RESULTS OF A FERTILISER EXPERIMENT ON SUGAR CANE

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In 1933 the Agricultural Departments of the African Explosives and Industries, Ltd., and the South African Potash Co. (Pty.), Ltd., decided to investigate the response to various fertilizer treatments on a typical wind-blown sand of marine origin under a crop of cane. The site selected for the experiment was at Umbogintwini.

The total area under the experiment is two acres, in open rolling country. The height above sea-level is 329 feet.

The geological conditions of the area are as described by Dr. Krige,[1] red sand of recent origin, and the soil is sandy. The depth of the water table is at least 20 inches. The area is not drained, but there is no danger of flooding. It is not possible to irrigate this area.

Prior to laying down the experiment the soil had been for two years under a volunteer crop of grass, which was finally burnt off. The area was ploughed twice, harrowed and ridged preparatory to planting the experiment.

The weeds which occur most commonly in this area are *Panicum maximum, Digitaria horizontalis, Bidens pilosa, Gnaphalium purpureum.*

On October 10th, 1933, five pits, 3 feet wide, 4 feet long and 4 feet deep, were dug at random over the experimental area.

An examination of the horizons yielded the following information:—

A_0.—Burnt off.

A_1.—11 inches to 14 inches—light brown, fairly fine sand.

A_2.—11 inches or 14 inches to 29 inches or 44 inches—a very light brown, tending to whitish grey sand, resting on reddish layers ¾ inch to 1¼ inches thick, 3½ to 5 inches apart. The reddish layers contain a fair proportion of clay. This horizon appears to be fairly strongly podsolised.

B.—44 inches to greater depths is composed of hard-packed sandy clay, red in colour. This forms a hard pan, which it is difficult to chip with a good sharp steel spade.

The depth of the surface soil is 16 inches. There is a total absence of stones, and the region of main root development is from ¼ inch to 16 inches down.

Three composite samples, taken from horizons A_1, A_2 and B, were sent over to the Agricultural Department Research Station of the German Potash Syndicate in Lichtefelde, for anlaysis by the Vageler Alten method.[2]

The analytical data obtained was as follows:—

(a) Capillary Rise.

Soil sample.	After 5 hours.	After 25 hours.	Final height
A_1	177 mm.	210 mm.	220 mm.
A_2	305 mm.	390 mm.	420 mm.
B	275 mm.	340 mm.	364 mm.

(b) Critical Layer.

A_1	21 cm.
A_2	41 cm.
B	35 cm.

(c) Moisture Equivalent.

A_1	13.1%
A_2	9.5%
B	13.6%

(d) Freedom of Water Movement.

A_1	40
A_2	93
B	81

(e) Chemical Analysis.

Soil Sample.	pH.		% C.	% N.	C/N.	Total P_2O_5.	Composition of Soluble Salts in milli. equivalents.			
	H_2O	KCl.					Na.	K.	Mg/2.	Ca/2.
A_1	6.0	5.0	1.1	0.08	14	0.018	0.1	0.05	0.09	0.16
A_2	5.2	4.3	0.7	0.03	23	0.010	Trace	0.02	Trace	0.07
B	4.7	4.0	0.7	0.04	18	0.015	Trace	0.03	Trace	0.08

Chemical Analysis—Continued.

Soil sample.	Composition of Colloidal complex with respect to basorbed bases in milli. equivalents (determined with n/10 KCl.).								V %.	Total bases in soil solution and complex per 100 gms. soil in milli. equivalents.			
	H.	$Al/_3$.	Na.	K.	$Mg/_2$	$Ca/_2$.	S.	T.		Na.	K.	$Mg/_2$.	$Ca/_2$.
A_1 ..	1.68	0.00	0.1	0.15	0.58	2.05	2.88	4.56	63	0.2	0.20	0.67	2.21
A_2 ..	1.06	0.20	0.1	0.08	0.30	0.46	0.94	2.20	43	0.1	0.10	0.30	0.53
B ..	1.29	0.67	0.1	0.09	0.40	0.71	1.30	3.26	40	0.1	0.12	0.40	0.79

Available K in pound equivalents per acre.

Soil sample.	From the Soil.	From the Colloidal complex.	Total/layer.	Total.
A_1	1.8	1.1	2.9	7.7
A_2	1.7	3.1	4.8	

Equal to 360 pounds K_2O per acre

when the soil layer of Horizon A_1 is 30 cm. and that of Horizon A_2 is 70 cm. thick. Weight dry in t/cm. = 120.

The analysts' comments which follow are of great interest, and certainly speak very highly for the accuracy of their method and also demonstrate the value of careful sampling :—

"The soil of the three samples A_1, A_2 and B is of a light sandy type with good physical properties. The water movement, which is of the greatest importance for base exchange in the soil, is good.

"The reaction of the A_1 horizon is slightly acid. With greater depth the acidity becomes more and more pronounced, as is shown by the analytical figures, and this both owing to the diminishing content of bases (S) and the increasing content of free aluminium. It is felt that fertilizers will have due effect on this soil type.

"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 fertilizers 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 75lbs. of K_2O per acre will prove beneficial under normal climatic conditions."

The average climatic conditions are :—

Average temperature..	67.2° F.
Average minimum temperature	55.3° F.
Average maximum temperature	79.1° F.

The average annual rainfall is 42.24 inches, with the following average monthly distribution :—

January	4.54 inches
February	5.11 ,,
March..	6.88 ,,
April	2.38 ,,
May	1.66 ,,
June	1.10 ,,
July	1.51 ,,
August	1.62 ,,
September	2.57 ,,
October	5.41 ,,
November	4.15 ,,
December	5.31 ,,
Average	42.24 inches

The climatic conditions during the period of growth, December 7th, 1933, to September 9th, 1935, were as follows[3] :—

Total rainfall over the whole period 97.85 inches. The total evaporation from a free water surface 78.33 inches over the whole period, with a daily average of 0.122 inch. The monthly average for maximum temperature was 76.16° F. and minimum temperature 60.24° F. The average monthly reading of the dry and wet bulbs was 69.28 and 63.50 respectively.

The precipitation was distributed as follows :—

1933.		1934.		1935.	
December	7.41	January	10.06	January	6.31
		February	3.80	February	5.74
		March	3.72	March	3.75
		April	6.60	April	1.97
		May	1.94	May	6.60
		June	0.66	June	15.38
		July	5.57	July	1.58
		August	1.30	August	3.46
		September	1.05	September	0.06
		October	1.32		
		November	2.97		
		December	6.60		

The average monthly evaporation from a free water surface was distributed as follows :—

1933. Daily average evaporation.		1933. Monthly total evaporation.	
December	0.16	December	1.12
1934.		**1934.**	
January	0.14	January	4.46
February	0.18	February	5.17
March	0.12	March	3.90
April	0.09	April	2.81
May	0.08	May	2.66
June	0.06	June	2.02
July	0.06	July	1.87
August	0.08	August	2.65
September	0.14	September	4.20
October	0.165	October	5.11
November	0.156	November	4.70
December	0.192	December	5.95
1935.		**1935.**	
January	0.215	January	6.66
February	0.18	February	5.12
March	0.146	March	4.54
April	0.128	April	3.85
May	0.07	May	2.71
June	0.07	June	2.09
July	0.08	July	2.51
August	0.10	August	3.06
September	0.13	September	1.17

The monthly averages of the dry and wet bulbs read as follows :—

		Dry.	Wet.
1933.	December	74.3	69.3
1934.	January	77.0	70.8
	February	75.2	69.3
	March	74.5	69.7
	April	72.9	68.5
	May	68.0	63.0
	June	63.4	57.9
	July	60.5	54.4
	August	65.4	60.6
	September	68.7	61.5
	October	70.5	63.8
	November	72.2	66.9
	December	75.5	69.4
1935.	January	75.0	68.7
	February	73.7	67.6
	March	72.0	66.5
	April	70.9	65.6
	May	64.7	59.7
	June	60.8	54.2
	July	61.3	55.1
	August	60.3	54.7
	September	67.45	60.9

Three varieties of cane were selected for this test, Uba, Co.290 and P.O.J.2725.

The cane was planted on December 7th, 1933, single and continuous in the rows for all three varieties, and cut into pieces with three to four buds. All three varieties were planted in rows 5 feet apart.

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

Formulæ.	Treatment.	N.	P_2O_5.	K_2O
O	No fertilizer	—	—	—
P	600lb. super 20%	—	120 w.s.	—
PK	600lb. super 20%	—	120 w.s.	—
	125lb. mur. potash 60%	—	—	75
NPK	600lb. super 20%	—	120 w.s.	—
	125lb. mur. potash 60%	—	—	75
	200lb. amm. sulphate 21.1%	42.2	—	—
N_2PK	600lb. super 20%	—	120 w.s.	—
	125lb. mur. potash 60%	—	—	75
	400lb. amm. sulphate 21.1%	84.4	—	—
NPK_2	600lb. super 20%	—	120 w.s.	—
	250lb. mur. potash 60%	—	—	150
	200lb. amm. sulphate 21.1%	42.2	—	—

It will be noticed that mineral fertilizers only were used.

The dimensions of each plot are 1-32 of an acre, with nine replications of each treatment.

Diseases and pests prevalent during the growth period were streak (the accurate percentage not determined), which was not very severe in the Uba and not noticed at all on the Co.290 or P.O.J.2725. Borers did a little damage, but this was negligible. The whole area missed to all intents and purposes any damage from locusts.

Right from the commencement the Uba appeared inferior to either the Co.290 or P.O.J.2725. The Co.290 grew particularly well and, judging by appearances in the early stages, gave the impression of superiority over the P.O.J.2725. Later on, however, the P.O.J. grew wonderfully well, and even observation in the field left no doubt but that this variety would ultimately lead the way as far as yields were concerned.

Although at about nine months' old the Co.290 appeared to afford, here and there, a slight indication of the trend of effects produced by the different fertilizer dressings, the other two, Uba and P.O.J.2725, never afforded any inclining whatsoever as to what to anticipate. Later on, and right up to the time the crop was harvested, this also applied to the Co.290.

The experiment was harvested on September 9th, 1935, and representative samples of cane were despatched to the South African Sugar Association Experiment Station, Mount Edgecombe, for analysis.

The effects obtained from the fertilizer dressings were as follows :—

	O.	P.	PK.	NPK.	N_2PK.	NPK$_2$.
Tons cane per acre..	48.98	53.47	59.31	56.61	56.06	58.06
Increase or decrease over controls	—	4.49	10.33	7.63	7.08	9.08
% increase or decrease over controls.. ..	—	9.67	21.12	15.58	14.45	18.54
Tons sucrose per acre	6.48	6.90	7.51	7.24	7.34	7.47
Increase or decrease over controls ..	—	0.42	1.03	0.76	0.86	0.99
% increase or decrease over controls ..	—	6.42	15.85	11.61	13.27	15.16
Sucrose % cane	12.99	12.69	12.46	12.59	12.92	12.72
Fahey bonus or penalty for purity (weighted)	0.13	0.07	0.06	0.05	0.03	0.05
Corrected sucrose % cane	13.12	12.76	12.52	12.64	12.95	12.77
Tons corrected sucrose per acre	6.56	6.94	7.55	7.27	7.37	7.49
Increase or decrease over controls ..	—	0.38	0.99	0.71	0.81	0.93
% increase or decrease over controls ..	—	5.73	15.03	10.68	12.12	14.19
Juice: Brix	18.7	18.4	17.9	18.2	18.3	18.3
Java Ratio	79.43	79.76	79.96	79.63	79.86	79.63
Purity	87.8	86.9	86.8	87.1	86.5	87.8
Reducing sugar ratio	0.71	0.72	0.64	0.70	0.74	0.71
Fibre % cane	12.64	12.41	12.59	12.49	12.50	12.61
Value (total) of sucrose per acre at £4.59689 per ton	£30 3 8	£31 17 11	£34 14 4	£33 18 1	£33 17 4	£34 9 4
Value of increase or decrease over controls..	—	£1 14 3	£4 10 8	£3 4 5	£3 13 8	£4 5 8
Cost of fertilizer treatment	—	£0 19 0	£1 10 10	£2 7 0	£3 3 2	£2 18 11
Nett gain over controls	—	£0 15 3	£2 19 10	£0 17 5	£0 11 6	£1 6 9
Standard error in tons between treatments at 19 : 1 odds	0.68	0.68	0.68	0.68	0.68	0.68
% standard error between treatments ..	9.42	9.42	9.42	9.42	9.42	9.42
Value of standard error between treatments	£3 2 6	£3 2 6	£3 2 6	£3 2 6	£3 2 6	£3 2 6
General mean in tons sucrose	7.22	7.22	7.22	7.22	7.22	7.22
% of yield in tons sucrose on general mean of corrected sucrose per acre	91.00	96.17	104.67	100.72	102.11	103.92

	Uba.	**Co. 290.**	**P.O.J. 2725.**
Significant difference in tons between varieties	0.68	0.68	0.68
% significant difference between varieties..	9.42	9.42	9.42
Value of significant difference between varieties	£3 2 6	£3 2 6	£3 2 6
% of varieties over general mean	72.34	103.26	133.74
Average tons sucrose per acre	4.54	7.45	9.65
Increase or decrease over Uba	—	2.91	5.11
% increase or decrease over Uba	—	64.11	112.55
Value of average tons sucrose per acre at £4.59689 per ton	£20 17 5	£34 5 0	£44 7 3
Value of increase or decrease over Uba ..	—	£13 7 7	£23 9 10

The details of the yields in tons of cane and tons sucrose per acre and analyses of the juice are as follows for the three varieties :—

Variety.	Treatment.	Tons Cane per acre.	Tons Sucrose per acre.	Corrected Brix.	Purity.	Sucrose % Cane.	Fibre % Cane.	Reducing Sugar Ratio.	Laboratory Mill Extraction.	Java Ratio.	Mg. per 100 ml.		Cl.
											P_2O_5 content.	K_2O content.	
Uba	O	28.70	3.42	17.7	85.9	12.03	12.31	0.87	70.1	79.1	32.0	311.0	177.5
	P	40.46	4.61	16.9	85.4	11.43	12.30	0.76	70.7	79.4	32.0	217.5	174.0
	PK	43.66	4.87	16.6	85.1	11.21	12.39	0.71	70.1	79.4	28.0	419.1	205.9
	NPK	41.19	4.72	17.1	85.8	11.46	12.61	0.68	69.9	78.1	36.0	366.0	166.8
	N_2PK	35.17	4.28	17.1	84.9	11.41	12.47	0.63	71.2	78.7	34.4	408.4	213.0
	NPK_2	43.15	5.03	17.2	86.1	11.74	12.64	0.55	68.6	79.5	36.0	408.4	213.0
Co. 290 ..	O	54.32	7.17	18.9	87.1	13.30	13.30	0.50	72.3	79.0	32.0	357.1	227.2
	P	53.57	6.72	18.5	86.0	12.59	12.78	0.44	71.8	79.2	28.0	367.7	227.2
	PK	62.77	7.79	18.1	85.6	12.44	13.21	0.43	71.8	80.2	24.0	454.8	262.7
	NPK	56.91	7.23	18.6	85.9	12.71	12.93	0.42	72.1	79.0	22.4	490.5	291.1
	N_2PK	59.97	7.60	18.6	85.9	12.68	13.07	0.52	72.7	79.2	18.4	425.0	195.2
	NPK_2	63.35	8.19	18.9	87.5	12.92	12.87	0.52	72.2	78.4	20.0	369.3	213.0
P.O.J. 2725	O	63.91	9.10	19.5	90.4	14.11	12.31	0.77	74.7	80.2	20.0	294.6	120.7
	P	66.38	9.48	19.8	89.4	14.28	12.16	0.96	73.9	80.7	16.0	294.6	134.9
	PK	71.49	9.98	19.2	89.9	13.85	12.17	0.78	75.1	80.3	16.0	278.9	198.8
	NPK	71.73	9.84	18.8	88.7	13.68	11.95	1.01	73.5	81.8	18.4	391.8	223.6
	N_2PK	73.03	10.21	19.1	88.9	13.90	11.96	1.07	74.3	81.7	19.2	403.0	142.0
	NPK_2	67.67	9.26	18.8	89.7	13.67	12.31	1.06	73.1	81.0	18.4	390.0	159.7

DISCUSSION.

Regarding the soil analysis, it is important to point out that, as a general rule, such an examination of a soil is of great value as an indication and control, but unless interpreted with the utmost care and attention may often become misleading if the results are applied too liberally to field methods.

To quote from a paper by Dr. F. Alten[4] concerning the method employed at the Lichterfelde Research Station for soil analysis :—

> "We believe we have found a means of following with quantitative accuracy the processes of solution and base exchange taking place in the soil, which are of vital importance to plant life. We are, however, fully aware that attempts at the quantitative application of the analytical results to field conditions may lead to failure on account of lack of care in taking the soil samples. Nevertheless, it may be said that, provided the soil samples are taken properly and the laboratory work done carefully, the relationships between soil and plant deduced from the analytical results approximate at least very closely to those actually obtaining under field conditions. Although further investigations may lead to improvements in the laboratory technique of these methods, they cannot affect to any great extent the principles involved, which are based without reserve on the laws of physical chemistry."

To obtain a good idea of the amounts of plant food a soil is capable of supplying to a crop, it becomes essential to examine the soil from diverse angles.

Cane draws its supply of nutrients from[5] :—

(1) the soil solution,
(2) the colloidal complex,
(3) the soil minerals,

and it depends on the following factors :—

(*a*) Depth of penetration through the soil layers by the root systems.
(*b*) Available water supply.
(*c*) Freedom of water movement in the soil.

In the table giving the results of the soil analysis there are several figures indicating the capillary rise. The manner by which the final figure has been obtained is as follows, according to Dr. F. Alten's figures[6] :—

$$y = \frac{x \times E}{x + q \times E}$$

where
y = height of rise in millimetres,
x = number of hours after which readings are taken,
E = final height of rise in millimetres,
q = time modulus.

When the reciprocal values

$$y = \frac{1000}{b}, \quad x = \frac{1000}{a}, \quad E = \frac{1000}{k}$$

are used,

$$\frac{1000}{b} = \frac{\frac{1000}{a} \times \frac{1000}{k}}{\frac{1000}{a} + 1 \times \frac{1000}{k}}$$

$$b = k + q \times a.$$

Taking x_1 and x_2 as the number of hours after which the readings are taken, and y_1 and y_2 as the height of the water column in millimetres after x_1 and x_2 hours respectively, the values for k and q are obtained by inserting the following values in the above equation :—

$$a_1 = \frac{1000}{x_1}; \quad a_2 = \frac{1000}{x_2};$$

$$b_1 = \frac{1000}{y_1}; \quad b_2 = \frac{1000}{y_2}.$$

When the ratio between the number of hours after which readings are taken is 1/5, the following relationships hold good :—

$$k = \frac{5b_2 - b_1}{4}.$$

$$q = \frac{b_1 - k}{a_1} = \frac{b_2 - 1}{a_2}.$$

In view of the fact that the water necessary for transpiration must move towards the plant roots at a certain minimum speed in order that the plant does not wilt, the available water content of a soil layer of sufficient thickness to permit a film of water 0.1mm. thick to pass through in one hour may be taken as standard.

As the minimum pore space amounts at the most to 50 per cent. of the apparent volume of the soil, the transportation of a layer of water 0.1 mm. thick will mean the infiltration of a layer of actual soil 0.2 mm. thick, i.e. that the water will rise in a column of the soil in question at a speed of 0.2 mm. per hour.

The thickness of the soil layer through which the water passes at the rate of 0.2 mm. per hour is termed the "critical layer," and the thickness of the "critical layer" is calculated from the height of rise of the water and its time modulus. The following example is based on a speed of water movement of 0.2 mm. per hour :—

"Critical layer" $= E \times (1 - 0.447 \times \sqrt{q})$,
or if E = 124 mm. and q = 0.089
the "critical layer" $= 124\ (1 - 0.447 \times \sqrt{0.089})$
$= 10.8$ cm.

Concerning the "Freedom of Water movement" the amount of water actually available to the plant may be taken as being at its best equal to that supplied by double the critical layer. Further, under the heading "Composition of colloidal complex with respect to absorbed bases in milliequivalents (determined with n/10 HCl) occur the sub-headings H, S, T, V.

H = hydrogen ions.
S = sum of basic ions in colloidal complex in milli-equivalents.
T = total absorbed ions (S + H + Al/3).
$V = \frac{S}{T} \times 100$, which is Hissink's degree of saturation.

In connection with the responses obtained from the different fertilizer dressings, the most striking phenomenon at first glance is the apparent lack of response to an application of 120lbs. P_2O_5 per acre. In looking for an explanation one must consider the possible fixation of large amounts of the phosphate applied. At the seventh annual meeting of this Association, some experiments carried out by Mr. Williams[7] at Cedara concerning the reversion of soluble phosphates to insoluble form in a doloritic soil were mentioned.

One may consider two possible causes for lack of response to a dressing of soluble phosphate :—

1. Chemical unavailability.
2. Positional unavailability.

In the first instance it must be remembered that the fixation of phosphate in the soil depends on the amounts of various soil minerals present which are capable of fixing phosphorus. According to Floyd Heck[8]: "If the ratio of active calcium to active iron and aluminium is high, the fixation will be largely in the calcium form, and the fixed phosphorus will be readily available. If the reverse is true, the fixation will be largely as the iron and aluminium compounds of phosphorus, which are difficultly available."

Under some conditions soluble phosphate in the form of superphosphate does not penetrate into the soil more than a few inches over a number of years (Lindsey A. Brown[9]). According to P. L. Hibbard[10]: "It appears that solubility of PO_4 increases in the order Ca, Mg, K, Na, NH_4. With Ca ion, solubility of PO_4 is one-quarter of that in pure water, whereas with Na and NH_4 it is about the same as with water only. . . . $CaCO_3$ is more depressing than $MgCO_3$, but both greatly reduce solubility of PO_4. When NH_4 is added PO_4 becomes more soluble, even in the presence of $CaCO_3$ or $MgCO_3$. The NH_4 ion generally increases the solubility of PO_4. . . . When Na and K are added with NH_4, the solubility of PO_4 is still more increased."

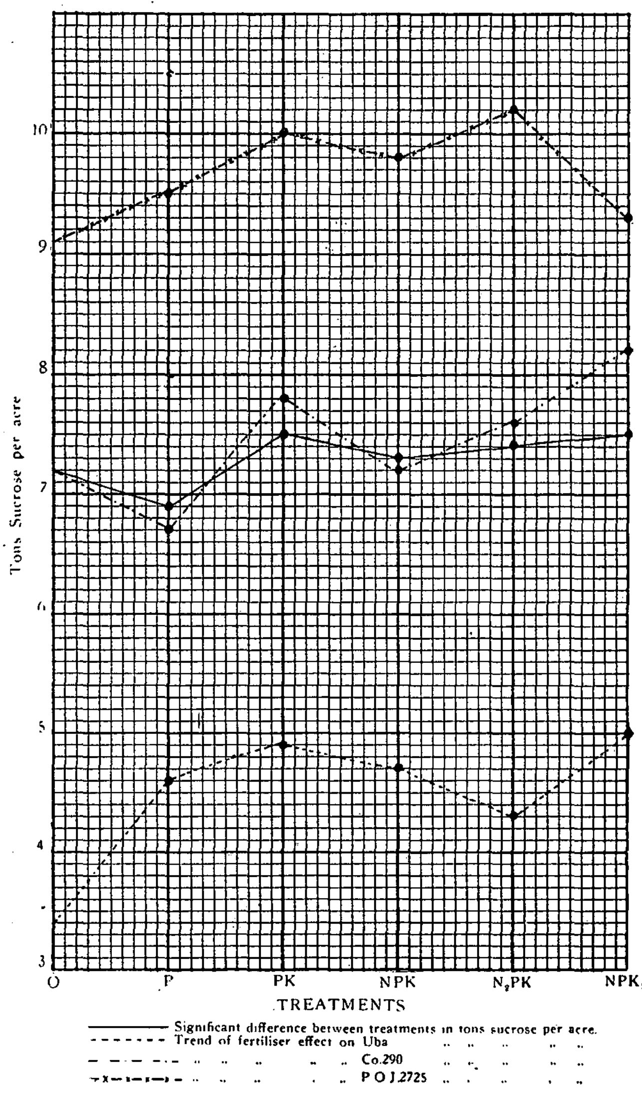
The pH of the soil is an important factor in connection with the solubility of soil phosphates. With low pH values, it appears that soluble phosphates will become difficultly available in the form of aluminium phosphate. This state of affairs may possibly apply to the soil in this experiment.

Secondly, the placement of the fertilizer in regions within easy reach of the root system is of great importance. "A positionally unavailable nutrient is one that is not within reach of the root system itself" (V. E. Spencer and Robert Stewart[11]). The difficulty which arises in this connection is the practical method of applying fertilizer to ensure its being placed in optimum approximity of the feeding roots. In this experiment the fertilizer was distributed along the bottom of the furrows and slightly mixed with soil just before planting the cane.

The use of all the combinations of fertilizer gave significant increases of yield with the exception of superphosphate alone. The highest yield obtained, and the one which brought the highest return, was a combination of superphosphate and muriate of potash, with a nett profit due to the application of £2 19s. 4d. per acre.

It is interesting to note that potash at the rate of 125lbs. muriate of potash or 75lbs. pure potash was the most economical amount. The quantities of potash per acre used were somewhat higher than it is the general custom to use on the sugar belt of Natal, but the significant economical response is adequate to prove the necessity of such an application on this soil type.

Neither the light nor heavy dressing of ammonium sulphate proved to be economical, although both gave a significant increase in yield over the control, although neither dressing increased the yield over the PK dressing. In this respect the application of ammonium sulphate appears to have had a depressing effect. It is a pity that organic nitrogen was not included in this trial, especially in view of the comments made by the analysts. A separate experiment is now being carried



out on a similar soil type, where an attempt is being made to investigate the effect of nitrogen in an organic form as against that supplied in inorganic form and both together.

Taking the varieties of cane separately, Co. 290 showed the greatest response to potash, and also in the PK and NPK series the greatest concentration of this ingredient in the juice.

The fertilizer treatments appear to have influenced in some measure the uptake of P_2O_5 and K_2O, the latter to greater degree than the former unfortunately; however, the figures are too erratic to draw any definite conclusions.

The trend of effects of the different fertilizer dressings on the individual yields is of some interest, because there appears to be some indication of a necessary NK ratio.

The graph illustrates that in the significant differences between treatments. 42.2lbs. per acre of nitrogen in the form of ammonium sulphate depressed the yield compared with that obtained from 120lbs. P_2O_5 from superphosphate and 75lbs. K_2O from muriate of potash. When the nitrogen was augmented to 84.4lbs. per acre, there was a rise in yield, but still not equal to PK. When 150lbs. of K_2O was applied together with the single dressing of nitrogen (42.2lbs.) and 120lbs. P_2O_5, the yield was equal to that obtained by using the PK dressing.

The Co.290 followed the same trend, and the NPK_2 or single dressing of nitrogen with phosphate and a double dressing of potash gave 0.4 tons of sucrose per acre more than the next highest, PK. On Uba both N and N_2 depressed the yield, but in this case also the double dressing of potash appears to have overcome the depressing effect of the nitrogen. On P.O.J.2725 one has the exception where N, the single dressing of nitrogen, depressed the yield, the double dressing of nitrogen and single dressing of potash gave the highest yield. When the double dressing of potash was used with the single dressing of nitrogen and superphosphate there is a depression of yield.

These latter remarks, and the curves representing them, are not based on "significance." The significant figures as shown by the curve, as well as all the others, are definitely in favour of the PK dressing, N having no real effect one way or the other. Although the NPK_2 dressing raised the yield to the level of that obtained by using the PK, it was in comparison of costs not economical.

SUMMARY.

An explanation is given of figures obtained for capillary rise, also for the critical layer according to a paper by Dr. F. Alten.

Significance between treatments was obtained for all the fertilizer dressings at 19 : 1, with the exception of superphosphate when used alone.

Possible reasons for lack of response to superphosphate applied alone are discussed.

Potash at the rate of 75lbs. K_2O per acre applied in the form of potassium chloride, used in conjunction with superphosphate, had very beneficial effects, and this dressing gave the highest yield of tons sucrose per acre, showing a profit due to the application of this mixture of £2 19s. 10d. per acre. Potash applied at the rate of 150lbs. K_2O per acre, in conjunction with 120lbs. P_2O_5, and 42.2lbs. of N, raised the yield to the same level as that obtained by using 120lbs. P_2O_5 per acre and 75lbs. K_2O per acre; this, however, was not economical.

Nitrogen applied in the form of ammonium sulphate at the rate of 42.2lbs. per acre, had a somewhat depressing effect, whilst 84.4lbs. of nitrogen from the same source tended to improve matters slightly but not economically.

The tendency of the effects of the fertilizers on the varieties, Uba, Co.290 and P.O.J.2725, used in this experiment is touched on. It is suggested, judging from these tendencies, that there appears to exist an NK ratio. Both Co.290 and P.O.J.2725 gave considerably superior yields of sucrose in tons per acre over Uba. P.O.J.2725 gave the highest yields and was superior to Uba by 112.55 per cent.

Thanks are due to the Agricultural Staff of African Explosives and Industries, to the Staff of the Mount Edgecombe Experiment Station, and to the Staff of the Research Station, Lichterfelde, for the valuable assistance afforded which enabled this paper to be compiled.

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The CHAIRMAN: Both Mr. Lintner's very interesting paper and Mr. Fowlie's seem to me to express a challenge to anyone connected with the practical side of sugar cane agriculture, in that they both show that there is quite a lot still to be found out about fertiliser and sugar cane. Mr. Fowlie summarises his fertiliser trials by saying that there is urgent need for further experimentation, and that his fertiliser trials at Umfolozi have given results hitherto which are not significant.

In this paper on the Umbogintwini experiment, we find very interesting features, one being the indication of response to potash. In that connection I think it is of interest to mention here some values that we have recently got at Tongaat from the citric soluble analysis of certain soils. We selected a field of sandy wind-blown beach soil, which has a past history of fertilisation with filter press cake, and we took a series of samples—actually 50 samples from a 75-acre field—for citric soluble analysis of these samples in our laboratory. Actually this field had had some samples taken from it some ten to eleven years ago. Those old analyses were available for comparison. The feature which is of interest on this point, is that we find potash over that period, and the potash values are now all extremely low, in fact by the Spurway Rapid Kit test method, which we also applied, it was extremely hard to get any indication of potash at all. On the other hand, the fertilisation history of that particular block seems to have built up the available P_2O_5, and we found that the P_2O_5 values were all on the high side.

Another interesting point that I would like to draw attention to in this paper is the indication of differential appetite on the part of cane varieties for different plant food requirements. It is shown to you here that Co. 290 responds to a greater extent to potash than either Uba or P.O.J. 2725. That, I think, calls for quite a lot of thought, because the Industry is extending on the lines of planting up varieties, and if each variety is to have special fertiliser treatment, then you will have to study that question.

In connection with the failure to get any response from nitrogen, I should like to ask whether there is any indication that response from nitrogen could be obtained by spliting up the treatment into small doses and giving nitrogen at periods throughout the growing period of the field.

The paper is open for discussion.

Referring to the possibility of obtaining a response to nitrogen by splitting the total amount up and applying it in several small applications the following figures from an experiment on Uba planted in a heavy red clay may be of some interest:

Section "A".

	Treatment per acre. (Approx. Sept. 1932, 3 weeks before planting.)	Average yield in tons cane per acre.
O	No fertiliser ...	40.8
P	400lb. Super 17.1% w.s. ...	45.4
NP	400lb. Super 17.1% w.s. ... 125lb. Sul. Ammonia ...	45.4
NPK	400lb. Super 17.1% w.s. ... 125lb. Sul. Ammonia 21.1% ... 225lb. Sul. Potash 48.5% ...	49.3
NPK_2	400lb. Super 17.1% w.s. ... 125lb. Sul. Ammonia 21.1% ... 450lb. Sul. Potash 48.5% ...	53.7
N_2PK_2	400lb. Super 17.1% w.s. ... 250lb. Sul. Ammonia 21.1% ... 450lb. Sul. Potash 48.5% ...	53.4

Section "B".

	Treatment.	September, 1932 (3 weeks before planting).	January, 1933.	April, 1933.	Total per acre.	Average tons Cane per acre.
O	No fertiliser ...	—	—	—	—	34.9
P	Super ...	200.0lb.	100.0lb.	100.0lb.	400.0lb.	44.6
NP	Super ... Sul. Amm. ...	200.0lb. 62.5lb.	100.0lb. 31.25lb.	100.0lb. 31.25lb.	400.0lb. 125.0lb.	39.8
NPK	Super ... Sul. Amm. ... Sul. Pot. ...	200.0lb. 62.5lb. 112.5lb.	100.0lb. 31.25lb. 56.25lb.	100.0lb. 31.25lb. 56.25lb.	400.0lb. 125.0lb. 225.0lb.	43.6
NPK_2	Super ... Sul. Amm. ... Sul. Pot. ...	200.0lb. 62.5lb. 225.0lb.	100.0lb. 31.25lb. 112.5lb.	100.0lb. 31.25lb. 112.5lb.	400.0lb. 125.0lb. 450.0lb.	46.5
N_2PK_2	Super ... Sul. Amm. ... Sul. Pot. ...	200.0lb. 125.0lb. 225.0lb.	100.0lb. 62.5lb. 112.5lb.	100.0lb. 62.5lb. 112.5lb.	400.0lb. 250.0lb. 450.0lb.	41.1

Section "C".

Treatment.		September, 1932 (3 weeks before planting).	January, 1933.	April, 1933.	August, 1933.	Total per acre.	Average cane per per acre.
O	No fertiliser ...	—	—	—	—	—	21.5
P	Super	250.0lb.	150lb.	100.0lb.	—	500.0lb.	33.6
NP	Super	250.0lb.	150.0lb.	100.0lb.	—	500.0lb.	37.5
	Sul. Amm. ...	62.5lb.	—	—	—	62.5lb.	
	Nit. Soda... ...	—	40.0lb.	40.0lb.	—	80.0lb.	
NPK	Super	250.0lb.	150.0lb.	100.0lb.	—	500.0lb.	45.3
	Sul. Amm. ...	62.5lb.	—	—	—	62.5lb.	
	Nit. Soda... ...	—	40.0lb.	40.0lb.	—	80.0lb.	
	Sul. Pot.	112.5lb.	168.5lb.	168.5lb.	—	450.0lb.	
NPK_2	Super	250.0lb.	150.0lb.	100.0lb.	—	500.9lb.	50.2
	Sul. Amm. ...	62.5lb.	—	—	—	62.5lb.	
	Nit. Soda... ...	—	40.0lb.	40.0lb.	—	80.0lb.	
	Sul. Pot.	225.0lb.	191.7lb.	191.7lb.	191.7lb.	800.0lb.	
N_2PK_2	Super	250.0lb.	150.0lb.	100.0lb.	—	500.0lb.	46.4
	Sul. Amm. ...	125.0lb.	—	—	—	125.0lb.	
	Nit. Soda... ...	—	80.0lb.	80.0lb.	—	160.0lb.	
	Sul. Pot.	225.0lb.	191.7lb.	191.7lb.	191.7lb.	800.0lb.	

It will be noticed that ammonium sulphate had rather a depressing effect more than anything else when applied either as a single dressing before planting-or in small application at intervals. The first initial application in the form of ammonium sulphate and the balance in two top dressings of sodium nitrate had a beneficial effect on the yield.

Mr. CUTLER: With regard to the determination of the critical layer of Vagelar and Alten we in the Division of Chemical Services in Pretoria have done a little work on it; we have examined quite a few samples by this method. We liked the method of displacement and in a series of about eight to ten soils the determination of the critical layer fitted in very well, but later, in further investigation some snags were encountered and the values did not fit in as well as could be desired.

Apart from the validity of the critical layer and of the Q value there is to us a good deal of interest in the figures. We found that the values from the Neubauer-Schneider germinating plant method. and the figures given by Vageler and Altens' method have in general a relationship to each other and it seems to me that it is possible to get the Q values by means of electro-dialysis or electro-filtration. This opens up a very interesting sphere of work.

Although the method of reasoning is a very pretty one and the argument nicely evolved, snags do crop up in some soils.

I may say that Vageler published a book (Der Kationen und Wasser-haushalt des Mineralbodens) dealing with the ions and the moisture relationships of the soil complex and it is a very nice piece of reasoning indeed.

Mr. LINTNER: Might I ask you what were the reasons for the non-success of this method? Could you enlarge on them?

Mr. CUTLER: We seem to meet difficulties where we got excess of one ion against the others—in Ca or Mg rich soil. Where you have a nicely balanced soil, just about saturated or near saturation the results are quite good. In the case of low saturation, over saturation or excess of one element the results do not seem so satisfactory.

Mr. LINTNER: I should like to ask whether you experience any difficulty with your Neubauer tests.

Mr. CUTLER: I might say quite frankly—we have run about 1,100—I rather like the method. I found that it did work well. One has to be very careful not to vary at all from the prescribed method —it is not possible to deviate at all from the instructions by Neubauer. That to my mind seems to be the cause of much of the difficulty that has been encountered before as far as I can see. I have gone through most of the papers on the subject—I think about 500 to 600—and I came to the conclusion after my own work and criticism of the papers that the method is good, but one must stick to the line of treatment prescribed; one cannot vary.

Mr. LINTNER: In Berlin some years ago at Lichtevelde I was told they experienced difficulty through the winter months with the Neubauer test.

Mr. CUTLER: The absorbtive power of the seed does fall somewhat over the year. We countered this by the use of soils of known value as well as blanks. As a matter of fact I turned an appropriate room into a thermostat. I put in a couple of radiators and by careful adjustment I was able to control the variation to within a degree of the normal.

Mr. LINTNER: Did you do that throughout the year?

Mr. CUTLER: I used the room for a year. It is a messy process, difficult and with a lot of little snags. These can be overcome but the truth is the results do not warrant the trouble except in special investigation. It is expensive. We found it averaged about £1/6/- per determination and compared to the cost of the critic acid determination that is very expensive.

But if a criterion of root availability is required, you have it in this method. It is well known that there is in some soils a marked diminution in the root availability of the K_2O and P_2O_5 in the subsoil and lower layers as compared with the quantities found in the citric acid method. The citric acid availability will be one thing and the true root availability another and I was able to determine by the Neubauer method quite a variation in root availability compared with depth in the profile in the case of about 20 soil profiles. Naturally it is not easy to correlate root availability by the Neubauer method with root availability in the field but I was in some cases able to explain certain results in field experiments by the reduced root availability according to the Neubauer method.

I also think the method is valuable in regard to such determinations as the root availability of the rock phosphates, the root available P and K in masure, composts, etc.

Mr. LINTNER: Is that confined to availability to cereals?

Mr. CUTLER: Yes.

Mr. LINTNER: Could you use the method with any success to determine availability for cane? The chief difficulty in work which concerns sugar cane is the choice of a suitable indicator plant.

Mr. CUTLER: You must give limits in all these determinations. You cannot just complete a determination and say this is going to be the result obtained in plot work on a strictly mathematically comparable basis. But the results within limits are probable clues to the requirements of the crop in the soil investigated if some factor be used as index to the root foraging power of the crop in question. But you cannot bind yourself down to a strictly comparable result without any leeway at all; that, of course, is the difficulty with all experiments in which the soil takes part. You take a soil sample out of a field and you make a determination on the sample. But what is the relationship between the soil sample and the soil profile it was taken from? That is the point.

Mr. DODDS: I would like to say how much I appreciate this admirable paper by Mr. Lintner. I only have one criticism to make. that is to say I wish we could have seen it in detail before, because it is rather a lot to digest during the time it is being read. That, of course, applies to nearly all the papers at the Congress, and I hope the time will come when it will be possible to circulate them some days beforehand.

The experiments in this paper are most interesting, both from the point of view of the comparison of varieties and the effect of fertiliser. A point that arises from the fertiliser results is similar to what we have always found in sandy soil. We get response to super-phosphate almost invariably, and to potash as a rule in sandy soil, but not to sulphate of ammonia, and seldom to any form of mineral nitrogen that we have tried. What the reason for that is we don't know. In this our experience is different to that of all other countries, where ammonium sulphate is the fertiliser for sugar cane in all types of soil, and even in all conditions of moisture supply, as you can tell us, Mr. Chairman, from your recent visit to Hawaii. I understood you learned that even in dry soils in those islands they have found a response to sulphate of ammonia which we do not get here. It is a question that needs a lot more study, and there is no adequate explanation yet forthcoming, as far as I can see. It is very interesting to note that the response to superphosphate appears to be significant in the case of Uba, but not apparently in the other two varieties.

Mr. LINTNER: Actually, if you take the plus and minus increase and decrease, you will note that super-phosphate has caused an increase.

Mr. DODDS: Is it significant in the case of Uba?

Mr. LINTNER: Yes.

Mr. DODDS: But not in the case of the other two varieties, and it appears that the phosphate content of the juice is greater in the Uba series than in the others?

Mr. LINTNER: Yes that is so and the NPK and NPK_2 series on the Uba section show the highest P_2O_5 concentration in the juice whereas for the other two varieties the controls show the highest concentration of this ingredient in the juice.

Mr. DODDS: There is just a possibility that the phosphate requirements of Uba will be found to be greater than that of the other varieties, a most important matter in view of the deficient phosphate conditions of our soil.

It is interesting to see the eventual response of P.O.J. 2725. We have found in other places that 2725 may make a poor start the first year and will grow very well during the second season. That is by no means always the case, however, and usually in sandy soils such as we have in this experiment, P.O.J. 2725 is not a very good variety, and it is interesting to see how well it has done here.

Mr. LINTNER: Mr. Chairman, I would like to ask you to tell the meeting what you have found regarding the fertiliser treatment of Hawaiian soils, with special regard to the practice in vogue which I understand is governed, as far as phosphate applications are concerned, by the concentration of this ingredient in the juice.

The CHAIRMAN: The point Mr. Lintner refers to is explained in a paper written by R. J. Borden, Chief Agriculturist of the Hawaiian Sugar Planters' Association Experiment Station, Honolulu, entitled "A Basic Fertiliser Plan and Schedule," in which the author lays down what he considers to be a basic plan of fertiliser quantities, from which to work up or down according to indications. He fixes the basic formula at 200 lbs. nitrogen, 200 lbs. phosphorus, as P_2O_5 and 200 lbs. potassium as K_2O and the deviations for each ingredient respectively should go up or down from those basic figures according to whatever indications are offered by field fertiliser trials, Mitscherlich pot tests, and either citric soluble or Rapid Kit Test methods of soil analysis. Borden also lays great stress on the importance of the phosphate and potash obtained from analysis of crusher juice; and, coming to Mr. Lintner's point, the basic phosphate treatment for a field which produces canes of which the crusher juice gives a P_2O_5 value of 0.01 or less is stated to be 300 lbs. P_2O_5 per acre per crop. A practical illustration is afforded by the fertiliser history of the Hutchinson Sugar Plantation on the island of Hawaii where some years ago they used phosphoric acid in the factory. The Manager, Mr. Campsey, related to me how they adopted a routine of putting large dressings of raw rock phosphate, which was cheap at the time, throughout their fields—large dressings, I forget for the moment the exact quantities, ranging right up to two tons an acre and over. And after a period of that treatment, phosphoric acid was eliminated from their factory work entirely.

Mr. FOWLIE: I would just like to refer briefly to the apparent effects of the different fertilisers on the quality of the cane. We have here, in this table of different varieties, the sucrose percentages and periods of each variety under the different treatments, and they appear to me to indicate that all the fertiliser treatments had a slightly retarding effect on the ripening of the cane. In each case the no fertiliser plots give a slightly better sucrose than any of the fertilised. And it is rather interesting to notice that the depression—I think that is the best word to use—is not visible in the case of the plots giving the highest final yield. I think this is probably due to the fact that the harvesting was done before the cane was quite fully matured. I would like to have Mr. Lintner's idea on that. That, I think, is borne out from my own idea, by the fact that sucroses and purities in these tests are rather low. They are certainly below the average of all the mills for this last crushing season.

Mr. LINTNER: The Uba and Co. 290 appear to have been mature judging from the reducing sugar ratio figures. The cane one can be dubious about, however, is the P.O.J. 2725 the maturity of which appears as though it might have been retarded somewhat by the dressings of nitrogen.

Mr. DODDS: Reducing sugar ratio is, of course, the best criterion of the maturity of the cane, and that does not indicate any great differences between the controls and the other plots. On the whole, the reducing sugar ratio is very low, and would appear to indicate that the cane was ripe, but the sucrose content is certainly low which may be the influence of that particular soil.

Mr. LINTNER: Have you noticed the reducing sugar ratios to be particularly low for Co. 290?

Mr. DODDS: The reducing sugar ratio for Co. 290, though not as low as in some varieties, P.O.J. 2725 for instance is almost always lower than in Uba; the reducing sugar ratio for all canes milled last season was only 2.6, which is the lowest we have ever had.

Dr. McMARTIN: I wonder if Mr. Lintner has any evidence that cane is one of those plants which makes use of different forms of nitrogen in different stages of growth. For instance, it has been shown that some plants, and, I think, grasses, in earlier stages they make use of nitrate nitrogen; when they get older they make use of some other forms of nitrogen, principally ammonia.

Mr. LINTNER: I am afraid I have not done any work in that direction with nitrogenous fertilisers. I have used nitrogen in different forms on pastures and cane but never for comparison.

Dr. Orchard, at Cedara, has shown that large amounts of nitrogen given in the form of ammonia on a paspalim sward are taken up in a surprisingly short space of time. I have always had an immediate apparent response on grassland to an application of ammonia sulphate but have confined the applications to spring and autumn dressings, the latter being given as a rule on the aftermath.

It appears to me that there is a great necessity for some careful work on the effect of various forms of nitrogen on cane in this country especially because we appear to obtain responses from organic nitrogen whereas often negative or depressing effects have been obtained from applications given in inorganic form.

Mr. COLEPEPER: Mr. Lintner has mentioned the apparent fixation of the super-phosphate when he applies 120 lbs. to the acre. I would like to ask were those the conditions where he put on a heavier dressing?

Mr. LINTNER: The dressing of phosphate was constant right through the experiment and I am inclined to think the pH of the soil and the free aluminium content of the soil was against availability of phosphate. It was not low enough for aluminium and iron phosphate to be available and possibly no calcium phosphate combinations were formed.

Mr. DODDS: I would like to state that at the Experiment Station, we have one field where, about ten years ago we put down a basic dressing of rock phosphate of 900 lbs. to the acre, and were rather disappointed for the first season or two at the lack of any apparent effect, either on the composition of the soil or the cane. But I must say that eventually it made its effect felt, and the yield of cane from that area is now altogether better than it was. Furthermore, we get no response now to repeated dressings of super-phosphate, and apparently that soil is no longer deficient in phosphorus.

Another point—we have recently done experiments with nitrochalk, which, as you know, contains both nitrate and ammoniacal nitrogen. I would like to know whether Mr. Lintner or anybody else here has experience of this fertiliser.

Mr. LINTNER: In the area Mr. Dodds refers to, where you applied the raw rock, were any comparative figures kept in relation to P_2O_5 in the juice?

Mr. BOOTH: I would like to ask Mr. Dodds if he recollects any other experiment being made on those lines. I certainly have a note that the content of the crusher juice of P_2O_5 does not appear to be influenced as a result of field dressings of phosphates. I think Mr. Dodds might have some definite experimental data on that; I have not.

Mr. DODDS: We have kept records of the phosphate content of the juice of the cane from all our experiments. They vary enormously, and it has been impossible up to the present to draw many positive conclusions from them. But they are on record, and we hope some day, when our records have further accumulated, that we may be able to draw some more general conclusions from them. One conclusion we find is that where phosphate fertiliser is withheld in a phosphorus deficient soil, the phosphate content of the cane juice is lower than from phosphate treated plots.

Mr. LINTNER: I would like to ask Mr. Dodds whether he noticed any greater penetration in the soil from the dressings of rock phosphate, than from dressings of super-phosphate.

Mr. DODDS: No, I don't think we have although Brown has recorded it in Pennsylvania. The soil I mentioned just now where we had applied these fairly heavy dressings of rock phosphate is a very shallow medium loam, and is underlaid by a very stiff clay. It always has been a very difficult field to work. I can only say that the surface soil appears to have been improved considerably in composition and texture, but I feel sure there can be no effect on the very refractory subsoil. Everywhere one comes across about nine inches or less of soil, and then stiff yellow clay.

The CHAIRMAN: Is there any further discussion? We have had a very interesting paper given us by Mr. Lintner, which has promoted a good deal of discussion. There has been a lot of time spent in compiling this paper, and I think you will all be very pleased to accord Mr. Lintner a vote of thanks to show your appreciation in the usual manner.