BOTANICAL STUDIES OF THE CANE PLANT

By A. McMARTIN, Ph.D.

The following paper is an attempt to show how a knowledge of the habits and development of the cane plant, considered from the botanical point of view, is an aid in understanding the cultural requirements of the plant, and how an appreciation of the differences in the different varieties of cane throw some light on their different behaviour in any locality.

As long as only one variety was being cultivated, this question did not arise, but with the introduction lately of different varieties, the suitability of one or the other for a given area is of prime importance.

The first stage in growth is the "germination" of the planted sett. This implies, generally speaking, the growth of roots from the sett—the sett roots—of the buds, and lastly the production of roots from the base of the young shoot—the shoot roots. The relative importance of these two types of root is worth considering in detail, as it sheds some light on not only the question of good "germination," but of the ultimate type of stand produced.

It is commonly seen in a stick of growing cane that when the buds, for some reason or other, such as damage to the growing tip, are stimulated into growth, the first buds to grow are the top ones; and their order of development is from the top downwards. On the other hand, when rooting is caused, this usually occurs from the bottom upwards. This common phenomenon, known as polarity, is well seen in many plants when propagated by cuttings; under such circumstances the top end of the cutting gives rise to buds, while the bottom end gives rise to roots, even if the cutting be planted upside down.

The same phenomenon can be seen in a stick of sugar cane, when used as a cutting, although to a much less marked degree. The first roots to develop are usually those at the bottom of the stick, and their order of development is from the bottom upwards, while at the top portion of the stick the buds usually grow first, and the roots later. The same applies to a stick cut into pieces. The bottom pieces tend to develop roots before buds, while the reverse holds for the top pieces. The effect of cutting is to hasten the development of the buds in the lower portions of the stick, the top buds in each cut piece usually starting into growth earlier than they would have were the stick still complete. It should be noted that polarity is only noticed in the very earliest stages of growth, the development of both roots and shoots usually being quick enough soon to mask the order in which they have been produced.

Under ordinary circumstances it does not seem to matter whether roots or buds develop first at any particular node, but although a bud can start into growth without the roots having developed, for its continued growth the latter seem essential.

The next stage in growth is the production from the base of the young shoot of its own root system, a process which seems to require in the first place the presence of a sett root system. Attempts to cause root production in young shoots cut off from the setts have so far failed, except when the shoot is cut off with a piece of the node including one or two sett roots.

In many cases in the field where a poor stand has been obtained, or "germination" has been reported a failure, it has been observed that development of both roots and buds have actually occurred, but that if owing to unfavourable conditions the sett roots die prematurely, before the shoots are large enough to produce their own root system, these shoots die. It will be realised that this condition obtains more readily at the bottom end of a stick, where, as was pointed out, there is the tendency for the roots to develop before the buds, and in a variety, such as Co.290, whose root system is susceptible to root troubles. A common cause of failure to secure a stand in this variety is due to the sett roots just growing a little way before rotting off, and before the buds are sufficiently developed. In the top portions of the stick, however, where the tendency is for the buds to develop first, they stand a better chance of having a functioning sett root system at the time of production of their own shoot roots, and hence can become established.

Differences in the manner in which the sett roots are produced can be seen in the different varieties. Broadly speaking there are two types; the P.O.J. canes produce the majority of their roots early and then the process slows down; the Co. canes and Uba produce their roots over a longer period, not so many developing at a time as in the P.O.J. canes.

Up till the time of production of its own shoot roots, the young shoot is living on the food supply of the cutting, hence the importance of the amount of the latter in the early stages. Experiments show that the size of the first shoot from a node can be influenced by the amount of internode on the cutting—the longer the latter, the better the growth of the former.

A vigorously growing young shoot soon sends out its own root system, and eventually becomes independent of the parent stick. These roots differ in structure from the sett roots, in that the latter are thin, much branched, and occupy a superficial position in the soil, whereas the former are thick and pursue a more downward course into the soil, going in some cases considerable distances before branching. The amount of branching of these is also much less than in the sett root, their function apparently being more that of anchorage, whereas that of the sett root is of absorbtion. The bulk of the absorbing root system is formed later from the base of the shoot by roots which in appearance are more like the sett roots—they are much branched and occupy a position nearer the surface of the soil than the anchoring roots, spreading out more horizontally than vertically. While this process is going on, of the establishment of the shoot root system, the sett root system gradually ceases to function; they are only temporary, and play no lasting part in the root system of the stool.

The earliness and vigour with which the first shoot roots are formed appears to play an important part in the ultimate growth of the shoot, any factor causing non-development of the former, or impairing their growth, having a marked effect on the rate of growth of the young shoot.

Though a shoot appears able to live for about two months without shoot roots (provided sett roots are present) its growth is enfeebled, and unless its own roots develop, it ultimately dies. It is thus seen that the vigour with which a stand of cane is established is correlated with the vigorous development of shoot roots, and as has been pointed out, their development in turn is correlated with the presence or absence of sett roots at the time the bud is developing, a condition which is fulfilled more easily at the top end of the stick than at the bottom.

We will now proceed to consider the development of the stool as a whole from this point onwards, but before doing so, the development of a single stick will be outlined.

A bud contains a young shoot, in an embryonic condition, with miniature leaves and joints, and protected on the outside by a few small leaves which have become waterproofed to keep the tissues within from drying out. Development of the bud simply consists in the enlargement of these already existing leaves and elongation of the internodes. Continued growth in length of the shoot is by elongation of the internodes behind the growing point, where they are formed as a series of thin flat discs. Comparing leaf growth with stem growth, a definite sequence of events is followed. The leaf blade first elongates, while the sheath remains short; the rate of elongation of the latter, however, once it has begun is very rapid, so much so that it attains its full length just a little time after the leaf blade has attained complete development. The elongation of the internode next follows. In any internode the rate of elongation increase up to a maximum and then decreases; at the same time the internode above has begun elongating, so that at any one particular moment a number of internodes are elongating at different rates. With the cessation of growth due to soil, climate, or pathological conditions, the leaf blades which have elongated are no longer pushed upwards, so to speak, by the elongation of the organs bearing them, and the top of the cane assumes a characteristic fan-like appearance. As the elongating internodes are still ultilising food materials manufactured in the leaf for their growth, sucrose accumulation in these joints is slow; it is, however, continuous, so that by the time the leaf has become dry, the internode is almost mature and has become a storehouse for accumulating sucrose. Due to this, the amount of sucrose in any one stick is influenced by the proportion of internodes bearing green leaves to those bearing dead leaves.

Passing on now to examine the stool as a whole, it is convenient to consider separately for the present the three sets of organs—leaves, stems, and roots.

The leaf is the assimilating system, i.e., it is the factory which manufactures the food material for the plant; the root is the absorbing system by which plant foods and water are taken in, and the stem is the means of communication between these two, as well as serving as the store in which the manufactured material has to be kept.

It is obvious in the first place that a good leaf area is necessary for a vigorous plant, but another important factor is the effect of leaf area on the root system. It has often been shown, and in grasses especially, that a poor leaf area leads to a poorly developed root system; as also, however, a poor root system causes a poor development of leaves, there seems to exist between the two a certain correlation, conditions which affect the one indirectly affecting the other. Varietal difference in leaf type is also of importance, especially with regard to the orientation of the leaf in respect to the stem. It has been shown with many plants that between leaves which are erect and leaves which are horizontal or drooping there are differences in temperature, in water loss, and there is the additional fact that a spreading leaf exerts a greater shade and affects the evaporation from the soil beneath as well as cutting off light and exposure, and creating unfavourable conditions for weed growth.

As regards the stem, the point it is most profitable to discuss is the branching habit of sugar cane.

When the first shoot has emerged from the node, it sooner or later produces side shoots from the bottom buds just beneath the soil surface. These in turn produce their side shoots, until a clump of shoots is formed, consisting of parent, daughters, grand-daughters, and so on.

That there is a limit to this process is obvious, as if side shoot formation occurred continuously at the rate at which it proceeded when the cane was young, the stools would grow to a much greater size than they do. What are the factors operating to limit the size of the stool? In the first place heredity plays a part, as there seems to be a definite limit to which any variety can tiller.

Barber[1] showed the difference in tillering capacity between different types in the following table, where A, B, C, D, E, and F represent the shoots of the first, second, third, etc., order, and the figures the number of canes in each order.

	A	B	C	D	E	F
Wild Saccharums ..	1	2	3	3	2	1
Saretha class	1	3	5	3	1	—
Sunnabile class.. ..	1	5	5	1	—	—
Thick tropical canes	1	3	(1?)	—	—	—

He further states that branching is a primitive character.

Other factors which operate are those connected with the growth of the stool at the time tillering is proceeding. For instance, the vigour of the parent shoot influences the number of daughter shoots, so that a good healthy first shoot is conducive to good tillering. The conditions governing the vigour of the first shoot have already been pointed out. The number of tillers increases up to a point, after which the new ones die as they come up, thus leaving the number of stems on a stool more or less constant. The fact that on the outside rows of fields, or in isolated stools, the number of shoots usually rises to a higher maximum suggests that one of the factors controlling tillering is light and exposure, the reduction of which by the formation of a canopy creates unfavourable conditions for the continued growth of the young shoots.

It may be said that the tillering of a cane depends on two sets of factors (1) its capacity to tiller, depending on its hereditary constitution, and (2) its ability to do so, depending on conditions obtaining at the time of tillering.

Apart from number of tillers, varietal difference is seen in the rapidity with which they are produced, some varieties producing an early flush of side shoots, and then loosing large numbers of later formed ones, whereas other produce them more slowly, and with a smaller mortality.

It is during this time, i.e., till tiller formation has reached its maximum, that the foundation of the crop is being laid, and the bulk of the crop which will be cut is that being formed during this period. The sequence of events then, from germination to this time, is probably the most critical in the life of a field of cane.

The root system is the least known of any part of the plant, due to the difficulty of studying the system in situ. More attention has been paid in recent years, however, to this important aspect of plant growth, and studies in the root structure of sugar cane have been carried out in several countries.

As was stated previously, the first roots to be formed are sett roots, which are more or less superficial in the soil and their structure suggests high absorbing capacity; they are only temporary. The next roots to develop are those from the bottom of the young shoot. They penetrate to the deeper layers of the soil, and can go a long way without any appreciable branching. Then from the shoot another set of roots is produced, which occupies a more superficial position, is much branched, and constitutes the surface feeding system. This process of root formation is continuous throughout the life of the cane, each new shoot forming its own root system. The net result is a root system consisting, as far as position in the soil is concerned, of two types—the surface root and the deep root—the former largely feeding, the latter largely anchoring.

It will readily be understood that the former type will be influenced very easily by changes in moisture content, which affect the top layers more than the lower soil layers, whereas the latter, while tapping the soil water and nutrients to a greater depth, will be more influenced by subsoil conditions.

Differences in structure are seen in these root types, the anchoring roots being thick and fleshy, whereas the feeding roots are thinner and more fibrous.

Varietal differences are very pronounced, both in the proportions of the types formed, and in the nature of the roots themselves. The P.O.J. varieties at present cultivated here produce a large number of surface feeding roots proportional to deep roots, whereas the Co. varieties and Uba produce a large number of very deeply penetrating roots. Varietal differences in the nature of the root consist of variations in thickness, in toughness, and in degree of branching.

The preceding is an outline of some of the more salient features of the development and habits of the cane plant, and it is proposed now to attempt to apply some of the points raised to a consideration of the differences between the varieties of cane now being grown.

Uba.—This is characterised by its very extensive root system. A very well branched surface system is accompanied by a large development of deep roots, which compared with other varieties are thinner, and tougher. It is probably this extensive root system that confers on Uba its drought-resisting powers.

Co.281.—The erect foliage admitting plenty of light between the rows enables weed growth to proceed, and at the same time the surface soil to be subject to evaporation. Tillering is slower than in Co.290. The erectness of its leaf and the comparative ease with which it curls probably acts as a check on excessive water loss, while like Uba it has an extensive root system which taps all soil layers, going down to considerable depths. The root system is hardy and resistant to root troubles, and usually little difficulty is experienced in obtaining a stand of this cane.

Co.290.—The drooping leaves cast a dense shade, hence reducing weed growth and at the same time probably accounting for the large loss of young side shoots noticeable in this variety. For the same reason the surface soil is not so subject to evaporation, and it may be that this is a contributing factor to the superiority of this variety over Co. 281 in a light sandy soil. The root system is built on the same plan as Co.281, but it is not so extensive. The deep roots are thicker and fleshier, more liable to break, and not so resistant to root troubles. The ease with which its sett roots rot render it difficult under adverse conditions to obtain a good stand with this cane.

P.O.J.2878.—The bulk of the root system of this variety is of the superficial, feeding type, deep roots being few, and render it unsuitable for any but the best type of soil, and for droughty conditions, but well adapted for irrigation; under these conditions the greatest number of roots are in a position to respond to an increased water supply. This shallow root system, together with the fact that the surface roots are rather thin, probably account for the ease with which this variety is blown over.

P.O.J.2725.—The root system in this variety is somewhat similar to the last, except that the surface roots are much thicker, are more profusely branched, and the deep roots are markedly branched. It has a much more satisfactory root system, and therefore its demand for the best soil is not so pronounced as P.O.J.2878. Being a superficial feeder, it naturally is not suited for light soil, but will respond to irrigation.

These foregoing notes show that in dealing with the new varieties of cane we are dealing with plants built along different lines, and that a knowledge of these differences is an aid towards understanding their different behaviour as regards soil type, water requirements, etc. It can not be expected that all varieties will do equally well under any given set of conditions, and it is not reasonable to condemn a variety as worthless because it has been planted under conditions to which, owing to its habits, it is not suited.

Reference.

[1] Barber, C. A.—Studies in Indian Sugar Canes, No. 3. Mem. Dept. Agri. India IX., 4, 1918, p. 133.

Experiment Station,
South African Sugar Association,
Mount Edgecombe,
Natal.
March, 1936.

The CHAIRMAN: This is another very interesting and instructive paper. Dr. McMartin spoke of its somewhat elementary nature. Perhaps it is so to him as a botanist, but I must say it contains lots of new and valuable information to most, if not all of us. There are many interesting points that have occurred to me during the reading of the paper. Dr. McMartin mentioned that germination was not, strictly speaking, the correct term to use for the beginning of visible growth from a sett, or cutting, as distinct from seed. I would like to know if there is any more precise technical term that one could use.

The cutting of the setts into pieces is done, as you know, in practice for various reasons. and I would like to know whether there is any justification for it from the aspect of polarity, that is to say whether it is more conducive to getting a complete shoot and root system from each separate node if the pieces are cut into sections. or whether it makes no difference. I have heard some planters say that there is a tendency for a cane planted as a whole, without being cut into pieces to develop roots and shoots only at one end respectively, and form only one new plant, instead of one from each node. I don't know whether there is any scientific foundation for that statement.

I welcome what he says about the size of internodes in setts used for planting. Those of us who act as judges at agricultural shows are in the habit of awarding prizes for plant cane to those specimens competing which show the longest and most vigorous internodes, and sometimes the reason for that is not altogether appreciated by the planter. I am glad to see it stressed and explained in this paper.

The comparison of canes of the different varieties at the end of the paper is also of very special interest, particularly with regard to Co. 281 and Uba. We have found that these varieties both show a high degree of resistance to drought, but that Co. 281 is decidedly superior to Uba in its drought-resisting properties. I would like to know if there is any suggestion of that in the root composition of the plants. Also I would like to enquire what the physiological indications are concerning the relative drought resistance of Co. 301.

I welcome also Dr. McMartin's warning and remarks about the planting of varieties in unsuitable localities. Unfortunately there has been a lot of that during the last year or two. Varieties have been planted in places where they could hardly be expected to give the best results, where a better choice of varieties might have had much more satisfactory results, and the variety has been blamed where really it is the judgment and selection of the planter that is at fault.

I have no doubt you will have many other points from the excellent paper to enquire about and discuss.

Dr. McMARTIN: Concerning the point raised by Mr. Dodds with regard to the term "germination," as I said, germination should, strictly speaking, only apply to a seed. I can think of no other term applied to a cutting. We usually speak simply of the growth. or development, of a cutting.

As regards the cutting of setts into pieces, I definitely do think that the stick should be cut, for the simple reason that it stimulates, as I have said, the lower buds into growth more quickly than if the stick is uncut. Also I have found sometimes as so many planters maintain, that if the stick is uncut there is a tendency for the top buds to develop at the expense of the lower ones.

The difference in drought resisting properties of Co. 281 and Uba I would not like to attribute merely to the type of root system. We have not done yet any detailed quantitative work of the root system of these different varieties. As far as I can see Co. 281 and Uba are built more or less along the same lines. I think if Co. 281 is more resistant to drought than Uba we must look for some reasons in addition to root structure. It is hardly fair, I think, to be asked at present to give a statement on varieies such as Co. 301 about which we know really so little; but from the little work I have done on the root system, I suspect that in the first place it is not quite so resistant to root troubles as Co. 281, but perhaps more resistant than Co. 290. We have had one or two cases in plots at the Experiment Station, where it has shown slight susceptibility to root trouble, but I am not so sure that had Co. 290 been planted under similar conditions, the plants which in Co. 301 show root trouble, in Co. 290 might not have grown at all. It is a good tillering variety. It tillers early and so far as I know does not lose its side shoots to the same extent as Co. 290. I think that is all I can say about Co. 301.

Mr. RAULT: I should like to put a question to Dr. McMartin when he deals with the sucrose formation by the plant. You have mentioned, as we all know, that the leaf is the laboratory where the sugar is formed and then sent to the stick, to the internodes. You finish up by saying "Due to this the amount of sucrose in any one stick is influenced by the proportion of internodes bearing green leaves to those bearing dead leaves." Does that mean to say that in a year like the past one when we had a higher sucrose, you think that we must have had leaves keeping green longer than the year previous, where we had, according to our figures, just as much rain. and where, I think. the leaves kept green, and still the sucrose in cane was very low Although it was said that the locusts had a lot to do with this by eating the leaves, and in bringing the sucrose down, we found in our district we were not affected very much by locusts, yet the sucrose in cane was very much lower during the previous year than during the past year. Has it to do with sunshine? A very strict account is taken of the hours of sunshine, and certain conclusions drawn from those conditions in explaining the rate of sucrose formation. We seem to find the loss of sucrose formation very obscure, as you have mentioned, and perhaps by a botanical study of the cane and its behaviour during the season you may be able to tell us why sucrose is higher one year than it is in another year.

Dr. McMARTIN: I agree with Mr. Rault that the sucrose of the cane is governed by very obscure causes, probably mixed up with the climatic factors, such as sunshine and moisture. It seems that the sucrose in any one particular joint would be governed by the difference in rate of accumulation and rate of utilisation of carbohydrate. In a growing joint which is being supplied carbohydrate from an actively functioning leaf, the material being supplied is being used up for the growth of that joint. When the joint becomes matured and the leaf becomes dry, the carbonhydrate is still being supplied to it, possibly from other leaves higher up, but as growth is finished, utilisation decreases and accumulation in the joint increases, and so I say that the green leaf area on a stick probably influences the sucrose in the stick, and this area is no doubt correlated with the growth conditions prevailing at the time, which may be excess moisture. Such a condition as Mr. Rault referred to, when last year there were no locusts on his cane, but there was low sucrose, may have been simply due to tne cane continually growing.

Mr. LINTNER: A point which interests me greatly is where Dr. McMartin points out the correlation between leaf area and the root. From what he said one would gather that the application of nitrogen would enhance the root system. and vice versa, with an application of phosphate one would assume you would get a corresponding increase of the leaf area. But in grass my experience in this country has been absolutely negative in that matter. You get no response from phosphate at all—not anything noticeable.

Dr. McMARTIN: I cannot say, I am afraid, what the effect of phosphate is, but I to know that on some of our soils here, especially sandy soils deficient in nitrogen, an application of nitrogen is immediately followed, even in the sett roots, by a vigorous development especially of the branching type of root.

Mr. COIGNET: I wish to ask whether a definite rotation of varieties could not be adopted, as distinct from rotation of crops. As soon as a new variety is grown in a new area, there is a more vigorous growth then if the same variety is planted for years and years.

Dr. McMARTIN: Yes, I think that it ought to be the policy of the Experiment Station to introduce more than one variety for any particular locality. It we cannot follow out a crop rotational system, which seems to be based on sound agricultural practice, I think it would be a good thing if we could have a rotation of varieties, due partly to the fact that the different varieties have different root systems: also in view of any possible deterioration of a variety caused by too-long planting in the one area, perhaps due to accumulation of soil fungi, which can become under certain circumstances parasitical on the cane roots. It has been shown, for instance, that some fungi evolve certain physiological races which can adapt themselves to one variety of plant. Therefore it is of value simply to change the variety and substitute a plant which has a root system to which this particular strain of root fungus has not adapted itself.

The CHAIRMAN: If there are no further questions, I will ask you to accord a very hearty vote of thanks to Dr. McMartin.

The CHAIRMAN: Before we begin, I would like to accord a very hearty welcome to our visitors, Dr. Van Zyl and Mr. Cutler, of the Division of Chemical Services, Department of Agriculture and Forestry, Pretoria, and Mr. Taylor, chemist and Acting Principal of the School of Agriculture at Cedara. Mr. Cutler has kindly given us a paper, which has been stencilled and copies are available. We have rather a heavy programme this morning for a single session, so I will now call upon Mr. Beater to read his paper on Soil Investigation.