THE EFFECT OF FERTILIZERS ON THE YIELD AND QUALITY OF SWEETPOTATOES

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INTRODUCTION

The sweetpotato occupies an important place in the Puerto Rican diet. It is of nutritional importance, not only for its high caloric value, but for its abundant vitamin content, especially vitamin A. The yellow-fleshed variety U.P.R. No. 3, for instance, is exceptionally high in carotene, thus providing an inexpensive and abundant source of vitamin A for man and animal.

The cultivation of sweetpotatoes ranks as one of the more important food crops of Puerto Rico. They are grown in all areas of the Island. From 1944 to 1948, the average production per year of the sweetpotato crop in the Island amounted to 1,601,355 hundredweights at a mean cash value of $3,120,000 annually (2).[2] The majority of the crop grown receives little or no fertilizer and a minimum of care. In general, the sweetpotato crops are grown on poor or marginal land with little attention to proper agronomic practices. The purpose of this work was to determine not only the major fertilizer (N-P-K) requirements, but also minor-element requirements, and the effect of fertilizers in general on the quality of sweetpotatoes as reflected in the starch and carotene content.

EXPERIMENTAL PROCEDURE

The investigation consisted of four field experiments covering a range of soil textures from loamy sand to heavy clay. The Loiza experiments I and II were established on Cataño loamy sand, a well-drained coastal lowland soil, alkaline in reaction (pH 7.6), devoted mostly to coconuts, citrus, sweetpotatoes, cassava, beans, and peanuts. The Sabana Seca experiment was conducted on Sabana Seca sandy clay loam, a coastal plain soil, which has a friable surface soil (pH 6.3) and a heavy plastic subsoil, and is under cultivation mostly to minor truck crops. The Corozal experiment was established on Lares clay, a lateritic acid clay (pH 4.5) of the terrace and alluvial fans of Puerto Rico, cropped mainly to sugarcane and pineapples.

The fertilizer treatments for the four experiments consisted of varying increments of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O).

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[2] Figures in parentheses refer to Literature Cited, p. 86.

Filter-press cake (a product of the sugar mills) applications and liquid fertilizer treatments were also used. The minor-element treatments included applications of copper, boron, manganese, magnesium, and calcium. The exact rates of application are described in the tables. All fertilizers were applied 15 days after planting, using the band method.

TABLE 1.—*Influence of major-element fertilizers on the yields of sweetpotatoes: Loiza experiments I and II on Cataño Loamy Sand and the Sabana Seca experiment on Sabana Seca Sandy Clay*[1]

No.	Treatment and rate of application per acre			Loiza experiment I: Mean yield per acre	Loiza experiment II: Mean yield per acre	Sabana Seca experiment: Mean yield per acre
	N	P_2O_5	K_2O			
	Pounds	*Pounds*	*Pounds*	*Hundredweights*	*Hundredweights*	*Hundredweights*
1	0	200	200	102	43	63
2	82	200	200	130	47	119
3	165	0	200	114	49	108
4	165	100	200	116	46	112
5	165	200	0	68	43	98
6	165	200	100	78	39	116
7	165	200	200	107	42	100
8	165	300	200	89	—	113
9	165	200	300	119	41	112
10	165	300	300	119	45	108
11	82	100	50[2]	92	45	98
12	18	18	9[3]	70	—	60
13	10 tons filter-press cake			—	29	—
14	20 tons filter-press cake			—	31	—
15	100	100	100	—	57	—
	10 tons filter-press cake					

[1] Least significant differences needed for comparison at:

5-percent point	39	14	15
1-percent point	52	19	20

[2] 1,000 pounds of a 8–10–5 commercial fertilizer per acre.

[3] Liquid fertilizer formula of 8–10–5 at rate of 17.5 gallons per acre which is equal in price to 1,000 pounds of a 8–10–5 commercial fertilizer.

The experimental design for all four experiments was a triple lattice with six replications of each treatment. The plot size was 20 feet long by 8 feet wide or one two-hundred-and-seventy-second of an acre. The propagating material consisted of 40 vine cuttings (the first 18 inches of the sweetpotato vine being used) per plot of U.P.R. No. 3, an outstanding Porto Rico sweetpotato variety developed by the Plant Breeding Department of this Station. The vines were planted in four furrows, 2 feet apart and 3 to 4 inches deep.

The carotene content and starch analyses were conducted on random samples of 10 sweetpotatoes per plot. In all cases, the same general shape and size were used which conformed with the U. S. No. 1 root. The material was prepared for analyses from 24 to 48 hours after harvesting. The carotene content was determined by the method of Moore and Ely (9) and starch by the method of Nielson (10).

TABLE 2.—*Influence of major-element fertilizers on the yields of sweetpotatoes: Corozal experiment on Lares Clay*[1]

No.	Treatment and rate of application per acre			Soil pH[2]	Mean yield per acre
	N	P_2O_5	K_2O		
	Pounds	*Pounds*	*Pounds*		*Hundredweights*
1	0	200	200	6.0	139
2	82	200	200	6.0	107
3	165	0	200	6.0	94
4	165	100	200	6.0	88
5	165	200	0	6.0	94
6	165	200	100	6.0	106
7	165	200	200	6.0	78
8	165	300	200	6.0	119
9	165	200	300	6.0	94
10	165	300	300	6.0	116
11	0	200	200	4.5	96
12	82	200	200	4.5	68
13	165	200	200	4.5	60
14[3]	165	200	200	4.5	85
15[3]	165	200	200	6.0	114
16[4]	82	100	50	6.0	93
17	0	0	0	6.0	81

[1] Least significant difference needed for comparison at:

5-percent point	24
1-percent point	31

[2] Normal soil pH 4.5; soil raised to pH 6.0 with 7,500 pounds $CaCO_3$ per acre.

[3] Plus 20 tons of filter-press cake.

[4] As 1,000 pounds of 8-10-5.

EXPERIMENTAL RESULTS

The results of the effect of the fertilizer treatments on yields and carotene and starch contents of the sweetpotatoes are given in tables 1 to 9. The major-element fertilizer (N-P-K) effects on yields are presented in tables 1 and 2, and the lime and minor-element fertilizer results in tables 3 and 4. The effects of major-element fertilizers on carotene and starch contents are given in tables 5 and 6, and of minor-element fertilizers on the same in tables 7 to 9. The hundredweight unit reported in yields represents U.S. No. 1, No. 2, and Jumbo grades. The carotene content is given in both the fresh-weight basis at time of harvest and the dry-weight basis (80°C.). The starch content is given on the dry-weight basis (80°C).

Influence of Major-Element Fertilizer on Yields

Nitrogen

The use of nitrogen influenced the yields of sweetpotatoes. In 2 of the 4 experiments an application of 165 pounds of nitrogen per acre was excessive.

TABLE 3.—*Influence of lime and minor-element fertilizers on the yields of sweetpotatoes: Loiza experiments I and II on Cataño Loamy Sand and the Sabana Seca experiment on Sabana Seca Sandy Clay*[1]

No.	Treatment[2]		Loiza experiment I			Loiza experiment II			Sabana Seca experiment		
	Element	Form applied	Rate of application per acre	Mean yield per acre	Relative yield	Rate of application per acre	Mean yield per acre	Relative yield	Rate of application per acre	Mean yield per acre	Relative yield
			Pounds	*Hundredweights*	*Percent*	*Pounds*	*Hundredweights*	*Percent*	*Pounds*	*Hundredweights*	*Percent*
1	None	—	—	107	100	—	42	100	—	100	100
2	Boron	Borax	30	113	105	50	45	107	30	116	116
3	Magnesium	Magnesium oxide	50	118	110	200	50	119	100	112	112
4	Copper	Copper sulfate	25	98	92	—	—	—	—	—	—
5	Manganese	Manganese sulfate	25	96	90	—	—	—	25	108	108
6	Calcium	Calcium sulfate	—	—	—	—	—	—	500	116	116
7	Boron	Borax	—	—	—	50	55	130	—	—	—
	Magnesium	Magnesium oxide				200			—	—	—

[1] Least significant difference needed for comparison at:
5-percent point 39 14 15
1-percent point 52 19 20

[2] All treatments received fertilizer at the rate of 165 pounds of N and 200 pounds each of P_2O_5 and K_2O per acre.

In the Sabana Seca experiment, the use of 82 pounds of nitrogen gave increases in yields over the zero nitrogen application (table 1). The Corozal experiment gave decreased yields with increased nitrogen applications (table 2). The decreases in yields caused by excess nitrogen were evident both at pH 4.5 (table 2, treatments 11, 12, and 13) and at pH 6.0 (table 2, treatments 1, 2, and 7).

The relative supply of available nitrogen in the soil at Corozal must have been quite high, as the application of 82 pounds of nitrogen gave a yield decrease. The field where the experiment was conducted was previously in pineapples. These had been heavily fertilized with high-nitrogen fertilizers. It is probable that the residual effect of the nitrogen fertilizer was responsible for the decrease in yield attributed to the application of nitrogen.

TABLE 4.—*Influence of lime and minor-element fertilizers on the yields of sweetpotatoes: Corozal experiment on Lares Clay*[1]

No.	Treatment[2]			Soil pH[3]	Mean yield per acre
	Element	Form applied	Rate of application per acre		
			Pounds		*Hundredweights*
1	None	—	—	4.5	60
2	Calcium	Calcium carbonate	3,500	5.0	76
3	do.	do.	7,500	6.0	78
4	do.	do.	12,500	7.0	90
5	Magnesium	Magnesium oxide	300	4.5	79
6	Magnesium Calcium	Magnesium oxide Calcium carbonate	300 7,500	6.0	110
7	Magnesium Calcium	Magnesium oxide Calcium carbonate	600 7,500	6.0	89
8	Boron	Borax	50	4.5	66
9	Boron Calcium	Borax Calcium carbonate	50 7,500	6.0	101
10	Boron Magnesium Calcium	Borax Magnesium oxide Calcium carbonate	50 300 7,500	6.0	103

[1] Least significant difference needed for comparison at:
5-percent point 24
1-percent point 31

[2] All received 100 pounds of N and 200 pounds each of P_2O_5 and K_2O per acre.

[3] Normal soil pH 4.5; soil raised to pH 5.0 with 3,500 pounds of $CaCO_3$, pH of 6.0 with 7,500 pounds $CaCO_3$, and pH 7.0 with 12,500 pounds of $CaCO_3$.

Excessive quantities of nitrogen cause heavy vine growth, and the result is a low yield of poor-quality roots. The general fertilizer recommendation in the United States for sweetpotatoes is 2 to 4 percent of nitrogen at rates of from 1,000 to 1,500 pounds per acre (4).

Phosphorus

In general, there was no effect on yields from the use of phosphorus fertilizers with rates of applications as high as 300 pounds of P_2O_5.

Potassium

The response to potassium was not consistent for the four experiments. Increases in yields were obtained with increasing potassium additions to the soil in the Loiza I experiment (table 1, treatments 5, 6, 7, and 9). This did not occur in the Loiza II experiment. There were no significant consistent responses to potassium in the Sabana Seca and Corozal experiments.

TABLE 5.—*Influence of major-element fertilizers on the starch and carotene content sweetpotatoes: Loiza experiment on Cataño Loamy Sand and the Sabana Seca of experiment on Sabana Seca Sandy Clay*[1]

No.	Treatment and rate of application per acre			Loiza experiment I			Sabana Seca experiment		
				Starch content (dry weight)	Carotene content		Starch content (dry weight)	Carotene content	
	N	P_2O_5	K_2O		Fresh weight	Dry weight		Fresh weight	Dry weight
	Pounds	*Pounds*	*Pounds*	*Percent*	*Mcg./gm.*	*Mcg./gm.*	*Percent*	*Mcg./gm.*	*Mcg./gm.*
1	0	200	200	55	80	269	61	101	322
2	82	200	200	55	87	286	63	124	378
3	165	0	200	51	95	298	62	117	349
4	165	100	200	55	86	269	68	123	363
5	165	200	0	55	133	367	67	129	357
6	165	200	100	50	95	292	66	124	360
7	165	200	200	57	105	338	64	125	379
8	165	300	200	58	103	334	66	122	362
9	165	200	300	58	102	330	66	125	381
10	165	300	300	56	94	291	61	131	375
11	82	100	50[2]	58	96	282	65	117	351
12	18	18	9[3]	49	98	312	61	117	361

[1] Least significant difference needed for comparison at:

5-percent point	8	23	75	7	15	51
1-percent point	10	31	99	9	20	67

[2] 1,000 pounds of a 8–10–5 commercial fertilizer.

[3] Liquid fertilizer, 8–10–5 at rate of 17.5 gallons per acre.

In the Loiza I experiment, increases in the yields of marketable sweetpotatoes were obtained with increasing potassium applications. This seems to be in close agreement with the work of Scott (11) and others where potassium fertilizers influenced size and shape of the sweetpotato. The general fertilizer recommendation for the United States calls for the use of from 80 to 150 pounds of K_2O per acre (4).

Filter-press cake, Commercial and Liquid Fertilizers

Filter-press cake, when used alone at rates of 10 and 20 tons per acre gave the lowest yields of the Loiza II experiment (table 1, treatments 13 and 14). When used with inorganic sources of N-P-K, it did not give any higher yields than were obtained with fertilizer only (table 1, treatment 15).

The yields obtained with the combination of filter-press cake and inorganic fertilizers were greater than those obtained with filter-press cake alone in the Corozal experiment. The use of filter-press cake with fertilizers

TABLE 6.—*Influence of major-element fertilizers on the carotene content of sweetpotatoes: Corozal experiment on Lares Clay*[1]

No.	Treatment and rate of application per acre			Soil pH[2]	Carotene content	
	NH_3	P_2O_5	K_2O		Fresh weight	Dry weight
	Pounds	*Pounds*	*Pounds*		*Mcg./gm.*	*Mcg./gm.*
1	0	200	200	6.0	126	445
2	82	200	200	6.0	124	422
3	165	0	200	6.0	113	380
4	165	100	200	6.0	118	412
5	165	200	0	6.0	117	396
6	165	200	100	6.0	121	402
7	165	200	200	6.0	124	409
8	165	300	200	6.0	133	445
9	165	200	300	6.0	129	431
10	165	300	300	6.0	123	404
11	0	200	200	4.5	107	367
12	82	200	200	4.5	120	431
13	165	200	200	4.5	116	334
14	165	200	200[3]	4.5	100	331
15	165	200	200[3]	6.0	106	374
16	82	100	50	6.0	121	389
17	0	0	0	6.0	112	396

[1] Least significant difference needed for comparison at:

5-percent point	16	80
1-percent point	22	106

[2] Normal soil pH 4.5; soil raised to pH 6.0 with 7,500 pounds of $CaCO_3$ per acre.

[3] Plus 20 tons of cachaza, filter-press cake, averaging about 1 percent each of N, P, and K on a dry-weight basis.

gave significantly higher yields than those where the fertilizer was used alone (table 2, compare treatment 14 with 13 and 15 with 7).

Capó *et al.* (5) reported no response to filter-press cake when used with fertilizers for sweetpotatoes grown on Fajardo clay at Río Piedras.

The application of liquid fertilizer (a commercial preparation of an 8–10–5) at rate equal to the cost of 1,000 pounds of a commerical 8–10–5[3]

[3] Equivalent to a 10–10–5 formula with the nitrogen expressed as NH_3 which was used in Puerto Rico prior to 1951.

in solid form showed, that on an equal-cost basis, the commercial 8–10–5 solid fertilizer gave significantly higher yields in the Sabana Seca experiment (table 1, treatments 11 and 12). In the Loiza I experiment, the difference was not significant.

TABLE 7.—*Influence of minor-element fertilizers on the starch and carotene content of sweetpotatoes: Loiza experiments on Cataño Loamy Sand*[1]

No.	Treatment[2]		Loiza experiment I				Loiza experiment II			
	Element	Form applied	Rate of application per acre	Starch content (Dry weight)	Carotene content		Rate of application per acre	Starch content (Dry weight)	Carotene content	
					Fresh weight	Dry weight			Fresh weight	Dry weight
			Pounds	*Percent*	*Mcg./mg.*	*Mcg./gm.*	*Pounds*	*Percent*	*Mcg./gm.*	*Mcg./gm.*
1	None	—	—	57	105	338	—	56	127	441
2	Boron	Borax	30	52	101	326	50	56	127	476
3	Magnesium	Magnesium oxide	50	59	102	318	200	62	127	437
4	Copper	Copper sulfate	25	55	97	302	—	—	—	—
5	Manganese	Manganese sulfate	25	53	95	282	—	—	—	—
6	Calcium	Calcium sulfate	—	—	—	—	—	—	—	—
7	Boron Magnesium	Borax Magnesium oxide	—	—	—	—	50 200	62	124	448

[1] Least significant difference needed for comparison at:

	Starch I	Fresh I	Dry I	Starch II	Fresh II	Dry II
5-percent point	8	23	75	29	13	55
1-percent point	10	31	99	40	19	76

[2] All treatments received 165 pounds each of N and 200 pounds each of P_2O_5 and K_2O per acre.

Influence of Lime and Minor-Element Fertilizers on Yields

Calcium

The yields of sweetpotatoes were measurably affected by the use of calcium carbonate in the acid Lares clay (table 4). The application of ground limestone (96 percent $CaCO_3$) to raise the soil pH gave increased yields with increased soil pH. From pH 4.5 to pH 7.0, the yields of sweetpotatoes increased significantly; the increase in yield was 50.2 percent from a soil pH of 4.5 to one of 7.0 (table 4, compare treatments 4 and 1).

The effect of lime on yield increases was also evident where varying levels of nitrogen were used (table 2, treatments 1, 2, and 11, 12); an average yield increase of 44.5 percent was realized with the use of lime at the various nitrogen levels. The yields of sweetpotatoes were significantly increased when lime was used with filter-press cake (table 2, compare treatments 14 and 15).

The Sabana Seca experiment gave yield increases from the use of calcium sulfate (gypsum) at the rate of 500 pounds per acre (table 3, treatments 1 and 6).

TABLE 8.—*Influence of minor-element fertilizers on the starch and carotene content of sweetpotatoes: Sabana Seca experiment on Sabana Seca Sandy Clay*[1]

No.	Treatment[2]		Sabana Seca experiment			
	Element	Form applied	Rate of application per acre	Starch content (dry weight)	Carotene content	
					Fresh weight	Dry weight
			Pounds	*Percent*	*Mcg./gm.*	*Mcg./gm.*
1	None	—	—	64	125	379
2	Boron	Borax	30	67	116	351
3	Magnesium	Magnesium oxide	100	59	134	405
4	Copper	Copper sulfate	—	—	—	—
5	Manganese	Manganese sulfate	25	63	121	362
6	Calcium	Calcium sulfate	500	62	135	412
7	Boron Magnesium	Borax Magnesium oxide	—	—	—	—

[1] Least significant difference needed for comparison at:

5-percent point	7	15	51
1-percent point	9	20	67

[2] All treatments received 165 pounds each of N and 200 pounds each of P_2O_5 and K_2O per acre.

Magnesium

The results of the magnesium treatments were not consistent. Magnesium gave a significant yield increase at the 1-percent level when 300 pounds of MgO were used in conjunction with lime, but gave no increase when used in conjunction with both lime and boron (table 4, compare treatment 3 with 6 and 9 with 10). Significant increases, however, were not realized from the use of 600 pounds of MgO. (Table 4, treatments 3 and 7.) No yield increases were obtained from the use of MgO in the Loiza and Sabana Seca experiments (table 3).

Boron

The use of boron gave significant yield increases in the Sabana Seca and Corozal experiments. The use of 30 pounds of borax in the Sabana Seca experiment gave an increase of 16 percent (table 3, treatments 1 and 2). The Corozal experiment showed an almost significant increase in yield when 50 pounds of borax were used in conjunction with lime (table 4, compare treatments 3 and 9). Borax alone gave no significant yield response (table 4, compare treatments 1 and 8). With both magnesium and borax, no significant yield increases were obtained in the acid Lares clay until

TABLE 9.—*Influence of minor-element fertilizers on the carotene content of sweetpotatoes: Corozal experiment on Lares Clay*[1]

No.	Treatment[2]			Soil pH[3]	Carotene	
	Element	Form applied	Rate of application per acre		Fresh weight	Dry weight
			Pounds		*Mcg./gm.*	*Mcg./gm.*
1	None	—	—	4.5	116	334
2	Calcium	Calcium carbonate	3,500	5.0	129	432
3	do.	do.	7,500	6.0	124	409
4	do.	do.	12,500	7.0	132	438
5	Magnesium	Magnesium oxide	300	4.5	97	311
6	Magnesium	Magnesium oxide	300	6.0	123	388
	Calcium	Calcium carbonate	7,500			
7	Magnesium	Magnesium oxide	600	6.0	123	406
	Calcium	Calcium carbonate	7,500			
8	Boron	Borax	50	4.5	126	413
9	Boron	Borax	50	6.0	129	449
	Calcium	Calcium carbonate	7,500			
10	Boron	Borax	50	6.0	124	432
	Magnesium	Magnesium oxide	300			
	Calcium	Calcium carbonate	7,500			

[1] Least significant difference needed for comparison at:

5-percent point	16	80
1-percent point	22	106

[2] All treatments received 165 pounds each of N and 200 pounds each of P_2O_5 and K_2O per acre.

[3] Normal soil pH 4.5; soil raised pH 5.0 with 3,500 pounds $CaCO_3$; pH 6.0 with 7,500 pounds $CaCO_3$; and pH 7.0 with 12,500 pounds of $CaCO_3$ per acre.

lime was added. It appears that in this soil, the major limiting factor for yield in sweetpotatoes is the low pH which may be corrected by liming.

Manganese and Copper

No yield increases were realized with the use of manganese or copper for sweetpotatoes in the Loiza experiment and manganese in the Sabana Seca experiment (table 3, treatments 1, 4, and 5).

Influence of Major-Element Fertilizers on Carotene and Starch Content

Nitrogen

The use of nitrogen fertilizers influenced the carotene content of the sweetpotatoes. In all four experiments, where nitrogen produced yield increases, there were also increases in the carotene content of the sweetpotatoes. When no significant yield increases were obtained with the use of nitrogen, there were no significant variations in the carotene content. Significant decreases in yield from the use of nitrogen were not accompanied by any significant change in carotene content.

The use of nitrogen fertilizers on nitrogen-deficient soils at rates (82 pounds N per acre) which produced significant yield increases, also increased the carotene content of the sweetpotatoes. This was statistically significant in the Sabana Seca experiment (table 5, treatments 1 and 2). Reductions in yields were obtained with the use of 165 pounds of N per acre in the Loiza and Sabana Seca experiments, without measurable change in the carotene content (table 5, compare treatments 2 and 7). In the Corozal experiment (table 6), significant yield reductions were obtained with increasing nitrogen applications on the limed and unlimed soil, and the carotene content showed no significant variation.

Nitrogen had no significant influence on starch content.

Phosphorus

There was an increase of the carotene content of the sweetpotato when accompanied by a significant increase in yields from phosphorus applications. In the Corozal experiment, the use of 300 pounds of P_2O_5 gave a significant increase in yield and carotene content (table 6, compare treatments 3 and 8). In the other experiments, no increases were obtained in yield or carotene content with phosphorus applications.

There was no significant influence of phosphorus on the starch content of the sweetpotatoes.

Potassium

No significant effect on the carotene content was noted for potassium, except for a decrease in carotene in the Loiza experiment (table 5, compare treatments 5 and 6). Ijdo (8) found that decreases of the carotene content of spinach by additions of potassium was only effective at low nitrogen levels. At high nitrogen levels, potassium had no influence on the carotene content. This may have been because all potassium treatments in the sweetpotato experiments were conducted at high nitrogen levels (165 pounds N per acre).

Potassium had no significant influence on the starch content of sweetpotatoes.

Influence of Lime and Minor-Element Fertilizers on Carotene and Starch Content

Calcium

The carotene content of the sweetpotatoes was measurably affected by the use of calcium carbonate in the acid Lares clay (table 9). The application of ground limestone (96 percent $CaCO_3$) to raise the soil pH produced an increase in the carotene content of the sweetpotatoes with the increased soil pH. From pH 4.5 to pH 7.0, the carotene content increased significantly 14 percent on a fresh-weight and 31 on a dry-weight basis.

When lime was used in combination with magnesium oxide (table 9, treatment 6), the carotene content increased over that for the treatment with magnesium oxide (table 9, treatment 5). A similar increase was not obtained when lime was used in combination with boron (table 9, treatment 9 minus treatment 8).

Significant increases were obtained in sweetpotato yields with the use of lime on the acid Lares clay (table 4) and with calcium sulfate (gypsum) in the Sabana Seca experiment (table 3). In most cases where the use of calcium gave significant yield increases, the carotene content increased appreciably.

Calcium had no significant influence on the starch content of the sweetpotatoes.

Magnesium

The carotene content of the sweetpotato was not influenced by applications of magnesium, nor were the yields affected. Ellis and Hamner (7) obtained no measurable effect on the carotene content of tomatoes grown in sand culture with wide variations in the supply of magnesium; Bernstein, Hamner, and Parks (3) noted no appreciable effect of magnesium on turnips grown in soils, but they did obtain a decrease in carotene content with deficient supplies of magnesium in sand culture.

Magnesium had no significant influence on the starch content of sweetpotatoes.

Boron

The use of boron produced no significant increases in the carotene content of the sweetpotato in the Corozal experiment at the original soil pH 4.5, or when lime was added to raise the pH to 6.0 (table 9, treatments 8 and 9). The Sabana Seca experiment exhibited significant yield increases due to boron without any effect on the carotene content (table 8). The Loiza experiments gave no significant differences in yield or carotene content attributable to boron.

Boron had no significant effect on the starch content of the sweetpotatoes.

Manganese and Copper

There were no indications that either manganese or copper significantly influenced the carotene content or yield of sweetpotatoes in the experiment on Cataño loamy sand (table 7).

DISCUSSION

The use of lime produced highly significant yield increases for sweetpotatoes in acid soils only (lower than pH 6). The addition of lime to the acid Lares clay made possible yields greater than those obtained with high rates of fertilizer applications without any lime. Even on the Sabana Seca sandy clay at pH 6.4, the use of a gypsum ($CaSO_4 \cdot 2H_2O$) gave significant yield increases. Calcium is essential for proper root development. The results of these experiments indicate that the use of lime on acid soils is of primary importance for obtaining high yields of sweetpotatoes in Puerto Rico. No fertilizer program should be undertaken for sweetpotatoes without due consideration for proper liming of the soil.

The correct balance of fertilizer nutrients is important for sweetpotatoes. The presence of excessive amounts of nitrogen produces lower yields. In the four experiments performed on three distinct soil textures, the application of 82 pounds of nitrogen was the maximum needed. In the Corozal experiment, there was sufficient soil nitrogen present to render the use of the 82 pounds of nitrogen excessive.

The yield increases attributable to potash applications were not consistent. In general, potash additions increased yields. Phosphorus applications generally produced no yield responses. In view of these results the recommendation of a 8–6–16 fertilizer at a rate of 600 pounds per acre is made for sweetpotatoes, instead of from 600–1,000 pounds of a 10–10–5 now in use.

It is of interest to note that the yields obtained in the four experiments compared favorably to those obtained in the United States. For the Cataño loamy sand, the highest yields obtained were 236 bushels[4] per acre of U.S. No. 1, No. 2, and Jumbo roots, 216 bushels per acre for Sabana Seca sandy clay loam, and 252 bushels per acre for Lares clay. The mean yields of sweetpotatoes per acre for the leading producing states of Louisiana and North Carolina are 115 and 95 bushels, respectively (1). Allowing for a cost of production per acre of sweetpotatoes of $100, a profit of over $150 per acre[5] could be realized with yields averaging that obtained in

[4] One bushel equals 55 pounds of sweetpotatoes.

[5] Calculated with sweetpotatoes selling at $2.50 per hundredweight.

the four experiments. With the proper utilization of variety, plant material, fertilizer, and agronomic practices, Puerto Rico is capable of producing ample yields of sweetpotatoes at a profit to the farmer.

The yields were influenced by time of planting. The Loiza I experiment produced higher yields than the Loiza II experiment. The longer days of the Loiza II experiment (March to July) with greater periods of sunlight gave lower yields than those obtained in the Loiza I experiment with its shorter winter days (October to February). Edmon *et al.* (6) reported similar results in yields attributable to planting dates. The carotene content was higher for the Loiza II experiment planted in the spring than the Loiza I experiment planted in the fall. Ellis and Hamner (7) obtained higher carotene content in tomatoes grown outdoors in summer than in those grown in the greenhouse in the winter.

SUMMARY

The effects of major and minor fertilizer elements on yield and carotene and starch content of sweetpotatoes were investigated, and the following conclusions were drawn:

1. Excessive quantities of nitrogen decreased sweetpotato yields. The use of 82 pounds of N per acre was the highest rate needed in the four experiments.

2. The use of phosphorus fertilizers with rates of applications as high as 200 pounds of P_2O_5 per acre had no effect on yields. With the use of 300 pounds P_2O_5 per acre, a yield increase was obtained only on the Lares clay at Corozal.

3. No consistent increases in yields were obtained with increasing potassium additions to the soil. There was a yield response to the potassium applications on the Cataño loamy sand of the Loiza I experiment. There was no significant response to potassium on Lares clay at Corozal, on Cataño loamy sand at the Loiza II experiment, or on the Sabana Seca sandy clay loam at Sabana Seca.

4. The yields of marketable sweetpotatoes were increased by the use of potassium on Cataño loamy sand at the Loiza I experiment.

5. Filter-press cake used alone gave low yields on Cataño loamy sand. The use of filter-press cake plus fertilizer gave good results both on the heavy Lares clay and on the Cataño loamy sand.

6. The yields of sweetpotatoes were measurably affected by the use of lime in the acid Lares clay. The application of lime to raise the pH gave increased yields with increased soil pH. The Sabana Seca experiment showed yield increases from the use of calcium sulfate (gypsum).

7. No consistent yield increases were obtained from the use of magnesium oxide.

8. The use of boron gave significant yield increases in the Sabana Seca and Corozal experiments, but not in the Loiza experiment.

9. No yield increases occurred with the use of manganese and copper.

10. There was no effect on starch content attributable to any major- or minor-element treatment.

11. The use of nitrogenous fertilizers influenced the carotene content of the sweetpotatoes; where nitrogen applications produced yield increases there were also increases in the carotene content.

12. Increases in carotene content were obtained with phosphorus only when the yields were significantly increased by addition of phosphorus.

13. No significant effect on carotene content was noted for potassium, except for a decrease in one experiment on a Cataño loamy sand.

14. The carotene content of sweetpotatoes was measurably affected by the use of calcium carbonate on acid soils (pH 4.5). Increases in pH were accompanied by increases in carotene content. In most cases where yields were increased by liming, the carotene content increased appreciably.

15. No responses were obtained from the use of boron, magnesium, copper, and manganese on the carotene content of sweetpotatoes. No effects were obtained on yields by use of these elements, except boron on a Sabana Seca sandy clay.

16. A recommendation is made for sweetpotatoes of 600 pounds of a 8-6-16 formula per acre.

17. The yields of sweetpotatoes compared favorably with yields for the leading sweetpotato-producing States of Louisiana and North Carolina.

18. Yields were increased by planting in the shorter days of winter as compared to the longer summer days. Carotene content, however, was increased with spring as compared to winter plantings.

RESUMEN

La investigación llevada a cabo con relación a los efectos de los elementos nutritivos, mayores y menores, que se encuentran en los abonos, sobre el rendimiento, y contenido de carotina y almidón de la batata, dió motivo para llegar a las conclusiones siguientes:

1. Las cantidades excesivas de nitrógeno aplicadas aminoró los rendimientos de la batata. Ochenta y dos libras por acre fué la proporción de nitrógeno más alta necesaria en los 4 experimentos.

2. El uso del fósforo, a razón de 200 libras de P_2O_5 por acre, no tuvo efecto sobre los rendimientos. Cuando se usaron 300 libras de P_2O_5 por acre en un suelo Lares arcilloso, se notó aumento en la producción del experimento en Corozal.

3. No se consiguíó aumento consistente en los rendimientos, cuando se aumentó progresivamente la potasa. Hubo aumento en el rendimiento con

las aplicaciones de potasa en los suelos lómicoarenosos del primer experimento en Loíza. Sin embargo, no resultó así en la arcilla Lares en Corozal, en la lómicoarenosa Cataño en el segundo experimento en Loíza, ni en el suelo arenoarcilloso lómico Sabana Seca.

4. Se obtuvo un aumento en los rendimientos de batatas propias para el mercado con el uso de las aplicaciones de potasa en el primer experimento en Loíza.

5. Los rendimientos fueron bajos cuando se usó la cachaza sola en el suelo lómicoarenoso Cataño.

6. Se afectaron marcadamente los rendimientos cuando se usó la cal en los suelos Lares arcillosos. La aplicación de la cal para subir el pH aumentó los rendimientos a la vez. En el experimento en Sabana Seca se registraron aumentos en el rendimiento con el uso.del sulfato de calcio (yeso).

7. No se obtuvo aumento consistente alguno por medio de las aplicaciones de óxido de magnesio.

8. Con el uso del boro, hubo aumentos significativos en los rendimientos de los experimentos en Sabana Seca y Corozal, pero no así en el experimento en Loíza.

9. No ocurrieron aumentos en los rendimientos cuando se usaron el manganeso y el cobre.

10. No hubo efecto alguno en el contenido de almidón que pudiera atribuirse a los tratamientos con elementos nutritivos mayores o menores.

11. El uso de los abonos nitrogenados influyó sobre el contenido de carotina en la batata. Cuando se registraron aumentos en los rendimientos, tribuibles al nitrógeno, también aumentó el contenido de carotina.

12. Se obtuvieron aumentos en el contenido de carotina atribuibles al fósforo en todos los casos en que los rendimientos aumentaron debido al uso de este elemento.

13. No hubo efecto significativo en el contenido de carotina cuando se aplicó potasa, excepto en un caso de disminución de la producción en un suelo Cataño lómicoarenoso.

14. El contenido de carotina se afectó marcadamento cuando se usó el carbonato de calcio en suelos ácidos (pH 4.5). Los incrementos en el pH fueron acompañados por los aumentos en el contenido de carotina. En muchos casos, cuando se aumentaron los rendimientos por medio de la cal el contenido de carotina también aumentó marcadamente.

15. El contenido de carotina aparentemente no se afectó cuando las aplicaciones de abono contenían boro, magnesio, cobre, o manganeso, Tampoco estos elementos tuvieron influencia alguna sobre los rendimientos, con excepción del boro en la arcilla arenosa Sabana Seca.

16. Se recomienda, para la batata, un abono con el análisis 8-6-16, a razón de 600 libras por acre.

17. Los rendimientos de la batata, en estos experimentos, comparó

favorablemente con los promedios de producción que se obtienen en los principales estados productores de batata, como lo son Louisiana y Carolina del Norte.

18. Los rendimientos fueron mayores cuando se sembró la batata durante los días cortos del invierno al compararse con la producción de las siembras hechas durante los días largos del verano. Sin embargo, se notó que el contenido de carotina fué mayor en la batata sembrada durante la primavera.

ACKNOWLEDGMENT

The authors wish to express their sincere appreciation to Mrs. M. del C. C. Fernández, Assistant Plant Physiologist, for supervision of the carotene and starch analyses; to Carlos Moscoso, Research Assistant in Plant Breeding, for cooperation in the Loiza I experiment; to Efraín Boneta, Assistant Plant Breeder, for technical assistance in the field experiments; to José Luis Vizcarrondo, Vocational Agriculture Instructor, Second Rural Unit, Medianía Alta, Loiza, José E. Martínez, Vocational Agriculture Instructor, Second Rural Unit, Sabana Seca, and R. Olivencia, Research Assistant in Agronomy at the Corozal Substation for their assistance in the field experiments; and to B. G. Capó, Assistant Director for Research, for valuable suggestions in the interpretation of the data.

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