripping the interrow in the compacted plots but not in the plots which had not been compacted. Bulk density values of the soil increased by an average of 5% after compaction. Moisture release curves revealed that the available moisture capacity was increased by the compaction treatment, mainly in the high tension range (100 to 1 500 kPa), while in the low tension range (7,5 to 100 kPa) compacted soils contained less water. On average, air-filled porosity values decreased by 40% after the compaction treatment. Results obtained from this experiment are likely to apply to such soil forms as Westleigh, Kroonstad and Katspruit and particularly to soils having similar textural properites as those of the Longlands form soil at La Mercy. Appropriate management practices for these soils are suggested.

Introduction

During the 1960s trials were conducted under rainfed conditions by the Experiment Station at Mount Edgecombe and at Shakaskraal, and by the Tongaat Sugar Company, (SA Sugar Association Experiment Station[1,2,3,4,5]). The results indicated that compaction of the soil by infield transport may have caused yield reductions but these were not statistically significant. To overcome the problems of soil and moisture variability which occurred in earlier trials, another trial was conducted under irrigated conditions on a deep uniform Makatini series soil at Pongola (Johnston & Wood[6]). Again there were no statistically significant reductions in yield and it was concluded that cane growth would be little affected by compaction if water was not a limiting factor. In 1979 a further attempt was made to study the effects of compaction on cane yield under rainfed conditions. The site was at the La Mercy farm of the Experiment Station on a Longlands form, sandy loam soil derived from Middle Ecca parent material which is known to be particularly susceptible to compaction. A schematic profile of the soil is given in Figure 1.

Experimental Procedure

A plant crop of the variety NCo 376 was established at the end of 1979. In December 1980 the cane was cut back, after which compaction and ameliorative treatments were applied. The trial was designed to study the effect of moderate and severe compaction on the growth of ratoon cane, its ultimate yield and physical characteristics of the soil. The compaction was done when the soil was moist. The effects of ripping the interrow soon after compaction and of applying extra nitrogen fertilizer, were also examined. The experimental layout was a split-split plot with four replications. Each plot consisted of six rows 20 m long at a spacing of 1,4 m. Two guard rows and 5 m at the ends of each row were discarded at the time of harvest.

The implement used for compacting the soil consisted of a 500 kg tractor-drawn frame mounted on a single truck axle and fitted with 1100 × 20, 8 ply tyres. Moderate and severe compaction was achieved with extra ballast weighing 3 200 kg or 5 200 kg to make up total masses of 3 700 kg and 5 700 kg respectively. Five passes of the weighted frame were necessary to cover the interrow and seven passes were needed for compaction of the row and interrow. Main treatments consisted of an uncompacted control (C1), moderate compaction of the interrow only (C2), moderate compaction of interrow and row (C3), severe compaction of the interrow only (C4) and severe compaction of the row and interrow (C5). The moisture content of the soil at the time of compaction in 1980 was about 14% and in 1982 it was about 9%.

A ripper on a three point linkage, with two shanks onto which 125 mm triangular wings had been attached, was used for the ameliorative ripping treatments. The sub-treatments consisted of one pass with the ripper in the interrow at a depth of 300 mm one month after compaction, a normal nitrogen application of 140 kg/ha and a high application of 200 kg/ha. Two dressings of nitrogen were applied (70 + 70 kg and 100 + 100 kg), the first just after compaction and the second, two months later.

A penetrometer was used before and after compaction to measure penetration resistance at the beginning of both the first and second ratoon crops. Air-filled porosity, bulk density and available moisture capacity values were determined from undisturbed core samples taken in December 1980 on the moderately compacted plots before and after compaction. Further bulk density measurements of the soil were taken in June 1982 using an undisturbed core sampler and a Troxler nuclear density gauge for comparison. To measure the degree to which the

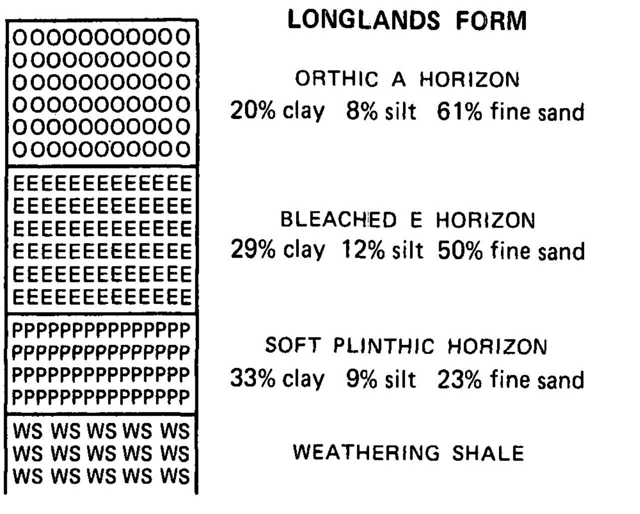

FIGURE 1 Diagram of a Longlands form soil profile at the site of the compaction trial.

soil had been compacted a Proctor test was carried out on the soil. Twenty sets of three samples each, were wetted so that their moisture contents differed and then subjected to the same force of compaction in a mechanical compacter. After compaction, the bulk density of each sample was measured and a mean value for each set of samples was obtained. Because some of the bulk density values were very high (>1 800 kg/m^3) the roots of cane in a severely compacted plot were examined and compared with those of cane in an adjacent plot which had not been compacted. To do this a pit was dug across the cane rows to expose the roots, which were then washed with lime. A 200 mm × 200 mm string grid was then superimposed (see Figure 2).

Root densities were measured by taking undisturbed soil cores adjacent to the plant. The roots from each core were removed, washed and weighed when they were dry. The second method of measuring root density was to count all those roots thicker than 0,25 mm in each square of the grid.

Results

Effect on yield

Yields from the first and second ratoon crops are summarised in Table 1 and the effects of soil compaction on yield are illustrated in Figure 3.

The main effect of compaction in the first ratoon was a maximum reduction of about 30% in the sucrose yield, while in the second ratoon the maximum reduction was nearly 50% in sucrose yield. Both moderate and severe compaction caused significant reductions in yield; most of the effect was due to compaction at the moderate level and increasing the severity of compaction reduced yields only by a relatively small additional amount. These effects are evident in the following comparisons of relative decline in yield which was obtained from the average yield data of the first and second ratoon crops of unripped treatments:

Interrow compaction : Control (C1) vs moderate (C2) -18%
Moderate (C2) vs severe (C4) - 9%

Full cover compaction : Control (C1) vs moderate (C3) -32%
Moderate (C3) vs severe (C5) +1%

Full compaction overall was far more damaging to yield than was compaction of the interrow alone, presumably because of direct damage to stools. Ripping the interrow in moderately compacted plots resulted in a marked increase in yield (Table 1). There were no yield increases in the uncompacted control plots which had been ripped and the treatment may have been slightly detrimental in some cases.

Soil measurements

(a) *Hand penetrometer measurements*

These were made on at least three occasions (see Figure 4) to test the effect of the various compaction treatments on soil strength. The results were variable because of the

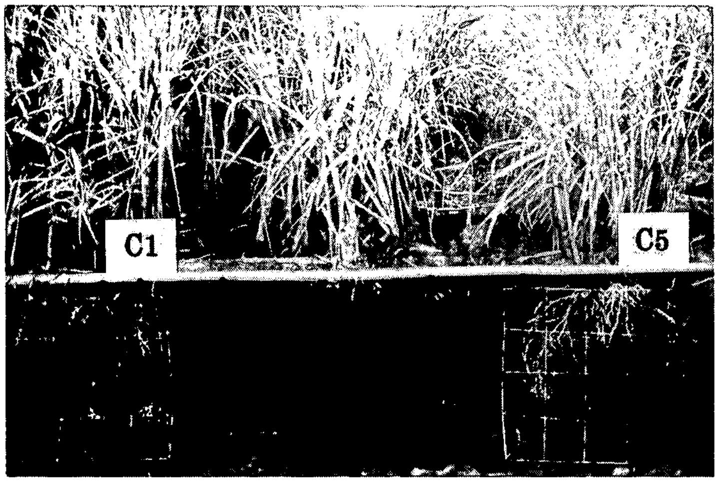

FIGURE 2 The exposed pit profile after root washing showing the 200 mm squares.

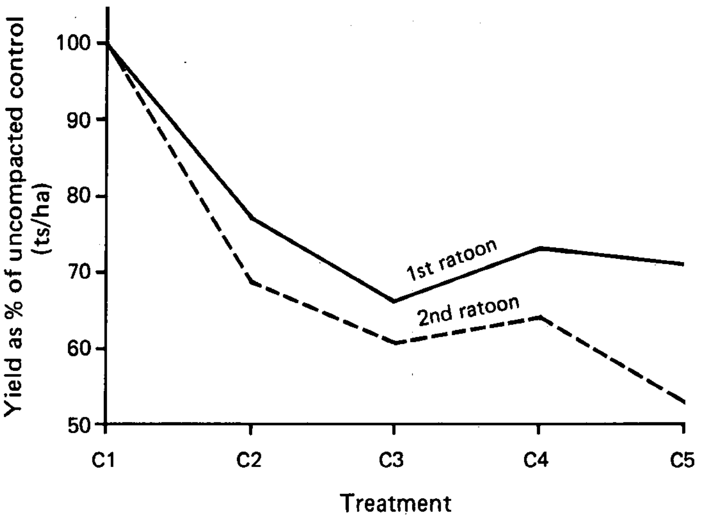

FIGURE 3 Relative yield response to compaction treatments during the first and second ratoons.

TABLE 1

A summary of cane and sucrose yields for the first and second ratoon crops

Treatments		Code	Unripped				Ripped			
			1st ratoon 18/12/80–4/5/82		2nd ratoon 4/5/82–29/8/83		1st ratoon 18/12/80–4/5/82		2nd ratoon 4/5/82–29/8/83	
			tc/ha	ts/ha	tc/ha	ts/ha	tc/ha	ts/ha	tc/ha	ts/ha
Nil	No compaction	C1	80	7,9	34	3,6	76	7,3	33	3,5
Moderate	Interrow compaction	C2	69	6,1	25	2,5	81	8,1	34	3,9
Moderate	Full compaction	C3	58	5,2	20	2,2	69	6,5	31	3,4
Severe	Interrow compaction	C4	63	5,8	22	2,3	68	6,2	29	3,0
Severe	Full compaction	C5	61	5,6	18	1,9	64	6,1	23	2,5
Mean			66,2	6,1	23,8	2,5	71,6	6,8	30,1	3,3
LSD (P=0,05)			8,8	0,9	6,7	0,9	8,8	0,9	6,7	0,9
LSD (P=0,05) ripped vs unripped			22,2	3,5	6,6	0,7	22,2	3,5	6,6	0,7

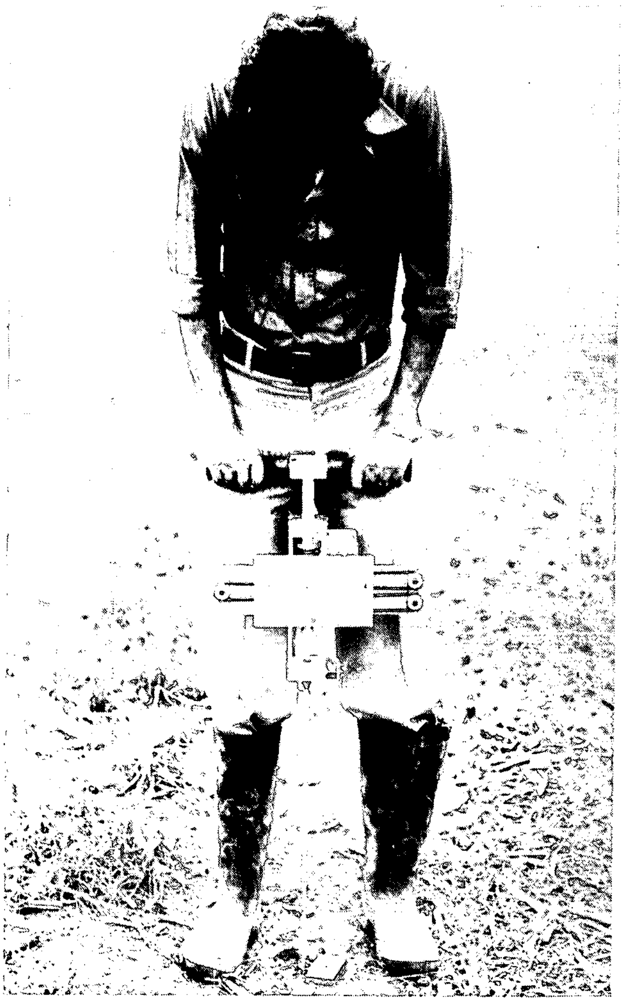

FIGURE 4 Using a hand penetrometer.

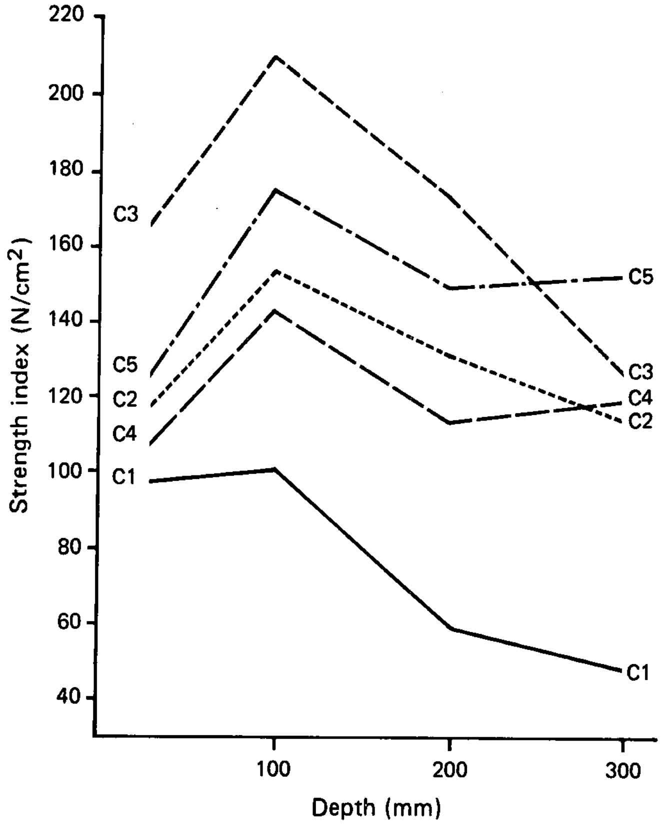

FIGURE 5 The effect of different compaction treatments on soil strength.

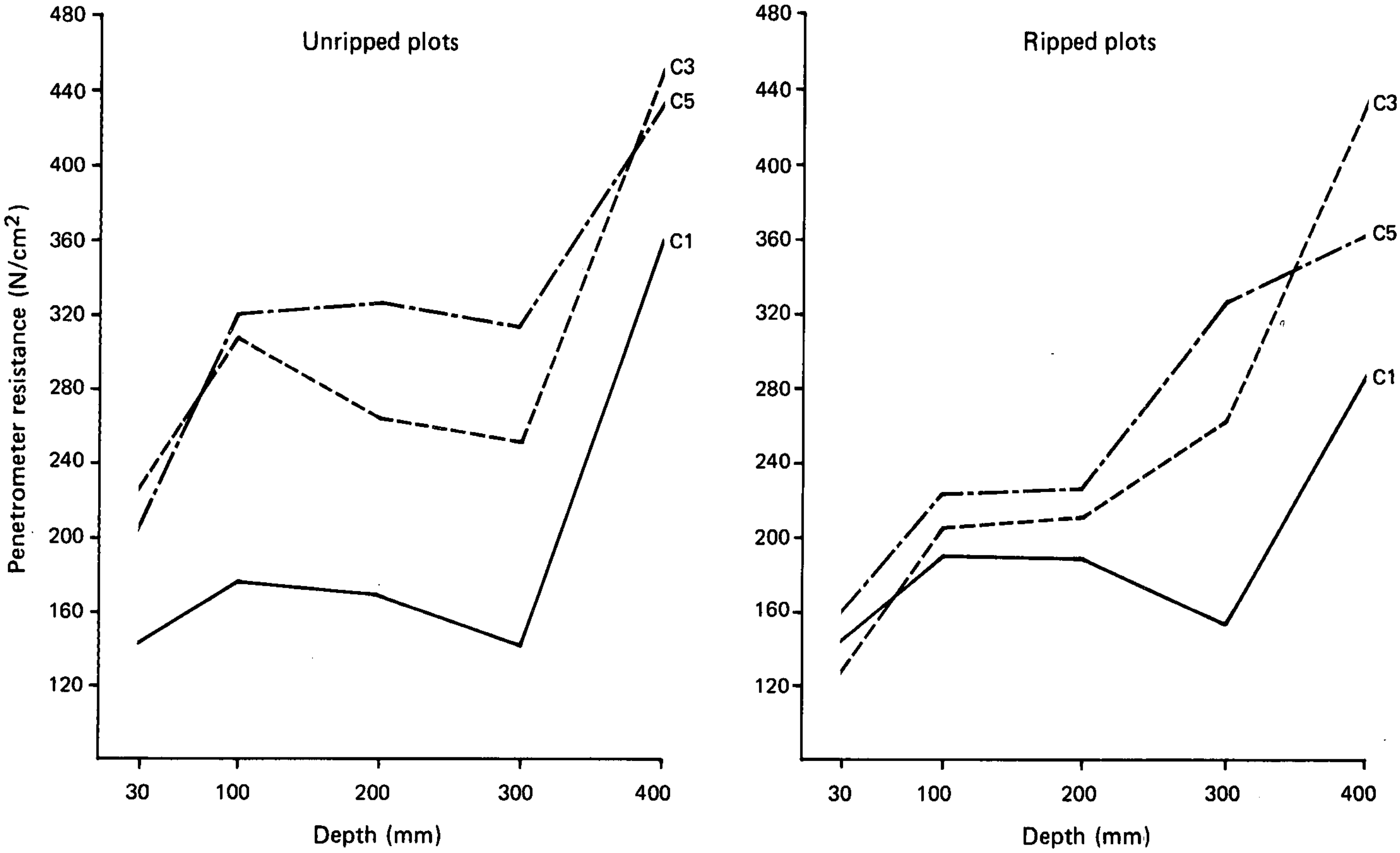

FIGURE 6 Residual effects of ripping on soil strength measured to a depth of 400 mm.

influence of moisture distribution down the profile. In the compacted plots, resistance to penetration reached a maximum at a depth of about 100 mm (see Figure 5). In many cases evidence of compaction was also found at depths of 200 and 300 mm. Below these depths natural pedological phenomena appeared to predominate (eg a soft plinthic B horizon). Neither of the severely compacted plots (C4 and C5) produced the highest resistance values at depths between 0 and 200 mm. A possible explanation is that shear failure caused the soil mass to loosen partially as a result of severe disruption.

The residual effects of ripping to reduce soil strength where compaction was moderate (treatment C3) and severe (treatment C5) are illustrated in Figure 6. A comparison of the curves illustrates that resistance to penetration to a depth of 200 mm was still markedly lower in the ripped plots after nearly 18 months.

(b) *Undisturbed core samples*

The reduction in air-filled porosity (see Table 2) in the soil of moderately compacted plots (interrow only) probably played a major part in reducing yields. The already low air-filled porosity values (mean 10,3%) were reduced even further and all values recorded after compaction were below the critical value of 10%. (Vomocil & Flocker[8]).

TABLE 2

Air-filled porosity, bulk density and available moisture capacity values before and after moderate compaction of the interrow only

Plot	Air-filled porosity % by volume		% diff	Bulk density		% diff	Available moisture capacity		% diff
	Before comp.	After comp.		Before comp.	After comp.		Before comp.	After comp.	
6	9,9	6,8	31,3	1 654	1 719	4	74	106	30
15	10,0	5,9	41,0	1 737	1 764	2	78	150	48
18	8,3	5,3	36,1	1 711	1 822	6	106	137	23
21	10,9	7,4	32,1	1 724	1 782	3	132	155	15
27	12,4	4,5	63,7	1 561	1 725	10	81	82	1
31	12,9	7,1	45,0	1 661	1 751	5	122	124	2
37	7,5	7,2	4,0	1 718	1 799	5	164	147	-11
Mean	10,3	6,3	38,8	1 681	1 766	5	107	127	16

Although the overall increase in bulk density as a result of compaction was only 5% (see Table 2) it was consistent in all plots sampled. The undisturbed cores were all taken from the moderately compacted plots and a greater increase in bulk density could be expected in soil which had been severely compacted.

(c) *Moisture retention*

Moisture retention studies on undisturbed core samples taken before and after compaction showed that the maximum amount of water retained by the soil increased following compaction (see Table 2 and Figure 7). On average the compacted soils retained less water between 7,5 and 100 kPa and more between 100 and 1 500 kPa than the soil which had not been compacted (see Figure 7) because of the change in pore size distribution. The proportion of water held by the smaller pores increases while that held at a low suction by the larger pores, decreases.

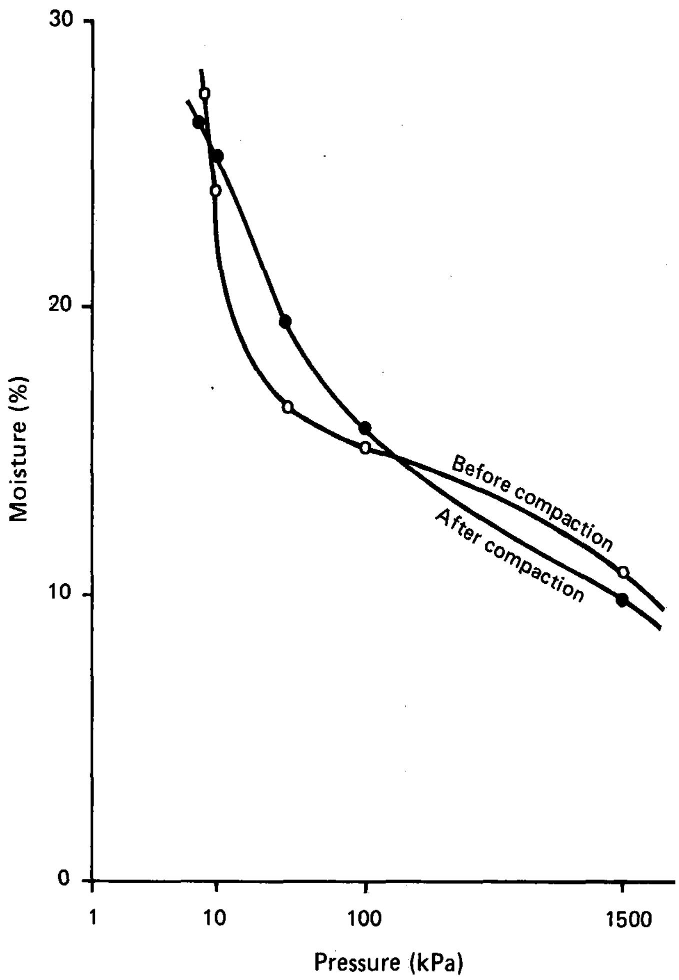

FIGURE 7 Typical moisture release curves before and after moderate compaction.

(d) *Bulk density*

Both methods of measuring bulk density, using either undisturbed cores or a Troxler density meter, showed with few exceptions that as soil compaction increased, wet bulk density values also increased (Table 3). Exceptions occurred where the soil had a high wet bulk density prior to compaction.

TABLE 3

Change in Troxler and undisturbed core wet bulk density values with increase in severity of compaction treatments

Rep. No.	Plot No.	Code	Bulk density at 200 mm	
			Troxler values	Undisturbed core values
1	3	C1	1 796	1 899
	4	C3	1 821	1 875
	1	C5	1 936	2 006
2	11	C1	1 767	1 764
	13	C3	1 831	1 842
	12	C5	1 959	1 947
3	36	C1	1 800	1 714
	39	C3	1 870	1 813
	38	C5	1 870	1 788
4	24	C1	1 801	1 724
	22	C3	1 920	1 966
	25	C5	1 898	1 876

C1 : uncompacted control
C3 : moderate full compaction
C5 : severe full compaction

Yield reduction due to compaction effects indicate that high wet bulk density values such as those recorded in the trial, were detrimental to good cane growth. From yield results and corresponding wet bulk density values it appears that values of more than 1 800 kg/m³ nearly always cause yield reduction.

(e) *Compaction*

The mean bulk density values obtained from the Proctor test were plotted against moisture content (Figure 8). The curve clearly shows that the tendency of soils to compact was at a minimum when the moisture content of the soil was between 2 and 8%.

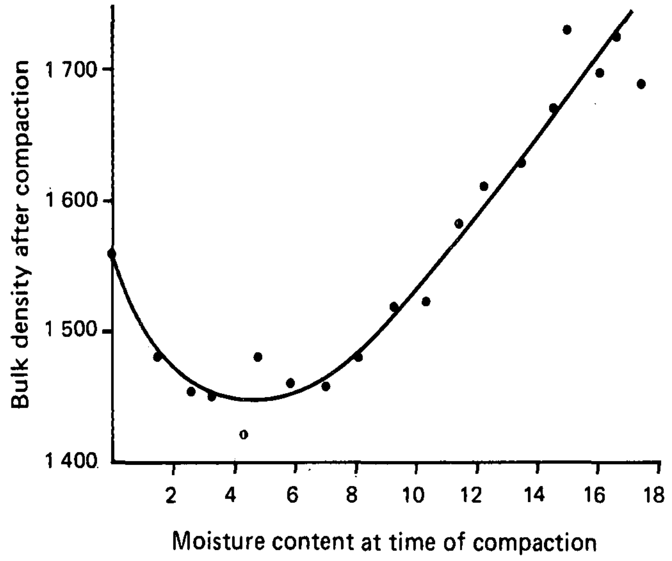

FIGURE 8 Change in wet bulk density values with increase in moisture content due to a standard compaction force.

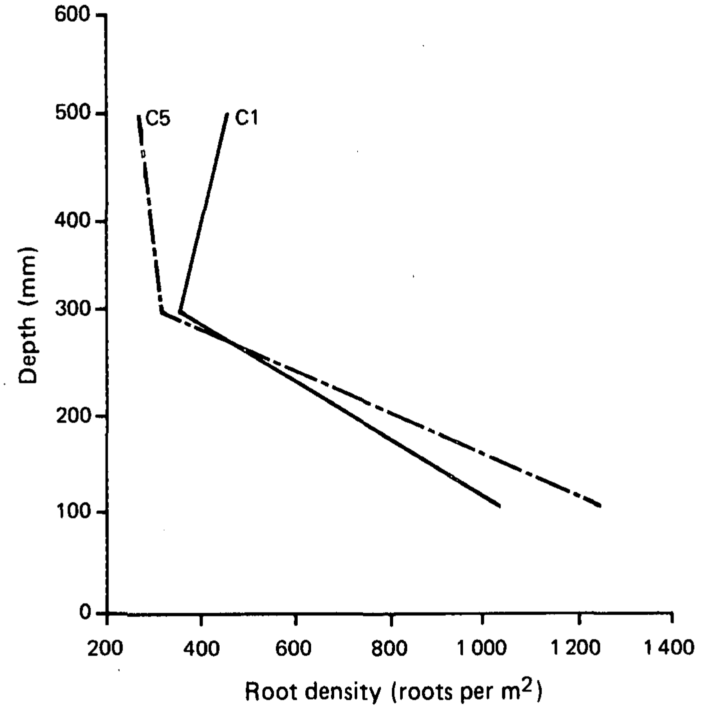

FIGURE 9 Comparison of root density in the uncompacted (C1) and severely compacted (C5) treatments.

(f) *Root washing*

Root density in relation to soil depth in terms of roots per square metre and grams per cubic decimetre, is shown graphically in Figures 9 and 10. Root density in the first 100 mm was greater in the severely compacted treatment than in the uncompacted treatment. However at depths between 300 and 400 mm this trend was reversed and an increased number of roots were able to penetrate more deeply into the soil in the uncompacted treatment than in the severely compacted treatment (see Figure 2).

Although root density in the severely compacted treatment was greater than that in the uncompacted treatment the roots were less fibrous. The thinner more fibrous roots in the uncompacted treatment had a larger surface area and were probably more efficient in extracting moisture and nutrients from the soil than the thicker roots in the severely compacted treatment.

Discussion

Reduction in cane yield following compaction of the soil is probably due to a combination of factors. Resistance to a penetrometer increased at depths between 300 and 400 mm (see Figure 6) supporting the observation that, at this depth, root densities in the severely compacted treatment declined sharply while those in the uncompacted treatment increased. When root penetration downwards in the soil is reduced, the effective rooting depth is decreased, leaving a smaller volume of soil from which water can be extracted. An increase in bulk density is normally accompanied by a decrease in air-filled porosity and when this falls below 10%, as occurred after compaction, roots may suffer from an oxygen deficiency which in turn restricts growth. This effect can become more pronounced during wet periods. Although increased compaction caused an increase in water holding capacity, more of this water is held in the smaller pores at high suction, making it less available to the plant. This may cause the plants to wilt earlier under high evaporative demand conditions even though the soil has sufficient water.

The Proctor test was useful for determining the soil moisture range at which the effects of compaction by infield transport are least likely to damage the crop. The critical moisture range

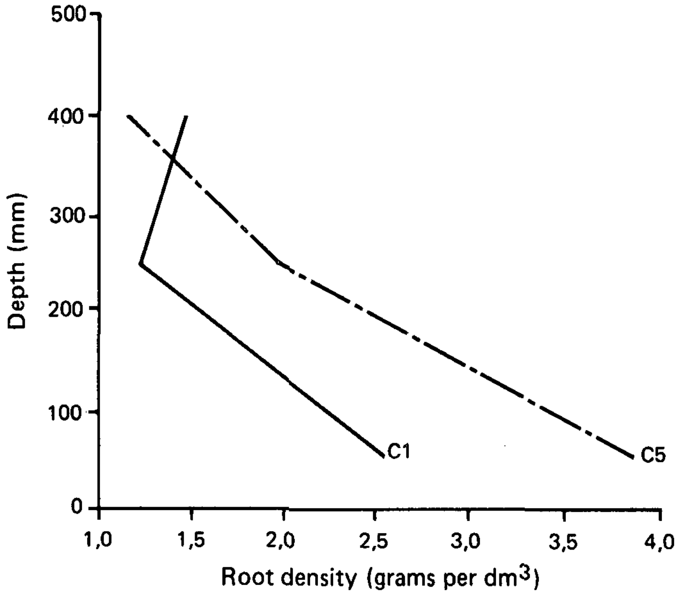

FIGURE 10 Comparison of root densities with depth in the uncompacted (C1) and severely compacted (C5) treatments.

was between 2 and 8%, but a moisture content of less than 10% is probably acceptable. These values would however only apply to a sandy loam, Longlands form soil with a high proportion of fine sand and other soils with similar physical properties.

The beneficial effects of ripping are considered to be an improved intake of water as a result of temporary fracturing of the surface crust and improved soil aeration at depth following partial loosening of the soil, thus allowing better root development. (Ricaud[7])

Conclusions

On a soil which has a tendency to compact, it is important to limit infield traffic to a minimum and to confine it to the interrow. Cane growing on such soils should, wherever possible, be harvested in the dry season only or when the soil moisture content is low. If compaction is identified as being a factor limiting growth, ripping the interrow can be effective in alleviating the problem. A wet bulk density value of 1 800 kg/m^3 or more for the Longlands form soil (Waldene series) is likely to cause a reduction in sugarcane yield.

The residual effects of compaction will be studied more closely and the efficiency of a tine ripper and a Paraplow in ameliorating a compacted soil will be compared in future work.

Acknowledgements

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