ABSORPTION OF PLANT-FOODS BY SUGAR CANE

By B. E. BEATER, B.A., and J. L. DU TOIT, M.Sc.

Reasons for the Study.

The object in presenting this paper is twofold: firstly, to substantiate if possible earlier work conducted along very similar lines in 1933[1], and, secondly to extend our knowledge of the plant-food requirements of sugar cane. The field of study is extremely wide—so wide in fact, that the writers have not felt entirely justified in drawing any definite conclusions from the analytical results. The results, however, are presented with the hope that they will assist the sugar cane agriculturist in obtaining some conception of what might be termed the "greediness" of sugar cane for fertilisers.

Review of Literature.

The absorption of plant-foods by sugar cane has been studied from time to time in various sugar growing countries of the world. Many writers have been content with a mere juice analysis as an indication of fertiliser requirements. Thus Walker[2] found that P_2O_5 in juice was proportional to a 1% citric acid extract and diminished with increasing elevation. Following up this investigation, Walker and Glick[3] state that juices below 0.05% K_2O require potash fertilisation, and those above 0.10% do not. However, they mention that further research work should be done to ascertain the quantities for different varieties under different conditions. Moir[4] points out that climatic conditions, time of uptake, interaction of fertiliser, all tend to complicate the problem of plant-food requirements. Saint[5] claims that potash uptake in juice is not influenced by climatic conditions. He correlates P_2O_5 in juice with rainfall. Later[6] he states that juice analysis gives a good indication of the absorption of the whole cane. He, however, considers such an analysis of little value in Barbados as a result of climatic and varietal variations. McCool and Weldon[7] found that the application of mineral nutrients to the soil as a fertiliser generally resulted in increased concentrations of these elements in the juice of the crop, and if any element is decidedly the limiting factor the other elements may accumulate until the limiting element is applied, which will probably lead to decrease in the other elements. Stewart,[8] studying the period of uptake, concluded that the major portion of the ash constituents was absorbed in the first twelve months of growth. The results of his investigation gave him reason to emphasise the importance of early fertilisation. Honig[9] states that the uptake of minerals comes practically to a standstill at about the ninth to eleventh month. Ayres[10] found that cane tops contained as much as 45% K_2O in ash, indicating, according to Ayres, an intensive growth. In our work we obtained results as high as 41.42% K_2O in ash of tops. A very thorough study of the ash constituents of P.O.J.2878 was made by Honig[11] in Java. Those interested are referred to the original comprehensive work. We give, however, the following table showing the ash constituents taken up by the total cane plant. The results have been converted to pounds per acre.

		Ash constituents absorbed in lbs. per acre.							
Name of Factory.	Tons per acre.	SiO_2	K_2O	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	SO_3
Wringinanom	71	731	469	31.3	31.9	29.6	3.9	124.0	171
Semboro	78	654	586	24.6	19.5	26.2	7.5	54.6	233
Winongan	70	473	377	19.2	25.1	26.6	3.0	53.9	157
Meritjan	64	515	283	26.3	29.1	25.5	—	47.1	74.6
Modjo	59	504	404	29.9	30.9	18.8	3.4	23.7	77.8
Klampok	73	1009	129	51.5	61.4	23.2	1.7	37.4	95.5
Kalimati	48	538	37	31.9	47.6	19.0	—	29.0	70.4

Fort and Holmes[12] studying the composition of the whole cane of Co.281 and Co.290, estimated that Co.290 would deplete the soil of the elements of fertility at a faster rate than Co.281.

Selection of Varieties.

All the canes analysed were selected from fields at the Experiment Station. The treatment of these fields has been carefully recorded over ten years or longer. These records were taken into consideration when sampling. All the samples, with the exception of the last, were selected from control lines of the present field trials. The following table presents details of the canes selected:—

TABLE I.

	Variety sampled.	Field.	Age at time of sampling.	Fertiliser applied over past two years (top dressings).	Estimated tonnage per acre at time of sampling.	Estimated tonnage per acre at time of cutting.
1.	Co.290	E_1	15 months plant	Nil	30	45
2.	Co.281	E_1	15 months plant	Nil	30	45
3.	Co.290	R_1	16 months third ratoon	360lbs. superphosphate, 120lbs. sulphate of ammonia, 60lbs. muriate of potash	20	25
4.	Co.281	B_1	15 months first ratoon	(as above)	25	35
5.	Co.290	B_1	15 months first ratoon	(as above)	25	35
6.	Co.301	B_1	15 months first ratoon	(as above)	25	35
7.	Co.290	A_1	17 months third ratoon	Nil.	15	20
8.	Co.290	A_1	17 months third ratoon	300lbs. super. 600lbs. amm. sulph. 60lbs. muriate	15	20

Soil Analyses.

The soils of E_1, B_1 and A_1 are approximately each of the same type. They consist of a sandy loam overlying a heavy loam, and followed by a thin layer of iron gravel. Immediately below this is a heavy, impervious silty clay, passing gradually into unweathered Ecca shale. These characteristics are least pronounced in E_1, where the soil becomes slightly more compact, being influenced by the neighbouring igneous intrusion (dolerite) on which R_1 is situated. The chemical analyses are given below and were made on the extract obtained by digesting the soil for 10 hours over water bath in HCl 1.115 S.G. The results are expressed on the oven-dry soil :—

TABLE II.

Field.	E_1	R_1		B_1 and A_1	
	Surface soil.	Surface soil.	Subsoil.	Surface soil.	Subsoil.
Insoluble residue	85.12	63.22	62.22	89.28	89.00
Soluble silica (SiO_2)...	0.77	0.99	0.70	0.31	0.22
Loss on ignition	4.41	12.81	12.43	3.93	3.62
Potash (K_2O)	0.08	0.21	0.13	0.09	0.08
Phosphoric acid (P_2O_5)	0.01	0.02	0.02	0.02	0.03
Lime (CaO)	0.22	0.44	0.36	0.18	0.17
Magnesia (MgO)	0.14	0.16	0.17	0.11	0.13
Alumina (Al_2O_3)	3.40	0.77	1.73	1.41	2.45
Oxide of iron (Fe_2O_3)	5.92	20.57	22.36	4.73	4.20
Not determined	—	0.81	—	—	0.10
Total	100.07	100.00	100.12	100.06	100.00

TABLE II.—*continued.*

Field.	E_1	R_1		B_1 and A_1	
	Surface soil.	Surface soil.	Subsoil.	Surface soil.	Subsoil.
Total carbon	1.26	3.35	2.85	1.19	1.17
Total nitrogen (N)	0.10	0.27	0.21	0.07	0.09
Carbon : nitrogen	12.6	12.4	13.6	17.0	13.0
Available potash	0.009	0.014	0.005	0.005	0.005
Available phosphoric acid	0.001	0.004	0.002	0.006	0.004
pH value	6.45	5.93	6.02	6.44	6.87
Moisture	3.55	6.67	6.97	1.99	2.76

Table III. below gives the mechanical composition of the soils in the immediate locality where the samples were taken :—

TABLE III.

Field :	E_1	R_1	B_1	A_1
Coarse sand	14.5	5.5	12.7	15.9
Fine sand	45.6	18.0	55.7	51.5
Silt	15.9	19.1	11.0	11.9
Clay	20.1	50.2	15.8	14.4
Moisture	2.6	7.3	2.6	2.5
Loss by solution ...	0.3	0.5	0.3	0.3
Difference (organic matter, etc.)	1.0	—	1.9	3.5
	100.0	100.6	100.0	100.0

It will be seen from Table III. that field R_1 is very high in clay, which accounts for the high iron content. Fields B_1, A_1 and E_1 are very similar in mechanical composition, E_1 showing the tendency, remarked on above, of becoming more clayey. The chemical analysis of R_1 shows it to be richer in total plant-foods than the other fields, though A_1 and B_1 have always been noted for the comparatively high availability of phosphoric acid.

Preparation of Samples.

Great care was given to the taking and preparation of the samples. Each sample comprised twenty-four sticks, chosen at intervals from the plots, care being taken that the sticks were fully grown. Trash lying on the ground and consequently soiled was cut off, otherwise the complete plant was taken for analysis and divided up as follows :—

(*a*) All *leaves*, whether dry or green.

(*b*) *Tops*.—These comprised the sheaths of the tops after the green leaves had been cut off, and that part of the stalk included normally in the top. This being the actively growing part we suspected a heavier concentration of elements here. Our analyses have borne this out.

(*c*) *Bagasse*.—This comprised the material remaining after passing the cane stalks three times through a laboratory handmill.

(*d*) *Juice*.—Expressed from the stalks by the laboratory handmill. There were several reasons for separating juice and bagasse. In routine work the juice is usually analysed for P_2O_5, K_2O, and perhaps Cl, and to include an analysis of these contents in this work would enable one to interpret better the findings of routine work. Secondly, it is well known that some of the constituents of the juice, particularly phosphoric acid, influence sugar manufacture.

The following table (Table IV.) is of interest in showing the relative proportions of these various sections to the total cane plant. The figures may be a useful reference to those desiring to calculate results to any new portion of the cane plant. It must be cautioned, however, that these eight samples are representative only of young Co. canes, and that dry material means oven-dry material.

TABLE IV.

Variety and Field.	Co.290. E$_1$	Co.281. E$_1$	Co.290. R$_1$	Co.281. B$_1$	Co.290. B$_1$	Co.301. B$_1$	Co.290. (control) A$_1$	Co.290 (fertilised) A$_1$
Dry leaves and trash % green leaves and trash	47.9	52.3	59.4	57.0	53.4	52.8	63.0	54.1
Dry leaves and trash % total cane plant .	9.6	10.7	12.0	11.6	11.7	13.2	12.2	12.0
Green leaves and trash % total cane plant	20.1	20.4	20.2	20.3	21.9	25.0	19.3	22.2
Dry tops % green tops	17.0	16.6	17.2	15.7	14.9	13.2	16.7	16.5
Dry tops % total cane plant	2.0	2.1	1.8	1.9	1.5	2.1	1.8	1.7
Green tops % total cane plant	11.6	12.6	10.2	11.8	10.4	15.6	11.0	10.3
Dry bagasse % wet bagasse	40.1	46.3	41.0	44.5	39.5	41.6	40.3	39.5
Dry bagasse % total cane plant	11.5	13.0	13.1	12.6	11.9	10.6	12.8	12.1
Wet bagasse % total cane plant	28.8	28.1	32.0	28.4	30.0	25.4	31.7	30.6
Juice % total cane plant	39.5	38.9	37.6	39.5	37.8	33.9	38.0	36.9

The green leaves and trash and green tops are left on the field, and from the table it will be observed that this amounts to about 30 per cent. of the total cane plant, or roughly, on a 30-ton crop, 13 tons per acre.

All the samples were passed through a shredder, subsampled and oven-dried (102°C.). The oven-dried material was then pulverized to a fine powder in a special mill, carefully mixed, oven-dried and placed in screw-capped bottles.

Routine Tests on Cane.

At the time of sampling routine tests were made of the juice and bagasse, with the following results :—

TABLE V.

Variety and Field :	Co.290. E$_1$	Co.281. E$_1$	Co.290. R$_1$	Co.281. B$_1$	Co.290. B$_1$	Co.301. B$_1$	Co.290. (control) A$_1$	Co.290. (fertilised) A$_1$
Sucrose % juice	18.74	18.90	18.44	19.38	16.98	18.04	17.31	16.80
Reducing sugars % juice	0.14	0.25	0.10	0.14	0.11	0.22	0.12	0.10
Sucrose % bagasse... ...	12.0	10.0	11.2	11.0	10.0	10.6	10.4	10.0
Sucrose % cane	15.90	15.17	15.11	15.87	13.92	14.86	14.17	13.72
Purity of juice	92.8	92.6	93.1	93.2	90.8	91.6	91.6	90.3
Fibre % cane	11.70	14.46	13.20	13.37	12.38	12.93	12.89	13.00

From these analyses it would appear that the canes, even though young, are fairly mature.

Chemical Analyses.

In analysing the plant material attention was given only to those elements which are commonly recognised as plant-foods. The role played by magnesium is not very definite. Owing to the comparatively large amounts found in the plant, it may be questionable to overlook its importance as a plant-food. Standard methods were used in the analyses, and mention only need be made of these.

The ash was determined on 10 to 15 gms. of material by burning in a muffle at low red heat. Nitrogen was determined by the Kjeldahl method, and potash and phosphoric acid by the volumetric cobaltinitrite and blue colorimetric methods respectively. Calcium and magnesium were determined gravimetrically.

The following tables give the results of our analyses. All analyses were made in duplicate, or in triplicate where close agreement was not obtained.

TABLE VI.—**Co.290, Field E_1** (from control section—unfertilised).

Section of cane plant analysed.	Ingredient.	% oven dry material.	% green or wet material.	% total cane plant.	% ash.
Green leaves and trash	Ash ...	8.67	4.15	0.83	—
	Nitrogen (N) ...	0.48	0.23	0.05	—
	Calcium (CaO) ...	0.42	0.20	0.04	4.84
	Magnesium (MgO) ...	0.30	0.15	0.03	3.52
	Potash (K_2O) ...	0.36	0.17	0.03	4.15
	Phosphoric acid (P_2O_5) ...	0.14	0.07	0.01	1.55
Green tops ...	Ash ...	6.61	1.12	0.13	—
	Nitrogen (N) ...	0.63	0.11	0.01	—
	Calcium (CaO) ...	0.21	0.03	0.004	3.17
	Magnesium (MgO) ...	0.49	0.09	0.01	7.49
	Potash (K_2O) ...	2.11	0.36	0.04	31.84
	Phosphoric acid (P_2O_5) ...	0.28	0.05	0.006	4.31
Bagasse ...	Ash ...	1.96	0.78	0.22	—
	Nitrogen (N) ...	0.21	0.08	0.02	—
	Calcium (CaO) ...	0.06	0.02	0.01	3.31
	Magnesium (MgO) ...	0.21	0.09	0.02	10.71
	Potash (K_2O) ...	0.20	0.08	0.03	10.46
	Phosphoric acid (P_2O_5) ...	0.06	0.02	0.007	3.06
Juice ...	Ash ...	—	0.37	0.15	—
	Nitrogen (N) ...	—	0.03	0.01	—
	Calcium (CaO) ...	—	0.03	0.01	8.11
	Magnesium (MgO) ...	—	0.09	0.04	24.32
	Potash (K_2O) ...	—	0.09	0.04	24.32
	Phosphoric acid (P_2O_5) ...	—	0.02	0.01	5.40

TABLE VII.—**Co.281, Field E_1** (from unfertilised control plot).

Section of cane plant analysed.	Ingredient.	% oven dry material.	% green or wet material.	% total cane plant.	% ash.
Green leaves and trash	Ash ...	9.16	4.79	0.98	—
	Nitrogen (N) ...	0.41	0.21	0.04	—
	Calcium (CaO) ...	0.52	0.28	0.06	5.73
	Magnesium (MgO) ...	0.30	0.16	0.03	3.27
	Potash (K_2O) ...	0.44	0.23	0.05	4.80
	Phosphoric acid (P_2O_5) ...	0.15	0.08	0.02	1.64
Green tops ...	Ash ...	7.99	1.33	0.17	—
	Nitrogen (N) ...	0.49	0.08	0.01	—
	Calcium (CaO) ...	0.25	0.04	0.005	3.06
	Magnesium (MgO) ...	0.42	0.07	0.01	5.26
	Potash (K_2O) ...	2.44	0.40	0.05	30.47
	Phosphoric acid (P_2O_5) ...	0.31	0.05	0.007	3.87

TABLE VII.—*continued.*

Section of cane plant analysed.	Ingredient.	% oven dry material.	% green or wet material.	% total cane plant.	% ash.
Bagasse	Ash	1.72	0.80	0.22	—
	Nitrogen (N)	0.14	0.06	0.02	—
	Calcium (CaO)	0.06	0.03	0.01	3.49
	Magnesium (MgO)...	0.13	0.06	0.02	7.85
	Potash (K_2O)	0.18	0.08	0.02	10.46
	Phosphoric acid (P_2O_5)...	0.06	0.03	0.008	3.49
Juice	Ash	—	0.40	0.16	—
	Nitrogen (N)	—	0.02	0.01	—
	Calcium (CaO)	—	0.02	0.01	5.00
	Magnesium (MgO)...	—	0.07	0.03	17.50
	Potash (K_2O)	—	0.08	0.03	20.00
	Phosphoric acid (P_2O_5)...	—	0.03	0.01	7.50

TABLE VIII.—**Co.290, Field R_1** (for fertiliser treatment see Table I.).

Section of cane plant analysed.	Ingredient.	% oven dry material.	% green or wet material.	% total cane plant.	% ash.
Green leaves and trash	Ash	8.47	5.03	1.02	—
	Nitrogen (N)	0.41	0.24	0.05	—
	Calcium (CaO)	0.49	0.30	0.06	5.72
	Magnesium (MgO)...	0.33	0.20	0.04	3.83
	Potash (K_2O)	0.27	0.16	0.03	3.13
	Phosphoric acid (P_2O_5)...	0.13	0.08	0.02	1.53
Green tops	Ash	6.55	1.13	0.12	—
	Nitrogen (N)	0.65	0.11	0.01	—
	Calcium (CaO)	0.21	0.03	0.004	3.20
	Magnesium (MgO)...	0.61	0.10	0.01	9.31
	Potash (K_2O)	1.72	0.29	0.03	26.33
	Phosphoric acid (P_2O_5)...	0.29	0.05	0.005	4.43
Bagasse	Ash	1.89	0.77	0.25	—
	Nitrogen (N)	0.20	0.08	0.03	—
	Calcium (CaO)	0.07	0.03	0.01	3.96
	Magnesium (MgO)...	0.25	0.11	0.03	13.49
	Potash (K_2O)	0.15	0.06	0.02	8.20
	Phosphoric acid (P_2O_5)...	0.09	0.04	0.01	4.76
Juice	Ash	—	0.37	0.14	—
	Nitrogen (N)	—	0.02	0.01	—
	Calcium (CaO)	—	0.03	0.01	8.11
	Magnesium (MgO)...	—	0.11	0.04	29.72
	Potash (K_2O)	—	0.05	0.02	13.51
	Phosphoric acid (P_2O_5)...	—	0.02	0.01	5.40

TABLE IX.—**Co.281, Field B_1.**

Section of cane plant analysed.	Ingredient.	% oven dry material.	% green or wet material.	% total cane plant.	% ash.
Green leaves and trash	Ash	5.83	3.32	0.68	—
	Nitrogen (N)	0.45	0.26	0.05	—
	Calcium (CaO)	0.30	0.17	0.03	5.14
	Magnesium (MgO)	0.20	0.12	0.02	3.43
	Potash (K_2O)	0.38	0.22	0.04	6.43
	Phosphoric acid (P_2O_5)	0.16	0.09	0.02	2.83
Green tops	Ash	6.93	1.09	0.13	—
	Nitrogen (N)	0.64	0.10	0.01	—
	Calcium (CaO)	0.08	0.01	0.002	1.15
	Magnesium (MgO)	0.30	0.05	0.005	4.33
	Potash (K_2O)	2.87	0.45	0.05	41.42
	Phosphoric acid (P_2O_5)	0.39	0.06	0.007	5.70
Bagasse	Ash	1.62	0.72	0.20	—
	Nitrogen (N)	0.20	0.09	0.02	—
	Calcium (CaO)	0.06	0.03	0.01	3.70
	Magnesium (MgO)	0.14	0.06	0.02	8.64
	Potash (K_2O)	0.27	0.12	0.03	16.67
	Phosphoric acid (P_2O_5)	0.16	0.07	0.02	9.88
Juice	Ash	—	0.41	0.16	—
	Nitrogen (N)	—	0.03	0.01	—
	Calcium (CaO)	—	0.01	0.003	1.83
	Magnesium (MgO)	—	0.05	0.02	12.19
	Potash (K_2O)	—	0.11	0.04	26.83
	Phosphoric acid (P_2O_5)	—	0.06	0.02	14.63

TABLE X.—**Co.290, Field B_1.**

Section of cane plant analysed.	Ingredient.	% oven dry material.	% green or wet material.	% total cane plant.	% ash.
Green leaves and trash	Ash	8.03	4.29	0.94	—
	Nitrogen (N)	0.49	0.26	0.06	—
	Calcium (CaO)	0.47	0.25	0.05	5.86
	Magnesium (MgO)	0.25	0.13	0.03	3.11
	Potash (K_2O)	0.31	0.17	0.04	3.92
	Phosphoric acid (P_2O_5)	0.20	0.11	0.02	2.49
Green tops	Ash	7.52	1.12	0.11	—
	Nitrogen (N)	0.69	0.10	0.01	—
	Calcium (CaO)	0.13	0.02	0.002	1.79
	Magnesium (MgO)	0.52	0.08	0.01	6.84
	Potash (K_2O)	3.03	0.45	0.04	40.36
	Phosphoric acid (P_2O_5)	0.41	0.06	0.006	5.45

TABLE X.—*continued.*

Section of cane plant analysed.	Ingredient.	% oven dry material.	% green or wet material.	% total cane plant.	% ash.
Bagasse	Ash	1.82	0.72	0.22	—
	Nitrogen (N)	0.20	0.08	0.02	—
	Calcium (CaO)	0.06	0.02	0.01	3.30
	Magnesium (MgO)...	0.22	0.09	0.03	11.81
	Potash (K_2O)	0.21	0.08	0.02	11.54
	Phosphoric acid (P_2O_5)...	0.14	0.06	0.017	7.96
Juice	Ash	—	0.46	0.17	—
	Nitrogen (N)	—	0.02	0.01	—
	Calcium (CaO)	—	0.02	0.01	4.35
	Magnesium (MgO)...	—	0.09	0.03	19.57
	Potash (K_2O)	—	0.10	0.04	20.65
	Phosphoric acid (P_2O_5)...	—	0.04	0.015	8.70

TABLE XI.—**Co.301, Field B_1.**

Section of cane plant analysed.	Ingredient.	% oven dry material.	% green or wet material.	% total cane plant.	% ash.
Green leaves and trash	Ash	6.78	3.58	0.89	—
	Nitrogen (N)	0.44	0.23	0.06	—
	Calcium (CaO)	0.30	0.16	0.04	4.49
	Magnesium (MgO)...	0.20	0.11	0.03	2.87
	Potash (K_2O)	0.40	0.22	0.06	5.97
	Phosphoric acid (P_2O_5)...	0.17	0.09	0.02	2.51
Green tops	Ash	7.76	1.02	0.16	—
	Nitrogen (N)	0.64	0.08	0.01	—
	Calcium (CaO)	0.09	0.01	0.002	1.16
	Magnesium (MgO)...	0.33	0.04	0.01	4.25
	Potash (K_2O)	2.70	0.35	0.06	34.79
	Phosphoric acid (P_2O_5)...	0.54	0.07	0.01	6.96
Bagasse	Ash	1.47	0.61	0.16	—
	Nitrogen (N)	0.20	0.08	0.02	—
	Calcium (CaO)	0.03	0.01	0.002	1.70
	Magnesium (MgO)...	0.14	0.06	0.014	9.18
	Potash (K_2O)	0.22	0.09	0.02	15.30
	Phosphoric acid (P_2O_5)...	0.17	0.07	0.018	11.56
Juice	Ash	—	0.34	0.12	—
	Nitrogen (N)	—	0.02	0.01	—
	Calcium (CaO)	—	0.01	0.002	1.76
	Magnesium (MgO)...	—	0.05	0.02	13.23
	Potash (K_2O)	—	0.07	0.02	20.59
	Phosphoric acid (P_2O_5)...	—	0.06	0.02	17.65

TABLE XII.—**Co.290, Field A_1** (control).

Section of cane plant analysed.	Ingredient.	% oven dry material.	% green or wet material.	% total cane plant.	% ash.
Green leaves and trash	Ash	7.44	4.69	0.91	—
	Nitrogen (N)	0.47	0.30	0.06	—
	Calcium (CaO)	0.42	0.26	0.05	5.64
	Magnesium (MgO)...	0.32	0.21	0.04	4.30
	Potash (K_2O)	0.25	0.16	0.03	3.36
	Phosphoric acid (P_2O_5)...	0.19	0.12	0.02	2.55
Green tops	Ash	6.52	1.09	0.12	—
	Nitrogen (N)	0.67	0.11	0.01	—
	Calcium (CaO)	0.14	0.02	0.002	2.22
	Magnesium (MgO)...	0.61	0.10	0.01	9.35
	Potash (K_2O)	1.93	0.32	0.03	29.60
	Phosphoric acid (P_2O_5)...	0.47	0.08	0.008	7.13
Bagasse	Ash	1.64	0.66	0.21	—
	Nitrogen (N)	0.19	0.08	0.02	—
	Calcium (CaO)	0.04	0.02	0.01	2.74
	Magnesium (MgO)...	0.23	0.10	0.03	14.02
	Potash (K_2O)	0.12	0.05	0.02	7.31
	Phosphoric acid (P_2O_5)...	0.14	0.06	0.018	8.84
Juice	Ash	—	0.36	0.14	—
	Nitrogen (N)	—	0.02	0.01	—
	Calcium (CaO)	—	0.03	0.01	6.94
	Magnesium (MgO)...	—	0.10	0.04	27.78
	Potash (K_2O)	—	0.04	0.01	11.11
	Phosphoric acid (P_2O_5)...	—	0.03	0.01	8.33

TABLE XIII.—**Co.290, Field A_1** (fertilised).

Section of cane plant analysed.	Ingredient.	% oven dry material.	% green or wet material.	% total cane plant.	% ash.
Green leaves and trash	Ash	8.07	4.36	0.97	—
	Nitrogen (N)	0.50	0.27	0.06	—
	Calcium (CaO)	0.50	0.27	0.06	6.26
	Magnesium (MgO)...	0.33	0.18	0.04	4.15
	Potash (K_2O)	0.20	0.11	0.02	2.54
	Phosphoric acid (P_2O_5)...	0.20	0.11	0.02	2.48
Green tops	Ash	6.66	1.10	0.11	—
	Nitrogen (N)	0.77	0.13	0.01	—
	Calcium (CaO)	0.13	0.02	0.002	2.02
	Magnesium (MgO)...	0.64	0.10	0.01	9.61
	Potash (K_2O)	2.01	0.33	0.03	30.25
	Phosphoric acid (P_2O_5)...	0.34	0.06	0.006	5.17

TABLE XIII.—*continued.*

Section of cane plant analysed.	Ingredient.	% oven dry material.	% green or wet material.	% total cane plant.	% ash.
Bagasse	Ash	1.76	0.70	0.21	—
	Nitrogen (N)	0.25	0.10	0.03	—
	Calcium (CaO)	0.08	0.03	0.01	4.54
	Magnesium (MgO)...	0.26	0.10	0.03	14.48
	Potash (K_2O)	0.16	0.06	0.02	8.80
	Phosphoric acid (P_2O_5)...	0.10	0.04	0.012	5.68
Juice	Ash	—	0.38	0.14	—
	Nitrogen (N)	—	0.03	0.01	—
	Calcium (CaO)	—	0.03	0.01	7.89
	Magnesium (MgO)...	—	0.10	0.04	26.31
	Potash (K_2O)	—	0.06	0.02	15.79
	Phosphoric acid (P_2O_5)...	—	0.02	0.007	5.26

Summarising the results of Tables VI. to XIII., the elements are found to occur in the following order :—

Leaves and trash ... $N > CaO > K_2O > MgO > P_2O_5$.

Tops ... ... $K_2O > N > MgO > P_2O_5 > CaO$.

Bagasse ... ... $N - MgO - K_2O > P_2O_5 > CaO$.

Juice... ... ... $MgO > K_2O > P_2O_5 > N > CaO$.

Stalks ... ... $MgO > K_2O > N > P_2O_5 > CaO$.

Total cane plant ... $K_2O > MgO > N > CaO > P_2O_5$.

The following table represents the percentage results on the stalks (bagasse plus juice) per cent. total cane plant and on the total cane plant :—

TABLE XIV.

Section of cane plant analysed.	Ingredient.	Variety and Field.							
		Co.290. E_1	Co.281. E_1	Co.290. R_1	Co.281. B_1	Co.290. B_1	Co.301. B_1	Co.290. (control) A_1	Co.290. (fertilised) A_1
Stalks ...	Ash	0.37	0.38	0.39	0.36	0.39	0.28	0.35	0.35
	Nitrogen (N)	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.04
	Calcium (CaO)	0.02	0.02	0.02	0.013	0.02	0.004	0.02	0.02
	Magnesium (MgO) ...	0.06	0.05	0.07	0.04	0.06	0.034	0.07	0.07
	Potash (K_2O)	0.07	0.05	0.04	0.07	0.06	0.04	0.03	0.04
	Phosphoric acid (P_2O_5)	0.017	0.018	0.02	0.04	0.032	0.038	0.028	0.019
Total cane plant	Ash	1.33	1.53	1.53	1.17	1.44	1.33	1.38	1.43
	Nitrogen (N)	0.09	0.08	0.10	0.09	0.10	0.10	0.10	0.11
	Calcium (CaO)	0:06	0.09	0.08	0.05	0.07	0.05	0.07	0.08
	Magnesium (MgO) ...	0.10	0.09	0.12	0.07	0.10	0.07	0.12	0.12
	Potash (K_2O)	0.14	0.15	0.10	0.16	0.14	0.16	0.09	0.09
	Phosphoric acid (P_2O_5)	0.03	0.05	0.05	0.07	0.06	0.07	0.06	0.05

To render these figures of further interest it is necessary to convert them to lbs. per acre of cane. This raises the question, are we justified in assuming that the ingredients will not change by the time the crop has matured to the assumed tonnage. As was stated earlier in this paper, there is very little change in the mineral composition after about twelve months, the major portion having been absorbed by the time the cane has reached this age. The youngest of the canes analysed in this series is fifteen months old, and we may in consequence safely assume that the increase in percentage of the total cane plant will not change much, though the total elements absorbed from the soil will naturally have increased in proportion to the increase in the crop.

Table XV. below represents the results of Table XIV. calculated as lbs. per acre, the assumption being that an acre will produce a 30-ton crop of stalks (43-ton crop of total cane plant):

TABLE XV.

Section of cane plant analysed.	Ingredient.	Variety and Field.							
		Co.290. E_1	Co.281. E_1	Co.290. R_1	Co.281. B_1	Co.290. B_1	Co.301. B_1	Co.290. (control) A_1	Co.290. (fertilised) A_1
Stalks ...	Ash	318	327	335	310	335	241	301	301
	Nitrogen (N)	26	26	34	26	26	26	26	34
	Calcium (CaO)	·17	17	17	11	17	3.4	17	17
	Magnesium (MgO) ...	52	43	60	34	52	29	60	60
	Potash (K_2O)	60	43	34	60	52	34	26	34
	Phosphoric acid (P_2O_5)	15	15	17	34	28	33	24	16
Total cane plant	Ash	1144	1316	1316	1006	1238	1144	1187	1230
	Nitrogen (N)	77	69	86	77	86	86	86	95
	Calcium (CaO)	52	77	69	43	60	43	60	69
	Magnesium (MgO) ...	86	77	103	60	86	60	103	103
	Potash (K_2O)	120	129	86	138	120	138	77	77
	Phosphoric acid (P_2O_5)	26	43	43	60	52	60	52	43

Before any remarks can be made upon these figures it will be necessary to convert them to their equivalents in lbs. of fertilisers. The results are given in Table XVI. below:—

TABLE XVI.

Section of cane plant analysed.	Ingredient.	Variety and Field.							
		Co.290. E_1	Co.281. E_1	Co.290. R_1	Co.281. B_1	Co.290. B_1	Co.301. B_1	Co.290. (control) A_1	Co.290. (fertilised) A_1
Stalks ...	Whale guano (10% N) ... ... }	260	260	340	260	260	260	260	340
	Sulphate of ammonia (21% N) }	124	124	162	124	124	124	124	162
	Nitrate of soda (15.5% N) ... }	168	168	219	168	168	168	168	219
	Limestone (50% CaO)	34	34	34	22	34	6.8	34	34
	Muriate of potash (60% K_2O)	100	72	57	100	87	57	43	57
	Superphosphate (17% w.s.)...	88	88	100	200	165	194	141	94

TABLE XVI.—*continued*

Section of cane plant analysed.	Ingredient.	Variety and Field. Co.290. E_1	Co.281. E_1	Co.290. R_1	Co.281. B_1	Co.290. B_1	Co.301. B_1	Co.290. (control) A_1	Co.290. (fertilised) A_1
Total cane plant	Whale guano (10%)	770	690	860	770	860	860	860	950
	Sulphate of ammonia (21% N)	376	328	409	367	409	409	409	452
	Nitrate of soda (15.5% N) ...	497	445	555	497	555	555	555	613
	Limestone (50% CaO)	104	154	138	86	120	86	120	138
	Muriate of potash (60% K_2O)	200	215	144	230	200	230	129	129
	Superphosphate (17% w.s.)...	152	253	253	353	306	353	306	253

Finally, in Table XVII. below are given the costs per acre based on the standard prices of the fertilisers :—

TABLE XVII.

Section of cane plant.	Fertiliser.	Average lbs. per acre found in plant.	Cost of fertiliser per acre.
Stalks ...	Whale guano	280	27/4
	Sulphate of ammonia ...	134	10/9
	Nitrate of soda	181	15/10
	Limestone	29	–/3
	Muriate of potash	72	7/3
	Superphosphate	134	3/10
Total cane plant.	Whale guano	828	80/9
	Sulphate of ammonia ...	394	31/9
	Nitrate of soda	534	46/9
	Limestone	118	1/2
	Muriate of potash	185	18/8
	Superphosphate	279	8/0

Discussion of Results.

From these figures it will be noticed that more than one pound's worth of mixed fertiliser is taken from the field per acre of cane (30 tons). Actually a great quantity of the nitrogen further goes to waste in the leaves and tops lying on the field after cutting, as microbiological activities require that there should be a certain balance of carbon to nitrogen permanently in the soil, roughly a ratio to twelve of one. Practically all the nitrogen goes to waste in burning.

If one cares to speculate one can also draw the conclusion from Table XVII. that the agricultural section of the Industry despatches to the factories every eighteen months or so the equivalent in plant-food of 5,000 tons of muriate of potash and 10,000 tons of superphosphate. The amounts actually absorbed by the cane are about double the quantities. These figures must not be interpreted too literally, as they are based only on a single series of analyses. Besides this, it is not yet established whether a balance-sheet drawn up on the results of chemical analyses such as those in this paper is of really great practical importance.

Various writers think that the feeding power of sugar cane is a good indication of the fertiliser requirement. Thus Locsin[13] states that an approximate standard can be obtained for each variety that will serve as a useful guide to the fertiliser requirement of the soil. Moir[14] states that what we should be more vitally interested in is what are we taking out of the soil and not returning, than information about maximum yields.

One cannot escape the fact that quantities of fertilisers are being transported from the fields (much is returned in factory waste, but not necessarily to the same fields), and one may reasonably expect the farmer to ask: "What happens to my fertiliser in the long run?"

On the basis that a plant crop receives 150 lbs. ammonium sulphate and a ratoon crop 60 lbs., which is more than many farmers care to apply, we can say that actually all the nitrogen applied is removed from the field in the stalks. On the basis of 80 lbs. muriate of potash for plant and 40 lbs. for each ratoon, our figures again show that more than we apply is taken away in the stalks. In the case of superphosphate, which is applied as an average dressing of 600 lbs. for plant and 300 lbs. for each ratoon, the case is different. Only one-third approximately is transported from the fields, the remainder it is believed becoming not readily available to the plant.

The best that experimental field trials can do, however scientifically laid out and interpreted, is to inform us what applications give best results under certain soil and plant conditions. As to whether the cane plant actually requires for its metabolism such quantities, as to what goes to waste to produce those beneficial results, they can make no definite statement.

Of course, it may equally be argued that an analysis of the plant material cannot be used experimentally to ascertain the optimum fertiliser application. No such claims are made. The analysis of plant material can be a guide to the fertiliser requirement of the plant. But as stated in the beginning, this paper had a two-fold object—to confirm our earlier work and to extend our knowledge in this sphere of experimental work. As regards the first, we can say that, within the limits of variation taking place, seasonal and varietal, our results are borne out largely by the earlier work. The findings of workers in other countries show also a similarity of results.

Concerning the second object, it is felt that the amount of work done may not be entirely adequate to the conclusions drawn. The writers are fully aware of this and regard the present paper still in the nature of an introduction to the subject. The study otherwise is too wide, and a clearer understanding of the plant-food requirements of sugar cane could only be obtained by considerably further co-operative work along lines somewhat similar to those we have outlined in this paper.

Summary.

A study has been made of the plant-food uptake of eight Co. canes.

No significant difference was found in the mineral constituents of the ash of these varieties, excepting that Co.301 was noticeably lower in calcium in the stalks.

A very high accumulation of potash is to be noted in the tops of all varieties.

Magnesium is well distributed throughout the plant, being first in quantity in the juice and stalks.

Roughly 40 per cent. of the juice ash is composed of potash and magnesium. The same can be said of the tops.

Heavy application of nitrogenous fertiliser appears to increase the amounts in all parts of the plant.

It is estimated that more than all the fertiliser added to a crop of cane (with the exception of superphosphate) is removed from the field in the stalks.

It is suggested that an analysis of the plant material may be a useful guide to fertiliser requirements, but considerably further study is required.

References.

1 Proc. S.Afr. Sug. Tec. Assn. 1933, 37.
2 Ind. and Eng. Chem. 1923, **15,** 164.
3 Int. Sug. J. 1923, **25,** 478.
4 Rpt. Assn. Haw. Sug. Tech. 1930, 175.
5 Rpt. Dept. Sci. and Agr., Barbados, 1928-1929, 62.
6 Rpt. Dept. Sci. and Agr., Barbados, 1929-1930, 76.
7 J. Amer. Soc. Agr. 1928, **20,** 778.
8 Rpt. Assn. Haw. Sug. Tech. 1929, 199.
9 Archief voor de Suikerind. in Ned.-Indië, 1934, **10.**
10 Haw. Pl. Rec. 1933, 197.
11 Archief voor de Suikerind. in Ned.-Indië, 1934, **10.**
12 Sugar Bulletin 1937, **16,** 2.
13 Sugar News 1931, **12,** 620.
14 Rpt. Assn. Haw. Sug. Tech. 1930, 175.

South African Sugar Association,
Experiment Station,
Mount Edgecombe,
March, 1938.

The PRESIDENT: In opening the discussion pointed out the number of analyses in the paper, and the amount of work involved. He stated that the high concentration of magnesium in the juice was contrary to his own findings.

Mr. BECHARD: Congratulating the writers, said that he was greatly sorry the paper had not reached his hands earlier, as there was much to be digested before one could really discuss it. He asked Mr. Beater if he could throw any light on the varietal absorption of phosphoric acid, or on the correlation between phosphoric acid in cane juice and fertilizer application.

Mr. W. A. CAMPBELL: In referring to the question of burning versus trashing asked Mr. Beater if he could say definitely whether burning was not more detrimental than trashing, as far as returning fertilizers to the field was concerned. He himself was inclined to believe that burning was harmful.

Dr. HEDLEY: In congratulating the writers drew attention to the vast amount of work involved in a paper of this nature. About 600 analyses were involved, as every estimation was done in duplicate. In passing, he drew the attention of members to the admirable way in which Mr. William Campbell attended the Congress meetings. He said it was encouraging to have one of the chiefs of the Industry taking such an interest in the work of the Technologists' Association.

Mr. DODDS: Drew attention to the importance of a paper of this type in correlating field experiment work with fertilizers. The new varieties were calling for new field experimental work. He referred also to the magnesium uptake, stating that it was a minor element which perhaps should not be lost sight of. We were inclined to concentrate too much on nitrogen, potash and phosphoric acid.

The PRESIDENT: Referring again to the magnesium figures said that magnesium passed through the molasses in sulphitation, while in carbonatation nearly all of it was taken away in the filter cake. Yet he found that the molasses from sulphitation contained twice as much potash as magnesium. He thus would not have expected to find magnesium higher than potash as this paper showed.

Dr. McMARTIN: Drew attention to the fact that for two reasons we could safely correlate plant analysis with fertilizer uptake. These were the possibility of (1) luxury consumption and (2) of the excess availability of plant food required to stimulate growth and which might not be found in the plant.

Mr. BEATER: In replying to the above discussion said that as far as Mr. Bechard's questions were concerned he himself had failed to find any correlation of phosphoric acid with varieties. He had also attempted to correlate fertilizer application with the uptake in the juice, but had hitherto not been able to arrive at anything.

In reply to Mr. Campbell he said he had not given consideration to burning versus trashing, but as far as the plant food problem was concerned he could not see any great disadvantage to burning. The only element lost was nitrogen. There was of course the other side of the question, namely the possible benefits of incorporating trash in the soil and the preservation of soil moisture by the trash layer. How these influenced plant food absorption he could not definitely say.

He stated in conclusion that the high magnesium content may be just a case of luxury consumption and should not be emphasised.

Mr. DU TOIT: Said that many overseas workers had also failed to correlate phosphoric acid with any variety. He said that the question of returning trash to the field would be dealt with in a paper on humus later.

The PRESIDENT: Thanked the writers and hoped that they would be able to continue their work.