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Influence of Mineral Deficiencies on the Growth and Yield of Sugarcane

George Samuels and Héctor Cibes-Viadé[1]

INTRODUCTION

Sugarcane ranks as the number one agricultural crop in many areas of the world. Scientific literature is voluminous with accounts of sugarcane-fertilizer experiments performed in the field and greenhouse to determine the response of sugarcane to fertilizers. However, very little information is available as to what a deficiency of a given mineral element under controlled conditions does to sugarcane growth and yields.

Martin (*8*)[2], in 1932, grew three varieties of sugarcane in nutrient solution to develop mineral-deficiency symptoms; however, no quantitative data were given as to growth or yields. Martin (*9*), in 1940, tested the varietal differences in growth and yields to differential nutrient deficiencies; he reported comparative yields of millable cane, Brix, and purity. Clements, Martin, and Moriguchi (*4*) made a careful study of the composition of H. 312806 grown in deficient nutrient solutions. Their data included the green weight of the various plant parts as well as chemical analyses of these parts. Humbert and Martin (*6*), in 1955, reported the visual symptoms and chemical analyses of four sugarcane varieties grown under controlled conditions in quartz sand using mineral-deficient nutrient solutions.

In field experiments with fertilizers differences in fertility are normally created by the addition of a fertilizer element. Response to the fertilizer element is usually measured by comparison of a zero, or low-fertilizer-increment treatment, with a larger incremental addition of the fertilizer element. In most cases it is difficult to obtain soils wherein severe deficiency of all mineral elements exists. It is also virtually impossible to insure that adequate quantities of all other mineral elements are present in a soil, except the one being studied. With the use of the nutrient-solution techniques it is possible, under controlled conditions, to study the true deficiency of a given element with all other elements present. This study permits a clearer

[1] Agronomist and Plant Physiologist, respectively, Agricultural Experiment Station of the University of Puerto Rico, Río Piedras, P.R.

[2] Italic number in parentheses refer to Literature Cited, pp. 75.

and basic evaluation of what each mineral deficiency does to plant growth and yield.

In this study the deficiency of the mineral elements nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, and boron were evaluated on four sugarcane varieties. More than one sugarcane variety was utilized in this work in order to determine whether there was a differential response by varieties for a given mineral-element deficiency.

PROCEDURE

The deficiency study of sugarcane was started August 26, 1958, and ended March 13, 1959, when the cane had reached an age of 6½ months, and a height of approximately 7 feet, and touched the roof of the greenhouse.

All deficiencies were developed on plants grown in sand culture. The fine quartz sand used was obtained from the Tortuguero area and is classified as a St. Lucie fine sand *(11)*. It was placed in concrete pits 3 feet on each side and 1½ feet deep. Each pit had an individual hole for draining out the excess nutrient solution.

There were 10 treatments, each replicated 2 times. The composition of the differential nutrient solutions used in this experiment are shown in table 1. Applications were made once a week at the rate of 2½ gallons per pit. Once in a while the pits were flushed with distilled water only to wash out excess salts or to prevent salt accumulation.

Sugarcane varieties Puerto Rico 980 (P.R. 980), Barbados 37161 (B. 37161), Mayagüez 336 (M. 336), and Hawaii 328560 (H. 328560) were used in this study. Two three-eye seed-pieces from each variety were planted in each of the four corners of the pits. Before planting the seed-pieces were immersed in hot water at 52°C. for 25 minutes as a prophylactic measure against the chlorotic streak disease. The seed-pieces were also treated with P.M.A. (phenyl mercuric acetate, 1:1000) solution for 5 minutes against the pineapple disease of sugarcane (*Ceratostomella paradoxa*).

At time of harvest measurements were made of cane height, distance from sand line to uppermost visable ligule on the cane top, and number of tillers. Weights were taken of cane tops, millable stalks, and roots.

GROWTH AND YIELDS

The effect of the various deficiency treatments on yields are given below.

TOTAL GREEN WEIGHT

The results of the treatments on the total green weight of plant are given in table 2.

The highest yields of plant material were obtained from the complete

TABLE 1.—*Composition of nutrient solutions used in the differential treatments of sugarcane reported herein*

Treatment	Composition of nutrient solutions as used in the experiment as—													
	Partial volume molecular concentration of—									Parts per million of—				
	$Ca(NO_3)_2$	$MgSO_4$	KH_2PO_4	$CaCl_2$	NaH_2PO_4	$NaNO_3$	K_2SO_4	KNO_3	$Mg(NO_3)_2$	Fe sequestrene	H_3BO_3	$MnSO_4$	$ZnSO_4$	$CuSO_4$
Complete	0.009	0.0045	0.0045							5	0.5	0.5	0.05	0.02
Minus N		.0045	.0045	0.009						5	.5	.5	.05	.02
Minus K	.009	.0045			0.0045					5	.5	.5	.05	.02
Minus P	.009	.0045					0.0023			5	.5	.5	.05	.02
Minus Ca		.0045	.0045			0.0045		0.0045		5	.5	.5	.05	.02
Minus Mg	.009		.0045		.0045					5	.5	.5	.05	.02
Minus S	.009		.0045						0.0023	5	.5	.5[1]	.05[1]	.02[1]
Minus Fe	.009	.0045	.0045							—	.5	.5	.05	.02
Minus B	.009	.0045	.0045							5	—	.5	.05	.02
Minus Mn	.009	.0045	.0045							5	.5	—	.05	.02

[1] The chloride instead of the sulfate of the indicated element was used.

treatment for all varieties, except P.R. 980 which gave its highest yields under the minus-boron treatment. B. 37161 had the greatest yield of plant material for the four varieties. Under the complete treatment, B. 37161 produced over twice as much total green weight as M. 336 or P.R. 980.

The lowest yields of plant material were produced under the minus-nitrogen treatment for all varieties, except P.R. 980 which gave its lowest yields under the minus-phosphorus treatment. The reduction in yield for the mean of the four varieties under the minus-nitrogen treatment was 87 percent as compared with results under the complete treatment.

The second-lowest yields of total green weight were obtained with minus-phosphorus treatments for all varieties, except P.R. 980 for which it was lowest (table 2). The absence of phosphorus reduced yields for the mean of four varieties by 79 percent as compared with the complete treatment.

TABLE 2.—*Total green weight (pounds) per plant of 4 sugarcane varieties produced under complete and various mineral-deficiency treatments*

Treatment	Yields per plant of total green weight harvested for—				Mean of 4 varieties
	B. 37161	H. 328560	M. 336	P.R. 980	
Complete	26.43	19.75	10.43	12.75	17.34
Minus N	2.31	3.37	1.16	2.18	2.26
Minus P	8.00	3.50	1.88	1.38	3.69
Minus K	10.31	9.00	3.86	7.87	7.76
Minus Ca	5.80	11.75	5.19	6.18	7.23
Minus Mg	12.62	11.62	5.07	12.31	10.41
Minus S	14.18	10.20	8.75	13.37	11.63
Minus Fe	12.25	14.18	4.62	13.27	11.08
Minus Mn	13.50	9.69	6.62	13.50	10.83
Minus B	10.74	11.75	4.74	15.00	10.56

The minus-potassium and minus-calcium treatments were about tied for third place in low yields, when we consider the mean of the four varieties. H. 328560 and M. 336 gave lower yields under the minus-calcium treatment, but it was just the reverse for B. 37161 and P.R. 980.

The minus-magnesium treatment gave much lower yields for all varieties, except P.R. 980, which showed no appreciable yield reduction when magnesium was absent. H. 328560 and M. 336 had about equal yield reductions under the minus-magnesium and minus-calcium treatments, whereas B. 37161 had greater yield reductions when calcium was omitted.

The absence of sulfur, iron, boron, and manganese was about equal in effect on yields for the mean of the four varieties, giving an average decrease of about 37 percent as compared with yields under the complete treatment. Certain varieties, however, showed a rather wide variation from the mean. For example, the minus-boron treatment gave about as low a yield as the minus-potassium treatment for B. 37161, and minus-boron and minus-iron treatments reduced yields markedly for M. 336. With P.R. 980 yields were actually higher than with the complete treatment when sulfur, iron, manganese, or boron was absent. In fact, the minus-boron treatment gave the highest yield of any for P.R. 980 (table 2).

MILLABLE SUGARCANE STALKS

Of greatest interest to the sugarcane grower is not total green weight, but millable sugarcane stalks, because it is the millable sugarcane stalks he sells for grinding by the sugarcane factory for conversion to sugar.

TABLE 3.—*Yields (pounds) per plant of millable sugarcane stalks produced by 4 sugarcane varieties under complete and various mineral-deficiency treatments*

Treatment	Yield per plant in green weight of millable cane stalks for—				Mean of 4 varieties
	B. 37161	H. 328560	M. 336	P.R. 980	
Complete	9.50	10.56	3.25	6.63	7.49
Minus N	0	1.81	0	.63	.61
Minus P	3.93	1.31	.18	.81	1.56
Minus K	4.18	4.00	1.37	3.06	3.15
Minus Ca	2.69	5.50	1.31	2.87	3.09
Minus Mg	6.25	5.25	1.18	4.25	4.23
Minus S	6.50	4.68	3.06	5.93	5.04
Minus Fe	5.75	6.50	1.63	5.00	4.72
Minus Mn	6.68	4.75	2.43	6.31	5.29
Minus B	5.75	5.18	1.75	6.81	4.87

Although the cane in this experiment was harvested at an age of 6½ months, much earlier than the commercial cane which is normally cut at about 12 months of age, the weights produced will give some idea of the influence of the treatments on the yields.

The actual green weights of millable sugarcane stalks produced by the four sugarcane varieties are given in table 3. The highest yield was produced by H. 328560, followed closely by B. 37161. In third place under the complete treatment was P.R. 980; M. 336 was last. Although B. 37161 had a greater production of total green weight harvested than H. 328560, the latter produced more millable cane stalks (table 3).

For ease in comparison of the various deficiency treatments on the four varieties, the relative yields of millable cane were calculated as given in table 4. The complete-treatment yields were assigned a relative value of 100 percent, and all other treatment yields were recalculated on this basis.

Once again the absence of nitrogen produced the lowest yields, giving an average of only 8 percent when compared with the complete treatment's 100 percent. B. 37161 and M. 336 failed to produce any millable cane at all when nitrogen was not present in the nutrient solution. Only H. 328560 failed to produce the lowest yields under the minus-nitrogen treatment; for it the minus-phosphorus treatment gave the lowest yields of cane stalks.

The minus-phosphorus treatment failed to produce the same degree of yield reduction in all four varieties. As stated, H. 328560 showed severe reductions in yields attributable to the omission of phosphorus; M. 336 and P.R. 980 were also greatly affected. B. 37161, however, had a greater yield reduction under the minus-calcium treatment, and under the minus-phosphorus treatment the relative yield was but 41 percent as compared to lows of 6 and 12 percent for the other three varieties (see table 4).

TABLE 4.—*Relative percentage yields per plant of millable sugarcane stalks produced by 4 sugarcance varieties under complete and various mineral-deficiency treatments*

Treatment	Relative yield per plant in green weight of millable cane stalks for—				Mean of 4 varieties
	B. 37161	H. 328560	M. 336	P.R. 980	
Complete	100	100	100	100	100
Minus N	0	17	0	10	8
Minus P	41	12	6	12	21
Minus K	44	38	42	46	42
Minus Ca	28	52	40	43	41
Minus Mg	66	50	36	64	57
Minus S	68	45	96	89	68
Minus Fe	61	62	50	75	63
Minus Mn	70	46	75	90	70
Minus B	61	49	54	102	65

The minus-potassium treatment produced a mean relative yield of 42 percent for the four varieties; there was little variation among the varieties. The minus-calcium treatment produced a very similar mean relative yield. However, B. 37161 had a marked reduction, giving a relative yield of only 28 percent as compared to 52 percent for H. 328560, when calcium was omitted.

The absence of magnesium, sulfur, iron, manganese, and boron was similar in effect on relative yields, giving an average relative yield of 65 percent as compared with 100 percent for the complete treatment. There was not too great a variation in relative yields of B. 37161 and H. 328560 attributable to the absence of magnesium, sulfur, iron, manganese, and boron; however, M. 336 and P.R. 980 showed a wide variation in relative yields. For M. 336 the minus-magnesium treatment produced a low relative yield of only 36 percent. The minus-sulfur treatment for this variety had little influence, producing a relative yield of 96 percent.

P.R. 980 did not have any marked decrease in relative yield attributable to the absence of sulfur and manganese. The minus-boron treatment actually effected a slightly higher relative yield of 102 percent as compared with 100 for the complete treatment.

SUCROSE

The sugarcane grower is interested not only in the tonnage of cane he can grow per acre, but also in the sucrose content of his cane. The reason for this is that the sugar factory pays the farmer not only for cane tonnage, but also for the sucrose content of the cane. The higher the sucrose content of the cane the more money the grower receives.

Although technical conditions prevented the determination of the actual sucrose-percent-cane, the two essential values of sucrose measurement, Brix and polarization of the cane juice, were determined for the four varieties. The values are given in table 5.

Sugarcane varieties vary in their sucrose content as a result of their genetical constituents. Under field conditions Méndez and Samuels (*10*) found that the particular varieties used in this study ranked thus in descending order of sucrose-percent-cane M. 336 > H. 328560 > B. 37161 > P.R. 980. For the greenhouse conditions of this study using the complete treatment as a basis, the ranking in descending order of Brix was H. 328560 > M. 336 > P.R. 980 > B. 37161, and for polarization M. 336 > H. 328560 > P.R. 980 > B. 37161.

The values obtained for Brix and polarization are lower in most cases than those obtained under field conditions because the cane was only 6½ months old, hence immature when harvested. However, values obtained under the various deficiency treatments are comparable for each variety.

Brix

The highest Brix values occurred not necessarily under the same treatment for each variety. For B. 37161 the minus-calcium and minus-magnesium treatments produced the highest Brix values (table 5). H. 328560 gave the highest Brix values under the minus-nitrogen treatment and M. 336 under minus-phosphorus. P.R. 980 had its highest Brix values under the minus-nitrogen and minus-calcium treatments. The complete treatment did not produce the highest Brix value for any of the four varieties.

The two varieties which produced millable cane under the minus-nitrogen treatment had very high Brix values. Clements, in a critical evaluation of quality in sugarcane, found that leaf-nitrogen content of the sugarcane at harvest was inversely correlated with the Brix content of the cane juice (*3*).

The influence of nitrogen-fertilizer application on sucrose values has been cited many times in the literature. The lowering of sucrose values is normally associated with heavy nitrogen applications which, in turn, stimulate growth and accumulation of nitrogen and water in the existing cane stalks, as well as new shoots or suckers which do not mature sufficiently by harvesttime.

TABLE 5.—*The Brix and polarization (degrees) values of sugarcane juice extracted from 4 varieties produced under complete and various mineral-deficiency treatments*

Treatment	The Brix and polarization values of sugarcane juice extracted from—				Mean of 4 varieties
	B. 37161	H. 328560	M. 336	P.R. 980	
			Brix		
Minus N	—	16.8	—	13.2	15.0[1]
Minus P	14.3	12.1	21.2	12.3	15.0
Minus K	9.1	11.1	10.2	8.0	9.6
Minus Ca	15.4	12.9	16.0	13.4	14.4
Minus Mg	15.3	14.0	15.1	12.2	14.2
Minus S	14.2	13.9	13.9	10.2	13.1
Minus Fe	13.3	14.6	14.9	12.2	13.8
Minus Mn	14.1	13.8	16.4	10.1	13.6
Minus B	13.1	14.9	13.5	11.5	13.3
Complete	11.2	14.0	13.5	11.8	12.6
			Polarization		
Minus N	—	56.3	—	31.0	43.7[1]
Minus P	42.2	31.7	—	34.8	36.2[2]
Minus K	18.3	28.4	13.0	14.8	18.6
Minus Ca	54.1	41.4	57.8	43.5	49.2
Minus Mg	39.2	41.6	34.2	31.4	36.6
Minus S	40.8	39.6	39.7	18.2	34.6
Minus Fe	37.7	45.2	46.1	39.5	42.1
Minus Mn	39.5	39.6	39.2	17.9	34.1
Minus B	34.1	43.9	38.7	28.2	36.2
Complete	25.1	40.9	41.3	29.5	34.2

[1] Mean of 2 varieties.
[2] Mean of 3 varieties.

Clements (*2*) stated that the addition of large quantities of nitrogen means an accompanying need of the sugarcane plant for more carbohydrates, and as a result, comparatively small quantities are stored by the plant. Nitrogen was insufficient for good growth under the minus-nitrogen treatment, and thus what few carbohydrates remained were stored as sugar. Thus a nitrogen deficiency, or low levels of nitrogen, tends to favor sugar formation, or high Brix and polarization values, and not to favor good growth or high cane tonnage.

The lowest Brix values were obtained with the minus-potassium treatment for all varieties (table 5). The influence of potassium deficiencies in lowering the sucrose content of sugarcane has been reported many times in the sugarcane literature. Samuels (*12*) found that potassium-deficient sugarcanes had lower Brix values than those adequately fertilized with potash. Work in Hawaii showed that under a minus-potassium treatment there was a large decrease in the sucrose of the cane, because of an increased ratio of reducing sugars to sucrose, and more than doubled amide nitrogen (*7*). Cibes and Samuels (*1*) also found the lowest Brix values on Smooth Cayenne pineapples when potassium was omitted from the nutrient solution.

The minus-phosphorus treatment gave extremely high Brix values only in sugarcane variety M. 336.

Inasmuch as the complete treatment did not produce high Brix values, many of the deficiency treatments had values close to or greater than that of the complete treatment. This may have been due to the fact that the cane, under the complete treatment were less mature than those canes under the deficiency treatments.

Polarization

In general, the polarization values followed the same trends in response to the deficiency treatments as did the Brix values. This was especially true for the high values under minus-nitrogen and low values under the minus-potassium treatment (table 5). Perhaps even more evident for polarization than Brix were the high values caused by the minus-calcium treatments. The minus-calcium treatment gave the highest polarization values for the mean of the varieties, followed by minus-nitrogen then minus-iron (table 5). Although liming has been shown to be beneficial for sugarcane growing in very acid soils, the gains have mostly resulted from increases in cane tonnage rather than sucrose. Doty, in Hawaii (*5*), found poor juice purities and a poor quality ratio when lime was applied. Samuels and González-Vélez (unpublished data) found that liming an acid Catalina clay increased cane tonnage but decreased sucrose-percent-cane.

HEIGHT OF CANE

The heights of the sugarcane plants at 6½ months of age for the four varieties are given in table 6.

The growth response in height followed rather closely the production of green millable stalks, insofar as the influence of the various deficiency treatments was concerned. The mean height of the varieties showed that the complete treatment gave the tallest cane. The severe reductions in yields of millable cane, produced with the omission of nitrogen and phosphate, were also reflected in the low height of the cane.

NUMBER OF TILLERS

Tillering, or the production of new cane shoots, is a desirable characteristic in sugarcane growth. Poor tillering is normally associated with poor growth conditions which, in turn, allow weeds to grow and thus raise production costs. Good tillering means fast closing in of the cane field and lower weeding costs. Excessive tillering can give rise to thin cane stalks.

TABLE 6.—*The height (inches) of 4 sugarcane varieties under complete and various mineral-deficiency treatments*

Treatment	Height of the sugarcane plant for—[1]				Mean of 4 varieties
	B. 37161	H. 328560	M. 336	P.R. 980	
Complete	77	84	41	71	68
Minus N	15	32	9	17	18
Minus P	41	27	14	20	26
Minus K	53	37	21	43	39
Minus Ca	32	36	19	29	29
Minus Mg	37	37	26	40	35
Minus S	47	52	26	36	40
Minus Fe	58	52	23	40	43
Minus Mn	58	53	40	44	49
Minus B	59	60	28	49	49

[1] Measured from the first visible dewlap of the sheath to the sand line.

The number of tillers per sugarcane plant is given in table 7. In general, the highest number of tillers was produced under the complete treatment, with the exception of P.R. 980 which produced more under minus-magnesium, minus-iron, and minus-manganese treatments.

Poorest tillering was found under the minus-phosphorus treatment. The poor tillering of sugarcane has usually been associated with phosphate deficiencies in commercial cane fields in many sugarcane-growing areas of the world. The minus-nitrogen, minus-potassium, and minus-calcium treatments also gave rise to poor tillering.

The minus-magnesium treatment favored a greater number of tillers than the complete treatment for P.R. 980 (table 7), and the other varieties under this treatment had good tillering comparable to the complete treatment. P.R. 980 also had higher tillering than under the complete treatment for the minus-iron and minus-manganese treatments, but this trend was not observed in the other varieties.

RATIO OF TOPS TO THE MILLABLE STALK

Sugarcane produces leaves as well as the cane stalk. Although the leaves are necessary in the life of the cane plant, it is the stalk of cane which is ground for sugar. A low ratio of tops to stalk is indicative of more millable cane and less tops, whereas a high ratio indicates that more leaves are being produced, and less millable cane. Thus, it is of interest to observe the quantities of leaves produced in relation to cane stalk by the various varieties, and the influence of nutritional deficiencies on these ratios of leaf top to millable stalk as shown in table 8.

TABLE 7.—*Number of tillers per plant produced by 4 sugarcane varieties under complete and various mineral-deficiency treatments*

Treatment	Number of tillers per sugarcane plant for—				Mean of 4 varieties
	B. 37161	H. 328560	M. 336	P.R. 980	
Complete	9	12	14	10	11
Minus N	5	10	7	7	10
Minus P	4	4	6	5	5
Minus K	5	6	7	9	7
Minus Ca	5	8	9	8	8
Minus Mg	9	11	10	18	12
Minus S	8	5	13	10	9
Minus Fe	4	9	7	16	9
Minus Mn	9	10	5	12	9
Minus B	8	11	6	8	8

The lowest top-to-stalk ratio for the complete treatment was obtained with H. 328560; P.R. 980 was a close second. B. 37161 had twice the top-to-stalk ratio of the leading two varieties. M. 336 was last, with a top-to-stalk ratio of 2.21, or that is to say, over twice as much leaves as millable cane. In commercial fields M. 336 is noted for its leafiness, and cane estimates are often misjudged because of this factor. On the other hand, cane-tonnage estimates for P.R. 980 in commercial practice, when first introduced, were lower than actually obtained, because of its lower top-to-stalk ratio.

Not all of the varieties reacted similarly in top-to-stalk ratio under given nutrient deficiencies. A phosphorus deficiency caused higher top-to-stalk ratios with M. 336 and H. 328560, but not with B. 37161 and P.R. 980. Except for the minus-phosphorus treatment, P.R. 980 had a higher top-to-stalk ratio for all deficiency treatments as compared with the complete treatment, whereas H. 328560 had higher top-to-stalk ratios for all treatments other than for minus-nitrogen. All deficiency treatments lowered top-to-stalk ratios for B. 37161, and M. 336 varied in its top-to-stalk ratios.

WEIGHT OF ROOTS

The weights of roots produced by the four varieties under the various treatments are given in table 9. The complete treatment produced the most roots, except for H. 328560, which produced more roots under the minus-boron treatment. The lowest weight of roots was produced under the minus-phosphorus, minus-iron, and minus-nitrogen treatments for the average of the four varieties.

B. 37161 had lowest root weights with minus-nitrogen, minus-phosphorus, and minus-iron treatments. P.R. 980 gave its lowest root weights under the minus-phosphorus and minus-nitrogen treatments. H. 328560 showed lowest root weights with the minus-phosphorus treatment and M. 336 with the minus iron.

TABLE 8.—*The ratio of the tops to the millable stalks produced by 4 sugarcane varieties under complete and various mineral-deficiency treatments*

Treatment	Ratio of tops[1] to millable stalks = 1 for —				Mean of 4 varieties
	B. 37161	H. 328560	M. 336	P.R. 980	
Complete	1.78	0.87	2.21	0.93	1.45
Minus N	0	.86	0	2.46	1.66
Minus P	1.03	1.67	9.44	.70	3.21
Minus K	1.46	1.25	1.82	1.57	1.53
Minus Ca	1.16	1.14	2.96	1.15	1.60
Minus Mg	1.02	1.21	3.30	1.90	1.86
Minus S	1.18	1.18	1.86	1.25	1.37
Minus Fe	1.13	1.18	1.83	1.65	1.45
Minus Mn	1.02	1.04	1.72	1.14	1.23
Minus B	.87	1.27	1.71	1.20	1.26

[1] The tops of the sugarcane plant as used here is defined as the difference between the total above-ground green weight of the plant minus the weight of millable stalks.

M. 336, which had the lightest yield of millable cane (table 3) for the four varieties, produced the heaviest weight of roots (table 9). B. 37161 had just the reverse, with heaviest weight of cane and lightest production of roots.

SUMMARY

Four sugarcane varieties, B. 37161, H. 328560, M. 336, and P.R. 980, grown in sand cultures in the greenhouse were allowed to develop deficiency symptoms caused by lack of major and minor elements. The elements

studied were nitrogen, phosphorus, potassium, calcium, magnesium, iron, manganese, sulfur, and boron. The most important results were as follows:

1. There were differential responses to the various deficiency treatments by the individual varieties as to total green weight and millable cane stalks.
2. The absence of nitrogen and phosphorus had the greatest influence in retarding growth and yields in plants at 6½ months of age for the average of all varieties.
3. The complete treatment produced the highest yields of total green weight and also of millable cane for the average of the four varieties. The minus-nitrogen treatment failed to produce millable cane for B. 37161 and M. 336.

TABLE 9.—*Weight (pounds) of roots per plant produced by 4 sugarcane varieties under complete and various mineral-deficiency treatments*

Treatment	Yield per plant in dry weight of roots for—				Mean of 4 varieties
	B. 37161	H. 328560	M. 336	P.R. 980	
Complete	7.25	5.20	11.80	6.50	7.69
Minus N	.31	.67	1.94	.42	.83
Minus P	.36	.25	1.12	.41	.54
Minus K	1.97	.90	1.00	.83	1.18
Minus Ca	1.60	2.16	1.07	1.25	1.52
Minus Mg	2.80	4.20	2.45	5.23	3.68
Minus S	1.35	.85	1.54	2.54	1.57
Minus Fe	.35	.80	.30	.95	.60
Minus Mn	3.05	4.60	2.90	5.35	3.98
Minus B	2.90	7.80	3.70	3.90	4.55

4. The minus-potassium and minus-calcium treatments were about tied for third place in yields of total green weight and millable cane.
5. The absences of magnesium, sulfur, iron, manganese, and boron were about equal in effects on yields for the mean of the four varieties.
6. The ranking in descending order of Brix was H. 328560 > M. 336 > P.R. 980 > B. 37161, and for polarization M. 336 > H. 328560 > P.R. 980 > B. 37161.
7. The highest Brix and polarization values were obtained from millable cane grown under the minus-nitrogen treatment and the lowest under the minus-potassium treatment.
8. The growth response in height followed rather closely the production of green millable stalks, insofar as the influence of the various deficiencies was concerned.
9. The most tillers per sugarcane stool were produced under the complete

treatment, with the exception of P.R. 980. Poorest tillering was associated with the minus-phosphorus treatment.

10. The top-to-stalk ratio under the complete treatment was lowest for H. 328560, with P.R. 980 a close second, B. 37161 a poor third, and M. 336 last.

11. The weight of sugarcane roots was in general highest for the complete treatment and lowest in the minus-nitrogen, minus-phosphorus, and minus-iron treatments. The weight of roots for the complete treatment of the 4 varieties descended thus: M. 336 > B. 37161 > P.R. 980 > H. 328560.

RESUMEN

Cuatro variedades de caña, B. 37161, H. 328560, M. 336, y P.R. 980 cultivadas en arena estéril y en invernadero, se dejaron que desarrollaran síntomas de deficiencia nutricional causada por falta de elementos nutritivos mayores y menores. Los elementos estudiados fueron nitrógeno, fósforo, potasio, calcio, magnesio, hierro, azufre, manganeso, y boro.

Los resultados más importantes de este estudio fueron los siguientes:

1. Individualmente, las variedades respondieron de distinta manera a los diversos tratamientos de deficiencia nutricional en cuanto a peso verde total y cantidad de tallos de caña propios para moler.

2. La carencia de nitrógeno y fósforo fue lo que más influyó en retardar el crecimiento y aminorar los rendimientos de las plantas a los 6½ meses de sembradas, como promedio para todas las variedades.

3. El tratamiento completo produjo los rendimientos mayores de peso verde total y de cantidad de tallos de caña propios para moler como promedio para cuatro variedades. El tratamiento sin nitrógeno no produjo tallos de caña propios para moler en lo que se refiere a las variedades B. 37161 y M. 336.

4. El tratamiento sin potasio y el de sin cal produjeron resultados similares para quedar en tercer lugar en cuanto a rendimiento en peso verde total y cantidad de tallos de caña propios para moler.

5. Las carencias de magnesio, azufre, hierro, manganeso y boro fueron más o menos iguales en sus efectos sobre los rendimientos en grado medio de las cuatro variedades.

6. En cuanto a Brix, las variedades ocuparon puestos en orden descendente como sigue: H. 328560 > M. 336 > P.R. 980 > B. 37161, y en cuanto a polarización M. 336 > H. 328560 > P.R. 980 > B. 37161.

7. Los valores más altos en Brix y polarización se obtuvieron de tallos de caña propios para moler desarrollados bajo el tratamiento sin nitrógeno y los más bajos bajo el tratamiento sin potasio.

8. El factor altura estuvo muy correlacionado con la producción de tallos

propios para moler, en lo que se refiere a la influencia de las distintas deficiencias nutricionales.

9. El tratamiento completo produjo el mayor número de tallos por cepa de caña, con excepción de la variedad P.R. 980. El número menor de tallos por cepa estuvo asociado al tratamiento sin fósforo.

10. La razón de tope a tallo en el tratamiento completo fue la más baja en la variedad H. 328560, seguida por la P.R. 980; la B. 37161 ocupó un precario tercer lugar y la M. 336 fue última en este sentido.

11. En general, el peso de las raíces fue mayor en el tratamiento completo y menor en los tratamientos que carecían de nitrógeno, fósforo y hierro. En cuanto al peso de las raíces, según las variedades, el orden en forma descendente fue M. 336 > B. 37161 > P.R. 980 > H. 328560.

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