Further Evidence on the Need of Magnesium for Pineapple in Oxisols

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INTRODUCTION

Magnesium is one of the essential elements which play a very important role in plant metabolism (*1,2,6,7,10,14,15*)[2]. The outstandingly beneficial effect of this nutrient on pineapple growth and production in Puerto Rico, when studied in conjunction with the trace elements, has been reported in two previous papers (*8,9*). The present paper presents more data on additional magnesium studies with pineapples.

EXPERIMENTAL

Two experiments were initiated in the autumn of 1960 at two different sites in the northern part of the Island, near Arecibo. The experiments were established in Bayamón sandy clay, an acid deep lateritic soil of the coastal plain derived from limestone and typical of the pineapple growing region (*12*).

Precautions were taken to control nematodes and white grubs. To control nematodes, the soil was treated before planting with DD[3] at the rate of 30 gallons per acre. For controlling white grubs, the experimental field was treated with Aldrin at the rate of 4 pounds of the technical material per acre.

Plots of 18 x 6¾ feet, with an area of approximately 1/35th of an acre, were used. On each plot 2 rows of pineapples were planted, 12 plants to the row. At this rate a total of 8,816 plants would be needed to plant an acre of pineapple. The Red Spanish variety was used in this trial.

The experiments followed a paired-plot design with 7 treatments and 6 replications. They were established to study the effect of different quantities of magnesium sulfate ($MgSO_4 \cdot 7H_2O$) applied to the soil on yields of pineapples. Rates of magnesium sulfate used per acre ranged from 75 to 1,200 pounds. A magnesium chelate treatment at the rate of 100 pounds of this organic compound per acre was also included in the first experiment. Nutritional sprays of magnesium sulfate at the rate of 15 pounds of the

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[2] Italic numbers in parentheses refer to Literature Cited, pp. 367–8.

[3] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee, warranty, or endorsement by the Agricultural Experiment Station indicating or implying superiority to other similar products not mentioned.

salt per 100 gallons of water were also included as one of the differential treatments in the second experiment. As in the previous experiments (*8,9*) pineapple plants in all treatments received soil applications of NPK in an amount which previous experience led to believe to be adequate.

Two sets of leaf samples were taken from representative plants in the replicated plots of each treatment of one of the experiments for chemical determination of magnesium, to determine possible correlation between leaf nutrient content and yield. Leaf samples were taken when plants attained an age of 5 and 9 months. The active and largest leaf was selected for this purpose (*13*).

Flower induction in the pineapple plants in both experiments was achieved by treating the crown of the plant with acetylene, approximately 1 year after the experiments began. This consisted by pouring on the crown of the plant about 30 ml. of a solution made by allowing 2 ounces of calcium carbide to react with water in a 5-gallon closed container.

When the plants were approximately 18 months old, the fruits were harvested as is usually done in commercial pineapple fields. The criteria used in evaluating the effect of the treatments were the weight and number of marketable fruit, yields per acre, and leaf-magnesium content. Magnesium determination was ascertained by the Parks, *et al.* procedure (*11*). Percentage transmission of the nutrient was determined in a Beckman Du Spectrophotometer. The data presented in this paper underwent statistical analyses.

RESULTS

Plant Growth

Periodic observations on plants during their vegetative cycle revealed that growth made by plants supplied with magnesium was far superior to that made by plants lacking this nutrient. This superiority in growth was more striking in plants which received rates of magnesium sulfate of 300 pounds or more per acre. The magnesium-treated plants were more vigorous and greener in color than the check or untreated one. Magnesium deficiency symptoms were noticed in the leaves of the plants which did not receive magnesium applications. These symptoms were similar to those reported elsewhere (*5*).

Fruit Yields

Results of the influence of magnesium on mean fruit weight and mean yield of fruit per acre are presented in table 1. In Experiment No. 1 significantly larger fruit yields were obtained in the plots receiving magnesium sulfate at the various soil rates used per acre, as well as in those that received magnesium chelate, than in the check plots (not receiving magnesium) (treatment 7). In table 1 it is also shown that among all the magnesium-treated plants, those receiving 300 and 600 pounds of the salt per acre were the heaviest yielders. Their yields were significantly superior to those of the plants receiving the two lowest and the highest rates of magnesium

TABLE 1.—*Effect of magnesium on pineapple yields in Bayamón sandy clay at two locations, Arecibo, P. R.*[1]

Treatment identification no.	Description of treatments	Mean weight of fruit	Mean yield of fruit per acre	Outyielded at	
				.05	.01
	Experiment No. 1				
		Pounds	*Tons*		
1	$MgSO_4$, 75 lbs. per acre	3.46	14.91	—	7
2	$MgSO_4$, 150 lbs. per acre	3.61	15.55	—	7
3	$MgSO_4$, 300 lbs. per acre	3.90	16.80	1,2,5,6	1,7
4	$MgSO_4$, 600 lbs. per acre	3.97	17.10	1,25,,6	1,7
5	$MgSO_4$, 1200 lbs. per acre	3.65	15.72	—	7
6	Mg chelate, 100 lbs. per acre	3.67	15.81	—	7
7	Check, NPK only	3.18	13.70	—	—
	Experiment No. 2				
1	$MgSO_4$, 75 lbs. per acre	3.80	16.37	7	—
2	$MgSO_4$, 150 lbs. per acre	3.87	16.67	7	—
3	$MgSO_4$, 300 lbs. per acre	4.35	18.74	1,2	7
4	$MgSO_4$, 600 lbs. per acre	4.20	18.09	7	
5	$MgSO_4$, 1200 lbs. per acre	3.89	16.76	7	—
6	$MgSO_4$, sprays[2]	4.15	17.88	7	—
7	Check, NPK only	3.41	14.69	—	—

[1] NPK was applied to all treatments in a 13-3-12 fertilizer at the rate of 20 hundred weight per acre distributed in 3 applications.

[2] Plants received 3 foliar sprays at the rate of 15 pounds $MgSO_4 \cdot 7H_2O$/100 gallons H_2O.

sulfate per acre (treatments 1, 2 and 5). Also, they were significantly superior in yields to the plants supplied with magnesium chelate at the rate used.

Table 1 also shows the mean fruit weight and mean yield of fruit per acre for the crop of Experiment No. 2. The results from this experiment agree with those obtained in Experiment No. 1, except that in this case among the plants supplied with magnesium, those which received 300 pounds of magnesium sulfate per acre were the heaviest yielders, their yields being significantly superior to those of plants receiving the two lowest rates of the salt per acre. It can be seen also in table 1 that magnesium sulfate foliar sprays led to a significantly increased fruit yield per acre. The effect of the various magnesium treatments on the combined yields of both experiments is graphically shown in figure 1, together with the percentage increase in yield (black bar) in favor of plants treated with magnesium when compared to the check plants (plants not receiving magnesium).

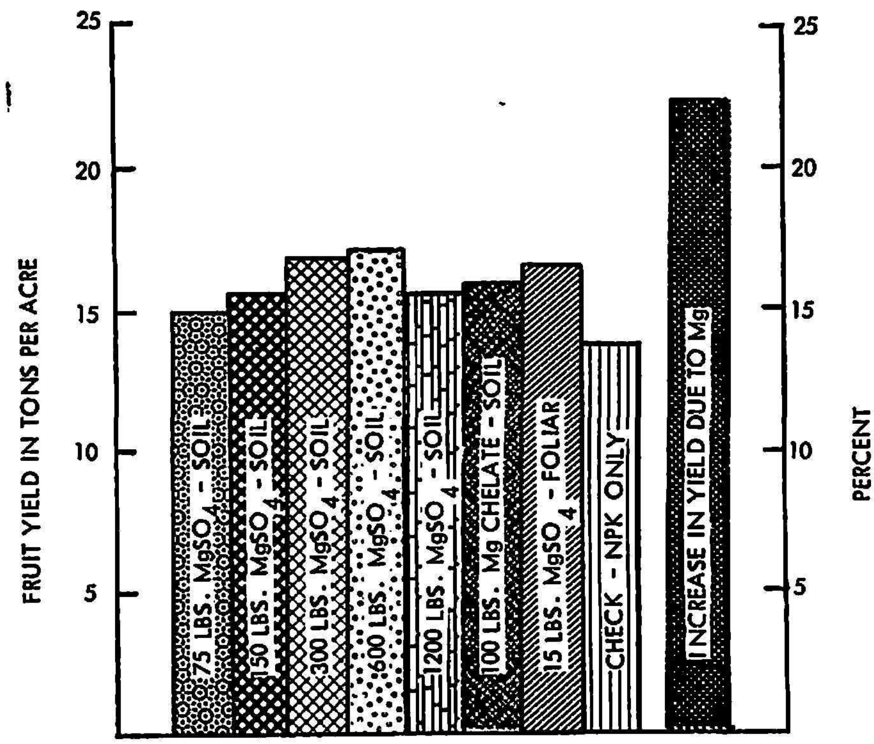

FIG. 1.—Pineapple yields as influenced by magnesium treatments when grown on a Bayamón sandy clay. Dark bar at right stands for percentage increase in yield in favor of plants supplied with magnesium as compared to plants not supplied with this nutrient.

LEAF ANALYSES AND REGRESSION STUDIES

Table 2 shows the results of magnesium determination in the active or largest leaf in 5-month and 9-month-old pineapple plants, supplied or not supplied with magnesium, together with their corresponding yields. From the data presented it appears that there is a close relationship between leaf magnesium and yield. Capó *et al.*'s mathematical equation, $Y_r = A + B$ arc-tan-percent Nu (*3*), used and explained in a previous paper (*9*), was tried once more in an effort to explain the above mentioned nutrient-yield relation, on both 5- and 9-month old plants. The equation was fitted to 42 individual values, whose means are shown by treatments on table 2. The regression equation obtained relating yield and nutrient composition of the pineapple leaf in 5-month old plants is:

$$Y_r = 33.2394 + 164.0643 \text{ (arc-tan-percent Mg)}$$

The test of significance of the fit of this equation pointed out that the regression of relative yield on arc-tan-percent Mg was highly significant, with a coefficient of determination of 28 percent.

For 9-month-old plants, the regression equation obtained relating yield and nutrient composition of the pineapple leaf is:

$$Y_r = 52.3004 + 177.3578 \text{ (arc-tan-percent Mg)}$$

In this case, the regression of relative yield on arc-tan-percent Mg was also highly significant, with a coefficient of determination of 33 percent. Thus, a somewhat better correlation between leaf nutrient content and yield was attained with 9-month-old plants. The linear relationships between arc-tangent-percent magnesium and relative yield of pineapple on 5- and 9-month-old plants are illustrated graphically in figures 2 and 3.

TABLE 2.—*Relationship between pineapple yields and leaf-magnesium content at 2 stages of plant growth, Experiment No. 2*

Treatment No.	Description of treatments	Mean yield fruit per acre	Leaf Mg content	
			5-month-old plants	9-month-old plants
		Tons	*Percent*	*Percent*
1	$MgSO_4$, 75 lbs. per acre	16.37	0.29	0.15
2	$MgSO_4$, 150 lbs. per acre	16.67	.30	.16
3	$MgSO_4$, 300 lbs. per acre	18.74	.32	.20
4	$MgSO_4$, 600 lbs. per acre	18.09	.32	.19
5	$MgSO_4$, 1200 lbs. per acre	16.76	.35	.19
6	$MgSO_4$, sprays	17.88	.32	.17
7	Check, NPK only	14.69	.24	.13

MAGNESIUM-PINEAPPLE YIELD RELATION

Capó (*4*) has shown that the relation between the fertilizer applied and the crop yield can be well explained by the following new fertilizer-yield-equation:

$$Y = \frac{A}{1 + B(X - C)^2}$$

where Y is the crop yield, X is the quantity of fertilizer applied, and A, B and C are parameters. Parameter A is the maximum crop yield. The equation is symmetrical and has its maximum value at $X = C$. That is, C is the level at which the fertilizer nutrient under study would be in best

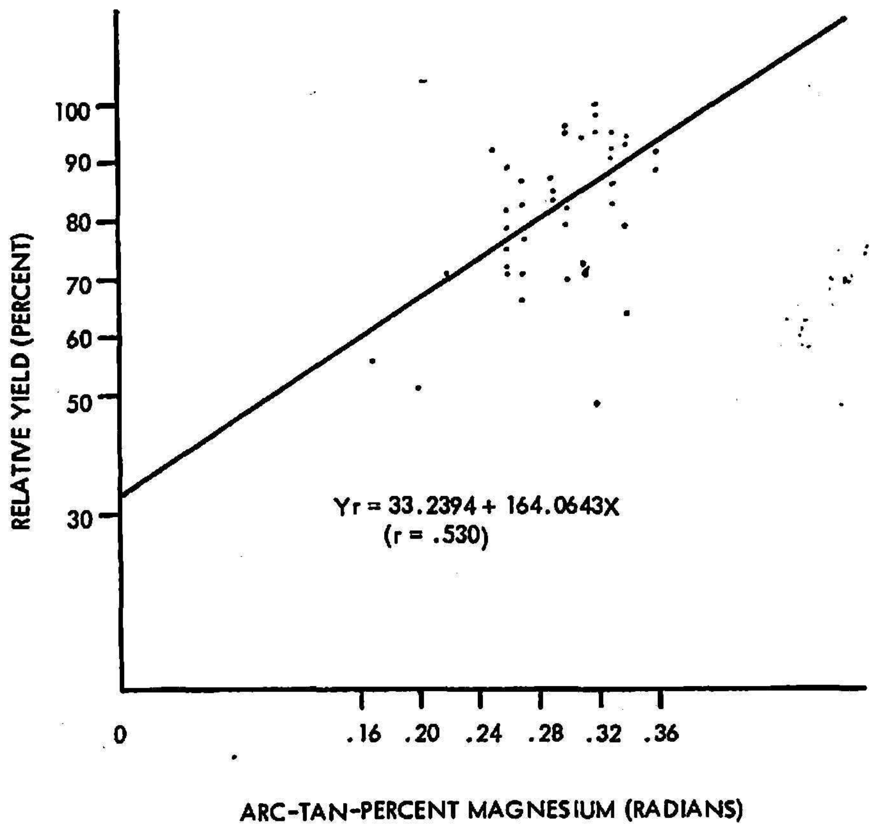

FIG. 2.—Regression of relative yield of pineapple on arc-tangent-percent magnesium as determined on 5-month old plants.

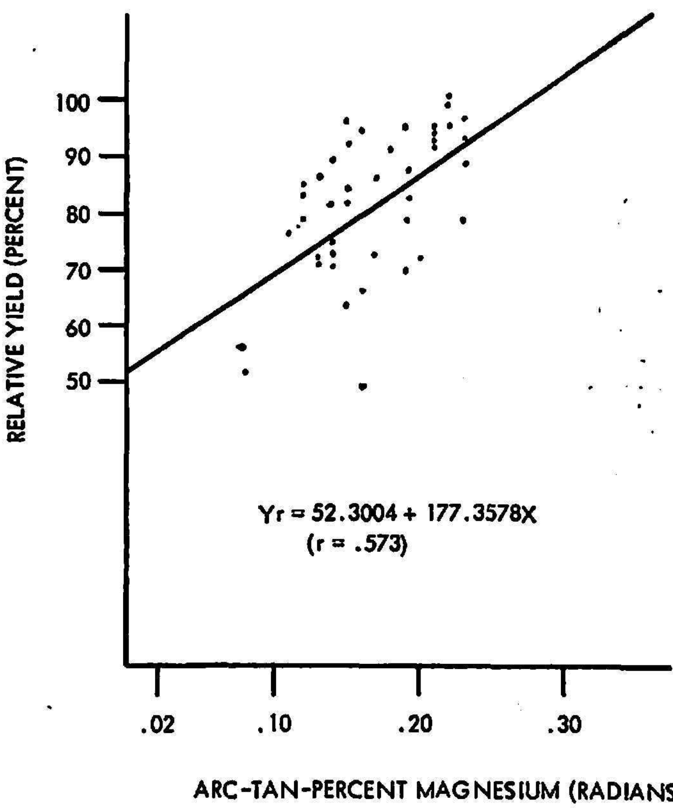

FIG. 3.—Regression of relative yield of pineapple on arc-tangent-percent magnesium as determined on 9-month old plants.

balance with the levels of all the other growth factors. The equation was fitted to the yield data obtained in the two pineapple experiments considered in this paper. Table 3 and figures 4 and 5 show how precisely the equation fits the observed pineapple yield data. The equation fitted the yield data very well (r = 0.953 and 0.831) and corroborates previous findings with sugarcane and corn yield data (*4*) that merits its use in similar fertilizer studies as a first step to determine eventually the optimum quantity of a fertilizer to apply to a crop to bring about a maximum net return to the grower.

Capó's new fertilizer yield equation was substituted for Y (crop yield)

TABLE 3.—*Yield in tons of pineapple per acre*

Treatment No.	Units of $MgSO_4$[1]	Experiment No. 1		Experiment No. 2	
		Y[2]	Y'[3]	Y	Y'
1	0.000	13.70	14.23	14.69	15.55
2	.075	14.91	14.79	16.37	16.04
3	.150	15.55	15.33	16.67	16.49
4	.300	16.80	16.29	18.74	17.27
5	.600	17.10	17.41	18.09	18.10
6	1.200	15.72	15.54	16.79	16.31

[1] 1 unit of $MgSO_4 \cdot 7H_2O$ = 1,000 pounds $MgSO_4 \cdot 7H_2O$ per acre.
[2] Y = Observed yield.
[3] Y' = Calculated yield.

Equation for Mg (Expt. No 1): $Y = \frac{17.48}{1 + 0.48\ (X - .69)^2}$

Equation for Mg (Expt. No. 2): $Y = \frac{18.12}{1 + 0.38\ (X - .66)^2}$

in the profit equation mentioned by Spillman (*16*). The equation was used to determine the maximum economic benefit that the pineapple grower may obtain based on the experimental data gathered.

The substituted profit-equation is as follows:

$$P = \frac{A}{1 + B(X - C)^2}(V - H - M) - XQ - J,$$

where: V is the market-value of 1 unit (1 ton) of pineapples while H and M represent respectively the cost of harvesting and marketing one unit of the crop, Q is the cost of 1 unit (1000 pounds) of magnesium sulfate applied per acre and J is the value of the fixed costs incurred other than the use of the magnesium sulfate fertilizer.

The value of X that corresponds to a maximum P (profit per unit area)

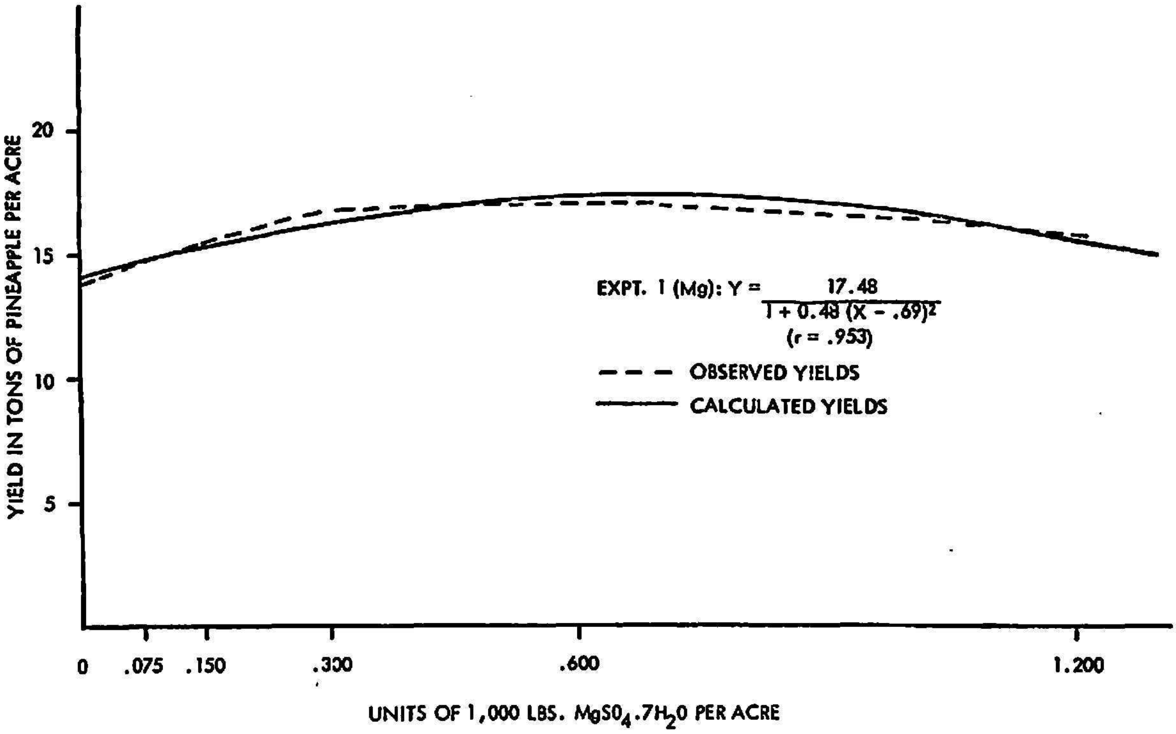

FIG. 4.—Magnesium sulfate-pineapple relation.

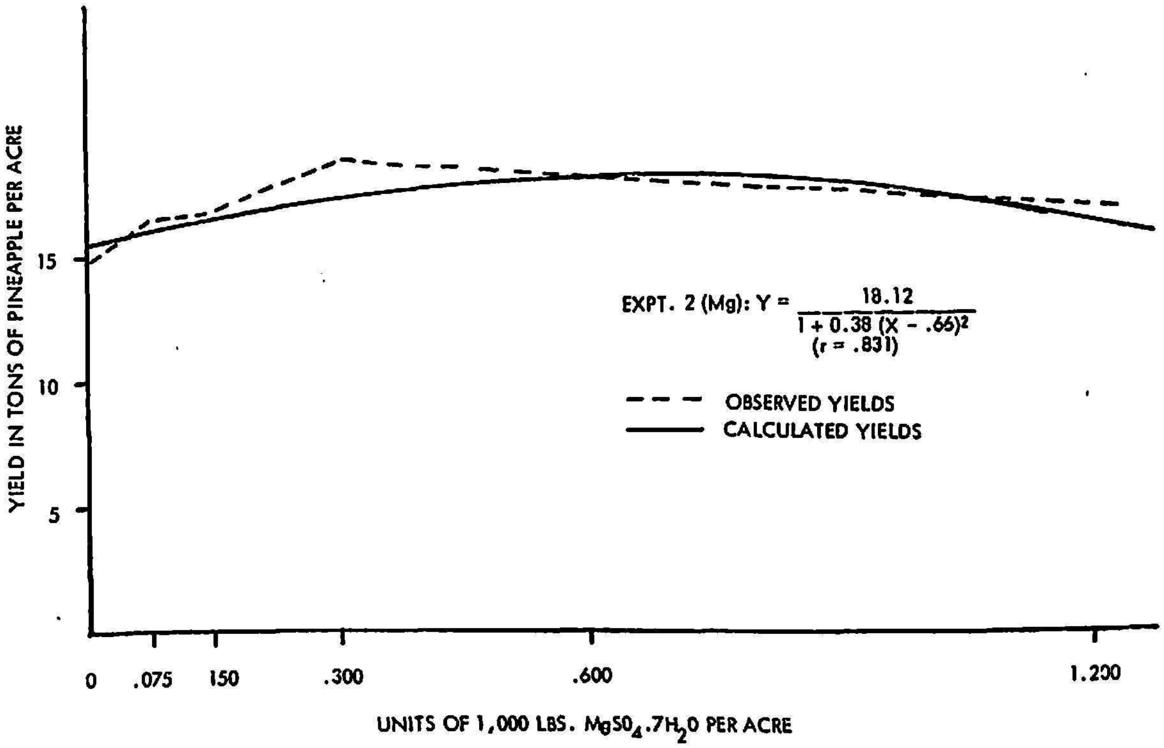

FIG. 5.—Magnesium sulfate-pineapple relation.

value was found to be 572 pounds of magnesium sulfate per acre in both experiments.

Substituting the corresponding figures for the symbols in the equations for both pineapple experiments, we have the following:

$$\text{Experiment 1 } P = \frac{17.48}{1 + 0.48(.572 - .69)^2}(\$23.00) - (.572)(\$45.00) = \$373.64$$

$$\text{Experiment 2 } P = \frac{18.12}{1 + 0.38(.572 - .66)^2}(\$23.00) - (.572)(\$45.00) = \$389.80$$

Thus, it may be concluded from the evidence presented that under the conditions in which the experiments were performed, the pineapple grower would obtain a return of more than $300 per acre over the cost of the 572 pounds of magnesium sulfate applied per acre.

DISCUSSION AND CONCLUSION

The results that have been presented in this paper point once more to the need of incorporating magnesium in the fertilizer mix or using it as a nutritional spray so as to favor plant growth and development, and thus increase yields of pineapples on the acid Bayamón sandy clay, the most widely used soil type for commercial pineapple growing in Puerto Rico.

It was of interest to find out in this study that significant increases in pineapple yields, over 1 ton fruit per acre, were obtained even when using as low a rate as 75 pounds of magnesium sulfate per acre. However, maximum increases in yields, over 3 tons of fruit per acre, were obtained with either 300 or 600 pounds of the salt per acre. The yields obtained with the 300- and 600-pound magnesium sulfate treatments in the first experiment and the yield obtained with the 300 pounds of magnesium sulfate in the second experiment were significantly superior to those obtained when the two lowest rates of magnesium sulfate were used, which clearly indicates that more magnesium was needed for highest yields. Since it was found that there was no significant difference in yield between 300 and 600 pounds of magnesium sulfate applications in both experiments reported, it may be concluded, that, as a soil application, 300 pounds of the salt per acre is enough to produce good yields of pineapples in the lateritic Bayamón clay.

As was reported in a previous paper (*9*), and confirmed in this study, magnesium foliar sprays were effective in increasing yields of pineapples, with the advantage that much less magnesium is needed as a nutritional spray. Therefore, it is once more concluded that magnesium should be used either as a soil application or as a foliar spray, as may be more convenient to the grower, so as to increase production and thus obtain a higher net income per acre.

As to the correlation analyses between leaf magnesium content and relative yields, it may be also concluded that the percentage magnesium content of the pineapple leaf can be used as an index to predict the relative yield of pineapples.

It was of interest to find out the high precision with which the new fertilizer-yield equation developed by Capó fitted the observed pineapple yield data, corroborating previous findings with sugarcane and corn.

The reader will certainly appreciate also the usefulness of the fertilizer-yield equation in the economic approach that has been discussed, as an example of the possibility of benefiting from the potential economical implications of experimental data of the type presented.

SUMMARY

Two pineapple experiments were established in Bayamón sandy clay, the most extensively used acid lateritic soil for pineapple growing in Puerto Rico. The experiments were conducted to study the effect of different amounts of magnesium sulfate applied to the soil on yields of pineapples. The influence of magnesium chelate and of foliar sprays on pineapple yields was also studied. The results obtained are briefly summarized as follows:

1. Pineapple plants supplied with magnesium were more vigorous and greener in color than similar plants not receiving this nutrient.
2. Significant heavier fruit yields were obtained from pineapple plants receiving magnesium sulfate at the various rates used as a soil application than from the pineapple plants not receiving this nutrient.
3. Magnesium chelate and magnesium sulfate foliar sprays were also responsible for significantly increasing fruit yields per acre.
4. Highest fruit yields were associated with high nutrient contents of magnesium in the leaves.
5. Highly significant correlations were found between pineapple relative yields and leaf magnesium content at two crop ages.
6. Results indicate that magnesium content of 5- and 9-month old pineapple plants can be used to predict relative crop yields.
7. Capo's new fertilizer-yield equation was used to describe the relation between the application of magnesium sulfate and the yields of pineapples. The equation fitted closely such fertilizer-yield data.
8. The optimum economic magnesium sulfate application for the two pineapple experiments discussed was determined.

RESUMEN

Este trabajo presenta datos obtenidos de dos experimentos sobre el rendimiento de la piña llevados a cabo en un suelo laterítico ácido del tipo Bayamón arcilloarenoso, que es el que se usa más extensamente para la siembra de esta cosecha en Puerto Rico. Los experimentos se hicieron

para determinar la influencia de distintas cantidades de sulfato de magnesio, aplicadas al suelo, en el rendimiento de fruta por acre. También se estudiaron el efecto del quelato de magnesio y las aspersiones foliares con magnesio en cuanto al rendimiento de fruta. Los resultados obtenidos se resumen a continuación:

1. Las plantas de piña tratadas con magnesio eran más vigorosas y más verdes que las que no se trataron con dicho nutrimento.
2. Las plantas a las cuales se les aplicó magnesio en distintas cantidades produjeron rendimientos significativamente mayores que las que no lo recibieron.
3. El quelato de magnesio y las aspersiones foliares con magnesio aumentaron significativamente los rendimientos.
4. Los rendimientos máximos estuvieron asociados con los niveles altos de magnesio en la hoja.
5. Se obtuvieron correlaciones altamente significativas entre el rendimiento ralativo y el contenido de magnesio en las hojas, a dos edades específicas en que se cosecharon las plantas.
6. Los resultados obtenidos indican que el contenido de magnesio de las hojas a los 5 y 9 meses de edad, puede usarse como un índice para predecir los rendimientos relativos de la piña.
7. Se utilizó la nueva ecuación abono-rendimiento de Capó para describir la relación entre la aplicación de sulfato de magnesio y el rendimiento. Los resultados indicaron que la ecuación abono-rendimiento describió satisfactoriamente la relación que se menciona.
8. Se determinó la cantidad de sulfato de magnesio más adecuada desde un punto de vista económico, en el caso de los dos experimentos informados.

LITERATURE CITED

1. Bear, F. E., Prince A. L., Toth, S. J., and Purvis, E. R., Magnesium in plant and soils, Bul. 760, N. J. Agr. Expt. Sta., 1951.
2. Boynton, D., and Erickson, A. L., A response of seedling cacao under nursery conditions, to Mg and Ca, 5th Inter. Amer. Cacao Conf. Turrialba, 1954.
3. Capó, B. G., and Samuels, G., The development of a mathematical concept to interpret the relation between plant composition and crop yield, *J. Agr. Univ. P. R. 37* (4): 249–64, 1953.
4. ——, Additional evidence on the applicability of the new fertilizer-yield relation, *J. Agr. Univ. P. R. 51* (2): 97–120, 7967.
5. Cibes-Viadé, H. R., and Samuels, G., Mineral deficiency symptoms displayed by Red Spanish pineapple plants under controlled conditions, Tech. Paper 25, Agr. Expt. Sta., Univ. P. R. 1958.
6. Fudge, B. R., Magnesium deficiency in relation to yield and chemical composition of seedy and commercially seedless varieties of grapefruit, *Proc. Fla. State Hort. Soc. 51:* 34–43, 1938.
7. Soto, Y., Yatazawa, M., and Yamamoto, M., Studies in the magnesium deficiency

in crops (Part 1), Nutritional damage in field grown wheat and rape, *Sci. Rpt. Shiga Agr. College 5:* 1–14, 1953.
8. Hernández-Medina, E., Pineapple response to magnesium in Puerto Rico, *Proc. Amer. Soc. Hort. Sci.* (Caribbean Region) *5:* 70–5, 1961.
9. ——, Magnesium, an important nutrient in pineapple production in a Bayamón sandy clay, *J. Agr. Univ. P. R. 48* (1): 17–24, 1964.
10. Martin-Prevel, P., Potassium, calcium and magnesium in the nutrition of pineapples in Guinea, II. Effect on commercial yield, *Fruit d'Outre Mer. 16:* 113–23, 1961.
11. Parks, R. Q., Hood S. L., Hurwitz, Ch., and Ellis, H. G., Quantitative chemical microdeterminations of 12 elements in plant tissue, *Ind. and Eng. Chem. Anal. Ed. 15* (8): 527, 1943.
12. Roberts, R. C., Soil Survey, Puerto Rico, USDA., Bureau of Plant Industry in cooperation with the Univ. P.R., Agr. Expt. Sta., Series 1936, (8), Jan. 1942.
13. Sideris, C. P., Krauss, B. H., and Young, H. Y., Assimilation of ammonium and nitrate by pineapple plants grown in nutrient solutions and its effect on nitrogenous and carbohydrate constituents, *Plant Physiol. 13:* 489–527, 1938.
14. Robinson, Jr., B. D., A note on magnesium unbalance symptoms in avocado pear trees, *East African Agr. and Forestry J. 27:* 47–8, 1961.
15. Smith, P. F., Reuther, W., and Scudder, Jr., G. K., Effect of differential supplies of nitrogen, potassium, and magnesium on growth and fruiting of young Valencia orange trees in sand culture, *Proc. Amer. Soc. Hort. Sci. 61:* 38–48, 1953.
16. Spillman, W. J., The law of diminishing increment, the law of diminishing returns, part I, World Book Co., Chicago, Ill., 1924.