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Influence of Fertilizers on the Production of Plantains with Irrigation[1]

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ABSTRACT

The fertilizer requirements of plantains (*Musa acuminata* × *M. balbisiana*, AAB) were determined for a San Antón sandy clay (Cumulic Haplustolls), with irrigation, on the southern coast of Puerto Rico. Significant responses per plant in number of fruit and weight per bunch were obtained with 168 kg N/ha. The use of the Capó fertilizer-yield equation indicated that applications of 259 and 282 kg N/ha would be required for a maximum yield of 155,988 fruit/ha weighing 45,030 kg. Levels of N in excess of 336 kg N/ha reduced production by restricting the number and weight of bunches/ha, with 673 kg N/ha having 22.8% less bunches than with optimum N fertilizer application. Leaf-N value of 3.20% at 10 mo of age was associated with response to N fertilizers and values of 3.66% with maximum production.

Optimum K_2O fertilization rates, required for maximum yields, were 420 and 405 kg/ha for number and weight of plantains, respectively, with 336 kg K_2O giving 99% of maximum yields.

Phosphorus increments up to 336 kg P_2O_5/ha failed to increase production per plant or per hectare. The unfertilized soil contained 45 p/m P (Olsen), and leaf samples from these plots contained 0.28% P in the leaf at 10 mo.

Applications of 94 kg MgO/ha were sufficient to attain 95% of maximum yield potential for number and weight of fruit per ha. Soil and leaf values (699 p/m Mg and leaf 0.48% Mg) for the no-Mg treatment exceeded published critical values for plantains.

For optimum production of plantains on an irrigated San Antón sandy clay, the use of 168 kg N and 336 kg K_2O/ha are suggested.

INTRODUCTION

In 1974-75, the plantain (*Musa acuminata* × *M. balbisiana*, AAB) ranked third in farm value for agricultural crops in Puerto Rico with an estimated value of $21,560,000 (5). The majority of these plantains, grown in the humid mountain region, receive rainfall and no irrigation. Continuing demand and high prices of the past few years have stimulated interest among local farmers to devote some of their level, irrigated lands to the growing of plantains instead of sugarcane.

Investigations into the fertilizer needs of plantains have been made for the humid mountain region of Puerto Rico (4, 10), but no such

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literature is available for the irrigated southern coastal plains. The purpose of this paper is to present the results of an experiment to determine the fertilizer needs of plantains when grown with irrigation on the southern coast of Puerto Rico.

MATERIALS AND METHODS

The horn-type Maricongo plantain was used in this study. The plants were grown on a San Antón sandy clay (Cumulic Haplustolls) at the Fortuna Substation located in the semi-arid southern river flood plain of Puerto Rico. The soil's chemical characteristics were as follows: pH, 7.4; organic matter, 2.88%; cation exchange capacity, 38.6 meq/100 g soil; available P, 52 p/m (Olsen method); and exchangeable cations in p/m: K = 380, Ca = 5463, and Mg = 765.

The Substation, located about 20 m above sea level, has a mean annual air temperature of 25.9° C with an average maximum of 31.1 and a minimum of 20.7° C. Rainfall averaged 685 mm/yr throughout the 16 mo of the experiment, which began December 11, 1974 and ended April 15, 1976. Pan evaporation averaged 185 mm/mo. Irrigation for the experiment was supplied by drip irrigation using 166 drops/min (6.1 l/plant/12h, daily) for the first 3 mo. It was then necessary to increase the wetting interval to 24 h/plant/day as the plants grew older. At 7 mo, damage to the plastic drip tubes by termites necessitated the use of gravity irrigation for the remainder of the experiment with 5 to 8 cm/ha applied weekly when needed.

Corms, pre-selected from plants with production of about 50 plantains per bunch from the Corozal Substation, were used as planting material. The corms were peeled to discard necrotic tissue, immersed in a solution of Nemagon 70 EC[3] (1,064 ml/739 l of water) for 5 min and planted 24 h later. At planting, a granular nematocide, Dasanit, was applied at a rate of 56 g/planting hole, the material being mixed with the soil and covering the corm. An additional 56 g was added every 6 mo on the soil surface in a 0.75 m radius around the plant.

The experimental plot consisted of four 7.6 m rows spaced 1.83 m apart with 1.52 m between plants within the row. The effective area used for sampling and harvesting consisted of the inner two rows less one plant at the beginning and end of the plot, or 6 plants/plot. The 1.52 × 1.83 m distance corresponded to 3,586 plants/ha (1,452/acre).

[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 or warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico or an endorsement over other equipment or materials not mentioned.

The fertilizer treatments consisted of varying levels of N, P_2O_5, K_2O, and MgO (table 1). The P_2O_5, as triple superphosphate, was applied below the seed at planting. The N, K_2O, and MgO were applied on the soil surface as ammonium sulfate, potassium sulfate and Epsom salt at 1, 4, and 10 mo after planting. Time of planting was December 11, 1974. Flowering occurred primarily during November, 1975. Fruit was harvested 92 to 109 days after flowering. Plants not bearing a bunch after January 1, 1976 were considered non-bearing.

The experimental design was partially-balanced incomplete blocks with 14 treatments replicated 6 times.

Soil samples (0–20 cm) were taken before fertilizer application and after harvest. Leaf samples were taken of leaf no. 3 (first fully-opened leaf designated as no. 1) at 10 mo after planting. These consisted of a 31 cm center section, excluding the midvein. The leaves were oven dried at 70° C, ground to pass a 1 mm sieve, and analyzed for nutrient components following wet ash digestion with sulfuric acid and hydrogen peroxide (8). Measurements were made of plant height and number of green leaves at flowering, and the number of days between flowering and fruit harvest was recorded. Inasmuch as there were no significant differences among treatments for the number of green leaves at flowering, for economy of space, these data are not presented. The average number of green leaves per plant were 14.4 with a range from 13.7 to 15.0.

The relationship of the amount of fertilizer applied to yields obtained was evaluated in accordance with the Capó fertilizer-yield equation (3):

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

where Y is the yield of the crop, and X is the quantity of fertilizer applied to the soil. In this equation A, B, and C are yield parameters. A represents the maximum yield obtainable for the given field with the optimum fertilizer application, C, under the prevaling conditions of the experiment. B may be assumed to represent an index of variability of the crop yield as the quantity of respective fertilizer material applied differs from the optimum application.

RESULTS

NITROGEN

Production per hectare

There were no significant increases in yield with increasing N applications, but significant decreases in production were obtained with the high rate of 673 kg N/ha (table 1).

TABLE 1.—*Influence of fertilizers on plantain production/ha for a plant crop under irrigation, Fortuna Substation*

Fertilizer/ha				Production/ha[1]				Fruit per bunch	Weight		Height	Flowering to harvest
N	P_2O_5	K_2O	MgO	Bunches		Fruit	Weight		Bunch	One Fruit		
Kg	*Kg*	*Kg*	*Kg*	*No.*	*%*	*Thousand*	*Kg*	*No.*	*Kg*	*Gm*	*M*	*Days*
						Nitrogen						
0	168	336	187	3,269 ab[2]	92[3]	140.5 ab	37,539 ab	43.0 a	11.5 a	268 a	3.51 a	105 a
168	168	336	187	3,566 b	100	154.0 b	44,932 b	43.2 a	12.6 b	292 b	3.35 a	98 a
336	168	336	187	3,368 ab	94	151.3 b	44,794 b	44.9 a	13.3 b	295 b	3.51 a	109 a
504	168	336	187	3,368 ab	94	146.3 b	41,090 ab	43.4 a	12.2 ab	281 ab	3.41 a	97 a
673	168	336	187	2,873 a	81	118.4 a	32,465 ab	41.2 a	11.3 a	274 a	3.29 a	100 a
						Phosphorus						
336	0	336	187	3,368 a	94	141.6 a	41,763 a	42.1 a	12.4 a	295 a	3.35 a	104 a
336	168	336	187	3,368 a	94	151.3 a	44,794 a	44.9 a	13.3 a	295 a	3.51 a	109 a
336	336	336	187	3,368 a	94	145.9 a	40,416 a	43.3 a	12.0 a	277 a	3.60 a	98 a
						Potassium						
336	168	0	187	3,170 a	89	125.9 a	35,504 a	39.7 a	11.2 a	282 b	3.41 a	103 ab
336	168	168	187	3,170 a	89	145.0 ab	38,040 a	45.8 a	12.0 ab	263 a	3.35 a	98 ab
336	168	336	187	3,368 a	94	151.3 ab	44,794 a	44.9 ab	13.3 b	295 b	3.51 a	109 a
336	168	504	187	3,566 a	100	159.4 b	44,932 a	44.7 ab	12.6 ab	282 b	3.41 a	97 ab
336	168	673	187	3,368 a	94	142.1 ab	38,395 a	42.2 ab	11.4 a	268 a	3.44 a	92 b
						Magnesium						
336	168	336	0	3,071 a	86	141.9 a	38,695 a	46.2 a	12.6 ab	272 a	3.26 a	96 b
336	168	336	94	3,368 a	94	140.4 a	40,079 a	41.7 a	11.9 a	286 a	3.60 a	99 ab
336	168	336	187	3,368 a	94	151.3 a	44,794 a	44.9 a	13.3 b	295 a	3.51 a	109 a
336	168	336	374	3,368 a	94	147.6 a	41,090 a	43.8 a	12.2 ab	279 a	3.57 a	108 a

[1] Based on a spacing of 1.83 × 1.52 m (6 × 5 ft) for a density of 3566 plants/ha (1452/acre).

[2] Values in the same column followed by one or more letters in common do not differ significantly at the 5% level.

[3] % bunches harvested based on 3566 plants/ha as 100%.

The pattern of response to N fertilizers was curvilinear and well predicted by the Capó fertilizer-yield equation. Using the equation, optimum N fertilizer applications of 259 and 282 kg/ha, for number and weight of fruits/ha, respectively, were associated with maximum yields. The coefficient of determination for number and weight of fruits/ha were 0.95 and 0.99, respectively. The use of 168 kg N/ha produced 98.6 and 96.7% of maximum yields for number and weight of fruit per ha, respectively.

The amounts of N applied had a dual effect on production. At rates up to 259 and 282 kg N/ha, increases in yield of number and weight of fruits per ha, respectively, were achieved. Production was reduced by higher rates. In the plots receiving 673 kg N/ha, 19% of the plants originally planted were not in production (table 1). The major part, 11.1% was due to plants which doubled over about halfway up the pseudostem before flowering. No flowering and stunted growth at 8.3% were the other two factors causing decreases in yield. The N rate influence on time of flowering was 304, 287, 292, 301, 298 days from planting for the 0, 168, 336, 504, 673 kg N/ha, respectively. It does not appear probable that the high N rates in the presence of a constant K supply retarded flowering excessively in this experiment.

The reduction in production due to high N rates was also evident in a plantain experiment on an Ultisol, in the humid mountainous interior of Puerto Rico. The number of bunches per ha was reduced by 46% when 1,121 kg N/ha were applied.[4]

Production per bunch

There was a significant response in fruit weight per bunch with 168 kg N/ha over the no-N treatment (table 1). In general, the response to the wide range of N levels (0 to 673 kg N/ha) was curvilinear, showing a production increase with low N applications and a decrease with high N. This was verified by the Capó fertilizer-yield equation.

The weight of one plantain was significantly reduced by no-N and 673 kg N/ha as compared to the 336 kg N/ha treatment (table 1).

Physical characteristics

The height and interval from flowering to harvest were not significantly influenced by the applied variable N rate (table 1). As mentioned in a previous section, the number of bearing plants per ha was reduced significantly by application of 673 kg N/ha.

[4] Unpublished findings by the senior author.

Foliar values

Leaf-N values of 3.50% were obtained in plots receiving 168 kg N/ha which achieved 98.4 and 96.4% of maximum yield for number and weight of fruits per ha, respectively. A leaf value of 3.66% N was associated with no further response to N applications of 336 kg N/ha. Caro-Costas et al. (4) on an Ultisol in the humid mountain region of Puerto Rico reported that a leaf-N value of 3.46% at 7 mo was associated with a positive response to N fertilizer and that no response was obtained from plants having a foliar N value of 3.97%. Vicente-Chandler and Figarella (10) obtained a N response with leaf N at 2.80%, and no response at 3.86%, in the same Ultisol.

PHOSPHORUS

Applications of up to 336 kg P_2O_5/ha produced no significant increases in production per ha/plant or in physical characteristics (table 1).

The unfertilized soil had values of 45 p/m P, and plants from these plots had 0.28% P in the leaf at 10 mo (table 2). Vicente-Chandler and Figarella obtained no response to phosphate application on an Ultisol when leaf-P values were 0.18% and above at 7 mo. (10).

TABLE 2.—*Chemical content of plantain leaves sampled at 10 months of age, and soil after harvesting plant crop*

Fertilizer/ha				Nutrient content of leaf, dry weight	Soil
N	P_2O_5	K_2O	MgO		
	Kg			%	*P/m*
			Nitrogen		
0	168	336	187	3.20	—
168	168	336	187	3.50	—
336	168	336	187	3.66	—
504	168	336	187	3.88	—
673	168	336	187	3.72	—
			Phosphorus		
336	0	336	187	0.28	45
336	168	336	187	.35	38
336	336	336	187	.32	45
			Potassium		
336	336	0	187	4.11	296
336	336	168	187	4.55	279
336	336	336	187	4.36	290
336	336	504	187	4.46	315
336	336	673	187	4.43	279
			Magnesium		
336	336	336	0	0.48	699
336	336	336	94	.48	763
336	336	336	187	.46	—
336	336	336	374	.47	650

POTASSIUM

Production per hectare

The number of fruits per ha was significantly increased with the 504 kg K_2O/ha application as compared to no K_2O (table 1).

Optimum rates of K_2O/ha were difficult to define using the data as presented in table 1. The use of the Capó fertilizer-yield equation provided answers as to the optimum K_2O rates for maximum production, these being 420 and 405 kg K_2O/ha for number and weight of plantains, respectively. However, the use of 336 kg K_2O/ha produced 99% of the maximum yields/ha for number and weight of fruit.

Production per bunch

Potash applications gave significant increases in number of fruits and weight per bunch (table 1). The weight per bunch and for one fruit, was significantly reduced with 673 kg K_2O/ha as compared to 336 kg K_2)/ha (table 1).

Physical characteristics

A high rate of 673 kg K_2O/ha shortened the flower-to-harvest interval (table 2). Plant height did not differ significantly among the various K_2O levels (table 1).

Foliar and soil values

Leaf-K values were high in all cases, being much higher than the 2.77% leaf-K value cited by Vincente-Chandler and Figarella (10) and the 3.27% cited by Caro-Costas et al. (4), as indicating sufficient K for plantains at a 7 mo sampling on an Ultisol in the humid mountain region. However, when adjustments are made for differences in methods of digestion of the leaf sample,[5] the leaf-K value associated with the 336 kg K_2O/ha treatment becomes 3.25%. This value is quite similar to the 3.27% leaf K cited by Caro-Costas et al. (4) for sufficient K.

The soil sample analyses did not reflect soil applications up to 673 kg K_2O/ha. This may have been due to improper sampling, although utmost care was used in the post-harvest sampling.

MAGNESIUM

No statistically significant increases in production were measured by Mg application ranging from 94 to 374 kg Mg/ha (table 1). The soil

[5] The nitric-perchloric acid digestion method used by Vicente-Chandler and Figarella (10) and Caro-Costas et al. (4) gave leaf-K values 25.4% lower than the values obtained by the sulfuric acid and hydrogen peroxide digestion used for the samples of this study.

with 699 p/m Mg and the leaves with 0.4% Mg were extremely high for the zero Mg treatment (table 2).

The time interval between flowering and harvest was significantly decreased by the no-Mg treatment (table 1).

DISCUSSION

Plantains growing on the south coast of Puerto Rico with irrigation do not exhibit a large demand for fertilizers as compared to those grown in the humid mountain region. Rates of 250 to 325 kg N, 125 to 163 kg P_2O_5, and 500 to 650 kg K_2O/ha are recommended for the humid mountain region (6). In the experiment reported herein, 95% or more of maximum yields of fruits per ha were obtained with 168 kg N, and 336 kg K_2O/ha with no significant yield responses to P_2O_5 or MgO applications. The reasons for this difference are primarily due to rainfall and soil fertility.

In the humid mountain region the rainfall average is 2145 mm annually (2), with a variable distribution ranging from a low of 99 mm in February to a high of 261 mm in September. The high rainfall intensities cause erosion and leaching of plant nutrients. The south coast has a lower rainfall, averaging 944 mm annually, and must receive irrigation for successful crop production.

The Ultisols of the humid mountain region are weathered soils low in bases with silicate clays of low cation exchange capacity (7); whereas the Mollisols of the south coast are fertile soils, relatively rich in organic matter, with a high base saturation throughout, and with clays having high cation exchange capacities.

Care must be used to avoid excessive N application for plantains growing on a San Antón sandy clay. Maximum weight of fruits per ha was associated with 260 kg N/ha, but 504 kg N/ha decreased production to 88% and 673 kg N to 71%.

Plantains have a high need for K and can extract from 1,500 to 2,000 kg K_2O/ha to produce a good crop (9). Inasmuch as 336 kg K_2O/ha applied as fertilizer could produce 99% of maximum yields, the San Antón soil must have large quantities of available K. The average exchangeable K in the soil before the initiation of the experiment was 380 p/m, equivalent to 1022 kg K_2O/ha; whereas for the humid mountain soils, Abruña et al. (1) reported an exchangeable K equivalent to 280 kg/ha. Despite the greater amount of available K in the San Antón soil, K application was necessary for maximum yields.

RESUMEN

Los requisitos de abono para plátanos del cultivar Maricongo (*Musa acuminata* × *M. balbisiana*) fueron determinados en el caso de un suelo San Antón (Cumulic Haplustolls) en regadío en la costa sur de Puerto Rico. Los niveles de N y K_2O fueron 0, 168, 336, 504, y 673 kg./ha., respectivamente; P_2O_5 a 0, 168, y 336 kg./ha.; y MgO a 0, 94, 187 y 374 kg./ha. El experimento tenía 6 repeticiones con 5 plantas por parcela. Además de la lluvia se aplicó riego por goteo. Con aplicaciones de 168 kg. N/ha. se obtuvieron resultados significativos con respecto al número de frutas por planta y peso por racimo. El uso de la ecuación abono-rendimiento de Capó indicó que, considerándose la producción por ha., rendimientos máximos de 157.988 frutas, con peso de 45,030 kg., se hubieran obtenido con aplicaciones de 259 y 282 kg. N/ha., respectivamente. Con aplicaciones de N mayores de 363 kg. N/ha., la producción de racimos por ha. fue más baja, arrojando una pérdida de 22.8% racimos menos por ha. al comparase con aplicaciones óptimas de N. Un contenido en N de 3.20% en las hojas, a los 10 meses de edad, reflejó carencia de N, mientras que el contenido de 3.66% reflejó suficiencia para máxima producción.

Cantidades óptimas de K_2O de 420 y 405 kg./ha. estuvieron asociadas con rendimientos máximos en número y peso de los plátanos, respectivamente, con la aplicación de 336 kg. K_2O, siendo suficiente para producir el 99% del máximo.

Con aplicaciones de fósforo de hasta 336 kg. P_2O_5/ha. no se lograron aumentos significativos en la producción tanto por planta como por ha. El suelo no abonado contenía 45/ppm (Olson) y las plantas de estas parcelas contenían .28% de P en las hojas a los 10 meses.

La aplicación de 94 kg. MgO/ha. satisfizo más del 95% de este fertilizante para un rendimineto máximo en número y peso de las frutas por ha. Los valores del suelo (699 ppm) y de la hoja (.48% Mg) en los tratamientos que no recibieron Mg estaban por encima de los valores críticos recomendados para plátanos.

Para una producción máxima de plátanos en un suelo San Antón en regadío, se recomienda el uso de 168 kg. N y 336 kg. K_2O/ha.

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