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EXPORTS OF MINERAL ELEMENTS IN THE CANE JUICES

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DETAILS OF THE EXPERIMENT

A set of eleven $3 \times 3 \times 3$ NPK factorial trials was laid out to study different aspects of the fertilization of sugar cane in Grande Terre. The following data were gathered over several years.

Initial soil analyses

At the time each trial was laid out, a composite sample of the surface soil for each of the twenty seven elementary plots was taken before manuring and pH, exchangeable potassium and total phosphorus were determined.

Foliar diagnosis

Two or three samplings of the tissue of the Top Visible Dewlap leaf lamina were taken between the third and seventh month in each plot and the percentages of N, P, K, Ca, Mg in the dry matter were determined.

Harvest results

The yield of cane per plot was obtained, samples of thirty whole cane stalks per plot were collected for the determination of the recoverable sucrose content, and sugar production in tons par hectare was calculated (Lemaire, 1961).

Mineral elements P, K, Ca, Mg in the juices

The juice sample collected for sucrose content was also used for the determination of the amount of mineral elements P, K, Ca, Mg entering the factory.

Final soil analyses

At the end of the cycle, comprising one plant cane and three or four ratoons, a second soil sample for each experimental plot was taken in order to determine pH, exchangeable potassium, total phosphorus.

All the individual plot data were analysed statistically by means of an IBM 704 computer at the C.N.R.S. (Centre National de la Recherche Scientifique) and the O.R.S.T.O.M. (Office de la Recherche Scientifique et Technique Outre Mer) by Charbonnel and van den Driessche (1961, 1964). The analysis of variance included the decomposition of the main effects and the two factor interactions. Partition of these into linear (l), quadratic (q), general (g) and additional (a) was adopted. For the complete interpretation of the tables, it is specified that, if the indices 0, 1 and 2 of the responses "y" indicate the levels, the linear component (l) of a main effect is represented by the difference $y_2 - y_0$, the quadratic (q) by the difference

$$\frac{y_0 + y_2}{2} - y_1,$$

the general (g) by the difference

$$\frac{y_1 + y_2}{2} - y_0$$

and the additional (a) by the difference $y_2 - y_1$ (Yates *et al.*, 1959).

Analytical work was done at the laboratory of the "Bureau des Sols des Antilles" according to analytical procedures developed by Gautheyrou and Gautheyrou (1960).

The trials are designated by the initials of the factory, the farm and the field chosen.

The trials SCC, BDC_1, BDC_2, GMC, GGM, SZB_1, SZB_2, MLV, BEG were laid out on heavy calcareous soils with montmorillonite in an area where the average yearly rainfall ranges from 1,200 to 1,500 mm. The trials BRJ and DPM were laid out in Grande-Terre too, but on soils with kaolinite and hydroxides.

The variety B.46364 was used in all the fields except for MLV and BEG where the variety B 49119 was planted. The manuring was done in one application, in the furrows at planting for plant canes and one month after harvesting for ratoons. The fertilizer treatments, which did not change during the experiment, consisted of the following:

Nitrogen – $N_1 = 60$, $N_2 = 120$, $N_3 = 180$ kg N/ha as sulphate of ammonia;
Phosphorus – $P_0 = 0$, $P_1 = 60$, $P_2 = 120$ kg P_2O_5/ha as di-calcium phosphate or triple superphosphate;
Potassium – $K_1 = 80$, $K_2 = 160$, $K_3 = 240$ kg K_2O/ha as muriate of potash.

PRESENTATION OF THE RESULTS

Numerous results may be drawn from such an experimentation. Only those refering to the influence of fertilization on the exports of mineral elements in the cane juices will be taken into account here after.

The results shown in the appended tables only refer to ratoon canes. The harvest year is indicated.

Table 1 – Harvest results

The simplified harvest results only include tons of canes per hectare (T.C. Ha), The type of the response (l, g, q, a) is indicated with the significant results at the 2.5% level.

TABLE I

Trials	Tons cane/hectare N_1	N_2	N_3	P_0	P_1	P_2	K_1	K_2	K_3
SCC									
1st Rat. 62	104	108	118 l	99	113	118 lg	99	116	116 lg
2nd Rat. 63	50	51	61 lga	49	54	59 lg	47	56	59 lg
3rd Rat. 64	67	81	86 lg	76	74	82 a	63	84	86 lqg
BDC 1									
1st Rat. 62	93	97	100	97	100	94	95	97	98
2nd Rat. 63	105	107	108	105	107	108	100	108	112 lg
3rd Rat. 64	82	87	88	87	84	87	81	88	89 lg
BDC 2									
1st Rat. 62	98	103	109 lg	103	103	103	99	104	107 lg
2nd Rat. 63	90	107	106 lg	101	102	101	98	98	107
3rd Rat. 64	76	80	84 lg	77	81	82	79	78	83
GMC									
1st Rat. 63	93	102	99 lqg	98	97	99	101	97	96
2nd Rat. 64	100	107	105 lqg	104	105	103	103	103	106
GGM									
1st Rat. 63	92	98	99 lg	96	99	94	92	98	99 lg
2nd Rat. 64	87	101	101 lg	95	97	95	92	97	98
SZB 1									
1st Rat. 63	84	98	102 lg	94	93	96	93	90	100
2nd Rat. 64	85	91	90	89	87	90	89	85	92 a
SZB 2									
1st Rat. 63	89	95	93	98	93	86 l	90	95	91
2nd Rat. 64									
MLV									
1st Rat. 64	108	120	121 lg	120	114	114	114	115	119
BEG	—	—	—	—	—	—	—	—	—
BRJ									
1st Rat. 63	56	70	76 lqga	68	64	70 qa	67	67	67
2nd Rat. 64	97	110	109 lg	106	103	107	99	109	108 g
DPM									
1st Rat. 64	123	150	154 lqg	146	141	141	139	141	148
Mean	89	98	100	95	95	96	92	96	99

Table 2 – Mineral element contents of the juices

The results are expressed in mg of element per litre of juice. They concern: the total phosphorus P in the juices in relation to nitrogenous and phosphatic fertilizer applications; the potassium K in the juices in relation to nitrogenous and potassic fertilizer applications; the calcium Ca in the juices in relation to nitrogenous and potassic fertilizer applications; the magnesium Mg in the juices in relation to nitrogenous and potassic fertilizer applications. The type of the response (l, g, q, a) is indicated with the significant results at the 2,5% level.

Table 3 – The export of mineral elements per hectare

This table combines the results of the two preceding ones, viz, the tonnage of cane per hectare (T.C.Ha) and the mineral contents of the juices. Special studies have shown a very close relationship between total P in volume of juices and total P in weight of cane stalk and this is also true for potassium.

On the analogy of fertilizers, the exports are expressed in P_2O_5 and K_2O. This relation is as follows:

P_2O_5 in g per ton of cane = 2.8 P in mg per litre of juice
K_2O in g per ton of cane = 1.2 K in mg per litre of juice

MINERAL ELEMENTS IN THE JUICES

The action of the fertilizer applications on the mineral elements content of the juices is particularly outstanding in the case of phosphorus and potassium, not so clear with calcium and magnesium.

Phosphorus in the juices

We have noted a reduction in the phosphorus content of the juices with increasing rates of nitrogen application. This action is more often linear and general, than additive. We have also found an increase in the phosphorus content of the juices with increasing rates of phosphate applications. This action is linear and general and fairly often additional.

If we refer to the table of exports per hectare we notice that the increase in production following an additional application of nitrogen does not result in increased exports of P_2O_5 per hectare in the stalks but, the contrary, in a reduction of these exports. This reduction is of the same magnitude as the increase of P_2O_5 exported following the additional applications of phosphatic fertilizers without any corresponding increase in production.

In conclusion, the grower who wishes to increase his sugar production by means of higher applications of nitrogenous fertilizers does not require a simultaneous increase in the phosphatic fertilizer applications to offset a higher uptake.

We may point out that a level of 250 mg of P_2O_5 per litre of juice (110 mg of P) is usually accepted by the factory for a good defecation of the juices. In some trials, after a few harvests without any application of phosphates, the juices show abnormally low contents; consequently it seems desirable to maintain a regular application of phosphate at the rate of about 50 kg of P_2O_5 per ha.

Potassium in the juices

Additional applications of nitrogen in the fertilizer treatment bring about a reduction of the potassium exported in the juices. This action is linear and general.

Additional doses of potash in the fertilizer treatment result in a very important increase of the potassium in the juices. The potassium content of the juices is increased 1.7 times on an average, when the fertilizer application rises from 80 kg to 240 kg K_2O/ha. This action is in all cases linear, general and additional.

If we refer to the table of exports of potash per hectare, we notice that the additional application of nitrogen, in spite of an increased production of cane per hectare, does not lead to a rise of the quantity of potash exported in the stalks; in fact, this quantity remains very nearly the same, around 125 kg of K_2O/ha when the production rises from 89 to 100 tons of cane. On the other hand, high doses of potash in the

TABLE 2

MINERAL ELEMENTS CONTENTS OF THE JUICES

Trials	P mg/litre						K mg/litre					
	N_1	N_2	N_3	P_0	P_1	P_2	N_1	N_2	N_3	K_1	K_2	K_3
SCC												
1st Rat. 62	71	67	61 lga	44	68	87 lga	637	596	534	380	568	819 lga
2nd Rat. 63	136	135	113	78	139	165 lg	1127	1053	1012	627	991	1574 lga
3rd Rat. 64	127	113	99 lg	59	125	155 lqga	906	826	721 lg	432	822	1198 lga
BCD												
1st Rat. 62	—	—	—	—	—	—	—	—	—	—	—	—
2nd Rat. 63	173	132	110 lga	108	139	168 lga	1160	901	940 lqg	698	1054	1249 lga
3rd Rat. 64	117	94	83 lg	59	108	128 lqga	1059	890	883 lg	636	958	1239 lga
BDC 2												
1st Rat. 62	—	—	—	—	—		—	—	—	—	—	—
2nd Rat. 63	164	137	120 lg	110	140	172 lga	1420	1101	1114	957	1101	1578 lga
3rd Rat. 64	134	91	82 lg	61	106	140 lga	1466	1142	1131 lg	1016	1113	1610 lga
GMC												
1st Rat. 63	229	181	138 lga	188	181	178	1119	1282	934 lga	1061	1056	1219 la
2nd Rat. 64	190	160	130 lg	153	155	172	968	952	796 lga	752	913	1050 lga
GGM												
1st Rat. 63	237	180	141 lga	174	183	201 lg	967	1026	844 a	747	937	1153 lga
2nd Rat. 64	175	128	100 lga	113	139	150 lg	886	901	754	614	848	1079 lga
SZB 1												
1st Rat. 63	162	117	96 lga	97	142	136 lqg	1566	1430	1243 lg	1193	1412	1633 lg
2nd Rat. 64	121	91	95 lg	67	114	127 lg	1368	1221	1019 lga	950	1160	1498 lga
SZB 2												
1st Rat. 63	133	98	94 lg	78	110	136 lga	1610	1478	1466	1196	1537	1821 lga
2nd Rat. 64	—	—	—	—	—	—	—	—	—	—	—	—
MLV												
1st Rat. 64	—	—	—	—	—	—	—	—	—	—	—	—
BEG	—	—	—	—	—	—	—	—	—	—	—	—
BRJ												
1st Rat. 63	225	157	147 lqg	159	178	192 lg	1250	1049	1014 lg	824	1108	1381 lga
2nd Rat. 64	202	150	121 lga	137	155	181 lga	1320	982	908 lqg	687	1036	1488 lga
DPM												
1st Rat. 64	231	183	167 lg	202	183	196	1087	878	728 lga	734	824	1133 lga
Mean	166	130	111	111	139	158	1171	1041	943	794	1025	1336

fertilizer application cause a very important increase in the quantity of potash exported per hectare in the stalks without a marked increase of the production since the quantities of potash exported increase from 90 kg to 170 kg per hectare for 7 additional tons of cane. There is certainly there a luxury consumption.

This interpretation is confirmed by the fact that the additional effect of dose 2 over dose 1 which is marked by a sharp increase of the potassium in the juices is significant 16 times out of 18.

A study to determine whether such high amounts of potash in the juices actually hamper factory efficiency would be worth-while undertaking. These results stress the necessity of both soil analyses and foliar diagnosis as proper guides to potash fertilization.

TABLE 2 *(continued)*

Trials	Mg mg/litre						Ca mg/litre					
	N_1	N_2	N_3	K_1	K_2	K_3	N_1	N_2	N_3	K_1	K_2	K_3
SCC												
1st Rat. 62	—	—	—	—	—	—	—	—	—	—	—	—
2nd Rat. 63	368	427	437 lg	452	403	377 lg	308	336	320	344	333	288 la
3rd Rat. 64	339	381	408 lg	411	374	345 lg	245	314	314 lg	305	298	270
BDC 1												
1st Rat. 62	—	—	—	—	—	—	—	—	—	—	—	—
2nd Rat. 63	199	259	258 lqg	261	243	213 lga	428	423	452	456	426	420
3rd Rat. 64	300	323	327	339	314	298 lg	292	307	340 lg	335	322	283 lga
BDC 2												
1st Rat. 62	—	—	—	—	—	—	—	—	—	—	—	—
2nd Rat. 63	171	207	233	210	221	181	392	420	440	431	400	422
3rd Rat. 64	265	298	313 lg	310	296	270 lg	289	325	331 lg	331	324	291 lga
GMC												
1st Rat. 63	268	276	313 lga	294	286	277	399	391	432 a	413	400	409
2nd Rat. 64	232	256	276 lga	259	250	254	352	367	373	379	362	350 lg
GGM												
1st Rat. 63	246	253	281	276	253	251	298	319	352 lga	339	324	307 lg
2nd Rat. 64	243	251	282 lga	272	257	247 lg	315	329	364 lga	356	329	323 lg
SZB 1												
1st Rat. 63	294	322	351 lga	341	327	299 lga	274	270	286	285	279	265
2nd Rat. 64	287	297	314	325	294	279 lg	270	291	291 a	299	288	265 lga
SZB 2												
1st Rat. 63	302	338	357 lg	350	326	321	265	278	274	275	274	269
2nd Rat. 64	—	—	—	—	—	—	—	—	—	—	—	—
MLV												
1st Rat. 64	—	—	—	—	—	—	—	—	—	—	—	—
BEG	—	—	—	—	—	—	—	—	—	—	—	—
BRJ												
1st Rat. 63	253	302	309 lg	311	286	266 lg	228	233	242 l	237	240	226 a
2nd Rat. 64	230	305	315 lqg	314	288	247 lga	200	232	255 lga	245	233	208 lga
DPM												
1st Rat. 64	210	244	280 lga	259	249	225 l	166	179	212 lga	186	189	182
Mean	263	296	316	312	292	272	295	313	330	326	314	299

Magnesium in the juices

Nitrogen applications result in an increased magnesium content of the juices, whereas potash fertilization on the contrary, reduces the magnesium content of the juices.

Calcium in the juices

Nitrogen applications increase the calcium content of the juices and the potash applications reduce it. These are parallel observations to those made for magnesium.

CONCLUSION AND SUMMARY

Applications of nitrogen have an important bearing on the mineral element contents

TABLE 3

MINERAL ELEMENTS EXPORTS PER HECTARE

Treatments		Tons Cane/ha	P mg/1	P_2O_5 kg/ha	K mg/1	K_2O kg/ha
Azote	N_1	89	166	42	1171	130
	N_2	98	130	37	1041	127
	N_3	100	111	33	943	116
Phosphorus	P_0	95	111	32		
	P_1	95	139	38		
	P_2	96	158	39		
Potassium	K_1	92			794	88
	K_2	96			1025	113
	K_3	99			1336	169

of the juices. A large proportion of the potash applied is recovered in the juices and one may wonder to what extent such high levels of potash do not hamper sugar processing.

The determination of the mineral elements in the juices in a set of 3×3×3 NPK factorial trials brings in very useful information for the control of the experiment and the interpretation of the results, since the variations of the fertilizer applications are distinctly reflected in juice composition. The interpretation of such a mass of information could not be completed without the help of electronic computers.

RESUMÉ

La fumure azotée exerce une influence non négligeable sur la composition des jus en éléments minéraux. La potasse apportée par la fumure se retrouve dans les jus en forte quantité et on peut se demander jusqu'à quel point des teneurs aussi élevées en potassium ne nuisent pas à un bon travail des jus en fabrication.

La détermination des teneurs en éléments minéraux des jus dans un réseau d'essais factoriels 3^3 NPK apporte des renseignements très précieux pour le contrôle de l'expérience et l'interprétation des résultats: les variations de la fumure se retrouvant très nettement dans la composition des jus. L'interprétation d'une telle masse de renseignements ne pourrait se faire sans accès à des calculateurs électroniques.

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Discussion

J. L. DU TOIT (S. Africa): This paper has an important bearing both on soil fertility and on juice clarification. It is clearly shown that the application of nitrogen will lead to an appreciable decrease in the phosphate content of the juice. Similarly, a reduction in the phosphate application will reduce the phosphate content of the cane. Now it so happens that in countries such as South Africa and Puerto Rico there has been a tendency in recent years to decrease phosphate and increase nitrogen applications. This must lead to an appreciable reduction in the phosphate content of the juice and the possibility of experiencing clarification troubles in the factory can not be ruled out.

H. F. CLEMENTS (Hawaii): I feel strongly that we should accumulate as much analytical data as possible on all experiments to enable us to project the results obtained to as wide a field as possible. In selecting suitable tissue for analysis, both sensitivity and variability are important. Without sensitivity the tissue is of no interest, but even with high sensitivity, the extent of variability may destroy the usefulness of such tissue. This however, is not always the case. For example, although the root tissue is most variable in composition, it is so sensitive to aluminum that it is in fact a very suitable tissue for this purpose.

I believe that anyone who is going to the trouble of laying down an expensive field experiment should conduct various tissue analysis from the different treatments. I think that the 3–6 leaf and sheath data will be found to be the least variable. I have also found root analyses to be particularly useful for aluminum.

It is most important whatever you do that you can project the data from a particular experiment to other fields.

Pedo

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