THE INFLUENCE OF FERTILIZER RATIOS ON SWEET POTATO YIELDS AND QUALITY

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The sweet potato 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 sweet potato ranks as one of the more important crops of Puerto Rico. They are grown in all areas of the Island. From 1963 to 1965, the average production per year of the sweet potato crop in the Island amounted to 13,600 tons at a mean cash value of $1,570,000 annually Annon 1966. The majority of the crop grown receives little or no fertilizer and a minimum of care. In general, the sweet potato crops are grown on poor or marginal land with little attention to proper agronomic practices. Most fertilizer studies have been devoted to rates of fertilizer applied. The purpose of this work is to evaluate the major nutrient requirements (N-P-K) of the sweet potato in regard to ratio and balance of elements rather than absolute quantities of materials used. The effect of these ratios is developed for yields and quality of sweet potatoes as reflected in the starch and carotene content.

EXPERIMENTAL PROCEDURE

The investigation consisted of three experiments covering a range of soil textures from loamy sand to heavy clay. The Loiza experiment was established on Catano loamy sand, a well-drained coastal lowland soil, alkaline in reaction (pH 7.6), devoted mostly to coconuts, citrus, sweet potato, 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 three experiments utilized varying increments of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) to establish the various ratios given in Table 1.

Table 1. Fertilizer ratios and quantity applied

Fertilizer ratio	Fertilizer applied pounds per acre N	P	K	P_2O_5	K_2O
N : K					
0 : 2	0	88	166	200	200
1 : 2	82	88	166	200	200
2 : 2	165	88	166	200	200
2 : 0	165	88	0	200	0
2 : 1	165	88	83	200	100
2 : 2	165	88	166	200	200
2 : 3	165	88	249	200	300
P : N					
0 : 2	165	0	166	0	200
0.5 : 2	165	44	166	100	200
1 : 2	165	88	166	200	200
1.5 : 2	165	132	166	300	200

The experimental design for all 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 propagation material consisted of 40 vine cuttings (the first 18 inches of the sweet potato vine being used) per plot of U. P.R. No. 3, a Puerto Rican sweet potato variety. 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 sweet potatoes 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 (1941) and starch by the method of Nielson (1943).

RESULTS AND DISCUSSION

Yields

The same N : K ratio did not produce highest yields of sweet potatoes for each soil tested. Highest yields were associated with a 1 : 2 ratio for the Catano loamy sand and Sabana Seca sandy clay, whereas, the Lares clay gave highest yields with a 0 : 2 ratio (Table 2).

Table 2. The mean yields per acre of sweet potatoes as influenced by fertilizer ratios.

Fertilizer ratio	Mean yield per acre in hundredweights			
	Catano loamy sand	Sabana Seca Sandy clay	Lares clay	
N : K			pH 6.0[a]	pH 4.5
0 : 2	102	63	139	96
1 : 2	130	119	107	68
2 : 2	107	100	78	60
2 : 0	68	98	94	60
2 : 1	78	116	106	
2 : 2	107	100	78	
2 : 3	119	112	94	
P : N				
0 : 2	114	108	94	
0.5 : 2	116	112	88	
1 : 2	107	100	78	
1.5 : 2	89	113	119	
Least significant differences needed for comparison at :				
5-percent	27	15	24	24
1-percent	40	20	31	31

[a] Normal soil pH 4.5; soil raised to pH. 6 with 7,500 pounds $CaCO_3$ per acre.

The differences in the ratio responses may be in part due to the amount of soil nitrogen available to the plant apart from that supplied by the fertilizer. The Catano loamy sand and Sabana Seca sandy clay were low in available soil nitrogen and required some nitrogen fertilizer (100 pounds N per acre) for high yields of sweet potatoes. However, when more nitrogen was applied (200 pounds N per acre), the yields dropped off indicating that the excess nitrogen applied caused depressed root yields.

The relative supply of available nitrogen in the Lares clay must have been quite high as each nitrogen increment gave a yield decrease over the no-nitrogen level (Table 2). The field where the experiment was conducted was previously in pineapples. These had been heavily fertilized with high-nitrogen fertilizers at rates up to 400 pounds N per acre for several years. It is probable that the residual nitrogen was sufficient to give adequate nitrogen supplies for high root yields. The application of nitrogen fertilizer in this case only served to simulate vine growth and depress root yields. A white potato fertilizer experiment planted in this soil several years later failed to show any response to nitrogen fertilizer application Landrau *et al* (1955), Anderson (1936), Morgan (1939), and Stino (1953) all report limited to no response to nitrogen application on fertile soils or those soils which have been in cover crops before planting sweet potatoes. The influence of increasing nitrogen in the presence of a constant potassium supply is best shown by the Lares clay and Sabana Seca experiments (Table 1 and Figure 1). Where some nitrogen is needed yields increase until the nitrogen level has been satisfied. After this increasing nitrogen causes yield decreases (Sabana Seca clay). Where soil nitrogen supplies are adequate, further nitrogen applications cause yield decreases (Lares clay experiment). At pH 6, the decrease for added nitrogen is linear. At pH 4.5 the decrease in yield is curvilinear with a decreasing change in slope as we change from and N : K ratio of 1 : 2 to 2 : 2 (Figure 1). This may be in part due to the fact that all of the added fertilizer nitrogen was not available to the plant. Recent work has shown that ammonium sulfate, the nitrogen source used in this experiment, when applied at high rates increases soil acidity Samuel and Gonzalez-Velez (1962) to levels where conversion of ammonia to nitrate nitrogen is hindered. Thus the full effect of the added nitrogen on decreasing yield could not be realized because of the inefficiency of nitrogen conversion at low soil pH.

High nitrogen applications stimulate vine growth as well as root production Johnson and Ware (1948) However, when nitrogen needs are satisfied, the additional nitrogen goes into vine production. Should potassium levels in the soil be in limited supply, high nitrogen application can induce potassium deficiencies and limit root yields at the expense of vine production. It was felt that increasing the potassium levels in the presence of high nitrogen could offset the harmfull effect of the nitrogen on root yields. The Catano loamy sand experiment showed quite well the ameliorating influence of potassium in the presence of high nitrogen. Yields increased progressively from 68 hundred weights per acre for the 2 : 0 N : K ratio to 119 with a 2 : 3 N : K ratio (Table 2). When the potash values exceeded the nitrogen values, yields returned to almost optimum for this experiment.

The beneficial influence of increasing potassium in the presence of high nitrogen did not prove as significant for the Sabana Seca sandy clay and was non-existent for the heavier textured Lares clay (Table 2).

Muller *et. al.* (1963) suggested that for sugar beets the importance of the N : K ratio in the fertilizer treatment must always be considered in close connection with the absolute level of the nitrogen fertilizer treatment as well as nitrogen available in the soil. At high nitrogen levels, the positive effect of a wide N : K ratio on yield is all the greater. At a low nitrogen level a much narrower N : K ratio will be effective. From this it follows than an absolute value cannot be given for the physiological optimum of the N : K ratio but that this is determined by the level of the nitrogen available to the plant.

It should be mentioned here that the amounts of fertilizer used in establishing the fertilizer ratios were quite high for a root crop such as sweet potatoes. Normally, fertilizer rates for sweet potato in Puerto Rico do not reach above 80 pounds per acre for N and P_2O_5, respectively, and 150 pounds for K_2O. Such high rates as 165 pounds of N per acre may have prevented full expression of the N : K relationship for sweet potatoes.

Increasing phosphorus levels in the presence of a constant supply of nitrogen and potassium did not appear to cause a marked influence on sweet potato yields for the three experiments in general. The Catano loamy sand sweet potato yields decreased as the P N ratio changed from 0 : 2 to 1.5 : 2 (Table 2). The Lares gave a slight but not significant decrease as P N ratio rose from 0 : 2 to 1 : 2. At a 1.5 : 2 ratio, the yields increased significantly.

It appears that the responses obtained with a varying phosphate supply was due to the amount of phosphate rather than the phosphorus : nitrogen ratio. Phosphate was not needed in the very light textured Catano sand with its neutral pH of 7.6. A rate of 300 pounds P_2O_5 per acre only served to depress root yields. On the other hand, the acid Lares clay limited to pH 6 needed high rates of phosphate before responses could be obtained. The lower rates – 100 and 200 pounds of P_2O_5 per acre – may have been unavailable to the plant and response was only found at the highest phosphate fertilizer application.

Stino (1953) working with sweet potatoes on a fertile clay loam in Egypt found that increasing phosphate in relation to potash from O : 2 to 1.5 : 2 P : N ratio gave a limited and variable response in root yield but ever increasing vine yield. Cibes and Samuels (1957) obtained large increases in vine growth at the expense of root production under phosphorus deficiencies in sweet potatoes.

Carotene and Starch

The carotene content of the sweet potato increased with narrowing N :K ration when potash remained constant for Catano loamy sand and Sabana Seca sandy clay (Table 3). There was no significant change in carotene content for the Lares clay. There was no trend for change in carotene when potassium was increased at constant nitrogen levels with the exception of a significantly large accumulation of carotene for the 2 : 0 N : K ratio on the Catano loamy sand experiment.

Table 3. The carotene and starch content of sweet potatoes as influenced by fertilizer ratios.

Fertilizer ratio	Catano loamy sand		Sabana Seca sandy clay		Lares clay	
					pH 6.0[a]	pH 4.5
	Carotene Mg/g	starch Percent	Carotene Mg/g	Starch Percent	Carotene Mg/g	Carotene Mg/g
N : K						
0 : 2	80	55	101	61	126	107
1 : 2	87	55	124	63	124	120
2 : 2	105	57	125	64	124	116
2 : 0	133	55	129	67	117	
2 : 1	95	50	124	66	121	
2 : 2	105	57	125	64	124	
2 : 3	102	50	125	66	129	
P : N						
0 : 2	95	51	117	62	113	
0.5 : 2	86	55	123	68	118	
1 : 2	105	57	125	64	124	
1.5 : 2	103	58	122	66	133	
Least significant differences needed for comparison at :						
5-percent	23	8	15	7	16	16
1-percent	31	10	20	9	22	22

[a] Normal soil pH 4.5; soil raised to pH 6 with 7,500 pounds $CaCO_3$ per acre.

Carotene tended to increase in the sweet potato as phosphorus levels rose. The increase in carotene was significant as the P : N ratio narrowed from a 0 : 2 to 1.5 : 2 ratio (Table 3).

It is interesting to note that the average carotene values for all the experiments was much higher than those citied by Coshran (1942) for the yellow fleshed "Puerto Rico" varieties in North Carolina.

The starch content showed no significant differences due to any of the N : K or P : N ratios used. Anderson (1936) and Morgan (1939) failed to find any influence of fertilizer level on the starch content of sweet potatoes.

SUMMARY

Field experiments in a Catano loamy sand, Sabana Seca sandy clay, and Lares clay were performed to evaluate varying ratios of nitrogen and potassium, and nitrogen and phosphorus on yields of sweet potatoes and their starch and carotene content. The results were as follows :

For the less fertile loamy sand and clay loam there was an increase in yields with a change from a N : K ratio of 0 : 2 to 1 : 2, however, yields decreased again when the N : K ratio reach 2 : 2. The more fertile clay soil gave decreased yields as the N : K ratio changed from 0 : 2 to 2 : 2. This indicated that for soils with lower available nitrogen supplies a 1 : 2 ratio gave optimum yields. For soils with high available nitrogen care must be used in keeping a wide N : K ratio.

Results with varying P : N ratios were mixed.

The influence of fertilizer ratios on starch content was insignificant. However carotene tended to increase with a narrowing N : K ratio for the loamy sand, and the sandy clay soils. Carotene content of the sweet potato increased with increasing phosphorus application.

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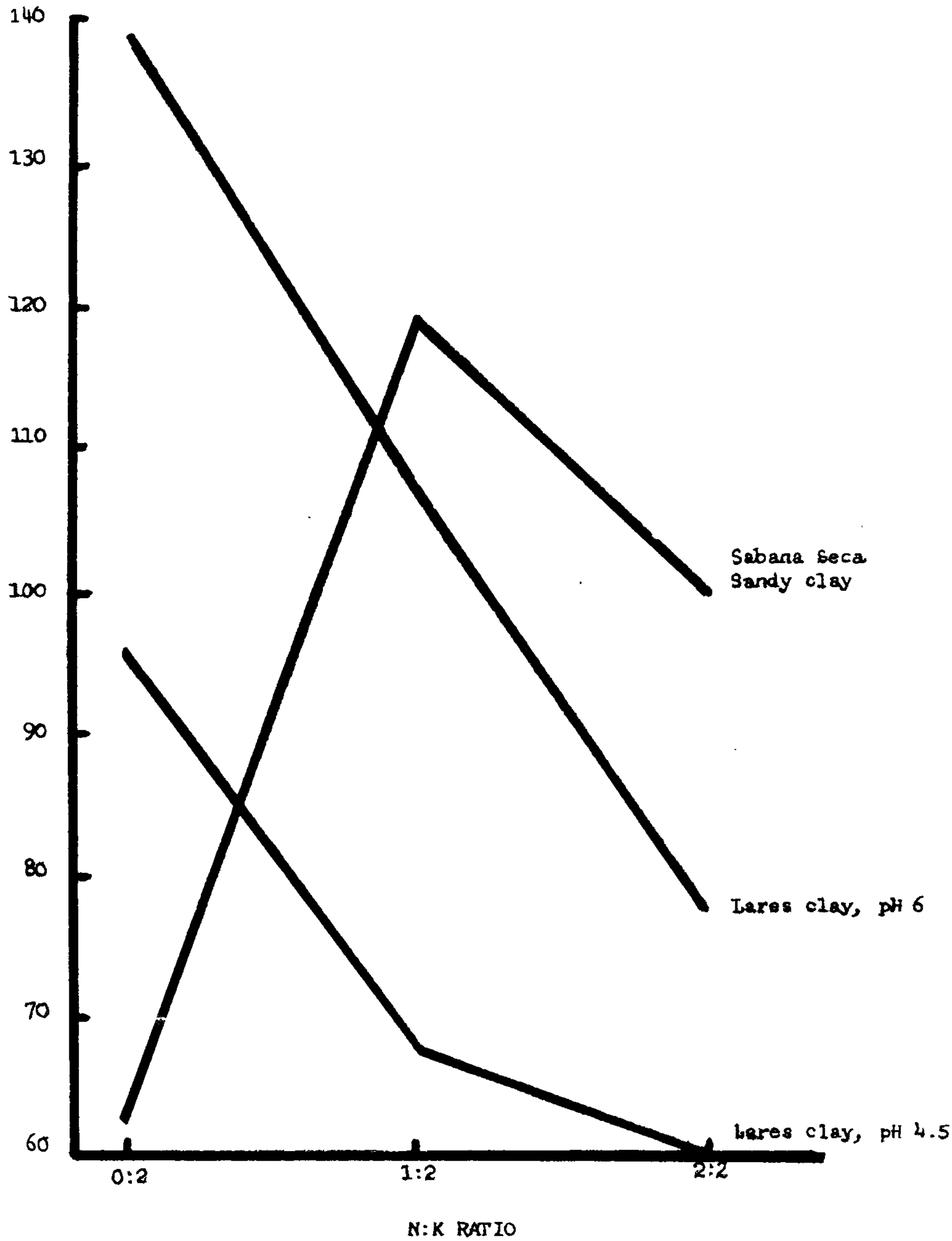

Fig. 1. - Influence of N:K ratio on Yields of sweet potatoes