Effect of Fertilizer N, P, K, Ca, Mg, and Si on Tomato Yields in an Oxisol[1]

R. Abrams, L. Cruz-Pérez, R. Pietri-Oms, and F. J. Juliá[2]

ABSTRACT

The effect of different levels of N, P, and K with and without Ca, Mg and Si, was studied on tomato cultivar Floradel at the Isabela Experiment Substation. The results obtained revealed that 224 Kg N and P/ha appear to be adequate for tomato production in a Coto clay, an Oxisol.

A fertilizer-yield equation was employed to describe the relationship between applications of nitrogen, phosphorus and potassium and the yield in metric tons/ha of marketable tomatoes, in an experiment conducted in the same soil. The equation fitted very well the yield data obtained with nitrogen and phosphorus, but not so well with that obtained with potassium. The poor fit of the potassium equation may have been due to the high level of potassium in the soil.

INTRODUCTION

Tomato is one of the most important vegetable crops grown in Puerto Rico. Its farm value in 1973 amounted to $1.2 million. The value of fresh tomatoes imported the same year was $3.7 million.

This Station in 1970 started a vegetable program to establish excellence in production goals through application of a complete package of technological practices. These practices include use of improved varieties, optimum planting dates, increased plant populations, application of required fertilizers, and proper control of pests such as weeds, insects, nematodes, and diseases.

This report furnishes data showing the effect of N, P and K with and without Ca, Mg, and calcium silicate on tomato yields in an Oxisol.

MATERIALS AND METHODS

Three experiments were conducted on a Coto clay (Typic haplorthox, clayey, kaolinitic, isohyperthermic) at the Isabela Agricultural Experiment Substation farm. Soil samples were taken for pH determination after initial preparation of the land.

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[2] Plant Breeder, Professor of Agronomy, former Professor of Soils, at present Chancellor, respectively, Mayagüez Campus, University of Puerto Rico; and Assistant Agronomist, Agricultural Experiment Station, Mayagüez Campus, University of Puerto Rico, Río Piedras, Puerto Rico.

EXPERIMENT 1

Fourteen fertilizer treatments and an unfertilized control were arranged in a randomized complete block design with six replications. The pH was raised in all experimental plots with calcium carbonate, except for those unfertilized and the calcium silicate treatments, in an amount equivalent to a 75-percent-base exchange capacity saturation. The calcium silicate treatments were incorporated in the soil with a rotavator and 84 kg/ha of magnesium were applied to all plots except those unfertilized.

Each plot consisted of four five-plant rows 121.9 cm apart, with plants set 91.4 cm within the row. Plot size was 4.88 m $\times$ 4.57 m. The two middle rows were harvested for marketable fruits.

EXPERIMENTS 2 AND 3

Experiment 2 consisted of nine fertilizer treatments. As in experiment 1, the pH in this experiment was raised in all plots by adding calcium carbonate in an amount equivalent to 75 percent of its exchange capacity.

In experiment 3 all the plots were treated with calcium silicate at the rate of 8.97 metric tons/ha, incorporating it in the soil with a rotavator.

The fertilizer treatments consisted of two levels each of N, P, and K determined on the basis of the results obtained in experiment 1. In experiments 2 and 3 the minimum application of nitrogen, phosphorus, and potassium were 224.2 N, 448.4 P, and 112.1 K kg/ha, except for the unfertilized control. Treatments in both experiments were arranged in complete randomized block designs with four replications. A total of 40 plants were planted per plot in four 10-plant rows 91.44 cm apart, with a distance of 60.96 cm between plants within the row. Plot size was 3.66 m $\times$ 6.10 m. The two middle rows were harvested for marketable fruits.

Tomato cultivar Floradel was used in all experiments. Diphenamide was applied as a pre-emergent herbicide at the rate of 13.34 kg/ha immediately after transplanting. Fertilizers were applied in one application in bands after the plants were set in the field. All plots were sprayed weekly during the growing period with insecticides and fungicides to control insects and diseases. Each experiment was harvested 10 times, the fruits divided into marketable fruits and culls.

RESULTS

EXPERIMENT 1

The yield responses of tomato cultivar Floradel to N, P, and K with and without Ca, Mg, and Si are presented in table 1 and graphically in figure 1.

Application of the first 112 kg of N/ha resulted in a marketable yield

TABLE 1.—*Effect of different levels of N, P, and K with and without Ca, Mg and calcium silicate on the yield of tomato cultivar Floradel*

Treatments N-P_2O_5-K_2O	Marketable yield	Total yield	Culls	Marketable fruits	Total fruits	Culls
Kg/ha	*Metric tons/hra*	*Metric tons/ha*	*Percent*	*Number*	*Number*	*Percent*
		Nitrogen				
0-224.2-224.2	10.60c**	12.85c	17.5	90596c	114799c	21.1
112.1-224.2-224.2	18.45b	21.85b	15.6	151244b	188606b	19.8
224.2-224.2-224.2	20.17ab	23.32ab	13.5	166526ab	201011ab	17.2
448.4-224.2-224.2	23.40a	26.40a	11.4	182861a	227928a	19.8
		Phosphorus				
224.2-0-224.2	13.27c	16.45c	19.3	114799c	153213c	25.1
224.2-112.1-224.2	16.50b	19.53b	15.5	136724b	171064b	20.1
224.2-224.2-224.2	20.17ab	23.32ab	13.5	166526ab	201011ab	17.2
224.2-448.4-224.2	21.35a	25.20a	15.3	170156a	211293a	19.5
		Potassium				
224.2-224.2-0	17.17ab	20.82ab	17.5	132495b	172570b	23.2
224.2-224.2-112.1	16.95ab	19.85ab	14.6	141869ab	176200ab	19.5
224.2-224.2-224.2	20.17a	23.32a	13.5	166526a	201011a	17.2
224.2-224.2-448.4	15.27b	18.35b	16.8	132949b	166218b	20.0
	N-P-K-Mg and 4.48 metric tons/ha $CaSiO_3$					
224.2-224.2-224.2	15.82NS	18.45a	14.2	139301NS	170156a	18.1
448.4-448.4-448.4	15.60NS	19.00a	17.9	129318NS	171518a	24.6
	N-P-K-Mg and 8.97 metric tons/ha $CaSiO_3$					
224.2-224.2-224.2	15.52NS	18.62a	16.6	129164NS	160473a	19.5
448.4-448.4-448.4	17.92NS	21.11a	15.1	156389NS	186945a	16.3

** Values in the same column followed by the same letter are not different at the 1-percent level.

increase of 7.85 metric tons/ha, equivalent to 74.06 percent of the yield of the no-nitrogen treatment. Increasing the rate from 112 to 224 kg/ha resulted in an increase of 1.72 metric tons/ha, and the highest level of nitrogen, 448 kg/ha, resulted in an increase of 4.95 metric tons/ha over the 112 kg/ha level. There was no significant difference in the marketable yield between the 224 and the 448 kg/ha of nitrogen applied.

This data reveals a response up to the maximum quantity of nitrogen applied, although no significant difference in yield was apparent between the two highest levels applied. The percentage of culls was reduced from 17.5 to 11.4 with an increase in the nitrogen level. The results obtained with respect to the number of fruits/ha follows a trend similar to that of the marketable yield.

P fertilization at the rate of up to 448 kg/ha resulted in a maximum marketable yield increase of 8.08 metric tons/ha or 60.89 percent over the yield of the no-phosphorus treatment. There was no significant difference in yield of marketable tomatoes between the 224 and 448 kg/ha treatments. Both the marketable yield and the total yield followed a trend very similar to that obtained with nitrogen.

No significant increase in tomato yield occurred as a result of K fertilization—marketable yield, total yield, percent culls and number of fruits.

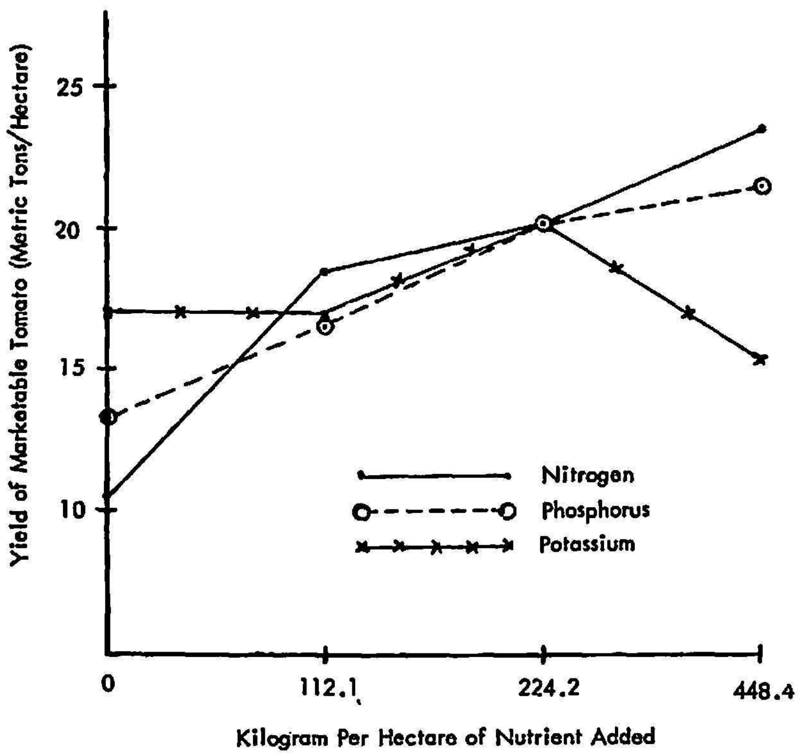

FIG. 1.—Response in yield of tomato to increasing levels of nitrogen, phosphorus and potassium.

Increasing the rates from 224 to 448 kg/ha resulted in a highly significant decrease of 4.9 metric tons/ha from the maximum yield of marketable tomatoes obtained with 224 kg/ha. Figure 1 shows graphically the small variation in response of marketable tomatoes to the different levels of potassium applied to the soil as compared with nitrogen and phosphorus.

The incorporation of 4.48 and 8.97 metric tons/ha of calcium silicate into the soil resulted in no significant increase in the yield of tomatoes at two levels each of N, P, and K. The yields obtained were lower than those from the same levels of N, P, and K without the silicate—marketable yield, total yield and number of fruits.

Capó's fertilizer-yield equation (2) was applied to the data presented in table 1 to determine its value in explaining the influence of nitrogen, phosphorus and potassium on the yield of tomatoes.

Capó's equation is:

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

where X is the quantity of fertilizer applied to the soil and Y is the yield

TABLE 2.—*Results obtained on fitting the fertilizer-yield equation to data of the nitrogen phosphorus and potassium experiment with tomato cultivar Floradel on a Coto clay, an Oxisol, at the Isabela Substation*

Fertilizer units[1]	Y[2]	Y[1 3]	Statistics of fitted equation
		Nitrogen	
0.00	10.60	12.06	A = 24.42
.10	18.45	16.33	B = 9.53
.20	20.17	21.12	C = .33
.40	23.40	23.27	C.D.[4] = .915
		Phosphorus	
0.00	13.17	13.17	A = 22.12
.10	16.50	16.67	B = 6.40
.20	20.17	20.08	C = .326
.40	21.35	21.36	C.D. = .9987
		Potassium	
0.00	17.17	16.44	A = 19.11
.10	16.95	18.49	B = 4.87
.20	20.17	19.08	C = .183
.40	15.27	15.54	C.D. = .665

[1] 1 unit = 1,121 kg per hectare.

[2] Y = observed mean marketable yield in metric tons per hectare.

[3] Y^1 = mean yield in metric tons/ha of marketable tomatoes estimated with the fitted equation.

[4] C.D. = coefficient of determination.

from the crop grown thereon. In that equation, A, B, and C are parameters. A represents the maximum yield obtainable in the given field with the optimum fertilizer application, C the optimum fertilizer application with regard to crop yield (under the prevalent climatic and other environmental conditions), and B may be assumed to be an index of the variability of crop yield as the quantity of the respective fertilizer material applied differs from the optimum application, C. The equation is symmetrical, being concave downwards for values of X near C.

Table 2 groups the data of the treatments with N as ammonium sulphate varying from 0 to 448.4 kg/ha. Figure 2,A gives an idea of the variation of marketable tomato yields with increasing applications of nitrogen. The graph shows how well the suggested fertilizer-yield equation fits the data of these experiments.

The statistics of the equation show that the estimated nitrogen *B* value is 9.53, and the coefficient of determination is 0.915, which gives a very good fit of the curve.

The estimated optimum nitrogen application for tomato is 330 kg/ha which agrees very closely with the nitrogen levels that produced the highest yields in these tests.

Table 2 also groups the data of the treatments with phosphorus as calcium

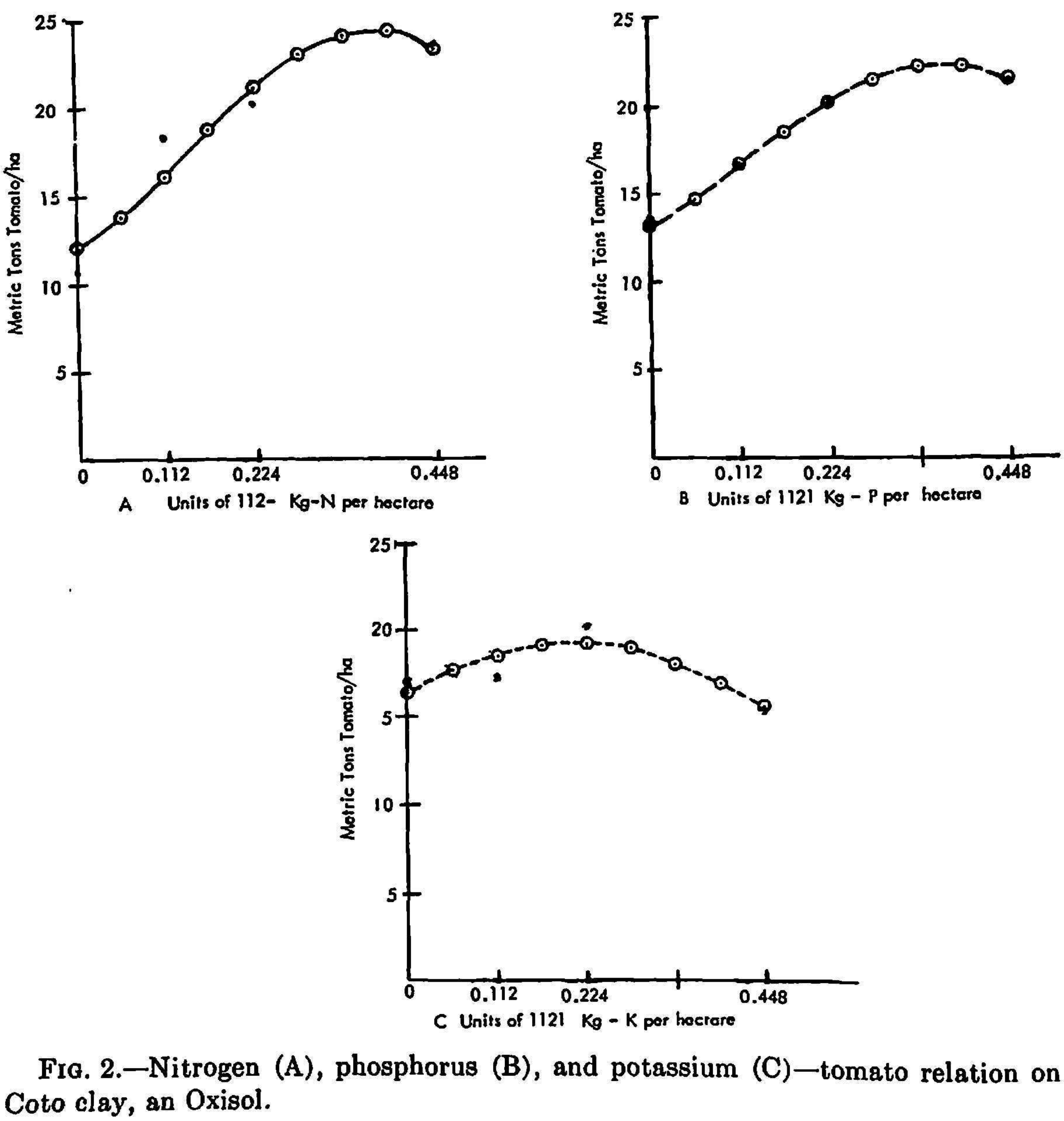

FIG. 2.—Nitrogen (A), phosphorus (B), and potassium (C)—tomato relation on Coto clay, an Oxisol.

superphosphate. Figure 2,B shows how well the fertilizer yield equation fits the yield of these experiments.

The estimated phosphorus *B* value for tomato is 6.40, lower than in the case of nitrogen and the coefficient of determination is 0.9987, a perfect fit of the curve.

The estimated optimum phosphorus application for tomato yield is 326.82 kg/ha, which also agrees very closely with the phosphorus level that produced the highest yields in these tests.

The data from the varying potassium applications is presented in table 2. Figure 2,C shows a poor fit of the fertilizer yield equation to the data of these experiments.

The estimated potassium *B* value is 4.87, and the coefficient of determination is 0.665 which shows that the equation does not fit the data sufficiently well.

The estimated *C* value was 183.16 kg/ha, which agrees very closely with the potassium level that produced the highest yields in this test. The lack of response to potassium fertilizers in this soil, as previously mentioned, is in line with the relatively low coefficient of determination (C.D.) of the potassium-fertilizer-yield fitted equation.

EXPERIMENTS 2 AND 3

Tables 3 and 4 present the data of the nine fertilizer treatments tested in two experiments, one with calcium carbonate and the other with calcium silicate. The results of these experiments show no significant differences in yield between the two levels each of N, P, and K applied to tomato cultivar Floradel. The results obtained in experiments 2 and 3 show that yieldwise, no other fertilizer treatment yielded more than that obtained with 224 kg/ha N, 448 kg/ha P and 112.1 kg/ha. From this point of view, these rates will be acceptable fertilizer applications for tomato production in Coto clay.

Corresponding yields with or without $CaCO_3$ and $CaSiO_3$ were about equal.

Total yields obtained in experiments 2 and 3 were higher than those obtained in experiment 1. Percentage of culls also was considerably higher, due perhaps to adverse climatic conditions, especially continuous rains during the harvesting season.

DISCUSSION

The amount of N required to produce maximum yields of marketable tomatoes was greater than recommended by Landrau and Samuels (3) or others generally employed in the region. In general, higher rates of N could

TABLE 3.—*Effect of different levels of N, P and K with and without Mg on the yield and number of fruits of tomato cultivar Floradel*

Fertilizer					Marketable yield	Total yield	Culls	Marketable fruits	Total fruits	Culls
N	P	K	Mg	Ca[1]						
Kg/ha				*Percent*	*Metric tons/ha*		*Percent*	*Number*	*Number*	*Percent*
0	0	0	0	0	9.03b[2]	12.67b	28.7	78717b	159039b	50.5
224.2	448.4	112.1	84.07	75	20.98a	33.29a	37.0	195730a	317852a	38.4
336.3	672.6	112.1	84.07	75	21.05a	30.62a	31.3	179395a	363681a	50.7
336.3	448.4	112.1	84.07	75	20.36a	29.68a	31.4	178741a	375705a	52.4
336.3	672.6	112.1	84.07	75	21.52a	34.41a	37.5	194686a	414728a	53.1
224.2	448.4	224.2	84.07	75	20.27a	34.17a	40.7	166063a	411324a	59.6
224.2	672.6	224.2	84.07	75	18.99a	29.41a	35.4	166327a	337136a	50.7
336.3	448.4	224.2	84.07	75	18.38a	37.01a	50.3	137308a	137308a	64.8
336.3	672.6	224.2	84.07	75	19.53a	29.84a	34.6	146380a	146380a	60.1

[1] pH adjusted with $CaCO_3$, except unfertilized control, to a 75 percent base exchange capacity saturation.

[2] Values in the same column followed by the same letter are not different at the 1-percent level.

TABLE 4.—*Effect of different levels of N, P and K with and without Mg, with calcium silicate incorporated to the soil, on the yield of tomato cultivar Floradel*

Fertilizer					Marketable yield	Total yield	Culls	Marketable fruits	Total fruits	Culls
N	P	K	Mg	Si						
Kg/ha				*Metric tons/ha*	*Metric tons/ha*		*Percent*	*Number*	*Number*	*Percent*
0	0	0	0	0	8.05b**	10.15b	20.69	70785.00b	134328.15b	47.30
224.2	448.4	112.1	84.07	8.97	19.98a	31.32a	36.21	166825.72a	397457.77a	58.00
336.3	672.6	112.1	84.07	8.97	18.38a	34.75a	47.11	174394.27a	415498.87a	58.02
336.3	448.4	112.1	84.07	8.97	18.11a	27.84a	34.95	155146.20a	351066.37a	55.81
336.3	672.6	112.1	84.07	8.97	21.84a	33.11a	34.13	185801.55a	418802.17a	55.63
224.2	448.4	224.2	84.07	8.97	20.65a	33.14a	37.69	196984.35a	432587.10a	54.46
224.2	672.6	224.2	84.07	8.97	19.15a	37.08a	48.35	177860.92a	469776.45a	62.13
336.3	448.4	224.2	84.07	8.97	20.63a	31.09a	33.64	203361.61a	384607.57a	47.12
336.3	672.6	224.2	84.07	8.97	18.59a	31.01a	40.05	161271.8a	393737.02a	59.04

** Values in the same column followed by the same letter are not different at the 1-percent level.

be used advantageously on this crop in this region, probably even more so if an increase in plant density per hectare is recommended.

A yield response from applied P was expected because of the natural acidity and high P fixation capacity of the Oxisols of the region. The yield increases from applied P also were of a higher level than obtained by Landrau and Samuels.

The lack of consistent increases in yields from applied K is in keeping with the results from other experiments conducted in the region with tomatoes by Landrau and Samuels (4), cabbage (3), cucumbers (6), sugarcane (5) and root crops. This same lack of response of Coto clay to potash fertilizer has also been observed in yam, tanier, field beans and cowpeas.[3]

High rates of applied K also can be detrimental to tomato yields. It appears that K requirement of tomatoes in Coto clay Oxisol is moderate to low. For practical purposes, however, 60 kg K/ha are recommended when exchangeable K is likely to be low.

RESUMEN

Se estudió el efecto de diferentes niveles de N, P, y K con y sin Ca, Mg y Si en la producción de tomates de calidad comercial del cultivar Floradel. La siembra se hizo en un suelo Oxisol en la Subestación Experimental de Isabela. Los resultados obtenidos indican que una aplicación de 224 Kg/Ha de nitrógeno y fósforo son suficientes para obtener la producción máxima de tomates de calidad aceptable para el mercado.

Al aplicar la ecuación abono-rendimiento se encontró que las aplicaciones óptimas de nutrimentos y las producciones máximas obtenibles así determinadas se ajustaron mejor a los datos obtenidos en los experimentos con nitrógeno y fósforo, que en el caso del potasio. El ajuste relativamente impreciso de la ecuación de potasio puede deberse al alto nivel de potasio en el suelo.

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