Effectiveness of magnesium source and rate in the fertilization of banana grown on an Ultisol in Puerto Rico[1,2]

Héber Irizarry[3], *Ricardo Goenaga*[4] *and Ulises Chardón*[5]

J. Agric. Univ. P. R. 84(1-2):35-45 (2000)

ABSTRACT

A 33-month study was conducted to determine the response of banana grown on a clayey, mixed isohyperthermic Aquic Haplohumults to four sources and five rates of magnesium. The sources of Mg were dolomitic limestone (10.4% Mg), magnesium oxide (Fert-O-Mag, 51.5% Mg), and magnesium sulfate (Granusol, 45.0% Mg; Kieserite, 17.5% Mg). The Mg rates were 0, 45, 90, 135 and 180 kg/ha/crop. We obtained data of marketable bunch weight, Mg concentration in the third youngest leaf and the exchangeable Mg at two soil depths for two ratoon crops, R1 and R2. Results showed that sources of Mg had no significant effect on the three attributes studied. The rate × ratoon crop interaction, however, was highly significant ($P \leq 0.01$) for bunch weight, leaf Mg concentration and the soil exchangeable Mg. Bunch weight, leaf Mg concentration and soil exchangeable Mg increased linearly with the amount of Mg applied in the first and second ratoons (R1 and R2). The highest bunch weight (28.4 kg) and the highest leaf Mg concentration (2 g/kg) were obtained with the application of 180 kg/ha in R2. This leaf Mg concentration, however, was considered sub-optimal for banana plants approaching the flowering stage and grown on highly weathered soils. The highest application rate of 180 kg/ha also increased the soil exchangeable Mg to its highest level of 1.6 cmol(+)/kg in R1 at a soil depth of 0 to 20 cm. Leaching and nutrient imbalance were factors that limited Mg availability. Although the banana response to Mg fertilization was linear, it was concluded that any further increase above the existing recommended rate of 55 kg/ha/year would increase production costs considerably unless a cheaper source of Mg is used.

Key words: Banana, fertilization, magnesium salt, leaching, weathered soil

RESUMEN

Efectividad de fuentes y cantidades de magnesio en la fertilización del guineo sembrado en un suelo Ultisol de Puerto Rico

[1]Manuscript submitted to Editorial Board 23 April 1999.

[2]This paper covers work carried out cooperatively between the Agricultural Research Service-USDA and the Agricultural Experiment Station, University of Puerto Rico. The authors are grateful to Nicolás Díaz and Javier Fuentes, Agricultural Research Technicians, for their assistance in carrying out the experiment.

[3]Research Horticulturist, Tropical Agriculture Research Station, 2200 Pedro Albizu Campos Ave., Suite 201, Mayagüez, P.R. 00680-5470.

[4]Research Plant Physiologist, Tropical Agriculture Research Station, Mayagüez, P.R.

[5]Chemist, Tropical Agriculture Research Station, Mayagüez, P.R.

Se determinó la respuesta del guineo, sembrado en un suelo altamente meteorizado, a cuatro fuentes y cinco cantidades de magnesio durante un período de 33 meses. Las fuentes de Mg fueron dolomita-calcítica (10.4% Mg), óxido de magnesio (Fert-O-Mag, 51.5% Mg) y sulfato de Mg (Granusol, 45.0% Mg; Kieserite, 17.5% Mg). Las cantidades de Mg aplicadas fueron 0, 45, 90, 135 y 180 kg/ha/cosecha. Se recopilaron datos de peso mercadeable del racimo, concentración de Mg en la tercera hoja más joven de las plantas y el Mg intercambiable a dos profundidades en el suelo para dos cosechas, R1 y R2. Los resultados demostraron que las fuentes de Mg no tuvieron efectos significativos sobre los tres atributos observados. Las cantidades de Mg aplicadas afectaron significativamente el peso del racimo, la concentración del nutrimento en la hoja y el Mg intercambiable pero la magnitud del efecto dependió de la cosecha. El peso mayor del racimo (28.4 kg) y la concentración más alta de Mg en la hoja (2 g/kg) se obtuvieron con la aplicación de 180 kg/ha de Mg en la cosecha R2. Sin embargo, la concentración de 2 g/kg de Mg en la hoja es considerada baja para la planta de guineo próxima a la floración y sembrada en un suelo altamente meteorizado. La aplicación de 180 kg/ha de Mg también aumentó el Mg intercambiable en el suelo al nivel más alto de 1.6 cmol(+)/kg en la cosecha R1 y a la profundidad de 0 a 20 cm. La lixiviación y el desbalance nutricional fueron factores que afectaron la disponibilidad de magnesio. Aunque la respuesta del guineo a la fertilización con Mg fue lineal, se concluyó que un aumento sobre la recomendación existente de 55 kg/ha/año del nutriente aumentará los costos de producción considerablemente a menos que se utilice una fuente más barata de magnesio.

INTRODUCTION

Banana and plantain (*Musa* spp.) are extensively cultivated in the tropics on highly weathered Ultisols and Oxisols. These soils are characterized by their low natural fertility, mainly in respect to P, K, Ca and Mg, and the presence of potentially toxic levels of Al and Mn (Sánchez, 1976). Even with these constraints, traditional crops can produce economic yields if these soils are properly managed.

A magnesium concentration of 3 g/kg in the lamina of the third youngest leaf of 7-month-old banana plants grown on an Ultisol has been considered near-optimum, and applying Mg fertilizer when foliar levels are below this concentration has been found to increase yields (Irizarry et al., 1988; 1990). A typical Mg-deficiency symptom in young banana plants grown on highly weathered soils is the presence of a pale-yellow streak extending from near the leaf-lamina margin toward the mid-rib in older leaves. We have also observed that after flowering, Mg-deficient banana plants attain leaf senescence at a faster pace, thus affecting fruit filling and consequently yield.

Magnesium uptake in banana grown on a typical Ultisol has been determined to be 55 kg/ha/crop (Irizarry et al., 1988). However, banana planted on a similar soil type for three successive years responded to the application of 275 kg/ha/year of Mg from dolomitic limestone the first year and magnesium oxide (Fert-O-Mag) in subsequent years

(Irizarry et al., 1990). Likewise, in this study the optimum economic application rate of Mg was found to be between 112 to 168 kg/ha/year. Since the Mg-supplying power of some of the local upland Ultisols may be as low as 35 kg/ha/year (Vicente-Chandler et al., 1974), about 55 kg/ha/year of Mg is recommended to supplement the N-P-K fertilization in banana grown on highly weathered soils (Agric. Exp. Sta., 1995).

Magnesium uptake from the soil may depend on the plant root surface area, the soil cation exchange capacity, and the competition and/or concentration of other cations in the soil solution (Ritchey and Irizarry, 1993). Since highly weathered soils are usually intensively limed, "Mg-fixation," caused by the coprecipitation of Mg with Al upon liming, may play a major role in limiting the availability of Mg in crops grown on these soils (Myers et al., 1988; Martínez et al., 1994; 1996). Low Mg uptake in banana grown on Ultisols and Oxisols is worsened by the high potassium requirement of the crop (Irizarry et al., 1988), and the antagonistic effect between K and Mg (Lahav, 1974; Murray, 1960; Soto, 1985).

The most commonly used sources of Mg-fertilizer are magnesium sulfate (Epsom salts and Kieserite), magnesium oxide (Fert-O-Mag) and potassium-magnesium sulfate (Sul-Po-Mag).

This study was undertaken to determine the effect of sources and rates of commercial Mg-supplying fertilizers in banana grown on a highly weathered soil, and to trace the vertical and lateral movement of Mg in the soil profile.

MATERIALS AND METHODS

An experiment was conducted between November 1993 and July 1996 at the Corozal Agricultural Research Station of the University of Puerto Rico. The site is located in the north-central humid region (18°20'N, 66°18'E; elevation 195 m). The mean monthly minimum and maximum temperatures during the experimental period were 19.4 and 30.5° C, respectively. Mean annual rainfall was 1,645 mm; Class A pan evaporation, 1,448 mm. The experiment was conducted under rain fed conditions, and moisture deficits occurred during the months of February, March, April, June, July and December.

The soil is a typical Ultisol (clayey, mixed isohyperthermic Aquic Haplohumults). Relevant chemical properties in the top 20-cm soil layer were pH, 4.8; extractable P, 3.7 mg/kg (Bray method 2); and 0.6, 5.4, 0.4 and 1.4 cmol(+)/kg of exchangeable K, Ca, Mg and Al, respectively.

Corms of the Grand Nain (*Musa* AAA) cultivar weighing about 2 kg were planted 1.8 by 2.4 m apart at about 2,240 plants per hectare. Each plot consisted of four experimental plants surrounded by guard rows *and ditches to prevent the overlapping of fertilizer treatment effects.* At planting, plants were fertilized with 11 g of P as triple superphosphate placed under the propagating corms.

Four sources of Mg and five application rates were arranged in a randomized complete block design with six replications. The sources were dolomitic limestone (10.4% Mg), magnesium oxide (Fert-O-Mag, 51.5% Mg) and magnesium sulfate (Granusol, 45.0% Mg; Kieserite, 17.5% Mg). Both Fert-O-Mag and Granusol are products manufactured by American Minerals, P.O. Box 2005, Dunedin, FL 34697. Kieserite is manufactured by Kali und Salz-Agricultural Advisory Department, P.O. Box 102029.34111 Kassel, Germany, and the dolomitic limestone was obtained from Ochoa Fertilizer Co., Inc., P.O. Box 363128, San Juan, PR *00936-3128.*[6] *The five rates of Mg were 0, 45, 90, 135 and 180 kg/ha/crop.* Fert-O-Mag and Granusol were mixed and applied with a 10-2-30 (N, P_2O_5, K_2O) fertilizer. The complete fertilizer, without Mg and with the Mg supplements, was applied at the rate of about 635 kg/ha/application three months after planting and every three months thereafter. The Kieserite and an additional treatment of Granusol were applied alone between the complete fertilizer applications. The fertilizer was applied in a circular band about 15 cm from the base of the plants. In the dolomitic limestone treatments the total Mg that corresponded to a 33-month cropping was incorporated into the top 20-cm soil layer before planting. The addition of about 5,170 kg/ha of dolomitic limestone to supply the Mg needed at the maximum rate increased the soil pH to 5.3. Therefore, the soil pH in other treatments was adjusted to near the same level with the incorporation of ground calcium carbonate. No additional liming was necessary because local Ultisols and Oxisols contain essentially no exchangeable Al above a pH of 5.0 (Abruña et al., 1970). Weeds, nematodes, the corm weevil, and yellow Sigatoka were controlled by following published recommendations (Agric. Exp. Sta., 1995).

A desuckering program was implemented about four months after planting to maintain the mother plant and two ratoon suckers in each stump. All plant residues generated by this and other agronomic practices were removed from the plots. Leaf tissue and soil samples were taken before the complete fertilizer applications about 6, 9, 12, 15, 24 and 27 months after planting. In each plot, tissue from the middle of the lamina of the third youngest leaf of four plants was composited, oven-dried, and ground to pass through a 20-mesh screen. Levels of K,

[6]Trade names in this publication are used only to provide specific information. Mention of a trade name or manufacturer does not constitute a warranty of equipment or materials by the USDA-ARS or the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

Ca and Mg were determined by the dry-ashing method and atomic absorption spectroscopy. One soil core was taken on the fertilizer band of each experimental plant, and three additional cores were obtained about 1 m away from the plants toward the middle of the plot at 0 to 20- and 20 to 40-cm soil depths. The samples taken from the plant's fertilizer band and those taken from the middle of the plot were composited separately, air-dried, ground, sieved through a 10-mesh screen and analyzed for pH, P, K, Ca, Mg, and Al. Soil reaction was measured with an epoxy combined electrode pH meter using a 1:2 soil-to-water ratio. Phosphorus was extracted by using Bray method 2 and determined colorimetrically; K, Ca and Mg were extracted with neutral 1M NH_4OAC, and the exchangeable Al with 1N KCl. All cations were determined by atomic absorption spectroscopy.

The vertical movement of the Mg applied on the fertilizer band was determined by subtracting from the various sources and rates the amount of Mg present in the 0 Mg treatment at 0 to 20- and 20 to 40-cm soil depths. The difference detected at the 20 to 40-cm soil depths was considered leached Mg from the surface application. Lateral movement of Mg was estimated in a similar manner, but using the soil sample data obtained in the middle of the plots at the two soil depths.

Two weeks after flowering, the false hand and the male floral bud were removed from the immature bunch, which was immediately covered with a polyethylene bag. Bunches were harvested about 112 days after flowering. The bunch marketable weight (bunch weight minus rachis weight), and leaf tissue and soil sample data obtained from two ratoon crops were statistically analyzed by using the ANOVA procedure, and regression analysis (SAS, 1987). Only coefficients significant at $P \leq 0.01$ were retained in the model.

RESULTS AND DISCUSSION

The plant crop was seriously affected by dry weather conditions from December 1993 through September 1994. During this period, the evaporation was twice the amount of rainfall recorded, 1,382 and 682 mm, respectively. Since this dry condition caused some abortion of bunches, data for the plant crop were discarded. Therefore, the results and discussion presented herein include only two ratoon crops, R1 and R2.

There was no significant effect of source of Mg, source × rate and source × ratoon crop interactions on marketable bunch weight, leaf Mg concentration or soil exchangeable Mg (analysis of variance not shown). Rate of Mg and rate × ratoon crop interaction were highly significant ($P \leq 0.01$) for the bunch, plant, and soil attributes studied. Therefore, results are reported for each Mg rate-crop combination.

Marketable bunch weight was linearly related to the amount of Mg applied in each ratoon crop (Figure 1a). The greatest response to applied Mg was obtained in the R2 crop, which produced bunches weighing 28.4 kg when fertilized with180 kg/ha. This rate, however, increased bunch weight to only 21.8 kg in R1. As compared to the 0 Mg treatment, the application of 180 kg/ha/crop of Mg resulted in a bunch weight increase of 16.3% in R1 and 12.3% in R2. Overall, bunch weight increase for each rate of Mg in R2 was about 25% higher than in R1. However, other factors such as the tendency of the banana plant to produce heavier bunches in older ratoons and changes in rainfall patterns may also have influenced the increase in yield obtained in R2.

The plant tissue and soil sampling data that represent R1 and R2 were obtained 15 and 27 months after planting, respectively. At that time the ratoon plants were about two months away from reaching the flowering peak.

Leaf Mg concentration significantly increased with increments in rates of Mg in both ratoon crops (Figure 1b), reaching approximately 2 g/kg in the R2 crop when fertilized with 180 kg/ha of Mg. However, a Mg concentration of 2 g/kg has been reported to be sub-optimal for commercial banana production (Soto, 1985). A 7-month-old banana plant grown on highly weathered Ultisols and Oxisols is considered well nourished if the Mg content in the third uppermost leaf is about 3 g/kg (Irizarry et al., 1988). We would have needed to apply in the R2 crop about 375 kg/ha of Mg to attain in the leaf the recommended concentration of 3 g/kg. This rate would have theoretically increased bunch weight to 32.2 kg. The current commercial source of Mg used by local fertilizer companies is Gramag (45.0% Mg), the sale price of which is about $634.50 per 1,000 kg or $1.41 per 1 kg of Mg. Therefore, it costs the growers about $77.55 to apply the recommended rate of 55 kg/ha/year to banana grown on highly weathered soils. If the recommended Mg rate is plotted in the graph of Figure 1a, the expected bunch weight is 19.3 and 26.0 kg for R1 and R2, respectively. Before hurricane "Georges," the farm gate price for high quality banana fruit averaged $7.00 per box of 18.1 kg. On the basis of this economic analysis, we concluded that any further increase in Mg fertilization above the existing recommended rate of 55 kg/ha/year would increase production costs considerably unless a cheaper source of Mg is found. There are deposits of Mg-bearing carbamate rocks in Puerto Rico containing dolomitic-limestone with up to 11.2% Mg (Vázquez et al., 1957). This product could be intensively used as a slow release cheaper Mg source for liming highly weathered soils.

Increments in rates of Mg from 0 to 180 kg/ha significantly increased the exchangeable Mg at two soil depths in each ratoon crop

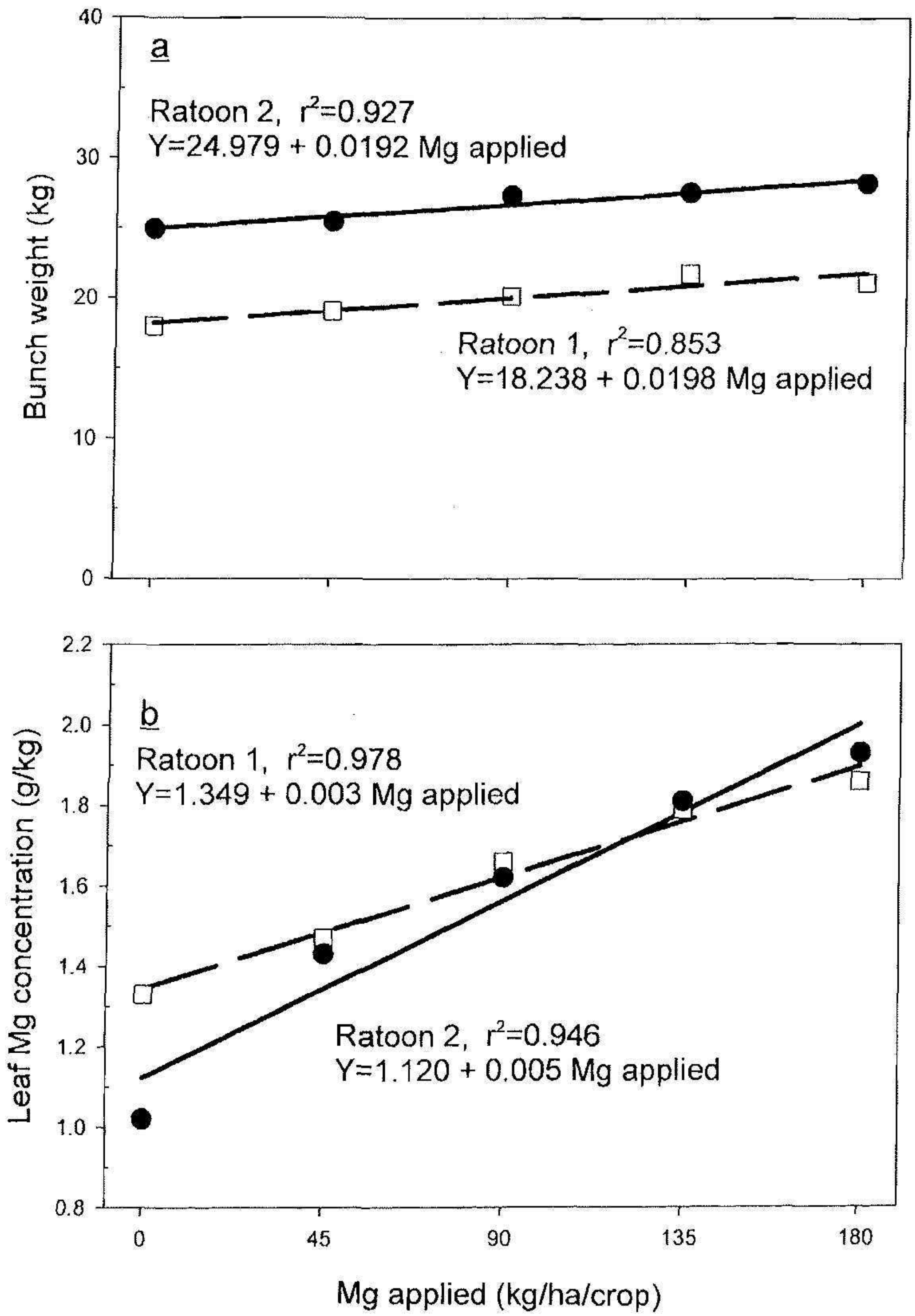

FIGURE 1. Bunch weight (a) and leaf magnesium concentration (b) in two banana ratoons (R1 and R2) grown on an Ultisol fertilized with five rates of magnesium.

(Figure 2). In the R1 crop the rate of 180 kg/ha increased the exchangeable Mg from 0.5 cmol(+)/kg with 0 Mg to the maximum of 1.6 cmol(+)/kg at a soil depth of 0 to 20 cm. This treatment increased the exchangeable Mg to 1.0 cmol(+)/kg at the lower soil depth of 20 to 40 cm. The high amount of exchangeable Mg detected in R1 at both soil depths may be caused by residual soil Mg from fertilizer not used by the plant crop, which was discarded and pruned before harvest because of a severe drought. In the R2 crop the highest rate increased the exchangeable Mg to 1.2 cmol(+)/kg at the 0- to 20-cm depth and to 0.6 cmol(+)/kg at the lower depth. Regardless of the soil depth, the greatest increase in exchangeable Mg was obtained in R1 crop at all rates. However, the presence of a higher amount of exchangeable Mg failed to increase the bunch weight and leaf Mg concentration in R1 plants (Figures 1a, 1b).

Leaching of Mg below the 20-cm soil depth was related to the rates of Mg applied in both ratoon crops (Figure 2). With the application of the highest rate, about 33 and 25% of the exchangeable Mg in excess of the 0 rate was located below the 20-cm soil depth in R1 and R2, respectively. Leaching has been identified as a major cause of nutrient losses, particularly in soil with low cation exchangeable capacity (Godefroy et al., 1975). Banana, like plantain, has a shallow root system concentrating most of its roots in the top 20 cm of soil (Summerville, 1939; Irizarry et al., 1981). Although the experiment was planted on a 20% slope, there was no evidence of Mg surface runoff or underground lateral movement. The exchangeable Mg detected in the soil samples taken in the middle of the Mg-fertilized plots was always similar to or somewhat lower than the values obtained from the 0 Mg plots at both soil depths (data not shown). This finding may be explained by the limited run-off allowed with the digging of ditches 4.9 m apart against the slope.

Increments in Mg rates significantly reduced the K/Mg and Ca/Mg ratios in both ratoon crops at the two soil depths (Figure 3). However, the maximum rate of 180 kg/ha/crop was not sufficient to reduce these ratios to acceptable levels. Soils for banana production are considered well balanced if K/Mg ratios are between 0.2 and 0.5 (García et al., 1978). Higher ratios are associated with nutrient imbalance and a Mg deficiency in plants. A Ca/Mg ratio in the range of 3.4 to 4.0 was considered satisfactory for intensive banana production in Costa Rica (López, 1983). The high K/Mg ratios obtained in our experiment were probably influenced by the amount of K applied as fertilizer, about 527 kg/ha/crop. However, a banana crop grown on highly weathered soils demands high quantities of K, about 710 kg/ha/crop, about 37% of which is removed from the field at harvest (Irizarry et al., 1988).

Because of the intensive nitrogen fertilization with a residual acid compound such as ammonium sulfate, the initial soil pH in the fertil-

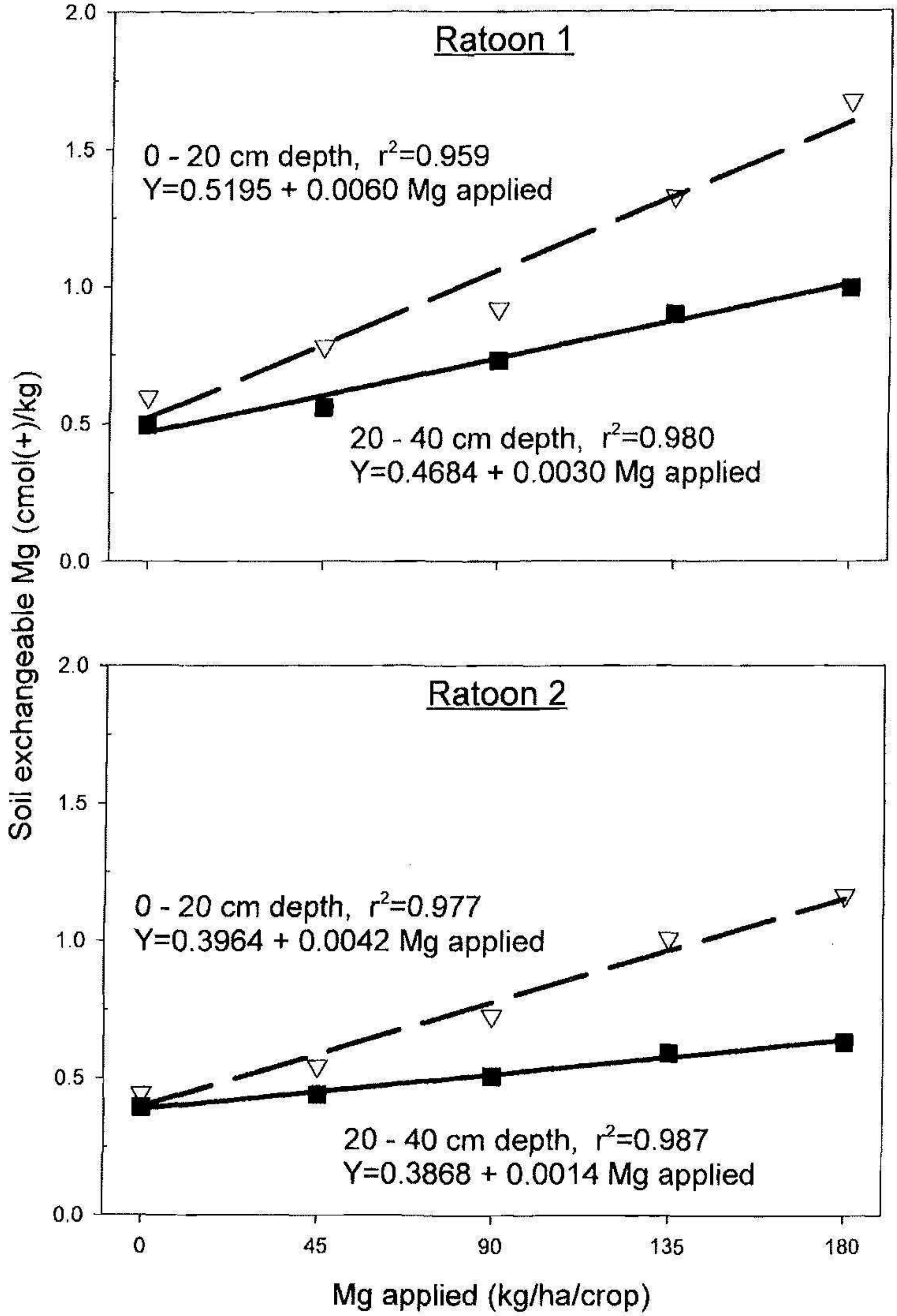

FIGURE 2. Relationship between the exchangeable magnesium at two soil depths in banana ratoons (R1 and R2) grown on an Ultisol fertilized with five rates of magnesium.

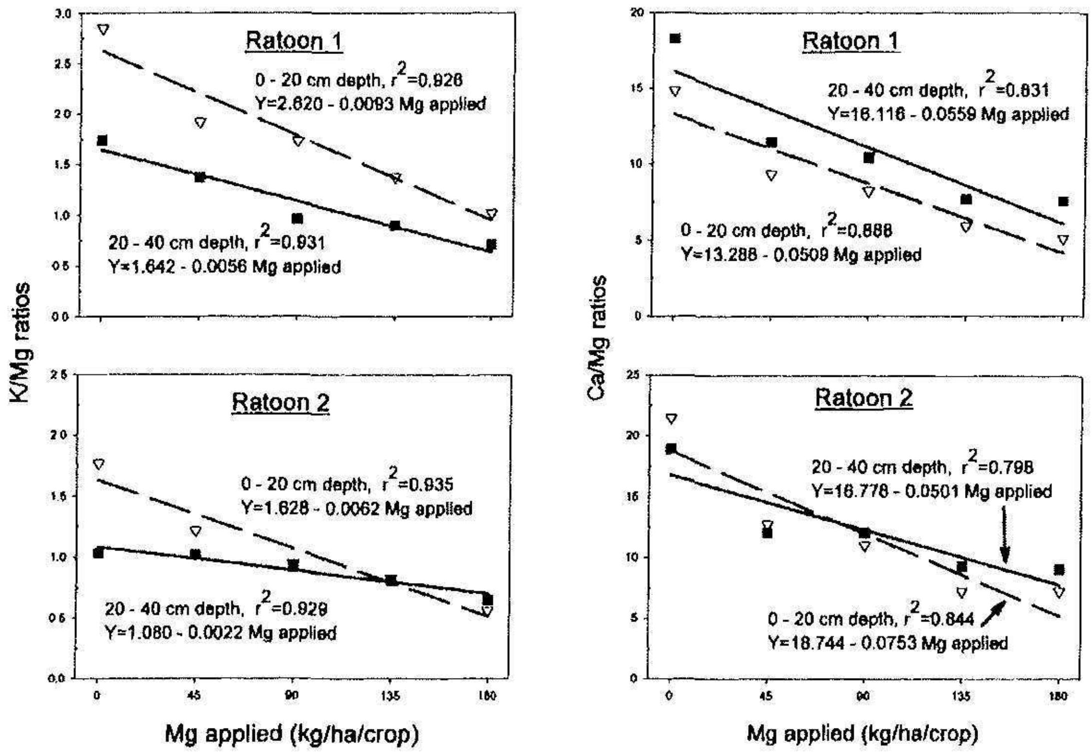

FIGURE 3. Relationship between the K/Mg and Ca/Mg ratios at two soil depths in banana ratoons (R1 and R2) grown on an Ultisol fertilized with five rates of magnesium.

izer band was reduced from 5.3 to as low as 4.7 at a soil depth of 0 to 20 cm, and to 4.5 at a depth of 20 to 40 cm in both ratoon crops. However, Al saturation in R1 and R2 plots averaged only 10.5% at a soil depth of 0 to 20 cm, and 25.3% below the 20-cm depth. Therefore, in this experiment we did not consider that "Mg fixation" (Myers et al., 1988; Martínez et al., 1994; 1996) played a major role in the availability of Mg to the crop.

LITERATURE CITED

Abruña, F., J. Vicente-Chandler, R. W. Pearson and S. Silva, 1970. Crop response to soil acidity factors in Ultisols and Oxisols. I—Tobacco. *Soil Sci. Soc. Amer. Proc.* 34:629-635.

Agric. Exp. Sta., 1995. Conjunto Tecnológico para la producción de plátanos y guineos. Univ. P.R., Río Piedras, P.R. Publ. 97.

García, V., E. Fernández-Caldas, C. E. Alvarez and J. Robles, 1978. Desequilibrios potásico-magnésicos en los cultivos de plátano de Tenerife. *Fruits* 33:7-13.

Godefroy, J., E. J. Roose and M. Muller, 1975. Estimation des pertes par les eaux de ruisselement et de drainage de elements fertilisants dans un sol de bananeraie du sud de la Côte d'lvoire. *Fruits* 30: 223-235.

Irizarry, H., J. Vicente-Chandler and S. Silva, 1981. Root distribution of plantains growing on five soil types. *J. Agric. Univ. P.R.* 65(1):29-34.

Irizarry, H., E. Rivera and J. Rodríguez, 1988. Nutrient uptake and dry matter composition in the plant crop and first ratoon of the Grand Naine banana grown on an Ultisol. *J. Agric. Univ.P. R.* 72:337-351.

Irizarry, H., E. Rivera and J. Rodríguez, 1990. Response of bananas (*Musa acuminata*, AAA) to magnesium fertilization in an Ultisol. *J. Agric. Univ. P.R.* 74:419-426.

Lahav, E., 1974. The influence of potassium on the content of macroelements in the banana sucker. *Agrochimica* 28(1-2):194-203.

López, C., 1983. Diagnóstico del estado nutricional de plantaciones bananeras en Costa Rica. *ASBANA* 6(19):13-18.

Martínez, G. A., L. Peña-Córdova and L. A. Figueroa, 1994. A thermodynamic evaluation of the addition of calcium and magnesium to an Ultisol: I-Ca $(OH)_2$ addition. *J. Agric. Univ P.R.* 78:99-110.

Martínez, G. A., L. Peña-Córdova and L. A. Figueroa, 1996. A thermodynamic evaluation of the addition of calcium and magnesium to an Ultisol: II—Ca SO_4 addition. *J. Agric. Univ. P.R.* 80:1-12.

Murray, D. B., 1960. The effect of deficiencies of the major nutrients on growth and leaf analysis of the banana. *Trop. Agric.* 37(2):97-106.

Myers, J. A., E. O. McLean and J. M. Bigham, 1988. Reductions in exchangeable magnesium with liming of acid Ohio soils. *Soil Sci. Soc. Am. J.* 52:131-136.

Ritchey, K. D. and H. Irizarry, 1993. Leaching of Mg fertilizers in Puerto Rican Ultisols. *J. Agric. Univ. P.R.* 77:167-180.

Sánchez, P. A., 1976. Properties and management of soils in the tropics. John Wiley and Sons Inc., NY.

SAS Institute, 1987. SAS/STAT: Guide for personal computers. Version 6. Cary, NC.

Soto, M., 1985. Bananos: Cultivo y comercialización. Litografía e Imprenta LIL S.A., Tibas, Costa Rica.

Summerville, W. A. T., 1939. Root distribution of the banana. *Queen. Agric. J.* 52:376-392.

Vázquez, L., O. Méndez and R. Padró, 1957. Preliminary report on calcitic dolomite of northern Puerto Rico. *Economic Development Administration*, Bull. 5, San Juan, PR.

Vicente-Chandler, J., F. Abruña, R. Caro-Costas, J. Figarella, S. Silva and R. W. Pearson, 1974. Intensive grassland management in the humid tropics of Puerto Rico. Agric. Exp. Sta., Univ. P.R. Bull 233.