THE JOURNAL OF AGRICULTURE
OF THE UNIVERSITY OF PUERTO RICO

Issued quarterly by the Agricultural Experiment Station of the University of Puerto Rico, Mayagüez Campus, for the publication of articles and research notes by staff members or others, dealing with scientific agriculture in Puerto Rico and elsewhere in the Caribbean Basin and Latin America.

VOL. 75 | OCTOBER 1991 | No. 4

Effect of N and K levels and planting density on pineapple fruit yield and quality[1]

Antonio Vélez-Ramos,[2] Pedro Márquez[3] and C. Chao de Báez[4]

ABSTRACT

A pineapple [*Ananas comosus* (L) Merr.] field experiment was established in which planting densities and levels of foliarly applied N and K_2O were evaluated. No significant treatment interactions were detected for fruit yield and quality and production of slips and crowns. Increasing plant population from 39,174 to 52,240 and to 67,925 plants/ha resulted in a significant fruit yield increase in the ratoon crop, but had no significant effect on the plant crop. Treatment combinations of N at 336, 560 and 784 kg/ha and K_2O at 246, 470 and 694 kg/ha had no significant effect on fruit yield and quality or slip and crown production in the plant crop. A significant reduction in fruit yield was obtained in the ratoon crop at the higher N-K_2O levels. The reduction in yield was attributed to salt accumulation on pineapple leaves as a result of foliar spraying, especially from urea. Nitrogen and K_2O levels did not significantly affect the production of slips and crowns in the plant crop. The combination of 470 and 417 kg/ha of N and K_2O, respectively, produced significantly larger slips and crowns in the ratoon crop. The concentration of N, P, Ca and Mg in the D-leaf was adequate for 4-month-old plants but N and K concentration was below adequate levels in 9-month-old plants, especially at the lower treatment application. In the ratoon crop all plant nutrients were low even at the higher application rates of N and K.

RESUMEN

Efecto de unidades de N y K y densidad de siembra en el rendimiento y calidad de la fruta de piña

Se estableció un experimento de campo con piña [*Ananas comosus* (L) Merr.] para evaluar unidades de N y K_2O y densidades de siembra. No se encontraron interacciones significativas entre los tratamientos usados para rendimiento y calidad de la fruta y producción de hijuelos y coronas. Al aumentar la densidad de siembra de 39,174 a 52,240 y a 67,925 plantas/ha el rendimiento de frutas aumentó significativamente en el retoño, pero no en la plantilla. Las combinaciones de N a 336, 560 y 784 kg/ha y K_2O a 246, 470 y 694 kg/ha no afectaron ni la producción ni la calidad de la

[1] Manuscript submitted to Editorial Board 24 May 1991.
[2] Agronomist, Department of Agronomy and Soils.
[3] Research Assistant, Department of Horticulture.
[4] Associate Statistician, Statistics Section.

fruta; tampoco la producción de hijuelos y coronas en la plantilla. El rendimiento de frutas disminuyó significativamente a las unidades más altas de N y K_2O. Esta disminución se le atribuye al afecto acumulativo de sales como resultado de las aplicaciones foliares de urea. La disminución en el rendimiento se observó también en el análisis combinado de la plantilla y el retoño. Las unidades de N-K_2O no afectaron significativamente la producción de hijuelos y coronas en la plantilla. La combinación de 470 y 417 kg/ha de N y K_2O, respectivamente, produjo hijuelos y coronas significativamente más grandes que los otros tratamientos. Se observó una concentración de N, P, K, Ca y Mg adecuada en la hoja-D en plantas de 4 meses de edad. Sin embargo a los 9 meses de edad, se observó una concentración de N y K inferior a los niveles óptimos. El contenido de nutrimentos en el retoño fue bajo en todos los tratamientos.

INTRODUCTION

Pineapple [*Ananas comosus* (L.) Merr.] is the most important fruit crop grown in Puerto Rico. Local production for fiscal year 1987-88 was 75,776 short tons with a gross farm value of $19.5 million, which accounted for 50% of the total farm value generated from fruits (1). About 90% of the total production of pineapple was processed. The remaining 10% was sold in the local and export fresh markets.

Research conducted in Puerto Rico with pineapples included studies of planting density and levels of N, P, K, Ca and Mg (2, 3, 4, 6, 7, 8, 9, 10, 11, 12). Samuels and Gandía (11), working with Red Spanish, found that 336 kg of N, 67 of P_2O_5 and 253 of K_2O/ha were as effective applied at planting as in split applications. They also reported that 225 kg/ha of N as urea outyielded ammonium sulfate as N source (12). Other studies showed significant increases in pineapple yield with the application of 428 kg/ha of N, but no response to P fertilizer (11). Hernández-Medina (3,4) reported beneficial effects of mg applications on pineapple growth and production.

In a plant density study with Red Spanish, González-Tejera (2) found that close planting distance (45,500 plants/ha) significantly increased yield of a plant crop to a maximum of 58,630 kg/ha. Ramírez and Gandía (7) obtained an increase of 22,500 kg/ha of fruit from cultivar PR 1-67 by increasing plant population from 16,858 to 33,105 plants/ha.

The present trend in world pineapple production is to split plant nutrient doses, except for P, in multiple foliar applications during plant growth and fruit setting. No previous work has been carried out in Puerto Rico to determine optimum economic fertilizer levels associated with plant density and multiple foliar sprays. The present investigation is intended to determine the effect of N and K levels and planting density on pineapple yield, fruit quality and production of slips and crowns.

MATERIALS AND METHODS

A field experiment was established in February 1987 at finca La Montaña, Aguadilla, P.R., on a Coto clay soil (Clayey, kaolinitic, isohyperthermic Tropeptic Haplorthox) with a pH of 5.04, 3 mg/kg P, 0.19 meq/100 g K, 2.73 meq/100 g Ca, 1.73 mel/100 g Mg, 7 mg/kg Fe and 2.5% organic matter. Three factors—N, K_2O and planting density—and three levels of each factor were arranged in a split block design with three replications. Treatment combinations of 336, 560 and 784 kg/ha N and 246, 470 and 694 kg/ha K_2O were assigned to the sub-plots, whereas planting densities of 39,174, 52,240 and 67,925 plants/ha were placed at random in the main plots. The main plots consisted of four double rows 71 cm apart and 68.6 m long with 1.53 m alleys between sub-plots. Sub-plots consisted of four double rows 71 cm apart and 20 feet long with 51 cm between rows. The distance between plants in the row varied according to the desired plant population as follows: 40 cm = 39,174, 30 cm = 52,240; 23 cm = 67,925 plants/ha. All treatments received at planting 112, 67, 134 and 56 kg/ha of N, P_2O_5, K_2O and MgO, respectively, as the fertilizer formula 10-6-12-3. Additional N and K were administered in 10 equal monthly foliar applications with a 190 L tractor mounted pump pre-set at 200 psi. The pump was attached to a 22-foot boom provided with 12 #8006 nozzles. The boom was connected to the pump with a 33 m pressurized rubber hose (fig. 1). The equipment was calibrated to deliver a volume of spray of 2,000 L/ha. Slips of Red Spanish pineapple, the standard commercial variety grown on the island, were planted 27 and 28 February 1987.

Pineapple plant samples were collected at 4 and 9 months after planting. The D-leaves (the most recently fully expanded leaves that can be easily removed from the plant by a sharp side-way hand twist) from 10 plants per plot were used to determine N, P, K, Ca and Mg reported on a dry-weight basis. Flower induction was achieved with ethrel at 2.47 L/ha 11 months after planting. The plant crop experiment was harvested in July-August 1988 and data collected on fruit yield and quality and production of slips and crowns. The experiment was continued for one ratoon crop. In the ratoon crop the N levels were adjusted to 202, 336 and 470, and the K_2O levels to 148, 282 and 417 kg/ha. The foliar sprays were reduced to six monthly applications. D-leaf samples were collected as in the plant crop. The ratoon crop was harvested July-August 1989 and data were recorded as in the previous crop.

RESULTS AND DISCUSSION

Table 1 presents pineapple fruit yield data for the plant and ratoon crops as well as the combined analyses. No significant treatment differences were obtained among N-K_2O combinations or planting densities in the plant crop, although large mean differences on the order of 14,666 kg/ha were obtained. The application of 336 and 246 kg/ha of N and K_2O, respectively, seems to be adequate under the conditions of this experiment. The location of the experimental site was a pasture farm

TABLE 1.—*Effect of N-K_2O levels and planting density on pineapple fruit yield*

Treatment N - K_2O level		Density, plants/ha			
		39,174	52,240	67,925	Mean
kg/ha		Plant crop (kg/ha)			
336	246	46,231	50,156	53,664	50,017
336	470	53,392	63,224	55,676	57,431
336	694	54,250	63,412	60,991	59,551
560	246	55,188	48,235	62,979	55,467
560	470	67,718	50,293	67,997	62,213
560	694	59,830	64,570	66,628	63,676
784	246	41,727	51,922	64,832	52,827
784	470	47,788	59,877	39,365	49,010
784	694	47,196	62,521	58,949	56,222
	Mean	52,591	57,205	59,009	56,268
		Ratoon Crop			
202	148	38,074	41,138	59,140	46,117 ab[1]
202	282	44,270	49,092	57,276	50,212 a
202	417	40,524	49,338	55,519	48,460 a
336	148	45,099	45,517	48,966	46,528 ab
336	282	37,981	39,451	57,192	44,875 ab
336	417	39,323	49,298	60,507	49,709 a
470	148	31,631	40,720	46,673	39,675 ab
470	282	31,141	37,088	40,485	32,238 c
470	417	33,316	37,645	41,195	37,386 c
	Mean	37,929 c	43,254 b	51,884 a	44,356
		Combined (plant and ratoon)			
538[2]	394[2]	100,005	100,306	111,826	104,045 bcde
538	752	100,467	121,276	119,401	113,715 ab
538	1111	105,221	115,148	113,040	111,136 abcd
896	394	115,278	96,481	112,462	108,074 abcd
896	752	113,454	96,697	124,122	111,424 abcd
896	1111	112,099	118,262	124,462	118,274 a
1254	394	104,230	100,682	94,838	99,917 cde
1254	752	76,006	105,248	91,656	90,970 e
1254	1111	97,976	108,271	91,901	99,382 de
	Mean	102,748	106,930	109,301	106,326

[1]Treatment means with letters in common are not significantly different ($P = 0.05$)
[2]Total N-K_2O for plant and ratoon crops.

never planted to pineapple. Soil analyses showed fairly good organic matter content (2.5%) but rather low K (0.19 meq/100 g). Scorching and death of terminal meristems was observed in plots receiving the highest level of urea (784 kg/ha), probably caused by the high concentration of salts in the spraying solution. These plants were smaller, had less uniform fruit induction and produced smaller fruits.

In the ratoon crop, increasing plant population from 39,174 to 52,240 and to 67,925 resulted in significantly higher fruit production. The significant treatment differences observed for the N-K_2O combinations resulted from a yield depression in plots receiving the highest level of urea, rather than from individual treatment effect. The combined (plant and ratoon crops) statistical analyses for yield showed a similar pattern to that of the ratoon crop. Under the present experimental conditions, a total fertilizer application of 752 kg/ha of K_2O and 538 kg/ha of N for a plant and a ratoon crop performed best. The yield reduction resulting from a high salt concentration in the spraying solution at the highest urea content was more pronounced in the combined analyses because of the accumulated effect.

Pineapple fruit quality parameters—Brix, pH and acidity—were not significantly affected by experimental treatments (table 2). These parameters indicate good fruit quality for both plant and ratoon crops. The Brix:acidity ratio ranged from 23.1 to 26.8 and from 23.5 to 28.9 for the plant and ratoon crops, respectively. Higher light intensity at harvesting time (July-August) contributed to increase the Brix:acidity ratio. According to Meléndez (of the Lotus pineapple processing plant, Barceloneta, P.R.), a Brix:acidity ratio from 24 to 30 is an indicator of good pineapple fruit quality for the Red Spanish cultivar (personal communication).

Table 3 shows the effect of treatments on the production of slips and crowns. No significant mean differences were observed between N-K_2O levels or plant densities for number and weight of slips and crowns, exept for the highest levels of N-K_2O (470 and 417 kg/ha) in the ratoon crop that produced significantly larger slips and crowns. This finding implies that more planting material (slips) can be produced by increasing plant population. A marked reduction in the number of slips and the weight of crowns was observed in the ratoon crop as compared to the plant crop.

Tables 4 and 5 show D-leaf composition as percent N, P, K, Ca and Mg. The D-leaf may be defined as the most recently fully expanded leaf that can be easily removed from the plant by a sharp sideway hand twist. Although the D-leaf nutrient content may vary with age, climate variety, the generally accepted adequate values in Puerto Rico on a dry weight basis are: N = 1.5-2.0%, P = 0.12-0.15%, K = 3.0-3.5%, Ca = 0.25-0.30% and Mg = 0.20-0.25%.

Major nutrient content of 4-month-old plants was adequate, except for Ca, which was low (>0.2%), especially in plots receiving high K. This finding may be the result of an antagonistic effect between the K and Ca ions, as reported by Siders and Young (12). N and K content increased as the applied N and K increased. At 9 months, the N in D-leaves was still adequate, with rather low readings at the lower application rate.

TABLE 2.—*Effect of treatments on fruit quality*

N - K_2O levels kg/ha		Density, plants/ha 39,174 Brix	39,174 pH	39,174 Acidity	52,240 Brix	52,240 pH	52,240 Acidity	67,925 Brix	67,925 pH	67,925 Acidity	Mean Brix	Mean pH	Mean Acidity	Brix Acidity
							Plant Crop (kg/ha)							
336	246	15.0	3.64	572	14.6	3.67	527	14.3	3.64	605	14.6	3.65	568	25.7
336	470	14.6	3.71	629	14.6	3.74	534	14.5	3.72	561	14.6	3.72	575	25.4
336	694	15.1	3.79	592	13.9	3.68	611	14.8	3.72	644	14.6	3.73	616	23.7
560	246	14.4	3.69	563	14.8	3.66	612	13.7	3.78	510	14.3	3.70	562	25.4
560	470	14.4	3.69	553	14.5	3.75	538	14.4	3.70	568	14.4	3.72	553	26.0
560	694	14.6	3.77	571	15.0	3.72	614	14.6	3.68	529	14.8	3.76	572	25.9
784	246	13.6	3.68	471	13.3	3.72	493	14.0	3.64	559	13.6	3.68	508	26.8
784	470	14.2	3.69	590	14.1	3.65	604	14.4	3.66	647	14.2	3.66	614	23.1
784	694	14.2	3.70	617	13.8	3.76	484	14.6	3.67	647	14.2	3.71	583	24.4
	Mean	14.4	3.70	573	14.3	3.71	557	14.4	3.70	586	14.4	3.70	572	25.2
							Ratoon Crop							
202	148	15.5	3.80	586	15.2	3.70	617	14.8	3.70	638	15.2	3.70	614	24.8
202	282	16.0	3.80	590	15.7	3.80	581	14.9	3.80	629	15.5	3.80	600	25.8
202	417	15.5	3.90	590	15.7	3.70	677	15.1	3.70	696	15.4	3.70	654	23.5
336	148	15.5	3.90	493	15.5	3.70	586	14.6	3.90	517	15.2	3.80	532	28.6
336	282	15.5	3.90	511	15.1	3.80	550	14.9	3.80	517	15.2	3.80	566	28.9
336	417	15.2	3.80	623	15.1	3.70	592	15.2	3.90	538	15.2	3.90	584	26.0
470	148	14.3	3.70	608	14.5	3.80	535	14.1	3.70	592	14.3	3.70	578	24.7
470	282	14.4	3.80	623	14.7	3.90	520	14.6	3.80	577	14.6	3.80	574	25.4
470	417	14.9	3.90	568	14.7	3.90	556	14.6	3.80	590	14.7	3.80	572	25.7
	Mean	15.2	3.80	577	15.1	3.80	580	14.7	3.80	588	15.0	3.80	582	25.8

[1]Meq./100 ml of juice.

TABLE 3.—*Effect of treatments on the production of slips and crowns*

N-K_2O levels kg/ha		Density, plants/ha 39,174 SN	39,174 SW	39,174 CW	52,240 SN	52,240 SW	52,240 CW	67,925 SN	67,925 SN	67,925 CW	Mean SN	Mean SW	Mean CW
							Plant Crop						
336	246	6.6	113	445	5.4	111	400	5.1	119	454	5.7	114	431
336	470	5.4	144	572	5.3	140	527	4.7	123	549	5.1	137	549
336	694	5.2	109	440	5.9	122	527	5.1	105	499	5.4	113	454
560	246	5.8	128	635	5.0	146	536	5.2	151	486	5.0	122	481
560	470	5.5	111	534	4.9	133	454	4.6	135	531	5.0	125	513
560	694	6.9	145	490	4.2	103	449	4.9	115	468	5.3	125	468
784	246	5.6	108	463	4.1	116	604	4.5	141	468	4.7	122	513
784	470	3.5	119	154	3.4	144	527	3.0	163	800	3.3	142	599
784	694	6.1	135	472	5.3	152	522	3.7	114	563	5.0	152	518
	Mean	5.6	125	504	4.8	131	449	4.4	127	513	4.9	128	490
							Ratoon Crop						
202	148	1.3	91	123	3.2	159	213	2.2	173	209	2.2	141	182
202	282	1.5	45	132	1.7	91	209	2.0	104	186	1.7	82	177
202	417	2.5	127	150	2.7	186	209	2.8	173	232	2.7	163	200
336	148	3.7	227	195	1.2	45	209	2.3	95	200	2.4	123	204
336	282	1.8	95	272	1.5	73	173	2.0	86	200	1.8	86	213
336	417	1.5	68	245	1.0	68	227	1.3	73	182	1.3	73	218
470	148	2.0	141	263	1.7	50	245	2.2	123	195	1.9	123	236
470	282	2.8	150	290	1.5	86	173	2.8	109	263	2.7	118	241
470	417	2.2	204	277	2.2	208	331	1.3	118	232	1.9	241*	286*
	Mean	2.1	150	218	1.9	123	209	2.1	118	191	2.1	132	213

[1]SN = Average number of slips per plant; SW = average weight per slip in g; CW = average weight per crown in g.
[2]* = Significant at P = 0.05.

TABLE 4.—*Effect of treatments on D-leaf nutrient content-plant crop*

Treatment N	K_2O	Population	D-leaf nutrient content 4 - Mo. old N	P	K	Ca	Mg	9 - Mo. old N	P	K	Ca	Mg
kg/ha		plant/ha	%									
336	246	39,174	1.74	.16	3.67	.23	.25	1.41	.12	2.25	.29	.22
336	470	39,174	1.87	.17	4.10	.23	.26	1.49	.12	2.51	.28	.23
336	694	"	1.86	.17	4.03	.13	.27	1.41	.10	2.52	.26	.24
560	246	"	1.97	.16	3.70	.23	.27	1.62	.11	2.16	.27	.25
560	470	"	1.99	.16	3.87	.20	.27	1.55	.13	2.68	.29	.23
560	694	"	1.93	.15	3.67	.10	.23	1.57	.13	2.76	.26	.23
784	246	"	2.35	.16	3.90	.30	.25	1.77	.16	2.33	.35	.24
784	470	"	2.28	.15	3.70	.17	.24	2.02	.11	2.56	.28	.24
784	694	"	2.18	.15	4.13	.17	.26	1.72	.13	2.70	.24	.22
336	246	52,240	1.83	.16	3.75	.40	.26	1.33	.11	2.17	.27	.22
336	470	"	1.81	.16	3.90	.20	.28	1.37	.12	2.49	.26	.24
336	694	"	1.71	.15	3.77	.13	.25	1.25	.14	2.68	.22	.24
560	246	"	1.95	.17	3.93	.17	.28	1.53	.13	2.45	.30	.27
560	470	"	2.01	.16	3.70	.20	.26	1.53	.12	2.48	.26	.20
560	694	"	1.91	.15	3.90	.13	.24	1.46	.12	2.70	.23	.21
784	246	"	2.37	.16	3.73	.17	.25	1.80	.11	2.37	.29	.26
784	470	"	2.35	.15	3.73	.23	.26	1.90	.11	2.65	.27	.22
784	694	"	2.21	.17	3.90	.20	.26	1.80	.10	2.61	.28	.22
336	246	67,915	1.67	.16	3.58	.20	.25	1.45	.11	2.00	.27	.25
336	470	"	1.84	.16	3.87	.17	.27	1.50	.11	2.41	.29	.26
336	694	"	1.87	.16	4.00	.20	.20	1.28	.12	2.80	.21	.23
560	246	"	1.93	.16	3.70	.17	.28	1.44	.11	2.08	.23	.23
560	470	"	2.00	.17	4.07	.17	.25	1.58	.12	2.82	.25	.23
784	246	"	2.23	.16	3.77	.20	.26	1.81	.12	2.46	.30	.25
784	470	"	2.30	.15	3.83	.17	.26	1.83	.11	2.67	.25	.24
784	694	"	2.09	.16	3.85	.13	.24	1.84	.11	2.72	.26	.23

TABLE 5.—*Effect of treatments on D-leaf nutrient content—Ratoon crop*

Treatment N	K_2O	Population	D-leaf nutrient content 4 - Mo. old N	P	K	Ca	Mg	9 - Mo. old N	P	K	Ca	Mg
kg/ha		plant/ha	%									
202	148	39,174	1.08	.11	2.10	.18	.26	1.19	.08	2.07	.17	.22
202	282	"	1.07	.09	2.20	.15	.21	1.18	.07	2.07	.13	.19
202	417	"	1.09	.11	2.63	.11	.18	1.15	.07	2.37	.10	.16
336	148	"	1.16	.11	2.23	.14	.23	1.29	.07	1.93	.15	.22
336	282	"	1.15	.09	2.27	.13	.21	1.28	.07	2.13	.13	.20
336	417	"	1.22	.09	2.57	.13	.18	1.31	.07	2.30	.11	.19
470	148	"	1.42	.10	2.37	.15	.23	1.59	.08	2.17	.12	.20
470	282	"	1.42	.09	2.43	.09	.18	1.71	.07	2.17	.10	.15
470	417	"	1.38	.11	2.73	.11	.18	1.53	.07	2.57	.10	.16
202	148	52,240	1.03	.11	2.04	.16	.21	1.12	.07	1.67	.19	.22
202	282	"	1.00	.11	2.27	.09	.19	1.24	.07	2.40	.15	.17
202	417	"	1.16	.11	2.67	.09	.18	1.29	.07	2.73	.15	.19
336	417	"	1.16	.11	2.67	.09	.18	1.29	.07	2.73	.15	.19
336	148	"	1.19	.11	2.33	.14	.23	1.34	.07	2.27	.15	.20
336	282	"	1.08	.09	2.13	.13	.19	1.14	.07	2.03	.15	.17
336	417	"	1.17	.09	2.21	.13	.18	1.34	.08	2.63	.17	.18
470	148	"	1.31	.10	2.32	.12	.21	1.47	.08	2.53	.15	.22
470	282	"	1.43	.10	2.40	.13	.19	1.51	.09	2.30	.14	.17

The same trend was observed for K, whereas Ca and Mg were adequate. In the ratoon crop (table 5), however, N and K were low (>1.5% and 2.75%, respectively), even at the highest application rates. Ca content was low (>0.2%), with Mg approaching critical levels, especially in plots receiving the higher amounts of K_2O. Planting density did not influence nutrient content of the D-leaf.

LITERATURE CITED

1. Antoni, M., M. Cortés, G. M. González and S. Vélez, 1990. Empresas Agrícolas de Puerto Rico en 1987-88. Situación y Perspectivas. *Esta. Exp. Agric. Univ. P. R.*
2. González-Tejera, E., 1969. Effects of plant density on the production of a plant crop of Red Spanish pineapple in Puerto Rico. Proc. Caribbean Food Crop Soc. (7th Annual Meeting).
3. Hernández-Medina, E., 1961. Pineapple response to magnesium in Puerto Rico. *Proc. Amer. Soc. Hort. Sci.* (Caribbean Region) 5: 70-5.
4. ——, 1964. Magnesium, an important nutrient in pineapple production in a Bayamón Sandy clay. *J. Agric. Univ. P. R.* 48 (1): 17-24.
5. Pennock, N., 1949. Field response of Red Spanish pineapple to nitrogen, calcium and iron and soil pH. *J. Agric. Univ. P. R.* 33 (1): 1-26.
6. Ramírez, O. D. and H. Gandía, 1976. Comparison of three planting distances and fertilizer application on the yield of pineapple variety PR 1-67. *J. Agric. Univ. P. R.* 60 (1): 31-5.
7. Ramírez, C. T. and E. González-Tejera, 1983. Spacing, nitrogen and potassium on yield and quality of Cabezona pineapple. *J. Agric. Univ. P. R.* 67 (1): 1-10.
8. Samuels, G., P. Landrau and R. Olivencia, 1955. Response of pineapple to the application of fertilizers. *J. Agric. Univ. P. R.* 39 (1): 1-11.
9. ——, S. Alers-Alers, and G. C. Jackson, 1958. Influence of fertilizers on yields of pineapples on a Coto clay. *J. Agric. Univ. P. R.* 42 (1): 12-26.
10. ——, and H. Gandía-Díaz, 1958. Influence of the number of fertilizer applications on pineapple yields. *J. Agric. Univ. P. R.* 41 (1): 7-11.
11. —— and ——, 1961. Ammonium sulfate and urea as nitrogen sources for pineapples in Puerto Rico. *Proc. Amer. Soc. Hort. Sci.* (Tropical Region) 5: 64-9.
12. Siders, C. P. and H.Y. Young, 1945. Effects of different amounts of potassium on growth and ash constituents of *Ananas comosus* (L) Merr. *Plant Physiol.* 20: 609-30.