

QUEENSLAND.

Bureau of Sugar Experiment Stations

---

FARM BULLETIN No. 2

---

PAPERS

ON

Cane Culture, Disease  
and Pest Control

---

Issued by direction of the Hon. H. F. WALKER,  
Minister for Agriculture and Stock.

---

BRISBANE :  
By Authority : Frederick Phillips, Government Printer.

## Foreword.

THE papers appearing in this Bulletin were read at the Second Annual Conference of the Queensland Society of Sugar-cane Technologists in March, 1931, at Bundaberg, by Officers of the Bureau of Sugar Experiment Stations. An earnest desire was expressed at the time by the Society, and many canegrowers, that these papers should be circularised, and, the permission of the Society having been obtained for their publication in this form, they are now being issued to those interested in the Sugar Industry.

H. T. EASTERBY,  
Director, Sugar Experiment Stations.

15th June, 1931.

## Contents.

|  | PAGE. |
|--|-------|
| Fertilizers and their Use .. .. .<br><i>By H. W. Kerr.</i>   | 5     |
| Tillage and Cultivation .. .. .<br><i>By H. W. Kerr.</i>   | 11    |
| Sugar-cane Diseases .. .. .<br><i>By Arthur F. Bell.</i>   | 17    |
| Cane Breeding and Its Relation to Disease Control<br><i>By Arthur F. Bell.</i>                             | 23    |
| The Present Status of Control of Some Queensland<br>Sugar-cane Pests .. .. .<br><i>By R. W. Mungomery.</i> | 31    |

## FERTILIZERS AND THEIR USE.

By H. W. KERR.

The use of fertilizers is becoming an increasingly important factor in cane production in Queensland. Farmers in all districts have learned that manuring is absolutely essential to successful cane farming, but there are many who have yet to appreciate the value of these materials as an aid in crop production.

There still exists a considerable degree of ignorance regarding the true function of fertilizers in their influence on plant growth. Even farmers who have consistently manured their lands fail to understand just what they are doing when they apply, say, a top dressing of sulphate of ammonia to a crop of ratoons. They know that under favourable conditions the effects on the crop become visible almost immediately, the leaves develop a deep green colour, and the cane puts on a vigorous growth. A frequent explanation is that the sulphate of ammonia acts as a crop "stimulant," but if the use of this stimulant be continued indefinitely, the stage will ultimately be reached when it ceases to produce the desired results. Let us examine briefly the question of plant nutrition, and see how such a theory agrees with the facts which have been revealed by studies in agricultural science.

As recently as the seventeenth century we find a profound degree of uncertainty as to what are the chief factors influencing plant growth. Thus, a careful thinker like Bacon stated as his opinion that water was probably the all-important substance which became elaborated into plant tissues. This view was apparently completely substantiated by the experiments of van Helmont, who grew a willow-tree in a large pot of soil for a period of fifteen years, during which time it was supplied with nothing more than distilled water. Although the plant gained in weight by more than 150 lb., no difference in the weight of soil in the pot could be detected.

Jethro Tull, in 1730, originated the theory that crop roots digested the fine particles of the soil with which they came in contact. As evidence, he showed that intensive tillage resulted in an increased crop, due, as he said, to the production of a greater proportion of fine particles for the nutrition of the plant.

Further, it was early known that plants contained carbon, for by incomplete combustion of vegetable matter charcoal was readily produced. The value of incorporating animal and plant residues with the soil was also appreciated, so it is not surprising to find the suggestion being advanced that crops fed directly on the soil humus as their source of carbon; and without soil humus there could be no crop.

Much of the confusion which existed was swept away by the brilliant work of a French investigator, de Saussure, during the early years of last century. By conclusive experiments he showed that crops absorbed their carbon entirely through their leaves in the form of carbon

dioxide gas gathered from the atmosphere. From the soil the crop received its water supply, and by chemical analysis of plants he showed that the soil also provided a definite small amount of mineral matter, which is found in the ash when the vegetable matter is burned.

The famous German chemist, Liebig, was a staunch supporter of de Saussure. Between them the "humus" theory was completely overthrown, and the foundations laid for the modern science of agricultural chemistry.

We now know that there are certain essential conditions and requirements necessary for successful plant growth. They may be summarised as follows:—

- (1) A suitable medium for the mechanical support of the crop;
- (2) Water;
- (3) Heat;
- (4) Light;
- (5) Air, for oxygen supply;
- (6) Nutrients.

Heat, light, and oxygen supply are factors essentially beyond our control, and, except under irrigated conditions, the crop is dependent on natural rainfall for its moisture. The provision of a suitable medium for the support of the crop and for the development of its root system comes under the heading of soil tillage and cultivation. The nutrients are the raw materials from which the plant manufactures its tissues, and we must study them in detail to acquire a clear understanding of plant nutrition.

If we should select a stick of cane and determine its composition, we would find first of all that it contained about 70 per cent. of water. The dry matter is largely composed of fibre, sugars, and proteins. If we should burn away all of the vegetable substance, we would find a residue of mineral matter, to the extent of about  $\frac{3}{4}$  lb. from 100 lb. cane. Let us further examine these constituent parts of the cane, and determine the simplest units or *elements* from which they in turn are built up. Sugars and fibre contain only carbon, hydrogen, and oxygen; proteins contain, in addition, nitrogen, phosphorus, and sulphur; the ash is composed of silica, lime, magnesia, potash, soda, iron, and small amounts of other elements. It has been shown that there are ten elements essential to crop growth. These are carbon, hydrogen, oxygen, phosphorus, potassium, nitrogen, sulphur, calcium, iron, and magnesium. If one of these is withheld, crop growth is not possible. The plant usually contains other elements in small amounts, but these are incidental. Where, then, does the crop obtain its supply of essential nutrients, or plant-foods, as they are popularly known?

Water from the soil and carbon dioxide from the air supply all the carbon, hydrogen, and oxygen required; and indeed these elements constitute over 99 per cent. of the cane crop. The remaining seven elements make up between them less than 1 per cent. of the weight of the plant. They are supplied to the crop by the soil, being absorbed through the roots in solution with the soil moisture.

Most agricultural lands are able to supply all the sulphur, magnesium, iron, and lime which a cane crop requires; but it frequently happens that there is a marked deficiency in one or more of the remaining three plant-foods—nitrogen, phosphorus, and potassium. In order

then to maintain the highest possible crop yields, it is necessary to supply any deficiency by the application to the soil of materials containing the required nutrients. These concentrated forms of plant-food materials applied in this way are known as *manures* or *fertilizers*. Such a fertilizer may consist of a substance which supplies only one of these three plant-foods; others contain a mixture of two; while those spoken of as *complete fertilizers* consist of a mixture of all three elements in various proportions.

The following list shows the composition of the chief ingredients employed in the preparation of these mixtures:—

#### (1) SOURCES OF NITROGEN.

*Sulphate of ammonia*, containing 20 per cent. nitrogen in the water-soluble condition, as ammonia.

*Nitrate of soda*, supplying 16 per cent. of nitrogen as nitrates.

*Blood, bone, and offal*, containing from 3-14 per cent. of nitrogen in the organic form.

#### (2) SOURCES OF PHOSPHORUS.

*Superphosphate*, with 22 per cent. of water-soluble phosphoric acid.

*Basic superphosphate*, yielding 18 per cent. of phosphoric acid, not water-soluble, but readily available to the plant.

*Rock phosphate*, the naturally occurring material from which the commercial phosphates are manufactured. It contains up to 38 per cent. of phosphoric acid in a slowly soluble condition.

*Bone*, containing about 22 per cent. of phosphoric acid, in addition to a small amount of nitrogen.

#### (3) SOURCES OF POTASSIUM.

*Muriate of potash*, yielding 50 per cent. of water-soluble potash.

*Sulphate of potash*, with 48 per cent. of water-soluble potash.

Of the nutrients which are taken up in solution by the roots, all except nitrogen are ultimately derived from the rock minerals found in the soil. Under the action of the destructive forces of nature, these minerals are undergoing a continuous process of breaking up and decay, and the resulting decomposition products are thus made available for crop nutrition. Obviously, the nature of the products of decay will be governed by the composition of the minerals from which they are derived. Therefore soils formed from rocks of different composition will vary widely in the relative amounts of the different plant foods found in the soil solution. One soil may be able to supply an abundance of available potash, while the phosphorus supply is decidedly deficient. Such is the case with many of our alluvial soils of the North derived from granite. The Woongarra red volcanic loam, on the other hand, is notably deficient in the amount of available potash which it is able to provide for crop needs.

At first sight it would appear to be a simple matter to determine what a soil lacks, in order to provide for any plant-food deficiency. Chemical analysis of the soil would show the percentage of the various

nutrients present, and the earlier soil chemists eagerly seized on this method of investigation. But it was soon found that the method was often misleading. A soil may often contain 10,000 lb. of potash per acre, yet it is incapable of supplying the modest requirements of a 20-ton crop of cane—which is only about 80 lb. of potash. The fact is that the crop can use the potash only when it is in the so-called available condition; and the amount of potash made available to the crop during its growth period will depend on the rate at which the potash-bearing minerals decay under the natural soil conditions.

The average of a large number of analyses of Queensland cane crops shows that 1 ton of cane (including tops and trash) absorbs from the soil—

- 2 lb. nitrogen.
- 1 lb. phosphoric acid.
- 4 lb. potash.

A 30-ton crop will then require—

- 60 lb. nitrogen.
- 30 lb. phosphoric acid.
- 120 lb. potash.

Or, expressed in terms of common fertilizer constituents—

- 300 lb. sulphate of ammonia.
- 135 lb. superphosphate.
- 250 lb. sulphate of potash.

—  
Total 685 lb. of the mixed fertilizer.

In addition, excessive rains during the wet season result in the leaching away of a further amount of the available plant-food before the crop roots are able to absorb it. Hence we can reckon that for our 30-ton crop the soil must be able to make available plant-foods considerably in excess of the amount contained in the 685 lb. of mixed fertilizer as calculated. In its virgin state, the soil might readily provide in a year all of the plant-food required by even a 60-ton crop. Under scrub vegetation, for instance, there is a considerable supply of available plant-food continually passing through the cycle—(a) absorption by tree roots; (b) passing into the leaves; (c) returning to the soil when the leaves die and fall; (d) decomposition of the vegetable matter in the soil to return the plant-food to the soil solution for reabsorption by the plant roots. When the natural vegetation is cut down and burned, this cycle is interrupted, and the available plant-food is diverted for use by the cane crop. Now, unlike the natural scrub growth, where all crop residues are returned to the soil, the cane, with all its plant-food, is removed from the land. Further, intensive cultivation of the soil stimulates the decomposition of humus and mineral matter; and some of the plant-food supply thus made available will be leached from the soil before the crop roots are sufficiently extensively developed to absorb it. Unless some attempt is made to compensate for this rapid removal of plant-food, the soil supply must become seriously depleted, with a consequent falling-off in crop yield.

This has been the story throughout the Queensland cane areas. Certain soils have been able to maintain a supply of nutrients for a

longer period than others, but even the most fertile lands will require, sooner or later, substantial additions of fertilizer if their fertility is to be maintained.

It has been stated that chemical analyses do not tell us absolutely what particular nutrient or nutrients are lacking in a soil. Certain soil tests do, however, provide us with a very useful guide in this respect, but the most reliable method of determining any deficiency is by means of direct field experimentation. Our problem is essentially this: Under the existing conditions of temperature, moisture supply, cultivation methods, &c., what crop might normally be expected? Provided other conditions are favourable, if our unfertilized crop falls below this value we might reasonably suspect that there exists a plant-food deficiency. We have already seen what a ton of cane requires in this respect; and we must therefore add to the soil at least the deficit between what the soil can normally supply and the total plant-food requirement of our crop.

This is stating the problem in its simplest terms, but actually the question is much more complex. However, the illustration should make it clear that the *kind* and *amount* of plant-food necessary to restore the balance of crop nutrients demanded by the increased crop might differ markedly from soil to soil. Unfortunately we have no method of determining the amounts of each plant-food which the soil can supply, and therefore must ask the soil the question by means of plot experimentation. If our experiment is well planned and carefully carried through, we will receive our answer in simple terms. As climatic and other environmental factors are by no means constant from year to year, our crop response to the same treatment will vary accordingly. By continuing our experiments over a period of years, it becomes possible for us to arrive at an accurate approximation of the kind and amount of fertilizer which will give, on the average, the most profitable return from fertilizing. The problem naturally becomes complicated by economic considerations, such as the fluctuating value of the crop, the purchase price of fertilizer constituents, &c. But our experiments have shown that under the present conditions it is possible to derive highly profitable returns from added fertilizer, provided that it contains the correct ingredients applied in the correct proportions.

We are now in a position to understand why the sulphate of ammonia alone gave splendid returns for a time, but later it ceased to increase the crop yield. The entire reserve of nitrogen in the soil is bound up in the soil organic matter or *humus*. This portion of the soil is the natural food of the numerous micro-organisms which live in the soil, and in the course of decomposition of this substance the nitrogen ultimately becomes available to our crop in the form of nitrate. If no attempt be made to restore the nitrogen supply by the ploughing under of leguminous crops, or the addition of fertilizers, the reduced supply of available nitrogen under our Queensland conditions rapidly becomes a limiting factor in crop growth. The sulphate of ammonia discussed above furnished a supply of nitrogen which, in becoming rapidly nitrified and made available for crop growth, produced its visible effects very readily.

So long as the nitrogen supply was the only factor limiting crop production the addition of sulphate of ammonia alone was all that was necessary. Conditions similar to these actually exist on many of the

rich Javan cane lands, and for many years the application of nitrogenous fertilizers alone has maintained their characteristically high degrees of productivity.

If, however, the phosphate or potash supply begins to enter as a limiting factor, the efficacy of the nitrogenous fertilizer alone will be seriously impaired; and if the situation becomes particularly acute, the response to nitrogen may be completely annulled. Hence, it is not a question of the failure of our "stimulant," but rather the entrance of new deficiencies for which no provision is being made. What we are actually adding in fertilizing is a concentrated form of plant-food, and the intelligent use of these materials is the true solution of the permanent productivity of our soils.

## TILLAGE AND CULTIVATION.

By H. W. KERR.

Why do you plough? Surely, our farmer will answer me, you are not seriously asking such a question; is it not a fundamental principle that ploughing and cultivation are absolutely essential to successful agriculture? Who would attempt to grow a crop of cane without recourse to modern tillage implements? But let us think back a little. Is it not also a fact that many of our best lands produced their heaviest crops without the aid of implements of any kind? Most of us have seen something of the results which followed the first planting of virgin scrub lands. Giant crops of 60 tons per acre were frequently harvested under these conditions, and three or four heavy ratoon crops followed, with nothing more than a light hoeing to scratch out a few weeds between the stumps and cane stools. Yet many of these cane lands to-day, even with the aid of modern cultivation implements, are not producing more than one-half of the tonnage of which they were originally capable.

Perhaps if we should study the differences between our old and new lands we should get some clue as to what our virgin lands possessed which is now lacking. And if it lies within our power to supplement the missing factors or conditions, then we should be able to restore something of the initial high-producing power of our soil.

The question of supply of available plant-foods is undoubtedly very important. This has been discussed elsewhere, and it has been shown that, without the addition of heavy applications of artificial fertilizers, the available plant-food supply in the soil becomes rapidly depleted. But there is something more than this required; for the application of even excessive dressings of fertilizer alone will restore but a fraction of the diminished crop returns, particularly if our cultivation methods are inadequate. There must then be something in the physical condition of our old soil which requires modification in order to restore its production power.

Now we probably remember quite clearly the excellent condition of tilth which characterised our virgin soil. The dense scrub growth was the natural protector of the soil in which it flourished. The heavy cover of foliage guarded the surface soil from the pounding action of torrential rains; the roots of the trees penetrated to a great depth, and the finer rootlets opened up the soil to allow free entry of the rain which fell, and stored up an adequate supply of moisture for the luxuriant plant-growth. Further, the cover of vegetation guarded the soil against the drying action of the sun and winds, and thus conserved the soil moisture for use by the natural flora. The decaying vegetation maintained in the soil an abundance of humus—that substance so important in providing an open-soil structure and increasing the water-holding capacity of the soil.

What has happened since the scrub was removed? First of all, a modest cane hole was all that was necessary to ensure the establishment of the cane crop, provided that the rainfall was reasonably good. The

modified conditions made available to the crop an abundance of plant-food which normally supplied the scrub vegetation. This was effected at the expense of the soil humus, which, under our agricultural system and our favourable climatic conditions, decomposes rapidly. Our tests have shown that under conditions of optimum soil moisture 3 tons of humus per acre may be lost to the land during a brief summer season. It would thus be absolutely impracticable, under intensive cultivation, to attempt to maintain the initial humus content of our soil.

Due to the beating of heavy rains to which our soil was now exposed, and the trampling of man and beast, the soil became packed and consolidated. The air and moisture supply, so essential to the crop, did not enter as readily; and with the passing of the first flush of fertility and heavy crop yields it became desirable to get the land under the plough. A good seed-bed was, in general, readily prepared, and again heavy crops were harvested, under favourable climatic conditions.

However, with the progress of time and under continued cane cultivation the soil seemed to lose the "life" which it earlier possessed; and only the intensive use of implements and adequate fertilizer applications can now restore something of the earlier productivity of the land.

Let us now examine our soil carefully in the field. We will generally find after, say, a second ratoon crop that the soil is firmly compacted. The loss of humus has made it more difficult to retain the favourable open structure of the soil, and the continued use of implements has further assisted in destroying the granular conditions of the soil crumbs. The heavy rains to which the land surface is exposed complete the work of driving the individual soil particles into a compact mass. If we should examine the soil at the depth to which our implements work, we would probably find (except in the case of sandy soils) that a definite plough-sole has been created, due to the packing action of that implement, unless definite steps have been taken to break it up.

We can now understand what we should aim at in all our farm cultural operations, and if we should make a close and careful study of our problem, we could probably devise a system whereby the faults which have arisen can be corrected.

Probably the most important aspect of an unfavourable soil condition is its relationship to the water economy of the crop. We know that a compact soil does not absorb and hold water as freely as does one with an open structure. Further, the presence of a hardpan in the soil prevents the free percolation of the excess rainfall of the wet season into the subsoil, and, by inhibiting the root development of the crop, forces the plant to rely on the scanty supply of the surface soil for its requirements.

All cultural operations should be carried out, then, with these facts clearly in mind; and we find that we can bring almost every phase of tillage under one of two headings—

- (a) The production and maintenance of such a set of conditions as will allow of the free entry of as much moisture as possible into the soil.
- (b) The retention of this moisture for use by the cane crop.

Because of the high water requirements of the crop, cane culture is effected most successfully in regions of abundant rainfall, or in areas

where heavy and frequent applications of irrigation water are possible. Experiments have shown that in the production of 1 ton of cane about 30,000 gallons of water are drawn from the soil by the cane plants. Therefore, for a 30-ton crop to be produced, the soil must be able to supply 36 acre-inches of water to the growing crop. Expressed in another way, each stool of cane in that acre of land will evaporate from its leaf surfaces no less than 150 gallons of water during the cropping period. When due allowance is made for the rainfall lost by surface run-off and subdrainage in times of heavy rain, and by surface evaporation from the moist soil, a rainfall considerably in excess of 36 inches will be required in order that our 30-ton crop will be possible. Even in districts where the rainfall exceeds twice this amount, the fact that the poor distribution during the wet season often causes excessive losses by drainage may preclude the effective use of more than 20 inches of rainfall by our crop.

We know too well that partial or complete failure of our cane crops is generally associated with an inadequate moisture supply in the spring months. During these periods of drought, crop growth is at a standstill despite favourable growing temperatures. Would it be possible to store some of the wet season's moisture in the soil for use by the crop in times of drought? If so, we might be able to combat these ills, and maintain favourable growing conditions despite the season. The solution of this problem is the secret of successful cultivation under these conditions, and in attempting to adopt a favourable system we would do well to consider some of the principles which are employed in regions where so-called "dry farming" is practised. Certain methods have been devised in areas where the rainfall is deficient whereby a supply of soil moisture is stored up prior to seeding; and in some instances good crops of grain have been grown to maturity without their having received a drop of rain during the growing period. Let us examine some of these principles, and see how far they may be applicable under our conditions.

The soil is our natural reservoir in which the water is stored for future use. It is evident, then, that the storage capacity should be large in order that the supply will be adequate. Therefore, we must see that our soil is brought to such a condition that the rain will be readily absorbed as it is received and that we have a good depth of open absorbent material. This suggests that we should plough our soil deeply when breaking up the land after the previous crop has been harvested. Wherever the soil is of good depth this is found to be an excellent practice. Deep tillage is, indeed, the secret of successful crop growth under semi-arid conditions. But, where the surface soil is, say, only 6 inches deep, ploughing to 10 inches might spell crop failure, for to bring to the surface 4 inches of "raw" subsoil, particularly when it is clayey, might completely ruin the tilth of the surface soil, besides adding a mass of material deficient in plant-food and humus. Many a farmer has had this experience, and has wrongfully condemned deep ploughing. In a case such as this it is desirable to deepen the surface soil, but this must be done judiciously—a little at a time.

Now, the value of the subsoil plough in creating a condition favourable for the ready absorption of rain water cannot be over-estimated. It is of immense assistance where a shallow soil is underlain by a stiff subsoil or where a hardpan exists in the soil either naturally or due to the packing action of implements. The efficient subsoil plough does

not bring the subsoil to the surface but simply cuts a gash in the compact substratum which allows of the free passage of the rain water from the saturated surface soil to the lower depths of our reservoir. It also provides a passage-way for the roots which will penetrate to these depths and make this moisture available to our crop in time of need. It is well known that cane roots are found at depths of 3 and 4 feet below the surface, provided they are not shut out by the presence of an impervious hardpan or subsoil. Unfortunately, the subsoiling implements which one commonly sees in this country are not correctly constructed. They are generally too broad at the point, and require tractor power to draw them through the subsoil. An efficient plough should be no more than an inch in width at the point, and the cutter or blade should not exceed one-half inch in thickness. Such a subsoil plough can be drawn by two horses, and will cut a gash from 10 to 16 inches in depth below the bottom of the furrow. It is customary to follow with the subsoiler in every second furrow ploughed with our mould-board or disc plough. Subsoiling is of no value in a sandy subsoil, as one might expect; but for heavy soils its value in allowing of the free penetration of water and air into the substrata cannot be over-estimated. After this treatment has been given it will be found that a hardpan rapidly disintegrates.

A soil prepared in this way may be capable of holding up to 25 per cent. of its weight of moisture; hence it will be seen that to a depth of, say, 30 inches over 7 inches or about one-fifth of that required by our 30-ton crop may be stored. A soil inadequately prepared may hold only 3 inches of available water in its surface foot.

Having provided for the uptake of this valuable moisture, we must guard against its loss so far as we are able. The chief avenues of escape are by surface evaporation and weed growth. When a soil is compact, and the surface becomes dried out, moisture is drawn up by capillary action from lower depths, and is readily lost from the land. Now, it is found that if the soil surface can be kept in the form of a loose dry mulch the soil capillaries are effectively broken, and evaporation losses are minimised. Again, weeds and grasses require water for growth equally as much as does cane, and every gallon diverted for their use means so much less for our crop; hence the necessity for intensive surface cultivation either with the discs or scarifiers after each rain to eradicate weed growth and restore the surface mulch. It has been found that a 2-inch mulch is quite sufficient in this respect, and deeper cultivation during the cropping period may even be detrimental; for the majority of the feeding roots of the crop are concentrated in the surface soil, and it is from this layer that the crop draws the major portion of its plant-food. But if heavy rains have compacted the surface soil to such an extent that the absorption of further rainfall will be seriously hampered, deeper cultivation, though it may cause a certain amount of root-pruning at the time, will be of ultimate benefit. Deep working of the interspaces is frequently called for in our Northern climate when the crop is young.

The time at which these operations should be carried out is of the greatest importance. All our efforts must be directed towards the production of a favourable medium for free root development and water absorption, as was our scrub soil in its virgin state. At that time the soil possessed the desirable granular or crumbly structure which is characteristic of a soil "in good heart." Paradoxical though it may

seem, the more one works the land in an attempt to induce this structure, the worse becomes the permanent physical condition of the land; and it grows increasingly more difficult to restore a good tilth under continuous cultivation. A soil when worked at the right moisture content mellows down readily, but if worked either too wet or too dry, the soil becomes either puddled or reduced to dust, and our desirable granular structure is lost. We should aim, therefore, at carrying out all operations when the soil is in the proper moist condition. Of course, this is not always possible, particularly when spring ploughing; however, a little care and forethought will often show that it is possible to achieve this to a very considerable extent. With a light-textured soil liberties may be taken, but on heavy land failure to work the soil just at the right time is fatal, and it may take years to wipe out the damage which can be caused by ploughing a heavy soil a day too soon.

The season at which land should be ploughed is a question which has received all too little attention. How frequently one sees a grower breaking up his hard soil in the months of June and July in preparation for a spring plant! The surface is often covered with trash and weeds which have seeded freely. The ploughing and reploughing of the land result in a considerable loss of moisture at a season when our rainfall is notably deficient. Under the cool and dry conditions, the crop residues do not rot well, and at planting time much undecomposed material is found in the soil. Frequently it is necessary to wait for spring rains before planting; and, knowing as we do so well the capricious nature of the weather at this season, is it any wonder that the crop is frequently a failure?

My observations, covering the majority of the Queensland cane districts, show that in general an autumn plant yields the most successful crop; and I would present for your criticism a system of land preparation which I believe could be studied with advantage, particularly in its relationship to Central and Southern Queensland conditions.

It has been pointed out that the months from August to December cover the critical period in the growth of the crop. A crop that receives a good start in life will finish well, except under unusual circumstances. Therefore, we should aim at starting off the crop under the best of conditions. We have seen that a 30-ton cane crop requires about 36 acre-inches of water during its growing period, and in the districts named we cannot, in general, expect that amount of moisture to be absorbed by the soil during the growing season, and used by the crop. Hence it would be advantageous if we could store up a supply of soil moisture in advance of the planting season, to carry the crop through the dry spring months. It will, then, be necessary to prepare our land in advance of the wet season. When the last ratoon crop has been harvested the old stubble should be ploughed out immediately, and the surface of the land thoroughly disced. This will create a good surface mulch and chop up the trash and other crop residues to some extent. A good deep ploughing will then turn under the vegetable matter, and give it a chance to decompose completely before planting time. The presence of the loose surface layer of soil will ensure good contact with the substratum. Any weed seeds present at this time will probably be destroyed if buried deeply, or on germination subsequent surface discing will control them.

Where the subsoil is compact or a hardpan exists, the use of the subsoil plough should follow. The discs and harrows will help to reduce



the clods of soil, and the roller may also be used to advantage for this purpose, as well as to destroy large air spaces, which will later hamper capillary rise of moisture. Conditions should then be favourable for the absorption of the rain which falls during January, February, and March, and the deep tillage will assist materially in preventing water-logging of many soils with imperfect drainage. Some of the Mackay soils are of this nature, due to the presence of an impervious hardpan at a depth of from 10-14 inches.

Such a fallow will generally do much towards mellowing the soil structure, particularly in the case of heavy soils. After periods of rainfall the surface of the land should be disced to break up the caked surface, and also to control weed growth. At the conclusion of the wet season the land should require a minimum of working to put it in condition for early planting. In planting at this time, when the soil is still warm, the sets will germinate readily, and the crop will become established before the advent of the winter months. Should a dry period follow, the crop roots will penetrate freely into the subsoil, and follow up the moisture supply which has been stored there. Instead of a shallow-rooted crop, then, we will have one which can draw its moisture from the full depth of soil and subsoil, and which will stand up well to droughty conditions.

Other things being equal, it will be found that a good ratoon crop follows more frequently on a good than on a poor plant crop; for the heavier growth of stubble produced by the plant crop ensures a better start for the ratoons. Hence, by providing conditions favourable for the plant, we are automatically assisting the ratoons. The latter get their start in life at a time when the rainfall is generally scanty. Therefore it is desirable that they should make best use of any moisture which remains in the soil at the time of harvesting the mature cane.

We have seen that the best way to conserve soil moisture is to break the soil capillaries by creating a surface mulch of loose soil. In this regard, the discs are again of great value. They should be drawn across the field—preferably in two directions at right angles—as soon as the trash has been burnt off after harvesting. Besides providing a surface mulch, they tend to destroy the uppermost “eyes” of the stool, and encourage the ratoon shoots to come from below. In this way the stool is kept well in the ground, and the shoot roots which then develop will have access to any available soil moisture.

The advisability of ploughing away from the stools in ratooning is one which can be decided only after a study of the local conditions at the time. If the soil is packed and dry, and would break up into clods which could not be worked down to a good tilth, it is probable that ill-effects would follow in the event of a subsequent dry spell. If, on the other hand, moisture conditions are favourable, ploughing away is highly beneficial. It removes a mass of old roots and dead portions of the stool, and on working the soil back again a mellow bed is again provided for the development of the new roots. Incidentally, such a furrow as is produced in this way is ideal for receiving the application of fertilizer which the ratoons will need, and the earlier they receive it the better use they will make of it.

## SUGAR-CANE DISEASES.

By ARTHUR F. BELL.

Since this is the first time an agricultural section has been included in the Conference of the Queensland Society of Sugar Cane Technologists, it was considered that papers presented at this year's meetings of the section should deal with the underlying principles rather than with specific investigations. Accordingly the following paper attempts a brief review of the subject of sugar-cane diseases, their cause, dissemination, and control. Although we shall discuss sugar-cane diseases in particular, it must be remembered that the principles apply to plant diseases in general. At the outset we shall define a plant disease as any abnormal condition of the plant, irrespective of how this condition has been brought about.

### Distribution of Cane Diseases.

In the distribution of sugar-cane diseases throughout the world, chance has been very unkind to Australia. Until the beginning of this century, at least, none of the sugar-cane countries had a quarantine system, and yet by that time practically all the major diseases were present in Australia, while many other countries had escaped almost entirely. Probably the four worst diseases of sugar-cane are gumming, leaf-scald, Fiji, and mosaic, and Queensland has them all.

Fortunately the distribution of major diseases is not general throughout Queensland. Gumming disease is serious in the Southern district, but is practically negligible in the Central district. In recent years outbreaks have occurred in the Mulgrave and Herbert River districts, but, under strict supervision, the disease is now completely under control, if not eradicated. Leaf-scald is general north of Townsville, and occurs in scattered areas in the Mackay district; owing to the rather rapid spread of the scald-susceptible P.O.J. 2714 in the Mackay district, it is to be expected that leaf-scald will soon become very evident. Mosaic is found throughout the State, but is becoming rare in the Northern district, although all too common in certain parts of the Mackay and Bundaberg districts. Fiji disease is common in the Beenleigh and Maryborough districts, but is decreasing in intensity; it has advanced as far north as Bundaberg. Downy mildew or leaf-stripe is practically confined to the variety B. 208 in the Burdekin irrigation area, and under the supervision of our field officer, Mr. A. P. Gibson, it is anticipated that this variety will soon be disease-free. Red Stripe, or Top-rot, is distributed throughout the State, but occasions losses only in the Burdekin and Northern districts. Officers of the Bureau have stressed the

importance of getting cane away to a good early start, as a means of combating the disease, and the improvement in the average standard of farming in the Burdekin district during the last few years seems to have brought the disease under almost complete control.

#### Types of Disease.

Plant diseases are of two types—infectious and non-infectious. The non-infectious diseases include the so-called physiological diseases and are usually brought about by some unfavourable environmental condition. The infectious diseases of cane in Queensland are of three types—viz., bacterial, fungous, and virus diseases. Bacteria are a lowly one-celled form of plant life; they are of various shapes, but those which cause the three main bacterial diseases of cane are short rods about 1/10,000 to 1/5,000 of an inch long. When suspended in a moist film they swim around by means of a long thin tail known as a flagellum. Diseases caused by bacteria include gumming, leaf-scald, and red stripe or top-rot.

The fungi are usually many-celled and much branched, so that they are much more plant-like in appearance than the bacteria. They reproduce by the production of spores which are equivalent to the seeds of higher plants. These spores are often thick-walled and able to withstand drying out and extremes of temperature; thus a fungus may survive a winter by virtue of the resistance of its spores. Examples of fungous diseases are red rot, peg leg, and downy mildew, or leaf stripe.

The viruses are ultra microscopic—that is to say, they are invisible under the highest-powered microscopes—and we are only aware of their presence by the effects they cause in the plants. Although most of the bacteria and fungi can be grown in the laboratory in culture tubes, this has not yet been done with the viruses. Mosaic is a virus disease, and we believe Fiji to be caused by a virus also, but so far we have been unable to prove this.

When a new disease is discovered the first step is the determination of the type of disease and the causal agency, for on these will mainly depend the methods of control available. Should any fungus or bacterium be found associated with the disease, it is necessary to isolate it in pure culture, inoculate a healthy plant and reproduce the disease, and, finally, reisolate the same organism from the diseased tissues, before it can be accepted as the causal agent. Virus diseases produce as a rule a very suggestive dwarfed appearance; as the viruses cannot be cultured artificially, elaborate inoculation experiments are necessary to demonstrate their presence. If the disease is found to be non-infectious, and not transmissible through cuttings, then the investigator must inquire fully into the climatic, soil, and cultural conditions, and endeavour to determine where they deviate from normal. In this type of investigation, chemical analysis and the use of the soil auger may be of valuable assistance; occasionally a mysterious "disease" is found to be due to a patch of ground having a coarse sandy subsoil which will not hold moisture.

#### Dissemination of Diseases.

Under this heading we will consider only secondary infection and not the extremely important primary infection brought about by the planting of diseased cuttings. The natural and artificial methods by means of which diseases are spread from plant to plant have a very important bearing on the methods of control, and a sound knowledge of these modes of infection is necessary as a basis for clean seed selection and the conducting of disease-resistance trials.

#### Dissemination by Natural Means.

The main agents in the so-called natural means of dissemination are wind, rain, and insects. Wind will blow spores considerable distances and is without doubt an important factor in the field-to-field as well as the plant-to-plant spread of diseases. Wind is, however, a much more potent agent in association with rain or very moist conditions, for two reasons:—

1. Many of the fungous spores and bacteria dry out readily; and
2. They require moisture in order to germinate and penetrate the plant.

In some cases this penetration can only be effected through wounds, but in others the parasites can penetrate soft unwounded tissue. The different methods by which diseases may be spread under these conditions are best illustrated by reference to a few particular diseases.

*Gumming Disease.*—The cane leaves, when blown violently by the wind, lacerate each other by means of the sharp spines which project along the margins of the leaves. The bacteria within the leaves ooze out through these scratches, swim around in the film of moisture, and are transferred to other leaves by contact or by the splashing of the film of moisture, which is then blown on to other leaves. The bacteria then enter the leaves of the new plant through the scratches mentioned above.

*Downy Mildew or Leaf Stripe.*—The spores of the fungus which causes this disease are borne in vast numbers on the under surface of the leaves. They are blown or splash on to the young eyes of adjacent cane, germinate, and enter the soft tissue of the eyes, and then gradually spread through the plant.

*Red Rot.*—This fungus may live over in old trash, &c., and the spores may be splashed up by heavy rain so that they fall on the lower buds, or into cracks in the rind, and so gain entry to the stem.

Insects may act as mere mechanical carriers or they may be the specific carriers of particular diseases. In the former case fungous spores, or bacteria which have oozed from the diseased plant, become attached to the legs or bodies of the insects and are distributed as they fly from plant to plant. Virus diseases are spread by specific sucking insects, of which the aphids are an important class. These insects, after feeding upon diseased plants, transfer to healthy plants, taking with them some of the infected plant juice, which is later injected into the healthy plant.

### Dissemination by Artificial and Mechanical Means.

Artificial methods of inoculation include the use of needles and hypodermic syringes, but these are of interest only in research work and resistance trials, and of no importance in commercial fields. One of the most important mechanical agents in the spread of disease is the cane knife, and our two most serious diseases—gumming and leaf scald—are readily spread by this means. It has been found that gumming bacteria may remain alive on a cane knife for weeks. Diseases such as gumming disease may also be spread mechanically by animals and implements passing up and down the rows during or immediately after rain.

Dirty cultivation may be an important factor in disease dissemination, and this is particularly the case with a disease such as mosaic, since grass and weeds harbour the insects responsible for the spread of the disease.

Soaking of cane plants, although a very desirable practice in droughty districts, may be dangerous if not done carefully. A few diseased setts in the soaking tanks may infect many setts of that and succeeding batches.

### Control.

In the control of sugar-cane diseases the question of expense limits us almost entirely to measures of prevention. Some of these measures of prevention will now be discussed briefly.

*Quarantine.*—The first measure which should be applied in any country is that of quarantine, since obviously the most effective way to control a disease is to keep it out altogether. In addition to the Commonwealth quarantine against foreign cane, we have divided the Queensland sugar belt into a number of quarantine districts, and are hoping in this way to check the further spread of diseases. It would be idiotic, for example, to take cane cuttings from Bundaberg to Cairns and risk introducing gumming and Fiji diseases with them. The boundaries of these quarantine districts have been widely advertised, and both the sender and the receiver of cane plants are liable to prosecution if plants are sent from one district to another without an official permit. In addition to the district quarantines, local quarantines are sometimes enforced to prevent the further spread of a disease which has broken out on a few farms.

*Seed Selection.*—If a disease has become more or less distributed throughout the district, it then becomes necessary to try and keep individual fields healthy by planting only selected disease-free cuttings. We have stated above that the planting of diseased cane, or primary infection, is a most important method of disease dissemination, and consequently primary infection should be vigorously combated. Unfortunately the selection of healthy planting material may be very difficult in the presence of certain diseases, such as gumming and leaf-scald, in which the symptoms may be masked for a long time. Where these

diseases are suspected the field selected for plants, and the adjoining fields, should be inspected periodically throughout the season.

*Field Sanitation.*—Plants, like human beings, can resist disease to a much greater degree if the environment is favourable for their development. Consequently, even though the cane in a field may be generally diseased, the losses due to the disease will be greatly minimised if the cultivation, weed destruction, drainage, and fertilizing practice are carried out intelligently and adequately. It is a matter of common knowledge that gumming disease is very destructive on badly drained lands, simply due to the lowered vitality of the plant.

Cane knives should be sterilised before passing from farm to farm and from field to field when diseases transmissible by this means are present. Old ratoons should be ploughed out and not left to produce ragged, neglected, volunteer growth, and, above all, the number of varieties on a farm should be restricted to three or four at most.

Variety collectors are disease collectors and are a menace to the community.

*Resistant Varieties.*—The use of resistant varieties, provided yield and sugar content are satisfactory, is the most economical and lasting of all methods of disease control. Unfortunately cane breeding and testing is necessarily slow, and when starting from scratch it takes an appreciable time to produce results.

There are two methods of obtaining new varieties:—

- (a) By introduction from other countries; and
- (b) The production of new varieties by means of systematic cane-breeding—

and of these the latter offers the far greater promise. In a paper written for the section on cane varieties, we have explained the lines along which the breeding and testing of seedlings are being undertaken. In addition the Bureau has introduced about 100 varieties during the past three years, and these are all being placed in disease-resistance trials. As gumming disease is of paramount importance in the Bundaberg district, the method of conducting gumming-resistance trials may be of interest. Under our present system these trials are of two types—preliminary and confirmatory. The preliminary trials consist of some 6-8 stools of a large number of new varieties and a few well-known standard varieties, all of which should be disease-free. They may or may not be planted between guard rows of some susceptible variety, according to the labour and space available. The trials are inoculated artificially by means of dipping a bunch of pins into a watery suspension of the gum and then stabbing the leaves. When intermediate guard rows are used, only these are inoculated, and the disease is then transmitted to the experimental plants by natural means; in the absence of guard rows all stools are inoculated. The inoculations are made at the advent of the summer storm season.

Observations on the progress of the disease are made periodically, and at approximate maturity the canes are selected or rejected after comparison of their apparent resistance with that of the well-known standard varieties. By means of this preliminary trial probably nine-tenths of the canes under test can be rejected without more ado. The varieties which show promise of possessing an adequate degree of resistance are planted in a confirmatory trial. In this case two-row plots are planted in duplicate, and we are enabled to observe the resistance of a larger population as well as confirm the vigour selection. With the experience of a few more series of trials we believe that these may be further simplified, and observations are being recorded to that end.

## CANE BREEDING AND ITS RELATION TO DISEASE CONTROL.

By ARTHUR F. BELL.

### Introduction.

Throughout the long history of agriculture the possibility of the loss of food crops from disease has always been a sinister menace, and the very earliest writings contain records of disastrous famines following outbreaks of disease in a staple crop. Such epiphytotics were regarded as plagues and pestilences visited upon the earth as manifestations of the displeasure of an aggrieved Deity and only to be avoided by the placation of the gods with sacrifice and ritual. This attitude persisted throughout the middle ages, and indeed it was not until the latter half of last century that the true nature of disease and its causation was understood. As a result of a brilliant series of researches carried out by de Bary between 1850 and 1860, it was proved that cereal rusts and Irish potato plight were not caused by supernatural agencies but by definite minute parasites which lived and multiplied within the tissues of the diseased plants. It is on this fundamental work of de Bary that the modern science of plant pathology has been built.

Very early in the history of plant pathology it was observed that different varieties and species of plants varied enormously in their resistance to specific diseases, and that the "wild" types were frequently outstandingly resistant. It was, therefore, only natural that workers in the field of disease control should envisage the breeding of new varieties in which would be combined the disease-resistance of the one parent and the succulence and yield of the other. The need begets the means and, largely in response to the needs of the plant pathologist, there arose the science of plant-breeding or plant genetics. Genetics is an even younger science than plant pathology, and did not become established until about the beginning of this century.

In view of the fact that most of the fungi, bacteria, and viruses which cause plant diseases have their complete existence within the host plants and, indeed, are often confined to a single tissue, it is reasonable to expect that very small changes in the composition of the host will markedly affect the parasites. Insect pests, on the other hand, lead a much more independent existence; they are never confined within the host in the strict sense of the term, and in their feeding they usually consume several types of tissue indiscriminately. The composition of the different tissues of a plant varies greatly, and so one would expect that very considerable changes would be necessary before the plant became unpalatable to its insect parasites. Consequently it is not surprising to find that while varietal resistance to disease is subject to extreme variation, the variation in varietal resistance to insect attack is relatively small. In other words, breeding for disease-resistance offers far more promise of success than does breeding for resistance to insect attack.

The application of the technique of plant-breeding in the production of new varieties ranks as the most important method of disease control

now available to the plant pathologist. In fact, with many crops, of which sugar-cane is one, it represents almost the sole avenue of attack.

Whereas in a market garden, with its ready accessibility and high monetary return per unit area of land, many diseases can be successfully and economically controlled by means of dusts, sprays, soil sterilisation, &c., such methods of control are obviously impracticable in the case of sugar-cane, which, besides being grown on plantation scale, has a low economic value per plant and has a growth habit which renders the operation of spraying and dusting machines difficult and expensive. The control of sugar-cane diseases must, therefore, lie not in cure but in prevention, and the use of resistant varieties is the most reliable measure of prevention.

### The Mechanism of Inheritance.

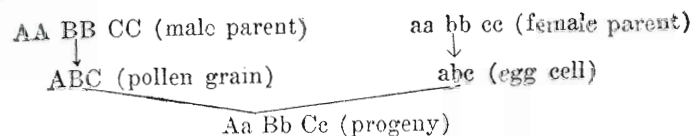
Before proceeding to the consideration of some special aspects of cane-breeding it is advisable to examine briefly the principles and mechanism of the inheritance of various characteristics by plants in general. All plants are composed of cells, and included within each cell is a very complex, deeply staining, globular body called the nucleus. The nucleus is the controlling organ of the structure and activities of the cell, and is also the vehicle of heredity. Within the nucleus itself are a number of deeply staining threads, which occur in pairs and are known as chromosomes. The number of these chromosomes is definite for each species; in the case of man and tobacco the number is 48 pairs, while the noble canes of the Badila type have 40 pairs. For the purposes of illustration, each chromosome may be represented by a string of beads in which each bead represents a gene or factor. Each factor is responsible, either wholly or in part, for some character of the plant. For example, one factor (represented by a particular bead on the string) may determine that the internode shall carry a deep bud groove; the next factor that the leaf sheaths shall be hairy; the third that the cane shall be resistant to gumming disease; and so on. The corresponding factors in each member of the pair of chromosomes relate to the same general characteristic of the plant, but they may or may not be identical. Factors are of two main types—dominant and recessive. Let us assume that the factor conferring resistance to gumming disease is dominant and the factor for susceptibility to gumming is recessive; these two factors may occur in the same plant (the one in one chromosome, the other in the other member of the pair), but only the dominant character will find expression. That is to say, the cane will be gumming-resistant even though it contains the factor for gumming susceptibility. Dominant and recessive characters are usually represented by capitals and small letters respectively.

The crossing of plants is effected in the following manner:—A pollen grain falls upon the stigma of a flower, germinates, and sends a germ tube down to the egg cell at the base of the stigma. The male nucleus from the pollen grain then fuses with the female nucleus from the egg cell, thus forming an embryo which contains factors from both parents. In order that the number of chromosomes should not be doubled at each time of crossing, a reduction division occurs in the formation of both pollen and egg cells, so that in the case of the noble canes forty single chromosomes from the pollen grain fuse with forty single chromosomes from the egg cell, and so the original number of forty pairs is restored in the embryo.

For the purposes of simplicity let us consider only three characters taken at random—viz., growth, reaction to gumming disease, and type of leaf sheath—and assume that the factors for vigorous growth and resistance to gumming disease are dominant, while the factor for hairiness of the leaf sheath is recessive. These factors would then be represented as follows:—

- |                          |                              |
|--------------------------|------------------------------|
| A—Vigorous growth.       | a—Poor growth.               |
| B—Resistance to gumming. | b—Susceptibility to gumming. |
| C—Smooth leaf sheath.    | c—Hairy leaf sheath.         |

If, then, a male parent having the factors AA, BB, CC be crossed with a female having the factors aa, bb, cc, the cross may be represented diagrammatically in this manner:—



The resultant progeny will have the characters of vigorous growth, resistance to gumming disease, and smooth leaf sheaths—since these are the dominant characters.

It will be noted that the paired factors in the parents are identical, and such individuals are termed homozygous, while the progeny, on the other hand, are heterozygous. So far as we can judge, all varieties of sugar-cane are heterozygous, and cane-breeding is naturally complicated thereby.

Considering for the moment only the characters of growth and reaction to gumming disease, the genetic constitution of the progeny referred to above is Aa Bb. If such a plant is now raised to maturity and produces flowers it is clear that the reduction divisions would give pollen grains and egg cells of the following constitution:—AB, Ab, aB, and ab; if this were now crossed back to one of the original homozygous parents there would be four types of progeny instead of only one as in the original cross. Thus it will be readily understood that on crossing two heterozygous parents which carry factors for hundreds of characters, the progeny will exhibit extraordinary variation and the chances of producing two identical individuals are very small.

When plants are propagated by seed, in order to preserve uniformity it is necessary to establish what is known as a pure line. This is achieved by "selfing" (that is, fertilizing the egg cells of the plant with its own pollen) until the selected plants become homozygous, after which they will breed true as long as no cross fertilization with other varieties takes place. Plants which have to be propagated from pure lines include maize, wheat, and cotton. Fortunately for the cane-breeder, cane is propagated vegetatively by cuttings, and hence the production of pure lines is unnecessary. Selfing is frequently used, however, even when pure lines are not desired, on account of the fact that this operation tends to accentuate characters, both good and bad. The progeny with the accentuated desirable characters is then used for further crossing. "Selfs" are often characterised by a loss of vigour, and then require to be crossed with another variety to regain vigour; on the other hand, crosses between some varieties may be more vigorous than either parent, this property being termed "hybrid vigour."

"Selfing" is not yet a routine operation in cane-breeding, and there are certain difficulties in the way of its utilisation. In a very simple case, the selfing of a cane heterozygous for two characters only—viz., Aa Bb—we get a progeny of the following types and proportions:—

$$Aa Bb \times Aa Bb$$

|   |
|---|
| AABB, AABb, aaBB, aabb, 2AABb, 2AaBB, 2Aabb, 2aaBb, 4AaBb |
|---|

It will be seen that in the simple case of two pairs of factors only one-quarter of the progeny have become completely homozygous; if the number of factors were increased to ten pairs only 1/1024 of the progeny would be completely homozygous after the first selfing. An examination of the above classes will indicate that even where only two pairs of factors are involved it may be well-nigh impossible to decide which of the progeny are most nearly homozygous. With more factors the question naturally becomes correspondingly complicated, and a careful study of the genetics of sugar-cane will be necessary before selfing can be conveniently employed on a sound basis.

#### Botanical Classification of Sugar-cane.

Sugar-cane appears to have originated independently in at least two localities, and there are marked differences between the canes indigenous to South-Eastern Asia and the canes indigenous to the Pacific Islands. There appears to be no sugar-cane indigenous to Australia, although there is an old report of the occurrence of a wild cane in the vicinity of Hervey's Creek, North Queensland. Sugar-cane is classified botanically within the genus *Saccharum*, which at present includes five species as follows:—

1. *Saccharum officinarum*, or "Noble" canes.—Stout canes with low fibre and of high sugar content. Practically all the cane varieties cultivated in Queensland belong to this group, of which Badila is a typical member.

2. *Saccharum sinense*, or Pansahi group.—Thin canes with high fibre, moderate sugar content, strong rooting system, and highly resistant to most diseases. This group includes the Ubas (Natal Uba, Porto Rican Uba, Kavangire, Zwinga, &c.); they were at one time extensively cultivated in China, Formosa, and Japan, and are often called the China canes.

3. *Saccharum Barberi*, or Chunnee group.—Thin hardy canes, low in sugar, disease-resistant, and very similar to the wild cane type. Grown mainly in North India, and of interest on account of the fact that Chunnee is one of the parents of P.O.J. 36, 213, and 234, which have been so prominent of late in the rehabilitation of the Louisiana sugar industry.

4. *Saccharum spontaneum*, or Glagah (the so-called "wild cane").—Thin, strong-rooting type, sending out long underground stolons; these canes stool prolifically, are able to thrive under adverse conditions and are highly resistant to most diseases. On the other hand, they contain no sugar and so are useless commercially.

5. *Saccharum robustum*.—Very long, thin, reedy canes, found in wet localities, and containing no sugar. This species was found and named by Dr. Jeswiet during the visit of the Brandes Expedition to New Guinea in 1928. Some hopes are entertained that this species may be useful for breeding purposes.

#### Historical Survey of Cane-breeding.

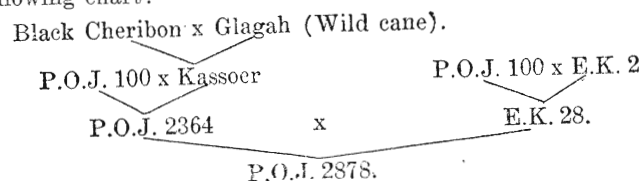
Sugar-cane is an agricultural crop of great antiquity; it was grown in China and India centuries before the Christian era, and gradually extended from the Orient westwards to the countries of the Mediterranean. On his second voyage in 1493, Columbus took cane cuttings to the West Indies, and thereafter the industry expanded with great rapidity and soon became centred in the Western hemisphere. Columbus appears to have introduced only one variety—the Creole cane—and for over two hundred years this remarkable cane was practically the only variety cultivated in the American zone. It so happens that this particular variety will not set fertile seed, and this was responsible for the deeply rooted conviction among sugar men that all sugar-cane flowers were sterile, and consequently that the raising of seedling canes was impossible. (As a matter of fact botanists had noted the fertility of sugar-cane seeds on several occasions, but the information would not appear to have been in the hands of sugar-cane agriculturists.) However, in the period 1880-1890 the sugar industries of Java and the West Indies were threatened with extinction on account of the ravages of sereh disease and root disease respectively. The gravity of the situation provided the necessary stimulus to investigation, and as a result the possibility of raising sugar-cane from seed was rediscovered in Java in 1887, by Soltwedel, and independently in the West Indies by Bovell and Harrison in 1889. Disease-resistant seedlings were soon produced, and the practice of seedling-raising rapidly extended to other countries, until at the present time every sugar-cane country of any importance has its cane-breeding station. Incidentally, it is interesting to note that a few seedlings were raised by the Queensland Acclimatisation Society as early as 1890.

With the notable exception of Java the seedlings produced during the first thirty years of cane-breeding were all field crosses—that is, the arrows were collected from cane growing in commercial fields where it had been wind-pollinated and, therefore, only the female parent of the seedlings was known. In Java it was observed that the hardy Indian canes of the Chunnee type, although poor yielders, were immune to sereh disease, and the earliest work was the controlled crossing of Chunnee with noble canes. After sereh had been controlled the Java workers reverted to the use of noble canes for both parents, and latterly they have introduced strains of wild "blood," but the crosses made at the experiment station have been controlled crosses throughout.

The method of seedling-raising from field crosses undoubtedly produced some excellent results, which include the following varieties known to Queensland:—D. 1135 (Demerara), M. 1900 Seedling (Mauritius), B. 147 and B. 208 (Barbados), and H. 109 (Hawaii). Nevertheless it was apparent that this method produced very variable results and the seedlings very frequently lacked disease-resistance and ability to withstand adverse climatic and soil conditions. Fortunately for the sugar industry, some fifteen to twenty years ago the cane-breeding section of the East Java Experiment Station came under the control of Dr. J. Jeswiet, and as a result of the work of this far-seeing scientist the whole aspect of cane-breeding has been changed during the past decade. Instead of depending more or less blindly upon the fortunes of chance, the cane-breeder now works to a definite preconceived plan, selecting and discarding blood lines in orderly fashion and advancing step by step towards a well-defined goal.

Naturally, Jeswiet had a great advantage over cane-breeders in most other countries in that he had at his disposal the wild and semi-wild cane. Actually the first use of the wild type of cane in hybridisation was made in India by Dr. C. A. Barber, but owing to his departure from India he was unable to carry this work to its conclusion. Jeswiet made many crosses between wild and noble canes, but the one which has proved most useful was a naturally occurring cross found in Java. This is the cane known as Kassoer, and its strong rooting, vigorously growing, disease-resistant qualities deeply impressed Jeswiet. He set out, by means of cross fertilization back to noble canes, and the development of a selection technique, to produce a cane which would combine the desirable features of both the wild and noble canes. As the whole sugar world knows, this effort was crowned with outstanding success in the production of P.O.J. 2878, but to appreciate properly the value of Jeswiet's methods it should be emphasised that in these few years there have been produced a large number of canes which greatly out-yielded the old standard canes but which are somewhat inferior to P.O.J. 2878.

The chief steps in the breeding of P.O.J. 2878 are illustrated in the following chart:—



It will be observed that Kassoer has one-half wild blood, P.O.J. 2364 one-fourth, and P.O.J. 2878 one-eighth; these steps are called the first, second, and third "nobilisations" respectively. The production of P.O.J. 2878 illustrates some of the principles of cane-breeding so well that we have constructed a model for your inspection.

Cuttings of the promising breeding canes of Java were not received in Queensland until 1928, so that up to the present sufficient arrows have not been available for intensive work, but these varieties will be extensively used during the coming crossing season.

#### Outline of Technique Employed in Cane-breeding.

The method of making controlled crosses varies somewhat in the different countries, the chief determining factor being the cost of labour. The main requirement is that an arrow of the variety selected as the female parent should be exposed to the pollen of the male in such a way that wind-borne pollen from other varieties is not likely to gain access to the flowers of the former. This is usually accomplished by one of two methods—(a) bagging the male and female arrows in a muslin bag, or (b) the female arrow is surrounded by several male arrows so that the latter themselves give the necessary protection from undesirable pollen. Generally speaking, the results from the bagged arrows are not satisfactory, and this method is mainly reserved for the production of selfs and testing for self-sterility. In order to avoid the complication of the production of a large number of selfs it is desirable that the female parent should either be self-sterile or produce viable pollen very sparingly, if at all. Conversely it is desirable that the variety selected as the male parent should produce fertile pollen in large amounts.

In Java it is usual to leave the female parent growing in the field and to surround the arrow with arrows of the male; the latter are stood in bamboo pots filled with water and have to be replaced every one or two days. This procedure is continued for about a week, when the male arrows are removed and the female arrow enclosed in a bag and left in the field for about three weeks, to allow the seed to set. At the expiration of this period the arrow is cut and bagged.

A somewhat more involved method of procuring mobile male parents was developed in India. Here a split bamboo cylinder is placed about the base of the cane and filled with soil, thus inducing the cane to put forth aerial roots. The arrowing canes are cut off just below the base of the cylinder and are carried to the female parents, which are left growing in the field.

Both the foregoing methods require a considerable expenditure of labour, and to obviate this as far as possible the sulphurous acid method was developed in Hawaii. This method, which is now widely used and which has given a great impetus to seedling-raising, is based upon the use of sulphurous acid as a preservative. Cane cut just as the arrow is emerging and stood in .03 per cent. sulphurous acid solution will flower normally, produce fully developed pollen and ovules, and set viable seed with no further treatment beyond the periodic replacement of the sulphurous acid solution. Consequently crossing may be carried out with both parents removed from the field and stood in sulphurous acid solution; they are kept in this manner for about three weeks, after which time the female arrows are cut and bagged. The use of preservative solutions has a somewhat adverse effect on the pollen viability and the setting of the seed, and in some places it is considered advisable to leave the female arrow growing in the field.

The harvested arrows are dried for a couple of days, and then the seed may be planted immediately or it may be stored over CaCl<sub>2</sub> in airtight containers. The seeds are germinated under warm moist conditions in wooden flats containing, as a rule, a mixture of rich soil, well rotted organic matter, and sand. When a few inches high the young seedlings are transplanted to individual pots and a few weeks later they are planted out in the field.

The seedlings in the field are inspected regularly and notes concerning all phases of their growth are recorded. At approximate maturity a certain percentage of the seedlings are selected on the basis of general visible characters, such as length and diameter of the stalks, number of stalks per stool, type of growth, character of the eye, and so on. (In Java upwards of 60,000 seedlings are planted out in the fields, but only some 400 to 500 survive this first selection.) The selected seedlings are then tested for density or polarisation and the unsatisfactory varieties discarded. The remainder are then planted out in one or two short rows and at maturity are again subjected to the same critical tests. By this means the selection is eventually narrowed down to some three or four varieties, which are then placed in field trials against the standard varieties. From the results of these field trials it is determined whether or not the varieties should be distributed.

It will be seen that seedling-raising involves an immense amount of tedious labour and record-keeping. Fortunately the problem of selection has been greatly simplified by the discovery that the standard

of quality of any particular cross or "marriage" is consistent—that is to say, the progeny of any one marriage are consistently good, bad, or indifferent—with the result that a cross may be continued or discarded on the basis of the first results. Consequently the modern cane-breeding programme consists of two phases—

- (a) A large number of trial marriages involving a relatively small number of progeny; and
- (b) A small number of proved good crosses from which are raised as many seedlings as practicable.

The cross P.O.J. 2364 x E.K. 28 has proved consistently good, and has resulted in a large number of excellent seedlings, including P.O.J. 2878, P.O.J. 2725, and P.O.J. 2714. In this connection it is of interest to note that this year the Hawaiian breeding programme included the formidable number of 1,500 trial marriages.

#### Seedling Canes and Disease Resistance.

Mainly due to the vagaries of chance, we have in Queensland more serious diseases of sugar-cane than any other country, with the natural result that the breeding of disease-resistant seedlings assumes a complexity unknown in these other countries. The Queensland sugar belt is divided into three very distinct districts—viz., wet tropical, dry tropical, and sub-tropical—and therefore it is not reasonable to expect that a seedling raised and selected in one district will necessarily be suited to the conditions of the other districts. Furthermore, all the serious cane diseases present in Queensland are not as yet generally distributed throughout the State, and the dominant diseases differ in each of these districts. Consequently, the Bureau of Sugar Experiment Stations has adopted a scheme under which fertilized arrows will be transferred each year from the South Johnstone Experiment Station to the Mackay and Bundaberg Stations for germination and selection. The type of cross will vary according to the particular needs of each district, and the selection of the resultant seedlings will be made in an environment similar to that in which they are intended to be grown.

If diseases are ultimately to be completely controlled by the use of resistant varieties, it follows that no seedling should be released from a breeding station unless it possesses the necessary standard of resistance, and so a very important phase of the work of the Division of Pathology lies in the testing of promising seedlings in disease-resistance trials. In future all seedlings selected in the second selection will be placed in trials to determine the degree of resistance to the major disease, or diseases, of the particular district, and only those canes which exhibit a satisfactory standard of resistance will be retained for possible field trials. The canes which ultimately become commercial canes will later be included in resistance trials involving the remaining major diseases of the State.

The manner in which the trials are conducted varies according to the disease, and this question will be discussed in some detail in another section. At the present time trials are being conducted to determine the resistance of various varieties to gumming, leaf-scald, Fiji, mosaic, and red stripe diseases. Attention is also being paid to the relative resistance of the different "blood lines" and information regarding the relative resistance of the various marriages will be accumulated year by year.

## THE PRESENT STATUS OF CONTROL OF SOME QUEENSLAND SUGAR-CANE PESTS.

By R. W. MUNGOMERY.

At last year's conference of this Society Mr. Jarvis very ably dealt with certain aspects of the control of the "Greyback" cane beetle, *Lepidoderma albobirtum* Water., and of the sugar-cane weevil borer, *Rhabdocnemis obscurus* Boisd. At the same time he suggested lines along which future investigations in control methods might be directed. Briefly, the position with regard to the "greyback" cane beetle is that this pest may be controlled by a rigid enforcement of the following points:—

- (1) The collection of beetles from their feeding trees;
- (2) The destruction of feeding trees adjacent to cane areas;
- (3) Soil fumigation of infested areas during February; and
- (4) Attention to certain cultural details.

The other important pest, the weevil borer, is parasitised in some localities to a high degree by the Tachinid fly parasite. In addition to providing suitable small areas of standing cane wherein this parasite may breed unmolested, care should be taken to plant only cane that is free from borer. Badly damaged blocks of cane should not be left to stand over, where the parasite is not established, on account of the danger of beetles migrating to clean fields. Short pieces of sugar-cane split in halves, and placed at intervals along the headlands and covered with trash, prove excellent traps for these migrating beetles. The traps should be examined regularly, and any beetles found at them should be destroyed. As I do not wish to recapitulate the problems connected with the control of these two major cane pests, I propose to deal mainly with the injurious species attacking cane in Southern Queensland, and I will now pass on to them.

"White Grubs" have been for years past, and still are, the worst insect problem confronting the sugar industry in Southern Queensland. Australia has a fairly rich Scarabæid fauna, and our districts contribute in no small way to the great variety of species found in this country. Our three chief southern cane pests are *Pseudoholophylla furfuracea* Burm., *Lepidiota frenchi* Blkb., and *Lepidiota trichosterna* Lea; *Lepidiota frenchi* is also a Northern cane pest. All of these grubs inflict damage to the root system, and concentrate in patches in the cane fields, giving affected blocks a very uneven appearance as regards growth. Other Scarabæid grubs causing damage to cane are species of *Dasygnathus* and *Anoplognathus*. Both of these do their greatest injury by eating into the ends of the sets and ringbarking them at the nodes. A few other species of "white grubs" are frequently met with when ploughing cane land. The most common of these are species of *Heteronyx* and *Sericesthis*, but since they have not been found harmful to cane growing, they will not be considered further.

Regarding the distribution of the more important species, the areas remain much the same as when this investigational work was first commenced. The Isis, Gin Gin, and Woongarra districts are the worst



infested areas, whilst the more southern districts of Maryborough, Nambour, and Beenleigh enjoy comparative freedom from grub attack. Coming now to the types of soils commonly infested, we find that *P. furfuracea* is confined chiefly to the red volcanics; *L. frenchi* remains for the most part in the forest loams; whilst *L. trichosterna* infests soils intermediate in character between the soils previously mentioned. For instance, *L. trichosterna* is sometimes found associated with *P. furfuracea* at Goodwood, whilst at Sharon and Avoca it has been found with *L. frenchi*. However, in no case have we found *P. furfuracea* and *L. frenchi* to be present in the same field. *Dasygnathus* and *Anoplognathus* grubs infest grass land chiefly, and they may frequently be found in cane land that has recently been placed under cultivation.

With reference to the extent of the infestation, the total acreage remains approximately the same, but this, as well as the degree of infestation, is greatly influenced by weather conditions. Favourable weather may promote the spread of certain fungous diseases of the grubs, and cane that is growing vigorously is much more able to resist grub attack than cane which is suffering from the effects of dry weather. On the other hand, droughty conditions, if prolonged into late spring and summer, may cause beetles to die in their cells, or they may be so weakened that reproduction does not take place. It might be worthy to note here that the same biennial outbreaks do not necessarily follow in the case of *P. furfuracea* as has been reported by other entomological workers to be the case with *L. frenchi*, which, in common with *P. furfuracea*, has a life cycle of two years. Records of collections made from year to year in the Isis district show that heavy infestations have not always been followed by correspondingly heavy infestations two years later, and this adds weight to the contention that weather conditions play a rather important part in this control.

### Control.

Since these insects are native pests and, in addition to infesting cane fields, they infest grass paddocks and surrounding country, it follows that we can never hope for their complete eradication. At most we can aim at bringing their numbers down to a minimum whereby their effects then become negligible. Control measures so far consist of a system of collecting the insects, combined with cultural, chemical, and biological control methods. Averaging the number of eggs produced per female beetle at thirty, we find that, theoretically, we must get a 94 per cent. control before we begin to make any headway in lessening the pest. This is a task of great magnitude to set before ourselves. Obviously every grower should co-operate to bring about this desirable end, and any neglect on the part of one individual may make the efforts of surrounding growers go for nought.

In the different stages in the life histories of these pests there are salient points which may be taken advantage of when devising methods for control. The control measures adopted against the various stages of the pests are as follows:—

#### CONTROL OF THE BEETLE.

*Lepidiota frenchi* is the only beetle of the three whose habits permit of its being extensively collected. Soon after emerging these beetles fly around and later hang up on small trees and fence posts, where mating

takes place. According to experiments carried out with this species elsewhere, it has been found that these beetles must feed for some time before their ovaries develop and they are capable of depositing eggs. If they are collected soon after they emerge in November or December, much good will accrue by destroying them and thereby lessening grub infestation in nearby fields during the ensuing year. As for *P. furfuracea* and *L. trichosterna*, the female beetles of these species are not attracted by lights, nor do they feed before laying their eggs. At present, therefore, we have no method of trapping these beetles in large numbers, and from their habits it appears that this will be a most difficult task to accomplish.

#### CONTROL IN THE GRUB STAGE.

Owing to the fact that these species of "white grubs" have a two-year life cycle, grubs may be found in the soil at any time of the year. They are, however, more plentiful during the hotter months of the year—from October to March—and, therefore, the majority of the ploughing should be carried out during these months in preference to the winter months. Frequent ploughings subject the grubs to the cutting and crushing effects of the discs, and they are also liable to be exposed to the hot rays of the sun, which often prove fatal to them.

Collecting the grubs from behind the ploughs appears to be a decided help in keeping the pest under control in places like the Isis district, but, despite this systematic collecting, it must be conceded that this district is much more heavily infested than the Woongarra district, where little or no collecting has been done for many years. However, superficial comparisons such as these are of little value, since differences in topography and fauna are apt to have far-reaching influences. Collecting has its weak points in that valuable parasites and predatory insects are often destroyed at the same time as the grubs. Receivers can do much to tighten up this weakness by refusing, if necessary, to accept parcels of grubs for payment where parasites have been included in the pick-up. It is possible to educate the collectors so that they can discriminate between grubs and such beneficial insects as robber fly maggots and predaceous wireworms, and to insist that they leave these latter unmolested in the soil. The system of collecting, however, makes no allowance for internal parasites, such as Dexiid fly larvæ. On certain farms in the Bundaberg district the degree of parasitism of third-stage grubs has been from 50 per cent. to 80 per cent. of those that were exposed by the plough, and obviously the destruction of these grubs would put a serious check on the natural increase of a valuable parasite. Another weak point in the system is that since grubs are paid for at so much per quart the small first-stage grubs are passed over in favour of the more bulky third-stage, which are the more profitable to pick up. When we consider that most of these third-stage grubs have completed the greater part of their damage, whilst the first-stage grubs still have another year's activity before them, it is all the more important that we should try to secure these smaller grubs. Possibly some scheme whereby these smaller grubs are paid for at higher rate would go a long way towards lessening this difficulty.

The chief artificial control measure—namely, soil fumigation—is also directed against the grub stage, this being one period in its life cycle when it is most vulnerable. Soil fumigation is carried out with a mixture of dichlorobenzene and carbon bisulphide. Such a means of overcoming grub damage is fairly costly, amounting to £2 16s. to

£3 12s. per acre for fumigants, to which must be added the cost of labour for injecting. Because of this high cost, fumigation is recommended chiefly as a means of cleaning up small infestations in plant or first-ratoon cane, and not as a means of treating large acreages that are heavily infested. While it is possible in Northern Queensland to profitably treat large areas that are heavily infested, economic considerations such as lower yields per acre prevent us from carrying out large-scale fumigation work here. A saturated solution of paradichlorbenzene in carbon bisulphide has been the standard fumigating solution for some years. In the Bundaberg district we are now using liquid dichlorbenzene, which is a 90 per cent. orthodichlorbenzene product, in place of the paradichlorbenzene. This is mixed with carbon bisulphide in the proportion of 1-2 by volume, and we find that this fumigant gives equally good results. In addition, the liquid dichlorbenzene is cheaper than the paradichlorbenzene, and as well as being easier to mix, it is less troublesome in the injectors. Every facility is being given to the farmers to clean up their areas, since some of the local farmers' associations have provided injectors and fumigants, both of which are being made available to those requiring them at cost price. Soil fumigation is becoming more and more popular as a means of dealing with these pests. Records show that in the Isis district the area fumigated in 1926 was in the vicinity of 2 acres, whilst in 1930 it was between 50 and 60 acres. The fumigant is injected into the soil in doses from 3.5 to 4.5 cub. cms. on each side of the stool and about 4 inches away in plant cane. In ratoon cane it is delivered right up against the stool. We aim at delivering the fumigant at a depth in the soil just above where the majority of the grubs are feeding, and 3 to 4 inches seems to be a good average depth.

Grubs often burrow deep in the ground during dry weather and again when they are about to moult. As this period of moulting is a very irregular one, it frequently happens that at the time we inject some of these grubs are located deep in the ground, and they invariably escape. So also do those that are to be found in the interspaces, and this survival on the part of a few represents one of the weaknesses of the system.

#### CONTROL OF THE PUPAL STAGE.

The pupa is the inactive or resting stage wherein reconstruction takes place, and, since during this stage the insect is located at an average depth of 17 inches in the ground, little in the way of control measures can be directed against it. Deep cultivation by means of steam ploughs and grubbers offers one way of contributing towards the commonsense principle of "every little helps" in the control of the pest. These operations are only possible on big plantations, and where it can be arranged they should be carried out during July, August, and September. In the two former months grubs are in an inactive prepupal condition, whilst by September they have usually changed to the pupal stage. At such times they are liable to be killed by these implements, or, failing this, their cells may be broken, thus causing them to emerge in a deformed condition, and fall a prey to ants, &c.

#### CULTURAL CONTROL.

Because of the fact that a great impetus is given to the pest to increase when ratooning is carried on over a long period of years, it is wisest, on farms where grubs are troublesome, not to ratoon beyond the

second ratoon crop. The practice of ploughing out and replanting soon afterwards is also unsound, on account of the small check imposed on the natural increase of the pests.

In addition to these facts, evidence has accumulated to show that beetles fly to standing vegetation to deposit their eggs, and for this reason it is not a good plan to leave cane to stand over on farms that are liable to become infested, nor to have crops of green manures and weedy fields during the fighting period of the beetles.

#### CONTROL BY PROTECTION, FRIENDLY ORGANISMS, AND THE INTRODUCTION OF PARASITES.

Birds such as the ibis and crow are two of our chief grub destroyers, and they should be given every encouragement. Others, such as the Indian mynah and peewit, destroy a large number of parasites in addition to grubs, so that the role they play in grub control is somewhat doubtful. The protection of our parasitic and predatory insects has already been discussed to a certain point when touching on the aspect of collecting grubs. Unfortunately some of these beneficial insects are themselves kept in check by hyperparasites, our common digger wasp, *Campsomeris tasmanicus* Sauss, being a notable example. It is attacked at different stages of its growth by a Bombyliid and Conopid fly, both of which greatly reduce its efficiency as a grub destroyer. Attempts have been made to breed Asilid or Robber flies in insectaries, and thereby increase their effectiveness, but these have failed owing to the cannibalistic habits of the flies. On the other hand, we may be able to make more use of the Dexiid fly, whose larvæ are internal grub parasites, and experiments will be continued in attempting to breed this fly on a large scale, and, if successful, parasitised grubs will then be distributed in centres of infestation. Biological control of some of these pests appears to be well within the bounds of possibility, and this line of investigation should be pushed ahead, both in regard to trying to increase the effectiveness of our native parasites and also with a view to obtaining a suitable parasite from a foreign country.

#### Minor Pests.

Another small beetle pest, *Rhyssalus morosa*, though not closely allied to those previously discussed, attacks cane in this district from November to January. The grub in its earlier stages lives in the soil, but when it is about half-grown it bores through the young shoots into the tender central tissues, causing a "dead heart" and death of the shoot. Fortunately the areas in which the pest is found are limited, so that we can overcome it by paying attention to the period of harvesting and planting. Cane harvested early in the season has usually produced ratoons 2 to 3 feet high by November, and these shoots are then no longer subject to serious damage. A few small shoots may die out, but when it is remembered that in the ordinary course of events a few of the weaker shoots usually do die, little actual damage amounts from their attack. Arrangements can usually be made with the cane inspectors of the mills to have such cane harvested early. By planting in February and March, the activity of this insect is on the wane, and little damage occurs, whereas spring plant cane often suffers damage.

**Soldier Flies.**

Sporadic damage is sometimes caused by the maggots of these flies attacking cane planted in spring. This usually happens in a comparatively dry spring, such as we experienced last year. The maggots cluster around the small roots springing from the set, and suck the juices from them. These roots then wither and die and the set is ultimately destroyed. The maggots become full-grown during March, when they pupate, emerging as flies usually about Easter time each year. If planting is carried out in autumn, the pest need cause us little concern.