A FACTORIAL EXPERIMENT WITH FERTILIZERS ON SUGAR CANE

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Investigations of the plant food requirements for sugarcane grown on the wind-blown, sandy soils of marine origin typical of the Natal coast, have occupied the attention of numerous investigators in past years. In some cases there has been shown to be little response to phosphate, whilst in the case of inorganic salts of potash and nitrogen a lack of response or even a depressing effect on yield has been shown.

In these cases all the fertilizer ingredients have been applied in the furrow at the time of planting the crop.

The objects of the experiment which forms the subject of this paper were to ascertain whether the response obtained to any one ingredient was affected by the quantity of the other ingredients used in combination with it. The method of application was altered by applying the nitrogen and potash as periodic side dressings, and to investigate the interaction between the plant foods recourse was had to the factorial type of design in planning the experiment.

Three levels of each plantfood were selected and used in all possible combinations; hence there are 27 treatments. In order to keep the experiment within a reasonable size, despite this large number of treatment combinations, a device known as "confounding" was used by which the necessity of including every combination of the treatments in a factorial design, i.e., all combinations of the different factors involved, in each block is avoided.

Yates (9) who, together with Fisher (3), first evolved the factorial design of experiment, describes confounding as follows:—

"In a confounded experiment the treatment combinations of each replication are divided into two or more groups (each group being assigned to a separate block) in such a way that the contrasts between the different groups represent high-order interactions which are usually of less interest than the main effects and interactions between two factors only. Thus in any one replication the contracts representing certain interactions are identified or 'confounded' with the block differences, and in consequence in the replication most of the information on these interactions is sacrificed. In so far as the reduction of block size has been effective in reducing the error variance, the precision of all the remaining comparisons is increased. Moreover, by confounding different interactions in different replications, i.e., by 'partial confounding' some information may be retained on all interactions—indeed, if the gain in precision resulting from the confounding is sufficiently great even the partially confounded interactions may be more accurately determined than would be the case if the experiment were not confounded."

As it was desired to retain some information on all interactions, this experiment was partially confounded, different arrangements being used for the two replications. It will be readily appreciated that increased precision is due to the large number of "hidden" replications of which there are 18 for the main effects, namely N, P and K, in the experiment, whilst the interactions between fertilizer ingredients are evaluated with equal precision, although there are actually only two true replications of each actual combination of ingredients.

Soil samples were submitted to the Division of Chemical Services, Pretoria, where they were tested for plantfood requirements by the Mitscherlich method. Unfortunately the results are not yet available. On the other hand a detailed chemical analysis was done by the Vageler Alten method of three soil horizons of this soil type, the results of which were published by Lintner (4) in the Proceedings of the Tenth Annual Congress of this Association. This analysis indicated a general deficiency of nitrogen, phosphoric oxide and potash, and an unsatisfactory C/N ratio. The top soil, horizon A, is slightly acid, the acidity increasing with depth, considered to be due to the diminishing content of the bases and the increasing content of free aluminium ions. The analyst recommended 75 lbs K_2O per acre in conjunction with Phosphatic and nitrogenous fertilisers, part of the latter in the form of a slow-acting organic manure in order to improve the moisture and humus content of the soil.

For the six years prior to planting this trial the experimental area supported a volunteer crop of Panicum maximum, and Dactyloctenium aegyptium which was grazed and mown at intervals.

The variety of cane selected for this test was Co.290, each plot being 1/40 of an acre in size, the rows of which were six planted five feet apart.

The cane was planted on the 13th of January, 1937. A fairly satisfactory germination was obtained. Apart from some damage due to termites the cane remained free from pests and disease.

Weather conditions immediately following planting were very satisfactory, but thereafter and for the next ten months the rainfall both in amount and distribution left much to be desired. During the last seven months of this crop weather conditions generally were excellent.

The following table gives the monthly distribution of the precipitation from the time of planting to the time of harvesting:—

	1937	1938	28 year average
January	3.94	5.54	4.86
February	5.92	6.08	5.25
March	1.96	0.98	6.27
April	1.85	5.63	2.42
May	0.28	1.37	2.08
June	1.80	1.22	1.61
July	1.27	2.88	1.61
August	1.52		1.64
September	1.26		2.44
October	2.80		4.58
November	2.40		4.43
December	9.78		5.37

The total rainfall for the period was 58.58 ins.

The fertilizer treatments were as follows, (lbs. per acre):—

N_2 = 237 lbs. 21.1% sulphate of ammonia.
N_3 = 474 lbs. 21.1% sulphate of ammonia.
N_3 = 948 lbs. 21.1% sulphate of ammonia.
P_1 = 250 lbs. 20% superphosphate.
P_2 = 500 lbs. 20% superphosphate.
P_3 = 1,000 lbs. 20% superphosphate.
K_1 = 83 lbs. 60% muriate of potash.
K_2 = 167 lbs. 60% muriate of potash.
K_3 = 334 lbs. 60% muriate of potash.

The treatment combinations are given in Table 1. (See page 3.)

The plantfood equivalents of the amount of fertilizers applied are in this case 50 lbs. for the lower levels 100 lbs. for the middle levels, and 200 lbs. for the higher levels.

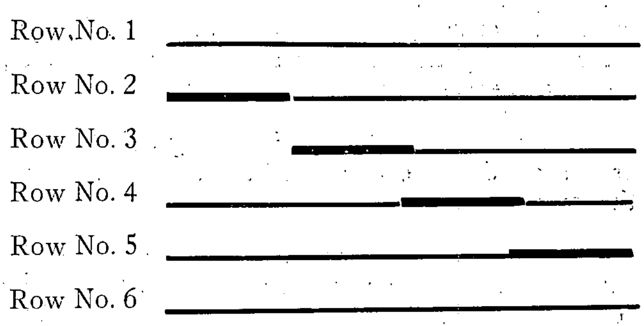
The fertilizers were applied as follows:—

1. **Superphosphate**:—In the drill at the time of planting.
2. **Sulphate of Ammonia**:—In three equal side dressings on the following dates.
   (a) 24th March, 1937.
   (b) 13th October, 1937.
   (c) 10th January, 1938.
3. **Chloride of Potash**:—In two equal side dressing with the Sulphate of Ammonia as under 2 (a) and (b).

Population Counts and Growth Measurements:—

In order to establish treatment effect on tillering and growth, as well as to determine whether it is possible to detect when the cane is young, differences obtained in the final yields, a tiller count and a growth measurement of the shoots was done on the 8th, 9th, 15th, and 16th of May, 1937, respectively.

The total number of tillers per plot were determined by taking a section in each of the four centre rows as illustrated below and making a complete count of each section.



The total number of tillers counted, therefore, represent 17% of the whole.

For growth measurements eight tillers were selected at random in each of the same four rows.

The treatment effects, main effects and interactions were calculated on the product of the combined height of the 32 tillers measured, and the total number of tillers counted in each plot.

The experiment was harvested during July, 1938, and representative samples of cane selected in the proportion of weights of canes and "bullshoots" in each plot, were despatched to the South African Sugar Association, Experiment Station, Mount Edgecombe for analysis.

The yields obtained from the fertilizer dressings on growth measurement and final yields are given in Tables 2 and 3. It should be noted that the yields in Table 2 represent the **totals** of two plots, and not the **average** for the particular treatment.

The calculation of the results obtained from the two sets of data are given in the Analyses of Variance in Tables 4 and 5.

Discussion.

It will be noticed that the responses to the main effects, namely N.P.K., are of considerable interest. Regarding Nitrogen we find that the response to this plant food is most marked, and does not support the findings of Lintner ([5]), Cauldwell ([1]), Dodds and Fowlie ([2]), and several others all of whom have reported either no response or depressing effects from this ingredient when applied in the form of soluble inorganic salts to sandy soils. The lack of

TABLE I.—PLAN AND YIELDS.

(A) Growth in feet after 4 months.
(B) Final yield in tons sugar per acre.

	Block 1.			Block 2.			Block 3.		
	W_1 (A) 8088.4 (B) 54.46			W_2 (A) 7939.3 (B) 51.47			W_3 (A) 7835.1 (B) 56.50		
	$N_1P_2K_3$	$N_2P_3K_3$	$N_3P_3K_1$	$N_3P_1K_2$	$N_2P_3K_2$	$N_3P_2K_1$	$N_2P_2K_2$	$N_2P_1K_3$	$N_3P_3K_2$
(A)	924.9	1005.3	1318.2	1013.4	847.7	919.2	861.0	1131.9	957.6
(B)	6.79	7.02	7.05	5.93	5.33	6.00	4.53	5.91	6.34
	$N_3P_1K_3$	$N_2P_1K_2$	$N_1P_3K_2$	$N_1P_2K_2$	$N_2P_2K_3$	$N_2P_1K_1$	$N_1P_1K_2$	$N_1P_2K_1$	$N_3P_2K_3$
(A)	756.5	1015.6	947.6	868.8	865.2	753.1	787.8	810.9	737.5
(B)	5.18	5.39	5.76	5.89	5.16	5.82	5.53	6.36	6.10
	$N_1P_1K_1$	$N_2P_2K_1$	$N_3P_2K_2$	$N_1P_1K_3$	$N_3P_3K_3$	$N_1P_3K_1$	$N_1P_3K_3$	$N_2P_3K_1$	$N_3P_1K_1$
(A)	771.2	681.3	667.8	849.4	835.8	986.7	923.1	858.5	767.4
(B)	5.45	5.91	5.91	5.25	5.69	6.40	6.82	7.06	7.85
	$N_2P_3K_2$	$N_3P_3K_1$	$N_2P_1K_3$	$N_2P_1K_1$	$N_1P_2K_3$	$N_3P_2K_1$	$N_1P_2K_1$	$N_2P_3K_1$	$N_3P_1K_1$
(A)	754.0	974.7	1025.9	918.0	683.9	1200.5	762.2	880.0	1186.3
(B)	6.92	7.34	7.14	7.39	6.58	7.21	6.49	5.76	9.18
	$N_3P_1K_2$	$N_1P_1K_1$	$N_1P_3K_3$	$N_3P_3K_2$	$N_3P_1K_3$	$N_1P_3K_1$	$N_1P_3K_2$	$N_3P_2K_2$	$N_3P_3K_3$
(A)	897.6	708.8	703.5	849.6	689.4	835.0	950.0	1000.4	1219.2
(B)	7.69	6.37	7.06	7.16	6.05	6.44	6.81	6.78	8.61
	$N_3P_2K_3$	$N_1P_2K_2$	$N_2P_2K_1$	$N_2P_2K_2$	$N_1P_1K_2$	$N_2P_3K_3$	$N_1P_1K_3$	$N_2P_2K_3$	$N_2P_1K_2$
(A)	874.5	647.9	702.1	629.8	504.0	502.7	665.8	914.6	846.5
(B)	6.48	6.37	6.10	5.79	5.10	5.90	5.85	7.06	7.19
	X_1 (A) 7289.0 (B) 61.47			X_2 (A) 6812.9 (B) 57.62			X_3 (A) 8425.0 (B) 63.73		
	Block 4.			Block 5.			Block 6.		

TABLE 2.—TOTAL YIELDS FOR SEPARATE TREATMENT COMBINATIONS.

(A) Growth in feet after 4 months.
(B) Tons of sugar.

		K_1			K_2			K_3		
		P_1	P_2	P_3	P_1	P_2	P_3	P_1	P_2	P_3
N_1	(A)	1480.0	1573.1	1821.7	1291.8	1516.7	1897.6	1515.2	1608.8	1626.6
	(B)	11.82	12.85	12.84	10.63	12.26	12.57	11.10	13.37	13.88
N_2	(A)	1671.1	1383.4	1738.5	1862.1	1490.8	1601.7	2157.8	1779.8	1508.0
	(B)	13.21	12.01	12.82	12.58	10.32	12.25	13.05	12.22	12.92
N_3	(A)	1953.7	2119.7	2292.9	1911.0	1668.2	1807.2	1445.9	1612.0	2055.0
	(B)	17.03	13.21	14.39	13.62	12.69	13.50	11.23	12.58	14.30

TABLE 3.—TOTAL YIELD DUE TO APPLICATION OF N, P, and K.

		1	2	3
N	(A)	14331.5	15193.2	16865.6
	(B)	111.32	111.38	122.55
P	(A)	15288.6	14752.5	16349.2
	(B)	114.27	111.51	119.47
K	(A)	16034.1	15047.1	15309.1
	(B)	120.18	110.42	114.65

TABLE 4.—**ANALYSIS OF VARIANCE.**

Growth in feet after 4 months.

Variation due to	Degrees of freedom	Variation	Mean variance
Blocks	5	189110.0	37822.0
N	2	184465.0	92232.5*
P	2	73365.3	36682.7
K	2	29045.1	14522.6
NP	4	194665.7	48666.4
NK	4	156786.4	39196.6
PK	4	28124.5	7031.1
NPK Unconfounded ...	4	83420.0	20634.5
NPK Confounded ...	4	81655.8	
Error	22	480566.6	21843.9
Total	53		

* Significant at 19 : 1 odds.

Significant difference between levels of main effects (totals of 18 replications) at 19 : 1 odds = 1,839 feet.

Conclusion.—The only significant factor was nitrogen, the highest level N_3 being best.

response to phosphates on the other hand confirms the findings of Lintner (6) on this particular soil and he suggests that this is probably due to the low pH of the soil, which is an important factor in connection with the solubility of soil phosphates. With low pH values it appears that soluble phosphates will become difficultly available in the form of iron and aluminium phosphates and that this state of affairs may possibly apply to the soil in this experiment. It is not at this stage attempted to give an explanation for the depressing effect of potash except to point out that previous experiments on this soil type have indicated that there is no advantage in applying quantities of potash salts exceeding 75lbs. K_2O equivalent per acre (7).

It is felt that the response to sulphate of ammonia dressings in this instance is closely linked up with the method of application and that the lack of response to fairly large applications of soluble inorganic fertilizers, generally so frequently reported from experiments on poor humus-deficient sandy soils, is intimately associated with the fertilizer placement in the soil. The question of fertilizer placement has of recent years received a great deal of attention in the U.S.A., and has been the subject of a very comprehensive report issued by the National Fertilizer Association of that country. Summarizing this report, we find " that applying fertilizer in the right place is fully as important as applying the right analysis in the right amount," and " that almost without exception in the numerous comparisons that have been made placing the fertilizer at the side of the seed or plant has been the most effective." In an experiment on cotton (8) on a sandy soil, it was found that applying 800 lbs. per acre of a complete inorganic fertilizer mixture in the drill as much as three inches below the seed produced yields below the no fertilizer plots, as well as adversely affecting germination. Almost a complete failure was reported by placing the fertilizer an inch below the seed.

It is suggested that the failure of response to superphosphate in this experiment might partly be attributed to placement in the drill at time of planting, injury being caused to the germinating cane by an excessive salt concentration in the sett zone.

TABLE 5.—**ANALYSIS OF VARIANCE.**

Final yields in tons sugar per acre.

Variation due to	Degrees of freedom	Variance	Mean variance
Blocks	5	11.2424	2.2485*
N	2	4.6462	2.3231*
P	2	1.8153	0.9077
K	2	2.6618	1.3309†
NP	4	4.5341	1.1335†
NK	4	2.8644	0.7161
PK	4	3.0139	0.7535
NPK Unconfounded ...	4	1.1288	0.2954
NPK Confounded ...	4	1.2345	
Error	22	8.1932	0.3724
Total	53		

* Significant at 99 : 1 odds.
† Significant at 19 : 1 odds.

Significant difference between levels of main effects (totals of 18 replications) at 99 : 1 odds = 10.32.
" " " " " " " " 19 : 1 " = 7.59.

Significant difference for first order interactions (totals of 6 replications) at 99 : 1 odds = 5.95.
" " " " " " " " 19 : 1 " = 4.38.

Conclusions.—The fertilizer ingredients causing significant differences were nitrogen and potash; phosphate could not be proved to have had any effect; and the only significant first order interaction was that between nitrogen and phosphate.

Nitrogen.—N_3 is highly significantly better than N_1 and N_2.

Potash.—K_1 is better than K_2; K_3 did not give any significant increase over K_2.

Interaction N × P.—Total yields due to separate combinations.

	N_1	N_2	N_3
P_1	33.55	38.84	41.88
P_2	38.48	34.55	38.48
P_3	39.29	37.99	42.19

This table shows that the increase caused by the application of nitrogen at the low level of phosphate was not maintained at the higher phosphate levels—in other words, there was an unfavourable interaction between these two factors.

The best combination of factors is therefore $N_3P_1K_1$.

In addition to the danger of injury when applying large quantities of soluble fertilizers in close proximity to germinating seeds or setts, the possibility of loss through leaching must be seriously considered. This applies particularly when large quantites of Nitrogen are used on sandy soils. Thus it was found that when this coastal sandy soil was placed in drums to a depth of three feet, and given a measured quantity of water equivalent to four inches of rain per month, the collected drainage water contained amounts of Ammonia Nitrogen varying from 100 to 450 parts per million. As it is most unusual to find more than one or two parts per million of Ammonia Nitrogen in soil drainage water, the low fixing power of this soil is very apparent. It would seem reasonable to assume therefore that the most efficient response from soluble nitrogenous salts will be obtained when these are split up into several side dressings and not applied as one dressing either at time of planting or subsequently; further investigation, however, might show that the actual quantities and the number of side dressings applied might have been varied, to yield more informative results.

In connection with the interactions we find the one between N and P the only one which passes the significance test. This interaction is of considerable interest and importance and is worthy of further investigation and study. Until more data is available, however, we can merely point out that the results indicate that the increase caused by the application of nitrogen in conjunction with the low level of phosphate was not maintained at the higher phosphate levels; in other words these two factors interacted unfavourably.

Of great interest is the correlation between early growth and final yield. Referring to Table 4 we find at the age of four months from planting evidence of a marked response to Nitrogen.

Although the results obtained for the other factors did not pass the significance test required, inspection of the figures will show that there are indications that the response was of the same nature as that obtained at harvesting.

In view of the fact that at this stage all the fertilizer had not yet been applied, greater importance may be attached to these indications, than appears at first sight. It is also of considerable interest that the response to nitrogen was found at six weeks after the first dressing of that fertilizer.

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The correlation coefficient between these measurements at four months and final yield is as follows:—

Correlation between growth, when young, and final yield (tons cane per acre).

Correlation coefficient (r) between average length of shoots and ultimate yield ..	= 0.54
Correlation coefficient (r) between number of shoots and ultimate yield	= 0.37
Correlation coefficient (r) between product of above two and ultimate yield	= 0.44
(r) for 50 observations at P = .01 ..	= 0.3541

Summary.

The factorial type of experiment is briefly described and its objects indicated.

Nitrogen applied as side dressings at the rate of 200 lbs. per acre in the form of sulphate of ammonia, has been found to give a marked response.

A depressing effect from potash was obtained.

An N.P. interaction was established.

A significant correlation was found to exist between early growth measurement and final yields.

Methods of applying fertilizers are briefly discussed, and the advantage of side dressings indicated.

Acknowledgements.

The authors wish to express their thanks to Dr. A. R. Saunders for his assistance in designing this experiment, to the Laboratory Staff of Mount Edgecombe Experiment Station for the analytical data, and to Mr. L. S. West, of Umbogintwini, who is responsible for the cultural, planting and harvesting operations.

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ADDENDUM

Since this paper went to press the results from the Mitscherlich Pot Trials carried out by the Division of Chemical Services, Pretoria, on this soil type have come to hand, [10] as follows :—

The pH of the soil was 5.4 with a resistance of 1400 ohms at 60°F. A chemical analysis of the soil by the fusion method gave the following results :—

SiO_2	90.76 %
CaO	0.38 %
MgO	0.49 %
P_2O_5	0.09 %
Fe_2O_3	3.51 %
TiO_2	1.04 %
MnO_2	0.05 %
Al_2O_3	3.19 %
K_2O	0.25 %
Na_2O	0.11 %
Moisture	0.22 %
Loss on ignition	1.94 %

The soil is sandy and has a total water holding capacity of 28%. Exchangeable bases in M.E. :—

Ca	1.5
K	0.3
Mg	0.6
Na	—

Total mineral N, 3.5 p.p.m. Total N, 0.067%.

The following treatments were tested out :—

No fertiliser, KPNCa, KPN, PN, PK, and KN.

P	: 1.93 gms. P_2O_5 as 11.28 gms. 17.1% superphosphate.	Equivalent to approx. 1 ton per acre.
K	: 2.89 gms. K_2O as 4.55 gms. KCl.	Equivalent to approx. 900 lbs. per acre.
N	: 2.12 gms. N as 6.06 gms. NH_4NO_3.	Equivalent to approx. 1200 lbs. per acre.
Ca	: as 27 gms. $CaCO_3$	Equivalent to approx. 2¾ tons per acre.

All the pots except the "no fertiliser" and KPNCa pots received 3 gms. $CaCO_3$, 0.96 gms. NaCl and 1.92 gms. $MgSO_4$, the KPNCa pots receiving 0.96 gms. NaCl and 1.92 gms. $MgSO_4$. (All nutrient quantities were based on the Mitscherlich plan.)

The pots were packed on 9th December, 1936, and planted thickly with Sudan Grass on the 10th December, 1936. Germination throughout the whole series was excellent within three days of planting. Gradual thinning-out of the plants was continued until 18th January, 1937, when each pot was left with 30 plants. At the beginning of February differences in height were already visible, and these became more marked towards ripening.

The "no fertiliser" and PK series were definitely lighter green in colour, whereas the KN series showed up normal, indicating, if anything, a nitrogen rather than phosphate deficiency in the soil.

From 2nd April watering was discontinued to allow plants to dry off as they were completely mature, and on 20th April the crop was harvested.

A residual winter crop was grown on the same soil, which did not produce any significant differences for the various treatments, except for the KPNCa series, which was better than all other treatments.

The harvest results of the Sudan grass crop are summarized in the following table :—

SUDAN GRASS SUMMER 1936/37.

	Mean harvest weight.	As % of KPN treatment.
KPN	93.3 gms.	100.0
PN	83.4 gms.	89.4
PK	50.7 gms.	54.3
KN	87.5 gms.	93.8
No fertiliser	52.0 gms.	55.7

(NOTE.—KPNCa results have not been inlcuded, as the lime factor in sugar cane has not yet been established.)

From Mitscherlich tables [11] it is found that there is 1.05 dz/Ha K_2O, 2.8 dz/Ha N, and 2.0 dz/Ha P_2O_5 in the soil. To obtain the optimum yields which are considered to be 60% of the maximum, amounts of plant-food required for this soil 1.10 dz/Ha K_2O, 5 dz/Ha N, and 1.60 dz/Ha P_2O_5. It is thus apparent that the amounts of K_2O and P_2O_5 in the soil are sufficient for an optimum crop, but that N must be supplemented by 2.2 dz/Ha N or approximately 11.0 dz/Ha sulphate of ammonia, which is roughly equivalent to 1,100 lbs. sulphate of ammonia per acre.

(The 60% of the maximum crop is arrived at by the following calculation :—

90% of the maximum crop with $K_2O \times 90\%$ of the maximum crop with $P_2O_5 \times 75\%$ of the maximum crop with N; for increases over 75% with N the response per unit is very low and will be of doubtful economy.)

Conclusion.

It will be noted that the trend of the figures obtained with the Mitscherlich pot test was a reasonable forecast of the results obtained in the field trial.

References.

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Dr. HEDLEY: You have before you an account of a very comprehensive experiment, and as there are a large number of people interested in this, this morning, I hope there will be a good discussion.

Mr. WATSON: I would like to make a few observations from a grower's point of view. This paper contains a number of features of absorbing interest to those dealing with problems of soil fertility, and also, I think, of high practical importance, directly or indirectly, to growers of sugar cane. In the achievement of their stated objective, that is the determination of interaction between ingredients, the authors have not perhaps been 100 per cent successful, and I think it is unfortunate that the interaction—the unfavourable interaction of NP—has been to a certain extent obscured by the fact that P, had as a matter of fact, already been thrown into the discard. It would, to my mind at all events, have been a clearer demonstration of the method of investigation employed if the NP interaction had been favourable. The authors have, however, achieved two definite objectives; they have shown a comparatively new method of plot technique, and they have also set the status of nitrogen in the permanent agriculture of the coast in an entirely new position. That raises the question: What have been the influences, one way or another, which have affected the development of the use of nitrogen in the fertiliser policy and permanent agriculture of our coast soils during the past few years? We have had a certain number of deterrent influences. Firstly, the fact that up to the present—I think I am correct—all results of experiments conducted in the Industry have shown no response to the use of inorganic nitrogen—no response, or very little response. Coupled with that is the fact that experiments with inorganic nitrogen in other parts of South Africa with maize have had no favourable response. So there has come about a general feeling that nitrogen, for some inexplicable reason, is not of much importance in our agricultural practice. A further deterrent factor is the rather unhappy experience of certain planters who have essayed to use sulphate of ammonia and other inorganic nitrogen on a field scale, applying it in the drill at the time of planting, drought occurring soon after, has caused damage to their fields. I have frequently heard planters say "No sulphate of ammonia for me. I used it and it killed off my plant cane in such and such a year." Undoubtedly the fourth deterrent reason is the cost of the fertiliser. A fifth might be named; the idea that has got about that whilst sulphate of ammonia produces luxuriant foliage, the effect on the plant stops there, and puts nothing extra over the weighbridge. The influences advancing the use of nitrogen have not been so many in number. They are limited to the experience recorded in other sugar countries, where frequently nitrogen is the dominant fertiliser ingredient, and also to the fact— the undoubted fact—that our fields, generally speaking, have the appearance of nitrogen deficiency such as is described in other parts of the world. I would like to refer, on this point, to the experience of a certain group of planters interests, whose fertiliser policy came more under the influence of the advancing factors than of the deterrent factors. They were more impressed by the look of their fields than by the experimental data available. Some time back, that group of interests used no nitrogen whatever in the fields. In the years immediately prior to 1934, not one ounce of nitrogen was given to either plant cane or ratoons. In 1935, a certain proportion of organic matter was used. In 1936, this group started to purchase inorganic nitrogen. In that year 140 tons were purchased, as a beginning. At the same time simple balanced plot tests were put down, which have subsequently been harvested, and which show similar indications of nitrogen response to that in the work at present under discussion. I feel that while these results had to be accepted with a very great deal of reserve indeed, they do not acquire slightly more importance in the light of the present disclosures. The policy was followed up in 1937. The amount of nitrogen purchased went up to 325 tons, next up to 470, finally, this year, to 660 tons of sulphate of ammonia, with a ten per cent decrease in area. The response, from a practical point of view, has been very satisfactory. The paper just submitted by these joint authors. together with the preceding one,, presented by Mr. John Lintner, are framed in a manner for submission to soil scientists rather than for direct consumption by the planter. The paper points the way to further investigation, but it also decidedly calls for a closer liaison between the research work of the laboratory and the experiment plot and the practical application of such research in the field. Mr. Dodds, Director of the Experiment Station, and a member of the Council of this Association, recently, in a circular issued to all planters, issued a similar appeal, that there should be a closer relationship, so the work of the various people who collaborate in keeping this Association going should not to any extent be lost, but should be interpreted or changed into actual practical results, I find reason to hope that this Association in this following session will deal with that aspect of scientific research in a serious way.

Mr. LINTNER: I would like to take this opportunity to congratulate Mr. Deenik very heartily indeed on his paper, which as Mr. Watson says, lays an experiment of a new design before us, and I think is one of the first of its type to be reported to this Association. I am sorry that the experimenter did not consider having controls in this experiment, because previous analyses of the soil done at Lichterfelde by the Vageler Alton caused the analysists to point out "The nitrogen content, as well as the total P_2O_5 content, is low in all three samples. The C/N ratio is also not satisfactory.

It is presumed that nitrogenous and phosphatic fertilisers will have beneficial effects. The partial use of slow acting organic manures as a source of both nitrogen and phosphates, which improve the moisture and humus content of the soil, is recommended.. The potash content is comparatively low for a soil of this description, and it is considered that a dressing of potash salts supplying 75 lbs. of K_2O per acre will prove beneficial under norma climatic conditions." Actually, in the results of another experiment at Umbogintwini, 75 lb. K_2O was found beneficial. It was also found, with phosphate at 120 lb. water soluble P_2O_5 per acre the yield was depressed.

I would like to draw the authors' attention to the fact that they mention that on this particular soil I have found that phosphate depressed the yield, and goes on to say I suggested that this is due to the low pH of the soil brought about by the increasing content of free aluminium ions. I don't think I actually said that but that the reference reads: "The pH of the soil is an important factor in connection with the solubility of soil phosphates. With low pH values, it appears that soluble phosphate will become difficultly available in the form of aluminium phosphate. This state of affairs may possibly apply to the soil in this experiment."

Also, I am disappointed that organic phosphate was not used here, which might have given a slightly different response and was the form of phosphate recommended by the analysists at the time who put their finger on the K_2O response on that soil. Also it is a pity that multiples of 75 lb. K_2O were not included with a control which might have elucidated the postion, more than the present experiment is capable of doing by enlarging on available data rather than by random choice of quantities. Nevertheless I find that it is very gratifying that the authors of this paper also find a close correlation between growth and ultimate yield, which was also the case, in an experiment at Tongaat where similar measurements were taken. One point which I think should have been included is the cost of the fertiliser applications per acre as compared with the gains obtained which would give some idea as to the practicability of such treatments in the field.

Mr. DODDS: This is a very valuable paper, that raises many interesting points for discussion and consideration. It is, as the previous speaker remarked, a real advance in experimental technique. However, there are certain questions one would like to have seen answered. Mr. Lintner has already anticipated one. The maximum response to certain fertilisers such as sulphate of ammonia is given. It would have ben interesting to know what was the maximum economic response, that is which application showed the maximum profit. You may remember, in the paper read by Mr. Fowlie yesterday, it was shown that the response to the application of 800 lbs. per acre of sulphate of ammonia at Umfolosi was significantly greater than to 400 lbs., but that 400 was the more economical quantity to apply in view of the diminishing return from the greater quantity and the cost of the sulphate of ammonia. It would also have been of interest, as noted by Mr. Lintner, to have had some plots without any fertiliser treatment at all, so as to show what the soil is really capable of without any fertiliser.Control plots may be regarded as almost essential, I think, in any comprehensive fertiliser trial.

The authors refer to the difference in results from these experiments and those of the earlier experiments with nitrogen, particularly sulphate of ammonia, as a fertiliser, and refer to those published by Mr. Fowlie and myself in 1931. There are several different factors concerned, of which I think the most important is that of rainfall. If you look back through the rainfall figures for the Coast for the six years 1926 to 1931—that is the six years immediately preceding the final results of the experiment to which they refer, the average rainfall was only 32.8 inches. In 1926, the first year the earlier experiments were laid down, we had a rainfall of only 25 inches, which was the lowest ever experienced on the sugar belt. At least three of those six years had abnormally low rainfalls, whereas, to take the recent period, the five years ending last year had a rainfall of 41.8 inches; that is to say an average increased rainfall for the period of nine inches per annum. We have shown, I think, in every experiment that has been carried out, that there is a favourable response to organic nitrogen; for example, whale guano gives a profitable response in every case that I can call to mind. But that is not the case with sulphate of ammonia—under dry conditions, at all events. Another important difference in practice is that in those days, all the fertiliser, following general practice in the country, was applied at the time of planting, and undoubtedly, I now think, that is not the best practice as far as sulphate of ammonia is concerned. There have been several occasions during the last few years on which profitable response to nitrogen has been shown and recorded. There are several articles published in the Sugar Journal of experiments carried out at the Station which demonstrated this. They are in the nature of preliminary reports, because the experiments have not yet been completed to final ratoons, but they have in several cases demonstrated a response to nitrogen, in all the common inorganic forms of nitrogen under the favourable weather conditions of the last few years wherever the nitrogenous fertiliser was not applied at time of planting. I agree with Mr. Watson that the time has arrived when it would be an advantage to summarise the findings of these recent experiments, and especially, perhaps, to include those that we hope to harvest during the coming season, and present them in a form which will be palatable, we hope, and intelligible to the average planter. These two papers that we have just considered, are of great interest to the technologist, but they are not put in the form which is most likely to appeal to the planter, and need some kind of interpretation. That, I think, is a direction in which this Association could be of considerable value to the planting side of the Industry.

Mr. COLEPEPER: I would like to reply to Mr. Lintner's remarks. In work of this nature, you have no sooner got the result of one experiment than you see a dozen other possible things you might have done and you wish you had done, but you can only, even in factorial experiments, investigate a limited range in any one time, and an experiment of this nature really is more or less exploratory at the start, and it is from information obtained in this way that you continue investigations. Mr. Lintner also asks whether we cannot give him some idea of the profit that one gets from these applications of nitrogen. Well, in this particular instance, as he mentioned, there is no true control. You have to compare your lowest level of nitrogen with your heaviest dressing, and in this particular case we find there is a nett profit of about eight shillings an acre due to the heaviest dressing of nitrogen when comparing it with the yields from the lowest dressing. I think it is reasonable to assume that the increase would have been much higher if compared with plots which had no nitrogen at all.

Mr. WATSON: Eight shillings an acre does not represent the whole profit. In my opinion there are all sorts of lateral advantages that cannot be brought into the balance sheet. I feel that it is sometimes misleading to introduce currency into experiments at all. You must leave that to the individual for whose benefit the experiment is made to draw his own conclusions.

Dr. HEDLEY: I call upon Mr. Deenik to reply.

Mr. DEENIK: Mr. Colepeper appears to have answered the majority of the questions arising out of the discussion. I would like to elaborate, however, on a point raised by Mr. Lintner namely on the level of the K_2O chosen. My interpretation of the experiment to which he refers was that some level of this ingredient was required and that this level must be less than 150 lbs. for certain levels of phosphates and nitrogen. The adoption of multiples of 75 lbs. would only have given one level of K_2O below the 150 lbs. while multiples of 50 lbs. would give two and at the same time enable us to ascertain whether levels above 75 lbs. K_2O need be considered at the levels of nitrogen and phosphate used. It will be agreed that this object was achieved.

With regard to the omission of controls i.e., no fertiliser treatment, this was considered justified as indications that some form of complete fertiliser for this soil was required had already been obtained in a previous experiment.

The question of balance was therefore far more important, and the experiment was primarily designed for this purpose.

I want to thank everybody for their comments on this paper.

Dr. HEDLEY: I think you will agree that the paper has been well discussed. It is decidedly interesting, and year by year we are getting new points of view on this fertiliser work. I ask you to accord a very hearty vote of thanks to the three authors of this paper. *(Applause).*