THE JOURNAL OF AGRICULTURE OF THE UNIVERSITY OF PUERTO RICO

Issued quarterly by the Agricultural Experiment Station of the University of Puerto Rico, for the publication of articles by members of its personnel, or others, dealing with any of the more technical aspects of scientific agriculture in Puerto Rico or the Caribbean Area.

Vol. LIV | October 1970 | No. 4

Leaf Composition as an Index of the Availability of Nutrients in the Soil

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INTRODUCTION

The determination of the quantity of a nutrient in a form available to a plant growing in a given soil has been the subject of study by soil scientists for many years.

The problem has been studied in numerous ways from many different angles. Among the procedures generally employed have been the following: Extraction of the soil with different solutions kept in contact with soil samples for varying periods of time, analysis of the tissues of plants growing in the soil, and fitting equations to the respective plant-growth data which include a constant representing the available content of the nutrient in the soil (*2*, *5*).[2] In many of these studies the aim has been to develop some procedure which will provide an index representative of the capacity of the soil to provide the crop with nutrients. The results of an additional attempt in this connection are presented below.

EXPERIMENTAL MATERIALS AND METHODS

As part of a research study on the calibration of soil tests, a series of experiments were performed to obtain, among other data, information on the relation between the available quantity of a nutrient in the soil and the leaf content of the nutrient. The first tests of this study were performed with the sugarcane variety P.R. 980 and the corn variety Mayorbela.

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The experiments which provided the data used herein were designed by Dr. J. A. Bonnet and Messrs. A. Riera and J. Juárez, with the advice of the author. Messrs. Riera and Juárez installed the experiments and were mainly responsible for their harvesting and the collection of samples. Many other members of the staff and private cooperators participated in this work.

The author wishes to acknowledge the cooperation and active help of Mr. M. Antoni and Mrs. Ada Márquez de Ray in the preparation of programs for the computer and processing of data.

[2] Italic numbers in parentheses refer to Literature Cited, p. 623.

Data from the first 39 experiments with sugarcane and the first 40 experiments with corn have been studied by fitting several types of mathematical equations in an attempt to characterize the relationship between the available nutrient content of the soil and the nutrient content in the leaf.

The experiments were performed in fields with soils representative of the major groups of soils into which the agricultural soils of Puerto Rico were classified for the study. In each experiment, nine levels of application of a given fertilizer material were tested, while the other fertilizer materials were applied at a uniform rate. The non-varying levels of the nutrients were: 300 pounds per acre for nitrogen, phosphorus and potassium; 182.5 pounds per acre for magnesium; and 1,600 pounds per acre for calcium. The levels of the fertilizer materials under study in each experiment varied from zero application to rates considered *a priori* to be excessive and probably harmful to the crop. The aim was to obtain data which might be useful in characterizing the relationships between the available nutrient contents of the soil on the one hand, and crop yield and leaf composition on the other, throughout a wide range of nutrient concentrations. The results of the study of the relation between fertilizer materials applied and crop yields have been published elsewhere (*3*). The present report deals with the results of the study of the relations between the available contents of various nutrients in the soil and the leaf contents of the corresponding nutrients.

The fertilizer materials were applied to the soil prior to planting. Samples of leaves, Nos. 3 to 6 (*4*) inclusive, were taken from the sugarcane experiments at approximately 4 and 7 months of age of the crop. The leaf samples were subdivided into blades and sheaths, and analyzed separately for the nutrient under study, among others. Blades and sheaths were analyzed separately because, although the blade is used in most methods of foliar diagnosis, the sheaths are used in some (*6*). Samples of corn leaves were taken as follows: The fourth leaf with its petiole at about 4 weeks of age; the sixth leaf with its petiole at the silking stage (about 7 weeks).

Graphs were drawn plotting the leaf-nutrient contents against the quantities of fertilizer materials applied. The study of these graphs indicated that, in general, the leaf content of a nutrient tends to increase in a form which might be represented by a smooth curve approaching some maximum value as an asymptote, especially in those cases in which the contents of the leaves of the plants in the zero-application plots were relatively low. This suggested that the relation between the available content of a nutrient in the soil and the leaf content of the same nutrient might be expressible by a diminishing-return curve such as the Mitscherlich (*5*) or the Pearl-Reed logistic (*8*). Equations of these two types were accordingly fitted to most of the data of the first and second sugarcane leaf blade and sheath samples and to those of the first and second corn leaf samples. In addition, the fertilizer-yield equation previously used (*3*) to describe the relation between the quantity of fertilizer applied and the crop yield was fitted to a large proportion of the same data.

The following forms were used in fitting the above-mentioned equations:

Mitscherlich: $$Y = A - BC^X.$$

Pearl-Reed: $$Y = \frac{A}{B + e^{-CX}}.$$

Fertilizer-yield: $$Y = \frac{A}{1 + B(C - X)^2}.$$

In these equations: Y represents the leaf nutrient content, X is the quantity of fertilizer material applied per acre, and A, B, and C are parameters. For fitting, the equations were expanded by Taylor's theorem, values were assumed for the parameters, and corrections to these assumed values were estimated by iteration, calculating the correction for each parameter one at a time in the IBM 1130 calculator.

Table 1 presents the coefficients of determination (in percent) obtained by fitting the equations to the leaf-nutrient data. As may be seen in the table, some fits were exceedingly good; some were very poor. In general, however, when one equation gave a good fit, the other two equations also gave good fits. Also, the data of some of the leaf samples could not be fitted well by any equation. Since the conclusions to be derived from the results obtained by fitting any one of these equations would be, therefore, very similar, it seems sufficient to present in more detail the results obtained and the conclusions derived by fitting any one of the three. However, because Mitscherlich's equation has the advantages from the theoretical standpoint that parameter A represents the maximum attainable leaf nutrient value, it has no point of inflexion, it is the better known of the three for studies of this kind, and it may be easily used to estimate the soil's available nutrient content, the results obtained by fitting Mitscherlich's equation are those presented and discussed in the following text.

RESULTS

NITROGEN EXPERIMENTS

Table 1,A, and tables 2 and 3 present the results obtained by fitting Mitscherlich, Pearl-Reed, and fertilizer-yield equations to the leaf-nutrient content data of the ammonium sulfate experiments performed with sugarcane at 8 experimental sites.

As may be seen in table 1,A, the explanation of the variability of the

TABLE 1.—*Coefficients of determination obtained on fitting Mitscherlich, Pearl-Reed, and fertilizer-yield equations to the sugarcane- and corn-leaf nutrient-content data (values multiplied by 100)*

A. Nitrogen experiments with sugarcane

Location	Blades						Sheaths					
	4 months			7 months			4 months			7 months		
	M.[1]	P.-R.	F.-Y.	M.	P.-R.	F.-Y.	M.	P.-R.	F.-Y.	M.	P.-R.	F.-Y.
Corozal	77	78	75	2	2	36	90	92	93	38	—	41
Guayama	82	90	77	89	92	85	86	93	87	75	—	78
Gurabo	97	97	84	64	63	64	97	96	87	85	87	94
Isabela	44	30	90	27	27	59	36	52	44	95	95	94
Lajas	62	98	75	81	82	81	82	95	88	50	—	69
Patillas	88	88	83	49	65	63	94	95	94	66	—	71
Río Piedras (T.)	18	26	20	3	3	19	66	63	61	21	—	19
Río Piedras (V.A.)	86	88	89	28	29	41	74	95	92	82	21	84

B. Nitrogen experiments with corn

Location	4 weeks		7 weeks	
	M.[1]	F.-Y.	M.	F.-Y.
Corozal	—	—	58	51
Guayama	96	93	—	—
Gurabo (T.)	87	82	65	64
Gurabo (Ma.)	97	44	96	44
Isabela	98	64	92	80
Lajas	55	37	51	38
Río Piedras (T.)	92	56	—	74
Río Piedras (V.A.)	40	39	2	—

C. Phosphorus experiments with sugarcane

Location	Blades						Sheaths					
	4 months			7 months			4 months			7 months		
	M.[1]	P.-R.	F.-Y.	M.	P.-R.	F.-Y.	M.	P.-R.	F.-Y.	M.	P.-R.	F.-Y.
Corozal	93	92	92	55	55	83	93	93	94	78	79	86
Guayama	85	96	97	60	61	66	74	78	78	53	53	72
Gurabo	85	—	93	39	39	36	83	91	90	73	73	72
Isabela	94	94	95	54	54	54	89	—	94	57	57	57
Lajas	97	99	98	85	85	84	98	99	99	81	79	80
Patillas	95	96	99	16	—	13	67	83	96	10	1	81
Río Piedras (T.)	50	50	51	24	24	20	60	60	60	68	67	65
Río Piedras (V.A.)	20	19	19	15	7	61	19	—	18	2	—	—

TABLE 1.—*Continued*

D. Phosphorus experiments with corn

Location	4 weeks		7 weeks	
	M.[1]	F.-Y.	M.	F.-Y.
Corozal	—	—	71	87
Guayama	63	71	—	—
Gurabo (T.)	92	91	75	—
Gurabo (Ma.)	89	96	90	—
Isabela	91	—	76	78
Lajas	91	93	65	65
Río Piedras (T.)	94	96	84	86
Río Piedras (V.A.)	80	78	86	90

E. Potassium experiments with sugarcane

Location	Blades					Sheaths					
	4 months			7 months		4 months			7 months		
	M.[1]	P.-R.	F.-Y.	M.	F.-Y.	M.	P.-R.	F.-Y.	M.	P.-R.	F.-Y.
Corozal	92	92	76	89	89	98	97	76	89	88	75
Guayama	8	54	48	74	75	81	81	72	73	73	70
Gurabo	86	—	29	78	73	95	—	87	98	—	93
Isabela	90	89	65	92	77	77	95	47	95	94	73
Lajas	97	97	77	94	81	95	95	71	97	98	80
Patillas	75	74	43	89	77	79	82	57	95	95	83
Río Piedras (T.)	98	97	74	69	67	99	—	76	87	80	74
Río Piedras (V.A.)	97	—	56	88	67	91	—	71	97	—	77

F. Potassium experiments with corn

Location	4 weeks		7 weeks	
	M.[1]	F.-Y.	M.	F.-Y.
Corozal	—	—	88	74
Guayama	84	81	—	—
Gurabo (T.)	87	57	84	—
Gurabo (Ma.)	88	67	55	—
Isabela	85	81	11	—
Lajas	95	—	37	52
Río Piedras (T.)	71	—	91	—
Río Piedras (V.A.)	79	—	46	—

TABLE 1.—*Continued*

G. Calcium experiments with sugarcane

Location	Blades						Sheaths					
	4 months			7 months			4 months			7 months		
	M.[1]	P.-R.	F.-Y.	M.	P.-R.	F.-Y.	M.	P.-R.	F.-Y.	M.	P.-R.	F.-Y.
Corozal	8	7	7	2	26	24	17	43	17	29	25	47
Gurabo	50	68	—	11	—	15	43	—	—	1	—	—
Isabela	3	—	39	7	—	11	1	—	—	87	—	90
Lajas	1	—	25	28	50	—	3	—	—	59	4	—
Patillas	4	28	54	—	—	—	—	4	40	1	—	—
Río Piedras (T.)	8	10	7	18	—	15	1	—	21	—	—	9
Río Piedras (V.A.)	1	—	—	5	—	—	22	—	24	4	7	3

H. Calcium experiments with corn

Location	4 weeks		7 weeks	
	M.[1]	F.-Y.	M.	F.-Y.
Corozal	—	—	33	25
Gurabo (T.)	5	—	40	3
Gurabo (Ma.)	38	51	3	27
Isabela	47	45	70	65
Lajas	3	52	6	33
Río Piedras (T.)	—	—	23	—
Río Piedras (V.A.)	2	—	2	—

I. Magnesium experiments with sugarcane

Location	Blades						Sheaths					
	4 months			7 months			4 months			7 months		
	M.[1]	P.-R.	F.-Y.	M.	P.-R.	F.-Y.	M.	P.-R.	F.-Y.	M.	P.-R.	F.-Y.
Corozal	76	77	76	77	88	93	84	96	94	84	5	96
Guayama	69	71	69	30	28	28	23	19	18	33	20	28
Gurabo	54	—	50	—	—	—	—	—	12	30	—	—
Isabela	69	—	81	3	—	3	25	7	40	5	—	80
Lajas	21	—	19	1	—	—	42	44	46	—	—	—
Patillas	41	—	47	32	6	30	32	36	46	39	5	37
Río Piedras (T.)	26	—	22	16	—	—	42	41	43	—	—	—
Río Piedras (V.A.)	49	—	54	25	—	23	48	7	68	26	—	26

TABLE 1.—*Continued*

J. Magnesium experiments with corn

Location	4 weeks		7 weeks	
	M.[1]	F.-Y.	M.	F.-Y.
Corozal	—	—	76	75
Guayama	53	54	—	—
Gurabo (T.)	23	23	20	23
Gurabo (Ma.)	27	23	5	11
Isabela	4	3	91	90
Lajas	43	87	39	36
Río Piedras (T.)	17	15	1	11
Río Piedras (V.A.)	84	85	17	14

[1] M. = Mitscherlich equation. P.-R. = Pearl-Reed equation. F.-Y. = Fertilizer-yield equation.

nitrogen leaf content, based on the rate of ammonium sulfate applied to the soil, varied from very poor in the case of the leaf blades in the experiment performed in the Toa sandy loam (T.) at Río Piedras to very good in the cases of both blades and sheaths taken at an age of 4 months in the experiment performed in a Machete clay at Guayama. A study of table 1, A indicates, in general, that: 1, Sheath nitrogen content is as closely related to ammonium sulfate applications as blade nitrogen content, as judged by the values of the corresponding coefficients of determination; and 2, both blade and sheath nitrogen contents at 4 months of age were more closely related to ammonium sulfate applications than the corresponding contents at 7 months.

The fact that the relation between the sheath and the available nitrogen in the soil is as close as the relation between the blade and the soil's available nitrogen is of interest because in the crop-logging procedures following Clements (*4*) the blade invariably is used for nitrogenous foliar diagnosis.

The fit between the observed and estimated leaf nitrogen values was in general better when the nitrogen content of the leaves of the zero-application plots was relatively low. For example, for the sheath data, the highest coefficient of determination, 0.967, was obtained with the data of the Gurabo experiment, table 3, where the nitrogen content of the first leaf-sheath samples from the zero-application plots was the lowest, 0.445 percent. In soils with higher available nitrogen contents, as estimated from the fitted equations, the relative increase of the tissue nitrogen content with applications of the nitrogenous fertilizer was smaller and the precision of the fit of the equation was not as high as otherwise. The more deficient a soil is, therefore, the more suitable it would be for the performance of

TABLE 2.—*Results obtained on fitting the Mitscherlich equation to the leaf-blade data of the nitrogen experiments with sugarcane variety P.R. 980*

Location		Corozal	Guayama	Gurabo	Isabela	Lajas	Patillas	Río Piedras	Río Piedras
Soil type		Cialitos clay	Machete clay	Mabí clay	Coto clay	Fraternidad clay, saline phase	Viví sandy loam	Toa sandy loam	Vega Alta clay loam
Planting date....		5/9/63	11/7/62	12/19/62	11/28/62	2/14/63	11/3/62	7/10/63	4/24/63
1st sampling date...........		9/9/63	3/11/63	4/19/63	3/29/63	6/14/63	3/7/63	11/12/63	8/26-7/63
2nd sampling date...........		12/9/63	6/17/63	7/17/63	6/29/63	9/13/63	6/7-8/63	2/7/64	11/26/63
Fertilizer treatments and nitrogen content of first leaf-blade samples (4 months)									
Treat. no.	Units of N[1]	*Nitrogen content in percentage of dry matter*							
1	0	1.620	1.320	1.310	1.470	1.235	1.410	1.605	1.345
2	.05	1.545	1.350	1.415	1.530	1.345	1.260	1.635	1.365
3	.10	1.575	1.390	1.455	1.530	1.375	1.295	1.615	1.455
4	.15	1.550	1.475	1.635	1.520	1.495	1.400	1.500	1.515
5	.20	1.685	1.490	1.625	1.545	1.510	1.550	1.690	1.350
6	.30	1.605	1.685	1.875	1.550	1.625	1.615	1.860	1.435
7	.60	1.665	1.595	1.910	1.585	1.655	1.715	1.740	1.575
8	1.20	1.780	1.775	2.040	1.640	1.665	1.765	1.665	1.725
9	2.00	1.790	1.840	2.100	1.550	1.710	1.910	1.770	1.770
Statistics of the equations fitted to the nitrogen data of the first leaf-blade samples									
A		2.574	2.324	2.072	2.511	2.333	1.894	2.627	2.352
B		.9917	.9266	.7767	.9842	.9324	.5972	.9865	.9720
C		.8708	.6677	.0372	.9598	.7750	.1573	.9294	.7413
C.D.[2]		.766	.817	.970	.303	.618	.881	.181	.864
Fertilizer treatments and nitrogen content of second leaf-blade samples (7 months)									
Treat. no.	Units of N[1]	*Nitrogen content in percentage of dry matter*							
1	0	1.105	1.050	1.065	1.100	1.275	0.895	1.460	1.160
2	.05	1.245	.965	1.130	.980	1.210	.905	1.520	1.145
3	.10	1.340	1.010	.870	1.110	1.180	1.035	1.370	1.380
4	.15	1.290	1.080	1.055	1.085	1.230	.915	1.345	1.430
5	.20	1.430	1.205	1.220	1.060	1.330	1.105	1.525	1.275
6	.30	1.380	1.290	.985	1.110	1.330	.890	1.615	1.380
7	.60	1.335	1.370	1.425	1.195	1.385	1.315	1.480	1.415
8	1.20	1.315	1.410	1.305	1.180	1.395	1.210	1.495	1.405
9	2.00	1.200	1.555	1.620	1.130	1.530	1.215	1.390	1.420
Statistics of the equations fitted to the nitrogen data of the second leaf-blade samples									
A		2.286	1.688	2.020	2.065	2.234	1.937	2.459	2.255
B		.9805	.6679	1.016	.9850	.9950	.9793	.9805	.9690
C		1.0234	.3779	.7371	.9479	.8397	.8009	1.023	.9015
C.D.[2]		.024	.885	.636	.270	.814	.491	.031	.281

[1] One unit of N = 1,000 lbs. of nitrogen per acre in the form of ammonium sulfate.
[2] C.D. = Coefficient of determination.

Table 3.—*Results obtained on fitting the Mitscherlich equation to the leaf-sheath data of the nitrogen experiments with sugarcane variety P.R. 980*

Location		Corozal	Guayama	Gurabo	Isabela	Lajas	Patillas	Río Piedras	Río Piedras
Soil type		Cialitos clay	Machete clay	Mabí clay	Coto clay	Fraternidad clay, saline phase	Viví sandy loam	Toa sandy loam	Vega Alta clay loam
Planting date		5/9/63	11/7/62	12/19/62	11/28/62	2/14/63	11/3/62	7/10/63	4/24/63
1st sampling date		9/9/63	3/11/63	4/19/63	3/29/63	6/14/63	3/7/63	11/12/63	8/26–7/63
2nd sampling date		12/9/63	6/17/63	7/17/63	6/29/63	9/13/63	6/7–8/63	2/7/64	11/26/63
Fertilizer treatments and nitrogen content of first leaf-sheath samples (4 months)									
Treat. no.	Units of N[1]	*Nitrogen content in percentage of dry matter*							
1	0	0.540	0.485	0.445	0.665	0.490	0.560	0.630	0.560
2	.05	.575	.515	.520	.690	.535	.490	.660	.525
3	.10	.585	.550	.555	.705	.565	.565	.640	.560
4	.15	.620	.605	.575	.720	.615	.555	.620	.555
5	.20	.615	.620	.625	.705	.635	.655	.665	.580
6	.30	.605	.630	.825	.675	.635	.660	.655	.595
7	.60	.625	.730	.960	.810	.685	.725	.665	.640
8	1.20	.735	.730	1.010	.725	.740	.840	.650	.925
9	2.00	.755	.850	1.185	.770	.785	.960	.745	.790
Statistics of the equations fitted to the nitrogen data of the first leaf-sheath samples									
A		1.564	1.543	1.161	1.681	1.554	1.549	1.621	1.525
B		.9898	.9964	.7230	.9846	.9923	1.004	.9849	.9833
C		.8924	.8207	.1485	.9569	.8601	.7513	.9550	.8045
C.D.[2]		.897	.864	.967	.362	.820	.940	.662	.744
Fertilizer treatments and nitrogen content of second leaf-sheath samples (7 months)									
Treat. no.	Units of N[1]	*Nitrogen content in percentage of dry matter*							
1	0	0.545	0.450	0.450	0.595	0.505	0.430	0.545	0.555
2	.05	.575	.390	.415	.605	.475	.415	.570	.570
3	.10	.625	.395	.410	.615	.495	.580	.505	.615
4	.15	.595	.470	.455	.605	.540	.515	.570	.605
5	.20	.595	.550	.445	.615	.600	.580	.580	.590
6	.30	.590	.470	.505	.610	.625	.580	.570	.645
7	.60	.585	.655	.580	.625	.610	.605	.550	.620
8	1.20	.630	.635	.630	.640	.640	.655	.565	.685
9	2.00	.625	.705	.645	.670	.635	.735	.590	.710
Statistics of the equations fitted to the nitrogen data of the second leaf-sheath samples									
A		1.566	1.437	1.428	1.587	1.500	1.496	1.535	1.572
B		.9835	.9948	.9920	.9841	.9671	.9925	.9829	.9868
C		.9738	.8341	.8633	.9658	.9248	.8553	.9826	.9278
C.D.[2]		.384	.746	.845	.952	.501	.664	.206	.816

[1] One unit of N = 1,000 lbs. of nitrogen per acre in the form of ammonium sulfate.
[2] C.D. = Coefficient of determination.

the experiment from which data are to be used in evaluating the constants of the equation relating soil available and tissue nutrient contents.

The fits between the actual and estimated leaf-nitrogen contents were better in general in the corn than in the sugarcane experiments. This may be deducted by comparing the values of the coefficients of determination in tables 1,A and 1,B and tables 2, 3 and 4, respectively. The fit also was better with leaves sampled at a younger age than with leaves sampled at a more mature age. This latter result may be due to the fact that the variation in the levels of nutrients in the sugarcane leaf tends to diminish with age (7).

At the ages at which the corn leaf samples were taken (4 and 7 weeks) the leaves contained considerably higher amounts of nitrogen in percentage of dry matter than the sugarcane leaves did at the ages at which they were sampled (4 and 7 months).

The data from the 16 experiments with ammonium sulfate presented in the tables seem to support the conclusion mentioned previously that a smooth curve approaching an asymptote, such as the Mitscherlich's curve, could be used to express in a rather precise way the relationship between the available nitrogen content of the soil and the leaf nitrogenous content, especially when the leaves are sampled at an early stage of growth.

PHOSPHORUS EXPERIMENTS

Table 1,C, and tables 5 and 6 present results of statistical studies performed with the leaf-nutrient data from the eight sugarcane experiments with calcium superphosphate.

As may be seen in table 1,C, the relation between the available phosphorus of the soil, expressed as calcium superphosphate, and the leaf phosphorus content was very good in most cases, exceedingly good in the Lajas experiment, and very poor in the Río Piedras (V.A.) experiment. The coefficients of determination were, in general, somewhat better for the blades than for the sheaths. They also were much higher for the leaves sampled at 4 months of age than for those sampled at 7 months.

In this case also the fits between the actual leaf nutrient contents and those estimated on the basis of the soil's content of the respective available nutrient, were higher when the soils were more deficient in said available nutrient. As in the case of the nitrogen experiments, the lower the content of available phosphorus in a soil, the higher the precision of the fit of the equation relating the soil and plant tissue phosphorus content. For example, in the Lajas experiment (table 6) the sheath phosphorus content at 7 months was the lowest, 0.050 percent, while the corresponding coefficient of determination, 0.806, was the highest of the set.

Tables 1,D, and 7, present the results of the leaf nutrient studies with

TABLE 4.—*Results obtained on fitting the Mitscherlich equation to the leaf data of the nitrogen experiments with corn variety Mayorbela*

Location		Corozal	Guayama	Gurabo	Gurabo	Isabela	Lajas	Río Piedras	Río Piedras
Soil type		Cialitos clay	Machete clay	Mabí clay	Toa sandy loam	Coto clay	Fraternidad clay, saline phase	Toa sandy loam	Vega Alta clay loam
Planting date....		2/12/64	9/17/64	8/1/63	9/22/64	3/28/63	4/18/63	4/5/64	7/10/63
1st sampling date..........		—	10/19/64	8/30/63	10/22/64	4/29/63	5/17/63	5/5/64	8/9/63
2nd sampling date..........		4/3/64	—	9/23/63	11/12-3/64	5/17/63	6/7/63	5/25/64	8/29/63
Fertilizer treatments and nitrogen content of first leaf samples (4 weeks)									
Treat. no.	Units of N[1]	*Nitrogen content in percentage of dry matter*							
1	0	—	3.150	2.825	1.690	3.190	3.970	2.970	2.895
2	.05	—	3.370	3.285	1.750	3.275	3.735	3.195	2.850
3	.10	—	3.440	3.560	1.765	3.480	3.530	3.210	2.935
4	.15	—	3.430	3.510	1.795	3.630	4.055	3.515	3.075
5	.20	—	3.380	3.760	1.835	3.815	4.295	3.555	3.220
6	.30	—	3.530	3.850	1.850	3.785	4.360	3.750	3.050
7	.60	—	3.770	3.950	1.935	4.075	4.135	3.625	3.090
8	1.20	—	3.960	3.965	2.030	4.285	4.445	3.835	2.940
9	2.00	—	4.280	4.050	2.045	4.215	4.400	3.905	3.395
Statistics of the equations fitted to the nitrogen data of the first leaf samples									
A		—	4.487	3.982	2.697	4.244	4.407	3.822	3.961
B		—	1.227	1.115	.9390	1.074	.6468	.8630	.9985
C		—	.4422	.0004	.7922	.0313	.0375	.0035	.8252
C.D.[2]		—	.965	.972	.871	.977	.554	.924	.401
Fertilizer treatments and nitrogen content of second leaf samples (7 weeks)									
Treat. no.	Units of N[1]	*Nitrogen content in percentage of dry matter*							
1	0	0.575	—	2.000	0.320	2.965	2.375	1.860	2.790
2	.05	.655	—	2.465	.310	2.820	2.995	2.165	2.545
3	.10	.770	—	2.420	.320	2.910	2.405	2.150	2.720
4	.15	.785	—	2.730	.315	3.110	2.655	2.370	2.745
5	.20	.920	—	2.950	.320	3.120	3.195	2.265	2.725
6	.30	.900	—	2.975	.325	3.110	2.915	2.560	2.765
7	.60	.930	—	3.145	.345	3.260	2.930	2.340	2.555
8	1.20	1.005	—	3.135	.335	4.485	3.195	2.675	2.590
9	2.00	1.005	—	3.185	.345	3.525	3.220	2.930	2.835
Statistics of the equations fitted to the nitrogen data of the second leaf samples									
A		1.699	—	3.163	1.301	3.575	3.167	2.880	3.668
B		.9582	—	1.136	.9828	.6881	.6494	.8322	.9836
C		.7939	—	.0014	.9842	.2295	.0246	.2127	.9751
C.D.[2]		.578	—	.963	.655	.920	.512	.801	.024

[1] One unit of N = 1,000 lbs. of nitrogen per acre in the form of ammonium sulfate.
[2] C.D. = Coefficient of determination.

TABLE 5.—*Results obtained on fitting the Mitscherlich equation to the leaf-blade data of the phosphorus experiments with sugarcane variety P. R. 980*

Location		Corozal	Guayama	Gurabo	Isabela	Lajas	Patillas	Río Piedras	Río Piedras
Soil type		Cialitos clay	Machete clay	Mabí clay	Coto clay	Fraternidad clay, saline phase	Viví sandy loam	Toa sandy loam	Vega Alta clay loam
Planting date		5/9/63	11/7/62	12/19/62	11/28/62	2/14/63	11/3/62	7/10/63	4/24/63
1st sampling date		9/9/63	3/11/63	4/19/63	3/29/63	6/14/63	3/7/63	11/12/63	8/26–7/63
2nd sampling date		12/9/63	6/17/63	7/17/63	6/29/63	9/13/63	6/7–8/63	2/7/64	11/26/63
Fertilizer treatments and phosphorus content of first leaf-blade samples (4 months)									
Treat. no.	Units of P[1]	*Phosphorus content in percentage of dry matter*							
1	0	0.125	0.174	0.135	0.148	0.140	0.177	0.155	0.165
2	.05	.140	.179	.160	.164	.145	.185	.155	.190
3	.10	.145	.180	.205	.162	.165	.190	.150	.175
4	.15	.140	.173	.180	.159	.165	.207	.170	.165
5	.20	.145	.201	.170	.164	.195	.212	.140	.175
6	.50	.170	.260	.235	.209	.225	.262	.155	.150
7	.75	.160	.271	.460	.209	.255	.298	.175	.180
8	1.00	.185	.294	.460	.284	.290	.347	.175	.215
9	1.50	.205	.289	.415	.296	.320	.314	.175	.185
Statistics of the equations fitted to the phosphorus data of the first leaf-blade samples									
A		1.123	1.170	1.127	1.141	1.144	1.181	1.140	1.157
B		.9889	.9915	.9778	.9924	.9937	.9927	.9875	.9874
C		.9514	.9020	.7411	.8919	.8706	.8816	.9817	.9837
C.D.[2]		.926	.854	.803	.938	.967	.855	.501	.197
Fertilizer treatments and phosphorus content of second leaf-blade samples (7 months)									
Treat. no.	Units of P[1]	*Phosphorus content in percentage of dry matter*							
1	0	0.135	0.130	0.160	0.140	0.140	0.125	0.155	0.165
2	.05	.145	.130	.125	.150	.140	.120	.125	.165
3	.10	.155	.135	.145	.165	.140	.140	.135	.155
4	.15	.145	.160	.160	.165	.130	.150	.125	.155
5	.20	.170	.150	.150	.145	.140	.135	.135	.150
6	.50	.170	.150	.145	.150	.145	.130	.135	.150
7	.75	.180	.150	.135	.155	.145	.135	.130	.145
8	1.00	.210	.185	.160	.210	.160	.130	.140	.155
9	1.50	.175	.170	.195	.190	.175	.150	.160	.155
Statistics of the equations fitted to the phosphorus data of the second leaf-blade samples									
A		1.137	1.126	1.129	1.136	1.122	1.101	1.119	1.144
B		.9881	.9879	.9878	.9882	.9878	.9699	.9872	.9866
C		.9661	.9713	.9753	.9664	.9754	.9916	.9879	1.005
C.D.[2]		.549	.604	.394	.545	.855	.159	.241	.147

[1] One unit of P = 1,000 lbs. of phosphorus per acre in the form of calcium superphosphate.

[2] C.D. = Coefficient of determination.

TABLE 6.—*Results obtained on fitting the Mitscherlich equation to the leaf-sheath data of the phosphorus experiments with sugarcane variety P.R. 980*

Location		Corozal	Guayama	Gurabo	Isabela	Lajas	Patillas	Río Piedras	Río Piedras
Soil type		Cialitos clay	Machete clay	Mabí clay	Coto clay	Fraternidad clay, saline phase	Viví sandy loam	Toa sandy loam	Vega Alta clay loam
Planting date....		5/9/63	11/7/62	12/19/62	11/28/62	2/14/63	11/3/62	7/10/63	4/24/63
1st sampling date..........		9/9/63	3/11/63	4/19/63	3/29/63	6/14/63	3/7/63	11/12/63	8/26-7/63
2nd sampling date..........		12/9/63	6/17/63	7/17/63	6/29/63	9/13/63	6/7-8/63	2/7/64	11/26/63
Fertilizer treatments and phosphorus content of first leaf-sheath samples (4 months)									
Treat. no.	Units of P[1]	*Phosphorus content in percentage of dry matter*							
1	0	0.060	0.068	0.050	0.060	0.055	0.090	0.065	0.085
2	.05	.060	.169	.070	.063	.055	.097	.060	.105
3	.10	.065	.082	.080	.059	.055	.126	.065	.080
4	.15	.065	.090	.075	.064	.065	.104	.070	.080
5	.20	.070	.104	.075	.079	.080	.108	.060	.080
6	.50	.085	.179	.120	.077	.100	.154	.065	.075
7	.75	.080	.187	.345	.099	.130	.207	.080	.080
8	1.00	.090	.233	.325	.184	.175	.246	.070	.110
9	1.50	.125	.233	.320	.208	.250	.180	.080	.100
Statistics of the equations fitted to the phosphorus data of the first leaf-sheath samples									
A		1.048	1.089	1.039	1.042	1.038	1.094	1.050	1.070
B		.9884	.9925	.9905	.9924	.9944	.9909	.9872	.9872
C		.9603	.8882	.7548	.8934	.8670	.9093	.9883	.9887
C.D.[2]		.926	.739	.828	.892	.978	.670	.604	.188
Fertilizer treatments and phosphorus content of second leaf-sheath samples (7 months)									
Treat. no.	Units of P[1]	*Phosphorus content in percentage of dry matter*							
1	0	0.055	0.065	0.055	0.065	0.050	0.065	0.075	0.080
2	.05	.055	.065	.060	.070	.055	.050	.070	.080
3	.10	.060	.070	.060	.070	.060	.060	.065	.065
4	.15	.060	.075	.060	.080	.060	.060	.070	.070
5	.20	.060	.080	.070	.075	.055	.065	.070	.070
6	.50	.070	.075	.070	.070	.060	.055	.070	.070
7	.75	.065	.080	.065	.075	.060	.065	.075	.070
8	1.00	.080	.085	.070	.090	.065	.060	.075	.070
9	1.50	.075	.080	.080	.085	.080	.065	.090	.080
Statistics of the equations fitted to the phosphorus data of the second leaf-sheath samples									
A		1.044	1.057	1.047	1.057	1.041	1.028	1.055	1.059
B		.9874	.9872	.9873	.9873	.9874	.9696	.9873	.9869
C		.9844	.9896	.9868	.9878	.9848	.9965	.9883	.9982
C.D.[2]		.779	.531	.732	.568	.806	.100	.678	.018

[1] One unit of P = 1,000 lbs. of phosphorus same acre in the form of calcium superphosphate.

[2] C.D. = Coefficient of determination.

TABLE 7.—*Results obtained on fitting the Mitscherlich to the leaf data of the phosphorus experiments with corn variety Mayorbela*

Location	Corozal	Guayama	Gurabo	Gurabo	Isabela	Lajas	Río Piedras	Río Piedras
Soil type	Cialitos clay	Machete clay	Mabí clay	Toa sandy loam	Coto clay	Fraternidad clay, saline phase	Toa sandy loam	Vega Alta clay loam
Planting date....	2/12/64	9/17/64	8/1/63	9/22/64	3/28/63	4/18/63	4/5/64	7/10/63
1st sampling date..........	—	10/19/64	8/30/63	10/22/64	4/29/63	5/17/63	5/5/64	8/9/63
2nd sampling date..........	4/3/64	—	9/23/63	11/2-3/64	5/17/63	6/17/63	5/25/64	8/29/63

Fertilizer treatments and phosphorus content of first leaf samples (4 weeks)

Treat. no.	Units of P[1]	Phosphorus content in percentage of dry matter							
1	0	—	0.420	0.290	0.160	0.242	0.473	0.280	0.330
2	.05	—	.435	.370	.145	.286	.350	.255	.330
3	.10	—	.470	.360	.165	.296	.419	.290	.345
4	.15	—	.480	.390	.170	.309	.459	.265	.320
5	.20	—	.495	.435	.175	.269	.372	.285	.340
6	.50	—	.540	.485	.200	.295	.595	.350	.335
7	.75	—	.540	.525	.230	.373	.659	.370	.365
8	1.00	—	.500	.535	.230	.404	.778	.400	.355
9	1.50	—	.555	.620	.240	.494	.853	.430	.390

Statistics of the equations fitted to the phosphorus data of the first leaf samples

A		—	1.448	1.349	1.149	1.156	1.399	1.260	1.316
B		—	.9901	.9999	.9898	.8977	1.020	.9934	.9884
C		—	.9251	.7970	.9334	.8314	.6465	.8754	.9618
C.D.[2]		—	.629	.916	.890	.912	.915	.940	.798

Fertilizer treatments and phosphorus content of second leaf samples (7 weeks)

Treat. no.	Units of P[1]	Phosphorus content in percentage of dry matter							
1	0	0.130	—	0.295	0.300	0.404	0.377	0.200	0.325
2	.05	.240	—	.300	.315	.394	.306	.170	.345
3	.10	.230	—	.305	.360	.348	.312	.180	.345
4	.15	.295	—	.310	.350	.382	.305	.175	.365
5	.20	.275	—	.340	.330	.364	.369	.185	.350
6	.50	.440	—	.395	.350	.416	.373	.230	.370
7	.75	.450	—	.375	.375	.387	.370	.220	.410
8	1.00	.475	—	.385	.405	.480	.423	.280	.395
9	1.50	.430	—	.480	.400	.554	.432	.275	.420

Statistics of the equations fitted to the phosphorus data of the second leaf samples

A		1.196	—	1.292	1.314	1.355	1.318	1.167	1.331
B		.9686	—	.9930	.9895	.9929	.9904	.9904	.9894
C		.7773	—	.8838	.9381	.8893	.9236	.9236	.9400
C.D.[2]		.707	—	.902	.750	.756	.655	.839	.860

[1] One unit of P = 1,000 lbs. of phosphorus per acre in the form of calcium superphosphate.

[2] C.D. = Coefficient of determination.

calcium superphosphate in corn. In table 1,D it may be seen that, in general, the agreement was good between actual leaf phosphorus content and the corresponding values estimated with the equations on the basis of the rates of calcium superphosphate used. In no case was the relation poor. Again, a better fit was obtained with leaves sampled at 4 weeks of age than with leaves sampled at 7 weeks. High values for the coefficients of determination were obtained even in cases in which the soils were able to supply relatively high quantities of phosphorus.

From the data of the 16 experiments with calcium superphosphate it may be likewise concluded, therefore, that the relation between the soil's available phosphorus and the leaf phosphorus-content is expressible with a high precision by a smooth curve similar to the Mitscherlich's curve, especially with leaves sampled at an early stage of growth. The fitted equations may therefore be used to estimate, on the basis of the leaf phosphorus content, the level of available phosphorus in the soil.

POTASSIUM EXPERIMENTS

Tables 1,E, and 8 and 9 present results of the curve-fitting studies performed with the leaf potassium content data of the sugarcane experiments performed with potassium chloride.

A study of table 1,E shows that, except in the case of the blades sampled at 4 months of age in the Guayama experiment, the relation between the available potassium content of the soil and the potassium leaf content was good, whether with blades or sheaths, and whether the samples were taken at 4 or 7 months of age.

In the Guayama experiment, where the fit was poor for the blades sampled at 4 months of age, the potassium content of the blades from the plots which did not receive potassium chloride applications was by far the highest of the 4-month blades sampled in all the sugarcane experiments. It seems once again that to characterize the relation adequately between soil- and leaf-nutrient contents, it is essential, as it is of course logical, to assume that there be a sufficient range of variability in the leaf nutrient content. This requires performance of the calibration experiment in a soil low in available potassium.

With regard to similar experiences, Ayres and Hagihara (*1*) state: "Results of many experiments, both here and elsewhere, are meaningless because the soils on which they were conducted were already adequately supplied with respect to the element in question."

Tables 1,F and 10 present results of leaf-content studies of the eight corn experiments performed with potassium chloride.

When the leaf samples were taken at an age of 4 weeks, the fit of all the equations relating soil- and leaf-nutrient content were from good to ex-

TABLE 8.—*Results obtained on fitting the Mitscherlich equation to the leaf-blade data of the potassium experiments with sugarcane variety P.R. 980*

Location	Corozal	Guayama	Gurabo	Isabela	Lajas	Patillas	Río Piedras	Río Piedras
Soil type	Cialitos clay	Machete clay	Mabí clay	Coto clay	Fraternidad clay, saline phase	Viví sandy loam	Toa sandy loam	Vega Alta clay loam
Planting date....	5/9/63	11/7/62	12/19/62	11/28/62	2/14/63	11/3/62	7/10/63	4/24/63
1st sampling date..........	9/9/63	3/11/63	4/19/63	3/29/63	6/14/63	3/7/63	11/12/63	8/26-7/63
2nd sampling date......	12/9/63	6/17/63	7/17/63	6/29/63	9/13/63	6/7-8/63	2/7/64	11/26/63

Fertilizer treatments and potassium content of first leaf-blade samples (4 months)

Treat. no.	Units of K[1]	Potassium content in percentage of dry matter							
1	0	1.285	1.690	0.630	1.315	1.150	0.985	0.625	0.810
2	.05	1.300	1.880	.780	1.545	1.460	1.505	.825	1.100
3	.10	1.395	1.705	1.020	1.670	1.480	1.705	.750	1.385
4	.15	1.370	1.935	1.320	1.585	1.440	2.025	1.085	1.600
5	.20	1.765	2.005	1.035	1.700	1.605	2.070	1.090	1.435
6	.50	1.865	2.085	1.535	1.850	1.830	1.705	1.275	2.005
7	2.00	2.110	1.960	1.395	1.935	2.195	2.275	1.960	2.115
8	5.00	2.195	2.210	—	1.925	2.255	2.280	1.950	2.175
9	10.00	2.445	1.885	—	2.130	2.280	2.190	2.045	2.165

Statistics of the equations fitted to the potassium data of the first leaf-blade samples

A		2.263	2.316	1.459	1.988	2.250	2.164	2.004	2.147
B		1.013	.4192	.8512	.6026	.9896	.9419	1.316	1.300
C		.1486	.9552	.0015	.0233	.1554	−.0034	.2338	.0122
C.D.[2]		.925	.077	.862	.897	.974	.750	.977	.973

Fertilizer treatments and potassium content of second leaf-blade samples (7 months)

Treat. no.	Units of K[1]	Potassium content in percentage of dry matter							
1	0	1.175	1.560	1.115	0.960	1.370	0.855	0.980	1.150
2	.05	1.245	1.680	1.140	1.510	1.220	1.245	.905	.900
3	.10	1.375	1.575	.855	1.490	1.385	.940	1.010	1.240
4	.15	1.210	1.430	.970	1.390	1.370	1.185	1.310	1.070
5	.20	1.185	1.575	1.465	1.620	1.440	1.430	1.120	1.160
6	.50	1.380	1.620	1.565	1.835	1.475	1.405	1.630	1.465
7	2.00	1.425	1.595	1.680	2.165	1.910	1.770	1.285	1.845
8	5.00	1.680	1.835	2.050	2.405	1.855	1.975	1.685	1.640
9	10.00	1.715	1.890	—	2.400	1.995	1.935	1.910	1.945

Statistics of the equations fitted to the potassium data of the second leaf-blade samples

A		1.753	2.236	1.965	2.333	1.947	1.918	1.954	1.822
B		.5215	.6741	.9309	1.141	.6528	.9181	.8525	.8137
		.7299	.9284	.3532	.1489	.3962	.2462	.7804	.2373
C.D.[2]		.889	.741	.783	.920	.943	.891	.691	.878

[1] One unit of K = 1,000 lbs. of potassium per acre in the form of potassium chloride.

[2] C.D. = Coefficient of determination.

TABLE 9.—*Results obtained on fitting the Mitscherlich equation to the leaf-sheath data of the potassium experiments with sugarcane variety P.R. 980*

Location	Corozal	Guayama	Gurabo	Isabela	Lajas	Patillas	Río Piedras	Río Piedras
Soil type	Cialitos clay	Machete clay	Mabí clay	Coto clay	Fraternidad clay, saline phase	Viví sandy loam	Toa sandy loam	Vega Alta clay loam
Planting date....	5/9/63	11/7/62	12/19/62	11/28/62	2/14/63	11/3/62	7/10/63	4/24/63
1st sampling date..........	9/9/63	3/11/63	4/19/63	3/29/63	6/14/63	3/7/63	11/12/63	8/26–7/63
2nd sampling date...........	12/9/63	6/17/63	7/17/63	6/29/63	9/13/63	6/7–8/63	2/7/64	11/26/63

Fertilizer treatments and potassium content of first leaf-sheath samples (4 months)

Treat. no.	Units of K[1]	Potassium content in percentage of dry matter							
1	0	1.385	2.335	0.750	1.505	1.300	0.790	0.360	0.595
2	.05	1.430	2.810	1.145	2.300	1.665	1.275	.635	1.240
3	.10	1.550	1.730	1.735	2.555	1.650	1.635	.705	1.425
4	.15	1.700	3.035	2.155	2.550	1.835	2.360	1.060	1.415
5	.20	2.270	2.990	2.000	2.955	1.890	2.725	.960	1.610
6	.50	2.460	3.710	3.180	3.475	2.450	2.205	1.615	2.680
7	2.00	3.445	3.755	3.270	3.735	3.165	3.745	2.775	2.890
8	5.00	3.565	4.255	—	3.430	2.880	3.590	2.980	3.320
9	10.00	3.695	3.295	—	3.830	3.555	3.485	3.315	3.610

Statistics of the equations fitted to the potassium data on the first leaf-sheath samples

A		3.608	3.781	3.284	3.560	3.218	3.426	3.133	3.085
B		2.264	1.358	2.356	1.361	1.834	1.932	2.666	2.071
C		.2217	−.0309	−.0351	−.201	.1730	−.3081	.3290	−.2121
C.D.[2]		.978	.809	.948	.773	.948	.788	.989	.906

Fertilizer treatments and potassium content of second leaf-sheath samples (7 months)

Treat. no.	Units of K[1]	Potassium content in percentage of dry matter							
1	0	1.535	2.235	1.300	1.115	1.780	1.220	0.850	1.170
2	.05	1.715	2.575	1.380	1.605	1.635	1.155	.940	.960
3	.10	2.160	2.190	1.240	1.840	1.850	1.055	1.105	1.510
4	.15	1.680	2.645	1.345	1.800	1.985	1.665	1.965	1.125
5	.20	2.485	2.320	1.695	2.040	2.030	1.505	1.515	1.425
6	.50	2.565	2.545	2.060	2.575	2.185	1.565	2.200	2.200
7	2.00	2.915	2.790	2.850	2.760	3.245	2.685	2.280	2.915
8	5.00	3.335	2.960	3.160	3.290	3.135	2.860	2.890	3.160
9	10.00	3.335	2.875	—	2.890	3.375	3.190	3.240	3.300

Statistics of the equations fitted to the potassium data of the second leaf-sheath samples

A		3.208	2.916	3.150	2.976	3.302	3.084	2.807	3.206
B		1.596	.5676	1.929	1.737	1.616	1.908	1.977	2.186
C		.1255	.4345	.3641	.0430	.3584	.5065	.725	.2951
C.D.[2]		.891	.731	.979	.948	.972	.955	.867	.966

[1] One unit of K = 1,000 lbs. of potassium per acre in the form of potassium chloride.
[2] C.D. = Coefficient of determination.

TABLE 10.—*Results obtained on fitting the Mitscherlich equation to the leaf data of the potassium experiments with corn variety Mayorbela*

Location	Corozal	Guayama	Gurabo	Gurabo	Isabela	Lajas	Río Piedras	Río Piedras
Soil type	Cialitos clay	Machete clay	Mabí clay	Toa sandy loam	Coto clay	Fraternidad clay, saline phase	Toa sandy loam	Vega Alta clay loam
Planting date	2/12/64	9/17/64	8/1/63	9/22/64	3/28/63	4/18/63	4/5/64	7/10/63
1st sampling date	—	10/19/64	8/30/63	10/22/64	4/29/63	5/19/63	5/5/64	8/9/63
2nd sampling date	4/3/64	—	9/23/63	11/12-3/64	5/17/63	6/7/63	5/25/64	8/29/63

Fertilizer treatments and potassium content of first leaf samples (4 weeks)

Treat. no.	Units of K[1]	Potassium content in percentage of dry matter							
1	0	—	3.115	2.970	1.475	4.025	2.890	3.705	2.810
2	.05	—	2.540	3.110	1.700	4.075	3.230	3.795	3.145
3	.10	—	3.020	3.590	2.330	3.970	3.555	3.700	3.095
4	.15	—	2.985	3.305	2.890	—	3.700	4.145	3.250
5	.20	—	3.280	3.340	2.930	3.915	—	4.270	3.045
6	.50	—	3.530	3.710	3.295	4.375	3.975	4.435	3.175
7	2.00	—	3.800	3.875	3.515	4.370	4.375	4.430	3.570
8	5.00	—	3.930	3.940	3.715	4.540	4.600	4.480	3.515
9	10.00	—	4.665	4.015	—	4.680	—	4.255	3.550

Statistics of the equations fitted to the potassium data on the first leaf samples

A		—	4.666	3.938	3.513	4.634	4.442	4.422	3.508
B		—	1.662	.8907	1.740	.6252	1.436	.6207	.5285
C		—	.7724	.0520	−.0441	.5834	.0313	−.1048	.1976
C.D.[2]		—	.842	.882	.873	.846	.947	.719	.790

Fertilizer treatments and potassium content of second leaf samples (7 weeks)

Treat. no.	Units of K[1]	Potassium content in percentage of dry matter							
1	0	1.620	—	1.695	1.550	2.740	3.010	2.150	2.080
2	.05	2.485	—	1.880	1.430	2.905	2.730	2.245	1.960
3	.10	2.975	—	1.815	1.770	2.820	3.240	2.195	2.125
4	.15	2.660	—	1.895	1.955	2.855	3.080	2.115	2.260
5	.20	2.720	—	1.745	1.995	2.690	3.650	2.205	2.095
6	.50	3.335	—	1.755	2.105	2.930	3.290	2.220	2.140
7	2.00	3.765	—	1.785	2.160	3.090	3.790	2.320	2.180
8	5.00	4.145	—	1.940	2.240	2.760	3.210	2.350	2.200
9	10.00	4.580	—	2.000	2.575	2.990	—	2.595	2.315

Statistics of the equations fitted to the potassium data of the second leaf samples

A		4.162	—	2.667	2.313	3.699	3.503	3.103	2.988
B		2.107	—	.8770	.8431	.8603	.5162	.9220	.8807
C		.1008	—	.9721	.0171	.9843	−.0549	.9463	.9736
C.D.[2]		.877	—	.549	.836	.114	.386	.905	.462

[1] One unit of K = 1,000 lbs. of potassium per acre in the form of potassium chloride.
[2] C.D. = Coefficient of determination.

cellent. For the leaves sampled at an age of 7 weeks, the fits were satisfactory for only the experiments at Gurabo and Río Piedras, both on Toa soils. Our conclusion that a closer relation exists between the original soil nutrient contents and the leaf nutrient contents at an early age than at a later stage, is again confirmed.

CALCIUM EXPERIMENTS

Table 1,G, and tables 11 and 12 present the results of the curve-fitting studies with the data from the sugarcane experiments with applications of ground limestone in varying amounts.

As may be seen in these tables, the correlation between the calcium content of the soil as calcium carbonate and the calcium content of the leaves was good only in the case of the sheaths taken at an age of 7 months in the Isabela experiment.

In the corn experiments, the corresponding data presented in tables 1,H and 13, the highest value of the coefficient of determination, 0.698, also was obtained in the Isabela experiment.

Table 14 presents the pH values of the top 8-inch layers of the soils in which these experiments were performed. The lowest pH value, 4.72, at Corozal, is already high enough for aluminum and manganese to exert no serious deleterious influence on plant growth. The minimum calcium content of both sugarcane and corn tissues analyzed was 0.150 percent for sheaths taken at 4 months of age, and 0.235 percent for corn leaves taken at 7 weeks of age, at Corozal, from the plots which received no calcium carbonate, the soil with the lowest pH value.

MAGNESIUM EXPERIMENTS

Tables 1,I, and 15 and 16 present the results of the curve-fitting studies performed with varying applications of magnesium sulfate to sugarcane. The data presented in tables 1,J and 17 are for the corn experiments with magnesium sulfate.

As may be seen in these tables, the fit between the available content of magnesium in the soil and the plant tissue magnesium content was excellent for the corn-leaf samples taken at 7 weeks at Isabela, where the plots which received no magnesium sulfate applications were the lowest of all the magnesium sulfate experiments with corn. It was fair for the sugarcane sheaths at Corozal, for the sugarcane blades taken at 4 months of age at Corozal, Guayama, and Isabela, and for the corn leaves taken at 4 weeks of age at Río Piedras (Vega Alta clay loam) and at 7 weeks of age at Corozal.

The magnesium content of the plant tissues in the cases in which the highest correlations were obtained were, in all but one, the lowest among the respective tissues of the 16 magnesium sulfate experiments.

TABLE 11.—*Results obtained on fitting the Mitscherlich equation to the leaf-blade data of the calcium experiments with sugarcane variety P.R. 980*

Location	Corozal	Gurabo	Isabela	Lajas	Patillas	Río Piedras	Río Piedras
Soil type	Cialitos clay	Mabí clay	Coto clay	Fraternidad clay, saline phase	Viví sandy loam	Toa sandy loam	Vega Alta clay loam
Planting date	5/9/63	12/19/62	11/28/62	2/14/63	11/3/62	7/10/63	4/24/63
1st sampling date	9/9/63	4/19/63	3/29/63	6/14/63	3/7/63	11/12/63	8/26–7/63
2nd sampling date	12/9/63	7/17/63	6/29/63	9/13/63	6/7–8/63	2/7/64	11/26/63

Fertilizer treatments and calcium content of first leaf-blade samples (4 months)

Treat. no.	Units of Ca[1]	Calcium content in percentage of dry matter						
1	0	0.405	0.425	0.590	0.585	0.410	0.540	0.400
2	.4	.460	.465	.555	.485	.447	.655	.395
3	.8	.455	.480	.630	.440	.510	.640	.360
4	1.2	.450	.490	.745	.515	.496	.490	.415
5	1.6	.470	.490	.755	.500	.504	.570	.425
6	2.0	.295	.565	.705	.535	.679	.665	.325
7	2.4	.450	.500	.585	.460	.501	.590	.445
9	3.2	.340	.500	.700	.485	.502	.640	.380
9	4.0	.435	.530	.605	.530	.452	.620	.410

Statistics of the equations fitted to the calcium data of the first leaf-blade samples

A		1.345	1.368	1.543	1.417	1.386	1.490	1.298
B		.9052	.912	.9077	.9075	.9079	.9106	.9082
C		1.014	.9757	.9889	1.004	.9858	.9859	.9969
C.D.[2]		.078	.499	.028	.012	.044	.077	.009

Fertilizer treatments and calcium content of second leaf-blade samples (7 months)

Treat. no.	Units of Ca[1]	Calcium content in percentage of dry matter						
1	0	0.475	0.730	0.665	0.435	0.415	0.990	0.605
2	.4	.465	.605	.705	.520	.330	.805	.610
3	.8	.685	.670	.725	.520	.320	.770	.625
4	1.2	.585	.760	.715	.485	.350	.970	.615
5	1.6	.675	.720	.930	.490	.435	1.010	.580
6	2.0	.585	.700	.760	.525	.375	1.215	.630
7	2.4	.550	.695	.575	.475	.340	.805	.605
8	3.2	.525	.555	.475	.505	.360	1.080	.605
9	4.0	.580	.670	.730	.550	.370	1.045	.630

Statistics of the equations fitted to the calcium data of the second leaf-blade samples

A		1.461	1.610	1.642	1.387	1.274	1.802	1.515
B		.9078	.9043	.9026	.9108	.9076	.9224	.9083
C		.9895	1.017	1.026	.9846	1.001	.9436	.9969
C.D.[2]		.024	.105	.067	.279	.001	.179	.047

[1] One unit of Ca = 1,000 lbs of calcium in the form of calcium carbonate.
[2] C.D. = Coefficient of determination.

TABLE 12.—*Results obtained on fitting the Mitscherlich equation to the leaf-sheath data of the calcium experiments with sugarcane variety P.R. 980*

Location		Corozal	Gurabo	Isabela	Lajas	Patillas	Río Piedras	Río Piedras
Soil type		Cialitos clay	Mabí clay	Coto clay	Fraternidad clay, saline phase	Viví sandy loam	Toa sandy loam	Vega Alta clay loam
Planting date		5/9/63	12/19/62	11/28/62	2/14/63	11/3/62	7/10/63	4/24/63
1st sampling date		9/9/63	4/19/63	3/29/63	6/14/63	3/7/63	11/12/63	8/26-7/63
2nd sampling date		12/9/63	7/19/63	6/29/63	9/13/63	6/7-8/63	2/7/64	11/26/63
Fertilizer treatments and calcium content of first leaf-sheath samples (4 months)								
Treat. no.	Units of Ca[1]	*Calcium content in percentage of dry matter*						
1	0	0.150	0.255	0.330	0.245	0.250	0.385	0.200
2	.4	.215	.270	.270	.200	.272	.470	.225
3	.8	.205	.305	.320	.230	.252	.510	.235
4	1.2	.225	.280	.315	.250	.291	.460	.205
5	1.6	.230	.265	.295	.220	.267	.495	.190
6	2.0	.210	.300	.310	.230	.335	.465	.225
7	2.4	.195	.275	.295	.225	.261	.410	.230
8	3.2	.180	.295	.315	.240	.280	.455	.230
9	4.0	.250	.315	.315	.235	.237	.435	.235
Statistics of the equations fitted to the calcium data of the first leaf-sheath samples								
A		1.099	1.176	1.213	1.044	1.179	1.364	1.118
B		.9094	.9099	.9080	.8173	.9068	.9064	.9090
C		.9893	.9886	.9984	.9974	1.001	1.002	.9932
C.D.[2]		.173	.426	.008	.030	.001	.006	.223
Fertilizer treatments and calcium contents of second leaf-sheath samples (7 months)								
Treat. no.	Units of Ca[1]	*Calcium content in percentage of dry matter*						
1	0	0.420	0.280	0.310	0.290	0.320	0.430	0.300
2	.4	.305	.280	.335	.265	.250	.405	.340
3	.8	.315	.305	.340	.335	.245	.395	.335
4	1.2	.305	.275	.345	.315	.215	.405	.300
5	1.6	.310	.315	.370	.360	.270	.370	.290
6	2.0	.290	.250	.360	.360	.230	.370	.360
7	2.4	.350	.325	.365	.330	.265	.385	.340
8	3.2	.250	.320	.390	.355	.255	.480	.310
9	4.0	.305	.270	.385	.365	.305	.385	.335
Statistics of the equations fitted to the calcium data of the second leaf-sheath samples								
A		1.253	1.194	1.235	1.116	1.166	1.309	1.224
B		.9046	.9079	.9118	.8219	.9090	.9082	.9083
C		1.020	.9972	.9792	.9738	.9970	.9988	.9956
C.D.[2]		.286	.014	.871	.591	.010	.001	.043

[1] One unit of Ca = 1,000 lbs. of calcium in the form of calcium carbonate.
[2] C.D. = Coefficient of determination.

TABLE 13.—*Results obtained on fitting the Mitscherlich equation to the leaf data of the calcium experiments with corn variety Mayorbela*

Location		Corozal	Gurabo	Gurabo	Isabela	Lajas	Río Piedras	Río Piedras
Soil type		Cialitos clay	Mabí clay	Toa sandy loam	Coto clay	Fraternidad clay, saline phase	Toa sandy loam	Vega Alta clay loam
Planting date		2/12/64	8/1/63	9/22/64	3/28/63	4/18/63	4/5/64	7/10/63
1st sampling date		—	8/30/63	10/22/64	4/29/63	5/17/63	5/5/64	8/9/63
2nd sampling date		4/3/64	9/23/63	11/12-3/64	5/17/63	6/7/63	5/25/64	8/29/63
Fertilizer treatments and calcium content of first leaf samples (4 weeks)								
Treat. no.	Units of Ca[1]	*Calcium content in percentage of dry matter*						
1	0	—	0.305	0.245	0.351	0.444	0.255	0.395
2	.4	—	.275	.300	.371	.441	.225	.405
3	.8	—	.250	.280	.329	.425	.320	.345
4	1.2	—	.240	.265	.412	.364	.245	.410
5	1.6	—	.175	.265	.380	.429	.210	.410
6	2.0	—	.265	.305	.338	.430	.240	.390
7	2.4	—	.245	.280	.406	.396	.230	.465
8	3.2	—	.175	.235	.449	.402	.215	.390
9	4.0	—	.225	.315	.421	.485	.290	.345
Statistics of the equations fitted to the calcium data of the first leaf samples								
A		—	1.178	1.177	1.260	1.325	1.156	1.215
B		—	.9044	.9086	.9132	.9093	.9078	.8133
C		—	1.021	.9947	.9757	.9950	1.001	1.0045
C.D.[2]		—	.376	.051	.469	.029	.0005	.019
Fertilizer treatments and calcium content of second leaf samples (7 weeks)								
Treat. no.	Units of Ca[1]	*Calcium content in percentage of dry matter*						
1	0	0.235	0.310	0.460	0.464	0.425	0.240	0.670
2	.4	.450	.300	.455	.472	.389	.305	.565
3	.8	.485	.480	.540	.472	.480	.255	.655
4	1.2	.340	.435	.530	.461	.466	.325	.655
5	1.6	.470	.365	.535	.475	.451	.275	.605
6	2.0	.405	.290	.485	.515	—	.345	.620
7	2.4	.455	.350	.565	.515	.479	.310	.570
8	3.2	.475	.325	.550	.501	.447	.325	.695
9	4.0	.485	.290	.535	.520	.436	.295	.640
Statistics of the equations fitted to the calcium data of the second leaf samples								
A		1.271	1.281	1.394	1.372	1.255	1.184	1.532
B		.9165	.9038	.9116	.9112	.8176	.9099	.9090
C		.9562	1.018	.9777	.9826	.9933	.9854	.9951
C.D.[2]		.331	.101	.399	.698	.056	.231	.016

[1] One unit of Ca = 1,000 lbs. of calcium per acre in the form of calcium carbonate.
[2] C.D. = Coefficient of determination.

From the results of the curve-fitting studies of the magnesium sulfate experimental data, it may also be concluded that the relations between the available content of magnesium by the soil and the content of magnesium by the sugarcane and corn leaves may be evaluated with greater precision with data obtained from experiments performed in fields relatively low in their available content of magnesium—the more so when the plant tissues are sampled during an early stage of growth rather than a late one.

GENERAL CONCLUSIONS

The curve-fitting studies of the data of the experiments performed with ammonium sulfate, calcium superphosphate, and potassium and magnesium chlorides, tend to support the following general conclusions:

1. The amount of a nutrient occurring in plant leaves, within certain limits, tends to increase with the increased availability of that nutrient in the soil upon which the plant is grown.

TABLE 14.—*pH values of the top 8-inch layers of the soils of the experimental fields*

Location	Soil type	pH Value
Corozal	Cialitos clay	4.72
Guayama	Machete clay	6.30
Gurabo	Mabí clay	6.74
Isabela	Coto clay	5.36
Lajas	Fraternidad clay, saline phase	5.20
Patillas	Viví sandy loam	5.10
Río Piedras	Toa sandy loam	6.50
Río Piedras	Vega Alta clay loam	5.19

2. The relation between the available nutrient content of the soil and the leaf content of the nutrient is expressible by a smooth curve approaching a maximum value as an asymptote. The Mitscherlich equation, among others, may be used satisfactorily to represent this relation.

3. The precision of the fit of this equation to the corresponding amount of the nutrient applied and the leaf nutrient content data is higher when the corresponding calibrating experiments are performed in soils with relatively low available levels of the nutrient under study.

4. The relation between the available nutrient content of the soil and the respective nutrient content of the leaves is closer when the leaves are samples at a relatively early stage of growth rather than when sampled at a more advanced age.

5. The precision of the fits of the corresponding equations for sugarcane blades and sheaths are about equal for each of the various nutrients studied.

TABLE 15.—*Results obtained on fitting the Mitscherlich equation to the leaf-blade data of the magnesium experiments with sugarcane variety P.R. 980*

Location		Corozal	Guayama	Gurabo	Isabela	Lajas	Patillas	Río Piedras	Río Piedras
Soil type		Cialitos clay	Machete clay	Mabí clay	Coto clay	Fraternidad clay, saline phase	Viví sandy loam	Toa sandy loam	Vega Alta clay loam
Planting date....		5/9/63	11/7/62	12/19/62	11/28/62	2/14/63	11/3/62	7/10/63	4/24/63
1st sampling date..........		9/9/63	3/11/63	4/19/63	3/29/63	6/14/63	3/7/63	11/12/63	8/26-7/63
2nd sampling date..........		12/9/63	6/17/63	7/17/63	7/29/63	9/13/63	6/7-8/63	2/7/64	11/26/63
Fertilizer treatments and magnesium content of first leaf-blade samples (4 months)									
Treat. no.	Units of Mg[1]	*Magnesium content in percentage of dry matter*							
1	0	0.075	0.175	0.280	0.160	0.280	0.172	—	0.185
2	.12	.085	.240	.290	.175	.290	.205	—	.230
3	.24	.115	.235	.330	.185	.310	.224	—	.205
4	.36	.130	.225	.320	.175	.290	.272	—	.220
5	.48	.150	.245	.310	.180	.240	.185	—	.200
6	.60	.100	.245	.285	.200	.280	.252	—	.230
7	.72	.145	.245	.320	.195	.345	.255	—	.260
8	.96	.170	.260	.325	.205	.310	.251	—	.245
9	1.20	.175	.280	.375	.195	.325	.257	—	.240
Statistics of the equations fitted to the magnesium data of the first leaf-blade samples									
A		1.076	1.197	1.277	1.159	1.267	1.190	—	1.191
B		.9915	.9907	.9905	.9896	.9898	.9905	—	.9900
C		.9180	.9378	.9447	.9685	.9634	.9405	—	.9562
C.D.[2]		.764	.694	.537	.686	.215	.411	—	.494
Fertilizer treatments and magnesium content of second leaf-blade samples (7 months)									
Treat. no.	Units of Mg[1]	*Magnesium content in percentage of dry matter*							
1	0	0.095	0.155	0.400	0.305	0.300	0.180	0.305	0.270
2	.12	.110	.130	.310	.335	.270	.235	.315	.245
3	.24	.140	.145	.370	.295	.290	.210	.275	.270
4	.36	.130	.155	.365	.320	.295	.220	.335	.260
5	.48	.165	.130	.325	.205	.280	.185	.275	.260
6	.60	.175	.185	.455	.295	.265	.240	.280	.250
7	.72	.175	.140	.365	.360	.295	.240	.290	.295
8	.96	.210	.160	.340	.380	.300	.200	.265	.275
9	1.20	.175	.185	.355	.295	.275	.280	.295	.280
Statistics of the equations fitted to the magnesium data of the second leaf-blade samples									
A		1.100	1.128	1.356	1.287	1.276	1.172	1.293	1.246
B		.9915	.9896	.9886	.9894	.9887	.9750	.9884	.9893
C		.9159	.9703	1.005	.9760	1.003	.9527	1.023	.9795
C.D.[2]		.767	.304	.002	.034	.010	.324	.164	.252

[1] One unit of Mg = 1,000 lbs. of magnesium per acre in the form of magnesium sulfate.

[2] C.D. = Coefficient of determination.

TABLE 16.—*Results obtained on fitting the Mitscherlich equation to the leaf-sheath data of the magnesium experiments with sugarcane variety P.R. 980*

Location		Corozal	Guayama	Gurabo	Isabela	Lajas	Patillas	Río Piedras	Río Piedras
Soil type		Cialitos clay	Machete clay	Mabí clay	Coto clay	Fraternidad clay, saline phase	Viví sandy loam	Toa sandy loam	Vega Alta clay loam
Planting date		5/9/63	11/7/62	12/19/62	11/28/62	2/14/63	11/3/62	7/10/63	4/24/63
1st sampling date		9/9/63	3/11/63	4/19/63	3/29/63	6/14/63	3/7/63	11/12/63	8/26–7/63
2nd sampling date		12/9/63	6/17/63	7/17/63	6/29/63	9/13/63	6/7–8/63	2/7/64	11/26/63
Fertilizer treatments and magnesium content of first leaf-sheath samples (4 months)									
Treat. no.	Units of Mg[1]	*Magnesium content in percentage of dry matter*							
1	0	0.095	0.255	0.235	0.155	0.240	0.167	0.180	0.150
2	.12	.105	.255	.265	.160	.230	.170	.170	.165
3	.24	.130	.252	.255	.175	.255	.174	.200	.185
4	.36	.135	.242	.285	.170	.245	.207	.235	.195
5	.48	.160	.248	.290	.160	.240	.169	.190	.195
6	.60	.150	.241	.265	.165	.250	.206	.185	.175
7	.72	.160	.245	.230	.180	.265	.297	.220	.195
8	.96	.175	.280	.260	.185	.255	.213	.225	.210
9	1.20	.170	.267	.260	.165	.255	.216	.225	.190
Statistics of the equations fitted to the magnesium data of the first leaf-sheath samples									
A		1.098	1.235	1.232	1.150	1.228	1.161	1.172	1.157
B		.9908	.9892	.9730	.9891	.9892	.9905	.9898	.9896
C		.9324	.9838	.9980	.9866	.9817	.9389	.9601	.9666
C.D.[2]		.837	.231	.0004	.246	.419	.323	.424	.482
Fertilizer treatments and magnesium content of second leaf-sheath samples (7 months)									
Treat. no.	Units of Mg[1]	*Magnesium content in percentage of dry matter*							
1	0	0.075	0.220	0.240	0.235	0.330	0.165	0.205	0.190
2	.12	.085	.210	.210	.230	.335	.185	.210	.200
3	.24	.105	.210	.235	.215	.325	.140	.185	.205
4	.36	.115	.220	.200	.245	.330	.170	.195	.210
5	.48	.130	.210	.225	.225	.330	.180	.160	.235
6	.60	.130	.230	.215	.225	.345	.175	.175	.200
7	.72	.140	.205	.215	.245	.320	.190	.210	.200
8	.96	.165	.230	.200	.265	.345	.180	.195	.210
9	1.20	.145	.235	.210	.220	.325	.200	.205	.225
Statistics of the equations fitted to the magnesium data of the second leaf-sheath samples									
A		1.076	1.199	1.215	1.218	1.319	1.135	1.181	1.188
B		.9909	.9892	.9885	.9890	.9888	.9741	.9888	.9892
C		.9301	.9835	1.020	.9907	.9979	.9714	.9985	.9812
C.D.[2]		.845	.329	.304	.047	.003	.393	.0002	.257

[1] One unit of Mg = 1,000 of magnesium per acre in the form of magnesium sulfate.
[2] C.D. = Coefficient of determination.

TABLE 17.—*Results obtained on fitting the Mitscherlich equation to the leaf data of the magnesium experiments with corn variety Mayorbela*

Location		Corozal	Guayama	Gurabo	Gurabo	Isabela	Lajas	Río Piedras	Río Piedras
Soil type		Cialitos clay	Machete clay	Mabí clay	Toa sandy loam	Coto clay	Fraternidad clay, saline phase	Toa sandy loam	Vega Alta clay loam
Planting date....		2/12/64	9/17/64	8/1/63	9/22/64	3/28/63	4/18/63	4/5/64	7/10/63
1st sampling date...........		—	10/19/64	8/30/63	10/22/64	4/29/63	5/17/63	5/5/64	8/9/63
2nd sampling date...........		4/3/64	—	9/23/63	11/12-3/64	5/17/63	6/7/63	5/25/64	8/20/63
Fertilizer treatments and magnesium content of first leaf samples (4 weeks)									
Treat. no.	Units of Mg[1]	*Magnesium content in percentage of dry matter*							
1	0	—	0.250	0.270	0.255	0.159	0.244	0.290	0.160
2	.12	—	.255	.300	.290	.174	.279	.290	.170
3	.24	—	.230	.255	.275	.193	.275	.325	.175
4	.36	—	.305	.285	.280	.181	.306	.335	.170
5	.48	—	.260	.295	.335	.209	.321	.315	.175
6	.60	—	.265	.275	.290	.110	.372	.295	.190
7	.72	—	.295	.280	.275	.185	.350	.305	.180
8	.96	—	.330	.280	.280	.184	.326	.295	.195
9	1.20	—	.300	.325	.325	.199	.315	.350	.195
Statistics of the equations fitted to the magnesium data of the first leaf samples									
A		—	1.235	1.260	1.262	1.158	1.265	1.288	1.153
B		—	.9906	.9895	.9896	.9892	.9907	.9893	.9895
C		—	.9387	.9727	.9678	.9844	.9321	.9763	.9706
C.D.[2]		—	.531	.273	.235	.041	.429	.174	.842
Fertilizer treatments and magnesium content of second leaf samples (7 weeks)									
Treat. no.	Units of Mg[1]	*Magnesium content in percentage of dry matter*							
1	0	0.185	—	0.195	0.205	0.111	0.220	0.255	0.185
2	.12	.205	—	.215	.220	.116	.226	.240	.200
3	.24	.230	—	.230	.195	.119	.205	.245	.190
4	.36	.320	—	.190	.260	.128	.209	.235	.205
5	.48	.290	—	.210	.280	.128	.218	.235	.210
6	.60	.310	—	.200	.230	.124	.233	.235	.180
7	.72	.305	—	.230	.255	.131	.199	.320	.170
8	.96	.295	—	.240	.210	.151	.264	.245	.225
9	1.20	.380	—	.200	.270	.155	.255	.215	.215
Statistics of the equations fitted to the magnesium data of the second leaf samples									
A		1.200	—	1.195	1.207	1.100	1.197	1.239	1.177
B		.9948	—	.9890	.9897	.9897	.9898	.9887	.9893
C		.8589	—	.9887	.9637	.9628	.9641	1.0053	.9807
C.D.[2]		.759	—	.054	.200	.912	.392	.006	.166

[1] One unit of Mg = 1,000 lbs. of magnesium per acre in the form of magnesium sulfate.

[2] C.D. = Coefficient of determination.

There seems no need to use different tissues for the diagnosis of adequacy of availability of different nutrients.

6. If Mitscherlich's equation is used to express the relation between the available nutrient content of the soil and the leaf nutrient content, the equation may be transformed for use in estimating the quantity of fertilizer material representing the capacity of the soil to provide the crop with its respective nutrient. Thus, if X = quantity of fertilizer material applied, S = quantity of fertilizer material corresponding to the capacity of the unfertilized soil to provide the crop with the respective nutrient, and M = total quantity of fertilizer material, then $M = S + X$.

The form of the Mitscherlich equation fitted to the data in this study was $Y = A - BC^X$. In each soil studied, the leaf nutrient content was thus expressed as a function of the quantity of fertilizer material applied to the soil, X.

Now, to express the leaf nutrient content Y, as a function of the total, M, nutrient content of the soil, it is necessary to use a more commonly used form of the Mitscherlich equation, namely,

$$Y = A(1 - C^{S+X}) = A(1 - C^M).$$

Where, as indicated above, S = original content of the soil, X = quantity of fertilizer material applied, and M = total quantity of the nutrient in the soil expressed in units of the given fertilizer material. The relation $B = AC^S$ makes the two forms of the Mitscherlich equation identical.

This latter form of the equation may be used to estimate the nutrient content of the soil from the leaf nutrient content. Thus, solving for M, we obtain:

$$M = \frac{\log (A - Y) - \log A}{\log C}.$$

Therefore, once the constants A and C of the corresponding Mitscherlich equation are determined for a given soil, crop variety, and fertilizer-material complex, the available soil content of the corresponding nutrient, expressed in units of the given fertilizer material, may be estimated for similar complexes from the respective nutrient content of a leaf sample taken at the stage of growth used to fit the soil-leaf nutrient relation.

7. The data of the calcium carbonate experiments, although not adequate to support the general conclusions mentioned above, need not necessarily be considered as contradictory.

SUMMARY

1. Data are presented on the influence of various levels levels of application of ammonium sulfate, calcium superphosphate, potassium chloride,

calcium carbonate and magnesium sulfate on the sugarcane and corn leaf contents of nitrogen, phosphorus, potassium, calcium and magnesium, at each of two stages of growth.

2. The relation between the quantity of a nutrient available in the soil and the leaf content of the nutrient is expressible by a smooth curve that approaches a value asymptotically. Mitscherlich's equation may be used satisfactorily for this purpose.

3. The capacity of a soil to provide a crop with a given nutrient may be estimated by using the following equation:

$$M = \frac{\log (A - Y) - \log A}{\log C},$$

where M = available quantity of a nutrient per unit of area expressed in units of the corresponding fertilizer material; Y = percentage dry-matter content of the respective nutrient by the plant leaves; and A and C are values of parameters previously estimated from the results of a calibrating field experiment.

4. The precision of the equation to be used for this estimation is higher when the calibrating experiment is performed in soils lower in available content of the nutrient than otherwise, and when the leaves are sampled at an early, rather than at a late stage of growth.

RESUMEN

1. Se presentan datos sobre la influencia de distintos niveles de sulfato de amonio, superfosfato de calcio, cloruro de potasio, carbonato calizo y sulfato de magnesio sobre el contenido de nitrógeno, fósforo, potasio, calcio y magnesio de las hojas de caña y maíz en dos etapas del período de crecimiento.

2. Se demuestra que puede expresarse la relación entre la cantidad asimilable en el suelo y el contenido en la hoja de un elemento nutritivo, usando una curva suave que se aproxime a cierto valor asintóticamente.

3. La capacidad del suelo para proveer a la cosecha con un elemento nutritivo en particular, puede estimarse si se usa la ecuación siguiente:

$$M = \frac{\log (A - Y) - \log A}{\log C}$$

en donde M = cantidad asimilable del elemento nutritivo por unidad del área, expresada en unidades del material fertilizante respectivo; Y = porcentaje a base seca del elemento nutritivo en las hojas; y A y C son valores de parámetros previamente estimados de los resultados de un experimento de campo.

4. La precisión de la ecuación a usarse en esta estimación es mayor

cuando el experimento de calibración se hace en suelos con cantidades asimilables bajas del elemento nutritivo, y cuando las muestras de las hojas se toman a una edad temprana, más bien que a una edad avanzada de crecimiento.

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