Influence of Calcium Nutrition on Bacterial Canker of Resistant and Susceptible Lycopersicon spp.

R. L. Forster and E. Echandi

Graduate Research Assistant and Professor, respectively, Department of Plant Pathology, North Carolina State University, Raleigh, 27607.

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ABSTRACT

Bacterial canker-resistant *Lycopersicon hirsutum* (P.I. 251305), *L. esculentum* (P.I. 340905), and *L. esculentum* × *L. pimpinellifolium* 'MR 4' and 'Bulgaria 12', and susceptible *L. esculentum* ('Manapal') and *L. peruvianum* (P.I. 251306) were grown from seed in a phytotron. Transplanted seedlings received nutrient solutions containing 55, 150, and 300 μg/ml calcium, respectively. Five-week-old plants were inoculated by stabbing the stem above the cotyledonary node with a dental root canal file dipped in a *Corynebacterium michiganense* suspension containing 10^7 cells/ml. Disease severity was inversely correlated with the concentration of calcium in the nutrient solution and in petiole and stem tissue. The (Ca + Mg)/(Na + K) ratio was negatively correlated with disease rating of individual plants.

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High calcium content in plant tissue of various crops has been associated with increased resistance to disease (1,6,7). However, the effect of calcium on resistance to bacterial canker of tomato has not been reported. This work was designed after observing that applications of $CaCO_3$ to tomato plants depressed bacterial canker severity and was undertaken to determine whether calcium nutrition influences bacterial canker in resistant and susceptible tomato accessions.

MATERIALS AND METHODS.—Plants of bacterial canker-resistant *Lycopersicon hirsutum* Humb. and Bonpl. (P.I. 251305), *L. esculentum* Mill. (P.I. 340905), and *L. esculentum* × *L. pimpinellifolium* 'MR 4' and 'Bulgaria 12', and of susceptible *L. esculentum* 'Manapal' and *L. peruvianum* Mill. (P.I. 251306) were grown from seed in Jiffy Mix (W. R. Grace Co., Travelers' Rest, S. C.) in controlled environment rooms (CER's) (3) in the North Carolina State University phytotron. Prior to transplanting, all seedlings received a standard phytotron nutrient solution (5) five days a week and deionized water two days a week. They were transplanted into sterilized coarse sand in 10-cm diameter plastic pots after 12 days of growth and separated into three groups. One group continued receiving phytotron nutrient solution (55 μg/ml calcium) and the other groups received nutrient solutions containing 150 and 300 μg/ml calcium prepared by supplementing the phytotron nutrient solution with $CaCl_2$. All groups received their respective nutrient solution five days a week and deionized water two days a week throughout the duration of the experiment. When plants were 32 days old, the CER temperature was changed to 24/18 C. Treatments were randomized in a split plot design with calcium concentration the main treatment, and accessions the subtreatments.

Stem inoculation with 10^7 cells/ml of *C. michiganense* (isolate CM7A) was after the manner described previously (3). Noninoculated control plants of each accession were maintained in the experiment. Disease ratings of wilt, taken 30 days after inoculation, were made on each plant when the sand was near field capacity and were based on a subjective scale published previously (3).

After the last disease rating, portions of plants were collected for elemental analyses. Petioles and stems from the midsections of two plants per treatment were dry-ashed separately at 490 C, and analyzed for calcium, magnesium, sodium, potassium, iron, zinc, and copper by atomic absorption spectrophotometry with a Perkin-Elmer Model 306 atomic absorption spectrophotometer.

RESULTS.—Wilt symptoms first appeared nine days after inoculation in the lower leaves of Manapal and *L. peruvianum* that received 55 μg/ml calcium. Two days later wilt symptoms appeared in these accessions that received 150 μg/ml calcium and in Bulgaria 12 that had received 55 and 300 μg/ml calcium.

Thirty days after inoculation, the mean disease rating of plants that received 55 μg/ml calcium was significantly higher ($P = 0.05$) than that for plants that received 300 μg/ml calcium (Table 1). This relationship was maintained for all accessions except Bulgaria 12 (Table 2). The disease rating of P. I. 340905 increased between 55 μg/ml and 150 μg/ml calcium levels, but at 300 μg/ml calcium it dropped lower than at 55 μg/ml.

A high calcium content in the nutrient solution was directly related to a high calcium content in petioles and stems (Table 1). This indicates that high calcium in the nutrient solution is related directly or indirectly to the low disease ratings. Sodium and potassium content of petioles and stems was inversely related to calcium content of the nutrient solution and plant tissue, whereas magnesium content in the tissue did not differ significantly (Table 1).

The (Ca+Mg)/(Na+K) ratio in plant tissue was inversely correlated with disease rating. However, the coefficient of determination (R^2) of (Ca+Mg)/(Na+K) indicates that only 23% of the variation in disease rating was associated with the variation in the ratio. Zinc and copper content in plant tissue decreased with high calcium nutrition. Iron content in plant tissue was variable relative to calcium nutrition. Zinc and potassium had significant correlation coefficients (0.42 and 0.53, respectively) when compared individually with disease ratings. When the seven elements were compared collectively to disease rating, 44% of the variation in disease rating was associated with the variation of the seven elements. Clearly, other factors relating calcium in plant tissues to disease rating remain to be elucidated.

DISCUSSION.—The (Ca+Mg)/(Na+K) ratio was studied because an earlier report (4) indicated that calcium supply influenced uptake of other cations as well

TABLE 1. Relationship of calcium in the nutrient solution to severity of bacterial canker of tomato and to plant tissue content of various elements

Calcium in nutrient solution ($\mu g/ml$)	Disease rating[a]	Element[b]							Ratio
		Ca	Mg	Na	K	Zn	Cu	Fe	(Ca + Mg)
		Content in tissues (%)				Content in tissues ($\mu g/ml$)			(Na + K)
55	3.4	1.6	0.31	1.5	5.0	43	16	170	0.3
150	2.8	2.8	0.27	1.0	3.4	29	19	89	0.8
300	2.5	3.7	0.25	0.6	3.8	22	11	151	1.0
$LSD_{0.05}$	0.6	1.0	0.10	0.3	1.2	19	7	59	0.3

[a]Disease rating scale: 0 = no wilting; 5 = entire plant wilted. Numbers are means of individual disease ratings of the 48 plants that received a given level of calcium for 30 days after inoculation.

[b]Numbers are means of 23 observations per treatment made on dry-ashed petioles and stems collected from midsections of plants 30 days after inoculation.

TABLE 2. Effect of calcium in the nutrient solution on severity of bacterial canker in tomato accessions[a]

Calcium in nutrient solution ($\mu g/ml$)	Bacterial canker severity rating[b] — Tomato accession or cultivars:					
	Lycopersicon hirsutum	Bulgaria 12	P.I. 340905	MR4	Manapal	*Lycopersicon peruvianum*
55	3.1	3.5	2.2	3.1	4.6	3.6
150	2.9	3.2	2.6	1.9	3.0	3.4
300	2.1	3.6	1.5	1.8	3.2	2.9
$LSD_{0.05}$ = 1.7 for accessions within concentrations						

[a]Five-week-old plants were inoculated using 10^7 cells/ml and incubated at 24 C day and 18 C night temperatures.

[b]Disease rating scale: 0 = no wilting; 5 = entire plant wilted. Numbers in table are means of disease ratings from eight plants per treatment made 30 days after inoculation.

as calcium. Sherwood and Huisingh (6) showed that this ratio was more closely related to alfalfa resistance to *Ditylenchus dipsaci* than was calcium. In our study, increased calcium nutrition also increased the (Ca+Mg)/(Na+K) ratio in plant tissues, and the ratio was more closely related to disease severity than was calcium content. It has been postulated by Bateman and Lumsden (1) and Edgington and Walker (2) that high calcium in plant tissues forms calcium complexes with pectic substances that account for resistance to *Rhizoctonia solani* and *Fusarium oxysporum* f. *lycopersici*, respectively.

Calcium content of tissues was not an absolute determinant of disease severity. For example, disease ratings were lower in bacterial canker-resistant MR-4 which contained a mean of 2.2% calcium than in bacterial canker-susceptible Manapal or *L. peruvianum* that contained 2.8% calcium.

A practical application of the results of this work might be the use of heavier calcium applications to the soil. Many western North Carolina tomato soils are low in calcium, and heavier applications of lime than are made now might be beneficial in reducing the severity of bacterial canker.

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