

# PATHOLOGICAL CONDITIONS AFFECTING THE GROWTH OF THE SUGARCANE PLANT FROM CUTTINGS IN NATAL

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It is generally agreed among planters that one of the important factors leading to the cutting of a good crop of cane is the behaviour of such a crop in its early stages of development. The establishment of a vigorous and uniform stand of young shoots after the planting of the cuttings is the goal attempted; how often this is missed, however, is testified by the frequency with which blanks have to be replanted; and the general consensus of opinion is that plants which have been thus supplied to make up for losses are never quite the same as those which have had an earlier start. It seems that, just as a sickly or misspent youth reduces the chances of a healthy life in after years, so a weak and patchy field of young cane militates against the production of a vigorous and healthy growing crop. To understand more fully the factors operating against this desired ideal, investigations have been carried out on the various causes of failure of the planted material, and what follows is an account of some of the results of this work. Written especially for the growers of cane, the report has been shorn of much botanical and mycological detail, which would be of interest more to the scientist and academically minded; rather have the aspects having a practical bearing on cane-growing been discussed, so that when failures are met with in establishment of a field, some of the reasons why this occurs may be appreciated.

Consideration of the ease or difficulty with which a field of cane becomes established involves the examination of two sets of variables; (1) the material planted, and (2) its environment at planting time; and on the manner in which the two interact, depends the ultimate density of population of shoots which emerge. The environment can be divided into soil type, moisture content, temperature and weather conditions generally, and organisms present in the soil—soil fungi, bacteria, insects, etc. The inorganic elements of the environment do not concern us so much in this discussion, which is intended to show the rôle played by the microscopic living forms present in the soil.

Turning our attention first to the material planted, it is well known that great variation exists in the vigour with which early growth takes place, and that this variation can be attributed in part to the type of planting material used. It is generally known that the top portion of the stalk is better from this point of view than the bottom, and that plant cane is better than ratoon cane.

The superiority in vigour of the top portion suggests some physiological difference between that

portion and the rest of the stalk, and that such a difference does exist is generally recognised.

An important factor controlling the vigour with which a bud begins to grow is the nature of the food material supplied to it; among other things, it must have a ready supply of carbohydrates from which to derive energy, by breaking down these carbohydrates into carbon dioxide and water. The more easily broken down the carbohydrates the more use they are to the bud, and the most useful from this point of view are the reducing sugars, sucrose having to be first inverted before it can be utilised. It is not unreasonable to infer, therefore, that one reason for the superiority of the top portion of the stalk when planted over the lower portion is its higher reducing sugar content. Evans (2) has shown in Mauritius that a significant negative correlation exists between the reducing sugar content of the sett and the number of days required for "germination," the higher the former, the fewer the latter.

The planted bud at this stage simply lives on the sett; it may be compared to the unweaned child, and is thus at the mercy of the physiological condition of the parent, and not until it becomes weaned—i.e. produces its own roots, can it become independent and live on material derived from an external source.

To investigate the difference in rate of growth between the two ends of the stalk when used for planting, the following experiment was carried out. A number of sticks of Co. 281 were cut and divided into top setts and bottom setts (the pieces at the extreme ends being rejected). The setts were then cut into single budded pieces and each piece cut to weigh the same weight—25 gms., and the ones selected for planting were chosen for uniformity of appearance and equal bud development. The top buds and the bottom buds were planted separately, and to ensure that if any difference was shown, it was not due to environment but to inherent difference in the buds, the setts were planted in a series of tins, filled with thoroughly mixed soil, all planted at a uniform depth, and all kept equally moist. Sixty setts of each kind were planted, and from the time of the first appearance of the buds above ground level, counts were made of their emergence.

The results are recorded in Fig. 1. An examination of the graph illustrating the growth of the bottom buds shows that the rate of emergence has occurred in three phases; the emergence was

at first slow, then it increased and finally it slowed down again. This type of curve is met with whenever one deals with the rate of growth of living organisms—whether it be the rate of growth of a single organ such as a stem or root, or of a crop as a whole, or of a population of individuals. It is known as a sigmoid growth curve, and the three phases are known as (1) the lag phase (2) the phase of logarithmic increase, and (3) the phase of decrease. Examining now the curve for the top buds, this does not appear the same until it is pointed out that when actively growing organisms are introduced into a new environment the lag phase of the curve, which characterises organisms in a more dormant condition, disappears. Thus these top buds have entered into the logarithmic phase of the curve immediately, showing a much quicker adjustment to the new set of conditions imposed on them than have the bottom buds.

Thus we see that there is this inherent difference between buds from the different ends of the stalk, a difference which it not unreasonable to suppose will be accentuated, the greater the difference in age between the tops and the bottoms, e.g. young cane has buds all more similar physiologically than eighteen months or two years old cane. That such differences can be increased by varying conditions also is borne out by the field observation, where the lag phase may become more pronounced; it must be remembered that the experiment was carried out under even and ideal conditions, which have promoted a much quicker and better development than is obtained under field conditions. Indeed, under adverse field conditions it is possible that the top buds themselves may exhibit a lag in growth; such conditions would probably, however, lead to total failure of the bottom buds, in the manner shown later on.

This curve not only goes to show that the manner in which the young shoots emerge after the cane has been planted follows a definite law and is not as haphazard as it would appear, but that by planting complete sticks and cutting them up, a perfectly even stand cannot always be expected, suggesting that many uneven stands encountered are due to the growth of the top buds and slow emergence, if not failure, of the bottom ones. This last point will become more clear when we realise, as will be shown later, that the slow growing pieces are those which are more subject to sett-rotting organisms.

So far we have been comparing buds on the same stick, but it can also be shown that differences exist between sticks as to the vigour with which their buds grow. For example, thin stalks produce much weaker young shoots than thick stalks; short jointed planting material, by producing, if development is good, a large number of crowded shoots, gives rise to a larger number of thin stalks, than does long-jointed material, which produces a smaller number of thicker sticks.

It should be pointed out here, that what has been said refers to the shoot produced from the bud planted—i.e. the primary shoot. The bulk of the population of sticks cut belong to later formed side-shoots—the tillers. Since the first formed tillers are offspring of the primary shoot, however, their vigour depends largely upon the vigour of the latter.

Early formed and vigorously growing primary shoots lead to early and vigorous tillering; the converse can often be seen in primary shoots which emerge considerably later than the majority of these shoots; for some reason or other their emergence is delayed, and when they do appear they are weak and spindly, and tiller poorly.

A parallel example may be cited of the desirability of using young material for planting from another crop which is propagated vegetatively—the potato. Here, where there is an extensive trade in the production of tubers for planting only, the grower lifts his crop before they reach the stage at which they are ready for table use, so that a quicker and more uniform stand of young plants may be obtained.

It is clear then, that the condition of the sett at planting time can exercise a measurable effect on the vigour of shoot production, and it now remains to consider some of the environmental factors influencing the early stages of growth.

It is usually found when a field of cane has been planted and the resultant stand is poor, that if the setts from the blanks are dug up they are in a state of decomposition. This can be shown to be due to the action of organisms living on the tissue of the planted cane; to understand more clearly, however, why some setts should rot and not others, some knowledge of the organisms concerned and the manner in which they live is required.

These organisms, such as fungi and bacteria, are microscopic living forms which have not the ability to manufacture their own carbohydrates from carbon dioxide and water, as green plants can, but must derive this material from some other source; i.e. their food is organic. Further, there are differences among themselves as to the manner in which they can utilise organic matter; e.g. a parasite is an organism which can only live on other living material, while the saprophyte lives on dead organic matter. These are two extreme cases, but in between are various types of organisms which are more adaptable in their requirements; some, for example, live as saprophytes on dead pieces of organic matter, but if they come into contact with a living organism, they may become mildly parasitic, depending on the degree of resistance shown by the organism attacked. If the latter is vigorously growing and in good health, the fungi or bacteria may be kept in check; if, however, it is weak, its tissues may become over-run by the invaders, and a diseased condition produced.

Such organisms as we are considering can be found in the soil; cane soils provide an admirable environment for their development, with the amount of organic material left behind by a crop in the nature of trash, old roots and stubbles. When cane setts are planted, therefore, from the point of view of these fungi the planter has simply increased the possible supply of food, and the ultimate fate of a sett will depend upon the degree of vigour shown, by means of which it escapes infection. In short, the more quickly it grows the more surely will it be unmolested, and the sett which will eventually fall to the prey of these organisms will be the one which is slow to start into growth. Speaking in terms of the sigmoid curve referred to before, the longer the lag phase the more liable will be the material to rot. Thus we see that the bottom portions will have less chance of giving rise to shoots than the top portions of the stalk, and that this will be more accentuated under conditions which tend to retard development generally, while not making so great a difference under conditions which promote quick growth. Such adverse conditions can, for example, be caused by excessive soil moisture, drought, or low temperatures.

The organisms considered so far are those normally inhabiting the soil, but these do not account for all the damage done when a sett becomes destroyed. Other organisms which must be considered are those which cause an internal rot of the seed-piece and which from experimental evidence are known to be inside such a sett at planting time. It can easily be demonstrated that many sticks of growing cane, when cut, are not sterile internally, but contain various micro-organisms in their tissues. These organisms have been found in apparently healthy cane, their presence appearing to have no effect on the health of the stalk (at least so far as observations have gone up to the present), as long as the stalk is part of the plant. When the latter is cut, however, these organisms by their activities cause a decomposition of the plant tissues, with accompanying visible changes, e.g. reddening, or the formation of a black core down the centre of the stalk. In other instances the cane does not undergo such an obvious colour change internally, but becomes light in weight, and small black pustules appear on the outside of the rind. That the reddening of cane which often occurs after cutting is due to micro-organisms is suggested by the fact that small pieces of such cane when placed under anaerobic conditions develop no red colour, nor when they are sterilized either by heat or by chemicals; moreover, under these conditions such pieces placed on a culture medium give rise to no growth of micro-organisms, whereas pieces cut from the inside of freshly cut cane and not treated, develop a copious growth when placed on such a medium. That these organisms are present inside the stick, can be demonstrated by sterilizing the outside and placing portions of the inside under conditions

suitable for growth of the former; even when the portions of stems were steamed under pressure in the autoclave, growth was obtained from the interior of the stem, though the outside was rendered perfectly sterile.

It would thus appear that a great deal of our cane has an internal microbiological flora, which does no harm when the cane is growing vigorously; but when growth is stopped or impaired, diseased symptoms may appear. Various fungi, bacteria, and yeast-like organisms have been found in such canes, and although these appear to be harmless on healthy growing cane, the fact that some at least of the organisms concerned have the ability to invert sucrose, suggests that their presence may not be entirely without economic significance. Such a problem, however, is outside the scope of this discussion, which is on their effect on such canes when cut into setts for planting. Such canes for the present we will term symptomless canes, as no way is known yet of telling by external appearance whether the cane is infected internally or not, at least while the cane is still growing.

It is necessary now to consider in a little more detail some of the micro-organisms and the particular manner in which they infect the cane.

#### *Cephalosporium sacchari*.

This fungus is the one which causes the reddening of the cane already referred to. Such a condition is commonly spoken of in Natal as Red Rot; this name, however, belongs to a sugarcane disease caused by the fungus *Colletotrichum falcatum*, which has not yet been observed here, every case examined of reddening of cane tissue having been associated with *Cephalosporium*. On growing crops it is found on drought-stricken cane, and on over-ripe cane, in which case it shows external symptoms of reddening, usually on the lower nodes on the stem. It is a wound parasite, i.e. it cannot gain entrance into a stem with a healthy unbroken rind, but can invade the interior via such places as cracks, withered aerial roots, and holes caused by stalk borers, and in planted cuttings through the cut ends. It appears to be a mild parasite, never having been found producing disease symptoms on growing plants of cane unless the latter are weakened by some other causes. Its effect on cut cane must not be overlooked, however, as it is known to be able to invert sucrose, as was shown by Van der Bijl (3). Confining ourselves at present, however, to the relationship between this fungus and sett growth, it appears that two sources of infection are possible. (1) It may be present inside the sett when planted, by using symptomless canes and (2) being present in the soil, it can gain entrance via the cut ends. Its effect on the sett depends, as was said before, on the vigour of the sett and environmental conditions.

If the conditions are in favour of the fungus, the sett rots, and no plant is produced; sometimes, however, the sett has sufficient vigour to start into growth, but the young shoot is eventually destroyed when anything up to a few inches high. On the other hand, the shoot may grow into a healthy stick but there is evidence that if that shoot has arisen from a sett which was attacked by *Cephalosporium* the latter fungus may grow up from the sett and into the shoot, slowly spreading upwards but producing no diseased condition as long as the shoot is vigorous. It is probable that in this way may arise the condition discussed previously, in which symptomless canes may have this fungus in their internal tissues. It is thus not improbable that this fungus can be propagated with the cane without the knowledge of the planter, but certain precautions could be taken to minimise the risk of infection, such for example as the avoidance for planting of all canes showing obvious external symptoms of reddening, or of cane which is cracked before cutting. As the fungus is more prevalent at the bottom of the stalks, this is another reason why this part of the stick should not be used for setts.

It has been stated that this fungus is also present in the soil, and gains entrance from the cut ends; from field observations however, it seems that this condition does not account for so much sett rot as that previously mentioned, as the rate of spread inwardly through the sett is slow, and often only penetrates a little way; even after a fairly large stool has been found, the original sett can be found with *Cephalosporium* only at the ends, where infection is due solely to the soil.

#### **Thielaviopsis paradoxa.**

Like *Cephalosporium* this fungus has been found both in the soil and inside the sett at planting time. Unlike it, however, it has never been seen to produce external symptoms on cane which it has attacked; the latter has to be cut down the middle, when a black core will be seen to have been formed. This fungus digests the middle walls of the cells, and produces a mass of black spores, accompanied by a fruity odour—hence its popular name of Pineapple Disease.

Infection from the soil can occur through sett roots which have rotted, probably due to some other cause, in which case the black spores are not always found down the centre of the sett, but under the rind, in the neighbourhood of the root ring; this difference gives a clue to the source of infection, when such a sett is examined microscopically. Infection is also possible, of course, through the cut ends of the sett, but from field observations it would appear that the amount of actual destruction of cuttings by this means is not so great as that caused by planting setts already containing the fungus.

#### **Melanconium sacchari.**

This fungus is commonly found wherever pieces of cane are left lying about in the field; such pieces become dry and light in colour, and the fungus breaks through the rind in little black pustules, which if examined microscopically are seen to consist of masses of black spores. This fungus is a common saprophyte in cane fields; but it has been seen to attack standing cane when the latter is considerably weakened, producing the condition known as Rind Disease. Moreover, like the two previous fungi, it has occasionally been isolated from apparently healthy cane. It has only been found causing sett rot under very dry conditions, when the sett dries and provides suitable conditions for the development of this fungus.

*Melanconium* appears to be able to attack individual joints of growing cane which have been formed under drouthy conditions; when normal conditions return, however, the cane recovers and disease symptoms may disappear. The fungus, however, is still present, and should such material be used for planting, is a possible cause of sett failure under adverse conditions.

Of the other organisms found in growing stalks of cane, the bacteria and yeast-like forms, very little can be said at present, except that setts which have been found under wet conditions suffering from a putrid, evil-smelling rot without any of the precise diagnostic features of the previously mentioned fungi have probably had as one contributing cause the presence of such organisms, in addition to those present in the soil.

One fact which ought to be emphasised concerning the three first-mentioned organisms at least, is their greater occurrence on ratoon cane than on plant cane, making the former less safe material for planting than the latter.

#### **Himantia stellifera.**

This fungus must have been observed by most planters, as it appears externally on the outside of the cane at the base, where it produces a white feathery looking growth, and often binds the trash on to the stick. This organism has never been found in the internal tissues of the cane, and it is easily eliminated from the planting material by simply cutting off the affected bottoms and destroying them. Its action, where it does attack a planted sett, is to smother the buds and young roots; it appears to penetrate very little into the tissues, unless they have already begun to decompose. This fungus is very common in cane fields, and is frequently found on old stubbles and roots after a field has been ploughed out. In one or two isolated instances it has been observed associated with small localised cases of root disease; in these instances the mycelium of the fungus was so abundant in the soil that the white threads could

be seen with the naked eye, and could be traced back to old decaying tree stumps; while round the cane roots, a thick, felt-like mass of mycelium had been formed, interfering with the normal functions of these organs. It appears to be more common on land that has been recently cleared from bush.

The sett-rotting organisms just described are those which have been found in the cane itself as well as in the soil. There are still to be considered those which so far have only been noted to be derived from the soil. The two principal ones observed are species of *Aspergillus* and *Penicillium*. These again are not actively parasitic, but attack a sett which is slow in developing, and along with the previously mentioned ones when they invade such a sett from the soil, destroy the tissues before the buds and roots have developed. This latter condition is common in cane which lies for a long time in the ground if planted in dry weather. Under these conditions the sett rot can be caused by the combined action of all these organisms, giving rise to a condition which may be simply termed gangrene. When *Melanconium* is present in the planted material, it may predominate, however, and give rise to the condition characteristic of Rind Disease.

When *Cephalosporium* and *Thielaviopsis* are present in the planted material, and cause an internal rot, this condition is more favoured by excessively wet conditions, and *Thielaviopsis* especially if accompanied by cold weather.

In short, it seems that Rind Disease and a general gangrenous condition are favoured by dry conditions, while internal rots due to *Thielaviopsis*, *Cephalosporium* and a more general type of bacterial rot are favoured by wet conditions.

These diseased conditions apply to the sett between planting time and the appearance of the shoots above ground, i.e. the pre-emergent phase of development, with the exception of one case, that of *Cephalosporium* wilting the young shoots after they emerge. This post-emergent Wilt is usually accompanied, however, in the first instance by the other soil organisms common on cane soils here, species of *Pythium* and *Rhizoctonia*. These two are often found in conjunction, and can cause a considerable amount of destruction of the fine fibrous roots of cane in all stages of development. They are a common cause of diseased root conditions in older cane, and especially in ratoon cane, and even when not actually causing disease symptoms, their presence interferes with normal development, by reducing the area of fibrous roots engaged in absorbing nutrients from the soil.

To summarise the foregoing points they are presented in tabular form, at the end of this paper. (Table I.).

The foregoing descriptions of the micro-organisms attacking sugar cane in Natal are only outlines of their life histories, but are sufficient to show that none of them can be considered dangerous and active parasites, such as organisms which attack healthy growing plants and destroy them. Nevertheless, however, they are not without economic significance, and the yearly toll of planted cane which falls to their lot is probably quite considerable. Naturally the planter wants to know how such a state of affairs can be remedied; this, unfortunately, is the most difficult task for the experimenter, as it is much easier to study the nature of a plant disease than to prescribe a cure. Control measures against disease are of two types:—

- (1) Prophylactic or preventive.
- (2) Therapeutic or curative.

Everyone is familiar with the saying "prevention is better than cure" when speaking of maladies of the animal organism; this is more forcibly true, however, when speaking of plant diseases, as owing to the nature of many of these diseases cure is usually impossible, once the symptoms have appeared.

When we come to consider, in particular, diseases of such a nature as that of planted cuttings, it is obvious that control measures intended to effect a cure would be in practice impossible, did such exist, and that all measures taken must be those to prevent the occurrence of disease symptoms; once a sett has started to rot it would be futile to do anything to stop it.

It is obvious from what has been said that from the point of view of health three sets of factors govern the chances of survival of a sugarcane cutting:—

- (1) The microbiological flora of the soil.
- (2) The microbiological flora of the sett.
- (3) The vigour of the latter at planting.

and that these are intimately bound up with environmental conditions of soil, weather, etc., at time of planting.

(1) The soil, providing as it does an ideal medium for the growth of certain micro-organisms, especially those of the type under discussion, is a means of ensuring their survival, so that once a sett has been killed these organisms are still able to continue their growth.

As, however, they have adapted themselves to the environment provided by the sugarcane plant, it must be obvious that their chances of survival are increased the longer this environment is continued. The agricultural conditions under which sugarcane is grown e.g. the practice of ratooning and the continuous culture of the same crop, thus provide an admirable medium not only for the survival of such organisms, but possibly for their actual

increase in the soil; borrowing a term from the science of hygiene, one might say that the continuous cropping of sugar cane tends to promote in the soil an unsanitary condition. To propose any alteration in such a system, however, would strike at the roots of the whole economic system upon which sugarcane agriculture in Natal is based, and it is not the purpose of this discussion to do so, except to point out that one of the underlying principles of crop rotation, where it is practised is to prevent, or ameliorate, such conditions; the change of crop altering the soil environmental conditions and thus bringing about an alteration of balance among the micro-organisms in that medium leading to the suppression of those organisms which multiply under one set of conditions.

Other points, however, suggest themselves, e.g. the stubbles left behind when a crop is ploughed out are fruitful source of food for these organisms, and from the point of view of soil hygiene would be better removed. From the point of view of the maintenance of organic matter in the soil, however, their decomposed remains are desirable, and the question rests finally on the difference between their beneficial and their harmful effects; possibly a compromise might be their removal from the soil and their decomposition in a compost heap, before being incorporated once more in the soil; this however, raises the question of costs, which again is outside the scope of this paper.

Other important items in the improvement of the hygienic conditions of the soil are those of cultivation, drainage and liming. The effects of ploughing are usually discussed purely from the point of view of improvement of physical condition, but this other aspect must not be overlooked. One of nature's best fungicides is simply sunlight; in fact, some of these fungi we have been considering have spores which have been found to lose their vitality after exposure to sunlight. The partial sterilization of the soil due to exposure to the heat of the sun is held by some to be one of the basic principles underlying such practices as the "sheraqui" fallow of Egypt, and the fallowing of land during the hot period in India.

To secure the maximum benefits from ploughing, therefore, as much as possible of the surface of the soil should be exposed; this implies turning over the soil as frequently as other agricultural exigencies will permit.

Improved sanitary conditions following adequate drainage and the application of lime are recognised, but once again the details of these operations could be discussed with more authority by an agriculturist than by a mycologist.

(2) From what has been said about the various fungi which it is possible to plant with the sett, it is obvious that some measure of control could be effected by the more careful selection of the mater-

ial to be planted. While obviously the planting of canes which show no symptoms of the presence of organisms cannot be avoided, yet there are occasions when external signs of disease are seen, and under such conditions selection could be practised. For example any part of a stalk showing the white feathery growth of *Himantia stellifera* should be rejected, and any case showing signs of reddening should be avoided. Cracked setts should likewise be avoided. (It should be emphasised here that it is not meant that setts showing any of these symptoms will not grow—it is simply meant that their chances of survival are decreased; such material planted under good conditions will probably show little or no difference in development from other, healthy material; but under adverse conditions the latter will have a better chance of forming shoots and roots than the former). Cane which has been drought-stricken or frosted is liable under these conditions to attacks of the Rind Disease fungus, and although it may recover and appear healthy at planting time, if it was known to have suffered from the attack of the fungus under the conditions mentioned, it would be wisely avoided as planting material. It is obvious also from what has been said before that greater risks are taken with planting ratoon cane than with plant cane.

(3) The vigour of the sett at planting time is probably the most hopeful way of overcoming such difficulties as we have been discussing. It has been shown that the buds from the top part of the stalk when planted start into growth much more rapidly than do the bottom buds, the latter showing a lag while they are adjusting themselves to their new conditions, and that it is during this period that they are more exposed to the attacks of micro-organisms. By planting only the top portion of the stalk, then, or the whole stalk of very young cane, sett rot could be considerably reduced. No hard and fast rule can be laid down about how much of the stick should be planted, but the best guide is given by the appearance of the buds themselves. Buds that have not gone brown, but are still white, provided they are well formed, and plump, are the most reliable for obtaining an early and vigorous start. The very youngest, immature buds are liable to be destroyed if decomposition sets in at the youngest portion of the stick, as it frequently does in these very soft, juicy, tissues. Thus in very young cane the more reliable buds are often those at the bottom of the stalk.

It appears to have been the general custom in the early days of sugar cane agriculture in Natal to plant only tops, and it still is to-day on some estates; but it is felt that it could profitably be practised by more. Where the planting season coincides with the milling season, there appears no reason why it could not be arranged to select the fields intended for cutting for planting material and to cut a larger top than is usually the case, re-

-serving this portion for planting and sending the rest of the cane to the mill. By doing so, not only superior planting material is obtained, but better cane will be sent to the mill. The question of the removal of the trash from the setts is an open one; although there is no doubt that the presence of the trash leads to a slightly slower emergence of roots and shoots, there are yet no data to show that it leads to much, if any, reduction in the population of shoots emerging. Some planters, however, have adopted this practice, and feel that it is worth the extra labour preparing such setts.

(4) The effect on environmental factors on the survival of a sett has been alluded to through this discussion. In fact, it is impossible to consider the other factors without their relationship to this one. If conditions of temperature, moisture, and soil conditions, physically and chemically, are ideal at planting time, even the worst looking setts can be induced into growth. Taking the longest view, however, it is perhaps unfortunate that it is so, as it tends to create the impression that any material when planted ought to be always capable of growth, and when disappointment is experienced to blame the environmental factors alone, which as we have seen are only contributory and not the sole reason for failure.

Included in environmental factors are those of fertilizers added to the soil, but of the effect of the various ingredients of a fertilizer mixture no experimental data are yet available; it should be pointed out, however, that even the best setts could be ruined by the application of chemicals in such quantities that the roots and buds are destroyed when they come into contact with a concentrated solution surrounding the sett. A destructive effect of filter-press cake has also been noticed, when it comes into contact with the sett in such a manner that it can form a paste round the latter.

#### Other Control Methods.

It would be conveying a wrong impression if one were led to believe that all varieties of sugar cane were subject to these generalisations to the same degree outlined in the foregoing discussion. That different varieties of plants respond to the same disease producing organisms in different ways is a commonplace, and one of the greatest benefits to be derived from the science of plant breeding is the production of disease resistant varieties.

The study of resistance of the varieties of sugar cane now grown in Natal towards these organisms described has not yet been carried out experimentally except in a preliminary manner, but field observations show that differences do exist; e.g. Co.290 appears less resistant to *Cephalosporium* than Co.281, while the latter has been found more often with *Thielaviopsis*.

The root system of Co.281 and P.O.J.2878 appear more resistant to root rots than do those of Co.290 and Co.301, while P.O.J.2725 appears more liable to Rind Disease in the setts. The resistance shown by Co.281 to root rot and *Cephalosporium* is exemplified when this cane is planted and remains in the ground for a considerable time before conditions are favourable for active growth, without rotting, whereas Co.290 rots readily; if however the Co.281 is, or becomes, infected with *Thielaviopsis*, it rots just as readily as the Co.290 does with *Cephalosporium*. Thus some planters have difficulty in establishing Co.290, but not Co.281, while with others the reverse is the case.

The last type of control to be discussed is one which always occurs readily to the mind wherever the subject of plant disease is mentioned—that of the destruction of the disease producing organisms by chemical or other treatments.

This method of control falls into three groups for the type of diseases we are considering (1) treatment which aims at destroying the organisms which attack the sett externally, whether from the soil or from the exterior of the planted material (2) that which aims at treating the sett internally (3) that which aims at destroying all the organisms, external or internal.

(1) External treatment involves sterilization of the soil and of the exterior of the sett. As complete sterilization of the soil would lead, however, to disastrous results, since this medium supports a flora of not only harmful, but beneficial micro-organisms, only partial sterilization is possible. This method aims at reducing the numbers of harmful organisms, and has been found very beneficial for plant diseases of certain types, particularly root rots.

It has been found by Bell (1) to give good results on sugar cane soils in Queensland, particularly when a variety with a susceptible root system is being grown. The beneficial effect of molasses on sugar cane soils also is attributed, in part at least, to a partially sterilizing effect.

External sett treatment aims at giving the exterior of the sett a coating of some fungicidal substance before planting, which will not only destroy any micro-organisms adhering to the rind, but will form a protective layer against soil micro-organisms which might come into contact with the cane after planting. It must be obvious that treatment of this kind can only be expected to give a measure of control against external infection, such as the condition previously referred to as pre-emergent gangrene, which is commonly found when cane is planted and encounters a dry spell, and cannot be expected to give the same control against internally borne infection.

(2) Internal sterilization can be accomplished by soaking the setts in some liquid fungicide, (which of course as well destroys any organisms on the surface). Preliminary work done here indicated that mercuric chloride could accomplish this, without damaging the sett, and that although improved growth resulted in some instances, in others a depressing effect on the growth of the young shoots was noticed, despite that fact that sett rot was reduced.

(3) A combination of both of these methods suggests itself, but nothing along this line has yet been attempted. It is felt, however, that even if results were obtained, the method would be an expensive one, and in practice impossible to carry out, at any rate with our present knowledge of soil sterilizing substances.

That an improvement in early development of cane can be procured by such means, however, is shown by an experiment which is at present being carried out here. It would be premature to draw conclusions as yet, as it is not known what effect these treatments will have on the ultimate crop produced, but the effect of some of the treatments on the emergence of the primary shoots show that bud-rot can be by such means controlled.

The experiment was carried out under field conditions, and in Fig. 2 and Table 2 is shown the results for four of the treatments. Mercury A and Mercury B are two mercurial dusts which are applied to the setts before planting; the formalin and the cresylic acid were watered on to the soil.

It will be seen that both of the mercurial dusts appreciably increased the total number of primary shoots which emerged but that B had a depressing effect on the rate of emergence; and resulting from this the rate of tillering is considerably slowed up. The formalin and the cresylic acid did not significantly effect the number of primary shoots, but formalin improved the tillering, and cresylic acid, though superior to the controls is not significantly so. (Full details of this experiment will be published later; it is merely recorded to show that some treatments are beneficial).

The variety used for the experiment was Co.301 and the ground suffered a long dry spell after planting, conditions under which a gangrenous condition develops on the planted sett. Of chemical treatments against such diseases as we have been discussing, the best so far appears to be some form of mercury: an externally applied dust prevents the condition referred to above, but not causing any internal sterilization will only be of limited use for such troubles as Pineapple Disease which is inside the sett, and favoured by wet conditions. Towards this end experiments with soluble mercurial insecticides are now being carried out.

## SUMMARY.

1. Buds from the top of the sugar cane stalk behave differently to those from the bottom when they are planted, in that they adjust themselves more rapidly to their new environment and commence growth more quickly. The buds from the bottom show a lag in emergence.

2. During this lag phase in development they are more liable to the attack of micro-organisms causing sett rots.

3. These organisms are present either in the soil, or may be transmitted in the internal tissues of cane stalks which appear normal and healthy to the eye—symptomless canes.

4. These organisms are weakly parasitic, and the degree of destruction they cause depends upon the vigour of the planted sett in commencing growth.

5. The setts may rot before the shoots emerge, or the young shoots may attain a few inches high before being destroyed. When sett or shoot rot does not ensue, however, but a plant is produced, some fungi, if present in the sett, may grow up through the tissues of the stalks, and produce canes showing no symptoms of infection, unless the latter encounter adverse conditions.

6. Infection due to external sources appear to be more common under excessively dry planting conditions, while sett rot caused by internal organisms appears to be favoured by conditions of excessive soil moisture.

7. Varietal differences are exhibited with respect to degree of resistance to the various organisms concerned.

8. The fungi under consideration are *Cephalosporium sacchari*, *Thielaviopsis paradoxa*, *Melanconium sacchari*, *Himantia stellifera*, *Aspergillus sp.* and *Penicillium sp.* on the setts themselves, and *Rhizoctonia sp.* and *Pythium sp.* on the roots.

9. Control Measures should aim at prevention of diseased conditions, as cure is not practicable. The following recommendations are made:—

- (i.) Only setts with white, but well formed buds should be planted. Tops of cane of millable age should be cut long enough to provide a cutting, and the rest of the stick sent to the mill.
- (ii.) Only plant cane should be used.
- (iii.) Thin sticks could be rejected, likewise excessively short jointed material
- (iv.) Stalks showing any external signs of reddening at the joints should be rejected, likewise cane that has suffered from Rind Disease accompanying frost or drought, even though it appears healthy at cutting time.

- (v.) Where whole setts are planted, such as when using young cane, bottom portions showing the growth of external fungus should be removed.
- (vi.) Cane which has developed cracks, or aerial roots, before cutting should be avoided, like-wise cane with stalk borer holes.
- (vii.) The physical condition of the soil at planting time should be as fine as possible, and the setts should not be covered too deeply. The shallowest covering that will not dry out, promotes healthier growth.
- (viii.) The application of chemical fertilizers should not be of such a nature and of such a quality that a concentrated solution forms round the sett.
- (ix.) Agricultural methods should aim at the improvement of hygienic soil conditions generally.

10. The use of chemical treatments of a fungicidal nature is under investigation. Preliminary experiments indicate that organic mercurial compounds give some measure of control against the gangrenous condition favoured by dry conditions, and lead to a greater population of shoots emerging. Different compounds, however, affect the rate

of shoot emergence and tillering differently, so that it is too soon to predict the ultimate effect of such treatments on the crop.

11. A beneficial effect from the application of some partial soil sterilizers has also been shown.

#### Acknowledgements.

Thanks are due to Mr. J. Kirkwood for assistance given with the isolation and growing in culture of some of the micro-organisms used in these investigations, and to the members of the agricultural staff for making possible the carrying out of experiments on a field scale, for statistical analysis of their results, and for providing much useful and provocative discussion.

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South African Sugar Association,  
Experiment Station,  
Mount Edgecombe,  
February, 1937.

DEVELOPMENT OF PRIMARY SHOOTS ON SUGARCANE CUTTINGS.

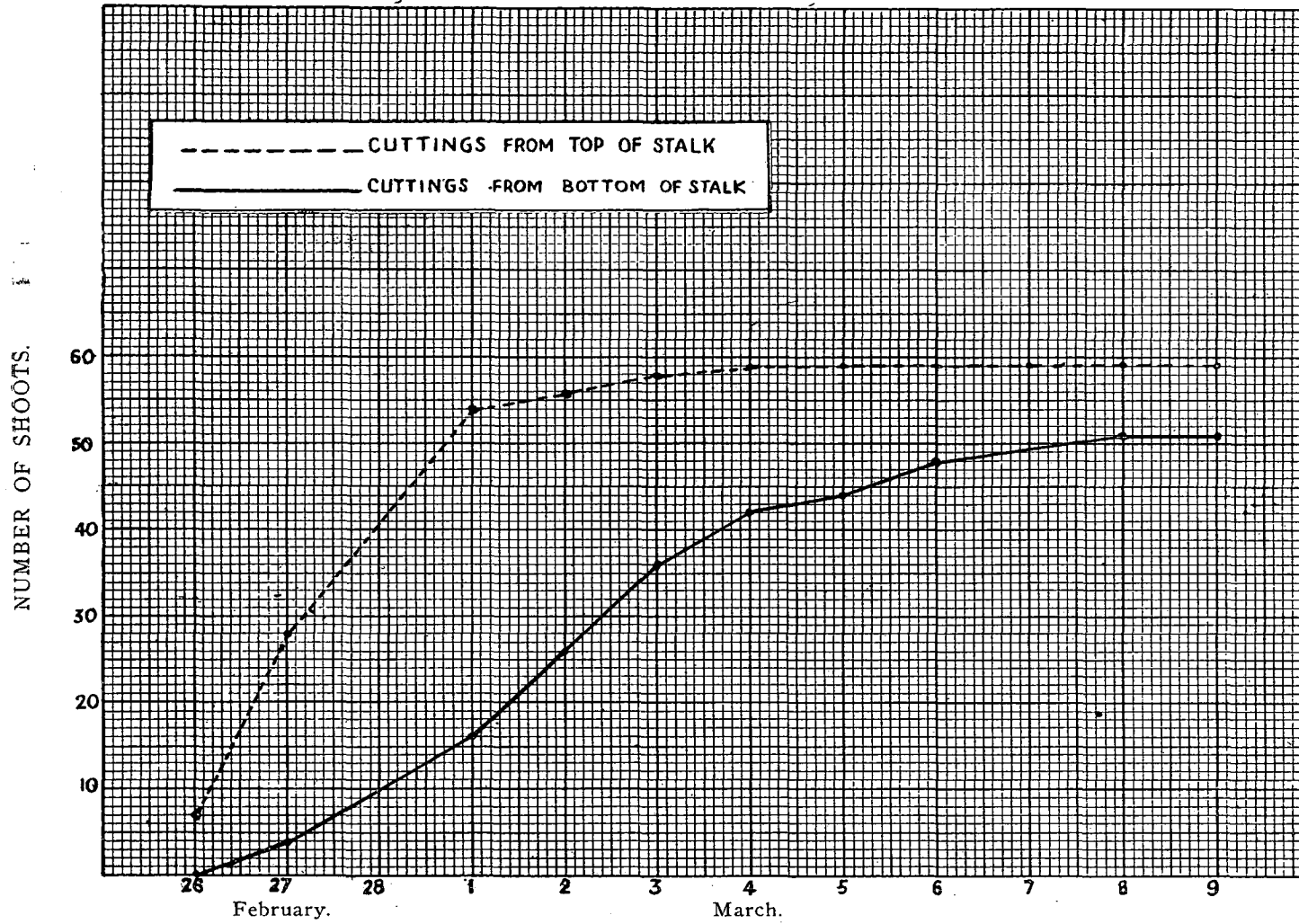


FIGURE 1.

EFFECT OF FUNGICIDAL TREATMENT OF CUTTINGS OR SOIL ON RATE OF SHOOT FORMATION.

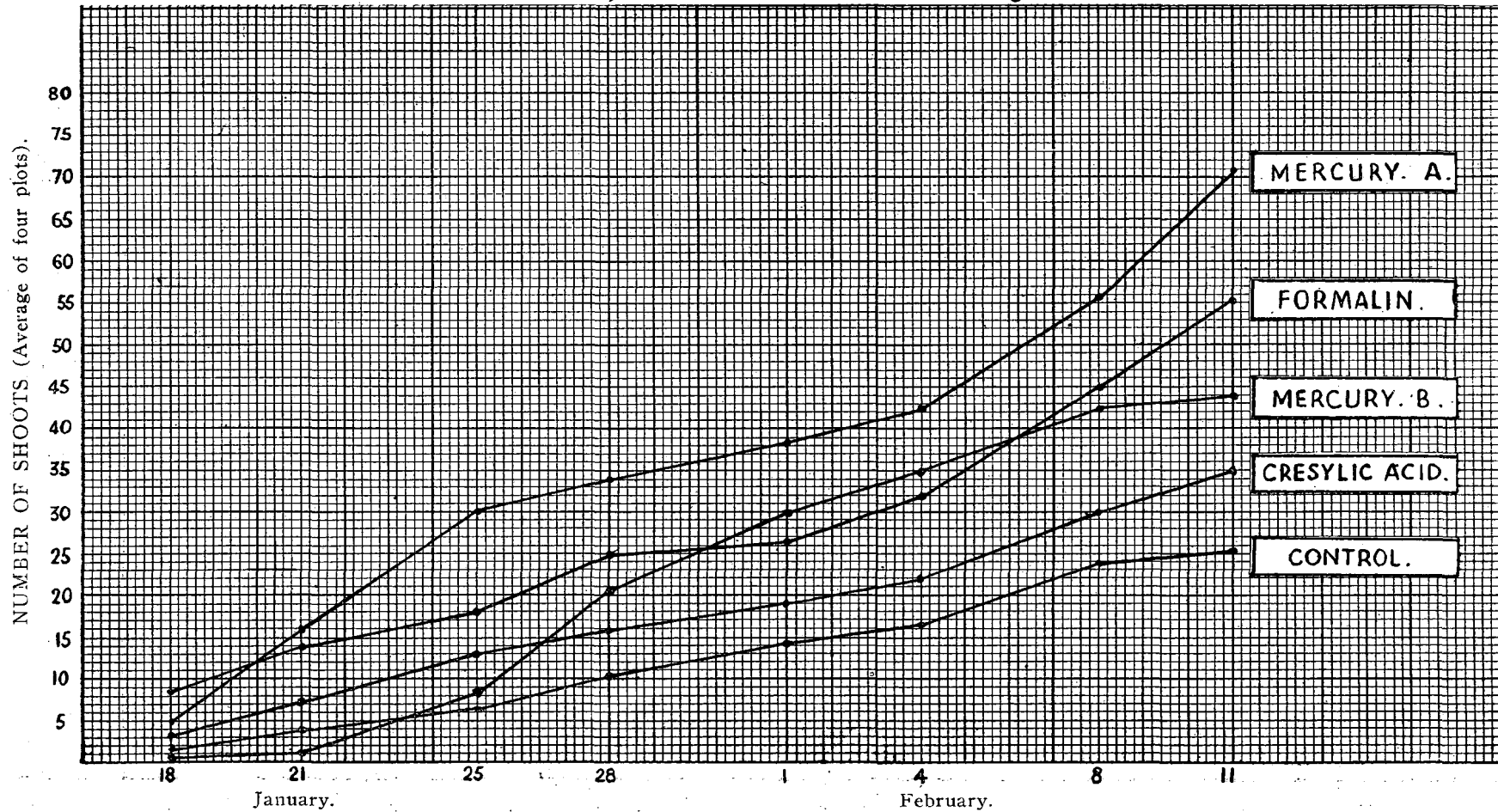


FIGURE 2.

TABLE 1.—PRINCIPAL DISEASES OF SUGAR CANE CUTTINGS AND YOUNG PLANTS IN NATAL.

Phase of development of cutting affected	DISEASE	Causal Organisms	Principal Source of Infection	Principal Diagnostic Features	Conditions favouring Incidence of Disease	Tissues of Setts affected
Pre-emergent	Gangrene	Thielaviopsis Cephalosporium Melanconium Aspergillus Penicillium (and other soil organisms)	Soil and sett (mainly former) Soil mainly	Rot is of a dry nature, and outside of sett can often be seen covered with variously discoloured areas due to growth of these micro-organisms	Dry	Whole sett generally
	Rind Disease	Melanconium	Soil and sett (mainly latter)	Rind becomes very dry, and black pustules appear, breaking through surface	Dry	Whole sett generally
	Pineapple Disease	Thielaviopsis	Mainly sett	Black core down centre of cutting	Wet (and cold)	Interior of sett
	Red Stem Rot	Cephalosporium	Mainly sett	External red discolouration first at joints: internal red discolouration, finally becoming muddy brown	Wet	Interior of sett
		Himantia	Mainly sett	White, feathery (or when plentiful, felty), mass of fungus over outside of stem	Unhealthy conditions generally e.g. lack of drainage, presence of undecomposed vegetable matter.	Exterior of buds and roots
	Wet Rot	Fungi, bacteria, yeast-like organisms, etc.	Interior of sett	General rot without any clear-cut diagnostic features	Wet	Interior of sett
	Bud Rot	Cephalosporium (usually)	Interior of sett	Bud commences to grow but rots before emergence	Usually dry	Bud
Post-emergent	Wilt	Cephalosporium (mainly) Rhizoctonia Pythium Himantia	Sett mainly  Soil mainly	Shoot attains a few inches high, then dies off. Roots show absence of feeding roots, or even die back to the sett	Wet	Shoots and roots
	Root Rot	Rhizoctonia Pythium	Soil	Shoot grows normally till adverse conditions are encountered e.g. dry spell and then growth is checked abnormally. Roots lack feeding branches.	Bad soil conditions generally (excess nitrogen accentuates root rot once it has begun)	Roots

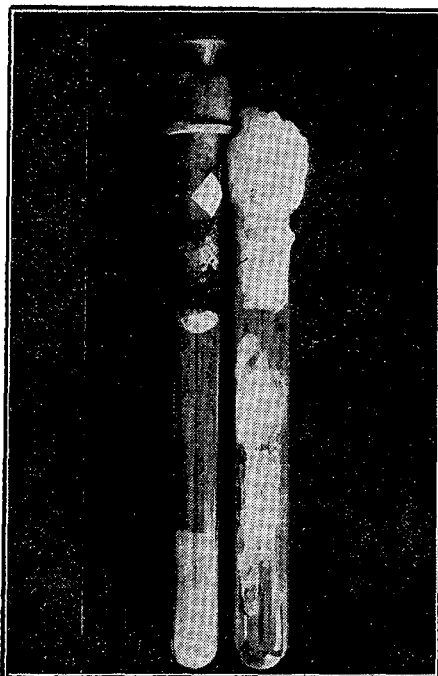
**Note.**—The descriptions given above only apply to the most typical forms of these diseases; under actual field conditions the distinctions are not so sharply marked, as usually a combination of disease producing organisms are at work. Usually, also, by the time a sett is dug up and examined, its tissues have become overrun by secondary organisms, rendering diagnosis of the original pathogen difficult. This is especially the case where rotting has been due in the first instance to internal causes, as when such setts are examined, invading organisms from the soil are usually found also.

TABLE II.

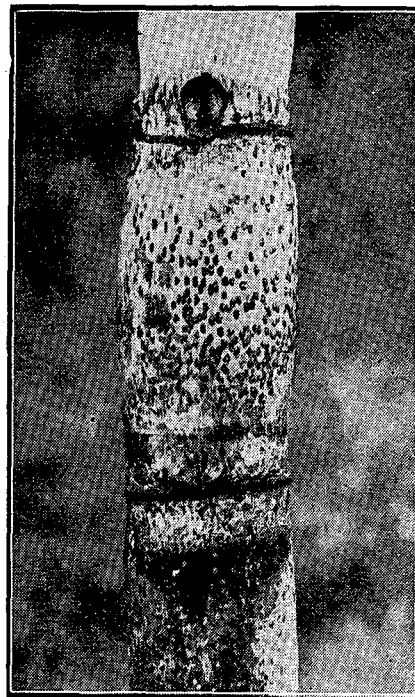
EFFECT OF SETT AND SOIL TREATMENT ON THE POPULATION  
OF YOUNG SHOOTS.

Treatment.	Number of buds planted.	Primary shoot development 2 months after planting.		Tiller development 2 months after planting.	
		Total Number	% of number of buds planted.	Total Number	Average No. per primary shoot.
<b>Setts treated before planting.</b>					
Organic mercurial compound A .. . . .	288	157	54.5%	381	2.4
Organic mercurial compound B .. . . .	288	176	61.1%	84	0.47
<b>Soil treated before planting.</b>					
Formalin .. . . .	288	112	38.5%	231	2.06
Cresylic acid .. . . .	288	86	29.8%	155	1.70
Control .. . . .	288	85	29.5%	79	0.9
Significant error of difference at 19 : 1 odds .. . . .		40 shoots	13.9%	87 shoots	

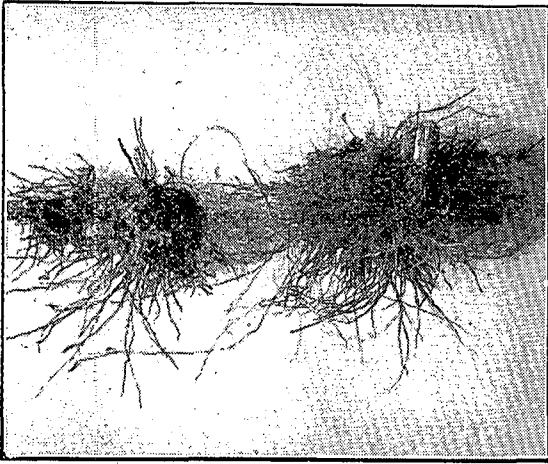
Variety used Co.301: Soil type—Poor sand overlying clay: Rainfall from time of planting (30/12/36) till first appearance of primary shoots (18/1/37)—0.73 ins.: till above counts were made—8.10 ins.



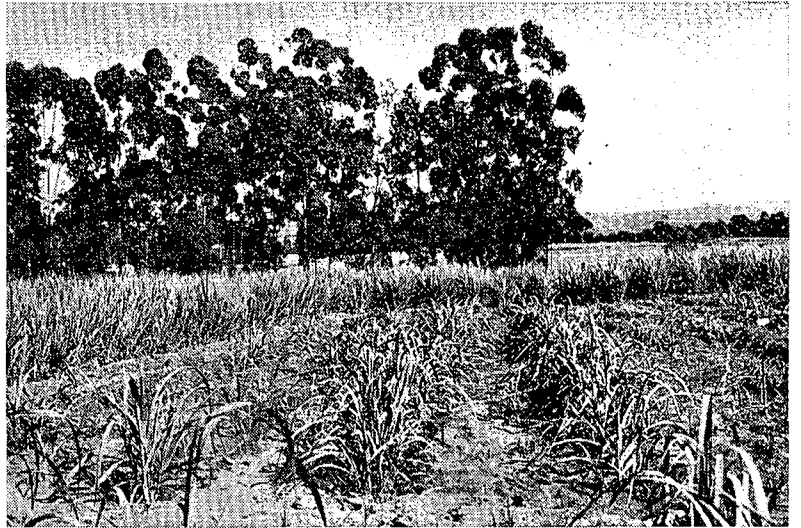
The tube on the left contains a slice of cane from the inside of a healthy looking stem placed on culture medium under anaerobic conditions; that on the right contains a slice from the same stem placed under aerobic conditions. Note the fungoid growth on the latter, and the absence of it on the former.



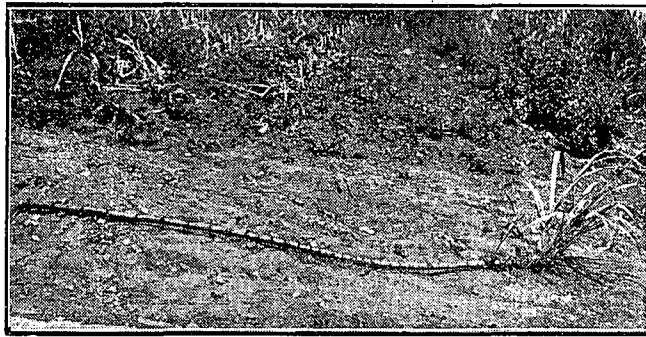
Stem showing the black spotting caused by Rind Disease.



The roots on the left have been subjected to the attack of root-pruning fungi to a much greater extent than those on the right. Note the much greater development of branch roots on the latter.



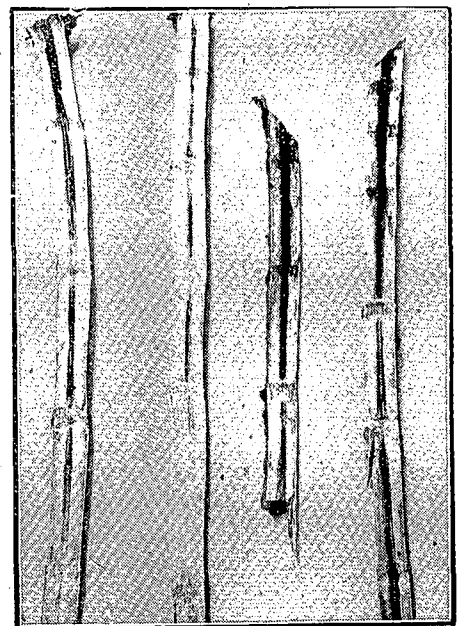
The two rows of plants in the centre foreground grew from cuttings treated with an organic mercurial compound prior to planting, while those on either side were untreated. An exceedingly dry spell was encountered after planting, and many of the buds on the untreated cuttings were destroyed.



Sugarcane stem which was planted complete, showing the development of the buds at the top only. (Although cutting the stick incites the lower buds into growth, the top always remains the most vigorous).



The rows in the centre were planted with the bottoms of stems, while those on the left of the figure were planted with tops. Note the poorer growth in the former.



Cuttings split open to show the internal symptoms of Pineapple Disease.

Mr. WATSON: Mr. Chairman, I would like to ask Dr. McMARTIN for an expression of opinion on two points arising out of his paper. In detailing the various methods of control suggested, it is not altogether made clear whether the sterilizing method is held out as being practical on a large field scale. I feel myself at first glance that, especially with the question of partial soil sterilisation, it could only be possible on small plots of some particular type of cane that one wants to get an excellent germination from, and that it will never be applicable to field scale.

The other point I would like him to express an opinion on refers to a report reviewed in the International Sugar Journal some months ago now, which describes a method used in Louisiana of promoting vigorous growth from a sett by removing the top before the sett is severed, allowing partial growth to commence in the buds before the sett is planted. We have seen that report, and we have started to try out the scheme at Tongaat, and we feel that we have been to a certain extent successful in getting a more rapid and higher percentage of germination; in fact we have extended that idea to using 18 months old cane for planting material removing the top and leaving it for a few days until the buds have made a little growth, then removing one cutting; repeating the process further down the stick. We have got no evidence of the success of applying that principle to the lower internodes of the cane. The indications are that germination is improved quantitatively and also speeded up by removing the top several days before using the plant for planting. The time that elapses between removing the top and planting seems to depend a great deal on weather conditions at the time, and varies from as little as three days to as much as seven or eight days before the bud is in a suitable condition to plant.

Dr. McMARTIN: On the first point, the practicable application of soil sterilisation, if you look on page 130 I say under (3), "It is felt, however, that even if results were obtained, the method would be an expensive one and in practice impossible to carry out, at any rate with our present knowledge of soil sterilizing substances." We can show results by sterilizing soil, but we would not be justified in recommending planters to use formaldehyde, for example, on a large acreage.

On the second point, the removal of the top I was aware that such a practice was adopted in other countries. I did not mention it here because I had no experimental data myself, but I see no reason why it should not be tried.

Mr. COIGNET: I am very interested in the improvement of the hygienic conditions of the soil. In Mauritius a very good practice of putting in the furrows a certain amount of molasses with a view to partial sterilisation of the soil is carried out.

Mr. BOOTH: Experiments I have done in a small way bear out, to a large extent, what Dr. McMARTIN has been saying concerning the vigour of the young cane before planting. For two or three seasons I have demonstrated that it is possible to plant cane in the beginning of October, cut that cane in January and plant it again, thereby doing what Dean Swift says, making two blades of grass grow where one grew previously. Developing that idea is an economic problem, and it leads up to a subject on which I was conversing with Dr. McMARTIN some time ago, the economic idea of establishing nurseries of cane to supply planting material.

I make a practice of cutting young cane, and soaking it in lime water. The cuttings of cane are left for 24 hours in lime water and then planted out, and being next to the factory, I use no bought fertilizers; I only use molasses. I have taken pieces of cane off a field which has been stripped for planting, when people take off so-called tops for ease of transport, and I have planted those after soaking with lime and have got a magnificent crop. The whole thing is an argument for seed cane plantations.

Mr. MURPHY: Mr. Chairman, I wonder whether Dr. McMARTIN would care to tell us what effect, if any, has the burning of cane against the non-burning of cane with regard to the sterilisation of the soil?

Dr. McMARTIN: I think actually that the temperature reached by the soil due to a cane fire is not nearly sufficient to cause any partial sterilisation at all.

Mr. LINTNER: In connection with that last question, it had occurred to me three years ago. I took maximum and minimum thermometers and placed them from one inch to seven inches below the surface of the soil, covered them over, and various types of fire were put through the cane subsequently. I repeated the experiment several times, and I may say that I never registered one degree difference on any of the thermometers in the soil. I would like to draw attention to the nutritive level of the soil in connection with the growth of cane cuttings. Various fungi, Dr. McMARTIN has pointed out, develop under wet conditions. On one occasion I had opportunity to have a pretty good observation of a condition of that description on a fertiliser experiment which I laid down at Ginginhlovu, which I think Dr. McMARTIN saw. There were increasing levels of fertility on very badly waterlogged soil, and you could actually walk up the furrows without any knowledge of the direction of the fertiliser treatment, and as the fertiliser increased so there was a better stand of cane, which I believe was attacked by *Cephalosporium*.

Secondly, I would like to ask Dr. McMARTIN his opinion regarding the possibility of crop rotation

on the coast with the possibility of a restriction of the cane area. It is possible to envisage in the future some sort of short low pasture crop, or something of that description, in rotation with cane. But meantime that has not come about to any great extent, and we have got to look at it from another point of view, the possibility of getting increased yields perhaps by rotating the varieties of cane. Do you think that by rotating different varieties of cane over a given area—the same area—one would benefit by any of the partial effects of crop rotation?

Thirdly, does this question of the possibility of the toxic effects of heavy fertiliser applications interest you? This was already referred to yesterday, and I pointed out that I did not think that the fertiliser in this country would in any way affect the soil to such an extent. Therefore I would like some sort of lead as to what the opinion is about the amounts that would be toxic when put in direct contact with young roots and shoots.

Dr. McMARTIN: In reply to Mr. Lintner on the question of crop rotation, we have as yet no data to support such a statement, but purely as a personal opinion I do feel that some benefit could be derived from the rotation of varieties if we cannot rotate crops. By, for instance, growing these new varieties after Uba, we don't know how much of the improvement we get is due to the fact that they have different root systems, perhaps less susceptible to the micro-organisms which have been accumulating in the soil growing Uba for a generation.

With regard to the question of fertilisers and cane growth, I do not think any fertiliser applications given in Natal are likely to do any damage to the setts.

Mr. DODDS: On the tour of the International Society of Sugar Cane Technologists in Queensland, we saw a most remarkable demonstration at Bunderberg Experiment Station of what is com-

monly called "sick" soil, that is soil which, for some reason or other, will not grow cane any more, having been growing cane for many years, and this field demonstration showed that fertilisation would not help in such cases. There were a certain amount of improvements brought about gradually by a change of variety, when P.O.J.2878 was substituted for P.O.J.2813. There was a remarkable improvement merely by changing over to a new variety. The biggest improvement of all was where sterilisation of the soil had been brought about, in this case by heat treatment. Still, sterilisation on a big scale is not very easily brought about. But the method which occurs to one as the most practicable is treatment with molasses, which, as we know, brings about partial sterilisation of the soil. I have no doubt the beneficial effects due to the application of molasses is largely due to this.

Among many interesting points brought up in this paper of Dr. McMartin's, I am particularly interested in what he has to say about the kind of material that one should use for planting. This crops up every year on the periodical visits of the Experiment Station staff to judge cane at the country shows, or in Durban. We give the preference in the competitions of cane for planting to the material which has long internodes and very often the planters question this decision, since there are so few buds to stalk in this cane. But evidently it is a case for quality rather than quantity of buds. We have been accumulating a certain amount of information and experience about the best material for planting at the Experiment Station. We have, as you know, during the past few years, been sending out cane for planting on a considerable scale. Whatever may be said regarding this form of activity for an Experiment Station—and there is a good deal to be said against it, at all events it helps to give us experience in what forms the best planting material, and that idea that I have just expressed about the longest jointed canes being the best I think has been amply confirmed.