THE BENEFICIAL EFFECT OF FILTER PRESS CAKE ON PINEAPPLE GROWTH, DEVELOPMENT, AND PRODUCTION

II. EFFECT ON THE RATOON CROP

Ernesto Hernández-Medina[1]

INTRODUCTION

In a previous paper (5),[2] studies were reported which had been undertaken in the effort to find some remedial treatment for the adverse effects of iron-manganese imbalance in the soil upon the growth, development, and production of pineapples in the plant crop. The results of these experiments demonstrated both qualitatively and quantitatively that filter press cake had an outstandingly beneficial effect on pineapple production, whereas applications of lime were markedly detrimental.

This paper reports on the effect on the ratoon crop of the same plant crop treatments.

EXPERIMENTAL PROCEDURE

CULTURAL METHOD

The lay-out of the pineapple experiments, treatments tested and other information regarding set up of experiments have been presented previously (5).

All ratoon plants in the different treatments of both experiments received the same kind of commercial fertilizer as the plant crop at the rate of 1 ton per acre in two applications. The fertilizer was applied according to the ordinary procedures followed by the pineapple growers in their field plantings.

On November 21, 1949, leaf samples were taken from the plants representative of the various treatments for chemical determinations of total and soluble iron and manganese content of the tissue. The same procedure was followed for collecting leaf samples and preparing them for chemical analysis as for leaf samples obtained in the plant crop, except that only one leaf sample was used for determining both total and soluble iron and manganese, as will be explained in chemical methods.

On December 21, 1949, plants in both experiments were treated with

[1] Assistant Plant Physiologist, Agricultural Experiment Station of the University of Puerto Rico, Río Piedras. The author is indebted to Dr. B. G. Capó, Biometrician and Assistant Director for Research, for assistance in the statistical work of regression and covariance. The chemical analyses of the plant tissue samples were made by Mrs. O. E. Vega de Rivera.

[2] Numbers in parenthesis refer to Literature Cited, p. 301.

calcium carbide in solution to induce flower initiation and subsequently fruit production. The same procedure of application was followed as for the plant crop.

HARVESTING

The fruits of the ratoon plants of both pineapple experiments were harvested mainly in May and June of 1950, that is, 5 or 6 months after the plants were treated with acetylene. Other criteria of growth considered in the experimental results were slip and sucker production and green and dry weight of plants. After harvesting, soil samples were collected from the replicates of each treatments for determinations of pH, organic matter, total nitrogen, and available iron and manganese, and for soil-conductivity tests.

METHODS OF ANALYSIS

Plants

For determination of soluble iron and manganese in the leaf tissue fractions which were frozen after harvesting, the procedure used by Somers and Shive (10) was followed, with a few minor modifications for extraction of the cell sap in a Carver press. The frozen plant-leaf tissue after being thawed and wrapped in a piece of muslin was subjected to a pressure of 2,750 pounds per square inch for three consecutive periods totalling 4 minutes of extraction. Five milliliters of distilled water were added to the tissue during each extraction period to aid in the removal of the cell sap. The extracted juice was made to volume with water in a 50-ml. volumetric flask and was used for determinations of soluble iron and manganese. The press cake was dried and weighed and then ground in a semimicro Willey mill to be used for determinations of insoluble iron and manganese.

It is assumed in this work that the available iron and manganese in the leaves which were analyzed was that found in solution in the cell sap and which was extracted as completely as possible by pressure in a Carver press. On the other hand, the fractions of iron and manganese remaining in the press cake were regarded as the inactive or unavailable portions of these elements. Based on the above-mentioned procedure for determinations of iron and manganese in leaf-tissue samples, total iron and manganese were obtained by adding the quantity of iron and manganese found by analysis in the juice sample to the quantity found in the extracted leaf sample.

Wet digestion of aliquots of the extracted juice or of the ground tissue was carried out according to the procedure of Somers and Shive (10), but with some modifications. Aliquots of the juice or of the ground tissue were first wet-digested in 50-ml. Erlenmeyer flasks with 1 ml. of concentrated sulfuric acid and 0.3 ml. of perchloric acid, followed by 0.5 ml. of hydrogen peroxide and, in some cases, by additional drops of this reagent until the solution was clear. After digestion the samples were transferred to 50-ml. volumetric flasks and made to volume. Iron and manganese were then determined by the same methods of analysis used for determining these elements in the plant crop (5).

Soils

Soil pH determinations were made using a Beckman glass electrode. Organic-matter content of the soil was determined by the rapid colorimetric method using the Cenco Wilde organic matter color Scale No. 28803, supplied by the Central Scientific Co., Chicago. Total nitrogen was determined by the Kjeldahl-Gunning method (1). Conductivity tests of soil samples were made following the procedure used by Bonnet et al. (4). Available iron was determined after extraction from the soil with Morgan's universal extracting solution, normal sodium acetate buffered at pH 4.8, with acetic acid as used for extraction of phosphorus from soil. The Saywell and Cunningham o-phenanthroline method was used for iron determination (9). Available or exchangeable manganese was run according to Peech's procedure and was determined by the periodate method of Peech (6).

In this report the results of both pineapple experiments will be considered together.

Experimental Results

PLANT GROWTH RESPONSE TO TREATMENTS

Throughout their growth period the ratoon plants which developed in the soil treated with filter press cake, in both types of soils, Bayamón silty clay from Arecibo and Fajardo clay from Río Piedras, surpassed the ratoon plants under other treatments in growth and development (figure 1). Though there were on an average three ratoon plants in each filter-press-cake replication, this was by no means a hindrance to plant growth and development. In fact, the filter-press-cake-treated plants were more vigorous and much better developed than ratoon plants under other treatments. Moreover, they were greener in color than any of the other ratoon plants, especially those in soil which received calcium carbonate to raise the pH to 7.2. As was the case with the filter-press-cake-treated plants of the plant crop (5), it was also easy to select the ratoon plants of this treatment since they were the tallest and best developed of all the plants.

EFFECT OF TREATMENTS ON FRUIT YIELD

The information gathered in both pineapple experiments on mean yield of fruits under each treatment is presented in table 1. The statistical

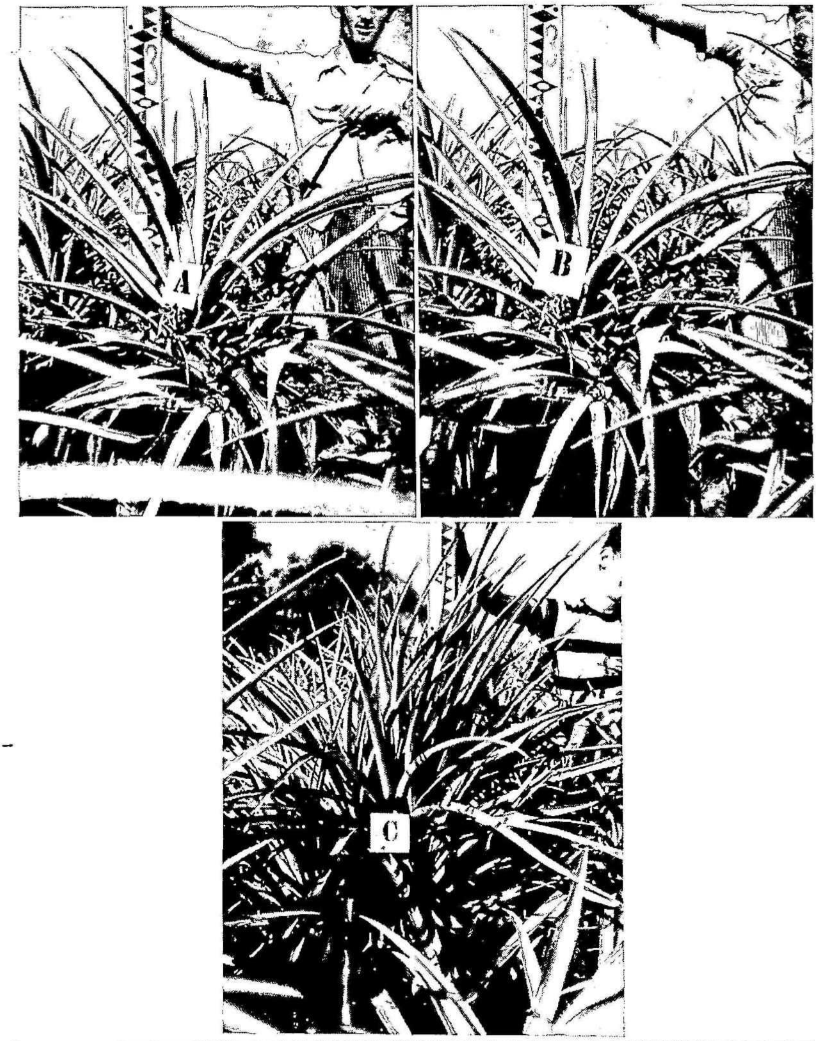

FIG. 1 A, B, C, D, E

analyses of the yield data indicated that there were highly significant differences between the mean fruit yields under different treatments. The results of the evaluation of the statistical significance of the mean fruit yield differences that may be attributed to the different treatments are also presented in table 1. They indicate that, in both the Arecibo and Río Piedras soils, the pineapple plants which developed in the substrate to which filter press cake was added yielded best, their yields being significantly superior at the 1-percent level to the yields of pineapple plants that underwent the other treatments. It is also evident from the yield

TABLE 1.—*Mean fruit yields of pineapple plants grown in Bayamón silty clay from Palo Blanco, Arecibo, and in Fajardo clay from Experiment Station Farm, Río Piedras*

[Ratoon crop]

Symbol	Treatments	Arecibo soil[1]		Río Piedras soil[1]	
		Mean yield of fruit	Outyielded at 1-percent level	Mean yield of fruit	Outyielded at 1-percent level
		Pounds		*Pounds*	
A	Soil pH adjusted with lime to 6.2	3.65	—	3.21	—
B	Soil pH adjusted with lime to 7.2	3.43	—	2.59	—
C	Filter press cake mixed with soil	7.08	A–B–D–E	5.84	A–B–D–E
D	Ferrous sulfate spray applied to plants	4.53	—	2.81	—
E	Control—no treatment	3.87	—	3.46	—

[1] Least significant difference between mean yield of fruits at the 1-percent level for Arecibo, 1.58 pounds; for Río Piedras, 2.20 pounds.

data for both experiments that, excluding the yields of the filter-press-cake-treated plants, there were no significant differences between the yields produced by pineapple plants undergoing other treatments.

SLIP PRODUCTION AS AFFECTED BY TREATMENTS

The data obtained on the mean number of slips for the various treatments, as well as the results of the evaluation of the statistical significance of the growth criteria that may be attributed to the various treatments, are shown in table 2. It is evident from these results that the pineapple plants grown in soil treated with filter press cake produced the greatest mean number of slips in both types of soils. However, in the Arecibo soil,

FIG. 1.—Vegetative growth made by ratoon pineapple plants prior to the application of calcium carbide to induce flowering: A, Soil pH adjusted with lime to 6.2; B, soil pH adjusted with lime to 7.2; C, filter press cake mixed with soil; D, ferrous sulfate spray applied to plants; and E, control—no treatment.

they were significantly superior at the 5-percent level only to the slips produced by the plants of treatment E (control) and significantly superior at the 1-percent level to the slips produced by the plants of treatment A whose soil was limed to raise the pH to 6.2. In the Río Piedras soil, the filter-press-cake-treated plants were significantly superior in number of slips produced at the 5-percent level only to the plants of treatment A, whose soil received lime to raise the pH to 6.2. This significance should not be taken as definite but as casual, since the experiment in itself was not significant. In other words, the *F* value obtained for the experiment was 1.59 while the required *F* value needed for significance was 2.65. It is

TABLE 2.—*Mean number of slips of pineapple plants grown in Bayamón silty clay from Palo Blanco, Arecibo, and in Fajardo clay from Experiment Station Farm, Río Piedras*

[Ratoon crop]

Symbol	Treatments	Arecibo soil[1] Mean number of slips	Arecibo soil[1] Outnumbered at— 5-percent level	Arecibo soil[1] Outnumbered at— 1-percent level	Río Piedras soil[2] Mean number of slips	Río Piedras soil[2] Outnumbered at 5-percent level
A	Soil pH adjusted with lime to 6.2	0.1	—	—	0.1	—
B	Soil pH adjusted with lime to 7.2	1.8	A	—	.4	—
C	Filter press cake mixed with soil	2.3	E	A	1.3	A
D	Ferrous sulfate spray applied to plants	.9	—	—	.5	—
E	Control—no treatment	.2	—	—	1.1	—

[1] Least significant difference between mean number of slips for Arecibo at 5-percent level, 1.7 slips; at 1-percent level, 2.2 slips.

[2] Least significant difference between mean number of slips for Río Piedras at 5-percent level, 1.1 slips.

also evident from the experimental results presented that, except for one case and in only one of the experiments, no significant difference was obtained between the mean number of slips produced by the pineapple plants of other treatments.

SUCKER PRODUCTION AS AFFECTED BY TREATMENTS

Table 3 shows the results gathered on the production of suckers by the pineapple plants undergoing the various treatments, and also the evaluation of the statistical significance of the mean number of suckers that may be attributed to the various treatments. The filter-press-cake-treated plants in both type of soils were superior in production of suckers, either significantly or highly significantly, to the plants of all other treatments.

In the Arecibo soil even the control plants (treatment E) produced significantly more suckers than the plants of treatment A, grown in soil that was limed to raise the pH to 6.2. Outside of this no significant difference was obtained in sucker production between the plants undergoing all other treatments in both pineapple experiments.

TABLE 3.—*Mean number of suckers of pineapple plants grown in Bayamón silty clay from Palo Blanco, Arecibo, and in Fajardo clay from Experiment Station Farm, Río Piedras*

[Ratoon crop]

Symbol	Treatments	Arecibo soil[1]			Río Piedras soil[2]		
		Mean number of suckers	Outnumbered at— 5-percent level	Outnumbered at— 1-percent level	Mean number of suckers	Outnumbered at— 5-percent level	Outnumbered at— 1-percent level
A	Soil pH adjusted with lime to 6.2	1.1	—	—	1.2	—	—
B	Soil pH adjusted with lime to 7.2	1.6	—	—	.7	—	—
C	Filter press cake mixed with soil	3.0	E	A–B–D	2.5	D	A–B–E
D	Ferrous sulfate spray applied to plants	1.7	—	—	1.4	—	—
E	Control—no treatment	2.0	A	—	1.2	—	—

[1] Least significant difference between mean number of suckers for Arecibo at 5-percent level, 0.86 sucker; at 1-percent level, 1.15 suckers.

[2] Least significant difference between mean number of suckers for Río Piedras at 5-percent level, 1.02 suckers; at 1-percent level, 1.36 suckers.

GREEN AND DRY WEIGHT OF PLANTS AS INFLUENCED BY TREATMENTS

After the ratoon fruits were harvested, the green and dry weights of the whole tops of the pineapple plants were obtained to find out whether there was any relation between weight of plants and their yields. The data for both pineapple experiments are presented in table 4. The results of the evaluation of the statistical significance of the green and dry weights of the plants as a consequence of treatment are also reported in table 4. They indicate that the pineapple plants grown in soil that was treated with filter press cake (treatment C) produced the greatest mean green and dry weights of plants. These green and dry weights were superior in a highly significant way to the green and dry weights of plants subjected to other treatments. It should be recalled that these were the plants which produced the heaviest fruit yields, slips, and suckers. It is also evident from the results presented that with only one exception (dry weight of untreated plants superior at the 5-percent level to dry weights of limed plants—Arecibo soil experiment), there were no significant differences between green and dry weights of plants representative of other treatments.

TABLE 4.—*Results of statistical analyses of mean green and dry weights of tops of pineapple plants grown in Bayamón silty clay from Palo Blanco, Arecibo, and in Fajardo clay from Experiment Station Farm, Río Piedras*

[Ratoon crop]

Symbol	Treatments	Mean green weight of plants	Outweighed at 1-percent level	Mean dry weight of plants	Outweighed at— 5-percent level	Outweighed at— 1-percent level	Dry weight of plants
	Bayamon silty clay, Palo Blanco, Arecibo[1]						
		Pounds		*Pounds*			*Percent*
A	Soil pH adjusted with lime to 6.2	5.77	—	1.61	—	—	27.85
B	Soil pH adjusted with lime to 7.2	5.38	—	1.53	—	—	27.47
C	Filter press cake mixed with soil	13.82	A–B–D–E	4.56	—	A–B–D–E	32.97
D	Ferrous sulfate spray applied to plants	7.40	—	1.76	—	—	23.76
E	Control—no treatment	7.45	—	2.33	A–B	—	31.32
	Fajardo clay, Experiment Station Farm, Rio Piedras[2]						
A	Soil pH adjusted with lime to 6.2	4.60	—	1.31	—	—	28.37
B	Soil pH adjusted with lime to 7.2	4.12	—	1.21	—	—	29.42
C	Filter press cake mixed with soil	10.09	A–B–D–E	2.88	—	A–B–D–E	28.55
D	Ferrous sulfate spray applied to plants	5.55	—	1.25	—	—	22.56
E	Control—no treatment	5.66	—	1.47	—	—	26.02

[1] Least significant difference between mean green weight of plants for Arecibo at the 1-percent level, 3.04 pounds; between mean dry weight of plants at the 5-percent level, 0.65 pound; at the 1-percent level, 0.87 pound.

[2] Least significant difference between mean green weight of plants for Río Piedras at the 1-percent level, 2.77 pounds; between mean dry weight of plants at the 1-percent level, 0.89 pound.

EFFECT OF SOIL pH ON YIELD OF FRUITS, NUMBER OF SLIPS, NUMBER AND WEIGHT OF SUCKERS, AND GREEN AND DRY WEIGHTS OF PLANTS

As was done with the growth criteria of the plant-crop pineapple experiments, a regression study was also made with the ratoon-crop pineapple experiments to find out the possible effect of soil pH on fruit yield, slip and sucker production, weight of suckers, and green and dry weights of plants. Table 5 reports the results of the regression studies. It is clear that with only two exceptions, in the Arecibo soil experiment, the regression coefficients on soil pH of the six criteria considered were all significant either at the 5- or 1-percent level. As in the plant-crop regression studies, the regression coefficients were all negative, indicating that there was an inverse relation between soil pH and the growth criteria considered.

The regressions of yield of fruits, number of suckers, and green and dry weights of plants on soil pH in the Arecibo soil experiment are shown in figure 2. To avoid plotting each fruit yield, number of suckers, and green and dry weights of plants with reference to each pH value obtained, the

TABLE 5.—*Results of regression studies of various growth criteria on soil pH for experiments in Bayamón silty clay from Palo Blanco, Arecibo, and in Fajardo clay from Experiment Station Farm, Río Piedras*

[Ratoon crop]

Criteria	Arecibo soil experiment regression coefficient[1]	Río Piedras soil experiment regression coefficient[1]	Observations
			Number
Yield of fruits	−0.872*	−0.734**	50
Number of slips	− .066	− .334*	50
Number of suckers	− .348*	− .471**	50
Weight of suckers	− .113	− .212*	50
Green weight of plants	−1.860**	−1.491**	50
Dry weight of plants	− .653**	− .392**	50

[1] One asterisk indicates significance, two asterisks high significance in this and later tables.

same procedure was followed as for the pH values and growth criteria of the plant crop (5), that is, the pH's values and the different criteria under consideration were grouped arbitrarily according to pH ranges and mean yield of fruits, mean number of suckers, and mean green and dry weights of plants. A summary of such grouping is presented in table 6.

It is clear from the summary presented and figure 2, that yield of fruits, number of suckers, and green and dry weights of plants were again adversely affected by increments of soil pH or increased alkalinity of the soil. In other words, increase in soil pH reduced fruit yields, number of suckers, and green and dry weights of plants.

The regressions of yield of fruits, number of slips, number of suckers, weight of suckers, and green and dry weights of plants on soil pH of the Río Piedras soil experiment are presented in figure 3. The same procedure was followed as for the Arecibo soil experiment in grouping pH values

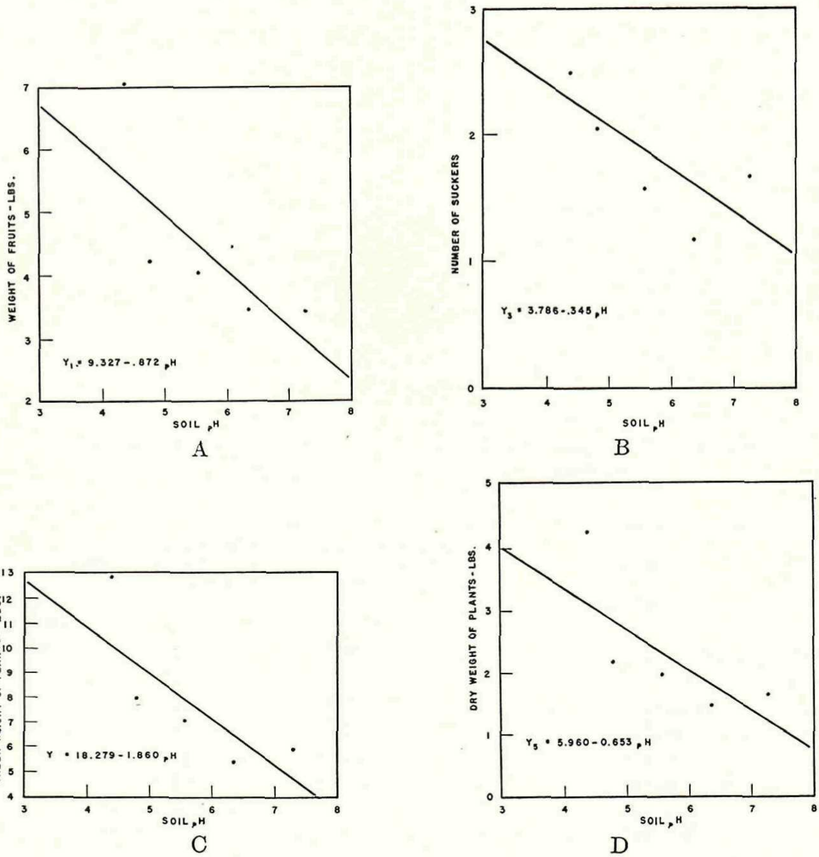

FIG. 2.—Regressions of weight of fruits (A), number of suckers (B), and green and dry weights of plants (C, D) on soil pH at 0–3 inches soil depth; experiment in Bayamón silty clay from Palo Blanco, Arecibo.

TABLE 6.—*Summary of criteria considered in regressions of yield of fruits, number of suckers, and green and dry weights of plants; experiment in Bayamón silty clay from Palo Blanco, Arecibo*

[Ratoon crop]

Number of plots	pH range	Mean pH	Mean fruit yield per plant or replication	Mean number of suckers	Mean green weight of plants	Mean dry weight of plants
			Pounds		*Pounds*	*Pounds*
10	3.91–4.60	4.46	7.08	2.50	12.84	4.22
17	4.61–5.00	4.77	4.21	2.06	7.84	2.19
7	5.01–6.00	5.39	4.09	1.57	7.02	1.97
6	6.01–7.00	6.26	3.47	1.17	5.46	1.46
10	7.01–7.50	7.24	3.42	1.67	5.84	1.63

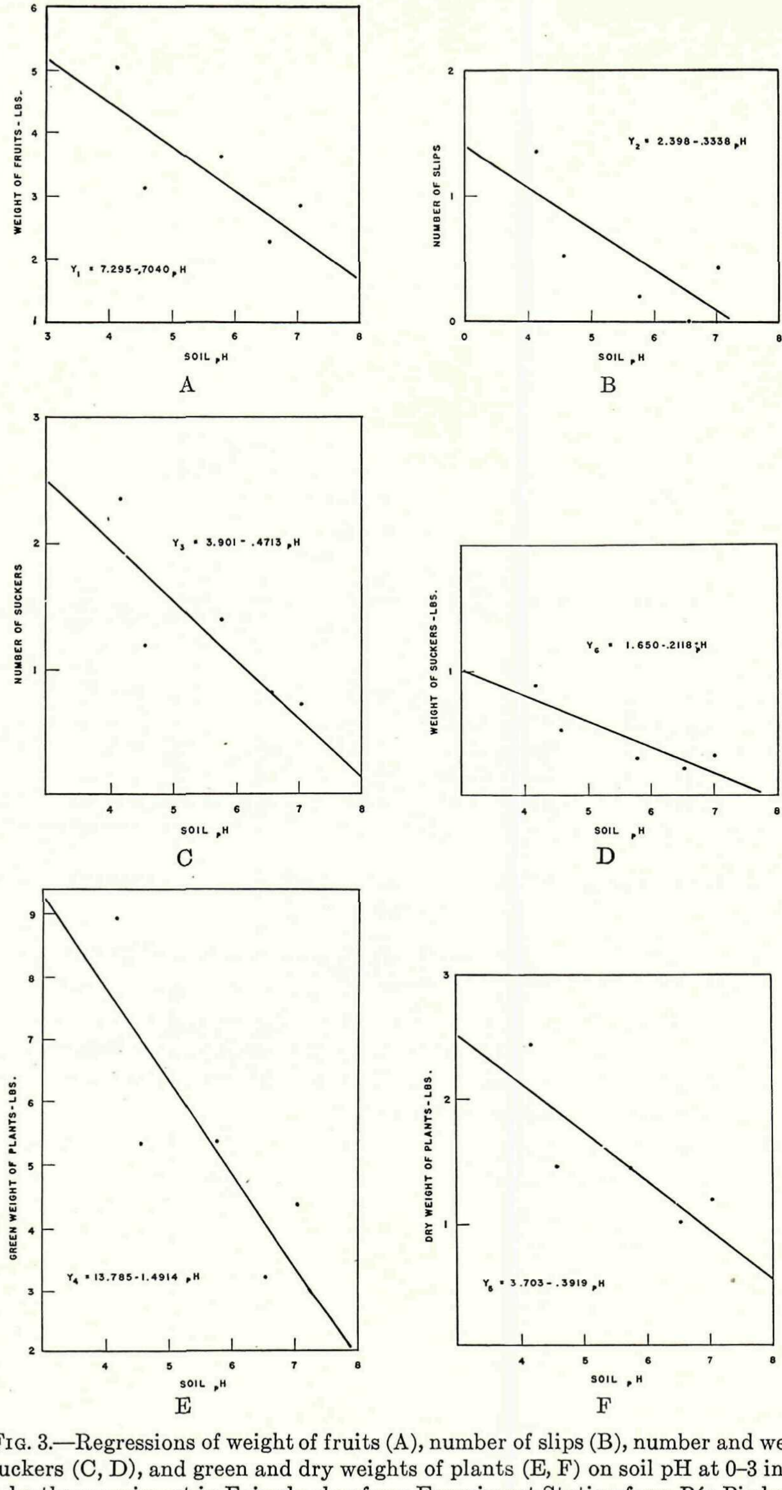

FIG. 3.—Regressions of weight of fruits (A), number of slips (B), number and weight of suckers (C, D), and green and dry weights of plants (E, F) on soil pH at 0–3 inches soil depth; experiment in Fajardo clay from Experiment Station farm Río Piedras.

according to pH ranges and the various growth criteria considered as shown in table 7.

The data in table 7 and figure 3, show the same definite trend for the Arecibo soil experiment; increments in soil pH adversely affected the growth criteria under discussion. In general, increments in soil pH were responsible again for lowering fruit yields, number of slips and suckers weight of suckers, and green and dry weights of plants under the conditions of this experiment. This indicates that a relatively acid condition of the substrate favored plant metabolism.

TABLE 7.—*Summary of criteria considered in regressions of yield of fruits, number of slips, number and weight of suckers, and green and dry weight of plants; experiment in Fajardo clay from Experiment Station Farm, Río Piedras*

[Ratoon crop]

Number of plots	pH range	Mean pH	Mean fruit yield per plant or replication	Mean number of slips	Mean number of suckers	Mean weight of suckers	Mean green weight of plants	Mean dry weight of plants
			Pounds			*Grams*	*Pounds*	*Pounds*
14	3.81–4.40	4.14	5.07	1.36	2.36	0.90	8.94	2.45
17	4.41–5.00	4.57	3.18	.53	1.20	.54	5.37	1.47
5	5.01–6.10	5.59	3.65	.20	1.40	.30	5.39	1.44
6	6.11–6.90	6.51	2.30	0	.83	.21	3.25	1.02
8	6.91–7.32	7.12	2.84	.43	.71	.32	4.40	1.20

GROWTH CRITERIA AS INFLUENCED BY TREATMENTS ELIMINATING SOIL pH EFFECT

To study the effect of the various treatments segregated from the effect of pH on fruit yields, number of slips, number and weight of suckers, and on green and dry weights of plants, covariance analyses were made for each growth criterion of each experiment. Tables 8 to 13, inclusive, present the results of the covariance analyses for the Arecibo soil experiment, and certain other data to be discussed later.

It is evident from the results presented that, except for the covariance analyses of mean weight of suckers (table 13), filter press cake was the only treatment which showed either a significant or highly significant effect on the various growth criteria under consideration when soil pH was ignored. This suggests again that some effect of filter press cake other than the change it made in pH, contributed beneficially to high yield production, increase in number of slips and suckers, and high production of plant material in the Arecibo soil experiment.

The results of the covariance analyses made on the above-mentioned criteria for the Río Piedras soil experiment are also presented in tables 8 to 13, inclusive. Again filter press cake was the only treatment that

TABLE 8.—*Summary of covariance analyses for mean yield of fruits of pineapple plants grown in Bayamón silty clay from Palo Blanco, Arecibo, and in Fajardo clay from Experiment Station Farm, Río Piedras*

[Ratoon crop]

Symbol	Treatments	Adjusted mean yield of fruits	Deviations from control	Least significant deviations at— 5-percent level	Least significant deviations at— 1-percent level
	Bayamón silty clay, Palo Blanco, Arecibo				
		Pounds	*Pounds*	*Pounds*	*Pounds*
A	Soil pH adjusted with lime to 6.2	3.928	0.339	2.648	—
B	Soil pH adjusted with lime to 7.2	4.180	.591	4.528	—
C	Filter press cake mixed with soil	6.621	3.032	1.468	1.972
D	Ferrous sulfate spray applied to plants	4.235	.646	1.260	—
E	Control—no treatment	3.589	0	—	—
	Fajardo clay, Experiment Station Farm, Río Piedras				
A	Soil pH adjusted with lime to 6.2	3.769	0.783	2.473	—
B	Soil pH adjusted with lime to 7.2	3.816	.830	3.667	—
C	Filter press cake mixed with soil	5.047	2.061	1.530	2.058
D	Ferrous sulfate spray applied to plants	2.288	−.698	1.452	—
E	Control—no treatment	2.986	0	—	—

TABLE 9.—*Summary of covariance analyses for mean number of slips of pineapple plants grown in Bayamón silty clay from Palo Blanco, Arecibo, and in Fajardo clay from Experiment Station Farm, Río Piedras*

[Ratoon crop]

Symbol	Treatments	Adjusted mean number of slips	Deviations from control	Least significant deviation at 5-percent level
	Bayamón silty clay, Palo Blanco, Arecibo			
A	Soil pH adjusted with lime to 6.2	0.122	−0.055	3.740
B	Soil pH adjusted with lime to 7.2	1.861	1.684	6.396
C	Filter press cake mixed with soil	2.263	2.086	2.074
D	Ferrous sulfate spray applied to plants	.876	.699	1.780
E	Control—no treatment	.177	0	—
	Fajardo clay, Experiment Station Farm, Río Piedras			
A	Soil pH adjusted with lime to 6.2	0.580	−0.114	2.120
B	Soil pH adjusted with lime to 7.2	1.460	.766	3.130
C	Filter press cake mixed with soil	.616	− .078	1.310
D	Ferrous sulfate spray applied to plants	.051	− .643	1.190
E	Control—no treatment	−.694	0	—

TABLE 10.—*Summary of covariance analyses for mean number of suckers of pineapple plants grown in Bayamón silty clay from Palo Blanco, Arecibo, and in Fajardo clay from Experiment Station Farm, Río Piedras*

[Ratoon crop]

Symbol	Treatments	Adjusted mean number of suckers	Deviations from control	Least significant deviation at 5-percent level
	Bayamón silty clay, Palo Blanco, Arecibo			
A	Soil pH adjusted with lime to 6.2	0.714	−1.672	1.863
B	Soil pH adjusted with lime to 7.2	.550	−1.836	3.193
C	Filter press cake mixed with soil	3.636	1.250	1.013
D	Ferrous sulfate spray applied to plants	2.112	− .274	.860
E	Control—no treatment	2.386	0	—
	Fajardo Clay, Experiment Station, Río Piedras			
A	Soil pH adjusted with lime to 6.2	1.821	1.147	1.825
B	Soil pH adjusted with lime to 7.2	2.073	1.399	2.718
C	Filter press cake mixed with soil	1.614	.940	1.106
D	Ferrous sulfate spray applied to plants	.819	.145	1.000
E	Control—no treatment	.674	0	—

TABLE 11.—*Summary of covariance analyses for mean green weight of pineapple plants grown in Bayamón silty clay from Palo Blanco, Arecibo, and in Fajardo clay from Experiment Station Farm, Río Piedras*

[Ratoon crop]

Symbol	Treatments	Adjusted mean green weight of plants	Deviations from control	Least significant deviations at—	
				5-percent level	1-percent level
	Bayamón silty clay, Palo Blanco, Arecibo				
		Pounds	*Pounds*	*Pounds*	*Pounds*
A	Soil pH adjusted with lime to 6.2	6.268	−0.689	4.965	—
B	Soil pH adjusted with lime to 7.2	6.922	− .035	8.512	—
C	Filter press cake mixed with soil	13.004	6.047	2.700	3.623
D	Ferrous sulfate spray applied to plants	6.872	− .085	2.292	—
E	Control—no treatment	6.957	0	—	—
	Fajardo clay, Experiment Station Farm, Río Piedras				
A	Soil pH adjusted with lime to 6.2	5.471	0.547	3.773	—
B	Soil pH adjusted with lime to 7.2	6.049	1.125	5.623	—
C	Filter press cake mixed with soil	8.847	3.923	2.288	3.073
D	Ferrous sulfate spray applied to plants	4.736	− .188	2.150	—
E	Control—no treatment	4.924	0	—	—

TABLE 12.—*Summary of covariance analyses for mean dry weight of pineapple plants grown in Bayamón silty clay from Palo Blanco, Arecibo, and in Fajardo clay from Experiment Station Farm, Río Piedras*

[Ratoon crop]

Symbol	Treatments	Adjusted mean dry weight of plants	Deviations from control	Least significant deviations at—	
				5-percent level	1-percent level
	Bayamón silty clay, Palo Blanco, Arecibo				
		Pounds	*Pounds*	*Pounds*	*Pounds*
A	Soil pH adjusted with lime to 6.2	2.121	.301	1.380	—
B	Soil pH adjusted with lime to 7.2	2.930	1.110	2.365	—
C	Filter press cake mixed with soil	3.709	1.889	.750	1.007
D	Ferrous sulfate spray applied to plants	1.210	−.610	.637	—
E	Control—no treatment	1.820	0	—	—
	Fajardo clay, Experiment Station Farm, Río Piedras				
A	Soil pH adjusted with lime to 6.2	1.522	0.232	1.224	—
B	Soil pH adjusted with lime to 7.2	1.692	.402	1.824	—
C	Filter press cake mixed with soil	2.571	1.281	.743	0.996
D	Ferrous sulfate spray applied to plants	1.049	−.241	.671	—
E	Control—No treatment	1.290	0	—	—

TABLE 13.—*Summary of covariance analyses for mean weight of suckers of pineapple plants grown in Bayamón silty clay from Palo Blanco, Arecibo, and in Fajardo clay from Experiment Station Farm, Río Piedras*

[Ratoon crop]

Symbol	Treatments	Adjusted mean weight of suckers	Deviations from control	Least significant deviation at 5-percent level
	Bayamón silty clay, Palo Blanco, Arecibo			
A	Soil pH adjusted with lime to 6.2	0.252	−0.899	1.492
B	Soil pH adjusted with lime to 7.2	.326	− .825	2.558
C	Filter press cake mixed with soil	1.449	− .298	.811
D	Ferrous sulfate spray applied to plants	.828	− .323	.689
E	Control—no treatment	1.151	0	—
	Fajardo clay, Experiment Station Farm, Río Piedras			
A	Soil pH adjusted with lime to 6.2	0.337	−0.148	1.128
B	Soil pH adjusted with lime to 7.2	.368	− .117	1.681
C	Filter press cake mixed with soil	.927	.442	.684
D	Ferrous sulfate spray applied to plants	.580	.095	.618
E	Control—no treatment	.485	0	—

showed either a significant or highly significant effect, but in this case only on yield and green and dry weights of plants disregarding pH effects. Once more this indicates that some factor other than pH effect contributed beneficially to favor growth criteria. Values obtained for mean number and mean weight of suckers, although not significant, were short of a significant value as compared to values needed for significance in other treatments as can be seen in tables 10 and 13, respectively.

TABLE 14.—*pH, organic matter, total nitrogen, conductivity, and available iron and manganese in treated and untreated Bayamón silty clay from Palo Blanco, Arecibo, and Fajardo clay from Experiment Station Farm, Río Piedras*

[Ratoon crop]

Symbol	Treatments	pH at 3-inches depth	Organic matter	Total nitrogen	Conductivity, mhos × 10^{-5} at 25°C.	Available Fe	Available Mn
	Bayamón silty clay, Palo Blanco, Arecibo						
			Percent	*Percent*		*P.p.m.*	*P.p.m.*
A	Soil pH adjusted with lime to 6.2	6.16	1.5	0.18	24	0.94	9
B	Soil pH adjusted with lime to 7.2	7.29	1.5	.19	19	1.74	5
C	Filter press cake mixed with soil	4.42	4.0	.35	30	3.22	138
D	Ferrous sulfate spray applied to plants	4.80	2.0	.24	19	3.22	98
E	Control—no treatment	4.84	1.5	.25	19	3.22	96
	Fajardo clay, Experiment Station Farm, Río Piedras						
A	Soil pH adjusted with lime to 6.2	6.00	3.5	0.27	38	3.08	5
B	Soil pH adjusted with lime to 7.2	6.96	3.0	.28	32	2.41	5
C	Filter press cake mixed with soil	4.11	4.0	.60	26	8.17	41
D	Ferrous sulfate spray applied to plants	4.49	3.5	.28	20	7.64	9
E	Control—no treatment	4.56	3.5	.29	20	6.70	6

RESULTS OF SOIL pH DETERMINATIONS AND SOIL CHEMICAL ANALYSES

The results of pH determinations and chemical analyses for organic matter, total nitrogen, conductivity, and available iron and manganese for the soil subjected to the various treatments at the end of both pineapple experiments are presented in tables 14 and 15.

It is evident from the data (table 14) that the pH values for the lime-treated Arecibo soil remained practically the same at the end of 2½ years as at the beginning of the experiments. Similar results were obtained for the pH of limed soils by Bonnet et al. (3). It is also evident that filter press cake reduced soil pH as compared with the control at the end of 2½ years.

Filter press cake considerably increased soil organic matter as well as total soil nitrogen and soil conductivity. Filter press cake did not influence the available iron of the soil by the end of 2½ years. However, lime did considerably reduce the available iron of the soil. Filter press cake increased the available manganese content of the soil. On the other hand, the use of lime reduced the soil content of this element. Similar results were

TABLE 15.—*Total and soluble iron and manganese content of midsection of active center leaves of pineapple plants grown in Bayamón silty clay from Palo Blanco, Arecibo, and in Fajardo clay from Experiment Station Farm, Río Piedras*

[Ratoon crop]

Symbol	Treatments	Total Fe	Soluble Fe	Soluble iron to total Fe	Total Mn	Soluble Mn	Soluble Mn to total Mn	Ratio of Fe to Mn
	Bayamón silty clay, Palo Blanco, Arecibo							
		P.p.m.	*P.p.m.*	*Per cent*	*P.p.m.*	*P.p.m.*	*Per cent*	*Soluble*
A	Soil pH adjusted with lime to 6.2	134.38	10.58	7.87	73.05	25.13	34.40	0.42:1
B	Soil pH adjusted with lime to 7.2	127.95	5.75	4.49	58.34	27.59	47.29	.21:1
C	Filter press cake mixed with soil	144.90	28.80	19.88	94.36	33.97	36.00	.85:1
D	Ferrous sulfate spray applied to plants	118.80	9.60	8.08	153.55	44.38	28.90	.22:1
E	Control—no treatment	95.49	13.79	14.44	164.44	41.83	25.44	.33:1
	Fajardo clay, Experiment Station Farm, Río Piedras							
A	Soil pH adjusted with lime to 6.2	227.92	30.72	13.48	33.85	7.82	23.10	3.93:1
B	Soil pH adjusted with lime to 7.2	203.46	19.56	9.61	32.49	7.96	24.49	2.46:1
C	Filter press cake mixed with soil	167.07	17.87	10.70	51.93	18.36	35.35	.97:1
D	Ferrous sulfate spray applied to plants	158.85	17.75	11.17	52.53	13.64	5.97	1.30:1
E	Control—no treatment	157.77	8.07	5.12	59.01	9.10	15.42	.89:1

obtained by Bonnet et al. (2, 3). In the experiments here reported no definite relation was found between these elements in the soil and yields of pineapples. However, highest yields of pineapples were directly related to the lowest soil pH, and the highest organic-matter and nitrogen content of the soil which was produced by treatment with filter press cake.

The pH values and chemical analyses for the soil of the Río Piedras experiment are also shown in table 14. The pH values for the lime-treated soils had changed slightly at the end of 2½ years. Results were similar to those of the Río Piedras soil experiment. As in the Arecibo soil experiment, filter press cake also reduced soil pH as compared to the control. It increased soil organic-matter to some extent and total soil nitrogen to a much more greater extent. Available iron was influenced slightly by filter press cake, but the use of lime reduced the available iron content of the soil. Filter press cake again increased the available manganese in the soil while lime slightly reduced it.

As in the Arecibo soil experiment, no definite relationship is shown between iron and manganese in the soil and yield of pineapples.

It should be noted in table 14 that the available iron was much lower than the available manganese. The available iron in the Arecibo soil was also much less than the available iron in the Río Piedras soil, while the available manganese was considerably greater in the Arecibo soil than in the Río Piedras soil. The Río Piedras soil was much higher in organic-matter content than the Arecibo soil; this different might be attributable to the fact that the Arecibo soil has been in continuous pineapple cultivation for the past 20 years, which may have helped lower its organic-matter content. On the other hand, the Río Piedras soil had been in pasture and never in pineapples.

RESULTS OF CHEMICAL ANALYSES OF LEAF TISSUE FRACTIONS

The determinations of total and soluble iron and manganese of the tissues of the fractionated active leaves of the pineapple plants of both experiments are presented in table 15. It is evident that the filter-press cake-treated plants in the Arecibo soil experiment had the highest total and soluble iron contents and the highest iron-manganese ratio as compared with plants under other treatments. Except for this one case, there was no definite relationship between the iron and manganese content of the plant tissue analyzed and yield of pineapple plants in the rest of the treatments for both the plant and ratoon crops.

Finally, there is no definite relationship between the total and soluble iron, and the manganese and corresponding ratios in the Río Piedras plant tissue analyzed and yields of pineapples.

DISCUSSION

The information presented in this paper on plant growth, development, and production of ratoon pineapple plants supplies additional information on the beneficial effect of filter press cake on a second pineapple crop.

The qualitative observations made on plant growth and development revealed that the filter-press-cake-treated plants had a luxuriant and profuse growth which was not evident in pineapple plants undergoing other treatments. This profuse growth was to be expected since more suckers developed in the filter-press-cake-treated plants than in plants under other treatments.

The higher yielding capacity of the filter-press-cake-treated ratoon plants as compared with that of pineapple plants under other treatments occurred because the greater number of suckers which developed from the original plant could produce more fruits. The greater number of fruits obtained from the ratoon plants under the filter-press-cake treatment as a whole did not adversely affect size or weight of fruits as compared with fruits obtained from suckers which developed under other treatments and which gave rise to a smaller number of ratoon plants. On a percentage basis filter-press-cake-treated plants produced a 40 to 45-percent increase in fruit over the control plants in both experiments, and a little more than the plants which were limed. This increase in fruit production was twice that of the plant crop for corresponding treatments (5).

The fact that control plants produced as much (a little but not significantly more) as the lime-treated plants confirms previous findings (5) that the use of lime so to control the iron-manganese ratio in the soil and in the pineapple plant as to increase fruit yields, is not a sound agricultural practice. It is suggested that lime be used only in soils deficient in calcium from intensive cultivation, or in acid soils which must be limed to raise their pH to 4.5 or 5.0 for pineapple growing.

The fruit yield of plants, suckers, and slips produced, as well as green and dry weight of plants were greater in corresponding treatments for the pineapple plants in the Bayamón silty clay soil from Arecibo than in the Fajardo clay soil from Río Piedras. This was also true of the plant crop. This might be attributed to the fact that the productivity index for the Arecibo soil has been found to be much higher, 90, than the productivity index for the Río Piedras soil which is 40 (8).

The regression studies of soil pH on the various growth criteria presented have again shown clearly that there is an inverse relationship between soil pH and fruit yields, and sucker and slip production, as well as green and dry weights of plants. In other words, increase in fruit yields as well as in the other growth criteria discussed were inversely proportional to increments in soil pH. This corroborates similar results obtained in the plant crop for yield of fruits, and slip and sucker production, and the fruit yields in pineapple field experiments (7). The fact that low soil pH, where manganese is supposed to be quite active, greatly favored plant growth, development, and production, points again to the possibility that factors other than manganese and iron adversely affect pineapple production in the Island, and that the use of lime to correct iron-manganese relationships is not wise under field conditions.

Except for one instance in the Arecibo experiment, no relationship was found between the iron and manganese contents of plant tissues and of the soil and the yield of the pineapple plants undergoing the various treatments. In both experiments the soil analyses indicated that the highest yield of fruits and other growth criteria were related to low pH, high organic-matter, and high nitrogen content of the soil which were produced by the addition of filter press cake.

Conclusion

The outstanding beneficial effect of filter press cake and the adverse effect of lime applications to the soil as evidenced by yields of the ratoon crops of both pineapple experiments once more offers opportunities of altering or modifying agricultural practices in behalf of pineapple production in Puerto Rico.

Summary

This paper presents the results of further studies carried out to establish the relationship between iron and manganese imbalance in the soil and remedial treatments on pineapple growth, development, and production. The experimental results obtained for the ratoon crop, or second crop, are briefly summarized as follows:

1. Pineapple plants which received filter press cake in the substrate surpassed plants under all other treatments in growth and development. They were the tallest and best developed.

2. Pineapple plants grown in soil mixed with filter press cake were the heaviest yielders, their yields being significantly superior at the 1-percent level to the yields of pineapple plants under other treatments.

3. Pineapple plants grown in soil treated with filter press cake produced the greatest mean number of slips and were superior in production of suckers either significantly or highly significantly.

4. Green and dry weights of filter-press-cake-treated plants were superior in a highly significant way to the green and dry weights of plants subjected to other treatments.

5. As a whole, except for the filter-press-cake treatment, no significant differences were obtained among the pineapple plants treated otherwise with respect to yield, number of slips and suckers, and green and dry weights of plants.

6. The results of regression studies of yield of fruits, number of suckers, green and dry weights of plants on soil pH for the Arecibo soil experiment, and for number of slips and weight of suckers for the Río Piedras soil experiment, showed that those growth factors were adversely affected by increments in soil pH or increased alkalinity of the soil. Increase in soil

pH was responsible for lower fruit yields, slip and sucker production, weight of suckers, and green and dry weights of plants.

7. Disregarding soil pH effect, filter press cake was the only material producing either a significant or a highly significant effect on fruit yield, slip and sucker production, and green and dry weights of plants.

8. No definite relationship was found between iron and manganese in the soil and yield of pineapples. The highest yields were directly related to the lowest soil pH and highest organic-matter and nitrogen content of the soil from the filter-press cake treatment.

9. Except for one case, no definite relationship was found between the iron and manganese content of the plant tissue analyzed and yield of pineapples.

10. The results strengthen the assumption that factors other than iron and manganese in the soil adversely affect pineapple production in the Island, and that the use of lime to alter the iron-manganese relationships in pineapple growing is not advisable under field conditions.

11. As judged from the experimental data for both plant and ratoon crops, the use of filter press cake in conjunction with fertilizer affords an opportunity of increasing yields of pineapples, low yields being a limiting factor in the pineapple industry in Puerto Rico.

Literature Cited

1. Association of Official Agricultural Chemists, *Official and Tentative Methods of Analysis*, Sixth Edition, 1945.
2. Bonnet, J. A., Riera, A. R., Tracing the mineral from the soil to the plant to the animal blood, I, *Jour. of Agric. Univ. P. R.*, **30**(**3**) 138–158, July 1946.
3. Bonnet, J. A., and Riera, A. R., Tracing the mineral from the soil to the plant to the animal blood, III, The effect of phosphorus and lime on the mineral composition of the soil and grass, *Jour. of Agric. Univ. P. R.*, **33**(**2**) 57–65, April 1949.
4. Bonnet, J. A., and Tirado Sulsona, P., *Soil Studies in Lajas Valley*, Bull. 86, Univ. of P. R., Agr. Expt. Sta., August 1950.
5. Hernández-Medina, E., The beneficial effect of filter press cake on pineapple growth, development, and production, I, Effect on the plant crop, *Jour. of Agric. Univ. P. R.*, **36**(**3**) July 1952.
6. Peech, M., Determination of exchangeable bases in soils, *Ind. Eng. Chem. Anal.*, **13** 436–441, June 1941.
7. Pennock, W., Field response of Red-Spanish pineapples to nitrogen, calcium, iron and soil pH, *Jour. of Agric. Univ. P. R.*, **33**(**1**) 1–26, January 1949.
8. Roberts, R. C. et al., *Soil Survey of Puerto Rico*, U.S.D.A. Bureau of Plant Industry in cooperation with the Univ. of Puerto Rico, Agric. Expt. Sta. Series 1936, No. 8, 503 p., issued January 1942.
9. Saywell, L. G., and Cunningham, B. B., Determination of iron-colorimetric o-phenanthroline method, *Ind. and Eng. Chem.*, **9** 67–69, 1937.
10. Somers, I. I., and Shive, J. W., The iron-manganese relation in plant metabolism, *Plant Phys.*, **17**(**4**) 582–602, 1942.