Foliar application of nitrogen, potassium and magnesium, and pineapple yield and quality[1,2]

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ABSTRACT

A field experiment was conducted on a Bayamón soil to evaluate the effect of foliar applications of nitrogen, potassium and magnesium on the yield and quality of pineapple cultivar Red Spanish. The application of 392 kg/ha of K and 224 kg/ha of Mg resulted in a significant increase in fruit yield over the lowest K-Mg application rate (224 kg/ha of K and no Mg) in the plant crop. Increasing N from 224 to 392 and to 784 kg/ha did not significantly increase fruit yield but reduced brix and acidity and increased pH of the fruit. A significant increase of 6,572 kg/ha of pineapple fruits was obtained in the ratoon crop with the application of 520 kg/ha of K and 74 kg/ha of Mg. Nitrogen levels had no significant effect on pineapple fruit yield and quality in the ratoon crop. The average length and width of the fruit and core diameter increased significantly as magnesium applications increased. Nitrogen and potassium content of the D-leaf of 4-month-old plants was adequate, but rather low in 10-month-old plants, regardless of N-K treatment. In the ratoon (22- and 26-month) leaf nitrogen was adequate, but potassium was low. Potassium treatments had little effect on leaf potassium content. Calcium and magnesium content ran low throughout the crop cycle, especially in the ratoon crop.

Key words: *Ananas comosus*, foliar fertilization, pineapple yield, pineapple quality

RESUMEN

Efecto de aplicaciones foliares de nitrógeno, potasio y magnesio sobre el rendimiento y la calidad de la piña

Se estableció un experimento de campo en un suelo de la serie Bayamón para evaluar el efecto de niveles de nitrógeno, potasio y magnesio en aplicaciones foliares sobre el rendimiento y la calidad de la fruta de piña (*Ananas comosus* (L.) Merr.) cultivar Española Roja. La combinación de 392 kg/ha de K y 224 kg/ha de Mg resultó en un aumento significativo de 8,349 kg/ha de frutas al compararlo con la aplicación de 224 kg/ha de K y cero Mg en la cosecha de plantilla. El incrementar el nitrógeno de 224 a 392 y 784 kg/ha no aumentó el rendimiento de frutas en forma significativa, pero redujo el brix y la acidez y aumentó el pH de la fruta. La aplicación de 520 kg/ha de K y 74 kg/ha de Mg produjo un aumento significativo de 6,572 kg/ha de frutas

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en la cosecha de retoño. En el retoño, el aumento en el nivel de nitrógeno no tuvo efecto significativo en el rendimiento y la calidad de la fruta. El largo y ancho promedio de la fruta y el diámetro del corazón aumentaron significativamente al aumentar el nivel de nitrógeno. El contenido de nitrógeno y potasio en la hoja-D fue adecuado en plantas de cuatro meses de edad pero fue bajo para plantas de 10 meses de edad, independientemente de la cantidad de nitrógeno y potasio aplicada. En el ciclo de retoño (22 y 26 meses) el contenido de nitrógeno en la hoja fue adecuado pero el contenido de potasio fue bajo. Los niveles de potasio aplicados no tuvieron efecto significativo sobre el contenido de potasio en la hoja. El contenido de calcio y magnesio en la hoja se mantuvo bajo a través del estudio, especialmente en las plantas más viejas (retoño).

INTRODUCTION

According to Cooke (1949), "Anyone can grow pineapples successfully on virgin land, but it requires real knowledge to plant pineapples repeatedly and successfully on the same piece of land." Pineapple demands large quantities of soil nutrients, especially nitrogen and potassium for optimum yields. Not only the relative amount of a specific nutrient is important, but also the ratio of selected nutrients. Thus, an increase in nitrogen availability may result in an increase in the level of potassium in the tissues and consequently immobilization (Marchal et al., 1970). The absorption of magnesium is influenced by both nitrogen and potassium content in the soil (Siders and Young, 1945; 1946). According to Molinier (quoted in Py et al., 1987), magnesium fertilizers are often applied in Hawaii in enough quantity to

TABLE 1.—*Fertilizer treatments.*

Plant Crop			Ratoon			Plant and Ratoon Combined		
N	K_2O	MgO	N	K_2O	MgO	N	K_2O	MgO
				kg/ha				
224	224	0	57	75	0	281	299	0
		56			37			93
		112			74			186
		224			148			372
392	392	0	200	220	0	592	612	0
		56			37			93
		112			74			186
		224			148			372
784	784	0	483	520	0	1267	1304	0
		56			37			93
		112			74			186
		224			148			372

ensure a K:Mg ratio of 5:1. Well documented information is available on the influence of cations K, Ca and Mg on pineapple fruit yield (Martin-Prevel, 1961a), on fruit quality (Martin-Prevel, 1961b) and on the mineral content of the D-leaf (Martin-Prevel, 1961c).

In Puerto Rico, Samuels et al. (1955; 1958), González-Tejera (1975) and González-Tejera et al. (1974) studied the effect of levels and sources of nitrogen and potassium fertilizers on pineapple fruit yield and quality. Hernández-Medina (1961; 1964) reported beneficial effects of magnesium on pineapple growth and production. These field trials were with side-dressed fertilizer applications and low planting densities. Current production practices in Puerto Rico include high plant populations (more than 60,000 plants per hectare) and multiple foliar fertilizer sprays. There is no information available on pineapple fertilizer requirements under these production practices. The present investigation was undertaken in order to gather information toward this end.

MATERIALS AND METHODS

A field trial was conducted in cooperation with the Pineapple Program of the Land Authority of Puerto Rico on Palo Alto farm. The soil was classified as Bayamón (Typic Haplorthox, clayey, oxidic, isohyperthermic). It had been planted to pineapple for more than 50 consecutive years. Laboratory soil analyses indicated low exchangeable K, Ca and Mg, and a pH of 4.3

For the plant crop, the experimental design used was a randomized complete block with three replications. The treatments were analyzed in split-plots with nitrogen levels (224, 392 and 784 kg/ha) assigned to the main plots, and the 12 factorial combinations of K-Mg to the subplots (Table 1). Potassium was applied at rates of 224, 392 and 784 kg/ha as K_2O. Magnesium was applied at 0, 56, 112 and 224 kg/ha as MgO. The main plots contained 12 continuous sub-plots consisting of four double rows 71 cm apart, 6.1 m long with 51 cm between rows. Plant distance within the row was 30 cm, thus making a stand of 51,000 plants per hectare. There were 1.53-m alleys between sub-plots. Slips of Red Spanish cultivar were planted in December 1987.

All plots received a pre-planting fertilizer application consisting of 1,120 kg/ha of a formula 12-6-10 equivalent to 134, 67 and 112 kg/ha of N, P_2O_5 and K_2O, respectively. Ten monthly foliar applications of urea, K_2SO_4 and $MgSO_4$ were made to supply additional N, K_2O and MgO according to the fertilizer treatment differentials in the plant and ratoon crops. Foliar treatment applications were made with a 20 L Knapsack sprayer. In the ratoon crop the foliar sprays were reduced to six

TABLE 2.—*Effect of N, K and Mg levels on pineapple fruit yield.*

Plant crop						Ratoon					
Fertilizer treatment						Fertilizer treatment					
		Nitrogen level (kg/ha)						Nitrogen level (kg/ha)			
K_2O	MgO	224	392	784	Mean	K_2O	MgO	57	200	483	Mean
kg/ha											
224	0	43,542	46,610	34,504	41,552 b[1]	75	0	34,453	40,196	32,554	37,734 d
224	56	39,708	52,543	44,503	45,885 ab	75	37	34,561	41,447	38,024	38,011 abcd
224	112	46,261	53,345	47,508	49,038 ab	75	74	39,457	37,911	32,868	36,712 bcd
224	224	44,979	50,968	47,062	47,670 ab	75	148	36,213	36,230	33,444	35,296 cd
392	0	45,315	48,711	44,177	46,068 ab	220	0	30,268	44,586	36,616	37,157 bcd
392	56	49,907	47,278	45,427	47,537 ab	220	37	41,230	42,657	44,086	42,657 ab
392	112	43,818	41,032	42,426	42,426 ab	200	74	38,121	40,903	36,802	38,609 abcd
392	224	43,333	58,887	47,482	49,901 a	200	148	36,382	48,735	33,134	39,417 abc
784	0	46,355	48,416	39,685	44,819 ab	520	0	42,201	35,485	30,470	36,052 bcd
784	56	46,943	42,060	47,555	45,519 ab	520	37	38,324	33,670	41,660	37,885 abcd
784	112	48,028	50,013	48,101	48,714 ab	520	74	41,671	47,490	43,758	44,306 a
784	224	42,814	51,618	54,888	49,773 a	520	148	40,251	42,410	38,319	40,327 abc
Mean		45,080	49,290	45,276	46,550	Mean		37,761	40,968	36,811	38,514

[1]Within columns, means followed by the same letter are not significantly different at $P \leq 0.05$.

TABLE 3.—*Effect of treatments on pineapple fruit quality.*

Plant crop					Ratoon				
Fertilizer		pH	Brix	Acidity	Fertilizer[1]		pH	Brix	Acidity
kg/ha				Meq./ 100ml	kg/ha				Meq./ 100ml
				Nitrogen levels					
224		3.89 b[2]	16.3 a	463 a[2]	281		3.71	15.8	522
392		4.05 a	15.9 ab	401 ab	592		3.71	15.9	537
784		4.02 a	15.8 b	381 b	1267		3.71	15.2	594
				K_2O and MgO levels					
K_2O	MgO				K_2O	MgO			
224	0	4.06	16.1	374 c[2]	299	0	3.66	15.8	553
224	56	4.02	16.0	396 bc	299	93	3.71	15.2	546
224	112	4.03	15.8	397 bc	299	136	3.67	15.9	533
224	224	3.98	16.0	410 abc	299	372	3.70	16.0	561
392	0	3.99	15.9	398 bc	612	0	3.67	15.7	565
392	56	3.95	16.0	436 abc	612	93	3.73	15.5	549
392	112	3.95	16.1	412 abc	612	136	3.69	15.7	528
392	224	3.91	15.7	461 a	612	372	3.72	15.4	553
784	0	3.97	16.0	422 abc	1304	0	3.73	15.7	549
784	56	3.97	16.0	422 abc	1304	0	3.73	15.7	567
784	112	3.96	15.9	445 ab	1304	93	3.73	15.7	569
784	224	4.02	16.2	429 abc	1304	372	3.73	15.9	540

[1]Total fertilizer applied for plant and ratoon crops.

[2]Within fertilizer and columns, means followed by the same letter are not significantly different at $P \leq 0.05$.

monthly applications and the total N, K and Mg applied was reduced proportionally.

D-leaf samples were collected at 4, 10, 22 and 26 months after planting and analyzed for N, K, Ca and Mg content in the ash. The plant crop was harvested from June to July in 1989 and the ratoon crop from July to August in 1990. Fruit yield per plot was recorded. A sample of pineapple fruits from each plot was collected and analyzed for the pH, brix and total acidity of the juice. Fruit length and width and fruit core diameter were measured.

RESULTS AND DISCUSSION

Increasing the level of nitrogen fertilization had no effect on fruit yield of the plant crop (Table 2). Mean fruit yield was 45,080 kg/ha

TABLE 4.—*Effect of treatments on fruit characteristics.*

Plant crop					Ratoon				
Fertilizer		Length	Width	Core	Fertilizer[1]		Length	Width	Core
kg/ha		- - - - - cm - - - - -			kg/ha		- - - - - cm - - - - -		
Nitrogen levels									
224		12.3 b[2]	11.7 b	1.79 b[2]	281		11.4	11.0	1.41
392		13.3 a	15.9 a	1.84 ab	592		11.5	11.0	1.43
784		13.2 a	15.8 a	1.86 a	1267		11.4	11.0	1.43
K_2O and MgO levels									
K_2O	MgO				K_2O	MgO			
224	0	12.4	11.7	1.85	299	0	11.1	10.8	1.36 c[2]
224	56	13.1	12.2	1.83	299	93	11.1	10.8	1.41 abc
224	112	13.0	12.2	1.91	299	136	11.4	11.0	1.42 abc
224	224	13.1	12.3	1.79	299	372	11.2	10.7	1.40 abc
392	0	13.1	12.4	1.89	612	0	11.4	10.9	1.39 bc
392	56	13.0	12.4	1.91	612	93	11.7	11.1	1.46 ab
392	112	12.8	12.0	1.90	612	136	11.5	11.0	1.42 abc
392	224	13.3	12.4	1.51	612	372	11.5	11.1	1.42 abc
784	0	12.8	12.0	1.89	1304	0	11.5	11.0	1.43 abc
784	56	12.8	12.2	1.90	1304	93	11.9	11.3	1.46 ab
784	112	13.1	12.4	1.89	1304	136	11.9	11.4	1.49 a
784	224	12.5	12.2	1.89	1304	372	11.3	11.0	1.41 abc

[1]Total fertilizer applied for plant and ratoon crops.

[2]Within fertilizer and columns, means followed by the same letter are not significantly different at $P \leq 0.05$.

when 224 kg/ha of N was applied; 49,290 kg/ha when 392 kg/ha of N was applied; and 45,276 kg/ha when 784 kg/ha of N was applied. The highest fruit yield (49,901 kg/ha) was obtained with the treatment combination of 392 kg/ha of K and 224 kg/ha of Mg but was only significantly higher than the yield obtained with 224 kg/ha of K and no Mg. The mean yield of these plots was 41,552 kg/ha, a difference of 8,349 kg/ha of fruit.

No significant response to nitrogen increments was observed in the ratoon crop. The yield obtained with the application of 520 kg/ha of K and 74 kg/ha of Mg (44,306 kg/ha) was significantly higher than the yield of other K-Mg treatments where no Mg was applied.

The lack of a more pronounced effect from N and K fertilizers on pineapple yield in this study may be explained on the basis of an unbalanced application of the two nutrients resulting in a higher supply of one nutrient and too little of the other. The antagonistic effect on the absorption and assimilation of NH_4 and K ions is well documented (Teiwes and Gruneberg, 1963).

Table 3 presents the effect of the treatments on pineapple fruit quality. In the plant crop, the fruit juice pH increased with a nitrogen increment up to 392 kg/ha, but brix and total acidity were significantly reduced. In general, the higher fruit acidity was associated with the upper levels of K and Mg, all of which is in agreement with previous findings (Py et al., 1987). Potassium and magnesium treatments had no significant effect on fruit pH or brix. There was no effect of the treatments on fruit quality of the ratoon.

Table 4 shows the effect of N, K and Mg fertilizers on the size and core of the fruit. In the plant crop, increasing N from 224 to 392 kg/ha significantly increased the length and width of the fruit. However, K and Mg application had no significant effect on these parameters. It is generally agreed that N fertilizer in pineapple is associated with fruit size, whereas K and Mg are associated with fruit quality (Py et al.,

TABLE 5.—*D-leaf composition in the plant and the ratoon crops.*

Fertilizer		4-month-old plant crop				10-month-old plant crop			
		N	K	Ca	Mg	N	K	Ca	Mg
kg/ha		%							
		Nitrogen levels							
224		1.55	3.11	0.19	0.17	0.95	2.29	0.15	0.15
392		1.88	3.00	0.19	0.17	1.29	2.39	0.11	0.16
784		2.17	3.11	0.20	0.18	1.37	2.32	0.10	0.15
		K_2O and MgO levels							
K_2O	MgO								
224	0	1.83	3.07	0.18	0.14	1.31	2.44	0.15	0.16
224	56	1.83	3.00	0.17	0.18	1.25	2.27	0.13	0.16
224	112	1.83	3.18	1.18	0.16	1.25	2.23	0.13	0.16
224	224	1.76	2.85	0.18	0.16	1.18	2.26	0.12	0.17
392	0	1.88	3.05	0.18	0.17	1.25	2.32	0.11	0.15
392	56	1.93	3.07	0.17	0.18	1.20	2.27	0.14	0.17
392	112	1.86	3.14	0.18	0.17	1.17	2.27	0.10	0.15
392	224	1.81	3.18	0.16	0.17	1.12	2.33	0.13	0.17
784	0	1.92	2.96	0.17	0.16	1.14	2.41	0.12	0.14
784	56	1.91	2.92	0.16	0.16	1.19	2.43	0.12	0.14
784	112	2.03	3.30	0.18	0.19	1.20	2.37	0.11	0.15
784	224	1.84	3.17	0.18	0.18	1.22	2.39	0.11	0.16

TABLE 5.—*D-leaf composition in the plant and the ratoon crops. (Cont.)*

Fertilizer		22-month-old plant crop				26-month-old plant crop			
		N	K	Ca	Mg	N	K	Ca	Mg
kg/ha		%							
		Nitrogen levels							
281		1.59	2.63	0.13	0.16	1.11	2.25	0.12	0.14
592		1.55	2.49	0.16	0.16	1.23	2.31	0.16	0.15
1267		1.89	2.50	0.17	0.17	1.60	2.29	0.15	0.14
		K_2O and MgO levels							
K_2O	MgO								
299	0	1.70	2.55	0.17	0.15	1.03	2.26	0.17	0.12
299	93	1.71	2.49	0.16	0.16	1.32	2.19	0.13	0.14
299	186	1.66	2.42	0.14	0.16	1.28	2.16	0.15	0.15
299	372	1.61	2.43	0.15	0.17	1.33	2.17	0.16	0.15
612	0	1.65	2.73	0.15	0.16	1.31	2.19	0.13	0.13
612	93	1.79	2.65	0.14	0.16	1.29	2.32	0.12	0.14
612	186	1.67	2.51	0.12	0.16	1.30	2.29	0.13	0.14
612	372	1.66	2.54	0.15	0.18	1.30	2.20	0.13	0.16
1304	0	1.75	2.65	0.16	0.15	1.29	2.44	0.13	0.13
1304	93	1.63	2.70	0.17	0.16	1.34	2.35	0.14	0.14
1304	186	1.62	2.63	0.16	0.17	1.39	2.34	0.12	0.14
1304	372	1.65	2.51	0.15	0.18	1.30	2.46	0.14	0.15

1987). No significant effect on fruit size was observed in the ratoon crop.

Pineapple D-leaf composition for both the plant and ratoon crops is summarized in Table 5. The N and K content for 4-month-old plants was adequate. Nitrogen content increased as N application increased. Leaf Ca and Mg content was low in both young and old pineapple plants regardless of treatment. Potassium and magnesium absorption was not associated with the application of K and Mg fertilizer. This finding is difficult to explain on the basis of ion availability or ion antagonism effect.

On the basis of the results obtained in this experiment it would appear that 300 kg/ha of N and 600 kg/ha of K_20 are required for a crop cycle of a plant and a ratoon crop of pineapple under the conditions prevailing at the study site. A definite response to Mg application was observed. On the other hand, on the basis of the D-leaf content of N, K and Mg, a responsible recommendation could not be made. More research is needed on levels of foliar applications of N, K and Mg before final recommendations can be made.

LITERATURE CITED

Cooke, P. C., 1949. The pineapple industry of the Hawaiian Islands. Dept. Fed. Malaya Johore Bahru.

González-Tejera, E., 1975. Effect of differential levels of N, K and Mg fertilizers on the fruit yield and quality of *Ananas comosus* L. (Merr.) var. PR1-67. Proc. Amer. Soc. Hort. Sci. (Trop. Region) 19:147-58.

González-Tejera, E., H. R. Cibes y H. Gandía, 1974. El uso de abono nitrogenado y potásico con aplicaciones únicas y múltiples y su efecto en el crecimiento y la calidad de la piña (*Ananas comosus* L. Merr.) Var. PR1-67. Proc. Amer. Soc. Hort. Sci. (Región Tropical). 18:104-15.

Hernández-Medina, E., 1964. Magnesium an important nutrient in pineapple production in a Bayamón sandy clay. *J. Agric. Univ. P.R.* 48(1):17-24.

Hernández-Medina, E., 1961. Pineapple response to magnesium in Puerto Rico. Proc. Amer. Soc. Hort. Sci. (Trop. Region) 5:70-5.

Marchal, J., P. Martin-Prevel, J. J. Laccoeuilhe et P. Lossois, 1970. Recherche d'un equilibre K/N dans la production de l'ananas frais au Cameroun. 11. Analyses foliaires. *Fruits* 25:87-95.

Martin-Prevel, P., 1961a. Potassium, calcium et magnesium dans la production de l'ananas en Guineé. I. Plan et déroulement de létude. *Fruits* 16:49-56.

Martin-Prevel, P., 1961b. Potassium, calcium et magnesium dans la nutrition de l'ananas en Guineé. II. Influence sur le rendiment commercialisable. *Fruits* 16:113-23.

Martin-Prevel, P., 1961c. Potassium, calcium et magnésium dans la nutrition de l'ananas en Guineé. IV. Etude de la croissance folliare. *Fruits* 16:341-51.

Py, C., J. J. Lacoeuilhe and C. Teisson, 1987. The Pineapple: Cultivation and Uses. Editions G. P. Maisonneuue and Larose, Paris. pp. 188-91.

Samuels, G., S. Alers-Alers and G. Jackson, 1958. Influence of fertilizers on yields of pineapple on a Coto clay. *J. Agric. Univ. P.R.* 42(1):12-26.

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.

Siders, C. P. and H. Y. Young, 1946. Effects of nitrogen on growth and ash constituents of *Ananas comosus* (L.) Merr. *Plant Physiol.* 21:247-70.

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.

Teiwes, G. and F. Gruneberg, 1963. Science and practice in the manuring of pineapples. Green Bulletin 3.