DEEP TILLAGE INVESTIGATIONS ON FIVE SOIL TYPES OF THE SOUTH AFRICAN SUGARBELT

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Abstract

The effects on sugarcane yields of deep tillage for land preparation on five different soil types in the coast lowlands of Natal are presented. Yields from the rainfed plant and first ratoon crops indicate that, in general, there is little advantage in ploughing or subsoiling to depths greater than the conventional 20—25 cm. The only worthwhile response to deep tillage was obtained in a recent sand, and data are presented which may help to explain this unexpected occurrence. It is considered that the extra costs of deep tillage are not warranted unless specific soil problems are known to exist.

Introduction

In 1967 a great deal of interest in deep ploughing was aroused amongst cane growers in Natal following the importation of large mounted and trailed ploughs by agricultural machinery firms. At about the same time, investigations conducted in the root laboratory at the S.A.S.A. Experiment Station (Glover[5]) indicated that cane roots penetrated and proliferated better in a disturbed dolerite soil than they were able to do in an undisturbed soil.

Investigations on alluvial soils of the Mississippi Delta (Saveson[8, 9]) showed that the greatest increases in sugarcane yields from deep ploughing (35 cm) and subsoiling (45 cm) were obtained in fine sandy loams and silty clay loams, whilst no responses were obtained in silt loams and clay alluviums. Compacted layers of soil or "pans", at depths of 12—45 cm, exist in the Delta area. They result from soil-forming processes and also from in-field traffic. Responses to deep tillage were variable, but occurred only in dry seasons and were also specific, it seemed, to some cane varieties. It was found that cotton responded by as much as 900 kg/ha in a dry year, to the shattering of the soil pans.

Deep ploughing (40—50 cm) of the acid, low fertility, claypan soils of the central states of America (Woodruff[12]) produced a response from maize, no response from oats and a reduction in the yield of barley. However, the deep application of nutrients resulted in yield increases from all three crops. These results are contrary to those obtained (Fehrnbacher[4]) on a silt loam claypan soil in Illinois. Subsoiling to depths of 20, 40, 65 and 90 cm did not improve maize yields either with or without the deep placement of fertilizer. In general, it is the opinion of overseas workers on various crops "that plant growth can be increased by deep ploughing only where root development and perhaps water movement are restricted by dense, compact, or fine-textured layers in the profile" (Burnett[3]). Where water is not limiting deep tillage is most unlikely to improve yields.

In 1963 the results of an observation experiment on a Dwyka-derived fine sandy loam at Shaka's Kraal, demonstrated that neither subsoiling nor ploughing improved yields when compared with rotavating only prior to re-establishing sugarcane (Pearson[7]).

Because of the rather limited data on deep tillage effects on sugarcane, it was decided in 1967 to test the response of this crop to deep and medium subsoiling and ploughing, on some of the most representative soils of the Natal sugar belt.

Experimental Methods

1. **Selection of sites:** Because of the expensive equipment required to undertake this work, the number of experiment sites was limited, but a reasonable selection of soil types was obtained so that the results could, to some extent, be used in reference to other soils. On the sites selected it was possible to study the effects of (a) disturbing a thick compactable Dwyka topsoil; (b) disturbing the massive clay abruptly underlying a permeable topsoil (Williamson/Waldene series); (c) breaking up flat-lying shales in the rooting zone (Milkwood series); (d) disturbing deep, strongly structured loamy clays (Shortlands series) and clay loams (Rydalvale series); and (e) disturbing a deep structureless fine sand (Fernwood series).

Site 1: Rydalvale, at Ukulu Properties (Pty) Ltd., Empangeni: A black montmorillonitic clay loam to clay, about 40 cm thick, on moderately porous yellowish brown weathering dolerite. This soil series represents 1,7% of the industry's soil (Beater[1]).

Site 2: Shortlands, at Ukulu Properties (Pty) Ltd., Empangeni: A very deep, red, very firm blocky clay. Water through-flow and acceptance rate are good despite the high clay content. The series represents 5,9% of the industry's soil.

Site 3: Fernwood, at the Central Field Station, Umhlanga Rocks: A grey fine sand more than 120 cm thick, overlying a red sandy clay. Fernwood sands represent 4,2% of the industry's soil.

Site 4: Williamson/Waldene at Huletts Sugar Corporation's Sinkwazi Estate, Darnall, North Coast. A fine sandy clay laom 50—70 cm thick, merging via a thick layer of iron concretions and clay material, to moderately porous weathered Dwyka tillite. These series represent 13,6% of the industry's soil.

Site 5: Milkwood at Natal Estates' Saccharine Estate, Mount Edgecombe: A dark grey brown micaceous clay, only 50—60 cm thick overlying slowly permeable, layered Lower Ecca shale. This series represents 4,4% of the industry's soil.

2. *Equipment used for the different treatments*

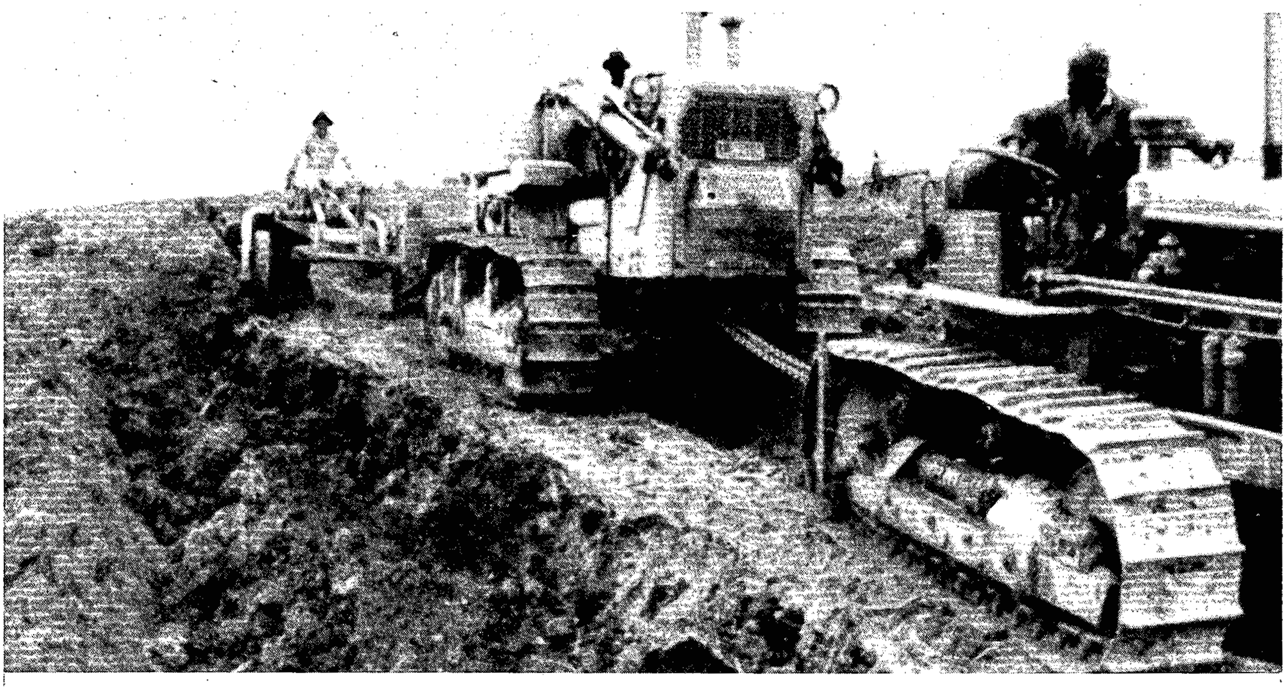
Deep ploughing: A Nardi 1½/DMR/E trailed, single furrow, mouldboard plough was drawn by a D8 or D7E caterpillar tractor in tandem with a D6 or D4 depending on the soil type. Considerable soil inversion and profile mixing occurred. The mean depth of ploughing was 92 cm but it varied between 75 and 100 cm. Only on the Shortlands site was it impossible, because of the resistance of the soil, to plough beyond a depth of 75 cm.

Medium ploughing: A Nardi 000/DMR/E trailed, single furrow, mouldboard plough was drawn by a D6 or D7E. Considerable soil inversion and profile mixing occurred. The average plough depth was 57 cm but it varied between 50 and 62 cm depending on soil type.

Deep Ploughing a Milkwood Soil.

Deep subsoiling: A double-shank implement with wings (60 cm from tip to tip) attached to the subsoiler shoes, having an angled cutter-bar fixed between the shanks which were 90 cm apart, was drawn by a Caterpillar D8. Two passes were made and the depth of penetration varied from 70—80 cm, the average being 75 cm. On the Rydalvale site, a straight-tip, double shank subsoiler with shanks 180 cm apart, penetrated to a depth of 75 cm, and then cross subsoiling with a single, straight-tip tine, to a depth of 100 cm, was carried out with a D7 Caterpillar tractor. At the Shortlands site a single-shank subsoiler with wings attached, attained a depth of 80 cm in a single pass. Cross subsoiling with the same implement to the same depth was also tested. Considerable soil disturbance was visible, particularly the lifting effect of the cutter-bar.

Deep Ploughing a Williamson/Waldene Soil.



Deep Ploughing a Shortlands Soil

Medium subsoiling: This treatment was included at the Rydalvale, Shortlands and Milkwood sites only. Double shank subsoilers with shanks 180 cm apart and having wings attached, were drawn by a D7E caterpillar tractor, making one pass only, and penetrated to a depth of 55 cm and 60 cm in the Shortlands and Rydalvale soils respectively. At the Milkwood site a three-shank straight tip ripper was drawn by a D6 catterpillar tractor, making one pass only to a depth of 40 cm.

Control: The conventional methods of land preparation, such as disc ploughing or Rome harrowing to depths of 20—25 cm, were used at all sites.

3. Timing of treatments and planting

The deep tillage treatments were carried out in the spring or summer of 1967 and the experiments were planted in the autumn or spring of 1968. The period between treatment and planting for the five sites was: Rydalvale, 3 months; Shortlands, 6 months; Fernwood, 8 months; Williamson/Waldene, 3 months; and Milkwood, 1 month.

Prior to ridging out and planting, all treatments were disc-harrowed as required for an adequate seed-bed.

Variety NCo 376 was planted at all sites with the exception of the Fernwood and Shortlands sites where N50/211 and NCo 310 were used respectively.

Phosphorus and potassium fertilizers were applied according to the pre-treatment soil analyses, and nitrogen at a rate of approximately 120 kg N/ha.

All experiments were rainfed with the exception of that on the Milkwood site, which was irrigated during the second half of the first ratoon crop only.

4. Crop growth measurements.

Shoot counts and stalk heights were obtained at approximately six-weekly intervals in the plant crops but not in the first ratoons.

Layout and design

Plot size: because of the nature of the experiments, plots were unusually large, as were the areas allowed for end effects. Large tractor turning spaces between plots were also necessary. The gross plot size was generally six cane rows 36 m long, the net plot size being two rows 24 m long. Turning space between plots was approximately 22 m in length. Design: The mean number of replications per treatment was six, in either a repeated latin square or incomplete random block design.

Results

1. Yields

The yield responses to the various deep tillage treatments in the plant and first ratoon crops are presented in Table 1.

TABLE 1 Yield response in tc/ha to deep tillage treatments compared with normal land preparation

Treatments	Rydalvale		Shortlands		Fernwood		Williamson/ Waldene		Milkwood	
	Plant	R1	Plant	R1	Plant	R1	Plant	R1	Plant	R1
Medium Ploughing			+5	+3			—2	—6	+6	—3
Deep Ploughing			+8	+7	+16**	+17	+3	—3	+2	—11
Medium Subsoiling	+5	+7	+7	+15					—4	—8
Deep Subsoiling	+5	+5	—4	+3	+6	+12	+1	—4	+1	+3
Mean Yield	97	112	105	110	75	97	93	80	48	100
S.E. of difference	±2,5	±3,0	±4,9	±7,7	±4,1	±12,1	±4,7	±5,9	±4,8	±7,7
C.V.%	7,9	8,1	5,6	8,4	15,0	26,2	9,1	12,5	17,2	13,6
Age of crop Months	21	23	21	17	15	19	21	19	22	25
Total rainfall (mm)	1625	1834	1603	1523	1205	1809	1621	1598	1675	2073

Rydalvale

Deep and medium subsoiling both resulted in a small, though statistically non-significant, yield increase in both plant and first ratoon crops. The higher yield was due to a small increase in the number of harvested stalks (about 5 000/ha).

Shortlands

The yield response to double or cross subsoiling (75 cm depth) was similar to that from the single pass deep subsoiling (75 cm depth) treatment, hence the mean response for these two treatments is used in Table 1 in the "deep subsoiling" column.

There was no statistically significant response to treatment in the plant crop of this very precise experiment (C.V. 5,6%). However, the superiority of medium over deep sub-soiling (+ 11,0** ± 3,7 tc/ha) is surprising. The same trend is apparent in the first ratoon. This difference is inexplicable and should be interpreted with caution. In general, there is a trend for deep tillage to be of some benefit, but the mean responses do not approach a level of statistical significance: plant crop 3,2 ± 4,4; 1st ratoon crop 6 ± 6,8 tc/ha.

Fernwood

The statistically significant response to deep ploughing in the plant crop was predictable at an early stage because of the higher stalk populations and rates of stalk elongation. The characteristically uneven growth which so often develops on recent sands in sucessive crops, probably caused the coefficient of variation of this experiment to increase from 15% in the plant crop to 26% in the first ratoon crop.

The response of 17 ± 12,1 tc/ha to deep ploughing in the ratoon crop did not attain a level of statistical significance.

A response to deep ploughing on the recent sands was unexpected because the likelihood of compacted or impervious strata occurring in these soils is remote. It is therefore of particular interest, and can be explained to some extent. Six sub-plot treatments were superimposed on the three tillage or "whole-plot" treatments. These comprised: (a) control (b) bagasse disc-harrowed into the soil at a rate of 52 t/ha, (c) filtercake at 95 t/ha broadcast and disc harrowed into the soil (d) ferrous sulphate applied at a rate of 6 kg/ha as a foliar spray (e) poultry litter at a rate of 10 t/ha in the furrow and (f) EDB (4,5) at a rate of 75 kg a.i./ha injected into the soil well before planting.

The response to deep tillage treatments appeared to be associated with the sub-plot treatments. The yield data for the plant crop are shown in Table II.

TABLE II Responses in tc/ha to deep tillage compared with conventional land preparation on a Fernwood sand.

Sub-plot Treatments	Whole plot treatments	
	Deep subsoiling	Deep ploughing
Control	3	12
Bagasse	7	10
Filter cake	7	14
Ferrous sulphate	4	36
Chicken litter	11	15
EDB	—2	2
Mean	6 ± 3,8	16 ± 3,8

The response to deep tillage was negligible in the presence of EDB, which itself caused a highly significant response in both the plant and first ratoon crops. In contrast, the response to ploughing in the absence of EDB was quite marked. It seems likely, therefore, that one of the main reasons for the response to deep ploughing was that nematodes were affected by the soil inversion and disturbance. A similar, and statistically significant interaction was measured in the first ratoon.

Williamson/Waldene

Despite the penetration of both ploughs and subsoilers through the relatively thick layer of iron concretions, and the considerable mixing of the profile which was particularly obvious in this Dwyka soil, there was no response in terms of crop growth characteristics or yield in either crop.

Milkwood

The layered Lower Ecca shale was severely disturbed by both ploughs and subsoilers. The shale brought to the surface necessitated two Rome harrowings and one light disc harrowing before a reasonable seed-bed was obtained. Germination of the setts in the deep-ploughed plots was relatively poor, and the cane in these plots appeared more drought-stricken 2—3 months after planting, then it did in plots of the other treatments. However, moisture stress was relatively severe in all treatments in the two summers of the plant crop, despite a reasonable total rainfall which was recorded for the full crop period. Yields from all plots were extremely poor and the coefficient of variation for the experiment was high, particularly in the droughted plant crop. The characteristically high variability in topsoil depth of the Milkwood series also contributed to the high C.V.%. The introduction of overhead irrigation and the cutting of trace lines half-way through the first ratoon crop, resulted in some plots being damaged and the harvest data from these were therefore omitted from the analysis.

There was no statistically significant response to any deep tillage treatment in either crop.

2. *Soil chemical analysis*

Soil sampling, some months after the tillage treatments had been carried out, revealed that only phosphorus and, to a lesser extent, potassium were affected on some sites only. The soil analyses for P and K for three sites only are presented in Table III.

TABLE III Amounts of available P and K in the soil after tillage treatments

	Soil	Control	Deep plough	Medium plough	Sub-soiling
P p.p.m.	Williamson/ Waldene	14	8	9	10
	Fernwood	219	74	—	114
	Saccharine	133	75	39	53
K p.p.m.	Williamson/ Waldene	92	51	51	70
	Fernwood	58	58	—	59
	Saccharine	182	171	154	130

3. *Soil physical analyses*

Undisturbed core sampling was carried out at the Shortlands and Milkwood sites after treatments, in an attempt to determine whether any soil physical characteristics had been altered. However, the sampling intensity was inadequate to permit any changes to be assessed with any degree of accuracy.

Discussion

The lack of a reasonably large response to deep tillage in the plant and first ratoon crops indicates either that the physical changes, which must have occurred in the soil, were short-lived, or that the changes were not beneficial to cane growth. It is pertinent to record here that at all sites the previous crops had been trashed rather than burnt, and therefore that the likelihood of soil compaction was small. The average cropping cycle in the industry is approximately eight years, so ploughing is infrequent, and the development of plough pans, such as occur where annual cropping is practised, is extremely unlikely.

The results reported here agree closely with those obtained by the Tongaat Group agronomists[11], who conducted deep tillage experiments on Clansthal, Fernwood, Waldene, Windermere, Cartref and Milkwood soils. The coefficients of variation were high, as seems common with this type of experiment, but once again it was only on a recent sand that a real response was obtained to deep ploughing. There are conditions under which deep ploughing may be of value, and they might be listed as follows:

(i) in highly leached acid soils where it is desirable to incorporate agricultural lime to depths of 60 cm or more.
This practice is currently being tested in the midlands mistbelt of Natal, and the growth response to deep placement of dolomitic lime is encouraging in a young, six-month old crop.

(ii) for the deep placement of ameliorants in saline-sodic soils, where, because of very slow permeability of the deflocculated soil, ameliorants might take many years to leach through the profile.

(iii) where weak sands overlie clay loams, and it is desirable to invert and mix the profiles.

The cost of deep tillage is obviously an extremely important factor. Based on owning-operating costs (Thos. Barlow[10]), and estimated operating speeds from various sources (Anon[1], Hill[6]), comparative costs might be as follows:

Deep ploughing	R79 per hectare
Medium ploughing	R36 per hectare
Deep subsoiling	R21 per hectare
Medium subsoiling	R15 per hectare
Conventional ploughing	R6 per hectare

The terms "deep" and "medium" in this context, refer to the depths penetrated by the equipment described in this text. When it is realised that deep or medium ploughing in some soils would also necessitate extra field operations to obtain an adequate seed-bed tilth, the extra costs of deep ploughing, based on the data presented, are not warranted.

Conclusions

Where specific soil factors that limit growth can be identified, deep tillage may be beneficial, but as a standard field practice for sugarcane land preparation, the extra costs incurred are not justified.

The conventional plough depth of 20—25 cm is apparently adequate under most conditions. A useful guide might be to plough or subsoil to a depth approximately 10 cm deeper than the depth of the proposed planting furrow.

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