SOIL STERILIZATION AND THE GROWTH OF TOPS AND ROOTS AT THE MOUNT EDGECOMBE ROOT LABORATORY

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Summary

Declining yields of successive ratoon crops on a Recent Red Sand soil (Clansthal series) were observed and measured at the Mount Edgecombe Root Laboratory.

Sterilization of this soil gave very markedly improved growth of tops and roots. The improved growth of tops apparently resulted from improved root growth.

Root growth in the sterilized soil was rapid, deep and extensive. In the untreated soil it was slow, and was restricted mainly to the superficial layers (0-30 cm) where the roots could be affected by short spells of drought.

Introduction

The well-known decline in yields of successive ratoon crops of sugarcane on our sandy soils has been observed at the Root Laboratory, where on a Recent Red Sand soil (Clansthal series) the yields of varieties N:Co. 376 and N50/211 have declined from very-high in the plant crop to barely-economical in the first ratoon crop and to sub-economic levels in the second ratoon crop.

The symptoms accompanying the decline were of progressively slower growth and increasing susceptibility to drought. Thus in the plant crop on the sand there was no sign of moisture stress even when drought periods were sufficiently severe to cause wilt on similar plants in a heavy clay soil (Shortlands series, Dolerite). In the first ratoon crop, the plants became susceptible to short drought periods after a few months of growth, although there was adequate moisture at all times from about 30 cm below the surface downwards. The second ratoon crop was even more susceptible to short dry spells than the first ratoon, though water was available closer to the surface. Indeed the wilt in the second ratoon was so severe that frequent supplementary irrigation had to be given in order to get sufficient plant material for the investigation of possible causes of failure.

As the growth of the tops differed, so did the growth of the roots. The roots of the ratoon crops grew more slowly, penetrated less deeply and had a different habit of branching. This is illustrated in Figure 1, which shows the deep, widespread and rapid proliferation of the main roots and their long branches in the plant crop, and the successively more shallow, less widespread and stubby branching of roots in succeeding ratoons.

The slower growth of the main roots in the first ratoon crop was at first ascribed to cold, since the plant crop had been cut at the end of July. Thus they grew at an average rate of less than 2 cm a day compared with some 5 cm a day in the plant crop. It was very noticeable, however, that such roots did not increase their rate of growth as they penetrated warmer, deeper layers, nor did new roots from later tillers grow any faster in the surface soils, which by then were warmer.

Growth of roots of the second ratoon crop was slower still, and the roots were more stubby and twisted than those of the first ratoon crop.

When symptoms of crop failure first appeared the following possible causes were investigated by the Plant Pathology, Microbiology, Entomology, Nematology and Plant Physiology sections of the Experiment Station: ratoon stunting disease (R.S.D.), nutrient deficiencies, root-damaging insects and nematodes, and pathogenic fungi.

There were no visible signs of R.S.D. in the cane stalks, nor, if it were present but symptomless, could it be transmitted to other more sensitive varieties.

Leaf and soil analyses showed that all essential elements were present in more than adequate amounts, except nitrogen, which was marginal by our standards.

There were a few root-damaging insects in the sand but not in greater amount than in other soils carrying healthy crops.

The nematode counts on soil samples at different times of year showed that there was little difference between the populations of various species in the sand and heavy clay soils.

Finally, visual inspection of roots, stalks and leaves, and the culturing of leaf and root samples in the laboratory showed no pathogenic fungi of sufficient importance to produce the symptoms.

In other words, none of these factors appeared to be the cause of failure, either singly or in combination. However, there was a possibility that the very heavy plant crop had removed more nitrogen and/or sulphur from the soil than had been replaced by subsequent fertilization. However, this was unlikely because the first ratoon crop had the equivalent of 130 kg/ha each of nitrogen and potassium, and soil analyses showed that no additional phosphorus applications were needed.

This attempt to produce healthy growth of the second ratoon failed. The failure was puzzling because further repeated checks for the presence of parasites or pathogens also failed, until by accident, while sampling roots near the base of a particularly unhealthy plant, a number of shallow roots were unearthed, each bearing well-developed root knots

similar to those caused by parasitic nematodes. Further sampling showed that root knots were not common and the few that could be found were formed only on the very superficial roots. Hence the failure to see them through the windows of the laboratory, which permit viewing only from some 25-30 cm below the surface downwards.

Tomato seedlings were then grown in the inter-rows as a catch crop for some of the nematodes. There was enough light for this purpose because the cane plants were sickly and the leaves did not meet across the inter-row. The tomato seedlings grew only about 75 mm high and no further. Their roots were very knotted and contained nematodes (Meloidogyne).

Soil sterilization to a depth of 45 cm with E.D.B. (Ethylene dibromide) was then applied beneath the partly grown crop. It was unsuccessful, probably because it was too late: the major flush of root development being past. Nevertheless it seemed possible that sterilization before root growth started might yield interesting results, particularly as field trials on the same soil series were showing that soil fumigation could improve crop growth.

Experiment

Because the existing stools of the second ratoon were of such poor quality that it was doubtful if new tillers would be produced in sufficient numbers to produce even distribution along the rows, it was decided to replant the whole Red Sand plot with freshly heat-treated setts of both varieties.

Three soil treatments were possible within the restricted limits of the plot.

The first treatment involved the removal and complete flash sterilization of a block of sand some 3 m long by 1.4 m wide by 2 m deep with methyl bromide. A further 20 to 30 cm depth of soil below the resulting pit was sterilized with the more persistent ethylene dibromide (E.D.B.). The sterilized sand was then replaced and repacked layer by layer as it was originally. During the removal of the sand there was some slumping of the sidewalls and the slumped sand was also sterilized before replacement. As a result, instead of having a neatly edged block of soil as shown by the dotted lines in the sectional diagram, Fig. 2, the true shape of the sterilized zone was as shown by the continuous lines. Thin overlapping flexible plastic sheets were placed in the position shown by the dotted lines to impede sideways movement of nematodes. These could only reduce the rate of such travel if it occurred, not block it completely. Indeed, shortly after replanting, termites could be seen through the windows reinvading the sterilized block where the fit between plastic sheet and window was poor.

The second treatment involved the excavation, exposure and replacement of a similar block of sand, but it was not sterilized. This provided a control which would display the result of disturbance if such existed.

The third treatment was the incorporation of additional organic matter in the surface soil. Well-rotted filter cake containing 2.52% N, 1.22% P and 0.21% K on a dry-matter basis and with a moisture content of 76% was applied at the rate of 125 tonnes/ha and intimately mixed with the sand to a depth of 60 cm.

The remaining five rows of undisturbed and untreated sand were the controls.

Before planting, all the rows received a heavy application of suitable fertilizer. Thus the row treated with additional organic matter received the same amount of fertilizer as those which were not so treated.

The setts were planted on the 19th August, 1969, in moist soil. Good, well-distributed rain fell shortly afterwards and the whole profile to a depth of at least 2 m was quickly restored to field capacity. There was no shortage of water in the surface layers of the soil during the first four months of growth. Air and soil temperatures were slightly below average in September, but since then they have been about average for the time of year.

Results

In all rows the first shoots appeared above ground at the same time, but within a few weeks marked differences began to appear. Growth was slow and tillering was poor in the untreated rows, in the row treated with additional organic matter and in the row which had been disturbed to a depth of 2 m but was not sterilized. Most of the leaves of the plants were light green in colour but some were yellowish green. A few young tillers died.

By contrast the plants in the sterilized row grew vigorously and tillered well: see Figs. 3 and 4 which illustrate the comparative shoot counts and stalk growth above a 15 cm/ peg as measured to the first visible dewlap. Their leaves were dark green in colour. Plants in the two rows alongside the sterilized row, which had access to some sterilized soil—see Fig. 5—grew much better than the controls but not as well as those on the sterilized block. They, too, had markedly greener leaves than the controls.

There was no doubt that the effect of soil sterilization was beginning to show in the tops of the plants at an early age.

Below ground the effects were even more dramatic. The roots of the plant in the sterilized row grew very rapidly downwards and branched well. For example, even in the relatively cold soil (about 20° C) some shoots were extending at rates up to some 75 mm/day as in the plant crop on warmer soils (about 25° C). Further, the very active shoot roots carried long secondary branches which were growing at rates up to 15 or 20 mm a day. The main roots reached the bottom of the windows, 138 cm below the surface, some eight weeks after planting in the cool August weather. This compared favourably with the rate of root extension in the same soil by the January-planted crop of the same variety (N:Co. 376) which took only one week less to attain the same depth.

By contrast, root growth was extremely poor in the unsterilized sand, whether it had been treated with

TABLE I
Average numbers of tillers and lengths of stalks per stool in the Red Sand plot 6 months after planting. All grown under natural rainfall.

Variety	Soil treatment	No. Stalks	Total length all stalks > 15 cm	Length of each stalk	Length of each of 3 tallest stalks
N:Co.376	Sterilized, disturbed	13.7	887 cm	65 cm	95 cm
	Past sterile, part disturbed	9.7	373 cm	39 cm	60 cm
	Unsterile, disturbed	8.3	161 cm	19 cm	31 cm
N.50/211	Unsterile + filter cake	13.7	245 cm	22 cm	36 cm
	Unsterile, control	3.3	75	18	34

filter cake or not. Nor did the aeration due to deep disturbance have any effect.

Some three months after replanting a few stubby, twisted roots became visible some 30 cm below the surface of the unsterilized soil. This was at a time when the roots in the sterilized soil were proliferating vigorously at depths more than four times deeper than this!

The roots of the plants in the rows alongside the sterilized block, which had access to sterilized soil on one side, developed mainly in that part of the soil which was sterilized. On average they did not grow as well or as quickly as those in completely sterilized soil.

Fig. 5 illustrates these aspects of top and root behaviour as seen through the windows 23 weeks after planting. It gives a better impression of the growth of the tops at this time than the data contained in Figs. 3 and 4.

Table I contains the comparative measurements of the average growth of the tops of three stools in each 3 m row, six months after replanting in the Red Sand. The results are expressed on a single stool basis.

This table shows how markedly the soil sterilization has increased tiller production, stalk height and total lengths of stalk in each stool of N:Co.376. It also shows the partial gains resulting from the acoidental partial sterilization.

Further it shows that, as far as variety No.50/211 is concerned, the beneficial effect of the filter cake in this soil is almost entirely due to the increase in the number of tillers carried at this stage of growth, not to any increase in stalk height; for the plants receiving the filter cake are no taller than those on the unsterilized soil. This equivalence of plant heights on the treated and untreated soil was mantained at all stages of growth up to this time.

The beneficial effect of sterilization would be of little value if the gains were small relative to normal growth, Table II, therefore, shows how the growth of the replant crop of N.Co. 376 compares with the growth of the third ratoon crops of the same variety in neighbouring plots on other soils where growth appears to be normal. The ratoon crops are, of course, about one month older than the replant crop because of the time taken to prepare the soil for the replanting.

It is obvious from this table that the crop on the sterilized soil has almost caught up in height and total length of stalk per stool with the best of the neighbouring plots (on the disturbed Dolerite) and is apparently better at this time than all the others.

The experiment is not yet complete, being due for harvest at the end of July 1970. Nevertheless, since the differences in growth of tops and roots resulting from sterilization are so large, and since most of the tiller and root formation is nearly over for this year, there is unlikely to be any major change in the behaviour of the plants before harvest.

Acknowledgements

I am indebted to many of my colleagues at the Experiment Station for patient, repetitive examinations of soil and plant in the search for possible causes of yield decline; in particular to Messrs. G. M. Thomson, K. E. F. Alexander, W. B. May and A. A. Hansen as well as Drs. J. Dick and G. Roth.

TABLE II
N:Co.376 Average numbers of tillers and lengths of Stalks per Stool in different soils.

Age months	Plant or Ratoon	Soil	Treatment	Water Regime	No. of stalks	Total length all stalks > 15 cm	Length of each stalk > 15 cm	Length of each of 3 tallest Stalks > 15 cm
6	Plant	Red Sand	Disturbed Sterilized	Rain	13.7	887 cm	65 cm	95 cm
7	3rd ratoon	T.M.S.	Disturbed	Rain	9.3	519 cm	56 cm	81 cm
		Dolerite	Disturbed	Rain	11.7	833 cm	71 cm	100 cm
			Undisturbed	Rain	7.0	389 cm	51 cm	83 cm
			Undisturbed	Irrigation	9.6	549 cm	56 cm	89 cm

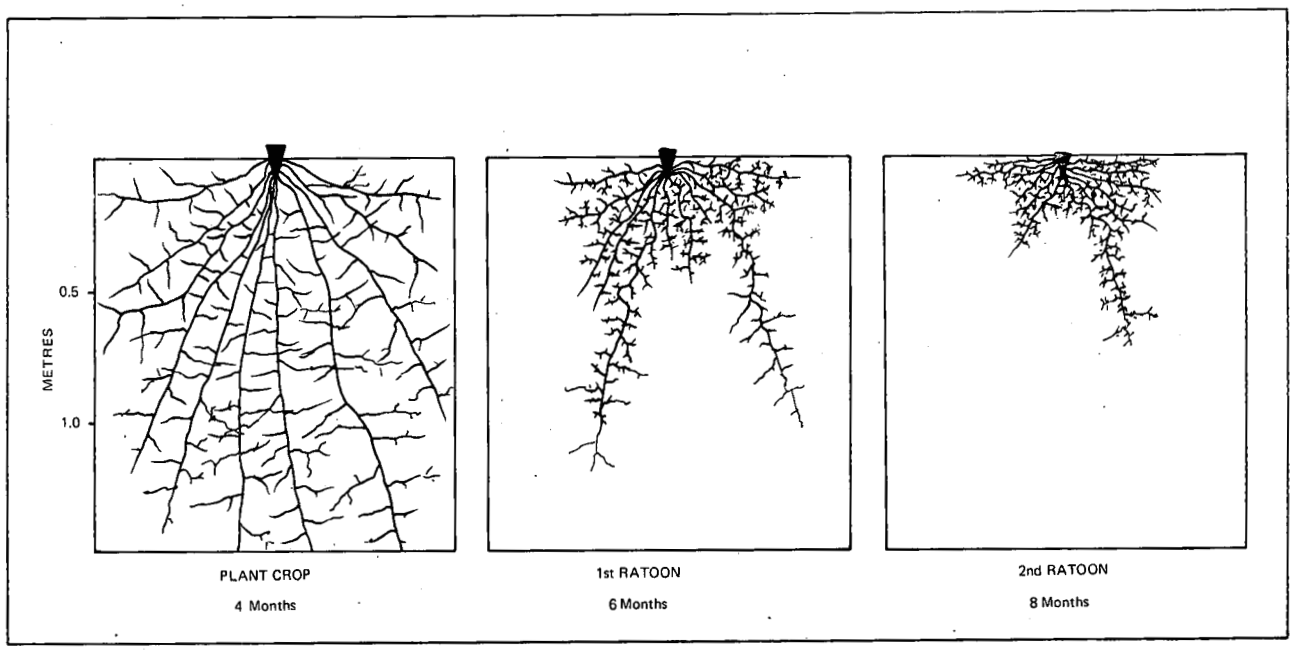


FIGURE 1: Root patterns in successive crops on Red Sand showing that the declining yield of tops is reflected in the declining extension of the root-systems.

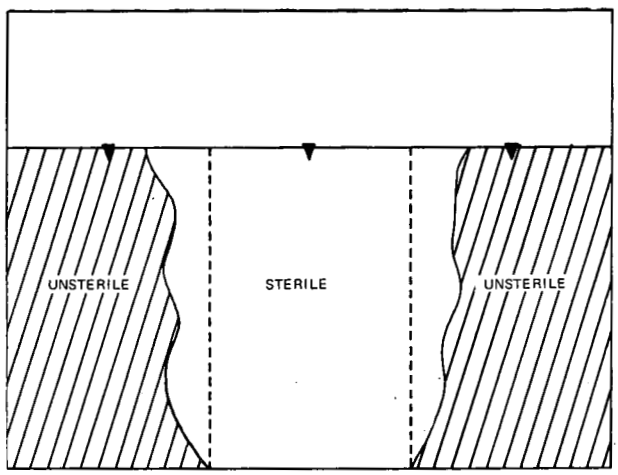


FIGURE 2: Cross-section of soil beneath the rows showing the intended, within the dashed lines, and the actual, within the continuous lines, boundaries of the sterilized block. The rows and plant spacing are shown by ▼.

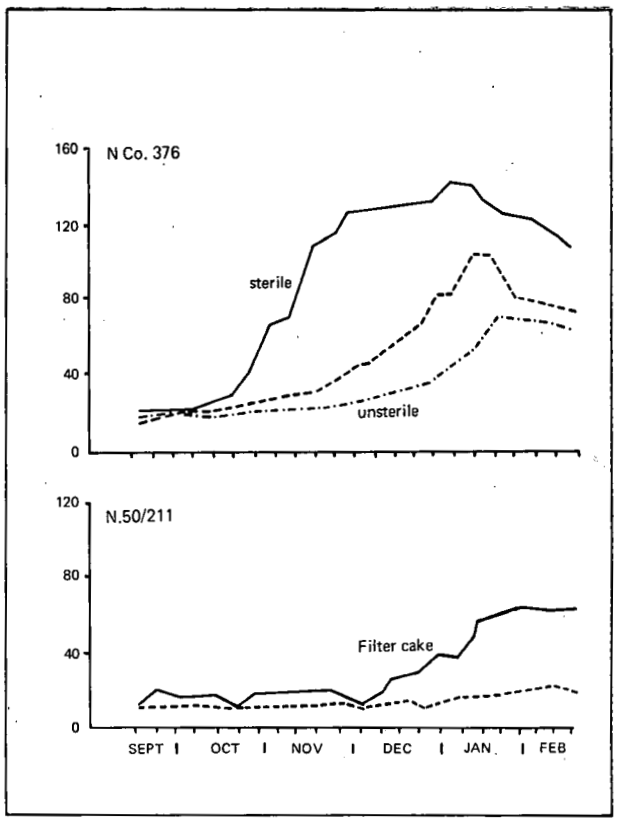


FIGURE 3: Weekly shoot counts per 3 m length of rows, > 15 cm in an average stool.

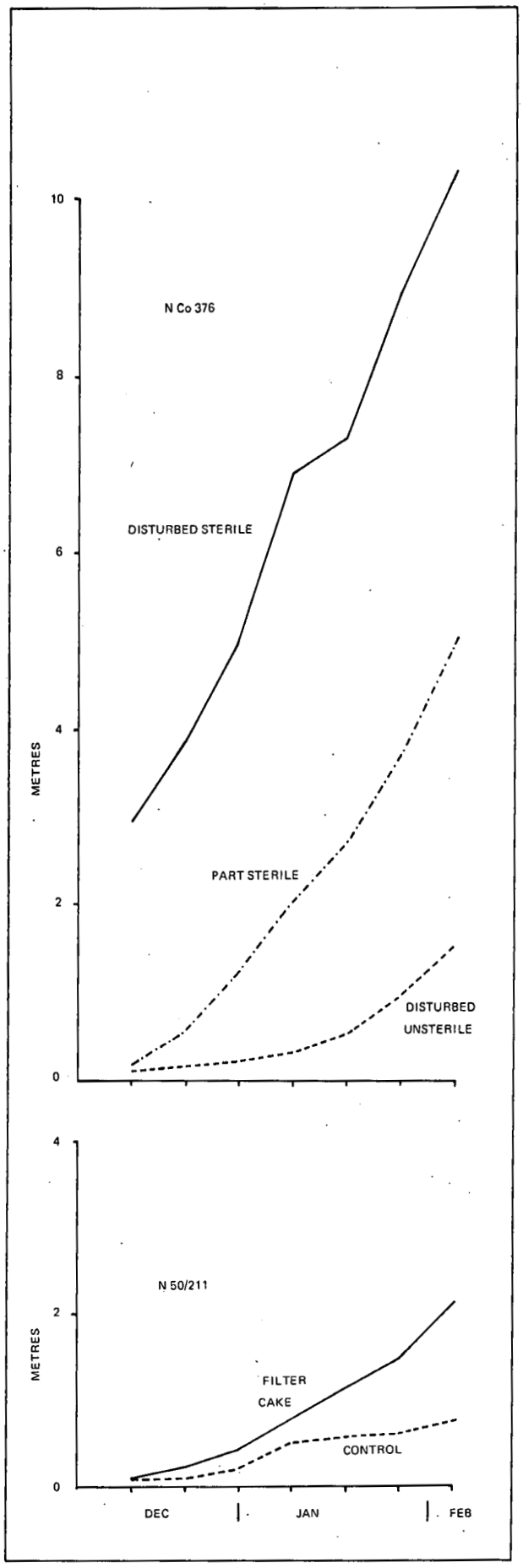
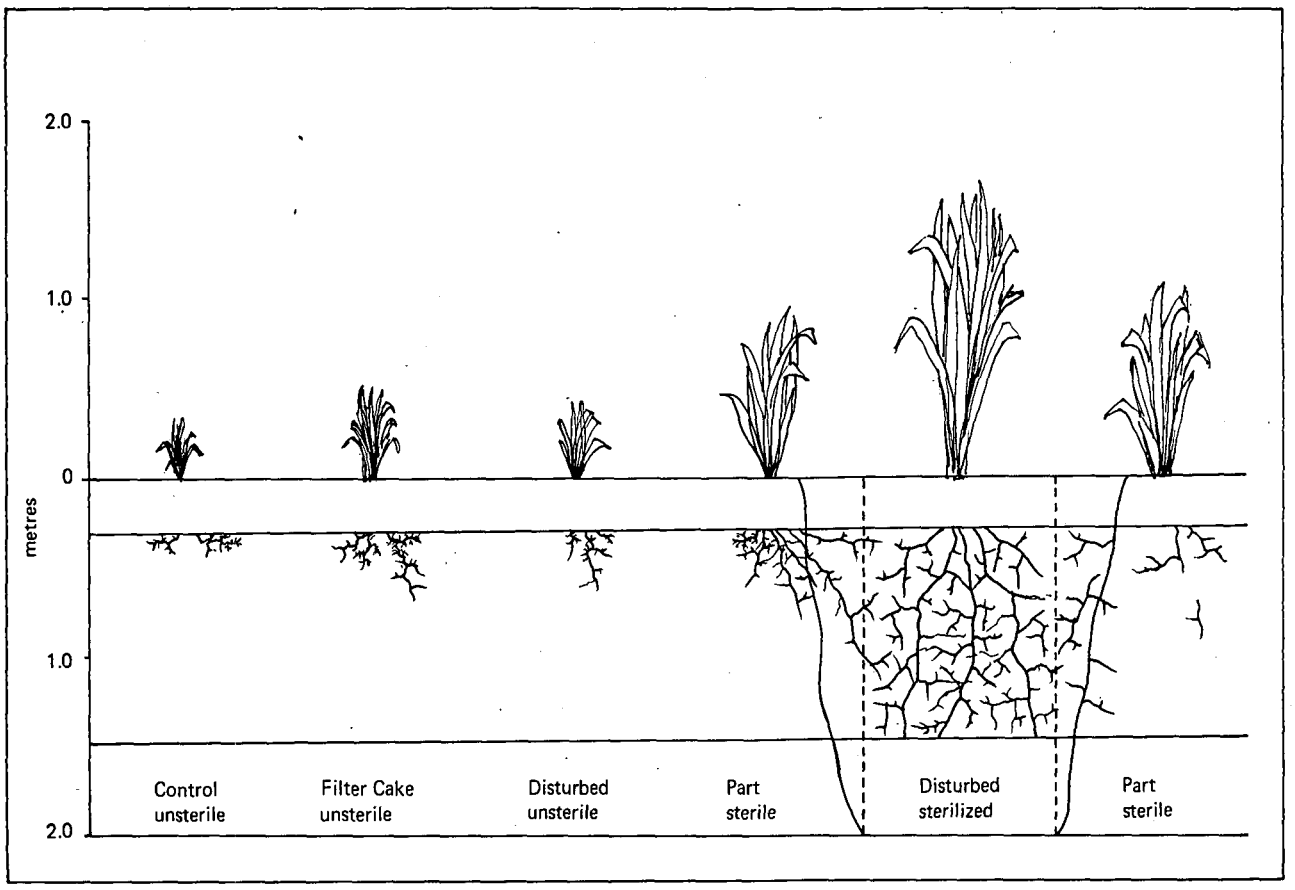


FIGURE 4: Weekly growth in total length of all stalks.

FIGURE 5: Top and root development 23 weeks after planting.



Discussion

Dr. Dick: Many of Mr. Glover's results confirm the findings we have made in the field.

I have always thought that nematode damage only occurred during early cane growth.

This is partly supported by the fact that you get a continued response to sterilization after the actual effect on nematodes has disappeared.

Nematode figures have sometimes increased in our treated plots more than in untreated plots and yet the response has been higher in the sterilized plots.

We were therefore not sure whether or not the response in the field was due to nematode control as there are other factors, such as flash release of nitrogen, that can cause an increase after sterilization.

Also, for some time we have been trying to predict the results to be achieved by sterilization by doing counts of nematodes in soil samples. But you cannot predict from the number of nematodes whether you will get a response or not.

We have, in field trials, had a considerable response to filter cake applied at forty tons per acre in the furrow. We have related this to the fact that we have found in increase in the predator type of nematodes and a decrease in the number of harmful ones.

Mr. Glover: A concentrated application of filter cake in the furrow can have a quite different effect to filter cake incorporated into the top two feet of soil, which would be a very thin application.

Dr. Dick: Our filter cake was concentrated where the roots were developing.

Mr. du Toit: I am not completely sure we have solved the problem, for two reasons.

Mr. Glover claims that extra growth was obtained in the plant cane, but that the first ratoon was poor and the second worse and he says this is usual in sandy soils.

But after replanting, where there has been no sterilization, results are very poor.

Why the good results at first? Were nematodes not present or, if present, were they ineffective?

Mr. Glover also says that the indications are that apparently it is only necessary to sterilize the top soil.

Rather than sterilize the top area of the soil, I suggest we sterilize in the furrow only and this would be much cheaper.

It is unfortunate that the counting system used for nematodes has been so far unsuccessful in determining what damage might be expected.

Dr. James: Were *Meloidogyne Pratylenchus* present in the top soil?

We are finding heavy damage in Rhodesia from this source in the sandy soils.

Regarding populations building up after fumigation, this is well known on crops such as potatoes and tomatoes.

It means if you inject once at the beginning of the season, at the end of the year the populations do increase and if you do not again fumigate, your nematode problem is worse than before.

Mr. Andries: Dr. Dick's and Mr. Glover's findings are rather frightening when one thinks of having to

institute control measures on a field scale.

What large scale measures should be taken for this problem?

Mr. Gilfillan: We started a trial in 1965 using DBCP and we have had a residual response over four crops, with a total increased yield of 40 tons of cane because of having treated at four tons of product per acre, plant crop only.

I assumed that nematodes were present in the top twelve inches because of the residual response we did get.

However, when we tried this on a commercial scale it did not work.

With fumigant type nematocides we have been unable to get predictable responses on a field scale.

Some previous findings from the root laboratory indicated that a ratoon crop existed for some time on its previous root system, which would explain the tremendous build up in eelworm numbers.

Mr. Moberly: Was Mr. Gilfillan's fumigation applied by pumping or was it dribbled in under gravity?

Mr. Gilfillan: Different methods were used.

The biggest trial was with D.B.C.P. which ran down tubes to nine inches and was then immediately covered.

Trials were under different moisture conditions and at different times of the year.

Dr. Hill: Applying the same product at Tongaat using hand injector guns, on a small field scale, we obtained a remarkable difference between controlled lines of cane and where we had injected.

This possibly indicates that our method of application was inefficient.

Mr. Bartlett (in the chair): Apparently more work should be carried out on the practical aspects of fumigating.