NITROGENOUS FERTILIZER FOR SUGAR CANE IN SOUTH AFRICA.

By H. H. DODDS and J. E. COLEPEPER.

The element nitrogen is almost universally regarded in sugar cane growing countries as the most important fertilizer for sugar cane, whether applied in bulky organic form such as pen manure, filter cake, meat meals or cotton seed cake, or inorganically combined in various commercial fertilizers such as sulphate of ammonia, cyanamide, or nitrate of soda.

It is only in South Africa that there has been some doubt, and perhaps still is, concerning the prime necessity for nitrogenous fertilizer in sugar cane cultivation.

This may be attributed to two possible reasons. Firstly, the almost universal natural deficiency of phosphorus in South African soils, and the overwhelming response to phosphatic fertilizer until that original deficiency has been supplied may have served to distract attention from nitrogen requirements of the soil.

Secondly, there is the time-honoured practice in this country of applying a complete mixed fertilizer containing soluble nitrogen at time of planting.

There is reason to suppose that recently planted sugar cane cannot utilize fertilizer material until the setts have developed a root system of their own — until that time the developing buds must be supported by the nutrient material of the internodes of the setts.

However, the presence of added fertilizer may influence the rapidity of development of the new root system as well as the germination of the sett and formation of new shoots.

Thus unpublished experiments done here by McMartin in 1938 in a heavy soil showed that, in the case of Co.301 at least, root formation of a newly planted sett was stimulated in the presence of medium quantities (150 lbs. per acre) of ammonium sulphate, provided that heavy dressings of superphosphate and ample supply of water, 5.6 ins. per month, were also furnished.

In the presence of 300 lbs. per acre of ammonium sulphate rooting was retarded.

Germination of the sett was found to be depressed in the presence of ammonium sulphate, causing a reduction in the number of shoots formed, but a marked stimulation in growth was apparent with the shoots that were able to develop, providing the supply of moisture was sufficient.

The experiment was repeated with Co.301 in a sandy soil in 1939, with results that on the whole confirmed the above.

Thus there might be some advantage on the whole in applying 150 lbs. of ammonium sulphate at time of planting, but not with 300 lbs.

Other experiments, quoted later, have indicated that for the continued optimum development of the plant further applications of nitrogenous fertilizer at intervals is necessary.

However, the practice of adding a small quantity of inorganic nitrogenous fertilizer to the cane at time of planting is not without some theoretical justification under favourable conditions.

There is no harm in applying phosphatic fertilizer at time of planting.

The leaching of soluble phosphates that takes place is very slight and the movement is a matter of only a few inches.

The movement and fixation of superphosphate has been dealt with by Brown in the U.S.A., and by Beater in a paper published more recently.

Studying two of our typical coastal soils, it was found that superphosphate generally remained fixed in the soil and was not lost to any appreciable extent. The phosphorus thus remains conveniently close until the new root system spreads and is able to utilize it. The only disadvantage may occur if the phosphatic fertilizer is applied in lumps instead of a powder or meal fairly evenly distributed over the soil. There is then apt to be local overcrowding of roots around the lumps of phosphate, tending towards an unevenly distributed root system whereby the plant is likely to suffer in times of drought. This is probably the cause of so-called "burning" sometimes attributed to superphosphates.

There may be grave disadvantages, however from supplying large quantities of nitrogen in the form of soluble salts prematurely to the plant. If there is an abundant supply of water some of the fertilizer will be leached out of the soil and wasted, which we have seen does not happen with phosphates.
It is for this reason that we find it the general practice in other countries, where soluble nitrogenous fertilizers are used, to apply them mainly or entirely when the root system of the cane plant is fairly well developed and can at once proceed to utilise them.

It seems very possible also that during the very dry growing seasons we occasionally get in this country, little response to inorganic nitrogenous fertilizer can be expected, water then being the limiting factor of cane growth.

This may partly account for the fact that in some seasons the relatively expensive organic forms of nitrogen, such as whale guano (whale meat meal), blood meal, and the like, have proved beneficial where inorganic nitrogen compounds as applied have proved ineffectual or even harmful. In these organic compounds the nitrogen becomes soluble by hydrolysis and oxidation very gradually, so that there is probably never any accumulation of nitrogen as nitrate in the soil moisture appreciably over and above that which the plant can progressively utilize.

Organic nitrogen may be economically supplied to the soil in other ways, such as by the application of waste products containing valuable proportions of nitrogen, as stable or kraal manure, and filter cake from the factory. In view of the relatively very small numbers of livestock existing in the sugar growing belt the supply of manure is always far below the demand, but it is, of course, of great importance that what there is should be carefully conserved and utilized.

The making of compost from manure and other waste products is perhaps not as practicable here as in countries where labour is cheaper and water more abundant, but it is a subject to which more attention should be given and which may have more importance for us than we realize.

Filter cake also has a restricted application, because of the limited amount produced by the factory and the fact that it does not pay to transport this bulky material to distant fields not adjacent to the factory tramline.

Nevertheless, filter cake can be a valuable manure under favourable conditions, especially in light soils. It normally contains only about 1 per cent. of nitrogen and about 2 per cent. of phosphate calculated as phosphoric oxide, but is useful in other ways. It consists largely of organic matter in which many of our soils are deficient, and it returns to the soil much of what the cane took away.

There are several chemical elements known to be required by the plant in minute proportions, for example, boron, copper, manganese, zinc, and others. They are not usually deficient in the soil in the very small quantities required, but may be so without the fact being realized. In such cases filter cake may have a special value by at least partially restoring such elements to the soil.

A very important way of applying nitrogen to the soil is by the practice of green manuring with leguminous crops, especially in these days of scanty and expensive commercial nitrogenous fertilizers.

It has now become recognised in many sugar-growing countries that the cultivation and ploughing-in of a leguminous green manure crop previous to planting cane can make it unnecessary to apply any further nitrogenous fertilizer to the plant cane crop, at least. Thus in Queensland and Louisiana it was found possible to dispense with nitrogen altogether for the plant cane crop, and in Formosa to reduce the requirements very considerably by green manuring.

There is evidence that this may be the case in this country also. Thus, an experiment harvested by us last season showed no response to various quantities of sulphate of ammonia applied as top dressing to plant cane, where the field had been green manured the previous season with velvet beans, even though the crop had been harvested for hay.

Experiments done in similar soils and harvested the same season showed a very definite response to top-dressings of sulphate of ammonia where the field had not been previously green manured.

In all experiments at this station we have been able to demonstrate a benefit to the succeeding plant cane crop from a course of green manuring; even where the green manure crop was not a legume but a plant such as buckwheat, which has the advantage of growing during our dry and cool winter season with a vigour that we have not yet found at that time of the year in any leguminous crop yet tried.

Usually, however, we found that the benefits from a year's course of green manuring were not sufficient to recompense for the loss of active production of sugar cane for a year from land under fallow. This was during the days when economic conditions in the industry were such that the maximum production of cane obtainable at that time (when Uba was the only variety of sugar cane in cultivation) was required every season from every available acre of developed land in the sugar belt.

Conditions are, of course, very different nowadays, when the industry appears to have reached its limits of economic expansion and the average yield of cane per acre has been considerably increased.

Now that lands have to be put out of production of cane, temporarily at least, in any case, there is inducement to build up the fertility of the soil by a long fallow period with a course of green manuring.
A crop that has proved of outstanding advantage in this country for green manure purposes is sunn hemp (*Crotolaria juncea*).

It is a very rapid grower of moderate moisture and temperature requirements, so that it will grow over a wide range of weather and soil conditions, but is perhaps at its best in light to medium loams. In many seasons it can be sown successfully very late, as late as February or early March, if weather conditions are warm and damp.

In the heavy loam soil of the Experiment Station it has given yields of green stuff of 14 tons per acre, which has only been surpassed here in a green manure crop by certain varieties of velvet bean; no doubt in more suitable soils even better yields have been obtained.

As far as I know, the amount of atmospheric nitrogen sunn hemp may be expected to collect and contribute to the soil in a single crop has not yet been worked out locally; but the root system is usually amply provided with nitrogen nodules, which appear to be formed as a rule without any special bacterial inoculation of the soil or seed.

In fact, of all the leguminous crops with which we have experimented, soya bean appeared to be the only one for which any specific inoculation appeared to be necessary for land that had not grown soya beans previously.

The literature on fertilizer experiments with sugar cane in Natal is somewhat scanty for a subject of such economic importance. This is largely due to the lack of an active experiment station during the years between the withdrawal of adequate financial support from the Winkle Spruit Experiment Farm of the old Natal Government, leading to its eventual gradual abandonment, and the establishment of the Experiment Station of the South African Sugar Association at Mount Edgecombe in 1925. Even when the latter had begun, relatively little fertilizer experiment was done during the first few years, the project of introducing and establishing new varieties being considered of primary importance and largely occupying the scanty resources of the station.

What appears to be the first recorded fertilizer experiment with sugar cane in Natal were published in 1912 by E. R. Sawer as Director of Agriculture for the Natal Government at that time, but the experiments, which were done at Winkle Spruit between 1905 and 1913, appear to have been planned and laid down by Mr. Sawer’s predecessor, A. N. Pearson.

The urgent need for phosphorus in unfertilized South African soil immediately became evident the effect of omitting phosphates from a fertilizer being disastrous, the nitrogen and potash only plots showing a gross loss of over £8 per acre.

The use of nitrogenous fertilizers as applied could not be justified in the returns. It was therefore concluded that there was an ample supply of soil nitrogen, though no analytical figures are quoted in support of this contention.

The highest profit, £7 2s. 0d. per acre, was shown by the superphosphate-potash mixture in medium dressings costing only £1 4s. 0d. per acre.

It is of interest to note that the value of the cane—Uba, of course—assumed in these calculations was 12s. per ton, cost of harvesting and loading being assessed at 2s. per ton.

The experiments were continued over three ratoon crops, each fertilizer treatment being repeated after each cutting.

On the whole the results of the plant cane experiments are confirmed. The general conclusion was “superphosphate is the most suitable and profitable form of phosphatic manure, but that its repeated application without potash is to be avoided.”

The effects of phosphorus, nitrogen and potassium were considered in various combinations, both with and without lime. The various combinations tried were NPKl, NPKm, NPKh, PK, NK, NP, P, P2, B, PK2, NPKL, and PL. These symbols have the following meanings:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Material</th>
</tr>
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<tbody>
<tr>
<td>L</td>
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</tr>
<tr>
<td>m</td>
<td>medium dressing, quantities as above</td>
</tr>
<tr>
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<table>
<thead>
<tr>
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<td>£15 0 0 0</td>
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<td>3 3 4</td>
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</tr>
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There is not space to go into details of the results and we will merely quote the conclusions. There were two replications of each treatment and 12 controls, each fertilized plot having a control on one side of it. The size of the plots is not stated.

The average yield per acre from the 12 unfertilized control plots over four cuttings was 32 tons and it was only at the fourth cutting that there was any indication of any serious diminution in yield. The fertilized treatments showing the best results gave an average increase of about 5 tons of cane per acre over the controls at each cutting.

The soil was a light red sandy soil over one-half of the experiment and a dark loamy soil over the other half. There was relatively little difference in yields from similar fertilizer treatments in the two sections, the last-named series showing on the whole lower yields, greater responses to fertilizer, and more definite indications of soil exhaustion at the fourth cutting.

Mr. Sawer left South Africa soon after the publication of "Cedara Memoirs," but the Winkle Spruit sugar cane experiments were harvested again as fourth ratoons in November, 1913, and the results published by C. Williams, then Chemist at the College of Agriculture, Cedara.

Generally speaking, the conclusions formerly arrived at were confirmed. However, the progressive diminution in yields continued, notwithstanding continued applications of fertilizer after each cutting; and Mr. Williams remarks that there were signs of nitrogen exhaustion and that there appeared to be a slight advantage from the use of nitrogenous fertilizer.

The superiority of superphosphate over other forms of phosphatic fertilizer and the need for potash was reaffirmed. It was also stated that while moderate applications of slaked lime showed a profit over the first two crops, they thereafter showed a loss, having presumably led to an exhaustion of fertility after too frequent applications.

Mr. Williams also suggested the use of organic nitrogenous fertilizers, and set forth the need for conservation and restoration of organic matter to the crop.

The only organic nitrogenous fertilizer used in the experiments was bone dust, in which the potential effects of the small content of nitrogen are likely to be masked by the effects of the much greater phosphat content.

The rainfall at Winkle Spruit during the period of these experiments is not mentioned, but the annual rainfall at Mount Edgecombe, according to the records of Natal Estates, Ltd., about 35 miles north of Winkle Spruit, during those years was:

<table>
<thead>
<tr>
<th>Year</th>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>1904</td>
<td>37.03</td>
</tr>
<tr>
<td>1905</td>
<td>49.05</td>
</tr>
<tr>
<td>1906</td>
<td>37.32</td>
</tr>
<tr>
<td>1907</td>
<td>47.57</td>
</tr>
<tr>
<td>1908</td>
<td>41.05</td>
</tr>
<tr>
<td>1909</td>
<td>43.56</td>
</tr>
<tr>
<td>1910</td>
<td>41.79</td>
</tr>
<tr>
<td>1911</td>
<td>52.43</td>
</tr>
<tr>
<td>1912</td>
<td>39.91</td>
</tr>
<tr>
<td>1913</td>
<td>50.00</td>
</tr>
</tbody>
</table>

showing an average rainfall well over the normal for Mount Edgecombe from 1887 to 1925 inclusive, which was 40.22 inches.

These Winkle Spruit experiments have been examined in some detail because they were the first experiments of the kind in Natal and the only ones for several years. They had the authority of the Department of Agriculture behind them and undoubtedly did much to influence opinion and practice in the sugar industry.

**Experiments of the German Potash Syndicate.**

A series of fertilizer experiments with sugar cane were published by the German Potash Syndicate in three pamphlets issued between 1925 and 1927. The objects of these experiments were (a) whether and to what extent crop production could be raised by the inclusion of potash in a fertilizer mixture, and what would be the most suitable amount of potash to apply, and (b) the same queries applied to nitrogen.

The answer given to the first question was a decided affirmative, in the case of each of the nine experiments recorded. The soils mainly belonged to one type, a sandy loam. The potassic fertilizer applied was 125 lbs. or 200 lbs. of potassium sulphate per acre, together with 150 lbs. of bone flour and 300 lbs. of superphosphate at time of planting.

The nitrogenous fertilizer used was 25 lbs. per acre of ammonium sulphate at time of planting, followed by 60 lbs. of sodium nitrate applied as a side dressing three and a half months later, or alternatively double the above quantities of each applied in the same way, corresponding to 14 lbs. or 29 lbs. in all of nitrogen per acre in the light and heavy dressings respectively.

An increase of yield of 2 tons of cane per acre attributed to the smaller dressing of nitrogenous fertilizer, representing a profit of £1 9s. 9d. per acre due to nitrogen, was found in a virgin sandy loam at Eshowe on the estate of the late W. Brockwell.
The average rainfall for these years was therefore much below normal. In these experiments there were duplicate plots of each fertilizer treatment, though sometimes more than two plots of the controls. Each plot was of 0.1 of an acre.

The number of replications, as in all these early experiments, is quite inadequate to give reasonable prospect of reliable results, according to modern standards. It must be kept in mind, however, that it is only within the past twelve or fifteen years that the need for more replications has been realised, following on the application of statistical analytical methods to agricultural experiment results.

As a result of these earlier experiments, so unfavourable to the use of nitrogenous fertilizer, we find the opinion became established generally that for some unexplained reason our soils, contrary to the experience of all other countries, did not respond to nitrogenous fertilizer for sugar cane.

However, we find that C. Williams again warned the sugar industry about taking this too much for granted at the first annual congress of the Sugar Association in 1923.

**Early Experiments at Umbogintwini.**

Messrs. African Explosives & Industries, Ltd., have always taken keen interest in the scientific development of the sugar industry, and have carried out fertilizer experiments and many other types of field experiment bearing on the sugar industry over many years.

The company was in a favourable position to lay down field experiments, having much land at their disposal after closing down their explosives factory at Umbogintwini in 1920. The so-called “danger area” or wide protective belt of land surrounding and isolating the explosives factory then became available for other uses, of which one was the laying down of fertilizer and other field experiments with various crops.

The information derived from these experiments was not only of value to the farming community in general, but also to the company, who had recently gone in for the manufacture of fertilizers on a large scale.

The first series of fertilizer experiments for sugar cane was planted at Umbogintwini in 1924, in a coarse sandy wind-blown soil characteristic of this area.

Eight different mixed fertilizer combinations were used, but there were no replications of plots, so that the individual results were of little significance. However, the average yield of the eight fertilized plots was much greater than that of the four controls, as follows:

<table>
<thead>
<tr>
<th>Tons cane per acre</th>
<th>Fertilized</th>
<th>Unfertilized</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40.0</td>
<td>23.8</td>
</tr>
<tr>
<td>No. of canes per acre</td>
<td>47,000</td>
<td>36,600</td>
</tr>
<tr>
<td>Average weight per cane, lbs.</td>
<td>1.7</td>
<td>1.3</td>
</tr>
<tr>
<td>Sucrose per cent. cane</td>
<td>13.1</td>
<td>12.6</td>
</tr>
<tr>
<td>Purity of juice</td>
<td>86.3</td>
<td>86.9</td>
</tr>
<tr>
<td>Tons sucrose per acre</td>
<td>5.24</td>
<td>3.00</td>
</tr>
<tr>
<td>Per cent. of control</td>
<td>175</td>
<td>100</td>
</tr>
</tbody>
</table>

The cane was of course Uba, with a streak disease rate of infection of about 10 per cent. It was cut at 21 months.

E. S. Caudwell published an interesting series of results of fertilizer experiments at Umbogintwini.

There were two nitrogen series, in the first of which the effect was studied of 31 lbs. of nitrogen per acre applied in a mixed fertilizer. The mixture...
consisted of 300 lbs. of superphosphate, 300 lbs. of raw rock phosphate, 100 lbs. of potassium sulphate, and as a source of nitrogen either (1) 200 lbs. of sodium nitrate, (2) 150 lbs. of ammonium sulphate, (3) 67 lbs. of urea, or (4) 300 lbs. of whale guano per acre, equivalent in each case to 31 lbs. of nitrogen per acre.

The fertilizer was all applied at time of planting and there was no response from the nitrogen over the same quantities of superphosphate, rock phosphate and potassium sulphate without nitrogenous fertilizer.

In a further series the same quantity and kind of phosphatic fertilizer was used, and sodium nitrate applied in top-dressings of 100 lbs., 200 lbs., 300 lbs. and 500 lbs. respectively. The sodium nitrate was applied in three dressings of 15 per cent. of the total one month after planting, 25 per cent. in April, four months after planting, and 60 per cent. ten months after planting.

The resulting yields, after being harvested 24 months after planting, were:

<table>
<thead>
<tr>
<th>Cane per acre in tons.</th>
<th>Lbs. nitrate of soda per acre.</th>
</tr>
</thead>
<tbody>
<tr>
<td>43.59</td>
<td>nil</td>
</tr>
<tr>
<td>46.69</td>
<td>100</td>
</tr>
<tr>
<td>46.39</td>
<td>200</td>
</tr>
<tr>
<td>42.99</td>
<td>300</td>
</tr>
<tr>
<td>41.51</td>
<td>500</td>
</tr>
</tbody>
</table>

There were four replications of each treatment and eight controls with no nitrogen. The size of each plot was 0.05 of an acre and the experiment was located in the typical sandy soil of Umbogintwini.

The contrast between the results of moderate applications of nitrogenous fertilizer applied as top-dressings and applied at time of planting is significant in view of later experiments.

The rainfall at Umbogintwini was 34.65 ins. in 1927 and 33.41 ins. in 1928, much below the average of 40.86 ins. for the period 1924-38 inclusive.

At the same time Mr. Caudwell gave the results of the first ratoon crop of the previous experiment planted in 1924 and harvested for the second time in 1928. No further fertilizer had been added, so the difference between the fertilized and control plots was due to the residual effect of the fertilizer. The average yield of the eight fertilized plots was now 27.99 tons per acre, and of the controls 23.21 tons.

**Experiments by the Sugar Association.**

The present site at Mount Edgecombe of the Experiment Station of the South African Sugar Association was occupied during 1925, and field work in preparing experiments began the same season, although no permanent buildings were erected until 1927.

A fertilizer experiment as well as other field experiments was planted late in 1925. However, the general mistake prevailing in those days of planting insufficient replications was made, only two, or in some cases three, replications of each fertilizer treatment being laid down.

The result was that the only conclusion that emerged was that phosphatic fertilizer, especially superphosphate, which was applied to the great majority of the plots, was of obvious benefit.

A further series of fertilizer experiments were planted in November and December, 1926, including separate phosphate, nitrogen and potash experiments.

There were four replications of each treatment, the size of plot chosen being one-twentieth of an acre in the phosphate series and one-sixteenth in the nitrogen and potash series, consisting of eight rows 54 ft. 6 ins. and 68 ft. in length respectively, 5 feet apart. Between every two plots there was an unfertilized cane row not included in the experiment. The variety of course was Uba, which was the only variety available in those days, while the new varieties now widely grown were under trial. The layout was that of a randomised block. The soil in the phosphate series was a crumbly dark brown heavy loam of fair depth, 12 ins. overlying weathered dolerite; it was decidedly acid with a pH of 5.5, very deficient in available phosphate, 0.006 per cent. P_2O_5 citric acid soluble, fairly well supplied with available potash, 0.011 per cent. and moderately high in nitrogen, 0.18 per cent.

The equivalent of approximately 90 lbs. of P_2O_5 per acre was applied in six different forms, all at time of planting.

<table>
<thead>
<tr>
<th>Lbs. per acre.</th>
<th>Form of Phosphatic Fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>Superphosphate, 17 per cent.</td>
</tr>
<tr>
<td>300</td>
<td>Raw rock phosphate, Egyptian.</td>
</tr>
<tr>
<td>375</td>
<td>Mixture of equal parts of above.</td>
</tr>
<tr>
<td>410</td>
<td>Bone dust.</td>
</tr>
<tr>
<td>320</td>
<td>Rhenania phosphate.</td>
</tr>
<tr>
<td>470</td>
<td>Basic slag, 19 per cent.</td>
</tr>
</tbody>
</table>

Both for the first crop and over a cycle of plant cane and four ratoons, superphosphate proved the best throughout, and the mixture of raw rock and phosphate the least profitable.11 No more phosphatic fertilizer was supplied, but the residual effects persisted up to the final crop, ten years after planting.12

In the nitrogen series 50 lbs. of nitrogen was applied in one of the following forms:—
The whale guano contained 12 per cent. nitrogen and only 1 per cent. P_2O_5.

The soil was a sandy loam 12 ins. deep, overlying a stiff yellow clay, and was distinctly acid, 5.5 pH. The land had been continuously under cane for many years.

The field before planting was fallowed for a year with a non-leguminous green manure crop, buckwheat, and treated with a heavy dressing, 900 lbs. per acre of raw rock phosphate to supply partly at least the acute deficiency of phosphorus, and 60 lbs. per acre of potassium sulphate to increase somewhat the low available potash, 0.009 per cent. There was only 0.002 per cent. of available and 0.02 per cent. of total P_2O_5 in the soil before the experiment, and 0.07 per cent. of nitrogen. Organic matter was very low, total loss on ignition being only 1.48 per cent. 250 lbs. per acre of superphosphate was applied at time of planting, to improve the available P_2O_5, the heavy dressing of rock phosphate the previous season having been found to have had little or no effect on the available P_2O_5. (Eventually it, or something, did raise the available P_2O_5 very materially, but only after about six years. At the same time the soil acidity became almost entirely neutralized, the pH rising to 6.8/7.1.)

The insoluble nitrogenous fertilizers, cyanamide and whale guano, were applied at time of planting, but the water-soluble fertilizers, ammonium sulphate, sodium nitrate and urea, were applied in two equal top-dressings two months and three months respectively after planting.

The crop passed through a severe drought period, only 59.39 ins. of rain falling over 21 months, of which 19 ins. fell in the month of March, 1927.

It was harvested in September, 1928, 21 months after planting. The yield figures were:-

<table>
<thead>
<tr>
<th>Tons cane per acre</th>
<th>Sucrose % cane</th>
<th>Net profit per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control—no nitrogen</td>
<td>25.11</td>
<td>15.3</td>
</tr>
<tr>
<td>Urea</td>
<td>26.29</td>
<td>15.4</td>
</tr>
<tr>
<td>Ammonium sulphate</td>
<td>27.90</td>
<td>15.3</td>
</tr>
<tr>
<td>Cyanamide</td>
<td>28.23</td>
<td>15.3</td>
</tr>
<tr>
<td>Whale guano</td>
<td>30.49</td>
<td>15.3</td>
</tr>
<tr>
<td>Sodium nitrate</td>
<td>31.47</td>
<td>15.2</td>
</tr>
</tbody>
</table>

There was no significant response to urea, ammonium sulphate or cyanamide, but the response to whale guano and sodium nitrate was significant according to "Student's" method of calculation, used in these days. However, the experiments cannot be considered entirely satisfactory in the light of present-day standards, because of the limited number of replications (four).

To test the residual effect of the fertilizers, if any, no further fertilizer was applied to any of the plots which were allowed to ratoon and were harvested again in August, 1930, 23 months later.

Similar gains were again recorded from the sodium nitrate and whale guano, but the results from the other three nitrogenous fertilizers were negative.

<table>
<thead>
<tr>
<th>Tons cane per acre</th>
<th>Sucrose M cane</th>
<th>Value of sucrose increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control—no nitrogen</td>
<td>30.92</td>
<td>15.28</td>
</tr>
<tr>
<td>Urea</td>
<td>29.32</td>
<td>15.61</td>
</tr>
<tr>
<td>Ammonium sulphate</td>
<td>30.89</td>
<td>15.39</td>
</tr>
<tr>
<td>Cyanamide</td>
<td>30.85</td>
<td>15.61</td>
</tr>
<tr>
<td>Whale guano</td>
<td>33.30</td>
<td>15.38</td>
</tr>
<tr>
<td>Sodium nitrate</td>
<td>35.60</td>
<td>15.36</td>
</tr>
</tbody>
</table>

The differences were again significant for the last two fertilizers, but not for the others.

The rainfall was much better over the first ratoon crop, 71.45 ins. falling over 23 months.

It is difficult to account for the apparent residual effect of a highly soluble and non-adsorbed fertilizer like sodium nitrate, though it might not be unexpected with whale guano. It may be due to beneficial secondary effects such as serving to neutralize soil acidity, though one would hardly expect the application of only 320 lbs. per acre of sodium nitrate to have any appreciable secondary effects.

**Experiments at Empangeni.**

Even as early as 1926 we had some evidence that, under very favourable soil conditions and good rainfall, a highly profitable response could be gained from ammonium sulphate. Thus an experiment planted in co-operation with Wilton Park Estate at Empangeni in December, 1924, and harvested two years later, showed significant and profitable increases in yield to an application of 250 lbs. of ammonium sulphate or 500 lbs. of blood meal per acre.

Incidentally, the application of ammonium sulphate as a top-dressing proved less favourable than at time of planting, but it must be pointed out that the top-dressing was deferred until three months after planting and thereby missed some excellent summer rains, which no doubt contributed to the utilization of the fertilizer by the canes treated at planting time.

These experiments showed a significant residual effect from the fertilizer in the first and second ratoon crops.
Over several successive years other fertilizer experiments were done at Empangeni (Wilton Park Estate), which coincided with a cycle of seasons of inadequate or badly distributed rainfall. For that or some other reason, we were never able to get any further consistently favourable responses to nitrogenous fertilizer. The rainfall at Empangeni was 44 ins. in 1924 and 70 ins. in 1925, and for the succeeding six years the average rainfall was 36.30 ins., with only one year (1929) when it was over 38 ins. and that had a very unfavourable distribution of rainfall. By the end of that period fertilizer experiments at Wilton Park, for various reasons, had been virtually discontinued.

The soil in these experiments at Wilton Park is a heavy chocolate loam very representative of a considerable area of cane lands.

**Rainfall and its Apparent Effect on Fertilizer Experiments.**

The deficient rainfall at Empangeni during the six seasons from 1926 to 1931 inclusive may be taken as typical of the sugar belt as a whole.

In a summary of field experiments presented to this Association in 1931, a response only to organic nitrogenous fertilizer, and not to inorganic nitrogen, was shown in co-operative experiments at Umzinto (E. J. Smith) and Chakas Kraal (C. J. Rapson).15

A very favourable cycle of rainfall years began in 1934, since when the average annual rainfall for the sugar belt as a whole has been 45.28 ins., or over 4 ins. more than the general average since 1926, 41.06 ins., and 8.5 ins. more than the average for the 1926-31 cycle, 36.71 ins.

During this period since 1934 there has not been a single year that the general average rainfall for the sugar belt has been below 40 ins. The seasonal distribution has also been very satisfactory, except in 1935 and 1937.

Most of the fertilizer experiments harvested during these last six years have been more or less favourable to the use of nitrogenous fertilizer.

**Experiments at Kulu.**

A fertilizer experiment was planted in September, 1936, at Kulu, about five miles north of Empangeni, in co-operation with Mr. C. F. M. Hibberd. The soil is a wind-blown sand representative of many areas under sugar cane along the coast. The cane variety in the experiment is Co.290.

Both the plant cane crop, cut at 13 months16 in October, 1937, and first ratoons, cut at 21 months17 in July, 1939, gave a highly significant (99 : 1) increase from top-dressings of 30 lbs. of nitrogen per acre, whether applied in the form of ammonium sulphate, 150 lbs., sodium nitrate, 200 lbs., or whale guano, 300 lbs. In the first ratoon crop these quantities were increased by 50 per cent.

Yields of 53 tons of cane per acre were obtained from the first ratoons. There was a small profit from the inorganic nitrogenous fertilizer in the plant cane crop and a substantial one in the first ratoons, £3 14s. 4d. per acre in the case of ammonium sulphate and £2 7s. 8d. from the sodium nitrate.

Incidentally, there was a significant response to the application of superphosphate to the plant cane crop which was not increased by the addition of potash (60 lbs. of chloride per acre) to the super. This small amount of potash was increased by 50 per cent. in the first ratoon crop, no further super being applied, but also without apparent result. There was no significant residual effect in the first ratoon crop from the superphosphate (600 lbs. per acre) originally applied.

This experiment is being continued into the later ratoon crops. The annual rainfall at Kulu was 56.8 ins. in 1937, 37 ins. in 1938, and 52.9 ins. in 1939.

**Experiments at Umhlali.**

Another series of fertilizer experiments in co-operation with Mr. G. P. Ladlay, of Umhlali, gave interesting results. The soil is a coarse but fertile sand, similar to that in the Kulu experiment. The variety was Co.281 and the experiment was planted in November, 1933, and harvested twelve months later.18

There was no significant response to 160 lbs. of sulphate of ammonia in the plant cane crop when applied at time of planting with 640 lbs. of superphosphate and 80 lbs. of potassium chloride per acre. The super alone gave a very significant increase, not further increased significantly by the potash; but the addition of 200 lbs. of whale guano gave a further significant increase, but of the value only of 11s. per acre over the cost of the fertilizer.

To the first ratoons, cut in 1935 when 11 months old in October, no further applications of fertilizer had been made, but there was a marked residual benefit from the superphosphate and from the whale guano; to some extent also from the potash, but none from the ammonium sulphate.19 The rainfall for 1935 was much greater than in 1934 or 1933 (see below).

Thus over the two crops there was a profit above the cost of the fertilizer of £6 14s. 10d. per acre from the superphosphate only, £7 11s. 1d. from the super and potash, and £8 1s. 9d. from the super, potash and whale guano, and only £5 16s. 4d. from the super, potash and ammonium sulphate.

The experiment was cut as second ratoons in November, 1936, after another 13 months' growth,
still without the addition of further fertilizer. There was still a residual effect from the original fertilizer applications at time of planting, but considerably less than at the previous crop and not of statistical significance if the effect of different fertilizer treatments are compared against each other, although all were still significantly better than the controls without fertilizer.

Fertilizer applications were renewed to the third ratoon crop, dressings of superphosphate, 480 lbs. per acre, potassium chloride, 80 lbs., sulphate of ammonia, 200 lbs., nitrate of soda, 250 lbs., and whale guano, 400 lbs., being selected.

The experiment was harvested as third ratoons, 11 months old, in October, 1937.

There was a slight increase and profit from the super alone compared with controls without fertilizer, amounting to 13s. 4d. per acre over the cost of fertilizer, reduced to 4s. 7d. by the addition of potash. These results were of no significance; but there was a marked significance from the application of each of the three forms of nitrogenous fertilizer, which gave practically the same increase of about 5 tons of cane per acre of approximately equal sucrose content with that from the controls.

Ammonium sulphate therefore showed the greatest profit (£2 9s. 7d. per acre over the cost of fertilizer) because of its lesser unit cost. Sodium nitrate showed a profit of £2 6s. 7d. and whale guano 17s. 8d. per acre.

The fertilized plots were top-dressed again after harvesting with 50 per cent. greater quantities of nitrogenous and potassic fertilizers, while omitting the superphosphate.

The crop was harvested as fourth ratoons, 13 months old, in November, 1938.

There was another marked increase in yield from all nitrogen treatments, nitrate of soda being slightly the largest, but sulphate of ammonia the most profitable because of its lower cost per unit. There was again no significant response to the potash without nitrogen, and no significant degree of residual effect from the superphosphate added to the preceding crop.

A profit of £5 14s. 9d. per acre was shown by the sulphate of ammonia plots over the cost of the complete fertilizer, £5 4s. 7d. by the nitrate of soda plots, and £2 19s. 1d. from the much more expensive whale guano. The indicated profit from the potash only (120 lbs. per acre) was 12s. per acre.

The annual rainfall at Umhlali for the period of these experiments was for 1933, 35.13 ins.; 1934, 41.20 ins.; 1935, 53.61 ins.; 1936, 56.67 ins.; 1937, 40.29 ins., and 1938, 56.88 ins. The fifteen-year average is 42.71 ins., and for the five years ending 1939, 53.10 ins.

Experiments at Tongaat.

R. G. T. Watson published in 1938 some very interesting work done by the Tongaat Sugar Co., in the effect of much larger applications of fertilizer than those commonly used in the industry. In most cases the increased fertilizer resulted in largely increased yields.

Thus in a low-lying drained swamp in sandy soil there was an increase from 34.2 to 41.6 tons per acre due to the application of 1,000 lbs. per acre of ammonium sulphate. However, in two areas of wind-blow sand soil there was no significant response to 800 lbs. per acre of ammonium sulphate. The cane in each case was Co.290. The rainfall in the first series was over 55 ins., and 49 ins. and 45 ins. respectively in the other two.

E. W. Steward described the results of similar fertilizer treatment to second ratoons of Uba cane by the same company. The cane was treated in February, 1936, six months after harvesting the previous ratoon crop, with 1,500 lbs. per acre of superphosphate (20 per cent.), 1,000 lbs. of ammonium sulphate in four equal dressings applied seven, ten, thirteen and sixteen months respectively after harvesting, and 333 lbs. of potassium chloride applied in two equal dressings seven and ten months respectively after harvesting.

A definite response to the fertilizer in appearance and growth of the cane soon became evident, and a yield of 49 tons of cane per acre was eventually harvested in June, 1937, at 24 months, compared with 24 tons from the control.

After allowing for cost of fertilizer and also for cost of transport and application of fertilizer and cost of harvesting and transport of the extra cane, a nett profit of £3 2s. 1d. per acre, or 15d. per ton of cane.

The soil was a wind-blow sand; the annual rainfall at Tongaat for 1935 was 47.54 ins., and for 1936 50.87 ins., both considerably greater than the 40 ins. normal annual rainfall for Tongaat.

A Long-continued Ratoon Fertilizer Treatment.

A crop cycle that has given excellent responses to nitrogenous fertilizer over the past few years is an experiment with Co.290 in a stony shallow clay loam at the Experiment Station.

Differential fertilizer treatment began with the second ratoon crop harvested when twelve months old in November, 1936. This crop was treated as late as March, 1936, with top-dressings of 50 lbs. per acre of nitrogen in the form of 320 lbs. of sodium nitrate, 400 lbs., being selected.
nitrate, 240 lbs. of nitrochalk, 240 lbs. of ammonium sulphate, and 480 lbs. of whale guano No. 1 respectively. There was a basic dressing of 320 lbs. per acre of superphosphate and 80 lbs. of potassium chloride.

It was not anticipated when this late application of fertilizer was made that the cane would be ready to harvest nine months later, but, as a result of late season rains followed by good ripening weather, it was ready.

However, there was no response to any fertilizer treatment, the average yield of cane per acre from all treatments, including controls, being 26.55 tons of 14.6 per cent. sucrose content.

The third ratoon crop was treated with the same amounts of the same fertilizers as the previous crop, two months after harvesting the latter. The crop was harvested again in October, 1937, at eleven months.

There was a marked response to each nitrogenous fertilizer, but not to the superphosphate and potash without nitrogen. There was no significant difference between any form of nitrogen, the average yield of sucrose per acre from nitrogen plots being 3.73 tons, compared with 3.23 from the controls and 2.80 from the phosphate and potash-only plots.

Similar treatment was given to the fourth ratoon crop, cut at thirteen months, excepting that the quantity of nitrogen applied in each case was increased from 50 lbs. to 80 lbs. per acre, with a corresponding response which again was highly significant in every case, ammonium sulphate again proving the most profitable.

The fertilizer treatment was repeated with the fifth ratoons, which were harvested again at thirteen months in November, 1939

Once more all the nitrogen treatments showed a significant increase, which yielded a profit of £1 6s. 4d. per acre from the ammonium sulphate and £1 5s. 6d. from nitrochalk; while whale guano and the superphosphate and potash-only plots showed losses of £1 10s. 9d. and £2 19s. 1d. -per acre respectively.

The omission of the superphosphate and potash would, if there were no interaction between these and the nitrogenous fertilizer, increase the profit to be expected from the nitrogen considerably, but even this would not convert the nett loss from whale guano into a gain. This is one of the very few instances in our experiments where whale guano has not shown a profit.

Since the Co.290 cane in this experiment is still standing up admirably, having yielded an average of 4.24 tons of sucrose per annum over a cycle of five ratoons, it is being continued with similar fertilizer treatment into sixth ratoons.

The rainfall for each crop since the ratoon fertilizer experiment was begun has been, in 1936, second ratoons, 47.80 ins.; 1937, third ratoons, 22.34 ins.; 1938, fourth ratoons, 45.67 ins.; 1939, fifth ratoons, 42.77 ins.

Experiments by the South African Potash Co., Ltd.

A series of experiments have been described to this Association over recent years with very comprehensive and instructive data collected by J. Lintner.

One of these experiments was carried out in cooperation with African Explosives & Industries, Ltd., in the red sandy soil of Umbogintwini already mentioned, and was planted in 1933 with the three varieties Uba, Co.290 and P.O.J.2725. Excellent yields of cane were obtained and a profit of nearly £3 an acre over the cost of the fertilizer shown from 600 lbs. of superphosphate and 125 lbs. of potassium chloride.

The gain was diminished, however, by applying also 200 lbs. or 400 lbs. of ammonium sulphate at time of planting, or by doubling the amount of potassic fertilizer.

The cane was harvested in 1935 after 21 months growth. Rainfall was plentiful throughout, the total during the crop being 97.88 ins.

Another experiment planted at Tongaat in sandy soil in October, 1933, and harvested 25 months later is also described. Here also nitrogen seemed to have no positive profitable effect, but rather the reverse, although applied in various amounts of a mixture of ammonium sulphate and whale guano with or without sodium nitrate.

The most prominent feature was the response to 20 or 40 tons per acre of filter cake.

These results were, in the main, confirmed by results of the first ratoon crop, harvested two seasons later without any more fertilizer having been applied.

The plots to which filter cake, 20 or 40 tons per acre, had been added originally gave marked residual benefit, especially from the 20 tons application.

In an experiment at Natal Estates (Burnside section), however, in a similar type of soil, planted in 1935 and harvested 14 months later, there was a very profitable response to 113 lbs. per acre of ammonium sulphate or 400 lbs. of whale guano, or a mixture of the two, added at time of planting, with 600 lbs. of superphosphate. In this case there
was no response to superphosphate alone, or super and potash without nitrogen.\textsuperscript{26}

Another experiment in a red clay soil of doleritic origin at Kearsney gave very interesting results over three successive crops, each cut after two seasons' growth in 1934, 1936 and 1938 respectively.\textsuperscript{27} The cane was Uba and ammonium sulphate, 125 lbs. per acre, appeared to have a depressing effect throughout when added with 400 lbs. of superphosphate. The best results were obtained from a complete mixture of the two fertilizers mentioned above plus 450 lbs. of potassium sulphate.

**A Factorial Experiment with Fertilizers at Umbogintwini.**

The results of an elaborate fertilizer experiment at Umbogintwini (African Explosives \& Industries, Ltd.) formed the subject of a paper at last year's conference.\textsuperscript{28} This described for the first time a factorial experiment in our sugar industry, and therefore marked an important advance in experimental technique. Unfortunately this experiment lacked any controls without fertilizer, so that it was not feasible to assess the actual value of the fertilizer responses indicated. The results are expressed in sugar per acre only.

The cane was Co.290 and was cut at 19 months, after a total rainfall of 58 ins., fairly well distributed. A response was demonstrated from top-dressings of ammonium sulphate as high as 950 lbs. per acre.

As pointed out in the resulting congress discussion, apparently the supply of moisture at critical periods of growth of the cane is of great moment in deciding whether there will be, under given conditions, a response to nitrogenous fertilizer ultimately or not.

**New Experiments Harvested during the 1939 Season.**

With the expansion of the resources of the agricultural section of the Experiment Station in 1937 by the provision of additional staff and motor transport, it was possible to organize an extended programme of planting of co-operative field experiments, and several of these were harvested for the first time in 1939.

One of these was at Chakas Kraal (Waldene Estate), where in a shallow sandy loam overlying shale there was planted an experiment with quantities of sulphate of ammonia ranging from nil to 1,200 lbs. per acre, applied at various intervals. Every series, including the control plots without nitrogen, were treated with 800 lbs. per acre of superphosphate and 80 lbs. of potassium chloride. There were two varieties included, Co.281 and Co.301.

The cane was harvested at 19 months, and it was found that all treatments with ammonium sulphate had proved highly profitable when compared with the controls, giving an increase of from 5 to 13 tons per acre according to treatment, or 18 to 34 per cent. increase in sucrose per acre.\textsuperscript{29}

The most profitable series was the 800 lbs. per acre plots, where this quantity had been applied in four doses, 200 lbs. at time of planting and 200 lbs. each at six, twelve and eighteen weeks intervals respectively after planting. The profit due to the ammonium sulphate, after deducting the cost of fertilizer, was £8 11s. 11d. per acre. The yield was approximately equal at 52 tons per acre of cane, or 8.6 tons of sucrose per acre from both of the two 800 lb. treatments and the 1,200 lb. series, all being much superior to the two 400 lb. series.

A duplicate of this experiment at the Experiment Station was harvested a few months later as 24 months plant cane and even higher yields attained —62 tons of cane or 9.8 tons of sucrose per acre. The soil was a heavy clay loam.

However, in this instance there was no response to the sulphate of ammonia in any quantity.\textsuperscript{30}

This may be attributed to the fact that the field was heavily green manured with velvet beans the season before planting. This matter is referred to earlier in this paper.

A fertilizer experiment was harvested at Braemar in co-operation with Mr. L. A. Cole in August.\textsuperscript{31}

In this case also Co.281 and Co.301 were used, in a fine loam overlaying Dwyka conglomerate; the cane was harvested as 22 months old plant cane.

A light dressing of ammonium sulphate, 120 lbs. per acre, was applied, either at time of planting or as a top-dressing. 600 lbs. per acre of superphosphate was also applied, and in some series 60 lbs. per acre also of chloride of potash.

The best yield was gained by the two series in which the sulphate of ammonia was top-dressed. None of the other series in which the nitrogenous fertilizer was applied at time of planting; or mineral fertilizers only applied, gave any significant increases over the control plots without fertilizer.

**Identical Experiments at Illovo, Verulam, and Upper Tongaat.**

An interesting series of three field experiments of identical design, planted the same season (1937) in three widely different characteristic and representative soils, was harvested in September last as 21 months old plant cane.

One was in a heavy clay alluvium at Illovo (Illovo Sugar Estates, Ltd.).\textsuperscript{32} another in a reddish
clay loam near Verulam (Verulam Central Factory)\textsuperscript{31} and the third in a loamy soil at Upper Tongaat (R. E. Goble)\textsuperscript{32} overlying Table Mountain sandstone.

The following quantities of ammonium sulphate were applied: (0) nil; (1) 200 lbs. per acre, all top-dressed; (2) 400 lbs., all top-dressed; (3) 400 lbs., 100 lbs. applied at planting and the remainder in three equal dressings of 100 lbs. seven, fourteen and twenty-one weeks respectively after planting; and (4) 800 lbs., 200 lbs. at time of planting and three top-dressings of 200 lbs. each.

800 lbs. per acre of superphosphate were also applied in each case, except in a series of controls without fertilizer.

One-half of the plots were planted with Co.301, and the remainder with either Co.281 or Co.290 whichever had proved the better locally. Further, one-half of the plots were treated with 160 lbs. per acre of chloride of potash, of which 80 lbs. were applied at time of planting and the balance seven weeks later; the other half of the plots receiving no potash.

In each case the application of 800 lbs. of superphosphate, 20 per cent., proved very profitable even without any other fertilizer, showing a gain over the cost of the fertilizer ranging from £2 4s. 7d. at Upper Tongaat to £9 2s. 3d. per acre at Verulam.

On the whole, 400 lbs. of sulphate of ammonia was more profitable than 200 lbs. or 800 lbs. throughout.

The maximum gain per acre from sulphate of ammonia was £10 12s. 4d. from 400 lbs. (all top-dressed) at Verulam, which gave 54.77 tons of cane or 9.22 tons of sucrose per acre, compared with 39.3 tons of cane or 6.66 tons of sucrose from the controls. The average yield from the 400 lbs. series at Illovo was 78 tons cane or 11.8 tons of sucrose per acre.

At Verulam and Upper Tongaat it was much better to apply all the sulphate of ammonia in topdressings rather than part of it at time of planting, while at Illovo it seemed to make no appreciable difference.

There was no significant response to potash in any series.

There was little to choose between the Co.301 and the Co.281 or Co.290. The Co.301 yielded more cane of less sucrose content than the others, the sucrose content per acre being much the same. Evidently the results of the ratoon crops, or other considerations, will have to decide this issue.

Interaction between Fertilizer Treatment and Cane Variety.

During the past season or two several fertilizer experiments have been harvested in which two or more varieties are included for parallel tests, and most of these have been mentioned above.

The results indicate a new complexity, since they point to differential requirements of different varieties in the same soil and other conditions.

To illustrate this point, several graphs have been prepared from the results of the experiments.

The points on the axes of abscissæ represent nil, 400 lbs., 800 lbs. and 1,200 lbs. of ammonium sulphate per acre respectively, while the ordinates represent tons sucrose per acre.

Graph No. 1.

This shows the differential response to a top-dressing of 120 lbs. of ammonium sulphate on the varieties Co.281 and Co.301, and illustrates the large response from the latter variety to even this comparatively small top-dressing.

Graphs 2 and 3.

These two graphs bear a remarkable resemblance to each other; they show the response to nitrogen in 400 lbs. and 800 lbs. applications—the dotted lines indicate the gains when part of the dressing is placed in the furrow together with the superphosphate and potash at planting time. The solid line shows the gains when all of the ammonium sulphate and potash is top-dressed, and only the superphosphate placed in the furrow. These two experiments are identical in design and are situated on different types of soil some 20 miles apart.

Graph No. 4.

An experiment similar in design to that of No. 2 and No. 3, but situated on alluvial flats. The graph shows further gains from 400 lbs. to 800 lbs. under these conditions. Whereas in No. 2 and No. 3 there was a depression in yields at the higher level.

Graph No. 5.

Shows a remarkable response to nitrogen, substantial gains being obtained even at the 1,200 lb. level in the case of Co.301. This is also one of the few cases in which there appears to have been a good response to applications of nitrogen at planting time in addition to top-dressings.

Graph No. 6.

Illustrates the effect of nitrogenous dressings to a field which has been fallowed and green manured before planting. Statistical analysis shows the small responses and depressions to be not significant.
Cost of Fertilizers and Value of Returns.

The value of £5.561 per ton of sucrose has been assumed for the purpose of these experiments.

At a price of £9 per ton, which was the average cost of sulphate of ammonia when the experiments were treated with this fertilizer, an increase of sucrose yield of 0.32 tons per acre will just cover the cost of 400 lbs. of sulphate of ammonia, or 0.64 tons for 800 lbs.

At the present day prices, however, which are now somewhere about £13 per ton for sulphate of ammonia—when it is procurable at all as a separate fertilizer—an increase of 0.47 tons of sucrose would be necessary to cover the increased cost, since there has been no corresponding increase in the price of sucrose.

Even at this increased price the unit value of sulphate of ammonia is only two-thirds of that of whale guano, and is still capable of giving profitable returns in top-dressings of 400 lbs. per acre, especially with Co.301.

Only in exceptional cases has the application of larger quantities than this proved more profitable.

There is no attempt in our small-scale experiments to take into account the cost of application of fertilizer (the cost of railway transport of fertilizer is now almost negligible), or to assess the cost of harvesting and transport of the increased yield of cane. This the owner or manager of the commercial-scale plantation must work out from his own data, which will vary considerably with the conditions.

At present, as stated, ammonium sulphate is difficult to obtain as a single fertilizer, but may be more readily purchased in a mixed fertilizer.

It is hoped that this will prove a temporary phase, since the advantages of applications of this fertilizer at times when a complete fertilizer is not required has been amply demonstrated. In our opinion, the purchaser of fertilizer should always have the option of buying “straight” fertilizers if he wishes whenever supplies are available.

Comparison of Results with those of other Countries.

Although there is much to be gained from the experience of sugar-growing countries more advanced scientifically than ours, a study of the fertilizer requirements of sugar cane in other countries calls to mind the statement of the late F. S. Earle, who said in his admirable book on sugar cane: “The use of commercial fertilizers is so largely a local question that it is difficult to give a general discussion that will not be more or less misleading, but no question is of greater importance.”

The climatic and soil conditions in this country are very unusual in sugar cane agriculture, and only approached in certain respects by those prevailing in southern Queensland and New South Wales, and possibly to some extent in Peru.

One feature almost universal in other sugar cane countries is that the application of nitrogenous fertilizer is very apt to reduce the sucrose content of the cane. We have no evidence of this in this country; and even where the cane is cut after only one season’s growth, which is not the usual custom with us, the sudden advent of cool dry weather, usually beginning in May, promotes a rapid ripening of the cane, whatever its previous treatment may have been, before it is normally necessary to harvest it.

This is a problem, therefore, which apparently need not concern us, although experimenters here almost always keep the possibility in mind, and the analysis of the cane from field experiments for sucrose content, at least, is general practice.

The fertilizer practice in various sugar cane countries was reported in some detail by one of us a few years ago, but no doubt practice will have changed appreciably in some countries with changing economic and other conditions.

Generally, however, the practice in other countries is to use ammonium sulphate far more than any other fertilizer, both because of its relative cheapness and the excellent response usually gained from it. The quantity used varies considerably, but is usually between 180 lbs. and 400 lbs. per acre per crop. Some countries, such as Hawaii and Puerto Rico, frequently apply much larger quantities, usually with intensive cultivation, including irrigation, and strict scientific control.

The continued use of ammonium sulphate in the agriculture of any crop entails steps being taken to neutralize the acidifying residual effect it has on the soil. This is usually done by applying lime in some form or other, or possibly by alternating it with sodium nitrate, which has the opposite residual effect.

General Conclusions.

The records of the subject of this paper are not very voluminous and widely scattered, so that it is difficult to prepare anything like an adequate survey within the limits of a paper such as this.

An attempt has been made, however, to consider the available information and trace the development of the subject from its early beginnings to the present day.

Several important considerations emerge from this summary.
1. The supply of moisture, which is sometimes very deficient for sugar cane in this country and may remain so over a cycle of years, is often a limiting factor and may seriously interfere with the response of the cane to fertilizer treatment. In such periods there seems to be some evidence that sugar cane may respond to gradually available organic nitrogen such as in whale guano, and not to the immediately soluble and rapidly available inorganic forms such as ammonium sulphate and sodium nitrate.

It will be interesting to see what information in these matters results from the numerous experiments now in existence after the present record dry summer. At the Experiment Station the rainfall for the first three months of the present year is only 5.53 ins., or 38 per cent. of the average rainfall for that period over the past 53 years at Mount Edgecombe.

2. With an adequate moisture supply, ammonium sulphate seems to be the most economical artificial nitrogenous fertilizer to apply, usually in quantities of 400 lbs. per acre, applied in one or more dressings, if possible during rainy weather, and in the case of plant cane not applied until the cane is well established and at least several inches high. The latter is more particularly the case in light sandy soils; too early application may impair germination, especially with deficient moisture.

3. There is some evidence that a greater response may be expected with Co.301 than with either Co.281 or Co.290 under conditions that have prevailed over the past season or two. No information on this point is yet available concerning the other varieties now also extensively under cultivation in this country, mainly Uba and P.O.J.2725.

4. It may be, that as in some other cane-growing countries, the cultivation of a leguminous green-manure crop before planting with cane may serve to supply, wholly or in part, the nitrogen requirements of the plant cane crop.

**Summary.**

The results of field experiments with different forms of nitrogenous fertilizer are surveyed, from the earliest available records of such experiments in 1912, to the present day.

The important effect of rainfall on the results of these experiments is examined.

Tentative suggestions are made for the optimum application of nitrogenous fertilizer under normal moisture and soil conditions, and the possibility pointed out of replacing the use of artificial nitrogenous fertilizer to some extent by green manuring with legumes.

Evidence for interaction between different cane varieties and fertilizer requirements is also discussed.

**Acknowledgments.**

The authors express their great appreciation and thanks for the indispensable help and interest of the co-operating planters and estates in many of the experiments described; also to Dr. A. McMartin for kindly revising some of the text.

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Experiment Station, 
South African Sugar Association, 
Mount Edgecombe, Natal. 
March, 1940.
No. 1

L. A. COLE., Esq., No. 2 — BRAEMAR
Soil: Grey-brown, sandy loam
Plant Cane — 22 Months Old

No. 2

A. E. COBLE, No. 2 — UPPER TONGAAT
Soil: Brown, sandy loam of good quality
Plant Cane — 21 Months Old
No. 3

CENTRAL FACTORY—VERULAM

Soil: Deep reddish-brown loam

Plant Cane — 22 Months Old

Ammonium Sulphate Dressings per Acre

No. 4

ILLOVO SUGAR ESTATES — LOWER ILLOVO

Soil: Coarse-textured, alluvial soil

Plant Cane — 21 Months Old

Ammonium Sulphate Dressings per Acre
WALDENE ESTATES No. 8 — CHAKA'S kraal

Soil: Shallow, clay loam

Plant Cane — 18½ Months Old

Ammunium Sulphate Dosing per Acre
The PRESIDENT in opening the paper for discussion regretted the absence of planters at the Congress.

Dr. ORCHARD said that work of the nature of this paper was the most essential link in the chain along which sugar was being produced, and it was also work which called for a great deal of energy. Results were often slow and disappointing, but the industry could never hope to progress well without building up a tradition of knowledge of this nature.

Dr. Orchard said he would like to resurrect a matter which had been put before us on various occasions during the past few days, particularly by Mr. Deenik and Dr. Fisher. It was also a matter which had been raised by Mr. Dymond in an excellent paper two years ago at our Annual Congress, and after the paper we have just heard it seemed appropriate to mention it again. He alluded to the preparation of compost. It was a matter which, in his opinion, was worthy of our attention. The practice of bringing back to the soil the organic matter and the elements of fertility had not only helped to maintain the productivity of the soil in China and in the East generally during the past 4,000 years, but it had actually made the soils more fertile than they had ever been before. It had kept them going for all this time during a period when artificial fertilizers were quite unknown. Now that fertilizers were so generally used, particularly in the cane belt, there was all the more reason for investigating the role of organic matter in the soil here in Natal with a view to getting the best out of the fertilizer which was used.

Fortunately cane was not a crop which called for long-continued periods of soil cultivation, which was the surest method of destroying the soil organic matter, and had it not been for this fact we could be sure that cane lands would very rapidly deteriorate in fertility. Moreover, the cane planter, unlike farmers who produce other crops, never seemed to be worried about the problem of finding greater quantities of farmyard manure in order to keep up the fertility of his land. But because he was in this fortunate position, it was no reason why he should not investigate the utilization of what lay available at his door. It seemed to him that in no part of the country could compost be made so easily as in the sugar belt. We had waste cane tops, trash, bagasse, filter-press cake, surplus molasses, plenty of water available, and with these basic substances the matter should not be difficult.

We had seen, from the excellent paper by Mr. Deenik on Tuesday, how the more widespread use of cattle in the sugar belt would bring with it an
automatic accumulation of valuable nitrogenous manure, which could be used for compost making. Mr. Dymond's paper of two years ago, together with the fact that some planters in the vicinity were already making compost, showed that the matter was beginning to attract attention. He had also analysed a sample of compost made by Dr. Martin, largely from trash and grass, which showed an excellent composition—it had 1.3 per cent. of nitrogen alone. Tambe and Wad, two workers in India, had also worked out a method for making compost on sugar plantations, whereby they had managed to reduce the cost of producing cane considerably, and which yielded excellent results. In this connection it would be interesting to know at what rate the sugar belt soils were losing their organic matter, due to its oxidation by the soil micro-organisms to carbon dioxide and water. It might be, however, that in spite of a high rate of destruction, which was almost inevitable under these moist and warm conditions, the rate of accumulation via cane roots and trash was sufficiently high to maintain the soil's organic matter. But the fact remained that very little was known by way of critical experiments, as to what could be expected from the use of extra organic matter in the soils, especially when supplemented by fertilizers, and if ever it became necessary to switch in some measure to pineapples, tea or any other cultivated crop, we might be quite sure that organic matter would assume an important role.

Dr. Orchard continued by mentioning that the vast quantities of water hyacinth found in the estuaries along this coast were most valuable. The plant had excellent composition—up to 1.4 per cent. of nitrogen, 1.0 per cent. of P₂O₅ and over 2 per cent. each of K₂O and CaO. This plant was apparently used extensively in parts of South America and the Indies for bringing on to the lands after being suitably rotted down.

Naturally the whole matter was a question of working out costs, and this was an aspect which many compost-minded people were apt to lose sight of, so much so that he had heard it said that being compost-minded was definitely not synonymous with being compost mentis. Nevertheless, it was a question which the Department of Agriculture was actively encouraging by word and deed at the moment on a large number of irrigation schemes throughout the country.

Dr. Orchard finally thanked those concerned for the opportunity they had afforded both Mr. Greenstein and himself, as officers of the Division of Chemical Services, to attend this most instructive Congress. The Chief of the Division, Dr. van Zyl, who had attended the Congress on previous occasions, had asked him to thank us, and at the same time express his regret at not being able to attend the present Congress himself.

Mr. LINTNER expressed appreciation for the references given, which, he said, would be very useful in future. He referred to an experiment at Mr. Hibble's which unfortunately did not conform to the results obtained by the Experiment Station. The results for nitrogen were negative, also phosphorus, whereas potash actually depressed the yield. He thought that of late we had been a little wild in our judgement of the fertilizer requirements of sugar cane. He referred to results in Hawaii, where vast quantities per unit area of fertilizer were used, and we had copied these methods without giving enough thought to them. There was, for example, the problem of plant food taken out of the soil, which should be an indication of the plant's requirements.

Mr. Lintner continued that he thought it would be an excellent thing if we looked back for a few years and got hold of an excellent paper produced by Dr. Hedley and Mr. Beater at our Congress in 1933. If we applied the knowledge gained from experiments of this nature, and associated it with various types, some real benefit ought to result. Balance of fertilizers was a most important thing. We put what we think is an adequate supply of phosphate and potash, but we are apt to choose our quantity of nitrogen rather at random.

Mr. B. CAMPBELL referred to the amount of nitrogen returned to the soil, or put into the soil by sunn hemp. Mr. Dixon of Natal Estates had made some determinations which covered roughly 150 acres. These samples were taken on a three acre basis so that figures ought to be fairly representative, and they were taken just prior to, and six weeks after, ploughing in of the sun hemp. In the case of a 20 acre field of windblown sandy soil the organic matter yielded an increase from 3.93 per cent. to 4.14 per cent. after ploughing in the crop. This was an increase of 5,000 pounds of organic matter per acre, or 5.3 per cent. of the original amount present. Nitrogen also increased from 0.216 to 0.231 per cent., a rise of 375 pounds per acre, or 6.9 per cent. of the original amount.

In answer to a query by Mr. Dodds, Mr. Campbell stated that the period of fallow was a little over a year. The crop of sunn hemp was good, some of the plots yielding over 20 tons to the acre. A heavier soil yielded increases of only 0.48 per cent. and 1.5 per cent. for organic matter and nitrogen respectively, calculated on the amounts originally present, but also on this basis, another windblown sand yielded an increase of 23 per cent. for organic matter and 7 per cent. for nitrogen.
Mr. LINTNER went into the Hawaiian aspect of basing fertilizer requirement on the amount of plant food from the soil, and remarked that although the general feeling was that there is inclined to be a luxury uptake of potash, only 50 to 60 per cent. of the tremendous amount of potash removed by a heavy crop was returned to the soil from which it was cut.

Mr. GREENSTEIN mentioned that knowledge gained during recent yeats shewed that better results were obtained immediately water conditions became more favourable, and said that it would be interesting to study the effect of any nitrogen application on cane lands which have been irrigated. In the Elgin district of the Western Province where fruit is grown the rainfall is about 50 inches per annum. It has been found, however, that by supplementary irrigation in summer and application of nitrogenous fertilizer enormously increased yields are obtained. It would seem that in some of the experiments quoted in this paper the increase from sulphate of ammonia was quite marked in the more rainy year. The experiment on page 18 shews that the effect of application of phosphate was only apparent after six or seven years. This was similar to results obtained at Potchefstroom where rock phosphate gave discernable responses only after a number of years.

Mr. DODDS, commenting on the absence of planters from the Congress, said that although a large number of papers dealt with agricultural subjects, they were mostly written by agricultural scientists for agricultural scientists. They were not of a nature that would appeal to the ordinary planter. Bearing this in mind the present paper was written as non-technically as possible, and such treatment of the subjects was not common although it should be more generally adopted.

Dr. Orchard's presence was very welcome and the question of compost which he had brought up was of great moment. Compost had proved of great value in countries which had a more plentiful supply of labour and water than we had, but for our conditions it was likely that fertility would be most economically restored by growing a succession of green manure crops. However, now that the difficulties due to inadequate water supply at the Experiment Station had been solved, compost experiments could be undertaken in the near future.

Mr. Lintner's remarks were very interesting, and in this connection a survey of the potash fertilizer position should be carried out in the same way as had been attempted for nitrogen in this paper. One of the deficiencies of the paper was that it contained no reference to the important subject of the amount of fertilizer material taken from the soil. Mr. Lintner's papers, especially the results of his experiments at Kearsney and Tongaat, shewed often a response to complete and balanced fertilizer which could not be attributed to any particular ingredient. This was important, but little work had been done as yet on the interaction between fertilizers. Mr. Lintner in his Tongaat experiments had obtained such outstanding results from the use of large dressings of filter cake that the casual reader was apt to ignore the other valuable information concerning the proper balancing of fertilizer.

Mr. B. Campbell's remarks and information about the amount of nitrogen restored to the soil by ploughing in sunn hemp as well as the yields of the crop obtained were valuable and interesting. Mr. Ingham might say that some of this accumulation of nitrogen was due to the absorption of ammonia from the atmosphere.

There may be a luxury demand for nitrogen as well as for potash for we had found at the Experiment Station that there was no increase in yield after a green manure crop although in the early stages of growth the richness of leaf colour was very marked. The same thing has been found to occur with applications of nitrate of soda or ammonium sulphate in Louisiana.

In connection with Mr. Greenstein's remarks, Mr. Dodds said that the rainfall at Mount Edgecombe could be considered deficient, as it was rather less than the rate of evaporation of 47 or 48 inches of water per year. Mr. B. Campbell might be able to indicate the performance of nitrogenous fertilizers under irrigation.

Mr. B. CAMPBELL stated that the results of experiments under irrigation had been very disappointing, probably owing to insufficient width of borderline between plots under these conditions.

The PRESIDENT, after stating that he thought water was the best fertilizer, concluded by moving a vote of thanks to the writers.