THE EFFECTS OF FILTER CAKE ON SOIL FERTILITY AND YIELD OF SUGARCANE

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Abstract

Filter cake trials with sugarcane in pot and field experiments have shown large yield responses to treatment with filter cake.

The first invaders of filter cake were found to be yeasts and bacteria (non-spore formers) which use the free sugars still available in the filter cake. The second invaders were several fungi which were able to attack the available fibrous matter in the filter cake. In a later stage of decomposition an invasion of spore forming bacilli and actinomycetes was found. These micro-organisms were shown to have a positive influence on soil aggregate stability. It may be of considerable practical significance that some micro-organisms which thrive in filter cake are antagonistic to *Pythium arrhenomanes,* the cause of a root disease in sugarcane.

Introduction

In certain parts of the cane belt isolated patches of land on T.M.S. soils of the Inanda series, support very poor crops of sugarcane. These areas are usually clearly demarcated, being surrounded by areas of tall, well-grown cane. There is no obvious reason for this phenomenon. The various causes which have been suggested include aluminium toxicity, deficiencies of silicon or zinc, and an imperfect balance of microbes in the rhizosphere.

Filter cake has been used in some trials as a replacement for superphosphate. Stimulating and depressing effects on the growth of sugarcane were found when the filter cake treatments were applied. The importance of filter cake applications is therefore still questionable. If the beneficial effect of filter cake is due only to its phosphorous content. then preference might be given to cheaper forms of P which can be applied more easily.

To throw further light on this problem, studies were made of the biological factors affecting soil fertility. To obtain more information, experiments were conducted in the greenhouse and in the field. The influence of filter cake on microbial activity, root pathogens and water-stable soil aggregate formation were studied.

Materials and methods

Two soils from Darnall were used for the pot experiments. One came from an area where the cane grew poorly and the other from an adjacent site where the cane grew relatively well. Both were light sandy soils, with clay contents varying from 5,8 to 7,8%

The field experiment was laid down at Doornkop in a problem field of the Doornkop Sugar Co. Ltd.

The various experiments were made up as follows:

Pot Experiment A

1. Good soil, untreated
2. Poor soil, untreated
3. Good soil plus fresh filter cake
4. Poor soil plus fresh filter cake
5. Good soil plus 1-year-old filter cake
6. Poor soil plus 1-year-old filter cake

Medium: Soil and filter cake mixed in equal quantities on a volume basis.

Pot Experiment B

1. Good soil, untreated
2. Poor soil, untreated
3. Good soil, sterilized
4. Poor soil, sterilized
5. Untreated good soil plus sterilized filter cake
6. Untreated poor soil plus sterilized filter cake
7. Sterilized good soil plus sterilized filter cake
8. Sterilized poor soil plus sterilized filter cake
9. Untreated good soil plus untreated filter cake
10. Untreated poor soil plus untreated filter cake
11. Sterilized good soil plus untreated filter cake
12. Sterilized poor soil plus untreated filter cake

Medium: One part of a filter cake was mixed with two parts of soil on a volume basis.

Procedures: The materials were steam sterilized. Sugarcane was planted in drums of 18-litre capacity. Both experiments were made up of three replications of a randomised block design.

Field Experiment

1. Control, no filter cake
2. Fresh filter cake at 67 tons/ha in the furrow
3. Fresh filter cake at 135 tons/ha in the furrow
4. Fresh filter cake at 90 tons/ha broadcast
5. Fresh filter cake at 180 tons/ha broadcast
6. Old filter cake at 67 tons/ha in the furrow
7. Old filter cake at 135 tons/ha in the furrow
8. Old filter cake at 90 tons/ha broadcast
9. Old filter cake at 180 tons/ha broadcast

A random block design was used with five replications for harvesting and an additional one for sampling. Plots consisted of five rows 9,14 m long. The following fertilizers were applied to all plots in the furrow.

Urea	336 kg/ha
Super and Raw	895 kg/ha
Muriate of Potash	336 kg/ha

In addition, 550 kg of agricultural lime was broadcast per hectare five months before planting and ploughed in.

Soil aggregation

The stability of soil aggregates was studied by means of a technique which was similar to those described by McCalla[1], Gracanin[2] and Low[3]. Artificial soil aggregates were prepared from air dried soil samples from the different treatments. These were ground in a mortar and sieved through a 1 mm sieve. The soil was then mixed with distilled water to form a paste, and placed on a perspex plate into which 40 similar holes had been drilled (see Plate 1, Figures 4, 6 and 8). The perspex plate was placed on a filter paper disc which lay on a smooth hard surface. Forty similar cylindrical cores each 3 mm × 6 mm were then established by filling the holes with soil paste and clearing the surface with a spatula to ensure equal quantities of soil in all holes. The surface of the plate was cleaned with sterilized cotton wool before inverting the plate on to filter paper. Excess soil solution was forced out of the soil into the filter paper by means of a close fitting rod which was pressed into each hole with the same pressure. The filter paper was then plated on agar media. The perspex plate containing the soil cores was placed in a petri dish between sterile filter paper discs and incubated at 30°C for five days or longer at 95 to 100% r.h. Following the incubation period the cores were pressed out of the holes on to filter paper and the aggregates tested for stability following the method described by Griffiths and Jones[4] and Low[3]. The cores were placed on a stainless steel wire sieve of approximately 500μ mesh, and drops of water were applied to the aggregates by means of a burette, the cock being adjusted to give a steady stream of 60 drops per minute. The height of the burette was set so that each drop of water fell 20 cm to strike an aggregate held on the sieve above a beaker. The number of water drops required to disintegrate each core was recorded.

The microbiological colonisation of the soil from the various treatments was investigated by plate methods and microscopic observations. Chemical analyses of the soils were also carried out.

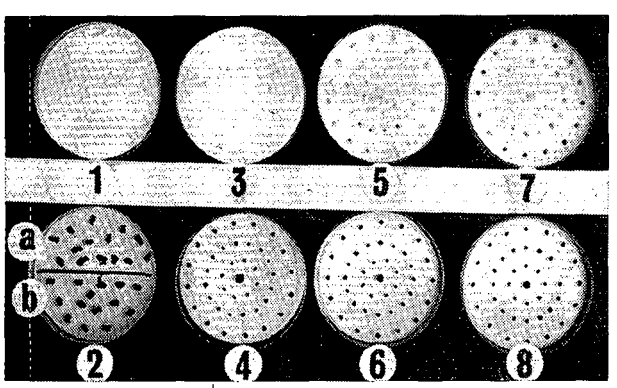

PLATE 1: 1. Sterile filter paper covering cell units; 2a. Artificial aggregates of sandy soil; 2b. Artificial aggregates of sandy soil + filter cake; 3. Filter paper disc covering (4) after one week's incubation; 4. Cell units of sandy soil after one week's incubation; 5. Filter paper disc covering (6) after one week's incubation; 6. Cell units of sandy soil + filter cake after one week's incubation; 7. Filter paper disc covering (8) after one week's incubation; 8. Cell units of sandy soil + filter cake after one week's incubation. Note marked development of fungi on 5 and 7 compared with 3.

Results

Influence of filter cake on sugarcane yield

The results of pot experiment A in terms of dry weight of plant cane are given in Table I. These data indicate that there were large responses to all filter cake treatments but there was no significant evidence of any differences between good and poor soils, or between sterilized and non-sterilized filter cake. Table II shows the results of pot experiment B where the fresh weights of the different treatments, as well as length, diameter and number of stalks and tillers are compared with those of the control treatments. Again it is obvious that filter cake had a marked effect on yield, due mainly to the greater number of stalks and tillers. However, there was again no significant evidence of any difference between the good and the poor soil.

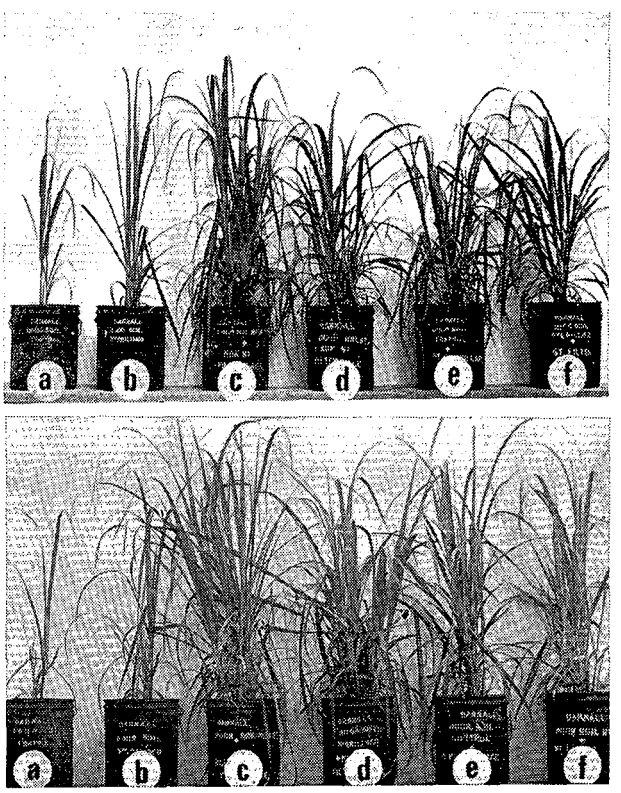

PLATE 2: Examples from Pot experiment B, five months after planting: 1a. Good soil, untreated; 1b. Good soil, sterilized; 1c. Good soil, untreated, + untreated filter cake; 1d. Good soil, sterilized, + untreated filter cake; 1e. Good soil, untreated, + sterilized filter cake; 1f. Good soil, sterilized, + sterilized filter cake; 2a. Poor soil, untreated; 2b. Poor soil, sterilized; 2c. Poor soil, untreated, + untreated filter cake; 2d. Poor soil, sterilized, + untreated filter cake; 2e. Poor soil, untreated, + sterilized filter cake; 2f. Poor soil, sterilized, + sterilized filter cake.

There was no significant evidence of any difference between sterilized and unsterilized soils in either pot experiment. However, from the data given it can be seen that there was a strong tendency for soil sterilization to have a beneficial effect on yield in the absence of filter cake. This is also demonstrated in Plate 2, Figures 1 and 2. From these illustrations, it is also apparent that there was very little difference in the growth of cane on the good and poor untreated soils.

TABLE I

Results of pot experiment A expressed as grams of dry weight of plant cane.

Treatment	Soil		
	Good	Poor	Mean
Control	43,1	53,1	48,1
Sterilized	124,2	79,9	102,0
Mean	83,7	66,5	75,1
+ fresh filter cake			
Control	216,6	220,7	218,6
Sterilized	222,3	182,8	202,5
Mean	219,4	201,7	210,6
+ 1-year old filter cake			
Control	214,2	251,5	232,8
Sterilized	214,4	241,1	222,7
Mean	214,3	246,3	230,3

TABLE II

Results of pot experiment B

Treatment	Means fresh weight g	Means stalk length cm	Mean stalk diameter mm	Number of Stalks	Number of Tillers
1	229	59	15,0	2	1
2	263	60	14,5	2	1
3	717	72	16,8	4	3
4	422	53	13,9	4	1
5	1 296	66	16,0	7	3
6	1 376	75	16,6	6	4
7	1 536	71	16,2	7	7
8	1 134	64	15,9	6	3
9	1 335	70	14,9	7	3
10	1 535	66	16,1	9	3
11	1 402	62	16,9	7	7
12	1 567	69	16,4	9	3
Means	1 068	66	15,8	6	3

In the two pot experiments it was noted that filter cake had a stimulating effect not only on the germination of sugarcane, but also on weed germination. Whilst in untreated soils scarcely any weeds developed (see Plate 3 Figures 1a and 1b), there was a highly stimulating effect of filter cake on weed germination in the treated good soil. However, weeds did not develop freely on the treated poor soil (see Plate 3, Figures 2a and 2b). The first ratoon results in the pot experiments, harvested after 15 months, were very similar to those in plant cane. This is shown in Table III where it can be seen that no treatment effects were significant except the residual effects of filter cake. An illustration of treated differences in the ratoon crop is shown in Plate 3, Figures 3 and 4.

TABLE III

First ratoon results of pot experiment A expressed in grams green weight of whole plants.

Soil	Good	Poor	Mean
Control	765	917	841
Sterilized	835	838	837
Mean	800	878	839
+ Sterilized filter cake			
Control	1 894	1 848	1 871
Sterilized	1 950	1 762	1 856
Mean	1 922	1 804	1 864
+ Non sterilized filter cake			
Control	2 075	2 018	2 047
Sterilized	1 624	1 878	1 751
Mean	1 850	1 948	1 899

The field trial at Doornkop, planted on December 22, 1967, was harvested after 21 months. Measurements and shoot counts were carried out during the experiment and the results are presented in Table IV. The most notable effect of filter cake was to increase the population of shoots, particularly where fresh filter cake was used in the furrow.

The yield results are shown in Table V. The filter cake treatments, on average, gave highly significant increases in yield when compared with the control but they also depressed sucrose % cane. Concerning the other factors only the furrow application was shown to be superior to broadcasting.

To obtain an indication of the nutritional influence of filter cake on soils, samples of fresh and old filter cake were analysed for nutrients. The results showed that the old filter cake contained much higher amounts of nitrogen and available phosphorous than did the fresh filter cake.

Soil samples from all treatments in pot experiment B were analysed one week before planting and one day after harvesting the first ratoon crop. The results showed that the large increase in available P due to treatment with filter cake was not appreciably depleted during the experiment.

Influence of filter cake on the microflora in soils

The influence of filter cake applications on the two soils from Darnall was studied by direct microscopic observations, soil dilution and plate count techniques, filter paper, soil contact techniques with tetrazolium tests, and the Warcup method for the isolation of various fungi from soil. Media such as 1/3-D agar, soil extract agar, potato dextrose agar (PDA) and Czapek-Dox agar were used.

TABLE IV

Height measurements and shoot counts 8, 20 and 44 weeks after planting the field trial at Doornkop

	Growth measurements and shoot numbers after				
	8 weeks		20 weeks		44 weeks
	Height cm	Number	Height cm	Number	Number
Control	5,11	68	12,03	148	206
Mean, fresh filter cake	5,21	85	12,46	208	266
Mean, old filter cake	5,36	69	11,92	184	249
Mean, furrow application	5,18	85	12,59	220	268
Mean, broadcast application	5,40	69	11,79	172	247

TABLE V

Plant crop yield data from the field trial at Doornkop

Treatment	TCA	S % C	TSA
No filtercake	43,6	15,1	6,58
67 tons/ha furrow, fresh	53,3	14,6	7,79
135 tons/ha furrow, fresh	55,8	14,3	7,90
90 tons/ha broadcast, fresh	53,5	14,4	7,69
180 tons/ha broadcast, fresh	52,9	14,6	7,69
67 tons/ha furrow, old	53,8	14,2	7,62
135 tons/ha furrow, old	57,7	14,2	8,17
90 tons/ha broadcast, old	48,1	14,4	7,01
180 tons/ha broadcast, old	52,3	14,4	7,52
Means	52,3	14,5	7,55

The colonisation of the different soil samples by various groups of bacteris, actinomycetes, yeasts and fungi, as well as nematodes, was studied in relation to soil aggregation and the stability of aggregates. Investigations were made on soil samples taken directly from the pots, and on artificially prepared soil aggregates.

Differences between the good and poor soils were clearly apparent when the untreated soils were studied on dilution plates. The good soil had a high bacillary population with *Bacillus mycoides* dominating, while the poor soil did not show as high a microbial population nor did it contain many *Bacillus mycoides*. The investigation showed that *Bacillus mycoides* is a good indicator of substances in the soil which are poisonous to micro-organisms. However, when fiter cake was applied to both the soils, there was a complete change in their microbiological status. The predominant microbes isolated from soils one to two weeks after the application of filter cakes were non-spore forming bacteria and yeasts. There was no longer a large difference between the two soil samples.

After several weeks the bacterial flora was reduced and an active development of fungi occurred. *Neurospora crassa* and *Trichoderma viride* were isolated and identified as the first invaders of filter cake, followed by various groups of Penicillia and later of Aspergilli, including *Aspergillus niger, A. versicolor, A. ustus* and *A. clavatus*. Other species which were identified included *Epicoccum purpurascens, E. nigrum, Pullularia pullulans, Trichocladium sp., Isaria sp., Gliomastix sp., Mucor spp.* These results confirm the general observation that bacteria tend to flourish at high soil pHs and fungi at lower soil pHs.

During the first few months of filter cake decomposition it was found that, in addition to many non-spore forming bacteria, there were a large number of antagonistic bacteria which produced antibiotics in the soils treated with filter cake. These were able to depress the growth of other bacterial colonies. During these early stages of decomposition no parasitic fungi such as *Pythium* or *Phytophthora* were isolated from the soils, but the dominant micro-organisms had a depressing effect on root parasites and a stimulating effect on plant growth.

Pure cultures of some of the isolates of antagonists were used to inoculate a large number of disease-causing fungi (see Plate 3, Figures 5 and 6). The antagonistic influence of two genera of bacteria growing in the equatorial zone of the Petri dishes is clearly visible as they inhibited the growth of *Colletotrichum falcatum* (Figure 5) and *Sclerotium rolfsii* (Figure 6).

After a period of approximately two years following the application of filter cake there was an increasing number of spore forming bacilli and actinomycetes in some of the soil samples. There was some indication that these micro-organisms were more prevalent in those soil samples where the filter cake had been decomposed to the greatest extent, but further tests would be necessary to prove this finding.

Inoculation experiments of pure cultures using

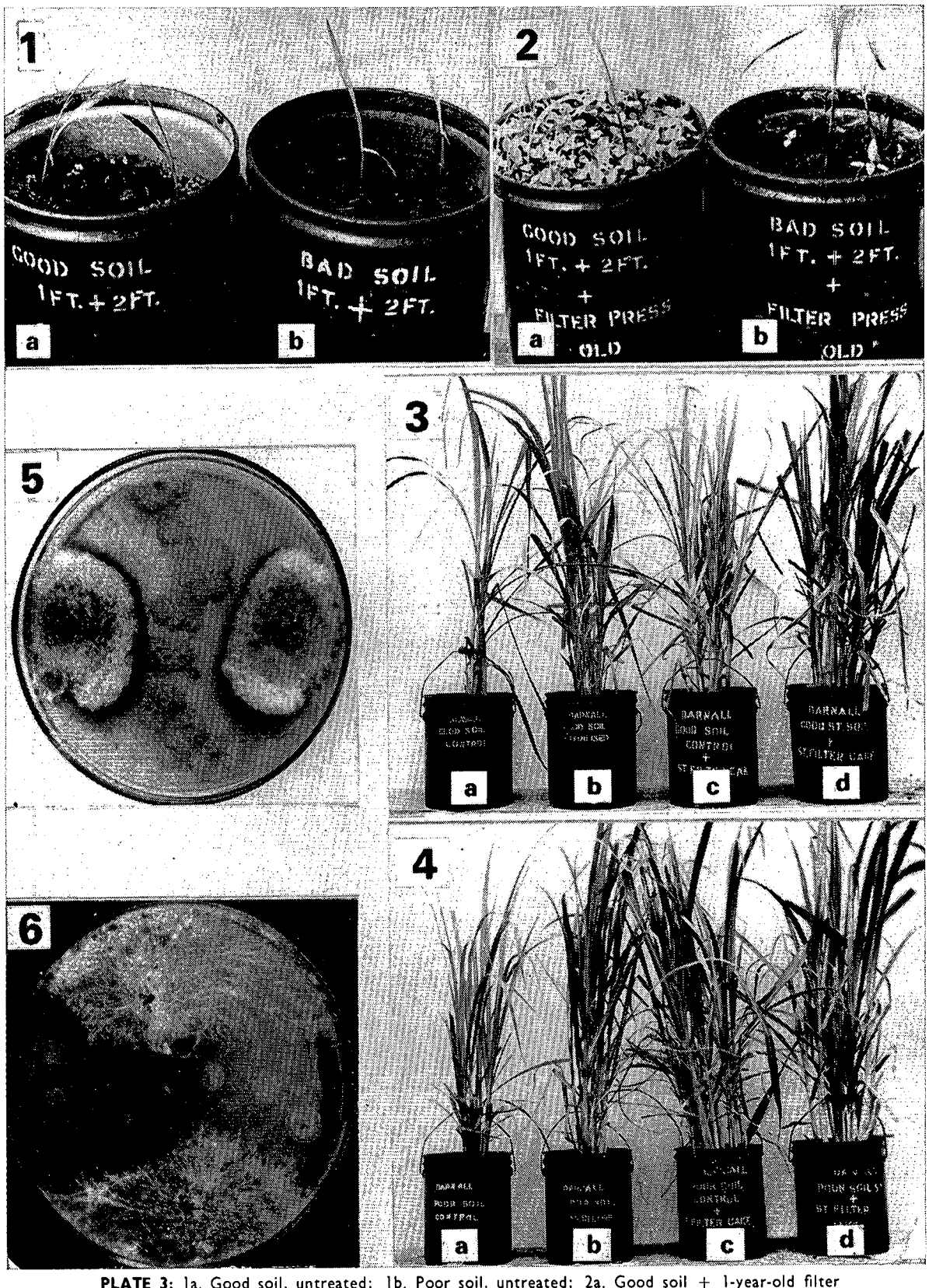

PLATE 3: 1a. Good soil, untreated; 1b. Poor soil, untreated; 2a. Good soil + 1-year-old filter cake; 2b. Poor soil + 1-year-old filter cake; 3a. Good soil, untreated 1st ratoon crop, 5 months old; 3b. Good soil, sterilized 1st ratoon crop, 5 months old; 3c. Good soil, untreated, + sterilized filter cake 1st ratoon crop, 5 months old; 3d. Good soil, sterilized, + sterilized filter cake 1st ratoon crop, 5 months old; 4a. Poor soil, untreated 1st ratoon crop, 5 months old; 4b. Poor soil, sterilized, 1st ratoon crop, 5 months old; 4c. Poor soil, untreated + sterilized filter cake 1st ratoon crop, 5 months old; 4d. Poor soil, sterilized, + sterilized filter cake 1st ratoon crop, 5 months old; 5. Bacterial colonies from soil treated with filter cake inhibit the growth of *Colletorichum falcatum* isolated from sugarcane; 6. Bacterial colonies from soil treated with filter cake inhibit the growth of *Sclerotium rolfsii* isolated from untreated soil.

these bacilli and actinomycetes have shown that they have a very strong antagonistic action on other groups of micro-organisms. Some of them, when tested for starch hydrolysis and cellulose decomposition, gave strongly positive results.

The application of filter cake to the soils caused a large increase in the numbers of saprophytic nematodes present. From observation, it would appear that these organisms also play an important role in the decomposition of filter cake in soils.

It was relatively easy to isolate phycomycetes from the untreated soils, but after treatment with filter cake only negative results were obtained. It was also impossible to find reddish spots or lesions or any indications of root attack on the young fibrous roots of sugarcane growing in filter cake-treated soil.

To obtain more information about one of the antagonists, a pot trial was conducted using *Trichoderma* as inoculum. Soil heavily infected with a suspension of *Pythium* spores obtained from infected sugarcane roots, was used as a growing medium for young sugarcane plants. Sterilized filter cake and filter cake overgrown with *Trichoderma* were added to the soil in some of the pots. It became clear that *Pythium* was only slightly depressed when sterile filter cake was used, but the treatment with filter cake containing *Trichoderma* gave complete control of *Pythium arrhenomanes*. The cane roots in pots containing *Trichoderma* were undamaged, whereas those in pots where the *Pythium* thrived were badly damaged.

Influence of filter cake on aggregation stability

The stability of aggregation of incubated soil cores from the perspex plates was tested after five days, and at 10-day intervals thereafter. Using the methods described above it was demonstrated that filter cake-treated soil had, in most cases, a higher aggregate stability than untreated soil after an incubation time of three weeks, and the difference increased as the incubation period lengthened. The relative stability data, using the number of drops of water required to disintegrate a soil core, are given in Table VI for each of the soils from pot experiment B. These were obtained five days and eight weeks after preparation of the artificial aggregates and the start of incubation. The values given are the means of 40 determinations. The aggregate stability after five days of incubation was relatively low, and there was not much difference between filter cake-treated soil and controls. However, after eight weeks' incubation, it required from seven to 21 drops of water to disintegrate control soil aggregates, and from 18 to 45 drops for filter cake-treated soils.

The most important micro-organisms, which have been mentioned above, almost certainly had a positive influence on soil aggregation. However, fungi seem to have had a greater effect than bacteria. Comparing the microflora of treated and untreated soil samples it appears that some mucous, gum forming bacteria are important in stabilising soil aggregation, whilst the non-spore forming bacteria have little or no effect. Actinomycetes and nematodes were also found to be a positive aid to soil aggregation.

TABLE VI

Aggregate stability of 12 soils from Pot experiment B following 5 days and 8 weeks of incubation.

Soil treatment	Aggregate stability Number of water drops	
	after 5 days	after 8 weeks
1	10,8	11,7
2	10,5	12,4
3	11,5	13,2
4	12,4	12,9
5	13,5	26,7
6	12,9	28,4
7	11,4	29,6
8	13,6	24,4
9	14,2	29,1
10	12,7	28,5
11	15,3	24,9
12	14,5	31,2

Discussion and conclusions

Soils treated with filter cake give remarkable sugarcane yields in pot experiments, as shown in Table I, II and III. A major effect of treatment with filter cake appears to be the increased tillering of treated crops (see Table IV). In the Doornkop experiment the number of tillers increased due to treatment by at least 15%, and by as much as 38%, the extent depending on the amount of filter cake applied, its placement and whether the material was old or fresh. From the results in Table IV it appears that furrow application of filter cake gives better results than broadcasting, and fresh filter cake seems to be better than old filter cake.

The highly significant effects of filter cake may be due largely to its nutritional value, since it contains appreciable amounts of N, P and Ca, and some K and Mg. However, this investigation shows that other factors should be taken into consideration. One of these is the marked effect of filter cake on soil structure which was observed in samples taken from pot experiment B two years after treatment. Nevertheless, it must be appreciated that the effects of filter cake on the soil are continuously changing as decomposition of the organic components proceeds. The chemical, physical and microbiological properties of the soil are in a continuous state of flux, and the chances of clearly identifying specific causes and effects are therefore remote.

It can be seen from the results obtained that bacteria, actinomycetes, fungi and nematodes are closely associated with the increasing stability of the soil aggregates. The fungi in the control samples were only present in the form of spores or chlamydospores, and there was no pronounced mycelial network. By using different methods, it was possible to show that filter cake-treated soil had a very active mycelial network which was able to hold separate soil particles together. Rod-shaped bacteria and bacilli were observed to be closely associated with the fungi in the soil, and the samples had a slimy appearance when investigated under a microscope.

These organisms, however, were not associated with the soil mass, but rather with the organic matter in the soil.

It is of interest to note that *Pythium arrhenomanes,* which causes a root disease in sugarcane, can be controlled by one or more of the antagonists which grow in filter cake.

Acknowledgements

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Discussion

Mr. du Toit (in the chair): We get varying responses to filter cake. Sometimes we can explain them on an N and P basis but not always.

I do not understand, however, why Dr. Roth used such large quantities of filter cake in the pot experiments—two parts of soil to one of filter cake.

In Taiwan, where they were also dealing with the microbiological aspect of the soil, they were using pig manure on bagasse but in very small amounts.

Dr. Roth: Such high quantities of filter cake were used in the pot experiments as pilot trials, only to establish the positive or negative effects. In field trials at Doornkop we used 30 or 60 tons per acre in the furrow and 40 to 80 broadcast and we had quite marked influences on yield.

Mr. Meyer: So much filter cake was used that the response might be due to the phosphate it contained.

Dr. Roth: The response is obviously the result of a healthy and well established root system in filter cake treatments and therefore also to a better nutrient uptake in general, not only in phosphate. To prove the microbiological qualities we will in future add the nutrients analysed in filtercake to the control treatment.

Professor Sumner: What does Dr. Roth mean by good and bad soil?

Dr. Roth: The soils were at Darnall, the good one being where in the past there had been no trouble growing cane and the bad one being where cane could not be grown.

Mr. Moberly: There are advantages in using fresh as opposed to old filter cake.

Dr. Roth: Old filter cake has more N but has a lower microbiological activity. The addition of N to fresh filter cake might therefore be an important factor.

Mr. Wood: As old filter cake would have a low moisture content, the nitrogen percentage would naturally be higher.

Dr. Roth: Even the fresh filter cake has been drying for some weeks so the moisture content was low. Old filter cake after decomposition has a fair amount of moisture.

Mr. Andries: What does Dr. Roth think of applying filter cake in the furrow as opposed to broadcasting it, from the point of view of improvement of the soil?

Dr. Roth: If furrow only application is applied less filter cake will be used but it will assist germination by opposing antogonistic organisms. However, broadcast applications will improve all the soil.

Mr. van Schalkwyk: These tests with filter cake were all done on sandy soils. Has any work been done on heavy clay soils?

Mr. Alexander: From experiments carried out at Doornkop filter cake appears to have a better effect on heavier soils than on sands, although in South Africa it is usually recommended that filter cake be applied to the sandy soils.

Mr. Singery: Filter cake applied on Mposa sands up to 100 tons per acre had a good effect on plant cane, a smaller effect on the first ratoon and thereafter no effect.