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FERTILIZER REQUIREMENTS OF COFFEE GROWN ON CATALINA CLAY IN PUERTO RICO

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INTRODUCTION

Coffee is the second most important crop in Puerto Rico. About twenty per cent of the population obtain their livelihood from it. Yet, the coffee production per unit of area is very low: less than two hundred pounds of marketable coffee per acre.

Among the more obvious reasons for the low production per acre of Puerto Rican coffee, one should note that the local variety grown of *Coffea arabica* has a relatively low yield, although its berries produce a quality liquor of excellent aroma and taste, greatly preferred in the European and Cuban market. Added to the loss of this specialized market is the heavy damage inflicted by recurrent hurricanes, which has prevented the proper renovation of the coffee and shade trees and the adoption of somewhat more costly but more effective methods of cultivation. The main portion of the coffee area is on soils of the Catalina, Alonso, Los Guineos and Cialitos series, which are acid and quite low in their base exchange capacity. Because of lack of adequate fertilizer experiments on these soils, coffee growers do not know the most effective and desirable fertilizer applications to obtain maximum yields of this crop.

In his bulletin on fertilizers for coffee, McClelland (2) presented the results obtained in a series of fertilizer studies with coffee carried out at the Federal Agricultural Experiment Station at Mayaguez and elsewhere on the Island. In the summary, he made the following statements:

1. "The production over an 8-year period showed that potash was effective in increasing yield, and that this was true particularly where nitrogen was used in addition to potash." (2, p. 32.)
2. "Growth and yield failed to show that the addition of phosphoric acid was of benefit." (2, p. 32.)
3. "Until further evidence is obtained on this point, it is believed that a fertilizer for coffee should run proportionally high in potash, such, for example, as one obtained by mixing ammonium sulphate and potassium sulphate in equal parts by weight and containing approximately 10 per cent nitrogen and 24 per cent potash." (2, p. 33.)

In order to obtain more information relative to the fertilizer requirements for coffee in Puerto Rico, a fertilizer test was started by Mr. Vicente Medina on the farm of Mr. Juan Esteva, at Lares, on January 12, 1932. This experiment was carried out as originally outlined until the seventh crop was harvested in 1939, when, as a result of a study of the yield data of the first six crops, it was decided to alter the procedure in use up to that time in the check plots. Thus, the plots that had received fertilizer applications for the first seven crops, were treated similarly for the eighth and ninth crops, the last ones of this experiment; but for these last two crops, fertilizer applications were given to some of the check plots which had received no fertilizer applications for the first seven crops.

As a result of the study of the first six crops of this experiment, another fertilizer test with coffee was started at Mayaguez. Only three crops were harvested in this experiment due to the sale of the farm on which the experiment was established, and that the new owner needed the land for other purposes.

A description of the treatments tested in these experiments and the results obtained follows in detail.

EXPERIMENT ON "CATALINA CLAY" AT LARES

Table 1 presents the treatments tested and the mean yields obtained in the plots that received the same fertilizer applications for the nine crops of the experiment established at Lares, on "Catalina Clay." In this experiment, the plots consisted of ten trees each, planted at a distance of eight feet between adjacent trees. Each plot was, therefore, 640 square feet in area, or approximately $\frac{1}{68}$ of an acre. The plots were arranged in a randomized block layout with ten replications. Five check plots, receiving no fertilizer applications, were included in each block of plots of the experiment. In table 1, however, the yields of those check plots that continued as such until the end of the test are the only ones presented.

In 1939, as has already been mentioned in the *Introduction*, a statistical study of the results obtained in the first six crops of this experiment was

made. As a result of that study, the following conclusions (1) were derived:

"The fact that no difference between the mean yields of treatments 'D', 'I' and 'J' exceeds the critical value for significance at the five per cent point, shows that potash applied in excess of 15 units did not increase significantly the yields, when the crop received in addition only five units

TABLE 1

Mean yields in hundredweights market coffee per acre of the fertilizer test performed at Lares for the nine crop cycle: 1933–1941

TREATMENTS				REPLICATIONS										
Letter	NH_3	P_2O_5	K_2O	1	2	3	4	5	6	7	8	9	10	Total
	units	*units*	*units*											
A	5	5	15	2.47	4.23	3.60	3.68	3.51	4.73	4.62	3.00	5.89	3.91	39.64
B	10	5	15	3.56	3.61	3.22	3.61	4.03	5.66	4.60	5.55	5.47	3.76	43.07
C	15	5	15	4.03	5.09	3.25	4.75	5.18	4.75	4.75	6.47	6.13	4.05	48.45
D	5	0	15	2.89	4.84	3.27	2.92	4.53	3.89	3.56	3.56	3.30	3.42	36.18
E	5	10	15	3.14	4.02	2.84	3.78	3.38	4.07	6.62	6.00	2.76	4.43	41.04
F	5	15	15	3.16	3.51	3.65	3.75	5.35	5.65	5.36	4.67	*4.82*	5.06	44.98
G	5	5	20	4.03	2.97	4.10	2.70	4.54	4.57	3.57	5.19	*4.32*	4.00	39.99
H	5	5	25	4.89	2.92	3.05	3.55	5.19	3.44	3.91	4.89	4.89	4.73	41.46
I	5	0	20	3.80	3.74	3.28	3.65	5.60	4.72	2.82	5.18	4.10	4.07	40.96
J	5	0	25	4.65	2.59	2.76	2.81	5.48	3.80	4.68	3.12	4.19	5.47	39.55
K	0	0	0	3.41	2.54	2.42	2.38	3.80	2.90	3.31	4.22	2.23	*3.17*	30.38
Total.....				40.03	40.06	35.44	37.58	50.59	48.18	47.80	51.85	48.10	46.07	445.70

Mean

(8) 3.964	(7) 3.999
(3) 4.307	(4) 4.146
(1) 4.845	(6) 4.096
(10) 3.618	(9) 3.955
(5) 4.104	(11) 3.038
(12) 4.498	
	44.570

Notes: 1 unit = 7.5 pounds of substance per acre. Values in italics are estimated.

of nitrogen. A similar conclusion is derived on comparing the mean yields of treatments 'A', 'G' and 'H', when the crop received five units each of nitrogen and phosphoric acid. Therefore, on this basis, it can be concluded that applications of potash at rates higher than the minimum 15 units used in this experiment were not effective in increasing the yields over the yield produced by the minimum 15 units of potash used.

"Neither five nor 10 units of phosphoric acid were sufficient to increase significantly the yields, when the crop received in addition five units of nitrogen and 15 units of potash. This conclusion is based on a comparison of the mean yields of treatments 'D', 'A', and 'E'. The application of 15 units of phosphoric acid in treatment 'F', however, produced a significant increase in yield when compared with the no-phosphoric acid application of treatment 'D'.

"Neither 10 nor 15 units of nitrogen produced any significant increases in yield over that produced by five units of nitrogen, when the crop received in addition five units of phosphoric acid and 15 units of potash. This is deduced from a comparison of the mean yields of treatment 'A', 'B', and 'C'.

"The tendency of the yields, however, is to increase with increasing amounts of both nitrogen and phosphoric acid. This is in full accord with the idea that the yield of a crop depends on the concentration of nutrients in the soil, and that the more nutrients, the higher the yield up to an optimum point. A small application of some nutrient may not prove its effectiveness in increasing the yield due to the heterogeneity of the soil, while a larger amount of the same nutrient may prove effective in so doing. This behaviour cannot be interpreted as indicating that the small application has no effect while the large application has a real effect. On the contrary, both applications are effective, only that the small one is not sufficiently effective to influence the yield statistically under the conditions in which the experiment is performed. This has happened in this case with the applications of phosphoric acid where the application of both five and 10 units did not produce a statistical increase in yield, while the 15-unit application did produce it.

"The applications of nitrogen were, according to the statistical analysis, not significant, but when used in conjunction with the application of five units of phosphoric acid—which had not demonstrated any significant effect by themselves—produced significant increases in yield.

"The applications of potash, beyond the minimum 15 units used, however, have produced no significant increases. This is not to be interpreted in the sense that potash is not necessary for high coffee yields, but in the sense that the nutrient requirements of the crop had been fulfilled with an amount of potash which was no larger, and may have been smaller, than the soil content plus the 15 units applied as minimum.

"If when the project is closed, the results are the same as those obtained to date, the recommendation would have to be in favor of the use of a fertilizer analysis containing the maximum amounts of nitrogen and phosphoric acid and the minimum amount of potash used in this test, that is, an application of about 112.5 pounds per acre each of ammonia, phosphoric

acid and potash. At that time there would be no evidence on which to recommend the use of a smaller amount of potash, since this range of potash application has not been investigated."

It must be pointed out that the use of the small amounts of phosphoric acid and the large amounts of potash tested in this experiment were due to the results obtained by McClelland (2) mentioned above. The results at the date of this study indicated, however, trends altogether different from those obtained by McClelland (2), and, accordingly, from the results expected at the time that the experiment was started.

The statistical analysis of the yield data obtained in the whole nine-crop cycle appears in table 2, and the results of the evaluation of the statistical significance of the yield differences that may be attributed to differences in the rates of application of the fertilizer substances are presented

TABLE 2

Analysis of the total sum of squared deviations of the data of table 1

SOURCE OF THE DEVIATIONS	DEGREES OF FREEDOM	SUM OF SQUARES	VARIANCE ESTIMATE	F
Blocks	9	27.3257		
Treatments	10	21.4278	2.1428	3.30**
Error	87	56.5363	0.6498	
Total	106	105.2898		

There are highly significant differences between the treatment means.
Values to be exceeded for significance between two 10-plot means:
At the 5% point..... 0.717 hundredweights market coffee per acre
At the 1% point..... 0.950 hundredweights market coffee per acre

in table 3. This table indicates that the conclusions to be derived from the results of the whole nine-crop cycle are about the same as were derived from the interpretation of the results of the first six crops of the experiment. The effect of the application of the 15 units of the nitrogen has now proved to be significant: a conclusion that was suggested but not verified by the previous study.

The lack of response to applications of potash in excess of the minimum application of 15 units, or 112.5 pounds of potash per acre, suggested the possibility of maintaining the crop yields with smaller applications of potash. To test this possibility, forty of the fifty plots which had received no fertilizer applications for the first six crops were selected for the determination of the effects on the crop yields of applications of potash below the minimum used up to that time. The treatments used in these

plots, and the results obtained in the two crops in which said treatments were tried, are presented in table 4.

Table 5 shows the results of the statistical analysis of the yield data of table 4. In table 5 it may be seen that the differences between the mean yields of the different treatments are not significant.

It should be noted that this lack of response to the potash applications was observed in plots which had received no potash applications for the previous seven crops. The conclusion that the potash applications did not increase the crop yields at the experimental site, under the conditions

TABLE 3

Significance of differences between the mean yields obtained with different amounts of application of each fertilizer substance

FERTILIZER SUBSTANCE	TREATMENT COMPARISON	DIFFERENCE BETWEEN MEAN YIELDS	REMARK AS TO SIGNIFICANCE OF DIFFERENCE
Nitrogen	B–A	0.343	Not significant
	C–B	0.538	" "
	C–A	0.881	Significant at 5% point
Phosphoric acid	A–D	0.346	Not significant
	E–A	0.140	" "
	F–E	0.394	" "
	E–D	0.486	" "
	F–A	0.534	" "
	F–D	0.880	Significant at 5% point
Potash	I–D	0.478	Not significant
	J–I	−0.141	" "
	J–D	0.337	" "
Potash	G–A	0.035	Not significant
	H–G	0.147	" "
	H–A	0.182	" "

and for the duration of the experiment, appears to be warranted by the above results. This conclusion is also in contrast with what was to be expected from McClelland's results (2).

EXPERIMENT WITH "CATALINA CLAY" AT MAYAGUEZ

The experiment at Lares started with 16-year-old trees. On that account, data on the fertilizer requirements of young coffee trees were still lacking. To obtain desired information, the other experiment mentioned in the *Introduction* was started at Mayaguez.

The latter experiment was established on a private farm at Km. 6.1 of

road No. 13 from Mayaguez to Las Marías, with six-year-old trees of the Puerto Rican variety of *Coffee arabica*. The soil of the experimental field was also a "Catalina Clay" and the trees were planted, as in the former experiment, at a distance of eight feet between adjacent trees. "Guaba" *Inga Inga* (L) Britton, and "guama" *Inga laurina* (SW) Wild, were used to provide the shade. The plots of this experiment consisted of 16 trees each, so that each plot was 1024 square feet, or approximately 1/42.54 of an acre, in area. Each treatment was replicated seven times. The

TABLE 4

Mean yields in hundredweights market coffee per acre of the fertilizer test performed at Lares for the two crop cycle: 1940–41

TREATMENTS				REPLICATIONS										
Letter	NH_3	P_2O_5	K_2O	1	2	3	4	5	6	7	8	9	10	Total
	units	*units*	*units*											
L	15	15	0	3.43	3.06	1.69	2.87	3.30	3.32	3.65	4.27	6.10	3.73	35.42
M	15	15	5	3.06	3.57	3.19	2.95	4.72	3.37	5.00	3.91	4.50	4.22	38.49
N	15	15	10	2.54	3.56	3.32	3.39	5.65	3.89	3.38	4.55	8.00	4.13	42.41
O	15	15	15	3.92	3.16	2.91	3.25	3.68	3.17	4.72	3.30	3.08	4.84	36.03

Note: 1 unit = 7.5 pounds of substance per acre.

TABLE 5

Analysis of the total sum of squared deviations of the data of table 4

SOURCE OF THE DEVIATIONS	DEGREES OF FREEDOM	SUM OF SQUARES	VARIANCE ESTIMATE	F
Blocks	9	21.8684		
Treatments	3	3.0195	1.0065	1.32
Error	27	20.5625	0.7616	
Total	39	45.4504		

The differences between the treatment means are not significant.

eleven treatments tested and the results obtained in three crops harvested in this experiment are presented in table 6. The fertilizers were applied in a narrow band six inches deep, just beneath the drip of the trees and around them. In cases where the land was too steep, the band was made in a half-moon shape on the upper side of each tree. Only one fertilizer application was made for each crop, during January, after the yearly harvest.

Table 7 shows the result of the statistical analysis of the yield data of

table 6. It shows that there were significant differences between the mean yields of the treatments.

Table 8 presents the results obtained in the evaluation of the statistical significance of the yield differences that may be attributed to differences in the rates of application of the different fertilizer substances. In it, one

TABLE 6

Mean yields in hundredweights of market coffee per acre of the fertilizer test performed at Mayagüez for the three crop cycle: 1942–44

TREATMENTS				REPLICATIONS								MEAN
Letter	NH_3	P_2O_5	K_2O	1	2	3	4	5	6	7	Total	
	pounds per acre											
A	100	0	0	2.38	2.42	2.67	1.59	1.41	1.03	1.39	12.89	1.841
B	100	100	0	1.75	2.20	3.42	1.91	1.69	2.97	2.92	16.86	2.409
C	100	0	100	2.49	2.98	1.72	0.61	1.88	2.15	2.79	14.62	2.089
D	0	100	100	3.22	2.65	3.59	2.82	1.68	1.56	1.23	16.75	2.393
E	0	0	100	3.09	1.96	1.34	2.56	1.17	2.60	1.98	14.70	2.100
F	0	100	0	5.13	1.79	2.36	2.50	1.65	2.40	2.55	18.38	2.626
G	100	100	100	2.57	2.90	3.11	2.47	1.08	2.49	1.94	16.56	2.366
H	200	100	100	2.57	2.39	2.98	1.72	0.95	1.89	2.84	15.34	2.191
I	100	200	100	5.78	2.52	3.22	3.07	2.38	4.96	1.31	23.24	3.320
J	100	100	200	2.98	3.64	1.09	3.15	2.32	4.46	3.11	20.75	2.964
W	0	0	0	1.71	2.88	1.89	0.47	1.08	1.72	1.42	11.17	1.596

TABLE 7

Analysis of the total sum of squared deviations of the data of table 6

SOURCE OF THE DEVIATIONS	DEGREES OF FREEDOM	SUM OF SQUARES	VARIANCE ESTIMATE	F
Treatments	10	16.6823	1.6682	1.99*
Error	66	55.1900	0.8362	
Total	76	71.8723		

There are significant differences between the treatment means.
Values to be exceeded for significance between two 7-plot totals:
At the 5% point..... 0.976 hundredweights market coffee per acre
At the 1% point..... 1.297 hundredweights market coffee per acre

may see that the only fertilizer substance that has affected the yields in a significant way has been phosphoric acid. This caused significant increases when applied at the rate of 100 pounds P_2O_5 per acre, in the absence of applications of nitrogen and potash, and also when applied at the rate of 200 pounds P_2O_5 per acre, in the presence of applications of 100 pounds

each per acre NH_3 and K_2O. In all the other cases, increases in the amounts of phosphoric acid applied were associated with increases in the crop yields, though in only one of the other four cases did this increase approach significance. In none of the cases were the yields affected significantly by increases in the amounts of nitrogen and potash applied. For increases in crop yield in this field during the period covered by this test, therefore, the phosphoric acid applications proved to be necessary,

TABLE 8

Significance of differences between the total yields obtained with different amounts of application of each fertilizer substance

FERTILIZER SUBSTANCE	TREATMENT COMPARISON	DIFFERENCE BETWEEN YIELDS	REMARK AS TO SIGNIFICANCE OF DIFFERENCE
Nitrogen	A–W	0.245	Not significant
	B–F	−0.217	" "
	C–E	−0.011	" "
	G–D	−0.027	" "
	H–G	−0.175	" "
	H–D	−0.202	" "
Phosphoric acid	F–W	1.030	Significant at 5% point
	B–A	0.568	Not significant
	D–E	0.293	" "
	G–C	0.277	" "
	I–G	0.954	" "
	I–C	1.231	Significant at 5% point
Potash	E–W	0.504	Not significant
	C–A	0.248	" "
	D–F	0.233	" "
	G–B	−0.043	" "
	J–G	0.598	" "
	J–B	0.555	" "

whereas the nitrogen and potash did not exert significant effects on the crop yields.

CONCLUSIONS

Two fertilizer experiments at Lares and Mayaguez were conducted on "Catalina Clay" with the Puerto Rican variety of *Coffee arabica*.

The experiment at Lares indicated that, for maximum coffee yields, nitrogen and phosphoric acid applications were required. The experiment at Mayaguez indicated that, for maximum coffee yields, phosphoric acid applications were necessary. The experiment at Mayaguez lasted

for only three crops, however, and it should be pointed out that though the beneficial effect of the nitrogen applications on the crop yields at Lares were not statistically significant with the results of the first six crops, they were with the results of the whole nine-crop cycle. Had the experiment at Mayaguez lasted long enough, the nitrogen applications might have proved to be essential for maximum crop yields. It should be remarked that the shade trees are leguminous and, therefore, they may contribute to supply at least a portion of the crop's nitrogen requirements.

Since, however, these experiments represent but two localities, further work should be done to determine the fertilizer requirements in other sections, at other altitudes, and in some of the other important soil types as regards coffee production.

SUMMARY

The results obtained in two coffee fertilizer tests performed with the Puerto Rican variety of *Coffea arabica* on "Catalina Clay" are presented, statistically analyzed, and discussed.

Nitrogen and phosphoric acid applications seem to be of greater importance as regards market-coffee production of the above variety in the soil type used, than are the applications of potash, which had no significant effects on the yields.

These results are in sharp contrast with the results obtained by McClelland, who found potash applications to be essential and phosphoric acid applications to be not essential for maximum coffee production in Puerto Rico. It should be noted that McClelland's experiments were carried out on other soil types, which were probably not in condition to provide the coffee trees with their potash requirements.

RESUMEN

Los resultados obtenidos en dos experimentos de abono realizados con la variedad Puerto Rico de *Coffea arabica* en el suelo Catalina arcilloso han sido presentados, analizados estadísticamente y discutidos.

Las aplicaciones de nitrógeno y ácido fosfórico parecen ser más importantes en cuanto se refiere a la producción de café comercial de la variedad Puerto Rico en el suelo Catalina arcilloso que las aplicaciones de potasa, las cuales no demostraron tener efectos significativos en dichos rendimientos.

Estos resultados difieren radicalmente de los resultados obtenidos por McClelland, quien encontró que las aplicaciones de potasa eran esenciales, y que las de ácido fosfórico no eran necesarias para la producción máxima de café en Puerto Rico. Debe llamarse la atención al hecho de que McClelland realizó sus experimentos en otros suelos, los cuales probablemente no

se hallaban en condiciones de proveer al cafeto la potasa requerida por el mismo.

ACKNOWLEDGMENTS

The experiment at Lares was initiated by Mr. V. Medina, Coffee Specialist, during the year 1932. Mr. J. Guiscafré Arrillaga and L. A. Gómez conducted this experiment during subsequent years. The experiment at Mayaguez was designed and initiated by Mr. J. Guiscafré Arrillaga and continued in later years by Messrs. L. A. Gómez, E. Hernández Medina and J. Lería Esmoris. Dr. B. G. Capó cooperated in the interpretation of the results at various stages of the work, and in the preparation of this manuscript.

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