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The Effect of Fertilizers on Sugarcane

By K. BUSHANAM, B. Sc Ag.,

The work reported in this paper was carried out at Coimbatore at the suggestion of Rao Bahadur B. Viswa Nath and the results provide information on the following points—Firstly an insight is obtained into the aspect of sugarcane nutrition under different fertilizer treatments as revealed in the final out-turn of cane and in the composition of the juice. Secondly from the agricultural aspect; answer and further research is indicated to the question of manurial treatment for crop increase consistent with quality of the juice. Thirdly from the utilisation aspect, indications are available in respect of increase in the actual sugar content of cane by fertilizer treatment and also on the effect on the other important factors like pH, fibre, etc. Fourthly light is thrown on the question of how far the sufficiency or deficiency of the major plant nutrients in the soil is reflected in the composition of the juice of the plant.

Materials and Methods. The variety of cane Co 213 was selected because it was, and is a cosmopolitan cane in the sense that it thrives under a variety of soil and climatic conditions, and information on different aspects of the cane is available in different parts of India. It was grown on the field scale in the New Permanent Manurial plots of the Central Farm, Coimbatore.

The following are the different fertilizer treatments whereby the effect of the major fertilizer constituents (nitrogen, phosphorus and potash) individually and in combinations with one another have been studied. Included in the series was a 'control' plot receiving 'no manure' and a 'cattle manure' plot receiving farmyard manure.

Thus the manurial treatments were :—

1.	No manure	(N. M.)	
2.	Nitrogen	(N)	N as Am. Sul, @ 1 cwt. acre
3.	Nitrogen + Potash	(N + K)	K. as Pot. Sul, @ 1 cwt. acre.
4	Nitrogen + Phosphoric Acid	(N + P)	P as super. @ 3 cwt. acre
5.	Nitrogen + Potash + Phosphoric Acid	(N + K + P)	C. M. as F. Y. M. @ 5 tons acre.
6.	Potash + Phosphoric acid	(K + P)	(For this cane crop 100 lbs. N/acre were applied).
7.	Potash	(K)	
8.	Phosphoric acid	(P)	
9.	Cattle Manure	(C. M.)	

There were three replications in each case i. e three sub-plots for cane harvest etc., and three separate determinations for every item of estimation.

The plots were under differential fertilizer treatments and cropping for fifteen seasons previous to the sugarcane experiments and the results of

partial fertilizer treatments have become sufficiently emphasised as to distinctly indicate the behaviour of a particular fertilizer constituent by itself and in combination or presence of others. The experiments in the field have thus much of the merit of the usual sand cultures without their obvious defects.

The following are the main lines of investigations.

Effect of different fertilizers on :—

1. Growth and yield (as revealed in the out-turn of cane, juice, and sugar, and also the average height and girth of cane and the number of canes per acre).

2. Organic composition (as revealed in the Brix, sucrose, and glucose contents of juice and also the co-efficient of purity, total titrable acidity, pH and nitrogen percentages of juice)

3. Mineral composition (as revealed in the total ash, and the individual ash constituents—SiO_2, K_2O, P_2O_5, CaO, MgO of juice and cane).

4. Fibre % of cane (which has a bearing on the c. c. s. 'commercial cane sugar' for factories).

Full data were collected and analyses were conducted for all these items and the results tabulated and discussed.

The methods of analyses adopted were those recommended by Spencer ("A hand-book for cane manufacturers and sugar chemists"), A. O. A. C. (Association of Official Agricultural Chemists), Browne ("Sugar analysis") and the "Association of Sugar Technologists in India" (Methods of Chl. control for cane factories and our refineries (referred to in 18, 19, 20 and 21 at the end).

Discussion The yield of millable cane, that is, the tonnage, is the main consideration to the cultivator who wants to sell the produce as cane. For one who wants to sell the produce as 'canes for chewing', it is the number of canes per acre, the height and girth of cane that matter. From the point of view of the factory owner it is the sugar content of the cane and the values of certain other important factors like pH, ash, coefficient purity, glucose, fibre content, etc., that are of importance. An attempt is, therefore, made in the following pages to discuss the data from these points of view.

General. The following are the average figures for important items—(average of all the 27 sub-plots or estimations).

1. Growth and yield of cane—Average yield of millable cane/acre 62,640 lbs. or 27·97 tons.
   - » % extraction of juice 63·1
   - Average No. of canes per acre 48,374
   - » height of cane 60"
   - » girth of cane 2·94"
   - » No. of internodes per cane 16

II.	Organic composition of juice—Average	Brix	17·35
	»	sucrose % of juice	14·40
	»	glucose % of juice	0·69
	»	coefficient purity	83·3
	»	total titratable acidity	28·1
	»	pH	5·40
	»	Nitrogen % of juice	0·12
III.	Mineral composition of juice—Average	Ash % of juice	0·60540*
	»	SiO_2 % of juice	0·01494
	»	K_2O % »	0·23780
	»	P_2O_5 % »	0·03796
	»	CaO % »	0·02659
	»	MgO % »	0·05456

* Ash forms 0·6 % of cane juice ; and the following is the

Average composition of the ash.

Sand	2·5 %
Potash	39·3 %
Phosphoric acid	6·3 %
Lime	4·4 %
Magnesia	9·0 %

IV. Fibre % of cane 13·27

TABLE I. Effect of different fertilizers on yield and growth of cane.

Fertilizer treatments	Wt. of millable cane per acre.	% increase over N. M.	Number of canes per acre	% Extraction of juice	Av. height of cane (inches)	Av. girth of cane (inches)	Av. No. of internodes per cane
1. N.M.	16·85±0·28	...	39,600±1,039	61·9	48	2·90	15
2. N	22·35±2·62	32·6	45,360±1,965	62·9	50	2·89	15
3. N+K	28·29±3·20	67·9	47,040±6,240	64·3	56	2·87	16
4. N+P	23·50±4·41	39·4	42,093±4,750	53·4	55	3·12	15
5. N+P+K	30·40±1·45	80·4	50,880±6 850	64·1	64	2·95	17
6. K+P	32·70±0·64	94·0	55,560±1,406	65·5	66	2·93	16
7. K	31·50±1·73	87·0	53,160±3,975	65·8	65	2·92	17
8. P	32·09±3·49	90·5	48,000± 693	65·2	65	2·87	15
9. C.M.	34·05±3·09	102·1	53,670±5,130	64·9	69	3·05	17

Yield of cane. The maximum yield of millable cane (34 tons) is obtained by the application of cattle manure, and this is 102 % over no manure yield. The next highest yield (32·7 tons) is from application of mixture of potash and phosphoric acid. On the whole each treatment has given significantly increased yields over 'no manure' treatment. The increases are very high but this is not surprising having regard to the fact that 'no manure' plot was being cropped for several seasons without any manure.

The application of nitrogen alone, increased yield by 32·6 % over that of 'no manure' plot. Addition of potash to nitrogen contributed to a further increase of 35·3 %, whereas the addition of phosphoric acid to nitrogen contributed to a still further increase of 6·8 % over and above

nitrogen manure. Simultaneous addition of potash and phosphoric acid to nitrogen increased the yield over that of 'no manure' by 80 4 %. Application of potassic manure alone gave an increased yield of 87 % over 'no manure' and application of phosphatic manure alone contributed to 90 5 % increased yield over 'no manure', whereas simultaneous application of potash and phosphoric acid contributed to 94 % increase over no manure.

Regarding the *% extraction of juice*, it is the maximum in potash, potash + phosphoric acid, and phosphoric acid treatments (in the decreasing order of merit). For some reason the % extraction is markedly low in nitrogen + phosphoric acid plot (53·4%) whereas the average figure is 63·1 %. It is interesting to note that (i) though potash as manure, is not indicated generally for other crops, it did fairly well with cane, (ii) that the potash + phosphoric acid treatment gave fairly high tonnage and high % extraction of juice.

The number of canes per acre under the different treatments were as follows:—Potash + phosphoric acid treatment gave the maximum number of canes (55,560) per acre and the cattle manure and 'potash alone' treatments occupy the second and third ranks.

The average height of cane was the maximum (09') in cattle manure plot; the second and third ranks were occupied by potash + phosphoric acid and potash plots.

The average girth of cane was the maximum (3·12") in nitrogen + phosphoric acid plot; and cattle manure, and nitrogen + potash + phosphoric acid plots occupied the second and third ranks. There was not much difference in *the average number of internodes* per cane. It varied from 15 to 17 per cane.

If *the average weight of cane* was considered, it was the highest in phosphoric acid, cattle manure, and nitrogen + potash plots. The following was the descending order of the treatments:—

Average weight of cane (lbs)

P.	1 50	K	1 33
C. M.	1·42	K + P	1·32
N + K	1·35	N + P	1 25
N + K + P	1·34	N.	1·10
		N. M.	0 95

TABLE II. Effect of different fertilizers on the composition of sugarcane juice.

Manurial treatments	Brix	Sucrose % of juice	Glucose % of juice	Co-efficient purity	Total titrable acidity	pH	Nitrogen % of juice
1. N. M.	17·74±0·24	15·17±0·26	0·60	85 5	28·7	5 43	0·16
2. N	18·00±0 17	15·05±0·15	0·57	83 6	32·0	5 46	0·16
3. N + K	17 47±0·21	14 67±0·25	0·65	84 0	29·3	5·48	0·13
4. N + P	16 91±0·19	14·57±0·23	0·77	86·2	28·7	5·29	0·14
5. N + K + P	17·27±0·20	14·80±0 17	0 67	85 7	28·3	5·27	0·11
6. K + P	17 33±0·30	14·30±0·09	0·63	82 5	27·0	5 41	0 09
7. K	17 45±0·33	14·24±0·72	0 62	81·7	24 3	5·50	0·10
8. P	16·69±0·00	13·46±0·03	0 94	80 7	26·3	5·26	0·09
9. C. M.	17·29±0·11	13·30±0 09	0·73	80·0	28·7	5 49	0·10

It looks as though it is not possible to increase the Brix or sucrose contents of cane by manuring, and that the aim should be at greater tonnage. The results show, if anything, that sugar content is adversely affected by manuring, the juice of 'no manure' plot containing the maximum % of sucrose.

Brix. Nitrogen seems to increase lightly the brix value; nitrogen + potash + phosphoric acid keeps it at the same level as cattle manure: phosphoric acid, and nitrogen + phosphoric acid slightly depress it.

Sucrose. It is the maximum in the case of 'no manure' and nitrogen, potassic and phosphatic manures applied singly or combined, and cattle manure decreases sucrose %; nitrogen + potash + phosphoric acid, nitrogen + potash and nitrogen + phosphoric acid are slightly better than these, but next to nitrogen only.

Glucose. High glucose content of cane, as high ash content, is not desirable from the point of view of sugar technology; and the quality of juice is inversely related to the amount of glucose. The differences in the glucose contents of canes from different treatments are too small to merit detailed consideration.

Co-efficient purity varies with Brix and sucrose and it is not very favourably altered by manuring. Of the various treatments nitrogen + phosphoric acid, nitrogen + potash + phosphoric acid and 'no manure' gave comparatively purer juices.

The *total titratable acidity* and the *pH of cane juice* are not co-variant. Nitrogenous manure slightly increases the total titratable acidity, potash decreases, while cattle manure, and nitrogen + potash + phosphoric acid keep it at the same level as 'no manure'. The decrease due to potash + phosphoric acid is not so marked as that due to either potash or phosphoric acid.

Regarding the pH values of the juice, phosphoric acid generally diminishes the value. Application of phosphoric acid along with nitrogen also diminishes pH. There is not much difference between nitrogen or 'no manure' but potassic manure increases pH.

Nitrogen content of cane juice. The nitrogen content of juices from plots receiving nitrogen alone or in combination with other manures, is generally higher than that for the rest of the plots; and application of potash + phosphoric acid distinctly reduces the nitrogen % of cane juice.

TABLE III. Effect of different fertilizers on the mineral content of cane juice

Manurial Treatments	Ash % of juice	SiO_2 % of juice	K_2O % of juice	P_2O_5 % of juice	CaO % of juice	MgO % of juice
1. N. M.	0·5651±0·0131	0·01164	0·2180	0·02862	0·02248	0·06052
2. N	0 5216±0 0209	0·01124	0·1864	0 02305	0 02470	0·05950
3. N+K	0 5973±0·0049	0 01326	0·2490	0·02637	0·02448	0·05664
4. N+P	0·5268±0·0070	0·00940	0·1951	0·04732	0·02770	0·05609
5. N+K+P	0·5930±0·0197	0·01438	0 2492	0 04581	0·03170	0 05340
6. K+P	0·6519±0·0099	0·01307	0·2742	0·05470	0·02768	0·05002
7. K	0 6178±0 0121	0·01344	0 2722	0 02255	0·02376	0·04983
8. P	0·6337±0·0039	0·01888	0·2309	0 05251	0 03069	0 05481
9. C. M	0 7215±0·0328	0 02917	0 2649	0·04375	0·02629	0·05027

Ash. There are marked differences between the ash contents of differently manured juices. Differences between nitrogen, nitrogen + phosphoric acid or 'no manure' are not significant; application of nitrogenous manures reduces the ash content of cane juice. Application of potassic or phosphatic manures alone or in combinations increase the mineral content. Nitrogen + potash, and nitrogen + potash + phosphoric acid also increase it, but not to the same extent as the former.

Potash. The nitrogen and K_2O contents of cane juice are negatively correlated ; and the K_2O and ash contents are intimately related because K_2O forms 40% of the ash. The differences between cattle manure and no manure or between nitrogen + potash + phosphoric acid and 'no manure' are significant; but the difference between cattle manure and nitrogen + potash + phosphoric acid is not. The K_2O % of juice is distinctly more wherever potash is applied i. e , in nitrogen + potash + phosphoric acid nitrogen + potash, cattle manure, potash, and potash + phosphoric acid, plots Cattle manure and potash + phosphoric acid manures increase the K_2O content greatly while nitrogenous manure decreases it.

Phosphoric acid. The differences between cattle manure and 'no manure' or nitrogen + potash + phosphoric acid and 'no manure' are significant, but the difference between cattle manure and nitrogen + potash + phosphoric acid is not. Potash, nitrogen, and nitrogen + potash plot juices contain less P_2O_5 than 'no manure' are, while juices from other plots contain more. Wherever there is application of phosphoric acid there is an increase in the P_2O_5 content of cane juice, but the addition of Nitrogen decreases it.

Lime. The juice from nitrogen + potash + phosphoric acid plot contains the maximum amount of lime. Phosphoric acid plot is next in order. The lime content of juice is not increased materially by nitrogenous or potassic manures, but the application of phosphatic manures, alone or in combination with others, increase it.

Magnesia. Content is the maximum in the 'no manure' juice, and least in the case of Potash. Application of nitrogen + potash + phosphoric acid reduces the amount of MgO in cane juice.

On the whole CaO and MgO contents appear to be more wherever Potash is wanting

The Mgo content of cane juice is nearly double that of CaO when generally the reverse is the case with plant materials.

Effect of different fertilizers on the fibre content of cane. The fibre contents of cane as effected by various treatments are as follows :—

TABLE IV

Manurial treatments (in descending order of fibre content).	fibre % of cane
N + P.	16·47 ±4 35
N	13·77 ±0 25
K	13·34 ±0·32
N. M.	13 297±0·34
P.	13·16 ±0·37
K + P	12·98 ±0·06
N + K	12 503±0 17
C. M.	12·497±0·68
N + K + P	11·48 ±0·34

The average fibre content of cane is 13·27 Canes from potash, phosphoric acid and nitrogen do not differ much in their fibre content from those of the 'no manure' plot. Nitrogen + potash, cattle manure, potash + phosphoric acid, and nitrogen + potash + phosphoric acid reduce the fibre % of cane. The value in N + P plot is abnormally high, and it is the least in nitrogen + potash + phosphoric acid plot.

Conclusions. The average out-turn of cane (Co 213 variety) is 27·97 tons per acre; the % extraction 63.

The juice contained about 16 to 18 % of total solids (Brix); 13 to 15 % sucrose, 0·57 to 0·94 % glucose, and gave a coefficient purity 80 to 86.

The pH value of the juice is about 5·26 to 5·50 which does not alter much with the fertilizer treatment given to the crop.

The total nitrogen and ash contents of the juice are on an average 0·1 and 0·6 % respectively. K_2O forms about 40 % of the mineral matter of the cane juice, P_2O_5 about 6 %, lime 4·4 % and MgO 9·0 % and SiO_2 about 2·5 %. The MgO content of cane juice is nearly double that of lime content whereas generally the opposite is the case with plant materials.

The fibre % of the Co 213 cane is about 13·27 % and it is independent of the nutritional conditions given to the crop.

Of the various fertilizers tried, cattle manure gave the maximum out-turn of millable cane which is also statistically significant, a combination of potassium sulphate and super gave the next best results; and 'no manure' the least.

The % extraction of juice is not altered much by the manures.

The quality of the juice from 'no manure' and nitrogen plots was superior to that from other treatments. Phosphoric acid and cattle manure plots gave higher Brix values. The sucrose % and coefficient purity of the cane juice are not much altered by the fertilizers; the glucose % varied; its % in the juice is higher when phosphoric acid is applied to the cane. It is interesting to note that 'no manure' plot juice contained the highest % of sucrose and nitrogen plot occupied the second position. The juice from complete mineral manure and cattle manure plots are comparatively poor in sucrose.

The differences in most of the above cases are also statistically significant.

Effect of soil constituents on the composition of cane juice.

The following table shows the differences in N, K_2O, P_2O_5 and CaO contents of cane juice from plots receiving and not receiving these respective manures :-

TABLE V

N		N		K_2O				P_2O_5				CaO			
N Plots		No. N Plots		K Plots		No. K Plots		P Plots		No. P Plots		Ca Plots		No. Ca Plots	
N Manures	N% of juice	No. N Manures	N% of juice	K Manures	K_2O% of juice	No. K Manures	K_2O% of juice	P Manures	P_2O_5% of juice	No. P Manures	P_2O_5% of juice	Ca Manures	Ca0% of juice	No. Ca0 Manures	Ca0% of juice
N	0·1588	N M	0·1564	K	0·2722	N·M	0·2180	P	0 05251	N M	0·02862	P*	0·03066	N·M	0 02245
N+K	0·1324	K	0 0984	K+N	0·2490	N	0·1864	P+N	0·04732	N	0·02305	P+N	0 02770	N	0·02470
N+P	0·1362	P	0 0869	K+P	0·2742	P	0·2309	P+K	0·05470	K	0 02255	P+K	0·02768	K	0 02376
N+K+P	0·1137	K+P	0·0884	K+N+P	0 2442	N+P	0·1951	P+N+K	0·04581	N+K	0·02637	P+N+K	0 03170	N+K	0 02448
Average	0 1353		0·1075		0·2599		0 2076		0·04959		00·2515		0 02944		0·02386
=26% more in N. treated plots.				=25% more in K treated plots.				=97% more in P. treated plots.				=20% more in Ca. treated plots.			

* Super Phosphate i. e. cal. Phosphate.

* It is seen that the application of N, K, P or Ca manures resulted in an increase in the percentage of these constituents to the extent of .0 to 25 percent. The juice analysis data do not bear any relationship of the yields of canes from different plots.

* These findings are in agreement with those of workers in other countries who have dealt with them piecemeal. Vide Reference—(1), (2), (4), (5), (8), (12), (13), (14), (15), and (16).

The deficiency or otherwise of a plant nutrient (N, K, P or CaO) in the soil is more or less definitely indicated in the composition of the plant juice.

The nitrogen and ash percentages of the juice appear to be negatively correlated. The K_2O and ash contents of juice are closely related. The lime and magnesia contents also varied with the fertilizer treatments. Generally their percentages are less when potash percentage of the juice is higher, and vice versa.

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References.

1. Gilbert and Harden. (*Jr. Agri. Res.* **35**, 185—192, 1927).
2. Saint. *Intern. Sugar. Jr.* **33**, 68, 1931.
3. Saint. *Facts about sugar* **26**, 224, 1931.
4. C. L. Locsin. *Facts about sugar* **26**, 541, 1931.
5. L. A. Hurst and M. Mckaiz. *Sugar News.* **12**, 620—621, 1931.
6. Geerligs. *Cane Sugar & its manufacture.*
7. B. Viswa Nath. *Madras Agric. Stn. Jour.*
8. P. E. Turner. *Trop. Agri.* 9, 2, 44, 63, 1932.
9. Mukerji. *Sci. Rept of Imp. Inst. of Agl. Rec Pusa* 102, 1930—31.
10. A. H. Rosenfeld. *Facts about sugar* **27**, 10, 440, 1932.
11. Mollison and Leather. *Agl. Ledger. No.* 8, 1898.
12. Beauchamp. *Facts about sugar* **29**, 133, 1934.
13. *Intrn. sugar Jr.* **31**, 67, 1931.
14. *Intrn. sugar Jr.* 3,5 418, 1933.
15. C. F. Walton & A. A. Fort. *Facts about sugar* **27**, 10, 440. 1932.
16. Lyman. *Intrn. sugar Jr.* **33**, 28, 1931
17. S. African Sugar Technologists. Assocn. *Intrn. sugar Jr.* **33**. 296, 1931.
18. Assocn. of Offical Agl. Chemists (A. O. A. C.)
19. Sugar Technologists Assocn. in India "Method of Chl. control for cane Factories gur refineries".
20. Spencer. A hand book for cane manufactures & sugar Chemists.
21. Browne, Sugar analysis.
22. O. W. Wilcox Agrobiology.
23. Vaidyanathan. "Analysis of Manurial expts. in India I. C. A. R. publications volume I, II, III, 1933.