NOTES ON SOME FERTILITY INVESTIGATIONS.

By W. H. FOSTER.

Some years ago one of our leading technologists remarked that little improvement could be anticipated in the milling process as compared with practice in the larger mills overseas, and improvement, therefore, must take place before the cane reached the factory. This is true, more so to-day, than ever before. The leading factories have attained a very fair level of efficiency, and any spectacular advancement must come from an improvement of the raw material.

The performance of the new variety canes justifies the soundness of this reasoning. Whereas an increase in production previously meant bringing under cultivation new areas, to-day we see increased production tion from the same, or even smaller areas.

This search for cane varieties of still more desirable milling qualities and more suitable to individual soil types, is likely to continue and in turn give rise to other problems. One of these affecting the agriculturist is the effect of the heavier cropping on soil fertility. It seems reasonable to suppose that with this heavier yield fertility will be reduced more rapidly, and a more careful study will have to be made of plant-food requirements to maintain the soil at its productive peak. Our agricultural practice must clearly leave the old extensive stage and become increasingly more intensive.

R.G.T.Watson,[2,3] has defined his views on an organised programme of field research to this Association at its 1938 Congress. His earlier work exposes the fallacy of supposing that one predetermined fertilizer mixture can supply the fertilization requirements of all soil types. I would like to refer to his map of soil types accompanying his paper "Some Practical Considerations in Designing a Programme of Field Trials."[3] This shows clearly how very scattered and broken are the major soil types within a small area. It is hardly likely that plant-food deficiencies found in, say, a red coastal wind-blown sand will correspond to those found in red clay loam or shale. The only logical method of arriving at a fair conception of plant-food requirements is to examine each soil type individually. Field trials are undoubtedly the correct method of investigating such problems, but knowing how very variable a soil type can be within itself, it is desirable to have some means of measuring this variability, in order to be sure that the site chosen for the trial may be as representative as possible of the type as a whole, and to know as to what areas the treatment indicated by the trial results can be applied with a reasonable anticipation of success.

Such measurements appear to be practicable; the so-called rapid chemical methods of estimating available plant-foods, which have been developed in recent years, placing a means at our disposal of mapping the soils in detail.

The successful application in Hawaii of the R.C.M. soil tests to their plantation problems, and the favourable report on these methods by the Field Section of the Natal Estates laboratory staff, lead us to investigate their value under local conditions. The methods are fully described by Campbell in the Proceedings of the Sixth Congress of the International Sugar Technologists' Society, and in various bulletins issued by the Hawaiian Sugar Planters' Association.

It is hardly likely, however, that the values found in Hawaii would apply to soils in this country. Indeed, it is quite possible that the standards will even be found to vary with each different soil type examined. As there is little recorded work on the subject from the sugar belt, it is necessary to ascertain whether there is a co-relation between the field trials and soil tests, and if such co-relation does exist, to determine its value.

As far as soil mapping is concerned, at Tongaat we have sampled fields during the fallow period after the soil has been broken by ploughing. The results so far have been interesting, and the grouping of plant-food values very frequently following the observed fertility trend of the field. The field is measured off into two-acre blocks and samples drawn therefrom. This is naturally a slow process, and it will be some little time before we complete a map of the sections.

In the meantime soil tests are being taken from field trials as they are harvested, and a resume of these is given, as not only may they prove of interest, but the discussion and criticism of this Congress should prove of value.

When this investigation was first commenced, samples of soil were taken by the field staff and sent to the laboratory. Soil tests of the first few trials harvested in 1939 indicated that where responses were obtained to plant-food additions, soil tests indicated a deficiency in these elements. However, soil tests of the control plots showed little, and at times no variation from those of the treated plots, although there was reason to believe that there should be a residual amount of the fertilizer untouched.

A number of research workers have indicated that little movement of phosphatic fertilizer occurs in the soil, though there is evidence to the contrary. It seemed possible, therefore, that this condition may exist in regard to our soils, not only as regards phosphates, but also the other elements, particularly as it is the practice to apply phosphates to the furrow at the time of planting and side dressing the established cane, still in well defined furrows, with the other two plant-foods.

Samples at this time were taken by the simple expedient of removing a slice of earth with a spade. The ease with which a sample may be drawn by this means from the cultivated interspace and the difficulty of taking one from the furrow, left little doubt as to the location of sampling. Therefore samples drawn separately from furrow and from the interspace should reflect whether fertilizers are dispersed throughout the soil or remain concentrated more or less where placed. In our field practice it is customary after harvest to relieve the field of trash by heaping it to rot into the alternate interspaces. The trash-covered interspaces are not cultivated. Samples were therefore drawn from (i) the cane row itself, (ii) the cultivated interspace which has been relieved of trash, and (iii) the interspace covered by trash and not cultivated.

The results obtained from some plots from Field Trial No. 13, given below, are typical of those generally found.

Plot No.	Treat-ment.	Lbs. per acre P_2O_5. (i)	(ii)	(iii)	Lbs. per acre K_2O. (i)	(ii)	(iii)
1.	PK	All	80	60	400	400	200
2.	NPK	in	120	60	400	400	220
3.	NPK_2	excess	140	60	400	400	400
4.	P	of	100	80	400	400	160
5.	PK	140	140	80	200	400	220
6.	NPK	lbs.	100	20	400	400	400
7.	NPK_2	per	120	60	400	400	400
8.	P	acre	140	20	400	400	400

It will be seen that despite intensive cultivation phosphates remain largely where they are placed. There is little, if any, movement across the cane row to the trash-covered area. The potash seems to be well distributed between the row and cultivated interspace, whilst there seems some spread across the row to the trash-covered area. Since potash is applied as a side dressing, it is reasonable to suppose that cultivation and weeding will soon cause its dispersal throughout the area, even if no natural dispersement took place.

The nitrogen tests are disappointing, showing no positional differentiation in the plot and only slight differences between the plots, and those not what could be expected.

Samples have been taken at monthly intervals from a portion of a field composed of the red coastal wind-blown sand soil type, and, as it has a distinct bearing on this subject of positional sampling the results are given in graph form, attached. The area was examined by R.C.M. tests before planting and showed 68 lbs. available P_2O_5 and 200 lbs. available K_2O per acre. The field was given 20 tons of filter cake and 400 lbs. of superphosphate per acre, applied in the furrow at time of planting. This is equivalent to 1,330 lbs. P_2O_5 and 44 lbs. of N per acre. Although the first crop has not yet been harvested, the results are very interesting. The samples have been drawn from the furrow and from the interspace. Cultivation has been particularly intensive.

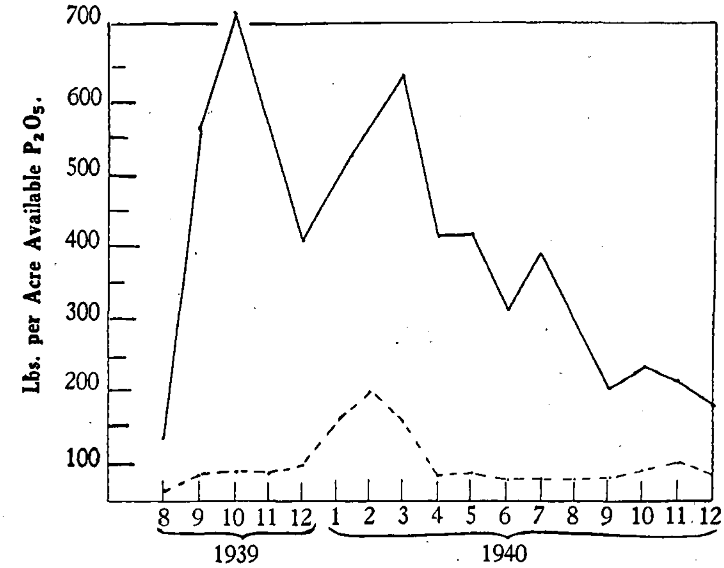
It will be seen that little movement of phosphates has occurred. The slight rise in phosphate content of the interspace samples during January to March, 1940, is of interest, since it is coincident with the application of nitrogen and potash fertilizer, and also with very intensive cultivation. The depletion of P_2O_5 in rows has proceeded steadily and it will be of interest to observe when it is completely used up. It is of interest to note that the phosphate fixation test gave what might be termed negative results for both row and interspace samples, until November, 1940.

The main feature in the potash curve is the sharp rise, both row and interspace, in the January to March, 1940, period, following the application of potash fertilization. The peak in both curves occurs at the same time, suggesting a rapid dispersal of this plant-food. This, however, may be due to mechanical agencies, since the field received particularly intensive cultivation about this period. The curve returns to normal almost immediately after the side dressings were applied.

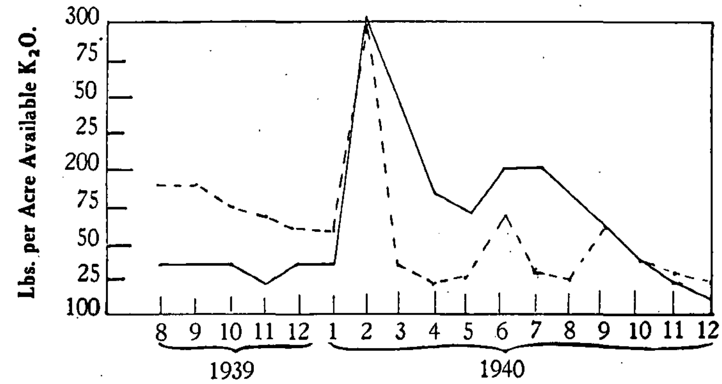
The curves for both ammonia and nitrate nitrogen show little difference between row and interspace, though it is just possible that the filter cake has given enhanced values to the figures for the rows. The application of sulphate of ammonia is not reflected in the tests, but it must be mentioned that the dressing represented only 20 lbs. N per acre. It has been suggested that there is a low level on both ammoniacal and nitrate curves towards the latter end of both summer seasons, which might point to the desirability of fertilizing during this period.

Although the foregoing results suggest little movement in phsophatic fertilizer but a quick dispersal of potash and nitrogen in wind-blown sand types of soil, the results of trial No. 14 on a stiff grey loam at Inyaninga would indicate that there is little movement in any one of the three plant-foods.

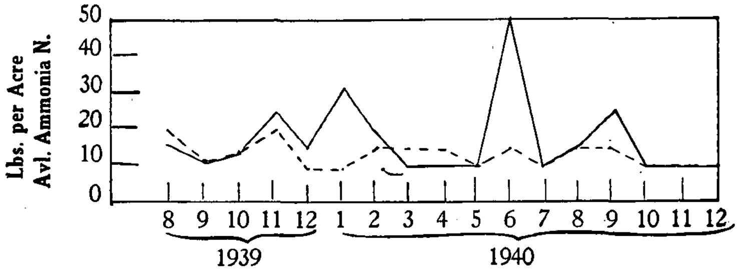
AVAILABLE P_2O_5.



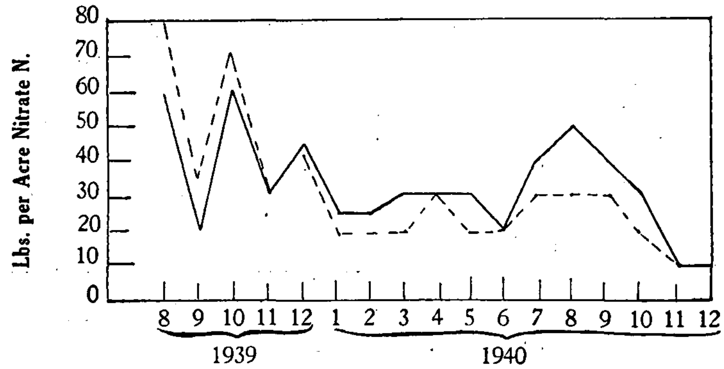
AVAILABLE K_2O.



AMMONIACAL N.



NITRATE N.



Cane Row ——— Interspace – – – –

Cultivation and Weeding noted, Sept., Oct., Dec., 1939 and Feb., 1940.

Potash and Nitrogen applied Feb., 1940.

The results of soil tests from this trial are :—

Treatment.	Lbs. per acre available P_2O_5	K_2O	Ammonia.	Nitrate.	Total nitrogen
P ...	102	56	25	30	412
PK ...	93	448	25	25	385
NPK ...	88	434	50	90	448
NP ...	71	224	70	90	500

Note.—The NP plots received NPK + lime during plant crop.

The nitrogen tests, which up to now had been so disappointing as to lead to a suspicion that the method was faulty, distinctly show the result of nitrogenous fertilization, and, moreover, agree with the heavier amounts of total nitrogen found by the usual standard method of determination. Phosphates and potash are found concentrated in the furrow.

Summarising our results, we may state that (1) little movement of phsophatic fertilizer occurs in either type of soil examined, (2) little movement of either potash or nitrogen is observed under conditions of trial No. 14, but (3) in sandy soils a quick dispersal and absorption of these two plant-foods are noted.

It must be concluded, therefore, that if concentrations of added plant-foods (fertilizers) are to be exposed, samples must be drawn from the vicinity of application of these plant-foods. In our case samples must be drawn from the cane line.

All soil samples were therefore drawn in this manner from the following trials described.

1. Field Trial No. 41. Field, 90 Kraal. Section, Tongaat. Cane variety, Co.281. Phosphate trial. Planted August, 1937. Harvested 7th October, 1939.

The soil is a dark grey loam, clayey, of good depth and good fertility. The design of the trial is a simple balanced block layout giving four levels of phosphates replicated six times. This design has been extensively adopted at Tongaat to investigate the plant-food requirements of our major soil types.

P_2O_5 has been supplied at the rate of nil, 100, 200 and 300 lbs. per acre, in the form of superphosphate, and applied at the time of planting. Nitrogen at the rate of 120 lbs. N per acre, and potash at the rate of 240 lbs. K_2O per acre, have been applied in three equal side dressings.

The results of the trials are :—

Treatment	X.	A.	B.	C.
Tons cane per acre...	67.16	73.26	73.46	73.45
As % of X yield ...	100.0	109.1	109.4	109.4

Significant difference, 6.5 per cent. of X yield.

Soil Tests	X.	A.	B.	C.
Available P_2O_5 lbs. per acre	117	200	213	227

A significant response to phosphatic fertilization is noted, the A level apparently being the economic level. Soil tests show an increased available P_2O_5 content for those plots receiving phosphatic fertilization, but for some reason the heavier applications given the B and C plots are not reflected in the soil tests.

2. Field Trial No. 46. Field, 90 Kraal. Section, Tongaat. Cane variety, Co.281. Potash trial.

Harvest, design and soil type as for Trial 41. Potash in the form of muriate, applied as side dressings at the rate of nil, 120, 240 and 480 lbs. K_2O per acre, for the X, A, B and C treatments respectively. Nitrogen 120 lbs. N per acre and phosphate 300 lbs. P_2O_5 per acre.

The results of the trial are :—

Treatment	X.	A.	B.	C.
Tons cane per acre...	88.19	91.66	87.10	84.88
As % of X yield ...	100.0	103.9	97.6	95.1

Significant difference, 8.0 per cent. of X yield.

Soil Tests. — All samples examined showed amounts of potash greatly in excess of 400 lbs. K_2O per acre.

No response to potash is noted, and this appears to receive confirmation from results of soil tests.

3. Field Trial No. 36. Field, 43 Mila Hill. Section, Tongaat. Variety, Co. 281. Nitrogen trial.

Harvest, design and soil types as for Trial No. 41. Nitrogen in the form of sulphate of ammonia, applied as side dressings at the rate of nil, 40, 120 and 180 lbs. N per acre, for the X, A, B and C treatments respectively. Phosphate 200 lbs. P_2O_5 per acre. Potash 240 lbs. K_2O per acre.

The results of the trial are :—

Treatment	X.	A.	B.	C.
Tons cane per acre...	96.02	91.69	93.92	91.72
As % of X yield ...	100.00	95.50	97.80	95.50

Significant difference, 6.9 per cent. of X yield.

Soil samples were unfortunately not obtained from this trial.

Nitrogen appears, if anything, to depress the yield.

Conclusions.—It is to be inferred from this group of trials that the fertility, during plant crop growth on this soil type, will be maintained by the application of 100 lbs. P_2O_5 per acre. Potash and nitrogen are apparently without effect.

There appears to be a certain relationship between yields and soil tests.

Note.—The above trials are illustrative of a number of trials laid down on the major soil types found on the estate.

It should be noted that this type of soil differs considerably from the grey loam at Inyaninga about to be discussed. Whereas the Tongaat soil is of a very high available potash content, the Inyaninga type is particularly deficient in this plant-food.

Field Trial No. 1. Field, 20 Wattles. Section, Inyaninga. Cane variety, Co.281. Potash trial.

The soil is a stiff, shallow, grey loam, overlying shale. The trial is of simple design, three levels of potash replicated five times.

The trial appears to have been laid down originally to test the effect of increasing the supplies of potash above what was then considered a standard dressing. The plant crop treatment appears to have been 45, 195 and 345 lbs. K_2O respectively, for the X, A and B levels. This was altered during the ratoon crop to nil, 120 and 240 lbs. K_2O respectively.

The following are the yields for the two crops and the results of soil tests taken after the ratoon harvest :—

Treatment	Tons cane per acre. X.	A.	B.	As per cent. of yield. X.	A.	B.
Plant crop .	35.23	39.01	42.44	100	110.7	120.5
Ratoon crop	48.46	60.41	60.67	100	124.7	125.2

Significant difference :—

Plant crop, 18.2 per cent. of X yield.

Ratoon crop, 16.2 per cent. of X yield.

Available K_2O lbs. per acre (R.C.M. soil test) :—

X plots 323, A plots 334, B plots 293.

The response to potash is significant at the B level in the plant crop, and at both A and B levels in the ratoon crop. The B level shows no superiority over the A level in the latter crop. Since potash was applied in far greater amounts in the plant crop than in the ratoon, one is lead to speculate as to whether the residual effect of this plant-food from the plant crop has not been passed on to the ratoon crop, thus augmenting the supplies of this element available to this latter crop. Unfortunately, we have no soil tests after the plant crop, whilst those taken after the ratoon harvest are not very informative, except for the fact that the experimental area shows a very much higher K_2O figure than the surrounding area.

The conclusion to be drawn is that there is a definite economical response to 120 lbs. K_2O per acre in the ratoon crop.

Field Trial No. 14. Field, 162 Desvaux. Section, Inyaninga. Variety cane, Co.281. Soil type as for trial No. 1.

The trial design may be described as a simple exploratory type consisting of five replications of four treatments.

Each plot forms a bed between drains which are sufficiently deep and wide to preclude any possibiltiy of fertilizer creeping from one plot to another, by either natural or mechanical agencies. The trial is situated quite adjacent to Trial No. 1 and is on the same type of soil. The two trials will thus confirm each other.

The treatments given the plant and ratoon crops were :—

Treatment	X.	A.	B.	C.
Plant crop	P	PK	NPK	NPK+lime
Ratoon crop ...	P	PK	NPK	NP

applied at the rate per acre of P, 200 lbs. P_2O_5; K, 270 lbs. K_2O; N, 200 lbs. N; and 8,000 lbs. CaO.

The yield and soil tests given below are of extreme interest.

Treatment	X.	A.	B.	C.
Tons cane per acre—				
Plant	35.59	43.39	45.19	45.32
Ratoon ...	32.24	39.59	48.15	44.34
Yields as % of X yield—				
Plant	100.0	121.9	126.9	127.6
Ratoon ...	100.0	122.8	149.3	137.5
Soil tests lbs. per acre—				
Available P_2O_5	102	93	88	71
P_2O_5 fixation	670	730	800	895
Available K_2O	56	448	434	224
Ammonia N .	25	25	50	70
Nitrate N ...	30	25	90	90
Total nitrogen	412	370	448	500
pH	5.8	6.0	5.2	5.1

Significant difference—

Plant crop, 4.6 per cent. of X yield.

Ratoon crop, 8.5 per cent. of X yield.

It will be seen that the plots receiving NPK treatments have given the heaviest yields during both crops. It may thus be inferred that complete fertilization is necessary.

The deletion of potash from the C treatments during the ratoon crop has brought about a very significant reduction in yield, emphasising the necessity of supplying potash to this type of soil. The intention of withholding potash from the C plots was to observe the effect of NP on fertilization, but in view of the high residual value of K_2O in the soil, due to the effect of previous potash fertilization, it is hardly safe to regard this as a purely NP yield.

A most pleasing feature of the trial is the manner in which the soil tests are co-related to the yields and fertilizer treatments. After the plant crop harvest, soil samples examined all gave tests similar to those of the control plots. Apparently the stores of added plant-foods had not been touched by the sampler. Samples taken after the ratoon harvest were drawn from the cane furrow.

Dealing first with the potash content, the X treatment values represent the controls and receive no potash. The A and B treatment plots both receive potash dressings, and the closeness of the soil K_2O content from these two treatments suggests that had the C plots received a potash dressing during the ratoon crop a similar K_2O content could be looked for. However, by withholding potash from the C plots during the ratoon crop, the available K_2O has fallen from 400 to 200 lbs. per acre. This, in view of the significant fall off in cane yield, must be regarded as below the concentration required to maintain maximum fertility. Turning to Trial No. 1, we find that the application of 120 lbs. K_2O per acre represented the economic limit of potash fertilization for the ratoon crop, and this corresponded to a soil test of 300 lbs. K_2O per acre. Should the A and B plots in Trial No. 14 show a further increase in soil K_2O content after next harvest, we may reasonably suppose that we have been supplying potash in quantities greater than that required, and the dressings should then be so adjusted as to bring about a soil test of from 300 to 400 lbs. K_2O after harvest. If this proves to be the case, the R.C.M. tests will prove of immense assistance in maintaining this type of soil at its maximum economical peak of fertility.

The soil tests for available P_2O_5 seem to indicate a deficiency of this element. However, since we have no field trial covering quantities of P_2O_5 fertilization, with which to co-relate the soil tests, it is rather unwise to hazard any comment on the matter. Attention might be directed towards the higher P_2O_5 content from X and A plots compared to B and C values, also the higher pH values of the X and A plots, compared to the B and C plots. B and C plots received dressings of sulphate of ammonia and show an accumulation of nitrogen. However, whilst these facts are of extreme interest and offer much food for thought, and should not be overlooked in future work, it would be unsafe and unwise to endeavour to suggest any reaction between these factors at this stage of the investigation. Much more confirmatory evidence is required.

The nitrogen tests show distinctly enhanced values for those plots receiving dressings of this element, suggesting that nitrogen is probably being applied in quantities greater than that required. This will be rather evident should a further increase in the nitrogen content be noticed next crop. A nitrogen trial would appear necessary to establish the nitrogen content of the soil corresponding to the optimum nitrogen application.

Summarising our deductions from these two trials (No. 1 and No. 14), we may state that complete NPK fertilization is necessary. Potash is required at the rate of 120 lbs. per acre for the ratoon crop, and that there is good ground to suppose that the available K_2O content of the soil should be kept at a figure not lower than 300 lbs. per acre, to ensure maximum fertility. There is some reason to suspect that P_2O_5 is being applied in too small a dosage to obtain maximum returns. On the other hand the accumulation of nitrogen, as shown by soil tests, would suggest that this plant-food is being supplied in quantities greater than are required.

The trial brings to light a co-relation between yields and soil tests and a standard figure for available K_2O is suggested.

Attention is directed to the type of plot employed in Trial No. 14—beds between drains. This seems to be the only design which precludes the possibility of border effect. The results obtained from this type of plot amply justify the expense of cutting the drains.

Trial No. 30. Field, 69 Quarry. Section, Tongaat. Cane variety, Co.290. Potash trial.

The design is standard 24-plot layout. The soil is a deep red loam giving a very high available K_2O soil test, which would suggest that little response to potash fertilization can be looked for. The results of the trial would tend to confirm this assumption.

Tons cane per acre—

Treatment	X.	A.	B.	C.
Plant crop ...	59.10	58.91	60.49	60.57
Ratoon crop .	81.08	79.87	82.72	80.13

Per cent. of X yield—

Plant crop ...	100.0	99.7	102.2	102.5
Ratoon crop .	100.0	98.5	102.2	98.8

The available K_2O content of samples from individual plots is of some interest, and the results are given below in diagrammatic layout :—

Plot No.	Lbs. per acre available K_2O.	Lbs. per acre available K_2O.	Plot No.
1	1,200	1,080	13
2	1,880	1,200	14
3	400	700	15
4	1,080	400	16
5	800	600	17
6	1,880	800	18
7	1,880	1,400	19
8	1,400	1,300	20
9	1,200	1,400	21
10	1,880	1,880	22
11	1,400	1,880	23
12	1,200	1,200	24

The variation in the plant-food in a piece of land chosen for its apparent uniformity is rather startling.

Apparently in this type of soil potash fertilization is without effect.

Summary.

The effect of positional soil sampling is discussed.

A description is given of a series of field trials on dark grey loam at Tongaat and at Inyaninga. Co-relation between soil tests, yields and treatment is shown to exist.

A description of a trial on red loam is given showing co-relation between soil test and trial returns. Soil tests expose a rather large variation in K_2O within the trial area.

In conclusion, it may be said that the foregoing trials, which are descriptive of a line of research commenced at Tongaat, offer, at this stage, encouraging evidence of a co-relation between soil tests and yields which, if properly established, will make practicable local soil mapping and help build up a sounder fertilization policy and, at the same time, save much field trial work.

References.

[1] Campbell, Bruce (1939) : "Hawaiian Rapid Chemical Methods at Natal Estates, Ltd., Mount Edgecombe." Proc. Int. Soc. of Sugarcane Tech. **6**, 617.

[2] Watson, R. T. G. (1938) : "Notes on Fertilizer Experiments Harvested at Tongaat during 1936 and 1937." Proc. S.A. Sugar Tech. Assoc. **12**, 33.

[3] Watson, R. T. G. (1938) : "Some Practical Considerations in Designing a Programme of Field Trials." Proc. S.A. Sugar Tech. Assoc. **12**, 100.

The PRESIDENT said this was a subject new to Mr. Foster, and he congratulated him on his work and the setting out of the paper. It would form a valuable record.

Mr. DODDS welcomed Mr. Foster to the ranks of field experimental chemists. He would find disappointments, but his work would be, as perhaps he had already found, not without satisfaction. He had found very little phosphate movement in the soils; this had also been found by Mr. Beater at the Experiment Station. The author did not find any immediate response to four tons of lime; this was also the experience at the Experiment Station. Lime did not affect the pH of the soil for a long time; it might take four or six years, but eventually it did.

Mr. Dodds did not agree that drains between the plots precluded end-effect. They certainly limited the range of the root system, but there was also the effect of an increased quantity of light on the exposed end rows as well as other consequences which are not so obvious.

Dr. McMARTIN said that an encouraging feature of the paper was the co-relation that was shown to exist between these tests and field trials.

He did not agree that new canes giving heavier yields necessarily took more plant-food out of the soil. They might just be more efficient machines than the older, low-yielding varieties.

Mr. BOOTH said he would study this paper when it was printed, and felt that there were many points in it that could be put to practical use.

Mr. FOSTER said that he had been a little cautious in his statement about the fertilizer requirements of the heavy-cropping canes. Our knowledge of these varieties and their plant-food uptake was not yet complete.

The PRESIDENT concluded the discussion by asking for a hearty vote of thanks for Mr. Foster's interesting paper.