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FERTILIZER EFFECTS ON PLANT COMPOSITION

Influence of K, Ca, and Mg Application on Acid Content, Composition, and Yield of Tomato Fruit

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Two field experiments involving various rates of K, Ca, and Mg were conducted to determine the influence of these cations on titratable acidity, total acidity, acid composition, and yield of tomato fruit. Potassium applications induced significant increases in titratable acidity, total acidity, citric acid content, and tomato yields. Neither Ca nor Mg applications produced significant differences in acid content or yield of fruit. Acids normally present as salts were converted to the hydrogen form by passing filtered tomato puree through the cation exchange resin, Dowex 50. Titratable and total acidity were determined by titrating aliquots of filtered tomato puree before and after resin treatment, respectively. Ion exchange and partition chromatographic techniques were employed to determine acid composition.

PATTERSON (*9*) in 1890 reported that K fertilization tended to produce tomato fruit with less sugar and more acid than where no K had been applied. Lee and Sayre (*7*) presented evidence which indicated an inverse relationship between soil moisture and acidity levels in tomato fruit. They further noted that the acid content of tomatoes varied during the season. In 1946, Lee and Sayre (*8*) reported that K fertilizers produced tomato fruit that were higher in total acid than where no K was applied. This was noted particularly where relatively large amounts of K were used.

Carangal *et al.* (*3*) observed that variations in the content of individual acids in tomato fruits grown under greenhouse conditions were not caused by an individual ion, such as NO_3^-, NH_4^+, or K^+, but rather by an interaction of ions.

Iljin (*5*) observed that plants affected with lime-induced chlorosis contained more citric acid than healthy plants. The amount was directly correlated with severity of the disease. Large increases in citric acid concentration were noted before symptoms of chlorosis became visible.

Bear and Toth (*1*) concluded that conditions approach optimum for cation nutrition of alfalfa when 65% of the exchange complex is occupied by Ca, 10% by Mg, 5% by K, and 20% by H. Lambeth (*6*) obtained similar results with a variety of vegetable crops.

The objective of this study was to determine the influence of K, Ca, and Mg applications on yield, titratable acidity, and acid composition of tomato fruit.

Experimental

Experiment 1. A split plot factorial experiment with 12 treatments and three replications was established on a Freehold sandy loam soil at Riverton, N. J. Each plot consisted of five rows, 5 feet apart and 30 feet long. Tomato plants were set 3 feet apart in the rows. Main plot treatments were 0 and 930 pounds of Ca per acre. Three rates of K application and two of Mg were superimposed in random arrangement on the main plots. Rates of K and Mg were 0, 166, and 332 pounds per acre and 0 and 152 pounds per acre, respectively. The Ca, Mg, and K were applied as calcite limestone, kieserite, and muriate of potash, respectively.

The Ca, Mg, $^1/_3$ of the N, and $^1/_2$ of the K were broadcast and thoroughly disked before planting. The remaining portion of the K and N were sidedressed. No P was applied because laboratory soil tests indicated a high level in the plot area. The pH of the soil was 5.9. The soil contained 477, 58, and 86 pounds per acre of Ca, Mg, and K, respectively, as determined by methods outlined by Hester and Shelton (*4*).

Southern grown Improved Garden State plants were set in the field on May 14 under ideal conditions. Ripe tomatoes were picked at 10-day intervals. Fruits from the August 24 picking were pureed and canned for subsequent analysis. Acid anions in the puree samples were separated by partition chromatographic techniques (*2*).

Experiment 2. A split factorial design with 18 treatments and four replications was used. Plots consisted of four rows spaced 5 feet apart and 30 feet long. Plants were set $2^1/_2$ feet apart in the row. The main plots included two rates of Mg. Sub-plots were made up of three rates of K and three of Ca and were superimposed in random arrangement on the main plots.

The K, Mg, and Ca treatments were based on the cation exchange capacity (C.E.C.) of the soil and its initial percentage saturation with these cations including H. The C.E.C. of the Evesboro sandy loam soil at Riverton, N. J., averaged 4.3 meq. per 100 grams as determined by the method of Peech *et al.* (*10*). The pH of the soil was 5.3. The initial percentages of K, Ca, Mg, and H on the exchange complex were 1.9, 26.1, 5.8, and 66.2%, respectively. The applications of 150 and 365 pounds per acre were calculated to adjust the C.E.C. from 1.9% K to 6 and 12%, respectively. Similarly, Ca was applied at rates of 600 and 1650 pounds per acre which were equivalent to increasing the exchangeable Ca from 26.1 to 61 and 122%, respectively. Magnesium applications of 24 and 108 pounds per acre were made to regulate exchangeable Mg levels at 8 and 16%, respectively.

Calcium as calcite limestone was

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Table I. Influence of K, Ca, and Mg Treatments on Tomato Fruit Yield and Acidity of Filtered Puree (Experiment 1)

Treatment, Lb./Acre	Yield, Tons/Acre	Titratable[a] Acidity	Total[a] Acidity
K 0	9.4	48	95
166	11.7	58	113
332	13.7	61	134
L.S.D. 5%	2.4	2.0	12
1%	3.3	2.8	16
Ca 0	11.5	56	115
930	11.7	55	114
L.S.D.	N.S.	N.S.	N.S.
Mg 0	11.4	55	114
152	11.7	56	114
L.S.D. 5%	N.S.	N.S.	N.S.

[a] Meq./liter of titratable and total acidity based on titration of 10 ml. of filtered puree with NaOH to a phenol red end point before and after resin treatment, respectively.

Table II. Influence of K Treatments on Content of Individual Acids in Filtered Tomato Puree (Experiment 1)

Treatment, Lb./Acre	Lactic Acetic Fumaric	Pyrrolidone Carboxylic	Malic	Citric	Phosphoric	Hydrochloric Sulfuric	Galacturonic
				Meq./Liter			
0	4.5	10.7	6.9	48.9	6.4	8.0	5.4
166	4.3	9.1	8.2	59.8	9.5	11.0	5.3
332	4.5	10.2	9.4	71.8	12.9	15.6	6.1
L.S.D. 5%	N.S.	1.0	1.8	8.2	3.4	3.6	N.S.
1%		1.4	2.4	11.1	4.6	5.0	
				Percentage of Total Acidity			
0	4.8	11.2	7.3	50.9	7.7	8.3	5.6
166	3.9	8.1	7.3	53.0	8.5	10.5	4.8
332	3.4	7.6	7.1	53.3	9.9	11.5	4.5
L.S.D. 5%	0.7	1.0	N.S.	N.S.	N.S.	2.4	0.8
1%	1.0	1.4				3.3	1.0

Table III. Influence of K, Ca, and Mg Treatments on Tomato Fruit Yield and Acidity of Filtered Puree (Experiment 2)

Treatment, % Exch. Cation	Yield, Tons/Acre	Titratable Acidity	Total Acidity
		Meq./Liter	
K 2	20.7	44.7	96.5
6	23.2	53.7	117.2
12	20.7	59.2	130.9
L.S.D. 5%	1.7	3.7	6.4
1%		5.0	8.7
Ca 26	21.5	52.3	113.8
61	21.8	52.2	116.4
122	21.4	52.1	114.3
L.S.D. 5%	N.S.	N.S.	N.S.
Mg 8	20.9	60.0	...
16	22.2	60.0	...
L.S.D. 5%	N.S.	N.S.	

Table IV. Effect of K Treatments on Content of Individual Acids in Filtered Tomato Puree (Experiment 2)

Treatment, % Exch. Cation	Acetic Lactic Fumaric	Pyrrolidone Carboxylic	Malic	Citric	Phosphoric	Hydrochloric	Sulfuric	Galacturonic
				Meq. per Liter				
K 2	1.3	6.6	6.6	51.9	5.4	5.5	6.5	4.4
6	2.2	6.3	5.7	61.9	5.8	14.6	7.5	4.9
12	1.9	8.4	5.4	68.1	7.3	18.6	8.3	5.0
L.S.D. 5%	0.7	1.3	1.1	3.4	N.S.	1.7	0.8	N.S.
1%		1.7	N.S.	4.6	N.S.	2.3	1.1	N.S.
				Percentage of Total Acidity				
K 2	1.4	6.9	6.8	53.9	5.4	5.7	6.8	4.6
6	1.9	5.4	4.8	52.8	4.9	12.6	6.5	4.2
12	1.4	6.4	4.1	52.0	5.6	14.0	6.1	3.8
L.S.D. 5%	0.4	0.8	0.7	N.S.	N.S.	1.5	N.S.	N.S.
1%		1.1	0.9	N.S.	N.S.	2.0	N.S.	N.S.

Table V. Influence of K and Ca Treatments on Concentrations of Inorganic Cations Associated with Acid Anions in Filtered Tomato Puree (Experiment 2)

Treatment, % Exch. Cation	K	Ca	Na	Mg	Cation[a] Sum	K,[b] %
			Meq./Liter			
K 2	51.45	2.93	1.04	6.21	61.63	84
6	67.60	3.47	1.11	6.53	78.71	86
12	87.33	3.44	1.43	8.00	100.20	87
L.S.D. 5%	12.65	N.S.	0.18	N.S.		
1%	17.65	N.S.	0.25	N.S.		
Ca 26	73.83	3.87	1.31	6.33	85.34	87
61	72.20	3.40	1.11	6.72	83.43	87
122	60.30	2.57	1.15	7.70	71.72	84
L.S.D. 5%	N.S.	0.77	N.S.	N.S.		
1%	N.S.	1.05	N.S.	N.S.		

[a] Removed from puree by ion exchange when converting anions to hydrogen form.
[b] K percentage of cation sum.

broadcast and disked deeply into the sandy soil before plowing and 1 month before planting. Southern grown Improved Garden State plants were set on April 29 with starter solution. All K, Mg, and $^{2}/_{3}$ of the N were sidedressed in two applications, one in early May and one in early June. The last sidedressing consisting of N only was applied in early July. Potassium, Mg, and N were applied as muriate of potash, kieserite, and ammonium nitrate, respectively.

Titratable acidity was determined at each picking which occurred at 7- to 10-day intervals. Twenty-five pounds of fruit, from each plot at the August 30 picking, were canned for subsequent acid separation as in Experiment 1.

Cations removed from filtered puree by the cation exchange resin were eluted from the resin with dilute HCl. Excess HCl was removed by evaporation, and organic matter was wet ashed with nitric and perchloric acids. Calcium, K, and Na were determined by flame photometry. Magnesium was determined by the thiozole yellow method outlined by Toth (*12*).

Results

Experiment 1. Increases in tomato fruit yields resulted from the application of K. Each increment of applied K increased the titratable and total acidity of the filtered tomato puree (Table I). The percentage increases in titratable and total acidity between the 0 and 332 pounds per acre rates of applied K were 27 and 41%, respectively. Titratable acidity made up approximately 49% of the total acidity. No differences in yield or acidity of fruit were noted due to Ca or Mg treatment.

Partition chromatographic separation of acids in filtered tomato puree showed that citric acid comprised about 53% of the total acidity (Table II). Potassium treatments induced highly significant increases in the citric acid content by 24 and 47% at the low and high rate of application, respectively. Increases in the citric acid content were responsible for the increases in titratable acidity noted above. The Ca and Mg treatments failed to influence the content of individual acids except that increasing rates of Ca decreased the malic acid content. Values for the influence of Ca and Mg treatments on individual acids may be calculated by determining the means of the three K treatments for each acid on a meq. per liter or percentage basis.

Rice and Pederson (*11*) reported pyrrolidone carboxylic to be present in tomato puree as an artifact—i.e., it developed during heat processing and storage. The pronounced increase in the amount of inorganic acid anions (hydrochloric, sulfuric) was believed to be primarily a result of the chloride ions from the muriate of potash.

When the concentration of chloride exceeded 8 meq. per liter of filtered puree, there was incomplete separation of phosphate and chloride. Thus, in Experiment 1, the fraction that contained phosphate also contained some chloride.

Experiment 2. A significant increase in tomato fruit yield occurred when the level of exchangeable K on the soil cation exchange complex was increased from the initial 2% level to 6%. None of the Ca or Mg treatments influenced tomato yield (Table III).

Highly significant increases were noted in titratable and total acidity between the 2 and 6, and the 6 and 12% levels of exchangeable K. The difference of 14.5 meq. per liter represented a 32% increase. A similar percentage increase was noted for total acidity. An average of approximately 46% of the total acidity was present in a titratable form for all three levels of exchangeable soil K.

No trends or significant differences in titratable or total acidity were noted between any Ca or Mg treatments.

The increase in citric acid from the 2 to 12% level represented an over-all increase in citric acid of 31% (Table IV). Citric acid comprised 53% of the total acidity regardless of pronounced changes in titratable or total acidity.

The hydrochloric acid content increased from 5.5 to 18.6 meq. per liter, a 238% increase, as the exchangeable K was increased from the initial 2% level to 12%. This acid is normally present as a salt since the pH of tomato puree is about 4.5.

As the rate of applied K increased, the malic acid content decreased, which is opposite to the trend noted in Experiment 1. In most cases, however, the concentration of pyrrolidone carboxylic, phosphoric, galacturonic, and sulfuric acids tended to increase as the level of exchangeable K increased.

The cations listed in Table V were removed from filtered puree by ion exchange when converting acid anions to the hydrogen form. Potassium comprised 84 to 87% of the total cations regardless of K or Ca treatments. Neither Ca nor Mg was influenced by the K treatments.

Calcium treatments had no influence on the content of K, Na, or Mg removed by ion exchange from tomato puree. The reason for the decrease in Ca content between the 26 and 122% equivalent levels of exchangeable Ca is not known.

Conclusions

Data from two experiments indicate that K nutrition exerts a strong influence on acid metabolism in tomato fruit. Pronounced changes in titratable acidity were primarily associated with changes in the citric acid content. Citric acid made up 53% of the total acidity in the Improved Garden State variety. Potassium comprised about 86% of the total cations directly associated with acid anions in the filtered puree.

Changes in concentration of acids other than citric, except hydrochloric, were less pronounced and did not always follow major changes in titratable acidity. In tomato puree, at a pH of about 4.5, the chloride ion was present as a salt and contributed little to the titratable acidity.

In Experiment 2, no yield increases were noted beyond the 6% exchangeable K treatment.

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