Influx of water is the source of turgor pressure placed on the fruit epidermis, leading to CC. During fruit development many tomato cultigens form an abscission zone in the pedicel. This jointed condition potentially regulates the flow of water into and out of the fruit during maturation (McCollum and Skok, 1960). If an abscission zone is not formed, as in jointless pedicels, water influx to the fruit may not be restricted during maturation, resulting in great turgor pressure being placed upon the epidermis during periods of high rainfall. There was a tendency for fruit with jointless pedicels tended to have higher incidences of CC than plants producing fruit with jointed pedicels. However, significant differences were found for only one of four generations tested. Comparison of two near isogenic lines, differing by jointed versus jointless condition, indicated that the jointed condition by itself is not sufficient to significantly increase resistance to CC.

Cuticle cracking in tomato is reported to occur most often at the MG stage of development (den Outer and van Veenendaal, 1987; Young, 1947), though data were not given. Our data support reports of CC occurring most often at MG, but the first appearance of CC is also possible during BR and TR stages. Severity of CC of an individual fruit may increase by up to 5 rating points, effectively changing from 12.5% of the fruit shoulder covered with cracks to 100% of the shoulder affected. In a MG harvest system, growers try to harvest before predicted rainfall if possible. Our results support this practice since fruit at the MG stage are vulnerable to CC. However, a careless harvest where numerous MG tomatoes are left on the vine would increase the vulnerability of these fruit to CC because of the reduced fruit load. Leaving fruit on the plant to ripen beyond MG following a significant rainfall (Emmons and Scott, 1997a) could increase the incidence and severity of CC thus decreasing marketable yield. This is an important consideration for growers considering vine-ripe harvesting. Varietal tolerance to CC would be more important than in the MG harvest system.

Literature Cited

Considine, J. and K. Brown. 1981. Physical aspects of fruit growth. Theoretical analysis of distribution of surface growth forces in fruit in relation to cracking and splitting. Plant Physiol. 68:371-376.

den Outer, R. W. and W. L. H. van Veenendaal. 1987. Anatomical investigation of tomatoes with swelling cracks. Groeten en Fruit 42(46):40-42.

Ehret, D. L., T. Helmer and J. W. Hall. 1993. Cuticle cracking in tomato fruit. J. Hort. Sci. 68(2):195-201.

Emmons, C. L. W. 1996. Characterization and determination of the inheritance of cuticle cracking (rain check) in the cultivated tomato (*Lycopersicon esculentum*, Mill.). PhD Diss., Univ. of Florida, Gainesville.

Emmons, C. L. W. and J. W. Scott. 1997a. Environmental and physiological effects on cuticle cracking in tomato (*Lycopersicon esculentum*, Mill.). J. Amer. Soc. Hort. Sci. (in review).

Emmons, C. L. W. and J. W. Scott. 1997b. Ultrastructural and anatomical factors associated with resistance to cuticle cracking in tomato (*Lycopersicon esculentum*, Mill.). Int'l. J. Pl. Sciences (in review).

Faust, M. and C. B. Shear. 1972. Russeting of apples, an interpretative review. HortScience 7:233-235.

Frazier, W. A. 1936. Further studies on the occurrence of cracks in tomato fruits. Proc. Amer. Soc. Hort. Sci. 33:536-541.

Frazier, W. A. 1937. Type and severity of fruit cracking in tomato varieties. Proc. Amer. Soc. Hort. Sci. 34:536.

Hayman, G. 1987. The hair-like cracking of last season. Grower 107(2):3-5.

Hochmuth, G. J., D. N. Maynard and M. Sherman. 1989. Tomato production guide for Florida. Fla. Coop. Ext. Circ. 98C:4-11.

Janse, J. 1985. Shrinkage cracks in tomatoes. Groeten en Fruit 40(19):45-47.

Koske, T. J., J. E. Pallas and J. B. Jones. 1980. Influence of ground bed heating and cultivar on tomato fruit cracking. HortScience 15:760-762.

McCollum J. P. and J. Skok. 1960. Radiocarbon studies on the translocation of organic constituents into ripening tomato fruits. Proc. Am. Soc. Hort. Sci. 75:611-616.

SAS Institute. 1979. *SAS Users Guide.* SAS Institute, Raleigh, N.C. 494 pp.

Scott, J. W. 1993. Breeding tomatoes for resistance to high temperatures, biotic and abiotic diseases. Hort. Bras. 11(2):167-170.

Scott, J. W. and J. P. Jones. 1995. Fla. 7547 and Fla. 7481 tomato breeding lines resistant to *Fusarium oxysporum* f.sp. *lycopersici* races 1, 2, and 3. HortScience 30(3):645-646.

Soule, James. 1985. *Glossary For Horticultural Crops.* Wiley. New York.

Tukey, L. D. 1959. Observations on the russeting of apples grown in plastic bags. Proc. Amer. Soc. Hort. Sci. 74:30-39.

Young, P. A. 1947. Cuticle cracks in tomato fruits. Phytopathology 37:143-145.

Zar, Jerrold H. 1984. *Biostatistical Analysis.* Prentice-Hall, Inc. Englewood Cliffs, N.J. 718 pp.

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EFFECT OF CALCIUM CARBONATE AND MICRONUTRIENTS ON THE DEVELOPMENT OF CROWN ROT OF TOMATO

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Additional index words. Fusarium oxysporum f. sp. *radicis-lycopersici*, iron, manganese, zinc.

Abstract. **Powdered calcium carbonate ($CaCO_3$) was used to amend a vermiculite:Canadian peat medium (1:1,v/v). Medium pH values of 4.0 (unamended), 4.9 (0.75 g $CaCO_3$/liter of mix), 6.2 (1.5 g/liter), and 7.3 (3.0 g/liter) were established. Each pH batch was divided into five subbatches. Each subbatch was amended with Na_2EDTA-chelated forms of iron (Fe, 17 kg·ha^{-1}), manganese (Mn, 10 kg·ha^{-1}), zinc (Zn, 19.4 kg·ha^{-1}), Fe+Mn+Zn (17+10+19.4 kg·ha^{-1}), or no minor element amendment. Two-week-old tomato seedlings (*Lycopersicon esculentum* Mill. cv. Walter) were planted into the various mixes infested the previous day with *Fusarium oxysporum* Schlecht. f. sp. *radicis-lycopersici* Jarvis and Shoemaker. Crown rot evaluations were made three weeks later. Disease incidence decreased with in-**

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creasing mix pH (52, 44, 35, and 10% for pH 4.0, 4.9, 6.2, and 7.3, respectively). The addition of micronutrients did not affect disease incidence at pH 4.0 or 7.3. However, at pH 4.9 the addition of Fe+Mn+Zn increased disease incidence. Moreover, at pH 6.2, disease incidence was increased by the addition of Fe, Mn, or Fe+Mn+Zn. The results demonstrate that the beneficial effect of liming and increased pH can be negated by the addition of chelated micronutrients providing the medium pH is not too high.

Jones and Woltz (1968; 1969; 1970) demonstrated in greenhouse and field experiments that soil amendments of calcium carbonate and hydrated lime greatly inhibited development of Fusarium wilt of tomato. Later Jones, Woltz, and Scott (1990; 1992; 1993) showed that soil amendments of powdered calcium carbonate resulted in excellent control of Fusarium crown rot of tomato. They further showed that this control of the Fusarium-incited diseases was due to an increase in soil pH, not to an increase in soil calcium since gypsum ($CaSO_4$) amendments, which increased the soil calcium, but not the soil pH, did not affect disease development. Jones and Woltz (1968; 1969) suggested that the inhibition of wilt was due to the increased soil pH which limited the availability of micronutrients needed for the growth, sporulation, and virulence of the pathogen. A little later they (1970) demonstrated that the beneficial effects of liming to a high soil pH could be reversed by the soil additions of Mn+Zn or Fe+Zn lignosulfonates which are available for plant growth at high soil pH values.

The present experiment was designed and carried out to determine the effect of adding Na_2EDTA-chelated micronutrients (Fe, Mn, Zn, and Fe+Mn+Zn) to calcium carbonate-amended soil. If the addition of micronutrients, in an available form, reversed the Fusarium crown rot-inhibiting effects of calcium carbonate and crown rot developed, this would be strong evidence that the basis of crown rot control by calcium carbonate was due to an induced deficiency or imbalance of micronutrients created by the increased soil pH.

Materials and Methods

A vermiculite:Canadian peat medium (1:1 v/v) was used in the experiment. The mix was divided into four main lots. Powdered calcium carbonate ($CaCO_3$) was used to amend three of the four lots creating medium pH values of 4.0 (unamended), 4.9 (0.75 g $CaCO_3$/liter of mix), 6.3 (1.5 g/liter), and 7.3 (3.0 g/liter). These four main lots were subdivided into five sublots. Each sublot was amended with Na_2EDTA chelated forms of iron (Fe, 17 $kg \cdot ha^{-1}$), manganese (Mn, 17 $kg \cdot ha^{-1}$), zinc (Zn, 19.3 $kg \cdot ha^{-1}$), Fe+Mn+Zn (17+10+19.4 $kg \cdot ha^{-1}$), or no micronutrient amendment. The chelated micronutrients were prepared by mixing Na_2EDTA with salts of the micronutrients as follows: 63.6 $kg \cdot ha^{-1}$ Na_2EDTA + 24.0 $kg \cdot ha^{-1}$ $FeCl_3$ + 24.0 $kg \cdot ha^{-1}$ $FeSO_4$, 63.6 $kg \cdot ha^{-1}$ Na_2EDTA + 27.6 $kg \cdot ha^{-1}$ $MnSO_4$, 63.6 $kg \cdot ha^{-1}$ Na_2EDTA + 48.0 $kg \cdot ha^{-1}$ $ZnSO_4$, and 192.0 $kg \cdot ha^{-1}$ Na_2EDTA + 24.0 $kg \cdot ha^{-1}$ $FeSO_4$ + 24.0 $kg \cdot ha^{-1}$ $FeCl_2$ + 27.6 $kg \cdot ha^{-1}$ $MnSO_4$ + 48.0 $kg \cdot ha^{-1}$ $ZnSO_4$. These micronutrients were mixed into the 1:1 medium, the amended mixes put into plastic trays (22 × 17 × 6 cm), each containing 1.6 liter of mix, and arranged into four randomized blocks in a 21 C growth room. A split plot design was used where whole plots were calcium carbonate variables and subplots were micronutrient variables.

Table 1. Effect of $CaCO_3$ on medium pH and on the incidence and severity of Fusarium crown rot of tomato.

$CaCO_3$ Amount (g/liter)	Medium pH^y	Disease incidence (%)	% plants girdled or dead
0.0	4.0	52 a^z	17 a
0.75	4.9	44 b	10 b
1.50	6.2	35 b	4 c
3.00	7.3	10 c	2 c

^{z}Mean separation by LSD test at the 0.05 probability level.
^{y}Measured in a saturated paste.

The *Fusarium oxysporum* f. sp. *radicis-lycopersici* used to infest the mix was grown 10 days at 28 C on potato dextrose agar plates. The surface mycelium and spores were washed off the plates and a 5.5 million spores/ml suspension prepared. The spore suspension (50 ml) was mixed into the medium of each tray. One week later 10 two-week-old tomato seedlings (cv. Walter) were transplanted into each tray. Plants were rated for disease development three weeks after transplanting. At that time a sample of the medium was taken from each tray and the pH was determined.

Results and Discussion

The application of 0.75, 1.5, and 3.0 g $CaCO_3$/liter of medium raised the pH from 4.0 (unamended) to 4.9, 6.2, and 7.3, respectively (Table 1). None of the chelated micronutrient amendments altered the initial pH of the medium.

Disease incidence (percent of the plants with symptoms) and severity (percent of the plants rated dead or nearly girdled by hypocotyl lesions) decreased with increasing medium pH (Table 1). Micronutrients, collectively, greatly affected disease incidence, but had a limited and inconsistent effect on severity (Table 2). Iron and Fe+Mn+Zn increased disease incidence from 24% (no micronutrients added) to 40 and 46%, respectively.

There was a significant interaction between medium pH and micronutrient amendments. At pH 4.0 (no lime) or pH 7.3 (3.0 g lime/liter of medium), micronutrients did not significantly affect disease incidence or severity (Table 3). However, at pH 4.9 the addition of the Fe+Mn+Zn mixture increased disease incidence from 27 (no micronutrients) to 75%. Moreover, at pH 6.3 the addition of Fe, Mn, or Fe+Mn+Zn resulted in an increased disease incidence from 6% (no micronutrient) to 39, 43, 56%, respectively.

It is clear that the addition of certain chelated micronutrients will reverse crown rot control given by lime amendments. These results are similar to those reported by Jones and Woltz (1969) working with Fusarium wilt and lignosulfonate-micronutrient complexes. Just how the micronutrients are involved

Table 2. Effect of micronutrients on the incidence and severity of Fusarium crown rot of tomato.

Micronutrient amendment	Rate $kg \cdot ha^{-1}$	Disease incidence (%)	% plants dead or girdled
Fe	17.0	40 ab	13.75 a
Mn	10.0	31 bc	4.0 b
Zn	19.4	35 bc	9.0 ab
Fe+Mn+Zn	17+10+19.4	46 a	7.5 ab
None	—	24 c	9.0 ab

^{z}Mean separation by LSD test at the 0.05 probability level.

Table 3. Interaction of micronutrients and soil pH on development of Fusarium crown rot of tomato.

Micronutrient amendment	Rate kg·ha[-1]	Soil pH (saturated paste) 4.0	4.9	6.2	7.3
		% diseased plants			
Iron (Fe)	17.0	66 a[z]	33 a	39 b	13 a
Manganese (Mn)	10.0	44 a	28 a	43 b	10 a
Zn (Zn)	19.4	49 a	47 ab	26 a	13 a
Fe+Mn+Zn	17+10+19.4	45 a	75 b	56 b	8 a
None	—	56 a	27 a	6 a	7 a

[z]Mean separation by LSD test at the 0.05 probability level.

in pathogenesis is not understood. Woltz and Jones (1968) reported that Zn and other micronutrients were essential for the growth, sporulation, and virulence of *Fusarium oxysporum* f. sp. *lycopersici*. *Fusarium vasinfectum* Atk. also requires Zn for growth and the production of fusaric acid (Kalyanasundaram and Saraswathi-Devi, 1955). Kalyanasundaram (1954) reported that soil amendments of zinc altered the susceptibility of cotton to *F. vasinfectum*, and Subramanian (1963) induced resistance of pigeon pea, *Cajanus cajan*, to *F. udum* by application of Mn to the soil. The effect of micronutrients on pathogenesis of tomato to *F. oxysporum* f. sp. *radicis-lycopersici* may be upon the host, pathogen, or both. Nevertheless, certain micronutrient treatments added to the medium as EDTA complexes reversed the disease-inhibiting effects of lime ($CaCO_3$) and the concomitant increased medium pH. This supports the hypothesis that an imbalance in micronutrient supply may be the mechanism by which liming retards development of Fusarium crown rot.

Literature Cited

Jones, J. P. and S. S. Woltz. 1968. Micronutrient effects on the in vitro growth and pathogenicity of *Fusarium oxysporum* f. sp. *lycopersici*. Phytopathology 58:336-338.

Jones, J. P. and S. S. Woltz. 1969. Fusarium wilt (race 2) of tomato:calcium, pH, and micronutrient effects on disease development. Plant Dis. Reptr. 53:276-279.

Jones, J. P. and S. S. Woltz. 1970. Fusarium wilt of tomato: Interaction of soil liming and micronutrient amendments on disease development. Phytopathology 60:812-813.

Jones, J. P., S. S. Woltz and J. W. Scott. 1990. Factors affecting development of Fusarium crown rot of tomato. Proc. Fla. State Hort. Soc. 103:142-148.

Jones, J. P., S. S. Woltz and J. W. Scott. 1992. Screening for resistance to Fusarium crown rot of tomato. Proc. Fla. State Hort. Soc. 105:345-347.

Jones, J. P., S. S. Woltz and J. W. Scott. 1993. Influence of soil pH, nitrogen source, and transplant drenches on development of crown rot of tomato. Proc. Fla. State Hort. Soc. 106:170-172.

Kalyanasundaram, R. 1954. Soil conditions and root diseases. XII. The role of zinc and manganese in altering host metabolism. J. Indian Bot. Soc. 33:197-202.

Kalyanasundaram, R. and L. Saraswathi-Devi. 1955. Zinc in the metabolism of Fusarium vasinfectum Atk. Nature 175:945.

Subramanian, S. 1963. Fusarium wilt of pigeon pea. III. Manganese nutrition and disease resistance. Indian Acad. Sci. Proc. 57:259-274.

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EFFICACY OF 1,3-DICHLOROPROPENE FORMULATIONS FOR CONTROL OF PLANT-PARASITIC NEMATODES ON TOMATO

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Abstract. **Several formulations of 1,3-dichloropropene and chloropicrin were compared with a methyl bromide/chloropicrin formulation for nematode control on tomatoes (*Lycopersicon esculentum* Mill.) grown on a sandy soil in Immokalee, Collier County, Florida, during 1995-96. Numbers of the root-knot nematode (*Meloidogyne incognita* [Kofoid and White] Chitwood) and root galling were lower in 1,3-dichloropropene-treated plots than in nonfumigated control plots, but root-knot nematodes and root galling were absent from plots fumigated with methyl bromide. At harvest, population levels of the stubby-root nematode (*Paratrichodorus minor* [Colbran] Siddiqi) had increased in all plots, regardless of treatment. Numbers of sheath nematodes (*Hemicycliophora* spp.) were low and unaffected by treatment. Formulations of 1,3-dichloropropene were effective in reducing the most serious nematode pest of tomatoes (*M. incognita*), but not below detectable levels. Additional data from future tests are needed to reliably assess the consequences of this level of nematode management.**

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Soil fumigation with methyl bromide/chloropicrin formulations is the most commonly-used pre-plant practice for control of soil-borne pests in tomato (*Lycopersicon eculentum* Mill.) production in Florida (Jones et al., 1995). However, the classification of methyl bromide as an ozone-depleting substance and its impending removal by the U.S. Environmental Protection Agency necessitates the development of alternative management strategies, including the use of alternative