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. XXXIX January 1955 No. 1

Response of Pineapples to the Application of Fertilizers

G. Samuels, P. Landrau Jr., and R. Olivencia[1]

INTRODUCTION

The use of commercial fertilizers on pineapple plants is an accepted practice of the pineapple growers of Puerto Rico. The exact fertilizer elements and the quantities needed have not been clearly defined. The fertilizer formulas used and the rates of application vary widely. In the fiscal year 1949–50, 4,075 tons of mixed commercial fertilizer were sold for application to soils used for growing pineapples in Puerto Rico. The formulas used range from a 6–8–8 to a 14–6–10 (8).[2] In the fiscal year 1950–51, 2,966 acres of pineapples were harvested with a cash value of $1,290,000 for the crop (5).

The fertilizer is supplied to pineapples in commercial production in from four to six applications per crop, using hand labor with placement at the base of the plant to leave a good portion in the axils of the leaves. The average application per plant is about 1 ounce of mixed commercial fertilizer which, on a basis of 12,000 plants per acre, amounts to 750 pounds of fertilizer per acre per application. Yet, despite such high fertilizer applications, yields have not increased proportionately. The average yield per acre in 1950–51 was 9.4 tons of pineapples (5). Estimates by agronomists well versed in pineapple-production techniques indicate (5) that yields should approximate 15 tons per acre of pineapples, with proper planting material, use of fertilizer, and control of diseases and insects.

The biological parasitic factors are of great importance in influencing pineapple yields in Puerto Rico. Alvarez-García (1) has shown that when parasitic factors such as the root-knot nematodes and soil-borne insects are properly controlled by chemicals, yields can be increased well over 100 percent, as compared with results from untreated soils and plants. Bird

[1] Agronomist, Assistant Agronomist, and Research Assistant in Plant Breeding, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R. The authors wish to thank B. G. Capó, Associate Director for Research, for his helpful suggestions in designing the experiment, and H. Gandía-Díaz, Associate Agronomist in charge of the Corozal Substation, and his staff, for help in the fieldwork.

[2] Numbers in parentheses refer to Literature Cited, p. 11.

and Pérez (2) also have shown that mealybugs and white grubs are responsible for low yields in pineapple plantings.

Until work had been carried out on the control of biological parasitic factors, it was the general opinion of many pineapple growers and research workers that, at least under Puerto Rican conditions, the pineapple plant had a poor root system, rooted very slowly, and was a poor feeder, hence must be fertilized heavily if good yields were to be obtained. However, this concept has since changed. We now realize that heavy nematode infestation and other insect and disease damage may weaken pineapple plants so that they no longer give a true picture of their own actual nutrient requirements.

Previous field-fertilizer experiments with pineapple by various research workers, (4, 6, 7) were all hampered by these then unknown factors of insect and disease damage. Therefore, new fertilizer experiments were initiated by the Agronomy and Horticulture Department of the Agricultural Experiment Station of the University of Puerto Rico in order to obtain a true picture of the response of pineapples, free from disease and insect injury, to fertilizers. This paper reports results from a plant crop of a pineapple-fertilizer experiment at the Corozal Substation.

PROCEDURE

The pineapple experiment was planted on a Lares clay at the Corozal Substation. This is a medium-friable clay occurring in terrace formations and derived from material washed from the lower Tertiary clays and shales. The soil pH was 4.8. The field selected was free from nematode infestation, as evidenced by inspection of root systems of the pineapple crop just harvested from the field prior to this experiment. The plants were sprayed with Resistox (2 pounds in 100 gallons of water) containing DDT; and with Aldrex to control mealybugs and ants. The Resistox-Aldrex treatment was sprayed monthly all over the field until July 9, 1952, when 15-percent Parathion at the rate of 1 pound in 100 gallons of water, was used to control mealybugs.

The treatments (table 1) included seven fertilizer levels and four fertilizer applications. The experimental design was a randomized split-plot one with the number of fertilizer applications compared in the main plots and the various fertilizer levels compared in the split-plots. There were six replications of each split-plot treatment. The treatments were so arranged that all plots received fertilizer 1 month after planting; all plots, except these labeled "one application", received another fertilizer application 4 months after planting; all plots, except those marked "one and two applications," received a third 8 months after planting; only the plots marked "four fertilizer applications" received fertilizer again 12 months after planting.

TABLE 1.—*Fertilizer treatments used in the pineapple experiment, Corozal Substation, 1953-54*

Fertilizer applied, in pounds per acre per application of—			Total amount of fertilizer applied in pounds per acre for the number of fertilizer applications indicated—[1]											
			First			Second			Third			Fourth		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
0	28	56	0	28	56	0	56	112	0	84	168	0	112	224
28	28	56	28	28	56	56	56	112	84	84	168	112	112	224
56	0	56	56	0	56	112	0	112	168	0	168	224	0	224
56	28	0	56	28	0	112	56	0	168	84	0	224	112	0
56	28	28	56	28	28	112	56	56	168	84	84	224	112	112
56	28	56	56	28	56	112	56	112	168	84	168	224	112	224
84	28	56	84	28	56	168	56	112	252	84	168	336	112	224

[1] First fertilizer application 1 month after planting, second fertilizer application 4 months after planting, third fertilizer application 8 months after planting, and fourth fertilizer application 12 months after planting.

The sub- or split-plots consisted of two rows, 36 feet long; the pineapple plants were 18 inches apart in the rows, 1½ feet apart between rows, and 4½ feet between plots, making a plot size of about 1/202 of an acre. There were 22 plants per row, or 44 plants per plot, which would give about 9,000 plants per acre. Slips of the Red Spanish variety, the main commercial pineapple variety of the Island, were planted on November 21–23, 1951. The first fertilizer application was December 22, 1951, the second, March 25, 1952, the third, August 6, 1952, and the fourth, November 10, 1952. The plants were treated with acetylene on November 29, 1952, to induce flowering. This consisted of spraying the crown of the plant with 25 to 30 ml. of a solution made by dispersing 2 ounces of calcium carbide in 5 gallons of water in a closed container.

Leaf samples were taken from the pineapple plants on the same day and just before a fertilizer application was made. The active or largest leaves of the pineapple plant were selected for this purpose. These leaves occur near the center of the plant and may be removed by a firm, steady pull without tugging or exerting too great a force. One leaf was taken per plant from four plants selected at random in the row, giving eight leaves per plot. When brought to the laboratory the collected leaves were washed with distilled water to remove soil and other surface contamination. The basal portions containing the white-colored tissue, and the tip, were severed from the leaves. The leaves were dried at 100° C., ground to pass a 40-mesh sieve, and digested with sulfuric acid and hydrogen peroxide. Analyses for nitrogen, phosphorus, and potassium were made on the digested material.

The experiment was harvested during May and June of 1953. Both weight and number of fruits per plot were taken. A slip count was also made just after harvesting. Slips are the axillary offshoots which arise from the buds found nearest the base of the fruits in the fruiting stalk of the plants and which are used for the commercial planting of pineapples.

RESULTS

YIELD OF FRUIT PER ACRE

Number of fertilizer applications

The number of fertilizer applications significantly influenced the yields of fruit (table 2). The use of one fertilizer application gave only the lowest yields per acre, as compared with other applications. With two fertilizer applications yields increased significantly from 11.7 tons to 13.2 tons per acre. The results from three fertilizer applications were almost significant at the 5-percent level, with an increase of 0.5 ton over that from two fertilizer applications. Four applications of fertilizer produced no better yields than two or three. For this experiment, the fourth application of fertilizer could have been safely omitted without reducing the yield of pineapples, and also saving fertilizer and labor.

Nitrogen

Application of nitrogen fertilizers definitely improved yields. With one fertilizer application the nitrogen added was insufficient to raise the yields per acre significantly. The largest quantity added per application was 84 pounds of N per acre. With two fertilizer applications yields increased significantly. The use of 168 pounds of N per acre in two applications of 84 pounds each, gave a significant increase in yield over the 112 pounds of N-per-acre treatment, or two applications of 56 pounds per application. But 168 pounds of N per acre, or three applications of 56 pounds each, produced significant yield increases over the use of 84 pounds of N per acre, or three applications of 28 pounds each. The use of four applications of N gave significant yield increases when compared with the results from the no-nitrogen treatment, but the tonnage produced per acre was not as great as produced when two or three applications totaling 168 pounds N per acre, were used. The mean of the results from four applications also indicated nitrogen was significant in increasing yields. The use of 168 pounds of N per acre in two or three applications gave results quite as good.

Phosphorus

The yield response to phosphate applications was not clear-cut. Phosphorus applications did tend to increase yields somewhat for the first and

TABLE 2.—*Mean yields of Red Spanish pineapples grown at various fertilizer levels, Corozal Substation, plant crop, 1951–53*

Treatment in pounds per acre per application of—			Mean yield of pineapples per acre for the number of fertilizer applications indicated—				
N	P_2O_5	K_2O	One	Two	Three	Four	Mean
			Nitrogen (N)				
			Tons	*Tons*	*Tons*	*Tons*	*Tons*
0	28	56	11.6	12.3	13.3	11.7	12.2
28	28	56	12.0	12.3	13.0	13.6	12.8
56	28	56	12.5	13.7	15.0	13.5	13.7
84	28	56	12.0	15.8	13.4	14.5	13.9
			Phosphorus (P_2O_5)				
75	0	56	10.7	12.2	15.2	14.2	13.1
75	28	56	12.5	13.7	15.0	13.5	13.7
			Potassium (K_2O)				
75	28	0	10.7	12.5	13.7	13.1	12.5
75	28	28	12.2	13.4	12.7	13.7	13.0
75	28	56	12.5	13.7	15.0	13.5	13.7
Mean of all treatments per application			11.7	13.2	13.7	13.5	13.5
Least significant difference needed for comparisons between treatments of same fertilizer application at:[1]							
5-percent level			2.0	2.0	2.0	2.0	0.7
1-percent level			2.6	2.6	2.6	2.6	.9

[1] Least significant differences needed for comparisons between mean of all treatments per application at: 5-percent level, 0.6; 1-percent level, 0.8.

second fertilizer applications. The application of more than 56 pounds P_2O_5 per acre, however, was harmful. Since the application of more than 56 pounds of P_2O_5 per acre required at least three fertilizer applications, the harm may have been due either to the larger amount applied or the relative lateness in the growth cycle in which the additional phosphate applications were made. Lack of response to phosphate fertilizers and actual depression of yields by high phosphate fertilizers for pineapples has been recorded in experiments by previous workers (4, 7).

Potassium

The use of potash fertilizers increased pineapple yields per acre. There were no significant increases in yields attributable to any particular number of fertilizer applications, although the mean of the four applications showed a very significant increase in yield when potash was applied. The difference in pineapple yields between the no-K_2O and the highest K_2O treatment (56 pounds of K_2O per acre rate) tended to decrease when the number of applications increased. The yield differences in tons of pineapples per acre were 2.2, 1.1, 1.3, and 0.4 for the respective number of fertilizer application treatments.

TABLE 3.—*Mean slips per plant produced by Red Spanish pineapples grown at various fertilizer levels, Corozal Substation, plant crop, 1951–53*

Treatment in pounds per acre per application of—			Mean pineapple slips per plant for the number of fertilizer applications indicated—				
N	P_2O_5	K_2O	One	Two	Three	Four	Mean
			Nitrogen (N)				
0	28	56	2.3	2.1	2.1	1.6	2.0
28	28	56	1.8	2.4	2.3	2.4	2.2
56	28	56	2.3	2.4	3.0	2.3	2.5
84	28	56	2.2	2.8	2.7	2.7	2.6
			Phosphorus (P_2O_5)				
56	0	56	2.0	2.3	2.9	3.5	2.7
56	28	56	2.3	2.4	3.0	2.3	2.5
			Potassium (K_2O)				
56	28	0	1.5	2.5	2.8	2.0	2.2
56	28	28	2.4	2.3	2.2	2.5	2.3
56	28	56	2.3	2.4	3.0	2.3	2.5
Mean of all treatments per application			2.1	2.4	2.6	2.4	2.4
Least significant difference needed for comparisons between treatments of same fertilizer application at:[1]							
5-percent level			0.63	0.63	0.63	0.63	0.32
1-percent level			.84	.84	.84	.84	.42

[1] Least significant difference needed for comparisons between mean of all treatment per application at: 5-percent level, 0.23; 1-percent level, 0.32.

YIELDS OF SLIPS PER PLANT

Inasmuch as the main source of commercial planting material for pineapples is slips, the influence of fertilizer on slip production is important. The number of fertilizer applications was not important in increasing the yield of slips per plant, after two fertilizer applications (table 3).

The number of slips per plant tended to increase with increasing nitrogen applications. This was more evident with two, three, and four fertilizer applications.

The use of phosphate fertilizers did not increase slip production. Where a total of 112 pounds of P_2O_5 was applied per acre in four applications the number of slips produced per plant was lowered significantly as compared with the no-P_2O_5 treatment.

Potash fertilizers tended to increase slip production. The response was significant only for the one-fertilizer-application treatment. The other treatment failed to show significant increases in number of slips from potash applications.

LEAF ANALYSIS

Leaf samples were taken to determine when the foliar diagnosis of the pineapple plant was feasible as a means of determining the crop's fertilizer needs. The results obtained, although limited to one crop, give rise to the belief that foliar diagnosis for pineapples is practicable (table 4).

Nitrogen

Leaf-N values disclosed rather well the nitrogen status of the pineapple plant in relation both to nitrogen fertilizer applications and to yields. For the first application of fertilizer, leaf N increased with increased nitrogen applications to the soil when leaf samples were taken 3 months after the fertilizer was applied. However, when leaf samples of the first application were taken 8 months after the fertilizer had been applied, the differences in leaf-N values disappeared, and all leaf values tended to be the same despite the quantity of fertilizer applied. Leaf samples taken 4 months after the second of the two fertilizer applications also revealed differences in leaf N with increasing nitrogen applications. It appears that for pineapples, as for sugarcane (3), the best time for leaf sampling is about 3 to 4 months after fertilizing the plant.

After two applications of fertilizer leaf-N values showed increases when yields also increased. A yield of 15.8 tons of pineapples per acre, which was significantly higher than the 13.7 tons per acre, was associated with a leaf-N value of 1.66 percent. Leaf-N values of about 1.28 percent were associated with lower yields of 12.3 tons per acre. Thus, leaf samples taken 4 months after the second of the two fertilizer applications showed, by

TABLE 4.—*Nutrient content of pineapple leaves from Red Spanish pineapples grown at various fertilizer levels, and their corresponding yields of pineapples per acre, Corozal Substation, plant crop of 1951–53*

Treatment in pounds per acre per application of—			Leaf nutrient content of pineapple leaves, dry-weight basis for number of fertilizer applications indicated—			Yields of pineapples per acre for number of fertilizer applications indicated—	
N	P_2O_5	K_2O	One[1]	One[2]	Two[2]	One	Two
			Nitrogen (N)				
			Percent	*Percent*	*Percent*	*Tons*	*Tons*
0	28	56	1.34	1.23	1.25	11.6	12.3
28	28	56	1.50	1.26	1.28	12.0	12.3
56	28	56	1.67	1.25	1.43	12.5	13.7
84	28	56	1.55	1.25	1.66	12.0	15.8
			Phosphorus (P)				
56	0	56	0.14	0.24	0.20	10.7	12.2
56	28	56	.17	.26	.20	12.5	13.7
			Potassium (K)				
56	28	0	4.60	4.25	4.31	10.7	12.5
56	28	28	4.88	4.39	4.24	12.2	13.4
56	28	56	—	4.56	4.39	12.5	13.7

[1] Leaf sample taken 4 months after planting.
[2] Leaf sample taken 8 months after planting

their leaf-N values, that yield response should be expected with nitrogen fertilizer application. Leaf-N values below 1.66 percent would be indicative of a nitrogen deficiency and of the probability that the application of nitrogen fertilizers would bring increased yields. With leaf-N values near 1.25 percent, the nitrogen deficiency was more intense, and so larger yield increases would be expected than with leaf-N values of 1.43 percent.

Phosphorus

Leaf-P values showed an increase with the first phosphate fertilizer application when leaf samples were taken 3 and 7 months thereafter. There were no increases in leaf P for leaf samples taken 4 months after the second fertilizer application. Even though phosphate fertilizers did not influence yields consistently when applied at different times and rates, leaf-P values below 0.17 percent 4 months after planting may be interpreted to be indicative of a phosphorus deficiency. A value of 0.17-percent leaf P appears to be a safe minimum for this experiment to represent sufficient phosphorus available for good pineapple yields.

Potassium

After the one application of fertilizer, leaf-K values increased with increasing potash applications. After two fertilizer applications, leaf-K values showed no appreciable increase with increased potash applications. As the yields for any particular "number-of-fertilizer-application" treatment showed no significant increases with potash applications, the leaf-K values obtained appear to indicate little or no yield response to potash applications in the field for this experiment. Experiments will have to be performed with pineapples grown on soils where responses to potash fertilizers can be obtained in order to secure leaf-K values for deficiencies of this element in the field.

DISCUSSION

The results of the response of the plant crop of Red Spanish pineapples at the Corozal Substation clearly indicate that high rates, or a large number of fertilizer applications are not needed for good pineapple yields when disease and insect damage are not limiting factors. It is true that yields of 16 tons of Red Spanish pineapples per acre are high. This is almost twice the general average of the Island, and equals Schappelle's highest yield obtained with 640 pounds of N per acre (7). It is also to be remembered that this yield was obtained with only two fertilizer applications, one-half that now used by the growers at lower rates. Thus, not only were yields increased, but labor and fertilizer costs were reduced.

That less fertilizer and fewer applications were needed in this experiment on a Lares clay does not mean, of course, that all pineapple soils in Puerto Rico can do with only two or three fertilizer applications totaling 168 pounds of N per acre for high yields. Experiments are now underway on a Bayamón sandy clay to determine the fertilizer response on this lighter textured pineapple soil. A definite aid in determining the correct number and rate of fertilizer applications is the use of foliar diagnosis. Although the information obtained is for one crop only, the close relationship between yield and leaf-nutrient values, especially for nitrogen and phosphorus, indicated that this method may prove of great service in determining pineapple fertilizer requirements.

Although the primary finding reported in this paper is the response of pineapples to fertilizers, the authors cannot help but stress the role of proper control of biologic-parasitic factors in obtaining proper fertilizer yield responses. For, if the pineapple plant's root system is attacked by nematodes, white grubs, and root rots, and the leaves by mealybugs, the plant cannot function normally. The intake of nutrients through the root system becomes limited, and the plant cannot make proper use of the nutrients available in the large volume of soil where its roots normally feed. Limited root feeding means less nutrients available to the plant for growth and fruiting, and also the need to fertilize heavier and more often near the base of the pineapple plant so that the few effective roots can feed it better.

SUMMARY

This paper reports the results obtained in studies carried out on Red Spanish pineapples at the Corozal Substation for a plant crop in the effort to determine the effect upon yields of the number of fertilizer applications and various levels of fertilizer applied. The experimental results may be summarized as follows:

1. The use of three and four fertilizer applications to pineapples gave no higher yields than did two only.

2. Increases in yields were obtained with nitrogen applications. The use of a total of 168 pounds of N per acre, whether applied in two or three applications, gave the highest yields of pineapple per acre.

3. There were no appreciable yield responses to phosphate fertilizers applied in excess of 56 pounds of P_2O_5 per acre and beyond 9 months prior to the harvest.

4. Potash fertilizers gave some yield increases, but these were not as appreciable as for nitrogen applications.

5. Yields of slips per plant were lowest for one fertilizer application. Slip yields increased with increasing nitrogen and potassium fertilizer applications.

6. Leaf-N values increased with yields. Leaf-N values below 1.66 percent were associated with significant and positive yield response to nitrogen applications

7. Leaf-P values of 0.17 percent and leaf-K values above 4.25 percent were associated with no significant increases in yield when phosphate and potash fertilizers were applied.

8. The importance of proper biological-parasitic control in obtaining proper response to fertilizers is emphasized.

RESUMEN

En este trabajo se informan los resultados obtenidos de los estudios llevados a cabo en la Subestación de Corozal para determinar cómo responde la piña Española Roja a la frecuencia de las aplicaciones de abono y a los distintos niveles de fertilidad.

Estos resultados pueden resumirse como sigue:

1. Cuando se aplicó abono a la piña por tres y cuatro veces, no se registró aumento alguno en los rendimientos que cuando se aplicó dos veces.

2. Los aumentos en los rendimientos se obtuvieron mediante las aplicaciones de nitrógeno. El uso de 168 libras de nitrógeno por acre, produjo el mayor rendimiento de frutas por acre ya fuera aplicado en dos o tres veces.

3. No se registró que el uso de los abonos fosfatados influyera sobre los rendimientos.

4. Los abonos potásicos aumentaron en algo los rendimientos, pero no en la forma que lo hicieron los nitrogenados.

5. La producción de "slips" por planta fué menor cuando sólo se hizo una aplicación de abono, sin embargo, se logró aumentar la producción de este material de propagación cuando se aumentó el número de las aplicaciones de abonos nitrogenados y potásicos.

6. El valor N-foliar aumentó con los rendimientos cuando el valor N-foliar quedó más bajo que el 1.66 por ciento, esto quedó asociado con la manera significativa con que el rendimiento respondió a las aplicaciones de nitrógeno.

7. Un valor P-foliar de 0.17 por ciento y un valor K-foliar sobre 4.25 por ciento se asociaron a aumentos no significativos en los rendimientos cuando se aplicaron abonos fosfatados y potásicos.

8. En este trabajo también se discute el control biológico-parasítico más adecuado para hacer que la piña responda mejor a las aplicaciones de abono.

LITERATURE CITED

1. Alvarez-García, L. A. and López-Matos, L., Influence of root-knot nematodes on the decline in vigor of the Red Spanish variety of pineapple in Puerto Rico, *J. Agr. Univ. P. R.* **38** (1) 61–72, 1954.
2. Bird, J. and Pérez, M. E., Cochinillas y gusanos blancos causan marchitez de las plantas de piña, Official Information Release, Agr. Exp. Sta. Univ. P. R., Río Piedras, (unpublished).
3. Capó, B. G., Samuels, G. and Bonnet, J. A., Why foliar diagnosis? *Sugar* **15** (12) 48–51, 1953.
4. González Ríos, P., A pineapple fertilizer experiment, *J. Dept. Agr. Labor of P. R.* **3** (1) 6–13, 1919.
5. Koenig, N., A comprehensive agriculture program for Puerto Rico, U.S.D.A. in cooperation with Commonwealth of P. R. pp. 1–195, U. S. Government Printing Office, Washington, D. C., 1953.
6. Pennock, W., Nutrient requirement of pineapples on Bayamón silty clay, Rept. P. R. Exp. Sta. (Mayagüez) 62–8, 1939, (mimeographed).
7. Schappelle, N. A., Fertilizer studies with pineapples in Puerto Rico, *J. Agr. Univ. P. R.* **26** (1) 41–60, 1942.
8. Vilá Mayo, R. Informe anual del servicio de inspección de abonos y alimentos concentrados, Dept. Agr. Comm. P. R. 1950–51, pp. 143–74, 1931.