SUGARCANE YIELDS AS INFLUENCED BY CROP DEVELOPMENT

By A. McMARTIN.

It is usually assumed that the early stages of a crop play some role in determining the ultimate yield, but to what extent various factors which influence early development produce effects which are maintained till cutting time is not always quite obvious.

The following observations are of the nature of a summary of data collected over several years from experiments in which a study has been made of germination, tiller formation, and yield.

Arising out of these studies, the use of a fungicidal dip as a pre-planting treatment for cane setts has been recommended as being the means of producing the biggest improvement on a stand of cane under our conditions.

In the present paper some of the other factors which influence the development of a crop will receive consideration. For a start, some basic properties of the propagation of cane from cuttings will be examined.

Regeneration in Plants.

A complete plant consists of three basic types of organ—roots, stems, and leaves—and the vegetative propagation of plants is made possible by the faculty possessed by many of producing missing organs when a portion of the plant is removed from its parent. Thus when a leafy stem is removed and planted, roots will be produced; or when roots are planted, buds are formed which develop into leafy stems. Portions of stems of some plants when planted without buds or roots can produce both. This property of producing, from new tissue, missing organs, to make a complete plant out of an incomplete one, is known as regeneration.

Polarity.

Regeneration does not proceed in a haphazard manner; the new organs are formed in a certain order. If we consider the plant as having a main axis, or axes if more than one stem is produced, as in sugarcane, and the portion where stems and roots meet as being the centre, it is seen that the youngest regions, where growth is taking place, are those furthest from the centre; these regions we refer to as the distal regions, and those nearest the centre of the plant the proximal regions.

When regeneration occurs now from a removed organ, buds develop at the distal end and roots at the proximal. This is so pronounced in some plants that stem cuttings must be planted with the distal end exposed and the proximal end in the soil; if inverted, buds develop underground and roots on the exposed end. It will be seen, further, that whereas stem cuttings are planted in the same position as they were growing originally, root cuttings must be inverted, to bring the distal region uppermost. This phenomenon, known as polarity, is further shown if a stem cutting, for example, is cut in smaller pieces —buds always develop at the distal end and roots at the proximal. The distal end of a cutting is thus the shoot pole and the proximal end the root pole.

With the sugarcane cutting, now, no true regeneration occurs, as the planted sett has buds and root primordia already formed, and waiting to develop. In their order of development, however, polarity is exhibited.

If a stem be planted whole, shoot development begins at the top, or distal region, and proceeds downwards, while root development begins at the bottom, or proximal end, and proceeds upwards. If, now, the cane is cut in two, each half behaves as the complete stem; similarly, cutting these halves further still preserves the orderly manner of development, in that the end of the cutting originally nearest the top of the cane behaves as a shoot pole, and the other end a root pole.

It should be noted that this does not mean that shoots or roots do not develop on the other regions of the cutting—polarity here refers to the order of development in time. Moreover, apart from this precision in the order of development relative to their position on the stem, the new shoots and roots develop in each sett in the same order of priority as that which would have been exhibited by that sett had it remained unsevered from the rest of the stem.

Thus, a cutting from the top of the stem not only develops shoots at the shoot pole first, but does so before roots develop from the root pole; while a cutting from the bottom of the stem develops roots from the root pole before shoots from the shoot pole. The intermediate portions exhibit transitional stages between these two extremes.

An exception is found in the very young immature nodes at the apex of the stem, beneath the youngest green leaf sheaths. Here very vigorous development takes place both of shoots and roots together.

This phenomenen of the precise manner in which the development of buds into shoots occurs is related to internal physiological conditions of the stem, principally those which arise from the inhibiting effect of one developing bud on another. It is a

common observation that as long as the apical bud of a growing cane stem remains healthy or undamaged, the lateral buds remain dormant, but that when the top is damaged, or checked severely in growth, development of the side buds begins, and from the top first. If these top developing buds are removed, the next ones lower down start into growth, and so on.

One explanation commonly accepted to explain this phenomenon is that bud inhibiting substances, of the nature of hormones, are produced by actively growing leaves which migrate down the stem and prevent the development of the buds in a proximal position. Thus the growing top prevents bud development lower down, but when removed, the next ones grow, and produce the inhibitors which prevent again the next lower ones from growing. It is also suggested that these bud inhibiting hormones are root stimulating ones, which accumulate at the basal end of the stem and incite the development of the root primordia into roots.

This inhibiting effect of one bud on another, or polar inhibition, can be overcome by cutting the stem into pieces, as in each piece the distal bud is free to develop without the inhibiting effect of the one above it. It is obvious also that by removal of the top of the cane the largest source of inhibitor is removed, as is seen by the fact that while in the standing crop the top completely prevents the development of lateral buds, in a cane sett the first developing bud does not prevent the development of the others, but merely retards them.

It was stated earlier that these hormones appear to migrate to the basal end of a cane stem; this refers to a growing stem, in a vertical position.

When the cane is planted it is laid horizontally, and in this position the hormones also migrate to the side of the sett which is now lowest. (This is a well-known feature of cuttings of other plants, where the root hormones accumulate at the lowest points of a horizontal cutting, and stimulate root development at these points.) If, now, the cane sett should be planted with one row of buds uppermost and one downwards, the latter are in the region of accumulation of the inhibiting hormones, and their development is more easily suppressed. Thus if a sett is planted with the top bud facing up, in developing first it inhibits the second bud, facing down, but allows the third bud, facing up, to develop next; the fourth bud, facing down, is nearly always completely inhibited. If the second bud faces up, it develops and inhibits the first and third. If, now, the sett is planted so that the buds face sideways, the normal order of development occurs, and the pronounced suppression of the buds facing downwards is removed. We may express the position thus : if the

buds are numbered 1 to 4 on a four-budded sett, their order of development is as follows :—

1. Top bud facing up—development order is 1-3-2-4.

2. Top bud facing down—development order is 2-4-1-3.

3. Buds sideways—development order is 1-2-3-4.

The last bud is nearly always completely suppressed.

Traumatic Response.

The division of the cane stem into pieces for propagation purposes involves the making of several cuts. In many cuttings, when a cut is made, regenerative changes occur at the cut end, leading to the formation of new tissue, which acts as a protective barrier, and among other functions prevents the entry of micro-organisms into the cutting. This response to wounding, or traumatic response, is well seen in cuttings which produce a callus at the cut ends.

With sugarcane, however, no new tissue formation occurs; indeed, traumatic response appears to be absent, so that the cutting has no efficient barrier to prevent micro-organisms gaining entrance from the soil. One possible defence may be the fermentation which sets up at the cut end, resulting in conditions on the wound which are unfavourable for the growth of soil organisms. Whether this be the case or not, it does not appear to be a very efficient means, as cutting decay is easily caused by organisms penetrating the wound. In fact, observation suggests that under Natal conditions one of the most common causes of failure of buds and roots to grow on a cutting can be traced back to the activity of micro-organisms destroying the cutting internally via the cut end.

Development of Tillers.

The shoot that emerges directly from the bud becomes the primary shoot, or mother shoot, of the group of canes which eventually arise from that bud, the others arising by branching from the base of the primary shoot. At the same time, roots are formed from the base of the shoots, resulting in these shoots eventually becoming independent of the sett and the sett-roots. The production of these shoot roots now are influenced to some extent by the manner of development of the shoots. As was stated earlier, the bud-inhibiting, but root-forming, hormones tend to accumulate on the basal regions, hence the buds which have developed from under the sett, and have curved round to emerge above ground, tend to produce roots more vigorously than those shoots on the top of the sett.

The most uniform shoot root development comes from those setts in which the buds have been planted sideways.

Thus the orientation of the sett in relation to the soil can determine not only the order of development of the buds, but the vigour of shoot-root production.

The number of tillers now which arise from primary shoots can be influenced by the development of these primary shoots. Each tiller arises from a small bud at the base of the primary shoot, hence the greater number of buds underground on the latter the more tillers can be produced. The length of underground primary shoot, and hence number of buds, in turn can be influenced by the manner in which it emerges from the sett. Thus a shoot which grows straight up from the sett has not so many underground buds as one which has to grow for some distance underground before turning upwards, such as a shoot which has to grow beneath a leaf sheath, when the trash is left on the sett, before turning upwards. Hence, leaving the trash on a sett produces primary shoots with long regions underground from which eventually a thicker crop of tillers emerge than when the trash is removed, permitting the primary shoot to emerge directly from the bud. The removal of trash, however, permits very much quicker emergence, and gives a much earlier crop of primary shoots. This aspect will be referred to again.

Germination under Field Conditions.

The developmental history of a cane sett into a young established plant as has been described applies to those growing under conditions in which all buds have a good and equal chance of developing. Under field conditions, however, this is not attained, and mortality of buds is higher. An investigation some years ago into the percentage of buds which grew showed that an average germination was only 26 per cent., reaching a maximum of over 70 per cent. under very favourable conditions. It was further found that germination of the buds on setts cut from the lower portions of a stem was 50 per cent. of that from top setts, and also that on a four-budded sett the germination from the two outside buds was only 50 per cent. of that of the inside buds. Thus, on a four-budded sett, the two inner ones have the greatest chance of survival, and of these the one that develops first is in the position of being able to suppress the other one. The higher mortality of the outside buds appears to be due to its proximity to the fermenting cut end, and possibly also to a certain amount of drying out.

The possibility of cut cane tissue when fermenting being toxic to buds was suggested by an experiment in which some cane stems were shredded and spread in a thin layer over the soil in pots in which setts were planted; in addition, another series was planted with the shredded cane mixed with soil, and a third had no shredded cane. The germination was as follows :—

Cuttings in soil alone	52 per cent.
Cuttings in soil plus shredded cane on surface	8 per cent.
Cuttings in soil plus shredded cane mixed with the soil...	2 per cent.

The toxic effect of cut cane tissue on germination now raises the question of the cutting of a cane stem into setts, as, obviously, the greater the number of setts cut from a stem the more fermenting surfaces are created; on the other hand, cutting counterbalances polar inhibition, and gives a larger number of buds a greater chance of developing, soil conditions apart. If a whole cane is planted—with, of course, the tops removed—the distal buds will become established, and if conditions are favourable bud development can proceed towards the proximal end; the latter buds will, of course, be slower, and if unfavourable conditions should be encountered may not germinate at all. At the other extreme, if a cane is cut into single-budded setts, all polar inhibition is removed, and all buds may grow with equal vigour; to obtain a good germination with single-budded setts, however, very good conditions are required.

This technique is regularly used in pot work, but has also been used successfully occasionally in the field where the best germinating conditions have been attained. For average conditions, however, it appears advisable to strike a compromise.

As was stated earlier, mortality of buds on the outside of a cutting may be high, so that only the inside ones should be counted as having a good chance of survival.

In a three-budded cutting this only leaves one, but in a four-budded sett there are two buds with a good chance of developing. For this reason, for conditions which, as they are frequently in Natal, are distinctly sub-optimal for germination, a four-budded cutting might be considered the average type for field planting. As was stated earlier, field counts showed an average germination of 25 per cent.—each four-budded cutting producing one shoot would yield this figure.

To investigate the effect on germination of setts planted in different positions, experiments have been carried out in which the setts have been dug up after germination was complete, and examined.

In one, recently completed, with N:Co.310, 1,200 four-budded setts were examined, and the following information was obtained : The total number of buds which grew, out of 4,800, was 3,730—about a 77 per cent. germination, which gave a very good stand of cane. Of these, setts planted with the buds sideways produced 1,267 primary shoots, with the top bud placed up 1,227 shoots, and with the second bud up 1,236 shoots. There was thus very little

difference between the different methods of placing the setts as far as total germination is concerned. It was obvious, however, by observation that the setts with the buds placed sideways had most roots on the young shoots. Taking the figures for the position of the bud on the sett, it was seen that out of 1,200 buds which were at the distal end of the sett 972 grew, while 1,099 second buds, 1,048 third buds and 611 fourth buds grew. Thus the highest germination was obtained with the two middle buds, and of these the second one produced more shoots. When poor germination is obtained, now, it is often found that the outside buds fail completely, and only one bud is produced, usually the one in the second position.

It has further been found that the effect of disinfecting a cutting is to give a greater chance to the end buds to develop.

This effect is additional to the use of disinfectants for the control of pineapple disease; when this disease is present, it can penetrate a sett so completely that the inside buds are as liable to decay as the outside ones.

Thus in one experiment with Co.331, which is extremely susceptible to pineapple disease, out of 400 setts only 85 grew when no disinfectant was used, and 180 of the dead setts showed positive signs of pineapple disease, while of disinfected setts 244 grew and only 14 showed the symptoms of that same disease. Of the untreated setts, the germination of buds was only 9 per cent., which consisted of 66 outside buds and 73 inside buds, while the treated setts produced a germination of 24 per cent., consisting of 218 outside buds and 164 inside ones; thus here the outside buds germinated even better than the inside ones.

It is interesting to note the relationship between primary shoot production and tillering. Figures showing germination percentages merely show the number of buds that grow, and do not take into account the rate in which they have been produced. The importance of this latter aspect of the subject was well shown in an experiment comparing the effect of different disinfectant treatments on the setts before planting. Here, untreated cane germinated to the extent of 29 per cent., while treatment with a disinfectant "A" increased it to 61 per cent., and with disinfectant "B" to 54 per cent. "A" thus appeared better than "B," but after two months the "B" plots in the trial had an average of nearly five times more tillers than the "A" plots. This was seen to be due to the slower rate of germination of the "A" treatment, although it ultimately reached a higher figure for germination percentage; the "A" treatment took twenty days to complete germination after the appearance of the first shoots, whereas the "B" treatment was finished in twelve days. If we divide the final germination figure by the number

of days to complete germination, giving a figure representing germination percentage per day, a figure which we might call the rate of emergence, the "A" treatment had a rate of emergence of 3 per cent., the "B" treatment of 5 per cent., and the untreated cane of 2 per cent.

If we divide the number of tillers by the number of primary shoots at two months, we see that "A" treatment gave a figure of 0.5, while that of "B" treatment was 2.4. It thus appears that figures showing germination percentage by themselves are misleading—the important figure is that of the rate of emergence.

The final outcome of germination, of course, is the stand of shoots produced, which appears to be at its maximum at from two to three months, depending upon growing conditions—hence the value of showing the total population of shoots at that time, as is now done in our trials in which various fungicidal treatments are compared one with another.

It should be noted that strict comparison can only be made between setts treated similarly as far as trash removal is concerned; as was stated earlier, the exception to the rule of quickly-emerging shoots tillering better is when the trash is left on, as these eventually produce more tillers, although slower in emerging.

An interesting observation was made, while examining the developing shoots from dug-up cuttings, on the relationship between the number of primary shoots developed per cutting and the number of tillers per primary shoot. One might imagine that if a cutting produced only one primary shoot, there would be more room and food material for the development of tillering than if, say, four primary shoots developed; examination, however, showed the following to be the case :—

Average number of tillers per primary shoot where one primary shoot developed, 2.5.

Average number of tillers per primary shoot where 2 primary shoots developed, 3.7.

Average number of tillers per primary shoot where 3 primary shoots developed, 3.6.

Average number of tillers per primary shoot where 4 primary shoots developed, 5.2.

Thus the larger the number of primary shoots a cutting produced, the greater the tillering.

The effect of disinfecting cane on this phenomenon was also of interest. Similar figures for cane treated with a fungicidal dip were as follows :—

Average number of tillers per primary shoot where 1 primary shoot developed was 4.7.

Average number of tillers per primary shoot where 2 primary shoots developed was 4.0.

Average number of tillers per primary shoot where 3 primary shoots developed was 4.4.

Average number of tillers per primary shoot where 4 primary shoots developed was 4.1.

Thus, not only does a disinfectant dip promote better primary shoot development, but it enables a more vigorous tillering to ensue from the primary shoots that are produced.

Germination, Tillering and Yield.

The final result of any attempt to produce a satisfactory stand of young shoots must always be judged in the yield of cane obtained. For this reason it is important to follow the course of development of a crop throughout its growth, and here contradictory results appear.

Whereas in some field trials an increase in germination has led to an increase in yield of cane cut, in others no such result has been obtained.

In one trial disinfected setts produced 40 per cent. more millable canes than untreated setts, while in others, again, the number of canes has been equal at cutting time whether the setts were disinfected or not, despite the fact that in the early months a marked response to the disinfectant dips was shown. Thus in one trial where disinfected setts produced almost twice as many shoots as untreated cane in the early stages of growth, during the winter months heavy mortality of shoots was observed, and the heaviest mortality was in the plots in which the largest number of shoots had been produced, so that the shoot population of the experiment was evened out. At cutting time 15 per cent. less canes were cut than young shoots were formed. This has been found in a few trials where shoot population counts have been made, viz. that the winter months act as a limiting factor on the number of shoots which a field can support; mortality during these months may be heavy, and if a larger number of shoots are produced by a young crop than can be supported by the conditions during that time, the numbers are reduced to a level at which they can be maintained. The most important single factor operating during these months is probably rainfall—in fact, it would appear from the trials carried out that where responses in final yield have been obtained due to an improvement in the stand of young cane they have been in years of sufficient rainfall.

Another important factor to consider is the effect of gaps in the field on yield, and the role of disinfectants in preventing these. Comparing experiments in which increased final yields have not resulted from an increased stand of young shoots, we find that in these cases few or no gaps were present in the untreated plots, i.e. the increase in young shoots was due to an increased primary shoot production in an otherwise even stand of cane. Where, however, gaps have been present in plots of untreated cane, an increase of 14 per cent. in final yield by disinfecting the setts has been obtained even under conditions of low rainfall. It seems obvious, then, that the relationship between early growth and final yield must be considered from two aspects : (1) the distribution of shoots throughout a field, and (2) the density of shoots, apart from distribution.

As has been said, a dense crop of young shoots in itself does not necessarily imply an increased yield, but it does seem important to obtain a stand in which gaps are reduced to a minimum. In other words, an even stand is probably more important than a dense one. The value of disinfecting setts, then, or any practice which aims at increasing germination, should aim rather at ensuring an even distribution of shoots, even if the stand at first appears thin, than at producing a dense crop of shoots, many of which will never reach maturity. If every four-budded sett produced only one shoot, there should be throughout a field one shoot for every twelve to eighteen inches, which would probably be sufficient, depending upon the tillering capacity of a variety and the growing conditions. It would appear that there is, for any set of conditions, a limit to the number of canes a field can support, and this in turn sets a limit on the number of young shoots which it is necessary to establish. This, in turn, determines the amount of seed cane to be planted, and experiments are being carried out in an attempt to determine the effect on yield of planting setts spaced out at different distances in the furrow.

It would appear, however, that as far as the effect on yield is concerned, very often more cane is planted than is necessary, in an attempt to attain a dense mass of young shoots.

Experiments have already shown that increasing the number of young shoots by planting double-stick as against single-stick has not led to an increased yield.

Factors other than yield, of course, require consideration. For example, the effect of an early and dense growth, by removing the trash from the sett and planting thickly, on weed growth is an important matter, and must be considered in relation to the cost of obtaining the yield. This may be particularly the case under conditions in which germination and early growth is normally slow—for example, in areas of high altitude, where competition from weeds is more acute in a young crop.

If, however, less cane could be planted than normally the practice at present, it ought to make possible the better selection of the material that is used for seed; in other words, the planting of a smaller seed rate per acre of well selected setts rather than a larger number of non-selected setts.

As was shown earlier, many factors pertaining to the cane itself influence the early development of the plant in the manner of root and shoot production, and it may be that under conditions more approaching the optimum for continued growth these factors are important. In Natal, however, the factors operating mainly in influencing the relationship between early growth and final yield, are those which allow excessive fermentation of the sett to proceed, or to become actually diseased, resulting in gaps. The avoidance of the latter is probably therefore the most important single item in establishing a field of cane under our conditions.

Summary.

Many factors influence the nature of a stand of young cane produced from setts. The early germinating phases are influenced by factors pertaining to the sett itself—its position relative to the complete cane from which it was cut, the manner in which polarity results in inhibition or retardation of bud development, the effect of bud placement in the ground on bud and root development, the removal of trash from the sett, being among important factors playing an important role in determining the number of buds which grow and their vigour.

The establishment of cane under our conditions, however, shows that bud development is often so poor that the effect of these is small compared with factors which preserve the sett in a good condition, and allow even only one bud to grow per sett. Further, it is found that a dense mass of young shoots does not always ensure an increased crop, as shoot mortality can occur during the dry months to such an extent that the beneficial effect of an early increased shoot development is lost.

Experiments indicate that distribution of shoots is more important than density, i.e. an even stand, although thin, is better than a stand which is dense in tillering but has gaps.

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The PRESIDENT drew attention to the results which showed depression in germination of cane due to shredded cane being mixed with the soil. He wondered what effect on germination would be caused by ploughing-in trash after the last crop had been harvested.

Dr. BATES said that the point raised was interesting, because in the case of other crops there was a harmful effect from such practice. The results suggested a pathological effect and this was of importance in sugarcane culture, which was essentially a monoculture practice in this country. It prompted the idea that pathological investigation of soils here might produce important resluts.

Dr. McMARTIN stated that it was well known that cane planted too soon after the ploughing-in of trash experienced a negative period, in which soil organisms competed with the cane, not only for nitrogen but also for oxygen.

There was also a disease factor to be considered. The effect was observed in the case of other organic matter, such as green manures like buchwheat or sunn hemp. This depression was temporary, and it was likely that benefit was eventually obtained from the organic matter ploughed-in.

Mr. MOBERLY asked whether the point at which the internode in a sett were cut was important. If the internode were cut immediately above the bud, could that bud be nourished by the internode below?

Dr. McMARTIN did not think the food material was restricted by the node. He said it was remarkable how little material was required to germinate cane. A bud could be planted with only a small piece of rind attached, and it would grow. It grew poorly, however, and not as vigorously as a bud with its attached internode. When planting under field conditions, even with single-budded setts, however, there was always a fair amount of internode available.

The PRESIDENT said that the author had mentioned that cane tops were very good planting material. He wished to know if differences were exhibited by different varieties in this respect, as he recollected that in the past it has been found that some top buds did not appear to be good planting material.

Dr. McMARTIN replied that the top buds of Co.301 were weak if the cane itself were young, and such material could produce uneven stands of cane. As far as he knew the tops of all varieties germinated well, but he was referring in particular to the green portion of two-year-old cane with the attached leaves. Such tops with about a twelve-inch sett made excellent plant material, and had been used satisfactorily in the whole of one year's planting on a large estate.

When setts were planted with trash adhering, the young shoots grew horizontally and tillers grew from the young internodes formed in these.

Dr. DODDS thought that since the distribution of the shoots was more important than the density, it followed that there was an optimum distribution in a given soil for a particular variety. If this were so, it would be interesting to study this under varying conditions.

Dr. McMARTIN said there did appear to be some such optimum number of shoots. This would vary

a lot with the variety and the growing conditions. A crop consisting of, say, 30,000 sticks, each weighing 2 lbs., would give a yield of 30 tons per acre. Theoretically this crop would be derived from 6,400-odd setts, and in actual practice he found about 6,300 were used in planting. This meant that on the average one primary shoot and four tillers were produced to each stool. Experiments were now being tried in which the number of setts was varied and these tests should give more factual information. There was only a certain number of shoots that a field could support, and planting should aim at using the small amount of setts necessary to produce that particular number of shoots.

Dr. BATES asked Dr. McMartin if he could say how mercurial fungicides acted. He knew that they did remarkable things, and had even been known to cure a disease in citrus. Some remarkable results had been obtained with graminaceous plants. It seemed that while we did not know how they acted, we knew they had an effect on the chromosome structure.

Dr. McMARTIN said he had never been able to follow that aspect further. It was curious that, in the experiment mentioned, not only were the mercurial fingicides good disinfectants, but they seemed to lead to better growth. He did not know what mechanism operated to produce this effect, but it was definitely more than merely a disinfecting action.