FERTILIZER RESPONSES

As Revealed by the 3 × 3 × 3 Fertilizer Exploratory Trials

By J. L. DU TOIT

The Sugar Industry has for many years been considered one of the chief users of fertilizers in South Africa. Its continued prosperity is largely dependent on the correct use of the essential plant foods. Ever since the establishment of the Experiment Station, fertilizer experiments have been one of the main activities of the station.

During the past few years the industry has become increasingly aware of the importance of fertilizers and their correct use. A rather drastic change in fertilizer practice has taken place with more emphasis being put on nitrogen and potash. The following table reflects the increased usage of fertilizers and the change in composition:

	Tons N used	Tons P_2O_5 used	Tons K_2O used	Tons N per 1 ton P_2O_5	Tons K_2O per 1 ton P_2O_5
1951	2,135	6,526	842	0.33	0.13
1953	3,327	5,725	1,712	0.58	0.30
1954	4,516	6,004	2,813	0.75	0.47
1955	5,856	5,183	4,564	1.13	0.88
1956	7,397	4,505	5,786	1.64	1.28

To what extent is this change in practice justified from fertilizer experiments which should in fact form the basis of such practice ? A large amount of experimental data has naturally accumulated over the years, and an attempt is now being made to tabulate and summarise all these results. The present report, however, deals only with the results of a recent series of experiments—the so-called 3×3×3 (read 3 by 3 by 3) fertilizer exploratory trials.

The 3×3×3 Fertilizer Trials

The meaning of these 3 × 3 × 3 trials is that THREE fertilizers are used at THREE levels singly and in combination resulting in 27 plots. Thus in our case the fertilizers nitrogen at three levels, phosphate at three levels and potash at three levels are used and some plots will receive only one fertilizer, e.g. nitrogen, while others will have nitrogen combined with potash or phosphate or both at the different levels and there will be one plot with no fertilizer at all.

The levels used are as follows: O, 100 and 200 lb. N, P_2O_5 or K_2O per acre, i.e. the lowest level of nitrogen, phosphate or potash means in effect that no fertilizer has been applied. At the medium level 100 lb. of N per acre (which is equal to 476 lb. ammonium sulphate), 100 lb. P_2O_5 (equal to 525 lb. 19 per cent superphosphate) and 100 lb. K_2O (equal to 167 lb. muriate of potash) per acre are applied. At the high level these fertilizer applications are doubled resulting in the application of 952 lb. ammonium sulphate, 1,050 lb. super and 334 lb. muriate per acre.

After the experiments are harvested it is possible to assess the effect of nitrogen, phosphate and potash on the yield at the different levels. It is also possible to find out whether the effect of any one fertilizer is altered by the presence of any of the others, e.g. whether nitrogen in the presence of phosphate, gives a response about equal to the sum total of the two individual responses, or whether this combined response is in effect appreciably different—much larger (or smaller) than the added responses of nitrogen by itself and phosphate by itself. If the latter is the case we have an interaction. As stated, these experiments also enable us to measure these interactions.

The series of 3 × 3 × 3 experiments was started in 1950 and to date twenty-eight of them have been harvested as plant cane crops, while first ratoon yields have been examined in twenty-one experiments. In one experiment a second ratoon and in another a second and third ratoon have also been harvested. The series is, therefore, by no means complete, but it is felt that a summary of results obtained can be presented at this stage with advantage.

In this summary the results will be dealt with largely as a whole, i.e. certain main deductions will be made from the average of all results as plant cane and as ratoons. These experiments are scattered over a large part of the industry and an attempt has been made to cover the main soil groups. The number of experiments on each soil group is, however, limited and where occasional reference to soil type or the soil group is made, this aspect should be borne in mind. The conclusions from one experiment, or a few experiments, may be misleading as a result of errors and soil variation. In dealing with the average results of a large number of experiments this limitation decreases but the generalised result does not necessarily apply to any one locality. It nevertheless enables us to draw some valuable valid conclusions which are in the main applicable in general.

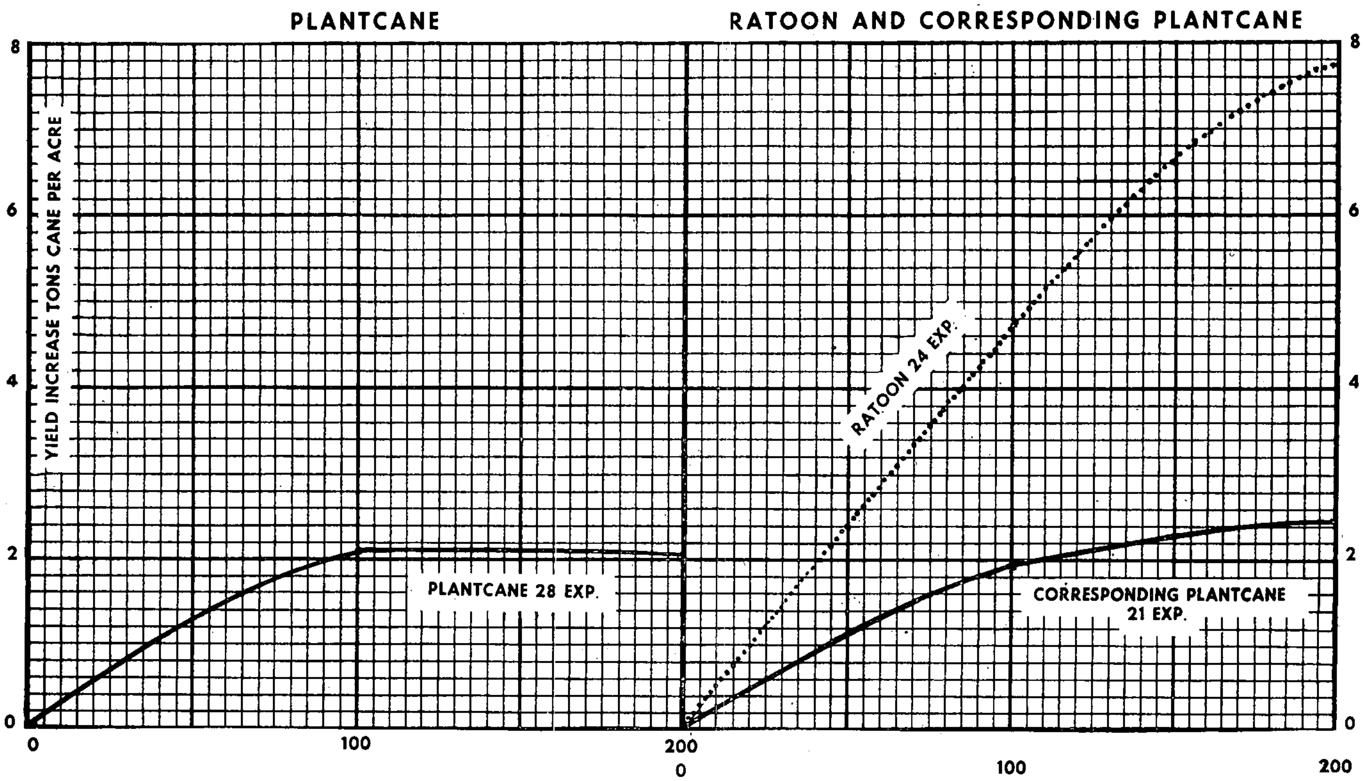
Nitrogen

Nitrogen was applied as a top dressing to the young plant cane or ratoons and never in split dressings, or in the furrow at planting. The response to nitrogen in plant cane has been examined in 28 experiments. The results are:

Increase due to 100 lb. N or 476 lb. per acre amm. sulphate equals 2.11 tons cane per acre.

Increase due to 200 lb. N or 952 lb. per acre amm. sulphate equals 2.08 tons cane per acre.

GRAPH No. 1 N. RESPONSE



Lbs. N. PER ACRE

There were six nitrogen responses which were found to be statistically significant or highly significant, i.e. there were six out of twenty-eight cases where we felt reasonably sure that nitrogen did in fact give a real response. These six responses were recorded on five Table Mountain Sandstone (TMS) soils and one on Table Mountain Sandstone Mist Belt (TMS MB) soil. In fact there were only five TMS experiments and all of them gave significant responses to nitrogen in plant cane. The average response to nitrogen in plant cane on TMS was:

Increase due to 100 lb. N or 476 lb. per acre amm. sulphate equals 5.58 tons cane per acre.

Increase due to 200 lb. N or 952 lb. per acre amm. sulphate equals 7.45 tons can per acre.

As stated, conclusions drawn from a few experiments must be treated with reserve but here the indications are very clearcut, namely that nitrogen responses in plant cane are really much better in TMS soils than on other soils.

In twenty-one experiments ratoons were available for examination and in one experiment two ratoons and in another three ratoons have been analysed.

The responses to nitrogen in ratoons were:

Increase resulting from 476 lb. per acre amm. sulphate equals 4.78 tons cane per acre.

Increase resulting from 952 lb. per acre amm. sulphate equals 7.79 tons cane per acre.

As can be seen the responses to nitrogen are far greater in ratoons than in plant cane. In the writer's opinion these are certainly not due to any appreciable residual effect of nitrogen applied to plant cane. Other experiments have shown that generally there is little or no residual effect of nitrogen on subsequent crops. If the plant cane crops from which these ratoons were harvested are examined separately the following is found:

Increase resulting from 476 lb. per acre amm. sulphate equals 1.88 tons cane per acre.

Increase resulting from 952 lb. per acre amm. sulphate equals 2.44 tons cane per acre.

It is quite clear, therefore, that in the experiments dealt with here the response to nitrogen in ratoons is much better than in plant cane. It must be stressed that in a large number of these experiments either a green manure crop was ploughed in, or a long fallow was given. It is believed that these practices may be largely responsible for the apparent poor response to nitrogen in plant cane.

In the twenty-four ratoon crops considered here no less than thirteen gave significant or highly significant increases due to nitrogen application.

Nitrogenous fertilizers are, of course, expensive and at present values it will require about three tons of extra cane to pay for the application of 476 lb. of ammonium sulphate. In only one-third to half the cases dealt with will such an application prove economical in plant cane, whereas the higher application of 952 lb. sulphate of ammonia proved economical in only about one-tenth of the cases dealt with. In ratoons, however, judged by the above standards, the lower application proved economical in about two-thirds of the crops and even the higher dressing was economical in more than half the cases dealt with.

It is interesting to record that no positive responses in plant cane or early ratoons were recorded to nitrogen in three rich alluvial soils, but in the one experiment carried to the third ratoon a significant response was obtained in this last ratoon and yields were increased by 6.38 tons cane per acre and 6.84 tons cane per acre respectively for 100 and 200 lb. per acre N.

Phosphate

Superphosphate was applied in the furrow before planting. In some cases no further superphosphate was applied in ratoons whereas in others a top dressing equal to the original furrow dressing was applied.

In plant cane the average responses for the twenty-eight experiments were:

Increase due to 100 lb. P_2O_5 or 525 lb. super per acre quals 3.11 tons cane per acre.

Increase due to 200 lb. P_2O_5 or 1,050 lb. super per acre equals 4.57 tons cane per acre.

Eleven of these results were significant or highly significant. The magnitude of average responses was, however, somewhat increased by the very high response obtained in one virgin soil. On the whole the best responses were recorded in granites, dolerites and basalts. The average plant cane results of eight experiments on these soils were:

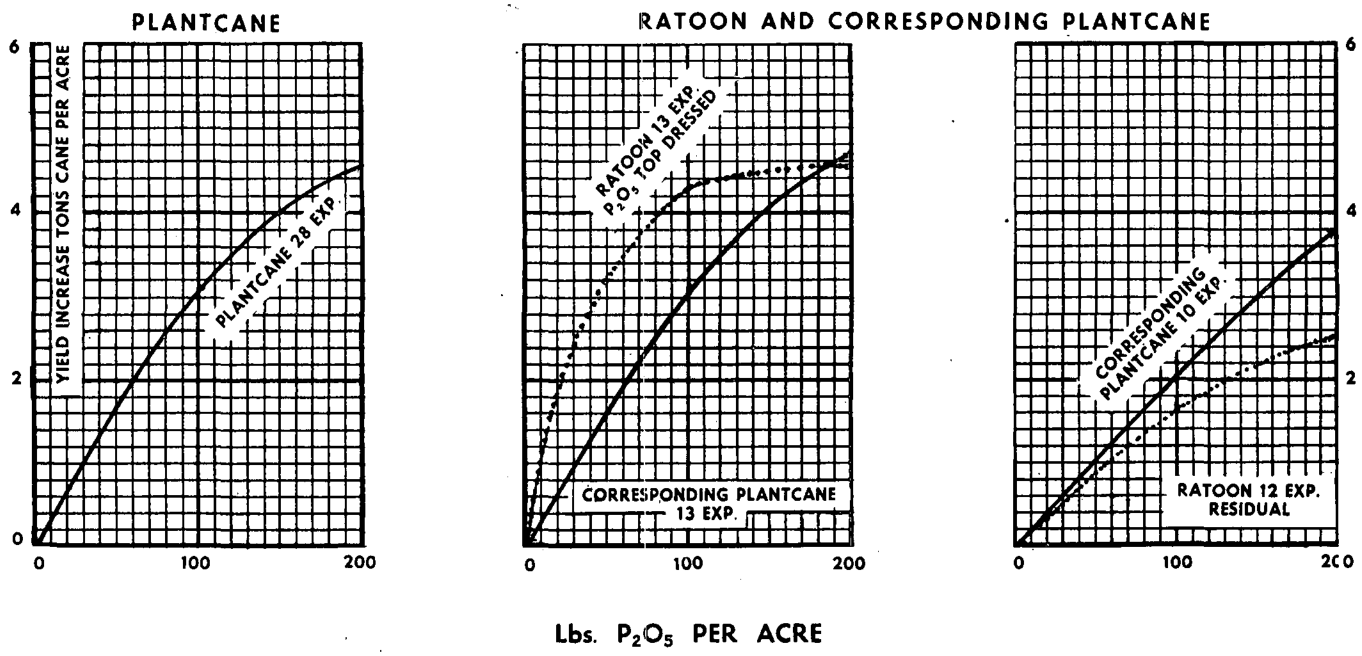
Increase due to 100 lb. P_2O_5 or 525 lb. super per acre equals 5.99 tons cane per acre.

Increase due to 200 lb. P_2O_5 or 1,050 lb. super per acre equals 7.24 tons cane per acre.

Once again no significant increases were recorded on the three fertile alluvial soils.

In half the number of experiments a phosphate application of 525 lb. super per acre was economical and in these the profit margin was large. More often than not the higher application of 1,050 lb. super per acre proved profitable. These results were based on the plant cane crop only, but in general the beneficial effect of phosphate on plant cane was carried on into the ratoons though on a somewhat reduced scale.

GRAPH No. 2 P_2O_5 RESPONSE



Twelve ratoons were cut from ten trials and here superphosphate was applied in the furrow for plant cane, but not top dressed in the ratoons. These ratoons showed the benefit derived from the original super application but it was not as big at the original plant cane responses as is shown in the following table:

	Increased Crop in Tons Cane per Acre	
	Plant Cane	Ratoons
After 525 lb. super per acre in Plant Cane	2.02	1.64
After 1,050 lb. super per acre in Plant Cane	3.68	2.55

In another thirteen experiments the ratoons received a top dressing of super equal to the original furrow application. Here there was not the marked falling off in response in ratoons and on the contrary the response at the medium dressing was not only maintained in ratoons but improved. The following table gives the increases obtained:

	Increase in Tons Cane per Acre	
	Plant Cane	Ratoons
525 lb. per acre super in Plant and Ratoon	3.13	4.29
1,050 lb. per acre super in Plant and Ratoon	4.63	4.54

The responses of plant cane to superphosphate, the residual effect of super in ratoons and the effect of top dressing super in ratoons are shown in the graph No. 2.

The results obtained from superphosphate in these experiments can be summarised as follows:

(1) Although responses to superphosphate in old cane fields are not so spectacular as in virgin soils, the augmentation of phosphate is still most important and can give highly profitable returns.

(2) There is considerable residual effect lasting into the ratoons from the application of superphosphate in the furrow.

(3) Top dressing superphosphate over a trash layer in ratoons is effective and must be used whenever the phosphate status of the crops demands it or is in doubt.

Potash

Potassic fertilizers were undoubtedly neglected in the sugar industry before 1950, but since then there has been an increasing realization of their importance in cane agriculture. The unit value of potash as muriate is lower than the unit value of nitrogen and phosphate. Though responses to potash as a rule may not be as spectacular as those from phosphate in plant cane or nitrogen in ratoons, its correct use can often result in the most profitable returns.

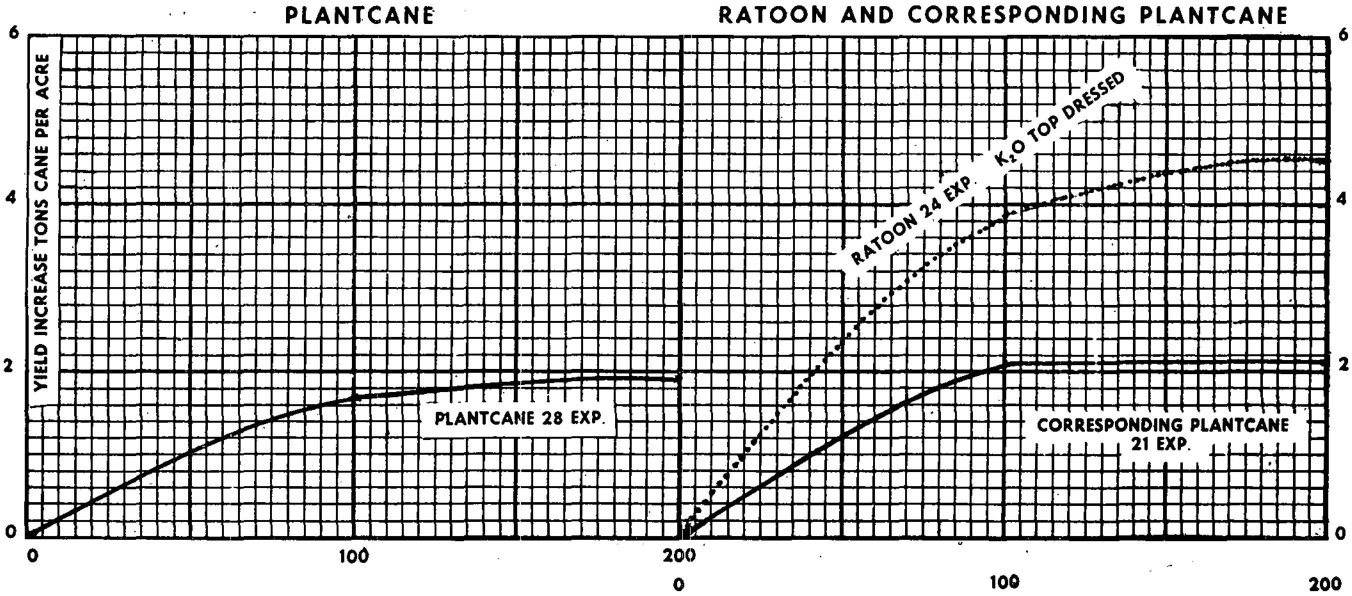
As in the case of nitrogen, potash was applied as a top-dressing to plant and ratoon canes and these dressings were never split.

The twenty-eight plant cane crops gave the following increases after muriate of potash application:

Increase to 100 lb. K_2O per acre or 167 lb. muriate equals 1.63 tons cane per acre.
Increase to 200 lb. K_2O per acre or 334 lb. muriate equals 1.91 tons cane per acre.

Nine out of twenty-eight experiments showed a significant or highly significant increase due to potash application. In ratoons the responses were

GRAPH No. 3 K_2O RESPONSE



Lbs. K_2O PER ACRE

bigger and more frequent. Thus in twenty-four ratoons cut from twenty-one experiments there were ten significant or highly significant responses. The following table shows the average responses in these experiments as ratoons and from corresponding plant cane crops:

	Increased Crop in Tons Cane per Acre	
	Plant Cane	Ratoons
167 lb. per acre muriate in Plant and Ratoon	2.07	3.90
334 lb. per acre muriate in Plant and Ratoon	2.10	4.57

Where, as pointed out, it takes about three tons of cane to pay for an application of 100 lb. N, it requires only about 0.9 tons cane to recover the cost of an application of 100 lb. K_2O. Thus, in two-thirds of the results examined in plant cane, 100 lb. K_2O or 167 lb. muriate application per acre proved economical and even an application of 334 lb. muriate per acre was profitable in more than half the experiments.

In ratoons two-thirds of the experiments show economical returns at 334 lb. muriate per acre and no less than five-sixths of the results show a profitable return at 167 lb. muriate per acre. If these results are compared with those of nitrogen and phosphate it can be seen why it is contended that a potash application, under present conditions, can be most profitable.

Potash responses have been found on all soil groups examined in our experiments, but on the rich alluvials it was found only in a late ratoon and the responses, particularly in ratoons, seem to be most pronounced in Recent Sands, Mist Belt, TMS and perhaps Granites. The results of six experiments, three each on recent sands and mist belt TMS are as follows:

	Increase in Tons Cane per Acre	
	Plant Cane	Ratoons
167 lb. per acre muriate in Plant and Ratoon	2.82	7.27
334 lb. per acre muriate in Plant and Ratoon	3.27	8.83

Though nutrient depletion by crop removal is by no means the only factor to consider in a fertilizer policy, it must be remembered that very large amounts of potassium salts are annually removed from the land in the form of millable cane. Unless they are replaced the soil must sooner or later be depleted.

Balanced Nutrition and Fertilizer Interactions

There was a time when phosphatic fertilizers were used in the sugar industry to the near-exclusion of all other forms of fertilizers. That time has passed for good. Recent experiments have shown conclusively the need for nitrogen and potash and the industry as a whole is aware of it. But experiments have also shown that phosphatic fertilizers remain an important necessity in large areas. We must not now allow this basic requirement to be neglected in turn.

More and more the industry will have to consider balanced nutrition in all its aspects. By balanced nutrition is meant not any special fertilizer mixture or mixtures but that the beneficial effect of one fertilizer is not hampered by the relative lack of some other essential nutrient. Thus there is no need to include potash in a mixture or as a straight fertilizer on a soil rich in potash, but if the relative lack of potash will prevent maximum yields being obtained from higher nitrogen applications then it must be included.

It has been explained that fertilizer interactions occur when their combined effects are different to their total individual effects. To illustrate in simplified form let us take the results in one of our experiments, with the yields in tons cane per acre:

	No. K_2O Applied	200 lb. K_2O Applied
No. N applied...	22.00	28.20
200 lb. N applied	28.84	47.74

Here we see that where no nitrogen has been applied the application of 200 lb. per acre K_2O or 334 lb. muriate increases the yield of cane from 22.00 tons to 28.20 tons. Where no potash was applied 200 lb. N or 952 lb. ammonium sulphate increases the yield from 22.00 tons to 28.84 tons. Both these yield increases were profitable amounting to 6.20 tons cane per acre for the potash application and 6.84 tons cane per acre for the nitrogen application. Now if both nitrogen and potash had been applied the yield increase would not be the expected 13.04 tons cane per acre but nearly double that, 25.74 tons cane per acre, or an increase from 22.00 tons to 47.74 tons cane per acre. Here evidently the combined effect of nitrogen and potash is far greater than their total individual effects and balanced nutrition has paid dividends.

Unfortunately this outstanding positive interaction cannot be expected in all experiments. In the experiments now under review eight significant interactions and one nearly significant interaction have been found. Two of these interactions, the abovementioned NK interaction and a PK interaction, were found in ratoons and all the other interactions in plant cane. The following table summarises these interactions:

		Increase in Tons Cane per Acre	
Interaction	Plant or Ratoon	Combined Effect	Sum of Indi. Eff.
NK	Ratoon	25.74	13.04
PK	Ratoon	16.34	−2.57
NK	Plant	13.48	3.47
NP	Plant	12.31	3.33
PK	Plant	5.96	−1.39
PK	Plant	10.73	4.10
PK	Plant	10.67	5.24
NP	Plant	6.33	−9.88
NP	Plant	13.79	−3.50

It is worth noting that in the seven plant cane interactions listed here, phosphate was involved on no less than six occasions, which again points to the importance of phosphates in plant cane. Undoubtedly, however, phosphates were low in these soils, but it does show the importance of making sure of phosphate supplies before starting high level applications of nitrogen and potash.

As stated these spectacular interactions are somewhat exceptional, but they do point to the need for proper balance in nutrition and emphasize that the maximum effect of one ingredient is not obtained if another is in insufficient supply.

The Effect of Fertilizer on Sucrose per cent Cane

All the above considerations have been based on a cane per acre basis, but now the effect of fertilizer on sucrose per cent cane will be considered. The following table gives the sucrose per cent cane for different treatments for both plant cane and ratoons:

	Pounds N Applied			Pounds P_2O_5 Applied			Pounds K_2O Applied		
	0	**100**	**200**	**0**	**100**	**200**	**0**	**100**	**200**
Plant Cane	15.45	15.31	15.18	15.32	15.36	15.27	15.34	15.30	15.31
Ratoons	15.13	15.14	14.94	15.13	15.09	14.98	15.01	15.07	15.12

From the above table it is clear that the average effect of fertilizer on sucrose content was small in this series of experiments, where all fertilizer dressings were given early and where most crops were cut as two-year-old cane. In the case of nitrogen, and particularly in plant cane, a decided downward tendency with fertilizer application is evident. This downward tendency is also evident in phosphate, but with potash the ratoon crops show a small gain in sucrose per cent cane.

Summary and Conclusions

This series of $3 \times 3 \times 3$ exploratory fertilizer trials has demonstrated the importance of nitrogen and potash—particularly so in ratoons where the relative responses are much higher than in plant cane. Good nitrogen responses are, however, also obtained in plant cane crops particularly on Table Mountain Sandstone soils. It is possible that in many cases a green manure crop, or a long fallow, has decreased the nitrogen requirements in plant cane but in the ratoons large and significant responses are common.

Phosphate responses, though not as spectacular as on virgin soils, are still quite common on many old cane lands and particularly so on Dolerites, Basalts and Granites. Superphosphate applied in the furrow at planting has a decided residual effect on ratoons. There is, however, no reason not to top dress phosphates on a trash layer in crops needing a further supply of phosphates, because the uptake is apparently good and the magnitude of the original plant response can in this way be maintained or improved.

As in the case of nitrogen, potash responses are better in ratoons than in plant cane. This is a fact even if the possibility of a residual effect from a potash application in plant is considered. Thus on the average the response from a 100 lb. per acre K_2O applied both to a plant cane crop and a first ratoon is better in the ratoon than the response from a 200 lb. per acre application on plant cane.

The series of experiments demonstrates forcibly the need for balanced nutrition. In a number of instances where more than one plant food was limiting, it was found that the combined response from the added fertilizers far outweighed the sum of their individual effects.

The effect of fertilizer on the sucrose content of cane is small. Nitrogen applications depressed sucrose content and their effect was somewhat bigger in plant cane than in ratoons. Phosphates apparently also had a slightly depressing effect on sucrose but this was not the case with potash applications where the sucrose was either maintained as in plant cane or seemed to be slightly increased in ratoons.

In 1951 fertilizers purchased had a ratio of P_2O_5 to N to K_2O of 100 : 33 : 13. The 1955 fertilizer sales reflected the following ratios: 100 : 113 : 88. This recent series of experiments completely justifies this dramatic change in fertilizer practice and indicates that the ratio of nitrogen and even more so potash can still be raised relative to phosphates. This change of practice has, therefore, not been haphazard and is in fact largely based on recent experimental results and information emanating both from the Experiment Station at Mount Edgecombe and from the Experiment Station's Fertilizer Advisory Service at Briardene, Durban.

Mr. J. L. Moerdyk said that throughout the world thousands of scientists were spending their time and the money available on experiments on fertilizer applications on different soils for different crops. A large proportion of this work was of a very high order and statistically sound (often the statistical angle is so stressed that one cannot see the forest for trees). In many of these experiments significant results for specific applications of N, P and K are obtained so that we definitely seem to be getting somewhere–but are we? How many of all the thousands of these significant results are applicable to the same soil five or ten years later? Can we in 1960 for the same crop on the same land say definitely that the 1957 results hold good? Certainly not.

For what reasons (apart from rainfall and temperatures which in any case we can't predict)?—simply because the medium we work on, "the soil," has changed during that period. In other words, the time and money and effort spent on this work is largely wasted. Evidently our approach is wrong—we are trying to find out what fertilizer to give to any particular crop on any particular field. But we know how much N, P, K, Ca, Zn, etc., a plant removes for a specific weight of material produced. We also know from hydroponics that if these amounts are supplied in readily-available form, that growth is normal. In hydroponics we have a stable medium, pure water, which has no chemical action on the foodstuffs, no fixing power, no adsorbent properties to turn available plantfood into non-available forms. We also know that the pH must be within a certain sphere.

Here I think we have the answer. Our research should concentrate on the soil. Our endeavours should be to find ways and means of keeping the medium as constant as possible. Perhaps by modifying our present-day methods, i.e. using agricultural lime, dolomitic lime, basic slag, etc., we can keep the pH within a definite range. Soil structure and aeration by means of grass leys, trash farming, etc., should be more thoroughly investigated.

When this has been thoroughly established, the question of fundamental proportions of N, P, K, Ca, Zn, etc., in the soil (as apart from later applications) should be studied. Times of application of food elements with the possibility of a change in the soil from chemical to organic form, should be studied. The coefficient of availability of soil fertility versus applied fertility, should receive attention, even though it may prove not to be very important.

When these aspects are thoroughly understood and if we can maintain a near-constant medium, the application of fertilizers becomes simplicity itself, because, as in hydroponics, we would merely have to supply those elements removed in those same quantities.

I think that while this research is in progress, we should, even on our changeable medium, start experimentation to see in how far this theory will work. Lay down experiments, say on sugar, under irrigation and fertilize completely, i.e. major and minor or trace elements on a 30-ton, 60-ton, 100-ton and 120-ton basis and see where we get treating the soil purely as a sponge in which to grow the plant, but making sure of soil drainage and aeration.

The Chairman, Dr. McMartin, stated that the experiments shewn by Mr. Du Toit were of great interest to both the scientists and those whose business it was to produce cane in the fields. Recently the Experiment Station had instituted a larger number of experiments extended throughout the sugar belt, the same type of experiment being repeated in several areas. The results given in Mr. Du Toit's paper was the result of grouping such experiments.

Mr. W. F. C. Jex said that Mr. Moerdyk's suggestion was one that should be followed up. He thought that results in the paper pretty well gave the answer to queries set by Mr. Moerdyk. However, until we are more sure of our fertilizer requirements for different situations, following up of the suggestion of the hydroponic idea might well prove of value. He said that the experiments quoted by Mr. Du Toit showed an increase of only a few tons per acre to the application of 200 lbs. N, but in his experience that in properly balanced soil 20 tons per acre was not uncommon. The natural fertility of the soil alone we could expect only from 20 to 30 tons per acre but if we were looking for yields of 50 to 60 tons per acre this could be realized only by the application of fertilizer. In time we might find that a relative requirement of fertilizer for cane might be changed in the future and we would then have to readjust our basic requirements.

Mr. J. L. du Toit, commenting on Mr. Moerdyk's remarks, said even if you based your fertilizer policy on the amount of plant food taken out of the soil, field experiments would still form an integral part of any testing programme. He did not think that making good losses of plant foods should be the only criterion used, but it should form part of a fertilizer policy.

Mr. J. L. Moerdyk said that the main theme that one should work upon was to provide only for the crop to come but also for crops expected in the future. We should therefore return to the soil the amount of plant food taken out. In the case of cane even if we had areas where one hundred tons per acre were obtained it was possible that there might be a deficiency of say potash or phosphate and these things must therefore be supplied to the soil.

Mr. Coignet was of the opinion that when applying the results of fertilizer trials in practice, consideration should be given to soil analysis of the fields to be treated. If this were omitted the crop might suffer as much from the excess of one fertilizer element as it would from its deficiency. It had been discovered that an excess of any particular plant food depressed the uptake of another. For instance, in a soil saturated with $Ca(OH)_2$, the P_2O_5 uptake by roots is depressed to such an extent as to reveal phosphate deficiency by foliar diagnosis and a drop in crop production in spite of the sufficiency of available P_2O_5 capable of producing a heavy crop under normal conditions. This phenomenon is even more pronounced in the case of trace elements, such as zinc, copper, manganese and the like. A terrific boost in crop production was obtained when the right amount was added to soils deficient in these elements, but toxic levels were soon reached and the addition of more may even cause complete crop failure.

Mr. Du Toit stated that the trash layer in ratoons was by no means the only reason why ratoons needed more nitrogen than plant cane because the same phenomenon is found in burnt fields. Furthermore, while the nitrogen status in a first ratoon is probably better in a burnt than a trashed field this did not apply to later ratoons when part of the nitrogen in the original trash layers became available to the plants. It was, however, difficult to assess what proportion of nitrogen in trash ever became available to subsequent crops and this was a further complication in accepting Mr. Moerdyk's suggestion. The amounts of phosphate and potash in trash must later on become available to the cane and so would probably be part of the nitrogen, but the extent of the latter was difficult to determine. It should also be remembered that plant nutrition although very important was only one aspect of crop production.

Mr. Rault stated that Mr. Du Toit had shown rather high figures for sucrose per cent cane, but he would like to know if an increase of cane tonnage by fertilization or better agricultural practice would necessarily depress the sucrose content.

Mr. Du Toit said that it did not necessarily follow that because yield was increased that sucrose concentration should suffer. If growth could be stimulated during early growth and the cane cut after one or two winters the sucrose content should be satisfactory. It had often been found that potash application not only increased the yield of cane per acre but also the sucrose content. Moderate applications of nitrogen might also increase sucrose although here the general tendency, particularly with higher amounts, was for sucrose to decrease. This decrease was seldom large in South Africa and as far as he knew invariably more sucrose per acre was obtained.

Dr. Douwes Dekker wondered if tons of cane per acre was the right way to express increased yield or should we express results of our tests in sucrose per acre or better still, in tons of sugar per acre. After all, we were out to produce not so much sugarcane as sugar. He asked if it would not be better to express in future results of fertilizer tests or likely tests in terms of available sugar per acre.

Mr. E. Hugot said that the formula applied in Reunion to gauge the financial interest of either a fertilizer test or of different varieties was: $R(S-5)$ where R = tons cane per acre and S = extractable sugar per cent cane.

Mr. Du Toit agreed with Dr. Douwes Dekker. It was normal at the Experiment Station to express yields both as tons cane per acre and tons sucrose per acre. The present survey formed part of a whole and in some of the old experiments sucrose data were missing, consequently yield was given as tons cane per acre. All sucrose results were known, however, in the present series and the results summarised. It was therefore possible to get the sucrose yields per acre. Mr. Du Toit further agreed that tons available sucrose would be a further improvement and hoped that an acceptable formula for determining available sucrose would be agreed to. He thought that harvesting, handling and transport costs should also be brought into the formula so as to assess the economic value of the crop. The latter part was particularly important in dealing with varieties differing appreciably in sucrose content. Cutting and loading costs were reasonably constant, but transport costs fluctuated considerably according to locality.

Mr. W. F. C. Jex asked if Mr. Du Toit could indicate a useful mixture of fertilizer to be used for normal conditions.

Mr. Du Toit in reply stated that this series of experiments had proved that the mixture 10 : 6 : 10 was in general excellent as a top dressing mixture. He felt, however, that further information was desired to get the optimum balance between nitrogen and potash.

Mr. Leclezio said that remarks like those of Mr. Moerdyk might be considered as a stimulus for research. If, however, the speaker had to present a paper for such a purpose, he would have mentioned the necessity of microbiological investigations in soil research. He referred to the work done in that field by the Tananarive research institute in Madagascar by which he had been much impressed. He believed the methods used by them for controlling the fertility status of the soils should find many applications in cane-growing countries. He said that much had been spent in Mauritius on foliar diagnosis, which had been found most convenient for determining requirements in K_2O and P_2O_5, but was unreliable as far as N was concerned. He would like to hear the comments of Mr. Du Toit in this connection. He was interested to hear Mr. Du Toit say that superphosphate was more available when sprinkled over the trash. He asked if combined applications of superphosphate with molasses and bagasse had not been tried out. As regards the influence of fertilizers on sucrose content, it had been found in Mauritius that the time of application, rather than the dose, was critical. He would like to know at what time applications were made in this country, in connection with the two-year crop cultivation.

Mr. Du Toit said that their experience of foliar diagnosis was similar to that of Mauritius: it worked well for potash and phosphate but not so well for nitrogen. However, it did give some indication of nitrogen status of the crop, which was more than could be said for soil analyses. Nitrogenous fertilizer application could, and must largely be based on the results of field experiments. It had been found that phosphate applied on top of the trash layer was well utilized by the cane crop. In the series of experiments now reported all top dressings were applied in the first year of growth and they were not split. Split dressings were, however, commonly applied in practice although experimental results were rather inconclusive. Second year applications were difficult but aerial applications were not being resorted to.

Mr. Kramer said that he had tried fertilizing in two-year-old cane from the air about three months before cutting. This cane has still to be cut but the improvement in the colour of the cane has been remarkable, especially in the case of ratoon cane. The fertilizer took longer to get to the trash than by other means of application but after a month the improvement in the cane colour was noticeable. He said that Mr. Du Toit had indicated that the fertilizer was applied to the top of the trash but he had found that by doing so the roots of the cane tended to come to the surface.

Mr. Du Toit could not see much wrong with the roots coming towards and feeding near the surface. Where fertilizer had been applied experimentally under the trash blanket it did not improve the crop.

Mr. Moerdyk stated that in maize large quantities of nitrogen could be used without harmful effects if the application was made in the original plowing. The nitrogen then changed into an organic form and did not have the same drying out effect than if it was applied at planting time.

Mr. Du Toit felt that the behaviour of cane and maize might be different, but an experiment had been planted where fertilizer had been applied on the trash before ploughing in.

Dr. Dodds said that Mr. Moerdyk referred to certain ideal soil conditions that soil research might help to show how to bring about, but expressed doubts of the value of the large number of comparative field experiments on the application of fertilizers to various crops, and suggested that this was being overdone. Dr. Dodds was of the opinion that, on the contrary, adequate field experimentation with fertilizers had never yet been done in our sugar industry, or probably elsewhere, in view of the time and expense involved in properly conducted field experiments. Mr. Moerdyk said that results of such experiments would not be applicable to the same land five or ten years later. It was certainly to be hoped that they would not be, if the grower followed the information revealed by the experiments.

Turning to Mr. Du Toit's paper, he could not agree that potash as a fertilizer was neglected before 1950. He, for one, recognized that large quantities of potash were removed from the soil by every sugarcane crop, and that before very long potash would need to be supplied.

However, the soil originally was so well provided by nature with potash that practically every soil analysis showed it still to be present in adequate quantity for immediate needs, and field experiments did not indicate any response to potassic fertilizer.

It was fortunate at that time, previous to 1950, that the question of the supply of potash to the soil could be temporarily shelved, because there was every indication that most of the soils growing sugarcane were deficient in nitrogen.

The sugar industry was not wealthy in those days; the price of cane was about 12s. 6d. a ton and a strict quota had to be applied to avoid over-production, unlike the present when the price is 40s. a ton and the demand for cane now unlimited.

Thus it was difficult enough to convince the planter of the necessity of using expensive nitrogenous fertilizers in addition to the relatively cheap phosphatic fertilizer he had become accustomed to use, without having to include potash immediately also.

Dr. McMartin said that Mr. Moerdyk had raised a fundamental point as to what we should use as our fertilizer policy. One could easily estimate the amount of plant food removed by a crop. However, if we took the case of potash, which had been removed by sugarcane in Natal for over a hundred years in enormous quantities, we found that only in recent years had the necessity for the application of potash become apparent in trials. He asked if Mr. Moerdyk suggested therefore that these large quantities of potash should always have been replaced.

Mr. Jex said that although potash might have been adequately available in the past, if we now wished to increase our yield we must add further quantities of potash. He felt that further research should be carried out to try and prove all the points raised by Mr. Moerdyk, but in the meanwhile one had to go on assumption.

Mr. Du Toit said that although it might, in general, be a good policy to replace plant foods that were taken out of the soil, it would obviously be uneconomic and unnecessary to replace potash, etc., losses if it was already in excess in the soil. His remark that potash was neglected in the past did not necessarily amount to a criticism of past experimental work. In general when cane prices were low the costs of fertilizer were also low. At the moment, however, the ratio of price of cane to price of fertilizer was favourable and planters should take advantage of it to increase their yields and profits.