A FEW PRELIMINARY OBSERVATIONS ON A FERTILISER EXPERIMENT ON SUGAR CANE.

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INTRODUCTION.

At the Seventh Annual Congress of the S. A. Sugar Technologists' Association, held in Durban in March, 1933, a paper on the "Absorption of Plant Foods by Sugar Cane," by Dr. E. P. Hedley and B. E. Beater, was read by Dr. Hedley. The paper, which was of interest to everybody concerned with the growing of sugar cane in South Africa, was of special interest to the agronomist because it gave important indications regarding the amounts of the principal plant foods taken out of the soil by a crop of cane. Also, the figures obtained afford, to some extent, a basis for investigating the quantities of artificial fertilisers to be applied to maintain the fertility of the soil, as well as to augment the yields of cane on the sugar belt of Natal.

Plants growing under their natural conditions afford an excellent medium for studying their requirements, and therefore, by cultivating cane in suitable surroundings and treating it with various fertiliser ingredients in varying quantities, one may reasonably expect to be in a position to discover the different degrees of response to minerals applied.

The absorption of plant food by cane, with its correlation to yield and soil type, together with innumerable other complex matters all bound up in an inter-relationship of the most intricate nature, requires a great deal of further elucidation by means of carefully planned and conducted field experiments.

In addition to the effects of variation of weather conditions, plant development is influenced by the chemical and physical properties of the soil. The mineral requirements of the crop must therefore be taken into consideration together with the physical and chemical properties of the soil with particular reference to the content of available plant food, always keeping in mind, however, that in this connection soil analytical data are no very exact indication of the real state of affairs.

The reaction of the soil also presents a wide field for investigation, since it is claimed that cane gives the heaviest yields of sugar in soils approximately neutral (according to Arrhenius). In this connection too, Mr. Brioux, Director of the Agric. Research Station in Rouen, has pointed out that although knowledge of the pH value gives a very true insight into the physiological properties of the soil, it does not suffice for determining the amount of lime to be applied per acre to neutralise the acidity.

The pH gives an idea of the "force" of the free acids in the soil, but one can easily understand that two different soils, with different physical properties but the same degree of acidity in terms of pH, will not react in the same manner to identical lime treatment; for example, sandy soils poor in colloids and very clayey soils. This indicates a necessity of determining the buffer capacity. To further illustrate this point the following figures were obtained by Dr. Orchard, Chemist at Cedara, on a red soil type; ½ acre plots having received applications of agricultural lime showed that only applications of two and four tons improved the pH value at all:—

	pH	
Control	5.26	
½ ton lime	5.29	
Control	5.21	
1 ton lime	5.11	The whole area received an initial dressing of 700 lbs. lime including the controls.
Control	5.21	
2 tons lime	5.41	
Control	5.21	
4 tons lime	5.61	
Control	5.31	

On virgin veld an application of slaked lime (equivalent to two tons $CaCO_3$ per acre) only served to raise the pH value by 0.4 of a pH unit, i.e., 4.6 to 5.0.

Careful observations of the effects of different treatments are essential in order not to form any hasty opinions because the effects of certain fertilisers are not always visible to the eye in the field but may be revealed by subsequent tests in the laboratory.

When the experiment, which it is the object of this paper to discuss, was laid down, the work already referred to on the absorption of minerals by cane had not, as yet, been completed at the Experiment Station, therefore Dr. Stubb's estimates for a 40 ton crop in Louisiana, mentioned in the Cedara Memoirs, formed the point of departure for the amounts of mineral fertilisers likely to be required by cane. These figures were reduced proportionally for a 20 ton crop, then these dressings were slightly augmented to allow for the very clayey nature of the soil.

THE EXPERIMENT.

The experiment was laid down on October 3rd, 1932, at Hazara Estate, Kearsney, the property of

Capt. J. Woollam. Prior to the experiment cowpeas "Vigna sinensis" were sown in January, 1932, and turned under in June, 1932, as green manure. The fertiliser treatment given to the cowpea crop was 360 lbs. of basic slag 16.1% P_2O_5 cit. sol. and 40 lbs. Muriate of Potash 60% K_2O; the total cost was 17/- per acre.

The field in which the experiment is situated is thirty acres in extent and situated 1,550 ft. above sea level. The field is inclined towards the south, although so slightly as to be hardly noticeable, and has an open aspect.

The soil is a red clay which has been under cultivation for about 15 years or more, and prior to the planting of cane was under wattles.

Five pits 1 x 1.5 x 1.33 yds. were dug at random over the area to be covered by the experiment, for the purpose of examining the soil profile.

It may be recalled that for the purpose of profile study the soil has been divided into three categovries or horizons, A B and C.

A horizon, which consists of a mass of partially rotted organic matter, was non-existent.

A horizon, which is the layer out of which substances have been washed during the process of soil formation either by chemical or mechanical means, is called the eluvial horizon. In the soil of this experiment A. horizon is represented by 9 - 12 inches of reddish brown clay loam containing a large amount of leaf refuse and old pieces of cane and root stumps.

B horizon is the layer formed through the depositing of some substance either by chemical or mechanical means, such as concretions, crust formations or pans which are often deposits of lime or iron. This horizon extends from the 12-29 inch level and is composed of a yellowish brown clay with very little trace of organic matter especially towards the bottom.

C horizon is the level from which the overlying layers have been formed. This horizon extends from the 28 inch level right down to the 48 inch level and further as a bright brick red clay with no apparent organic matter present at all.

Subsequent examination of the roots showed the main region of distribution to extend to about 20 inches below the surface.

Samples of soil taken from each horizon of the four walls of the pits dug for the examination of the profile were submitted to the Experiment Station at Mount Edgecombe, for chemical analysis, which, done in duplicate, showed as follows:—

	A horizon. %	B horizon. %	C horizon. %
Carbon	4.363	3.362	0.641
Nitrogen	0.273	0.168	0.054
C : N ratio	16.000	20.100	11.600
Available potash K_2O ..	0.012	0.009	0.005
Available phosphate P_2O_5	0.002	0.001	0.0002
Total potash K_2O	0.090	0.063	0.055
Total phosphate P_2O_5 ..	0.082	0.052	0.059
Loss on ignition	19.840	18.790	14.530
Hygroscopic moisture ..	6.610	6.310	4.310
Hydrogen ion concentration (pH)	4.750	4.640	5.270
Nitrate nitrogen (parts per million)	1.640	2.410	2.340
Silica (SiO_2)	39.150	36.800	40.260
Iron (Fe_2O_3)	14.200	15.800	16.920
Calcium (CaO)	0.350	0.275	0.251
Magnesia (MgO)	0.121	0.060	0.069
Alumina, etc. (Al_2O_3, TiO_2, Mn_3O_4)	26.930	27.090	28.640

Further samples of soil from each horizon were sent to the Pretoria University where Bacterial Counts were carried out, with the following results:—

No Azotobacter (by Crumb method) were found to be present in any of the samples.

Bacterial numbers were:—

A horizon	11,781,250	per	gram	dry	weight
B horizon	843,750	"	"	"	"
C horizon	406,250	"	"	"	"

Actinomyces:—

A horizon	2,625,000	per	gram	dry	weight
B horizon	125,000	"	"	"	"
C horizon	62,500	"	"	"	"

The average rainfall is between 45-50 inches per annum. The total rainfall over the period October, 1932, when the cane was planted to November, 1934, when it was harvested was 101.74 inches.

LAYOUT AND TREATMENTS.

The whole experiment consists of three different sections (A, B and C), each section comprising 18 plots 1/20th of an acre, with three replications of each treatment and controls in each section.

The fertiliser treatments per acre, were as follows:—

SECTION A.

Three replications:—

O	..	O —Control.
P	..	P —400lb. super, 17.1% water soluble.
NP	..	N —125lb. amm. sul., 20.6% N.
NPK	..	N_2—250lb. amm. sul., 20.6% N.
NPK_2	..	K —225lb. pot. sul., 48.5% K_2O.
N_2PK_2	..	K_2—450lb. pot. sul., 48.5% K_2O.

The total amounts of fertilizer were applied in the furrows 16th September, 1932, and the cane planted 3rd October, 1932.

The object of putting the fertiliser in the furrows approximately three weeks before planting was to avoid the possibility of the rootlets coming into contact with a too concentrated soil solution.

During the year 1933, three lots of leaf samples were taken and analysed at Mount Edgecombe Experiment Station.

The leaves were taken from sticks chosen at random in each plot and grouped together which made a thirty leaf sample from each treatment. The leaves taken were fully mature green leaves.

All analyses were made in duplicate.

The following were the figures obtained on dry substance:—

SECTION A.

	O.			P.			NP.			NPK.			NPK_2.			N_2PK_2.		
	April 1933.	July 1933.	Feb. 1934.	April 1933.	July 1933.	Feb. 1934.	April 1933.	July 1933.	Feb. 1934.	April 1933.	July 1933.	Feb. 1934.	April 1933.	July 1933.	Feb. 1934.	April 1933.	July 1933.	Feb. 1934
Total Nitrogen (N_2) ..	1.44	1.37	1.38	1.46	1.46	1.31	1.56	1.46	1.36	1.25	1.43	1.40	1.55	1.45	1.39	1.63	1.40	1.40
Phosphoric acid (P_2O_5)	0.42	0.37	0.24	0.43	0.38	0.29	0.44	0.33	0.34	0.44	0.32	0.30	0.46	0.31	0.30	0.47	0.37	0.30
Potash (K_2O)	2.10	2.40	1.96	1.95	2.27	1.94	1.99	1.91	1.71	2.32	2.05	2.13	2.60	2.22	2.25	2.62	2.75	2.19
Calcium (CaO)	0.31	0.32	0.19	0.32	0.42	0.24	0.32	0.41	0.24	0.29	0.39	0.21	0.30	0.40	0.21	0.30	0.39	0.23
Magnesia (MgO)	0.59	0.65	0.52	0.64	0.79	0.62	0.66	0.84	0.65	0.60	0.84	0.56	0.58	0.81	0.56	0.54	0.80	0.56
Silica (SiO_2)..	1.36	1.44	1.28	1.38	1.72	1.45	1.16	1.45	1.43	1.15	1.48	1.14	1.23	1.63	1.18	1.25	1.62	1.17

The experiment was harvested from 14th to 17th of November, 1934.

The results from Section A were as follows:—

Plot No.	Formulæ and treatment.		Average yield per acre.	Value of average yield.			Cost of application of fertiliser.			Value of average yield less cost of fertiliser.		
			Tons.	£	s.	d.	£	s.	d.	£	s.	d.
1, 7, 13	O	No fertiliser	40.8	24	9	7	0	17	0	23	12	7
2, 8, 14	P	400lb. Super 17.1%	45.5	27	6	0	1	9	0	25	17	0
3, 9, 15	NP	400lb. Super 17.1%, 125lb. Sul. ammonia	45.4	27	4	9	1	19	7	25	5	2
4, 10, 16	NPK	400lb. Super 17.1%, 125lb. Sul. ammonia, 225lb. Sul. potash	49.3	29	11	7	3	7	5	26	4	3
5, 11, 17	NPK_2	400lb. Super 17.1%, 125lb. Sul. ammonia, 450lb. Sul. potash	53.7	32	4	5	4	15	3	27	9	3
6, 12, 18	N_2PK_2	400lb. Super 17.1%, 250lb. Sul. ammonia, 450lb. Sul. potash	53.4	32	0	9	5	5	11	26	19	10

Section B.

This section received a total fertiliser treatment identical to Section A with the following variations in time of application, each plot receiving half its total dressing before planting with two subsequent top dressings:—

		Sept. 3rd, 1932. Lbs.	Jan. 5th, 1933. Lbs.	April 3rd, 1933. Lbs.	Total. Lbs.
O	Control—no fertiliser.				
P	Super ..	200.00	100.00	100.00	400
NP	Super. ..	200.00	100.00	100.00	400
	Sul. amm...	62.50	31.25	31.25	125
NPK	Super. ..	200.00	100.00	100.00	400
	Sul. amm...	62.50	31.25	31.25	125
	Sul. pot. ..	112.50	56.25	56.25	225
NPK_2	Super. ..	200.00	100.00	100.00	400
	Sul. amm...	62.50	31.25	31.25	125
	Sul. pot. ..	225.00	112.50	112.50	450
N_2PK_2	Super. ..	200.00	100.00	100.00	400
	Sul. amm...	125.00	62.50	62.50	250
	Sul. pot. ..	225.00	112.50	112.50	450

Leaf samples were taken from the plots in this section in exactly the same manner as from Section A with the following results on dry substance:—

SECTION B.

	O.			P.			NP.			NPK.			NPK_2.			N_2PK_2.		
	April 1933.	July 1933.	Feb. 1934.	April 1933.	July 1933.	Feb. 1934.	April 1933.	July 1933.	Feb. 1934.	April 1933.	July 1933.	Feb. 1934.	April 1933.	July 1933.	Feb. 1934.	April 1933.	July 1933.	Feb. 1934
Total Nitrogen (N_2) ..	1.64	1.36	1.05	1.40	1.49	1.33	1.66	1.34	1.39	1.58	1.52	1.34	1.37	1.31	1.33	1.42	1.36	1.34
Phosphoric acid (P_2O_5)	0.46	0.30	0.25	0.48	0.36	0.35	0.44	0.31	0.34	0.46	0.35	0.35	0.46	0.31	0.32	0.46	0.29	0.31
Potash (K_2O)	2.16	1.66	1.66	2.16	1.76	1.65	1.99	1.44	1.61	2.32	1.88	2.01	2.53	2.00	2.20	2.66	2.00	2.28
Calcium (CaO)	0.29	0.40	0.31	0.29	0.40	0.31	0.27	0.46	0.26	0.28	0.41	0.23	0.30	0.40	0.23	0.30	0.42	0.23
Magnesia (MgO)	0.52	0.91	0.64	0.54	1.11	0.72	0.57	1.00	0.75	0.53	0.85	0.61	0.52	0.81	0.56	0.50	0.81	0.51
Silica (SiO_2)..	1.42	1.75	1.48	1.34	1.47	1.56	1.19	1.33	1.43	1.24	1.38	1.37	1.29	1.39	1.47	1.28	1.46	1.52

Harvested, the plots yielded per acre, as follows:—

Plot No.	Formulæ and treatments.		Average yield per acre. Tons.	Value of average yield. £ s. d.	Cost of application of fertiliser. £ s. d.	Value of average yield less cost of fertiliser. £ s. d.
6, 12, 18	O	Control—no fertiliser	34.9	20 18 9	0 17 0	20 1 9
5, 11, 17	P	400lb. Super, 17.1%	44.6	26 15 2	1 9 0	25 6 2
4, 10, 16	NP	400lb. Super 17.1%, 125lb. Sul. ammonia	39.8	23 17 7	1 19 7	21 18 0
3, 9, 15	NPK	400lb. Super 17.1%, 125lb. Sul. ammonia, 225lb. Sul. potash	43.6	26 3 2	3 7 5	22 15 9
2, 8, 14	NPK_2	400lb. Super 17.1%, 125lb. Sul. ammonia, 450lb. Sul. potash	46.5	27 18 0	4 15 3	23 2 9
1, 7, 13	N_2PK_2	400lb. Super 17.1%, 250lb. Sul. ammonia, 450lb. Sul. potash	41.1	24 13 2	5 5 11	19 7 3

SECTION C.

In this section the total amount of superphosphate applied was 500 lbs. instead of 400 lbs. For N and N2 half the amount was given as ammonium sulphate and the balance as sodium nitrate. K was equivalent to 450 lbs. potassium sulphate and K2 800 lbs. per acre.

The fertiliser was applied pe racre, as follows:—

		Sept. 16th, Lbs.	Jan. 5th, Lbs.	April 3rd, Lbs.	Aug. 15th, Lbs.	Total. Lbs.
O	Control—no fertiliser.					
P	Super. ..	250.0	150.0	100.0	—	500.0
NP	Super. ..	250.0	150.0	100.0	—	500.0
	Sul. amm.	62.5	—	—	—	62.5
	Nit. soda .	—	40.0	40.0	—	80.0
NPK	Super. ..	250.0	150.0	100.0	—	500.0
	Sul. amm.	62.5	—	—	—	62.5
	Nit. soda .	—	40.0	40.0	—	80.0
	Sul. pot. .	112.5	168.5	168.5	—	450.0
NPK_2	Super. ..	250.0	150.0	100.0	—	500.0
	Sul. amm.	62.5	—	—	—	62.5
	Nit. soda .	—	40.0	40.0	—	80.0
	Sul. pot. .	225.0	191.7	191.7	191.7	800.0
N_2PK_2	Super. ..	250.0	150.0	100.0	—	500.0
	Sul. amm.	125.0	—	—	—	125.0
	Nit. soda .	—	80.0	80.0	—	160.0
	Sul. pot. .	225.0	191.7	191.7	191.7	800.0

Leaf samples were taken from this section in the same way as those taken from the other sections, and analysed. The following were the results on dry substance:—

SECTION C.

	O. April 1933.	O. July 1933.	O. Feb. 1934.	P. April 1933.	P. July 1933.	P. Feb. 1934.	NP. April 1933.	NP. July 1933.	NP. Feb. 1934.	NPK. April 1933.	NPK. July 1933.	NPK. Feb. 1934.	NPK_2. April 1933.	NPK_2. July 1933.	NPK_2. Feb. 1934.	N_2PK_2. April 1933.	N_2PK_2. July 1933.	N_2PK_2. Feb. 1934
Total Nitrogen (N_2) ..	1.56	1.33	1.19	1.41	1.48	1.39	1.50	1.35	1.31	1.60	1.40	1.26	1.51	1.35	1.32	1.53	1.44	1.25
Phosphoric acid (P_2O_5)	0.47	0.29	0.27	0.47	0.33	0.35	0.44	0.31	0.38	0.47	0.35	0.35	0.48	0.32	0.36	0.48	0.32	0.35
Potash (K_2O)	1.94	1.45	1.73	2.00	1.65	1.90	2.09	1.40	1.80	2.70	2.12	2.54	2.62	2.05	2.35	2.80	2.20	2.26
Calcium (CaO)	0.34	0.50	0.22	0.34	0.46	0.22	0.36	0.57	0.20	0.32	0.45	0.23	0.28	0.50	0.18	0.27	0.41	0.20
Magnesia (MgO)	0.52	0.95	0.56	0.55	0.97	0.64	0.62	1.12	0.63	0.51	0.86	0.61	0.46	0.89	0.48	0.54	0.86	0.53
Silica (SiO_2)..	1.56	1.55	1.30	1.27	1.49	1.39	1.55	1.52	1.47	1.43	1.60	1.34	1.42	1.57	1.36	1.43	1.75	1.45

Harvested, the yields from the plots gave the following figures per acre:—

Plot No.	Formulæ and treatments.		Average yield per acre. Tons.	Value of average yield. £ s. d.	Cost of application of fertiliser. £ s. d.	Value of average yield less cost of fertiliser. £ s. d.
1, 7, 13	O	No fertiliser	21.5	12 18 0	0 17 0	12 1 0
2, 8, 14	P	500lb. Super.	33.6	20 3 2	1 12 0	18 11 2
3, 9, 15	NP	500lb. Super, 62.5lb. Sul. ammonia, 80lb. Nitrate of soda	37.5	22 10 0	2 5 4	20 4 8
4, 10, 16	NPK	500lb. Super, 62.5lb. Sul. ammonia, 80lb. Nitrate of soda, 450lb. Sul. potash ..	45.3	27 3 7	5 1 0	22 2 7
5, 11, 17	NPK_2	500lb. Super, 62.5lb. Sul. ammonia, 80lb. Nitrate of soda, 800lb. Potash	50.2	30 2 5	7 16 8	22 5 9
6, 12, 18	N_2PK_2	500lb. Super, 125lb. Sul. ammonia, 160lb. Nitrate of soda, 800lb. Sul. potash	46.4	27 16 9	8 9 11	19 6 10

COMMENTS.

In the first place it must be pointed out that the differences in yield between some of the plots with similar treatments was considerable, resulting in a high experimental error. Although treatment differences were not statistically significant, the experiment nevertheless is of interest since similar effects were obtained in all three sections from the different applications of fertiliser.

The chemical analysis shows that the soil is practically lateritic (following Russell's figures, although in the soil analysis the clay fraction was not treated separately). On account of high contents of free iron and aluminium, one would suspect the possibility of formation of iron and aluminium phosphates which if not freshly precipitated are sometimes considered chemically unavailable. On the other hand, Hance, according to the Hawaiian Planters' Record, 4th Quarter, 1933, page 188, claims that "cane (D1135) can utilise tricalcium, ferric aluminium and reverted phosphates. In fact the ferric, aluminium and reverted phosphates series showed more stalk development and more millable cane than did those receiving soluble phosphate in the culture solution, although the latter showed on an average a larger number of stalks per plot."

Loss on ignition is very high, but it must not be forgotten that although the content of apparent organic matter in the soil was great, this figure is largely an indication of a very high colloidal clay content.

Mr. Beater, of the South African Sugar Association, Experiment Station, Mount Edgecombe, showed the actual organic matter content of the A horizon to be 7.40%. The method followed for this determination was that described by J. R. H. Coutts of the University College, Maritzburg, in a paper read before the S. A. Association for the Advancement of Science, Pretoria, 1929, where he says, "It has been shown by G. W. Robinson, Jones and Evans (84) that the treatment of the soil with hydrogen peroxide destroys the unstructured (i.e., the 'Humified') organic matter. Hence, if the losses on ignition of the original soil and of the peroxide treated soil (Io and Ip) are both found, the difference will give three-quarters of the organic matter in the original soil, $\frac{4}{3}$ (Io-Ip)."

The available phosphate is slightly below normal in the A horizon for local soils, and in B and C horizons about the average.

Available potash in the A horizon is just about medium, whilst the other two horizons show average amounts.

The Bacterial analysis done at the Pretoria University, thanks to Prof. Hector, showed a decrease in Bacterial numbers from the top downwards. The decrease agrees with the data given in S. A. Waksman's "Principles of Soil Microbiology," where he states: "Study of the distribution of Bacteria in different soil horizons has revealed the fact that the numbers do not decrease gradually but by a series of drops as one passes from one sub-horizon to another . . . ." The sharp decline in this case is probably due to the compact nature of the soil in the lower horizons, with lack of aeration, organic matter, etc.

The absence of Azotobacter, which are aerobic, non-symbiotic nitrogen-fixing Bacteria in the soil is interesting. Again, according to S. A. Waksman: "In the majority of cases the absence of azotobacter in the soil is due to the reaction since they cannot develop when the pH value is below 6.0." This state of affairs can be modified by an application of lime to raise the pH.

The absence of nodules on the roots of the cow-peas examined was probably due to the seed not having been inoculated before sowing. As only a small percentage of the plants were examined, however, it is not absolutely certain that there was a total absence of symbiotic nitrogen-fixing Bacteria of this strain.

Regarding the actinomyces, these organisms according to Waksman are among the few capable of attacking the organic (humus) substances and bringing about their decomposition, and also that some species are very active in decomposing cellulose in soils with insufficient moisture. Owing to their sensitiveness to pH, the numbers are influenced by soil reaction, increasing with alkalinity pH 6.8-pH 8, and the nitrogen assimilated is apparently liberated again in the form of ammonia. It is important to arrive at a better understanding of the functions of these organisms, as their possible action upon the trash so often incorporated in the soils is of ultimate interest to farmers.

Regarding the leaf analyses, higher dressings of potash give higher concentration of this mineral in the leaves, and correlated with heavier yields of cane, contrary to data obtained from plots at the Experiment Station. Also the figures show a certain relationship between magnesium and phosphates which reached highest concentration on the NP plots.

Regarding the response to fertiliser treatment, in Section A superphosphate and potash augmented the yield considerably. In the initial stages it appeared as though the plots which had received superphosphate only were hanging back, and not much better than the controls. The yields, however, did not confirm this observation. The comparatively high dressings of potash, in the form of potassium sulphate, gave extremely interesting results, especially since the soil is by no means low in available K_2O according to the chemical analysis.

In spite of the high figure for available K_2O there is still a marked response in yield. The high absorptive powers of a clay soil immobilise a large percentage of the potash applied so that this demonstrates that soil analyses, although an excellent means of showing deficiencies in the soil, do not indicate the amounts of fertiliser ingredients to be applied to obtain increases in yield.

Nitrogen in Section A, given in the form of ammonium sulphate, did not increase the yield, and in this connection it is to be regretted that a PK series was not included to ascertain whether superior yields could not have been obtained in the absence of nitrogen, or, on the other hand, whether some of the increases on the K and K2 plots were not also partially due to the inclusion of nitrogen, with consequent improvement of the Nitrogen-Potash ratio.

It must be remembered that very often the effect of an incomplete fertiliser dressing is limited by the absent ingredient. Experiments in France and England have illustrated this point.

In Section B, contrary to what occured in Section A, the plots with superphosphate only appeared to come on better than the others. This observation, however, proved to be entirely superficial when it came to harvesting. Nitrogen had a depressing effect on the yield. It is interesting again to notice, however, that the heaviest yield obtained was from the plots receiving the highest dressing of potash, which has apparently counteracted the effect produced by the nitrogen application.

It is possible that the amounts of superphosphate and potash applied as top dressings were absorbed in the topmost few centimetres of soil, and were not within reach of the feeding points of the root systems, which were attained by the nitrogen salt which leached down to lower levels.

From the total yield obtained in this section it seems to be indicated that the method of application adopted in Section A was more beneficial and created a better balance of plant food material at the disposal of the root systems than was the case when the dressings were split and top dressings applied.

In Section C the effect of the nitrogen was slightly different compared to the other two sections, the single application of nitrogen with a portion given in the form of sodium nitrate giving an increase of yield.

It is also to be regretted, however, that a PK series was not included in this section, but it is interesting to notice that the application of 500 lbs. superphosphate did not increase the yield over the 400 lbs. applied in the other two sections, and also the very high dressings of potash in K2 did not assist in counteracting the depressing effect caused by the N2. It is difficult in this case to fall back on the view that the potash was absorbed in the first few centimetres of soil. The dressing was sufficiently heavy to justify the assumption that a portion should have leached down to the root system to counteract the detrimental effect of the double dressing of nitrogen since an increase was obtained between K and K2.

The heavy dressings of potash in this section were not applied with the view to obtain necessarily economic returns, but to refute the popular belief that heavy dressings of this ingredient are liable to have toxic effects on cane.

CONCLUSION.

The salient points of interest in this experiment from a fertiliser point of view are: (1) The fact that phosphate, in the form of super, applied at the rate of 400 and 500 lbs. per acre augmented the yields considerably when compared to the controls. This, however, was to be expected since phosphate is the mineral factor which limits production on account of the low percentages of this ingredient in the soil. (2) That potassium sulphate, applied in conjunction with the superphosphate, gave considerable increases in yield, this in spite of depressing effects from the application of nitrogen, which suggests that there is further useful work to be done in this connection on the different soil types occurring on the sugar belt of Natal.

The application of nitrogenous fertilisers in the form of ammonium sulphate alone appeared to have a depressing effect on the yield throughout the experiment. Only once (NP Section C), when the nitrogen dressing was split and half the amount of N applied as sodium nitrate, was there a favourable response.

In connection with the response obtained from the various ingredients in this experiment it is interesting to note that Mon. Demolon, of the "Institut des Recherches Agronomiques de Versailles," has found that in a great many cases three formulæ suffice for fertiliser work on soils, one main formula and two supplementary ones of which one is reinforced with phosphate and the other with potash.

Further lots of fertiliser have not been applied locust invasion and for this reason sucrose tests were not taken. In order to gain a better knowledge of the total tonnage obtained per acre the cane was not topped as drastically as it should have been on account of side shooting.

Further lots of fertiliser have not been applied to this experiment, but the experiment is being continued in order to gain some idea of the residual effects of the different dressings given. If possible it is intended to make a more thorough study of the leaves to discover whether any correlation exists between the mineral content and yield.

Thanks are due to the staff of the Mount Edgecombe Experiment Station, to Prof. Hector of the Pretoria University, Mr. Booth, Chemist at Doornkop, Dr. Orchard of Cedara, for help afforded and to Capt. J. Woollam for his efficient collaboration.

CHAIRMAN: We are very much obliged to Mr. Lintner for his very interesting paper on this subject of fertiliser experiments. To me, as an engineer, the subject is rather beyond my scope, but there are several planters present—cane growers—to whom, I am sure, the subject is most interesting. It is now open for discussion.

Mr. MOBERLY: I wish to congratulate Mr. Lintner on the great care which he has taken over his experiment. I am sorry to see that, owing to unavoidable circumstances, he was unable to take sucrose tests, because I think that that would have added considerably to the value of his comparative figures of the value of the crop. It is well known that fertilisers, particularly nitrogen, have a considerable effect on the sucrose content. Also, there would seem to be a growing opinion that potash tends to augment it, if anything. So, if this experiment is continued I hope that nothing will prevent the sucrose test being taken, so that more real values can be given to the comparative value of the crop.

Mr. LINTNER: As a matter of fact it is intended to take sucrose tests in future. An attempt was made to take sucrose tests this time but the results were so unreliable, owing to damage done to the cane by locusts, that they were discarded.

Mr. BOOTH: I myself did the sucrose tests, and also suggested that the figures obtained should be abandoned as I did not think they were of any value. As has been remarked in the paper, the locusts paid a visit to this crop, which nullified the value of the tests.

Mr. DYMOND: In connection with the determination of the sucrose content of an experimental crop of cane, there is no standard method to my knowledge of determining the sucrose content in such plots. I know that sometimes it is done by sending the bulk samples to the mill and applying the Java ratio. I think it is necessary that we should lay down some standard method for determining the sucrose content of experimental plots.

There is another point of interest to me in Mr. Lintner's paper, and that is the remarkable results obtained at Cedara with increasing quantities of lime following which the pH shows very little variation or increase. Were these pH tests done by the potentiometer?

Mr. LINTNER: Yes, with a quinhydrone electrode.

Mr. DODDS: I am intensely interested in this excellent piece of work described to us by Mr. Lintner. It is of special interest to compare it with the results of our experiments at the Experiment Station. We have been working, in many respects, on somewhat similar lines. I am very glad to see field experiments carried on in this particular type of soil, which is one of our important soil types in Natal and carries a considerable area of cane, but we have never yet been able to tackle it from the Experiment Station. This soil is rather peculiar in its composition and properties. Mr. Lintner refers to it as a somewhat lateritic soil. Although we are told that there are no true laterites in this country, the composition of this soil undoubtedly shows that it approximates to a laterite, as you can see, if you refer to the high acidity of the soil, the large amount of combined water, and the relatively high concentration of iron and of alumina. I should say it is probably the moderately high content of silica which would prevent it from being classified as a truly lateritic soil apart from what its presumed origin may be.

It is also of special interest to compare the effect of the increase in quantities of lime on the reaction of the soil. We have had a very similar experience to Mr. Lintner's at the Experiment Station. We have worked out the lime requirements of the soil by a method developed in Trinidad by Hardy and Lewis a few years ago, in which the empirical method is adopted of adding saturated lime water to the sample of the soil until the pH comes to the point of true neutrality 7.0. That is, on the face of it, a very promising method of working out the lime requirements of the soil, as it appears to follow in principle closely what one does in field practice to the soil. But we found it did not seem to work out in that way in some cases and at the Experiment Station we have found that in one instance at least, where we applied two tons of lime per acre, there was no change in the pH of the soil. What were the reasons for this I do not know; possibly the effect takes some time to become evident, and of course watch will be kept on that. Mr. Lintner remarks that in the case of cow peas that were grown as a green manure crop, there were no nodules found on the roots. He attributes this to the lack of specific bacteria in the soil. That is rather an interesting point. We have experimented with a large range of legumes at the Experiment Station, and we have found that in only one of the leguminous crops it is necessary to inoculate. In all other cases, including the cow peas, we found that the necessary bacteria already appeared to exist in the soil, which appears to indicate that there would be no advantage from inoculation. The sole exception is soja beans, which we have found do need to be inoculated; I believe this is a fairly general experience.

It is very interesting to compare the yield tables. The one given on page 162 follows very closely the results of many of our experiments, both at the station and in field tests, where superphosphate alone gives, if not actually the best yield, at all events the biggest gross profit. But in sandy soils—I presume this soil was of a sandy character, although the physical analysis is not stated—we have found a response to potash also.

Mr. LINTNER: No. The soil in question is a clay soil.

Mr. DODDS: It is rather surprising in that case to find a large response to potash. Where we have found response at all has been hitherto in soils of a more or less sandy character. That, as Mr. Lintner says, is a point that evidently requires much further study.

To conclude, I would like to say again how much I welcome papers of this type which add to the knowledge which is so urgently required in our Industry.

Mr. R. G. T. WATSON: Mr. Chairman, I noticed in Mr. Lintner's paper that the rainfall for the period of this experiment was approximately 50 inches a year, which is decidedly above the average for the cane-growing area as a whole. We are accustomed to compare our annual rainfall in Natal with other countries producing twelve-month-old crops, where they get annual rainfalls of the order of 80 inches or over, or have vast irrigation facilities. I notice Mr. Lintner expresses the rainfall in this paper in terms of rainfall over the whole period—101.74 inches of rain for the 24 months growth of that crop—and I would like to ask those who can inform us on the subject who are present to-day, to what extent it is permissible to compare total rainfall on a two year crop with one year's rainfall on an annual crop elsewhere. It seems to me if it is permissible to compare rainfall for a two year's crop with a year's rainfall for an annual crop, the idea that we are limited by rainfall in this country must be to a certain extent diminished, except for small areas, that being so, the idea of heavier fertilisation and more exact fertilisation—differential soil fertilisation—should come in for more study.

Mr. LINTNER: In answer to that question, I presumed, in giving that figure, that a certain amount of moisture is necessary to bring a ton of cane to maturity, but I do not know what quantity of water is a safe cane proportion. Dr. McMartin could tell us. I considered it logical to group two years together, as being one season of growth for Uba cane in this part of the country.

Dr. McMARTIN: Yes, your idea is probably right.

Mr. LINTNER: Said and done, it is the precipitation over the whole of the growing period which is of interest.

Mr. R. G. T. WATSON: That is my point, that we are apt to consider only one year, instead of two years.

Dr. HEDLEY: There is another matter in connection with this question of rainfall, namely, the necessity for information regarding the distribution. A heavy rainfall in the winter is not as useful as a heavy rainfall in the summer. We have shown that at the Experiment Station. It would be valuable therefore if Mr. Lintner could supply that data.

Mr. LINTNER: The distribution was as follows:

1932.		1933.		1934.	
October ..	5.10in.	January ..	4.40in.	January ..	10.18in.
Nov.	4.62in.	Feb.	6.07in.	Feb.	6.97in.
Dec.	7.50in.	March	3.41in.	March	5.21in.
		April	2.61in.	April	4.89in.
		May	0.32in.	May	3.82in.
		June	0.55in.	June	1.28in.
		July	2.03in.	July	2.97in.
		Aug.	0.41in.	Aug.	2.80in.
		Sept.	1.89in.	Sept.	0.65in.
		October ..	3.33in.	October ..	2.88in.
		Nov.	10.28in.		
		Dec.	7.57in.		

Mr. FOWLIE: In connection with that question of rainfall, I would like to say a few words. The amount of rainfall over a period—either one year or two years—is never a very exact guide as to the amount of what one might call available rainfall for the crop. The amount available for the crop must depend on the state of moisture of the soil during the growing season, and in that connection the amount of evaporation must be taken into account as well as the amount of rainfall. The amount of evaporation in this country is high, and if you take a two-year period instead of a one-year period in considering the growth of the crop, the amount of evaporation is probably more than twice as much as it would be during the one year where the one-year crop is grown. The result is that during the two-year period we have a growing crop of cane, almost invariably there are periods when the amount of moisture in the soil drops below what one might call the optimum amount, and the crop suffers from drought, even although at other times the amount of moisture may be in excess, and there may be considerable run-off, which is another point that has got to be considered. A moderate and gentle rain does far more good to a growing crop than a heavy downpour of two or three inches in a few hours. In the latter instance a great deal runs off and is therefore useless for the crop. Rainfall figures are only of assistance in giving an idea of what crop may be expected if all the conditions are taken into proper consideration.

Mr. LINTNER: In answer to that, in the first place I would like to ask Mr. Fowlie how he suggests one should deal with evaporation in co-operative field experiments, where it is impossible to have an open sheet of water. This is possible at the Experiment Station, but not on field plots of this nature. I presume, however, an evaporimeter properly installed in the field would be of value. His reference to evaporation is interesting because this factor depends on climatic conditions. In the summer rainfall area the evaporation is considerable on account of high temperatures. Large areas of South Africa are semi-arid which means that the evaporation is greater than the precipitation. An illustration of that point I had once in the Kroonstad area. At the Experiment Station, Kroonstad, two years ago, I was told that for a rainfall of 13 inches there had been a total evaporation of 75 inches. You can well imagine the state of affairs under these conditions, from the point of view of soil moisture. An examination of the profile does sometimes afford some information regarding the water movement in the soil. Soils being subjected to a process of leaching—a washing down of the minerals in the soil—as against soils subjected to excessive heat will show the effects on examination, although it is also possible that existing horizons may reflect the effects of weathering which occurred during some past geological era.

Mr. FOWLIE: In reply to Mr. Lintner's remark as to how I should estimate the evaporation, I know that is the difficulty. We can get evaporation figures for the country, as he has given us for Kroonstad. I have seen them for other places. We are now trying to get them for the Experiment Station. I only meant to raise the question so that people would consider, in comparing this country with other countries, that we are up against what one might call not being able to get full value for the rainfall that we do get, because of its distribution and because of the high evaporation.

Mr. DODDS: They have in Hawaii a figure known as the effective rainfall, which is the rainfall over and above a fixed quantity—I think half an inch—that has fallen within the previous 24 hours. The effective rainfall is the rainfall over and above that preliminary fall. It might be of interest to work that out for a few of our localities in this country.

Mr. RAULT: With reference to relative moisture, and evaporation, could Mr. Dodds tell us the effect of irrigation in winter time. I have found that on many occasions winter days are the lowest for relative humidity and one could expect that on such days irrigation is badly needed. Such may not be the case in tropical lands, where winter very often coincides with rainy weather.

Does Mr. Dodds remember the comparative figures of Mauritius, Java, Hawaii against our own with reference to relative humidity.

Mr. DODDS: Although it is not directly connected with the subject of this paper, my opinion on the irrigation of cane during cool weather is that it is of relatively little avail in promoting growth. It has been pointed out more than once that work is urgently needed on that subject—the value of water in relation to temperature. We have certainly found that it is very difficult to make cane grow during the winter time, no matter how much irrigation it gets, and I recollect in particular an experiment that we had carried out at the Experiment Station in collaboration with Mr. McClean. The idea was to make cane throw out aerial roots in order to transplant the cane, if possible, for breeding purposes. To do that, we followed the practice which has been adopted very successfully in India, of tying a bag of soil round one of the nodes of the cane, and keeping the bag well watered; in most tropical countries the result is that a luxuriant mass of roots appears within a short time around this node, enabling the cane to be cut off below this point, and transplanted. In our case, we found no development of root whatever in this experiment. It would seem, under our winter conditions, that the growth of the root system of the cane is not stimulated, and that is the limiting factor of growth and not the amount of moisture.

Mr. DYMOND: Referring again to the question of lime, and its application, and the very small effect the quantities used had on the soil as recorded by Dr. Orchard, might I ask Mr. Lintner to give us further information on the time that elapsed between the application of the lime and the determination of the pH, also the method of lime application, and whether he would advocate the application of lime in the furrow, rather than broadcast.

Mr. LINTNER: The time that elapsed between the application and the testing was exactly a year. I cannot answer the second question adequately on account of not having sufficient experience with liming cane, but would certainly imagine it is better to broadcast the lime on the surface of the soil and plough it in. I would like Mr. Dodds' views on that subject.

Mr. DODDS: In our case, at Mount Edgecombe, where we tested the effect of lime on the soil, the soil was tested at intervals of two years and four years, respectively, after the application of lime. In neither case was there any appreciable change. For the first two years there was no effect on the crop either. That is to say, the plant cane crop showed no response to lime. But the first ratoon crop did show a response to lime, both alone and also applied in the form of filter cake. What is going to happen to the second ratoons still remains to be seen.

The lime was broadcasted and ploughed into the ordinary plough depth. When the sample was taken, it was taken with the auger to the same depth of cultivation. I may say that the general practice recommended in the application of lime is, of course, to broadcast it, and then plough it in, since lime is not, strictly speaking, a fertiliser, but a corrective, and therefore should be used in such a manner as to bring it into contact with as big a surface of the soil as possible. To get experimental evidence on that particular point, last season we planted a series of experiments at Chaka's Kraal, in which both lime and filter cake have been applied in the rows and broadcast respectively. We hope next year to have some results on this.

CHAIRMAN: This has been very interesting. We are very much obliged to Mr. Lintner for his paper. It is to be noted that he styles it "A few Preliminary Observations," from which we take it that this experiment, or similar experiments, are to be continued by him in the near future. We hope we will have further information from him at some future conference. I ask you to accord him a hearty vote of thanks.

Carried.