MAINTENANCE OF SOIL FERTILITY IN THE SUGARCANE PLANTATION

By H. H. DODDS.

This problem, always of fundamental economic importance in the agriculture of sugarcane, is one of particular importance and difficulty at the present time. Of special importance because of the national (and international) need to gain the maximum production of sugar at the present time; and of special difficulty because of the acute shortage and high costs of commercial fertilizers that were cheap and plentiful before the war, and could be relied upon then to maintain production if properly applied, though not necessarily economic, in view of world overproduction and low prices of sugar.

Theoretically, there should be little loss of the elements of fertility from the soil in the production of sugar, the final product being a pure carbohydrate consisting solely of carbon, hydrogen and oxygen that the sugarcane has obtained from the unlimited supplies in the atmosphere.

How different this is from the position of the grain and livestock producer who must give up in his main products large quantities of the essential fertilizer elements nitrogen, phosphorus, potassium and calcium, so that he cannot avoid losing completely from his soil a certain amount of fertility that must sooner or later be replaced, if production is to be maintained.

Thus it was formerly one of the boasts of German agricultural economists that in exchanging white sugar for cereals while retaining the molasses, they were transferring soil fertility on a large scale from America to Germany.[3]

Of course the sugarcane crop, like all plants, also takes up these fertilizer elements from the soil, but there are opportunities in the sugar industry of arresting these elements before they have gone beyond recall and of returning them to the soil. Thus the chemical treatment of the juice results in the precipitation of much of the nitrogen, phosphorus and calcium recovered ultimately in the form of filter cake, though some of these elements, and most of the potassium pass through the clarification process and are eliminated from the main product of the industry, the sugar, during recrystallization, and remain in the concentrated mother liquor known as molasses.

Some small quantities of the fertilizer elements do not go into solution in the juice but remain in the solid state in the fibre and pass into the bagasse, used exclusively in this and in most cane-growing countries as a fuel in the sugar factory, notwithstanding its possibilities of forming more valuable products utilizing its fibrous properties.[11, 14, 16, 9].

BY-PRODUCTS OF SUGAR MANUFACTURE.

Let us examine, if possible, what proportion of the original fertilizer elements of the cane pass into the four main by-products: cane trash and tops, filter cake, molasses and bagasse.

Each 100 tons of cane, containing approximately 31 tons of total solids, consisting of 15 tons fibre, 14 tons sugar, and 2 tons of other soluble solids, receives approximately 31 tons of imbibition water and about one half-ton of additional solids either as chemicals used in processing, or substances in solution or suspension in the imbibition water.

This gives rise to the following products :—

			Tons solids.
Bagasse	32	containing approximately	15½
Sugar	11½	containing approximately	11½
Filter Cake	5	containing approximately	2
Molasses	3	containing approximately	2½
	51½		31½

Thus 20 tons of water remain in the products as they leave the factory, the remaining 80 tons of the original 100 (69 tons from the cane and 31 from the imbibition water) being evaporated in process.

According to analyses at this station the portion of the cane crop (Co.281) removed for milling contains 0.16 per cent. nitrogen on the dry sample (0.05 tons per 100 tons), 0.15 per cent. phosphate as P_2O_5 (also approximately 0.05 tons per 100 tons of original cane) and 0.97 per cent. potash as K_2O (or 0.30 tons per 100 tons).[8]

The bagasse ash contains approximately 1.9 per cent. of phosphate as P_2O_5 and 6.6 per cent. of potash as K_2O, and since the ash is approximately 1 per cent. of the original moist bagasse it follows that the phosphate content of the original bagasse was 0.02 per cent. P_2O_5 and the potash content 0.06 per cent. This amounts to considerable quantities of these fertilizer elements over the whole crop since the moist bagasse is equivalent to one-third of the original cane. Nevertheless bagasse ash is of little value as a fertilizer, consisting as it does very largely of silica, and the potash and phosphates being largely vitrified, or at least in highly insoluble forms.

Consequently the phosphorus and potash that remains in the ash must be regarded as practically lost from the point of view of fertility maintenance.

The filter cake though much smaller in bulk, is far more important as a source of fertilizer. The average contents of fertilizer elements in sulphitation filter cake in this country are nitrogen 0.8 per cent., phosphates as P_2O_5 2.5 per cent., potash as K_2O 0.2 per cent., and lime as CaO 14 per cent.[19] These refer to air-dried samples containing about 10 per cent. moisture, and since the filter cake as it usually comes fresh from the factory contains about 60 per cent. moisture, the foregoing figures should be divided by two to arrive at the average composition of normal wet cake.

The molasses, though containing considerable proportions of the nitrogen and potash originally in the cane, is not generally returned to the soil as fertilizer, since the valuable carbohydrate it contains makes it more valuable for other purposes. Much of it is used for fermentation as a source of alcohol and other products, and although the mineral components may be recoverable in the residual liquor known as "dunder," they are usually then too dilute to be practicable to apply direct to the cane or to concentrate economically.

Molasses in this country contains on the average about 0.3 per cent. of nitrogen and 4 per cent. of potash,[5] of which little find their way back to the fields.

Of the actual factory by-products we are therefore largely confined to filter cake.

It is fortunate that most of the phosphorus originally in the cane and a considerable portion of the nitrogen find their way into this by-product which is not otherwise required and is easily collected and returned to the fields.

Filter cake, however, is a bulky material and it may be uneconomical to use it in fields far from the factory and railway or tramline because of the cost of handling and transport in such cases.

The annual production of filter cake at the factory amounts to approximately 250,000 tons per crop, say 100,000 tons of the dry cake containing 2.5 per cent. of phosphates, equivalent to 2,500 tons of P_2O_5 in all, or approximately the equivalent of 17,000 tons of superphosphate. This represents most of the phosphates in the cane and nearly all the phosphates added in the factory during juice treatment, equivalent to about 0.3 lbs. of P_2O_5 per ton of cane or about one-third of the total phosphate in the cake, and in fact happens to be exactly equal to the phosphates contained in a 5,000,000 ton crop of cane according to the analysis already quoted.

CANE TOPS AND LEAVES.

However, this does not mean that the phosphorus requirements of the cane fields can be totally met in this way, since more than half of the original sugarcane crop and more than half of the phosphorus is left in the field or partially burned as the leaves and tops. No doubt some of this material finds its way back into the soil, but a good deal is blown or washed away and dissipated as dust or ashes, or even as dried-up leaves.

The return of these cane tops and leaves to the soil as far as possible is of great importance, even more for their organic than their mineral content. The maintenance of organic matter in the soil is dealt with later in this paper.

By far the best means of using at least some of the cane tops is to use them for their feeding value for stock over and above the transport stock of the plantation. Many planters have found it a profitable sideline to keep dairy cattle, selling the cream at the nearest creamery, and utilizing the separated milk to feed pigs. Of course, if dairy cattle are to be kept the diet of cane tops (adequate as a sole diet for trek oxen) must be suitably balanced with some concentrates and protein, entailing the cultivation of some leguminous feed crop. This, however, further benefits the soil, even if the crop is taken away for fodder. Thus we have on the credit side the proceeds from the sale of cream, the natural increase in cattle and pigs, greatly increased quantities of manure for use in composting or direct, and a beneficial crop rotation for the soil used in growing the leguminous feed crop. In this way profitable sidelines can be built up on the small sugar estate while contributing materially to the maintenance of soil fertility. This is no untried scheme, but one that I know is working well on many Natal sugar plantations.

In any case a good deal of this organic waste, especially when the cane is burned, is lost to the soil, and while the organic matter can be built up again by the cane plant from water and the carbon dioxide of the atmosphere, the drain of mineral phosphates, and of potash where the soil is not naturally well supplied with that element, must be met from outside sources such as commercial fertilizers, Karroo manure, and the like.

This is even more the case with nitrogen. We have seen that most of the phosphorus entering the factory is recovered, but most of the nitrogen is lost in the atmosphere in the combustion of the bagasse and in the boiling of the juice and syrup, so that only one-third of the nitrogen entering the factory in the cane is conveniently recovered in the filter cake.

Nevertheless, the filter cake each season represents a reservoir of 800 tons of fixed nitrogen, equivalent to 4,000 tons of ammonium sulphate.

CROP REQUIREMENTS OF FERTILIZER.

For the actual production of the crop, however, it is not so much a matter of restoring the balance of fertilizer elements as of presenting the young cane plants and ratoons with a quantity of fertilizer in rapidly available form found by experiment and experience to be required for maximum profitable growth. This has been shown to be in most soils in this country to be for the plant cane crop 600 lbs. per acre of superphosphate and 80 lbs. of nitrogen.[15]

The requirements of the ratoon crops for phosphorus are usually smaller and vary from nil to 600 lbs. according to soil and general conditions; but the requirements of nitrogen appear to be the same for each crop whether plant cane or ratoon, usually 80 lbs. of nitrogen corresponding to 400 lbs. of ammonium sulphate though it may need considerably more in certain cases to get the maximum response and profit.[6]

The nitrogen requirements of the plant cane crop are best met by growing and ploughing in a leguminous green manure crop such as sunn hemp or velvet bean or the like before planting the cane. It is difficult to determine how much nitrogen such a crop fixes from the atmosphere and how much is merely taken from the soil, but the net result is that there is no need to apply nitrogenous fertilizer to the following plant cane crop.[4]

Such a green manure crop also confers the great advantages of giving the soil a much needed change of crop after a cycle of sugarcane crops, and contributes organic matter to the soil.

Weather conditions during our harvesting season do not make possible the growing of a green manure crop between the ratoon rows, such as is practised in certain tropical countries. Straight nitrogenous mineral fertilizers are now almost impossible to get during present war conditions and sometimes their prices are prohibitive as some of our recent experiments have demonstrated, but recently supplies of ammonium nitrate have been available, which is capable of giving profitable results in certain cases; its present price is £27 per ton (after deducting the farmer's rebate) equivalent to 16/- to 17/- per unit of nitrogen according to whether the guaranteed nitrogen content is 32 or 34 per cent. Incidentally, the lower content of nitrogen may be the best for our humid climate since it implies a greater content of the water-repelling and anti-caking agent coating the fertilizer particles.

Failing this, Karroo manure is to be recommended as a nitrogenous and phosphatic fertilizer for ratoons or for plant cane that has not been green manured, if used in the crude unmilled form obtainable at about 12/6 per ton. Three tons are equivalent to 80 lbs. of nitrogen and 400 lbs. of superphosphate.

Mixed fertilizers are less profitable and less adaptable than straight fertilizers for the sugar planter, but the official mixture "H" may be used in some cases with profit where there is no objection to applying a heavy dressing of superphosphate simultaneously with the nitrogen. 1,000 lbs. of this 8 : 10 : 0 mixture is equivalent to a mixture of 400 lbs. of ammonium sulphate with 600 lbs. of 16 per cent. superphosphate.

CONSERVATION OF ORGANIC MATTER IN THE SOIL.

Organic matter performs several important functions in the soil, such as retaining moisture much more than the mineral portions, checking erosion by wind or water, and promoting either by chemical or bio-chemical means the solubility and availability of chemical elements of importance to plant life, especially phosphorus and potassium.

Sugarcane agriculture is fortunate in that it deals with a large plant with a correspondingly large root system. Consequently after each crop there is a large residue of organic matter left in the soil from the old roots. In fact, in Hawaii, which has long been in the foremost rank of cane sugar productivity, 6 to 7 tons of sugar per acre per crop, the maxim has been adopted and successfully demonstrated for many years that to conserve organic matter in the soil it is only necessary to make it grow big crops. They have the natural advantages, however, of an originally fertile soil and ample supplies of water for irrigation.

In many of our sugarcane soils in this country it is necessary to add organic residues from the surface crops to those supplied by the roots.

COMPOSTING OF CROP WASTES.

One very effective method of doing this, developed by a very large factory estate, is to compost the trash in the field after the last cutting with filter cake from the factory, while growing sunn hemp on the compost heaps.[7] The question arises whether the results of this practice are both more effective and more profitable than the less expensive alternative of ploughing the trash and the filter cake and a green manure into the soil and allowing the composting to take place there.

Certainly composting needs to be done on a fairly large scale to keep down its cost sufficiently.

Thus a small quantity of compost was prepared at the Experiment Station for field experiment purposes from velvet bean and sunn hemp tops and cane trash at a cost for labour and transport of 6/6 per ton and contained (when utilized) 0.27 per cent. of nitrogen.[12] This was used in a fertilizer experiment in the heavy clay loam soil of this station in comparison with equivalent quantities on a nitrogen content basis of ammonium sulphate, crude unmilled Karroo manure and bird guano.[17] There was a gain in yield of from two to five tons of cane per acre from each, but a net loss of 15/- per acre from the compost, 24/- per acre from the bird guano and 32/2 per acre from the ammonium sulphate at prevailing prices. Karroo manure showed a profit of 18/9 per acre, the price being 13/- per ton; any price over 16/9 per ton would have shown a loss also. The limiting cost, below which the compost would have shown a profit was 5/6 per ton. The College of Agriculture at Elsenburg, C.P., have published details of making a compost of good average quality from farmyard manure and vegetable waste at 4/6 per ton.[13]

The limiting value for the bird guano was £14 a ton and for the ammonium sulphate £11 a ton, so that the latter would have shown a profit under the conditions of this experiment at normal pre-war prices, and the former would have shown a profit if sold at the price of Government Guano.

Each of the fertilizers were applied together with 500 lbs. per acre of superphosphate, which used by itself in this experiment without any nitrogenous fertilizer increased the yield of sucrose per acre by half-a-ton, thus showing a profit of £1 16s. 3d. per acre after deducting £4 15s. 0d. per ton for the cost of the superphosphate.

A somewhat similar experiment carried out by ourselves, with the help of Mr. T. Roberts, at Waldene Estates, Chaka's Kraal, in a coarse sandy loam gave a very marked profit of £8 3s. 4d. per acre from 80 lbs. of nitrogen applied as a farm compost.[18] The limiting cost here was as high as 21/9 per ton. The best profit, however, £12 17s. 2d. per acre, was shown here also by the application of 10 tons per acre of crude unmilled Karroo manure containing 160 lbs. of nitrogen costing 13/- per ton. At the price of 35/- per ton for the milled manure the result would have shown a heavy loss.

It is evident that in sandy soils especially compost is capable of promoting great increases in yield of cane; but whether this is the most economical method of application of the nitrogenous substance essential to forming the compost I consider still remains to be demonstrated. Without the necessary nitrogen, decomposition of trash will be extremely slow, and if the trash be applied to young plant cane without thorough decomposition it will retard growth because of its wide carbon-nitrogen ratio.

At all events organic matter should be conserved and returned to the soil whenever practicable in some form or another.

I consider the widespread and growing practice of burning the trash, whether on the cane before cutting or on the cane trucks or on the ground after harvesting, as a wasteful one, only to be justified in those highly productive lands having an excess of organic matter and where the accumulated trash would otherwise form an unmanageable burden.

CONTROL OF SOIL EROSION.

Another fortunate advantage of the sugarcane crop is that it does not lend itself particularly to soil erosion, partly because of its extensive root system which binds the soil, and partly because land under sugarcane once planted is occupied for several years. It is, therefore, ploughed and exposed to the erosive effects of rain and wind only at very long intervals, and is still better protected if the trash is not burned but allowed to remain on the ground after cutting.

It is necessary, therefore, that on hillside soils, such as form the majority of our cane lands, the cane rows be graded or contoured as necessary to avoid erosion between the rows during heavy rains.

MYCORRHIZAL ASSOCIATION.

Another advantage often claimed for organic matter in the soil is that it promotes mycorrhizal association between certain soil fungi and the roots of cultivated plants. The relation between the host plant and the fungus is a very complex subject on which much research has been recorded.

Mycorrhizal association, of which we hear a good deal nowadays, is not necessarily symbiotic, but may even be to some extent parasitic to the host plant under certain conditions,[2, 10] and in any case does not appear to be essential to the normal vigorous life of the sugarcane plant.

If the sulphate ion, as in ammonium sulphate, is really fatal to mycorrhizal association as some authorities claim,[1] it is really a small matter to the sugarcane crop compared to the overwhelming benefit conferred by ammonium sulphate, demonstrated beyond question in countless instances in nearly every commercial crop and every country.

The urgent and ever-increasing demand for mineral fertilizers in every country, and the astronomical figures for output, even during war-time, cannot be explained on the grounds that their benefit to agriculture is a world-wide delusion.

SUMMARY AND CONCLUSIONS.

The ultimate destination is traced as far as possible of the principal elements in sugarcane of importance in fertilizers and manures, and the possibilities of restoring them, the importance of filter cake in this respect being stressed.

The crop requirements of phosphorus and nitrogen are then discussed and various means of supplying the latter described.

The conservation of organic matter in the soil is next considered and the results of field experiments with compost and other organic manures detailed showing that the economical limits of the cost of compost vary in different types of soil. The profitable use of crude Karroo manure for sugarcane is also demonstrated.

The subjects of soil erosion and mycorrhizal association are also briefly discussed.

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Dr. FISHER said he had heard that the application of molasses to the soil stimulated the nitrogen fixation by means of azotobacter; if that were so it would help to obviate some of the difficulties resulting from the shortage of nitrogenous fertilizers. He wanted to know, however, whether any work on this subject had been done in this country.

Dr. DODDS in reply said that no experiments to test out this theory had been done here, but where molasses had been used in experiments to improve yields in the heavy soils of this Experiment Station, the results had been negative. At Natal Estates, where a good deal of molasses was used, it was found that it could be used directly on ratoon crops with beneficial results especially in sandy soils, but it was necessary with plant cane crops to use it with great discrimination before planting, so as to allow it to complete its cycle of fermentation before the cane was put in. Molasses as a result of alcoholic fermentation had of course a sterilizing effect on the soil, which then had, from a bio-chemical point of view a new start. This, quite apart from its chemical composition, was one of the benefits of the application of molasses. At present, however, only very limited quantities were available for application to the land.

Mr. LEWIS wanted to know whether there would be any advantages in putting surplus molasses in the filter cake pits where it could remain for eight or nine months. They were using their filter cake at distances as far as twenty miles from the factory. He would like to know whether Dr. Dodds considered that still economical?

Dr. DODDS pointed out that molasses, provided it was sufficiently dilute so as not to inhibit fermentation, could be used to advantage with compost, but in some experiments carried out at the Experiment Station, it was found that the application of molasses to compost did not add to the value of the latter beyond that corresponding to the chemical composition of the molasses which was of course not very much. He therefore thought that there were other more useful applications of molasses than as a fertilizer. The cost of transport and handling of filter cake could not be expressed in terms of mileage only, because so much depended on the local topography and other conditions affecting transport. The present value of filter cake of average composition was about 15/- per ton, and it was for the planter to decide how much he could profitably spend in purchase and transport and handling of the material. It would, however, have a greater value on sandy soils than on heavy soils. He said that it had been found that eight to ten tons of dry filter cake, corresponding to about sixteen to twenty tons of the wet material would supply about as much phosphorus and nitrogen per acre as required by the crop. It should be borne in mind that filter cake from the Oliver type of filters should be left to mature four or five months before using it on the fields, otherwise the tiny particles of bagasse in the fresh filter cake fermented, and undesirable fermentation products were left in the soil, while the nitrogen content of the soil was temporarily diminished as a result of bacterial activity. Filter cake could be either broadcast and then ploughed in or applied in the furrows. Both these methods gave beneficial results, but it was found to be better to broadcast the filter cake and to plough it in so that it was well mixed with the soil, as apart from its fertilizer value, the organic matter and lime in the filter cake further improved the soil structure and neutralized acidity.

In reply to another question Dr. Dodds said that pen manure used to be widely manufactured in Mauritius and in the West Indies, but when the price of ammonium sulphate dropped to £8 a ton the custom fell into disuse, which was in some respects unfortunate as it was a most economic way of using up factory waste products. With the present inflated price of fertilizers it was likely that pen manure was once more used extensively.

Molasses was a very valuable foodstuff for animals and used in this way on sugar plantations it helped to restore the soil fertility, but he had not considered this aspect in his paper as he thought there were so many industrial uses for molasses that it would not in future be available for the many useful purposes to which it could be put on a farm.

It had been found without exception at the Experiment Station that no response could be obtained from the application of nitrogenous fertilizers on plant cane after a green manure crop had been ploughed in. From the first ratoon there was nearly always a response, however, and he would therefore recommend the use of ammonium nitrate or sulphate as top-dressings for all ratoon crops, provided they were not applied too late in the season to be completely utilized. A good deal would depend on the weather, soil conditions and moisture, but if applied too late in the season the very soluble nitrogenous fertilizers might be washed away with the winter rains or they might even prove to be injurious by promoting too late a growth. A very common result of applying inorganic nitrogenous fertilizers was an improvement in the colour of the cane, giving it a rich green colour, but that did not necessarily imply an increase in yield, although it usually did.

Mr WHEELER said that in tropical East Africa he had seen land where cane had been grown for forty years continuously and the only fertilizing material that had been applied was filter cake originally, and eventually a mixture of factory ash, filter cake and molasses at the rate of six tons per acre. When he left Uba cane was still yielding 22 to 24 tons per acre.

Dr. DODDS said that the estate referred to was originally of very great fertility, consisting mainly of alluvial soil, and by returning some of the waste products the exhaustion was greatly delayed. Organic matter had probably increased as a result of the extensive root systems left behind, but there must have been some steady loss of fertilizer elements such as phosphorus and nitrogen, and the company did not expect this soil productivity to continue indefinitely. They were now getting concerned about the fertility of their soil and had written to the Experiment Station for advice concerning the best method of restoring fertility by green manuring and the application of commercial fertilizers.