Table 3. Reaction of four isolates of *Bremia lactucae* on Dm resistant genes.

Cultivar	Dm genes	Reaction of isolates[z] ISO1	ISO2	ISO3	ISO4
Lednicky	1	–	–	–	–
UCDM 2	2	+	+	+	+
Dandie	3	+	+	+	+
R4 T57/E	4	(+)	(+)	(+)	+
Valmaine	5/8	+	+	+	+
Sabine	6	+	+	+	+
LSE 57/15	7	+	+	+	+
UCDM 10	10	*	*	*	–
Mondian	11	*	–	–	–
Hilde	R12	+	+	(+)	+
Empire or Pennlake	13	+	+	+	+
UCDM 14	14	+	+	+	+
PIVT1309	15	–	–	–	–
LSE 18	16	+	+	*	+
Cogham Green	0	+	+	+	+

[z] – = no sporulation
+ = profuse sporulation
(+) = sparse sporulation
* = 1 to 5 plants of about 50 with sporulation

sistance but is from an accession of *Lactuca serriola* (4). Using a commercial cultivar vs an accession or breeding line would facilitate the transfer of desirable horticultural traits. Breeders are presently attempting to incorporate resistance to pathotype II and III into lettuce cultivars adapted to Florida conditions since IV can break down into these components (13).

Although only a few isolates of *B. lactucae* have been tested so far in Florida, it is possible that a mixture of more than one pathotype might exist. In California, Pathotypes III and IV represented 31% and 63%, respectively, of numerous isolates collected during 1987 to 1989 (13). Isolates of *B. lactucae* collected throughout the Everglades Agricultural Area during 1989-1990 downy mildew epidemic are currently being tested for virulence phenotype to further characterize the Pathotype populations in Florida. This information will be useful in the development of future downy mildew control strategies.

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FACTORS AFFECTING DEVELOPMENT OF FUSARIUM CROWN ROT OF TOMATO

JOHN PAUL JONES, S. S. WOLTZ, AND J. W. SCOTT
University of Florida, IFAS
Gulf Coast Research and Education Center
Bradenton, FL 34203

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Abstract. **Fusarium crown rot of tomato (*Lycopersicon esculentum* Mill.) caused by *Fusarium oxysporum* Schlecht. f. sp. *radicis-lycopersici* Jarvis and Shoemaker, occurs frequently in the sandy soils of Florida, especially in the southwestern district. Several experiments were carried out under controlled conditions in growth rooms and chambers, and in the field to determine the effect of various factors on disease development. Disease incidence and severity were less on 1 and 2 week old plants than on 3 to 6 week old plants in the greenhouse. The optimum light duration for disease occurrence in growth chambers was 12 hours daily, and the optimum temperature was 68F. In general, disease development decreased with decreasing spore concentration in a growth room. A concentration of 12.5 or 24 million microspores/ml of inoculum produced consistent results with a high percentage of severely diseased plants, whereas lower concentrations produced slight symptoms, making disease evaluations difficult. Increasing rates of $CaCO_3$ in growth room studies increased the pH and soluble Ca content of the medium and decreased disease incidence and severity. Increasing rates of $CaSO_4$ in growth room studies increased the soluble Ca content of the medium more than $CaCO_3$, but did not affect pH of the medium or disease development. Adjusting the pH upward with $NaHCO_3$ greatly alleviated crown rot**

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without any increases in soluble Ca. Disease control was associated with the pH, not with the soluble Ca content of the medium. Rapid reversals of pH, reversed disease development eliminating the possibility that microflora were involved in control. Buffering the inocula to high pH's did not affect disease development. Wounding of the crowns of tomato seedlings greatly increased the incidence and severity of crown rot in a series of greenhouse experiments. In a field experiment, soil pH and Ca drenches did not affect disease. However, direct seeded plants were much more severely affected than bare-rooted seedlings or container grown plants. Yields of container-grown seedlings were not reduced by crown rot, although yields of direct seeded plants and bare-rooted seedlings were adversely affected.

The first occurrence of Fusarium crown and root rot of tomato in Florida was probably recorded by Cox in 1963 (1). He observed a rot of the main and fibrous roots in field plants and isolated an unidentified species of *Fusarium*, as well as *Rhizoctonia solani*. However, Sonoda (4), over a decade later, was the first to describe the disease in Florida in detail and to identify the pathogen as *Fusarium oxysporum* f. sp. *radicis-lycopersici* (F.o. r-l). The disease remained a curiosity in Florida tomato fields until the early 1980's when it became increasingly common. Now it is one of the most frequently encountered soilborne diseases of tomatoes grown in the acid, sandy flatwood soils of southwest Florida. Yields have been estimated to have been reduced by as much as 15% by the disease (1988 FFVA Committee on Contemporary Control of Vegetable Diseases with Chemicals).

Because of the current prevalence and severity of crown rot, several experiments were undertaken to determine the effect of temperature, light duration, plant age, spore concentration, calcium/pH, and wounding on disease development.

Materials and Methods

GENERAL: Inocula used in the greenhouse and growth room studies were prepared from F. o. r-l cultures grown 7 days on potato dextrose agar plates at 82F and 30 ft.c. continuous illumination. The cultures then were comminuted in a blender with sufficient tap water to obtain a spore concentration of approximately 25 million/ml of inoculum or to a desired concentration in the spore concentration experiment.

'Walter' tomato seedlings were used in all but the field test, where 'Sunny' was used, and were seeded in a commercial nonfertilized peat:vermiculite mix at pH 6.1. All were grown in a greenhouse at ambient light and temperature until used, generally 2 weeks after seeding.

In all growth room and greenhouse experiments the roots and hypocotyls of the 'Walter' seedlings were dipped into the inoculum and transplanted to a 1:1 mix of Canadian peat:vermiculite amended generally with 0.75 g $CaCO_3$ powder per liter of mix resulting in a pH of 4.0 to 4.3. A randomized complete block design with 4 replications was used in most experiments with each treatment containing 100 inoculated seedlings. However, in the Ca/pH experiments, a factorial design was used with 4 replications arranged in randomized complete blocks. Each treatment contained 100 inoculated seedlings.

Percentages were transformed to arc sin percentages for all statistical analyses, then reconverted for presentation.

Temperature Experiment: Two-week-old 'Walter' seedlings were root-dip inoculated (25 million spores/ml of inoculum) and dibbled into small trays (7.4 x 10 in.) of Canadian peat:vermiculite and incubated at 50, 59, 68, 77, and 86F (10, 15,20, 25, and 30C, respectively) in controlled temperature chambers at 850 ft.c. and 12 hr daily light duration. After 7 days the plants were pulled and the crowns and roots washed and evaluated for disease severity.

Light duration experiment: Two-week-old 'Walter' seedlings were root-dip inoculated (26 million spores/ml of inoculum) and dibbled into small trays of Canadian peat:vermiculite and incubated in growth chambers at 71.6 F (22C) with daily light durations (850 ft.c. intensity) of 4, 8, 12, 16, or 20 hours. After 7 days the plants were pulled and the crowns and roots washed and examined for disease severity.

Plant age experiment: 'Walter' plants used in this experiment were 1, 2, 3, 4, 5, or 6 weeks old from the time of seeding and were raised in the greenhouse in March and Apr. of 1990. The plants were uprooted and root-dip inoculated (41 million spores/ml of inoculum), incubated in the same greenhouse under ambient conditions for 9 days when they were pulled up and the roots and crowns were washed and examined for crown and root rot symptoms.

Spore concentration experiment: Inocula of different spore concentrations were prepared by washing spores off 7-day-old PDA culture plates and diluting with tap water to the desired concentrations. The concentrations actually used were determined by counting the number of spores with a Levy Improved Neubauer Corpuscle Counting Chamber and a microscope. The concentrations used were: 50,000; 175,000; 350,000; 1,075,000; 2,800,000; 6,800,000; 12,400,000; and 23,600,000 microspores/ml of inoculum. Two-week old 'Walter' seedlings were root-dip inoculated dibbled into a 1:1 Canadian peat:vermiculite mix, and incubated in a growth room at 1,000 ft.c. illumination (12 hour day) and 71.6F (22C) temperature. Four days after inoculation the numbers of obviously diseased seedlings were recorded. After another 3 days, the plants were extracted from the mix and the crowns and roots were washed and rated for disease severity.

Wounding experiments: The effect of wounding on the development of crown rot was investigated in a series of three experiments. In the first two experiments half of the plants were wounded in the crown by puncturing several times with an insect pinning needle, half of the plants remained nonwounded. In the second experiment, the 'Walter' seedlings were wounded with the needle in the crown or hypocotyl. A portion of the plants were left nonwounded and a portion were root-wounded by snipping off half the root length with scissors. Twelve-week-old 'Sunny' container plants were used in the third experiment. The following treatments were used: 1) root wounding by cutting the root pyramid in half, 2) wounding the crown by puncturing several times with an insect pinning needle, 3) wounding crown and roots as described previously, and 4) nonwounding. All plants in all three experiments were root-dip inoculated in inoculum containing approximately 26 million spores/ml inoculum, transplanted

to virgin EauGallie fine sand, and incubated in the greenhouse under ambient conditions. After 2 weeks, the plants were removed and the crowns and root washed and evaluated for disease severity.

Calcium/pH experiment 1: The 1:1 mix of Canadian peat:vermiculite mix was amended with calcium carbonate (0, 0.75, 1.5, 3.0, and 6.0 g of $CaCO_3$ powder/liter of mix) or $CaSO_4$ (0, 1.02, 2.04, 4.08, and 8.16 g $CaSO_4$/liter of mix). The amendments were added 4 days before 2-week-old 'Walter' seedlings were root-dip inoculated (22 million spores/ml of inoculum) and transplanted into the various mixes. The inoculated plants were maintained in a growth room at 71.6F (22C) and 1000 ft.c. (12 hour day). After 5 days, all plants were pulled and the crowns and roots washed and evaluated for disease severity.

Calcium/pH experiment 2: The 1:1 Canadian peat:vermiculite mix was amended with: 1) increasing rates of calcium carbonate (0, 0.75, 1.5, 3.0, and 6.0 g/liter of mix, 2) increasing rates of calcium sulfate (0, 0.5, 1.0, 2.0, and 4.0 g/liter of mix), 3) a constant rate of $CaSO_4$ (4.0 g/liter) plus increasing rates of $NaHCO_4$ (0, 0.9, 1.8, 3.5, and 7.0 g/liter of mix, and 4) increasing rates of $CaSO_4$ (0, 0.5, 1.10, 2.0, and 4.0 g/liter of mix plus an increasing rate of $NaHCO_3$ (0, 0.9, 1.8, 3.5, and 7.0 g/liter of mix). Two days after the amendments were added, 2-week-old 'Walter' plants were root-dip inoculated (24 million spores/ml of inoculum), transplanted to the mixes, and incubated in a growth room at 1000 ft.c. (12 hour day) and 71.6F (22C). After 7 days, the seedlings were uprooted, washed, and evaluated for disease severity.

Calcium/pH experiment 3: To determine the effect of a pH reversal on disease development, the trays of mixes used in the previous experiment were reused in this experiment. In this experiment, $CaCO_3$ was added to the $CaSO_4$-amended mixes and H_3PO_4 was added to the $CaCO_4$ and $NaHCO_3$-amended mixes of Ca/pH experiment 2. This caused the pH of the medium mixes to be reversed from the previous experiment. The amount of H_3PO_4 (25 ml of concentrated phosphoric acid/liter of water) added to the $CaCO_3$-amended mixes was 0, 44, 88, 175, or 350 ml/tray of mix. The amounts added to the $NaHCO_3$-amended mixes were 0, 34, 69, 138, or 275 ml/tray and the amounts of $CaCO_3$ added to the $CaSO_4$ trays of the previous experiment were 0, 0.75, 1.5, 3.0, or 6.0 g/liter of mix. One day after the amendments were added two-week-old 'Walter' seedlings were root-dip inoculated (25 million spores/ml of inoculum), transplanted to the mixes, and incubated in a growth room at 1000 ft.c. (12 hour day) and 71.6F (22C). After 7 days the seedlings were pulled up, washed, and evaluated for disease severity.

Inoculum pH experiment: To investigate the mode of action of the control given by a slight increase in soil or medium pH, five root-dip inocula (25 million spores/ml of inoculum) were prepared from 1-week old PDA cultures comminuted in a microblender in buffered solutions prepared from H_3PO_4, NaH_2PO_4, and Na_2PO_4 which had been adjusted to permit a final pH value of 3.5, 4.5, 5.5, 6.5, or 7.5. Two-week-old 'Walter' seedlings then were root-dip inoculated (one set of 100 plants/inoculum) and set into media where the pH had been adjusted with $CaCO_3$ to 5.0, 5.9, or 7.3. A few drops of each buffered inoculum also were spread on water agar plates and the germination percentage (number of spores germinated/number of spores counted) was determined after 6 hours incubation at 82F (28C). After 7 days incubation in a growth room at 71.6F (22 C) and 1000 ft.c. (12 hour day), all plants were pulled up and the crowns and roots were washed and evaluated for disease severity.

Field experiment: Soil pH (6.8 vs. 6.3), calcium hydroxide ($Ca(OH)_2$) drench (3 lb./100 gal., 200 ml/plant hole vs. no drench), and plant age (direct seeded, three-week-old bare-rooted seedlings, 10-week-old container plants) were evaluated for their effects on the development of crown rot of 'Sunny' tomatoes in the field (EauGallie fine sand) during the spring of 1990. The original pH of the field was 6.3 and the 6.8 pH regime was established by applying calcium hydroxide. One-half of each subsubplot was infested with the crown rot pathogen 2 weeks after the field was bedded, fertilized, fumigated (350 lb/acre of methyl bromide 67%-chloropicrin 33%), and covered with black polyethylene mulch. The crown rot *Fusarium* was grown 3 weeks in a growth room at 82F (28 C) on vermiculite saturated with a nutrient solution high in NH_4-N and micronutrients (5). The resulting curd then was broken up and 200 ml were put into each plant hole. Each ml of the inoculum contained 48 million spores. A split, split, split plot design with 5 replications was used where pH's were whole plots, calcium hydroxide drenches subplots, plant age subsubplots, and pathogen infestation subsubsubplots.

Standard fertilizer and foliar pest control practices were utilized. All plants were staked and tied. The container plants were harvested once mature green, whereas the dibbed in and direct seeded plants were harvested mature green twice. After the final harvest, all plants were dug, and the roots and crowns were washed and evaluated for crown rot symptoms. Yields are expressed as percentages of the noninfested plot yield. Percentages were transformed to arc sines for statistical analysis.

Results and Discussion

Temperature: Disease incidence and severity increased as the temperature increased from 50 to 68F (10-20C) and decreased as the temperature was further increased from 68 to 86F (20-30C) (Table 1). The optimum temperature for disease development was 68F (20C).

Light duration: Light duration (850 ft.c. intensity) very slightly but statistically affected disease incidence (Table 2). The percentage of diseased plants increased from 4 to 12 hours and decreased from 12 to 20 hours. Disease severity (percentage of plants evaluated as being very severely affected or dead) was markedly affected by light duration, increased as the duration of light increased from 4 to 12 hours and decreased with further increases in light duration.

Plant age: Plant age did not affect disease incidence to any extent (Table 3). However, fewer 1-week-old plants were diseased than any other age plants. One and 2-week-old plants were far less severely diseased than the other plants.

Spore concentration: Four days after inoculation disease incidence decreased as spore concentration decreased from 23.6 to 6.8 million spores/ml (Table 4). After 7 days, all concentrations equally affected disease incidence causing 85 to 99% of the plants to develop symptoms (Table 4). However, the percentage of plants rated as severely

Table 1. Effect of temperature on crown rot incidence and severity of 'Walter' tomato seedlings.

Temperature (F)	Crown rot (%)	
	Incidence	Very severe to dead
50	6	0
59	51	2
68	89	24
77	76	13
86	63	0
LSD_{05}	14	5

Table 2. Effect of light duration (850 ft.c.) on crown rot incidence and severity of 'Walter' tomato seedlings.

Light duration (hr)	Crown rot (%)	
	Incidence	Very severe to dead
4	82	14
8	85	26
12	95	37
16	78	20
20	71	16
LSD_{05}	20	11

Table 3. Effect of plant age on crown rot incidence and severity of 'Walter' tomato seedlings.

Plant age (wk)	Crown rot (%)	
	Incidence	Very severe to dead
1	45	14
2	84	15
3	99	65
4	100	74
5	99	44
6	98	78
LSD_{05}	24	27

Table 4. Effect of spore concentration on crown rot incidence and severity 4 and 7 days after inoculation of 'Walter' tomato seedlings.

Spore conc. (no. spores x 10^6/ml)	Crown rot (%)		
	4 day incubation	7 day incubation	
		Incidence	Severe to dead
23.6	59	99	85
12.4	22	99	59
6.8	8	98	39
2.8	3	87	13
1.075	3	97	34
0.35	2	92	12
0.175	1	95	31
0.050	0	93	11
LSD_{05}	14	NSD	21

[z]NSD = no significant difference

diseased to dead after 7 days generally decreased as spore concentration decreased.

Wounding: Wounding the crowns of bare-rooted seedlings greatly encouraged disease development in 2 experiments (Table 5). However, wounding the roots or hypocotyl did not affect disease development to any extent. In fact, the percentage of healthy to slightly diseased plants remained as great or larger as that of the nonwounded plants.

Wounding the crowns of container plants also greatly increased the incidence and severity of crown rot (Table 5). Root wounding only slightly increased disease severity, and wounding both crowns and roots did not increase disease incidence or severity compared to wounding the crowns alone.

Table 5. Effect of wounding bare-rooted 'Walter' seedlings and container-grown 'Sunny' plants on crown rot severity in 3 experiments.

Bare rooted seedlings Area wounded	Disease severity (%)		
	0 to slight	Moderate to very severe	Dead
Experiment 1			
Crown	0	39	61
Nonwounded	54	39	7
LSD_{05}	9.5	NSD	6.4
Experiment 2			
Root	59	25	16
Crown	34	28	38
Hypocotyl	81	5	14
Nonwounded	62	30	8
LSD_{05}	17	12	16
Experiment 3			
Container Plants			
Root	74	26	0
Crown	4	74	22
Root + Crown	0	78	22
Nonwounded	100	0	0
LSD_{05}	15	22	5

[z]NSD = no significant difference

Table 6. Effect of $CaCO_3$ and $CaSO_4$ on medium pH and soluble calcium content (2:1 water:medium extract) and on crown rot development on 'Walter' tomato seedlings.

$CaCO_3$ rate[z] (g/liter medium)	pH	Crown rot (%)		
		Ca ppm	incidence	dead
0	3.5	0.7	100	96
0.75	4.3	11.9	99	36
1.5	5.7	13.8	95	29
3.0	7.2	20.8	73	9
6.0	7.8	22.1	70	0
$CaSO_4$ rate (g/liter medium)				
0 0	3.6	7.9	100	91
1.02	3.6	26.4	99	93
2.04	3.6	53.1	100	96
4.08	3.6	79.2	100	85
8.16	3.7	162.5	100	94
LSD_{05}			20	18

[z]$CaCO_3$ significantly different (5% level) from $CaSO_4$ in regard to disease incidence and severity.

Calcium/pH: Increasing rates of $CaCO_3$ amendments increased the soluble Ca (2:1 water:medium extract) content and pH of the medium in the first experiment and decreased the incidence and severity of crown rot (Table 6). Increasing rates of $CaSO_4$ increased the soluble Ca content of the medium more than the $CaCO_3$, but did not increase the medium pH and did not result in reduction of disease incidence or severity. Disease control was a function of medium pH *rather than* soluble Ca concentration.

In the second experiment increasing rates of $CaCO_3$ increased the pH and soluble Ca content of the medium and greatly decreased disease incidence and severity (Table 7). Once again, increasing rates of $CaSO_4$ increased the soluble Ca content of the medium to levels equal to or higher than those obtained with $CaCO_3$, but they did not increase the medium pH and did not decrease the occurrence or severity of crown rot. When increasing rates of $CaSO_4$ were augmented with increasing rates of $NaHCO_4$ the medium pH increased and disease control was obtained. Additionally, if a high rate of $CaSO_4$, which raised the soluble Ca content of the medium but did not increase soil pH or disease control, were augmented with $NaHCO_3$, the medium pH increased and the incidence and severity of crown rot were materially reduced. Moreover, where $NaHCO_3$ was used with a low rate of $CaSO_4$ the medium pH's were increased without an accompanying increase of soluble Ca in the medium, and disease control was obtained. Disease control was associated with medium pH, not with soluble Ca content. Moreover, only a slight increase in pH from 4.0 to 4.9 generally was sufficient to greatly alleviate disease occurrence and severity.

In the third experiment where the pH's in the second experiment were reversed by the addition of $CaCO_3$ or H_3PO_4 and immediately thereafter the trays reset with root-dip inoculated plants, disease control occurred where the disease previously had been rampant and where disease control previously had occurred, disease incidence and severity were greatly increased (Table 8). Consequently, disease development could be turned on or off by adjustments in the medium pH. The application of Ca without an accompanying increase in pH did not result in disease control whereas an increase in pH without an increase in Ca did result in control.

In the first two experiments the medium amendments were added 2 to 4 days prior to setting the inoculated plants into the amended medium. This very short time should have prevented any shift in soil flora and therefore eliminated the possibility that the control ensuing from a pH increase was due to a large flush of growth of competing or antagonistic microorganisms. Additionally, the medium pH's of the second experiment were reversed one day (in the third experiment) and inoculated plants set the

Table 7. Effect of $CaCO_3$, $CaSO_4$, $CaSO_4$ (const. rate) + $NaHCO_3$, and $CaSO_4$ (increasing rate) + $NaHCO_3$ on medium pH and soluble calcium content (2:1 water:medium extract) and on crown rot development of 'Walter' tomato seedlings.

Rate[z] g/liter medium	pH	Ca ppm	Crown rot percentage: Incidence	Crown rot percentage: Dead
$CaCO_3$[y]				
0	4.0	13	91	64
0.75	4.9	27	34	2
1.50	6.2	41	17	2
3.00	7.3	73	9	2
6.00	7.7	70	11	2
$CaSO_4$				
0	4.0	15	96	67
0.5	3.8	36	98	92
1.0	3.7	53	89	76
2.0	3.7	98	96	82
4.0	3.5	170	100	90
$CaSO_4$ + $NaHCO_3$				
0 + 0	4.0	18	98	94
0.5 + 0.9	4.9	10	42	9
1.0 + 1.8	5.5	13	38	6
2.0 + 3.5	7.5	16	35	8
4.0 + 7.0	8.0	15	22	9
$CaSO_4$ + $NaHCO_3$				
0 + 0	4.0	15	87	75
4.0 + 0.9	4.3	100	59	15
4.0 + 1.8	5.0	96	51	10
4.0 + 3.5	7.6	69	20	1
4.0 + 7.0	8.9	30	23	4
LSD_{05}			16	25

[z]Rate = g/liter of medium
[y]$CaCO_3$ significantly different (5% level) from $CaSO_4$ but not from $CaSO_4$ + $NaHCO_3$ in regard to disease incidence and plant death.

Table 8. Effect of pH reversal on medium pH and crown rot development of 'Walter' tomato seedlings.

Rates[z] g/liter medium			Old pH	New pH	Crown rot (%): Incid.[y] Old	Incid.[y] New	V sev.-dead Old	V sev.-dead New
$CaCO_3H_3PO_4$								
0	0		4.0	4.2	91	94	64	42
0.75	44		4.9	4.3	34	95	2	92
1.50	88		6.2	4.5	17	99	2	97
3.0	175		7.3	4.7	9	99	2	97
6.0	350		7.7	4.9	11	95	2	99
$CaSO_4CaCO_3$								
0	0		4.0	4.2	96	90	67	26
0.5	0.75		3.8	5.1	98	68	92	9
1.0	1.5		3.7	6.3	89	58	76	2
2.0	3.0		3.7	7.3	96	67	82	6
4.0	6.0		3.5	7.5	100	38	90	2
$CaSO_4NaHCO_3H_3PO_4$								
0	0	0	4.0	4.2	98	88	94	40
0.5	0.9	34	4.9	4.3	42	98	9	83
1.0	1.8	69	5.5	4.4	38	100	6	98
2.0	3.5	138	7.5	4.6	35	100	8	94
4.0	7.0	275	8.0	4.8	22	100	9	97
$CaSO_4NaHCO_3H_3PO_4$								
0	0	0	4.0	4.2	87	77	75	12
4.0	0.9	34	4.3	4.3	59	100	15	95
4.0	1.8	69	5.0	4.3	51	100	10	96
4.0	3.5	138	7.6	3.7	20	100	1	100
4.0	7.0	275	8.9	5.2	23	100	4	100
LSD_{05}					16	24	25	14

[z]$CaCO_3$, $CaSO_4$, $NaHCO_3$ rates = g/l of medium. H_3PO_4 rate ml of a 25 ml concentrated H_3PO_4 per liter of water solution per 250 ml of medium.
[y]Incid. = incidence, v. sev-dead = very severe to dead.

Table 9. Effect of buffered inoculum on crown rot incidence and severity of 'Walter' seedlings transplanted to different pH media.

Medium pH	Inoculum pH						Inoculum pH					
	3.5	4.5	5.5	6.5	7.5	Mean	3.5	4.5	5.5	6.5	7.5	Mean
	Disease incidence (%)						Very severe-dead (%)					
5.0	100	88	99	99	100	97[z]	75	77	72	66	81	74 a
5.9	68	78	95	94	80	83 b	25	25	53	31	33	33 b
7.3	54	67	77	77	56	66 c	12	25	27	16	6	17 c
Mean	74 a	78 a	90 a	90 a	78 a		37 a	42 a	51 a	37 a	40 a	

[z]Mean separation by LSD test, 5% level.

next day with a complete reversal of disease occurrence: severe disease occurred where control had ensued and excellent control was obtained where the disease previously had been devastating. It is difficult to imagine that these results could have been due to a change in microflora.

Inoculum pH: The percentages of germinated spores after 6 hours incubation on water agar were 84, 93, 97, 79, and 80% from inoculum buffered at pH 3.5, 4.5, 5.5, 6.5, and 7.5, respectively. Inoculum pH did not statistically affect germination of the microspores on water agar plates or disease development regardless of the pH of the medium (Table 9). However, the pH of the medium itself greatly affected crown rot incidence and severity with the highest pH resulting in the least disease. Apparently, inhibition of crown rot by an increase in soil or medium pH was not due to an inhibition of germination of the spores clinging to the inoculated roots and crowns.

Field experiment: Neither soil pH nor $Ca(OH)_2$ drenches affected the incidence or severity of crown rot (Table 10). Overman and Jones (3) also reported no control or reduction of crown rot by increasing the soil pH in the field from 6 to 7.5. Presumably no reduction was obtained in either experiment because the low pH was still high enough to result in considerable control. However, plant age in the present experiment materially affected disease severity. Nearly 75% of the seeded plants died compared to 38 and 7% of the dibbled seedlings and container plants, respectively. A high percentage of the surviving plants developed symptoms during the season regardless of plant age at the time of field establishment. Total fruit yield also were not affected by soil pH or $Ca(OH)_2$ drench (Table 11). However, yields of direct seeded plants and seedling plants were reduced 41 and 15%, respectively, compared to plants in noninoculated plots. Container plant yields es-

Table 10. Effect of soil pH, $Ca(OH)_2$ drenches, and method of plant establishment on crown rot development on 'Sunny' tomatoes in the field.

Factors	Plant establishment[z]					
	Seed	Seedling	Container	Seed	Seedling	Container
	Incidence (%)[y]			Dead (%)		
High pH, Ca drench	87	58	73	75	22	2
High pH, no Ca drench	93	78	77	88	32	5
Low pH, Ca drench	65	73	62	45	47	10
Low pH, no Ca drench	95	80	72	88	50	10
Mean	85 a[x]	72 a	71 a	74 a	38 b	7 c

[z]Plants established in the field by direct seeding, dibbling of 2-wk-old seedlings, or by transplanting 6-wk-old container plants.
[y]% disease incidence on surviving plants.
[x]Mean separation by LSD test, 5% level.

Table 11. Effect of soil pH, $Ca(OH)_2$ drench, and method of plant establishment on yields of 'Sunny' tomatoes in the field.

Factor	Total yield (lbs)				Yield reduction (%)[z]			
	Seed[y]	Seedling	Cont.	Means	Seed	Seedling	Cont.	Means
High pH, Ca drench	143	435	633	404 a[x]	51	14	4	23 a
High pH, no drench	106	573	641	440 a	18	0	4	7 a
Low pH, Ca drench	379	346	670	465 a	28	27	0	18 a
Low pH, no drench	113	381	637	376 a	67	21	0	29 a
Means	185	434	645		41.5 a	15.5 b	2.0 c	

[z]Based on yield of plants in noninoculated plots.
[y]Plants established in the field by direct seeding, dibbling of 2-wk-old seedlings, or by transplanting 6-wk-old container plants.
[x]Mean separation by LSD, 5% level.

sentially were not adversely affected, although 71% of the plants, when dug after the last harvest, had crown and root symptoms. These results are similar to those obtained in Ohio (2) where yields of tomato transplants set on rockwool were not decreased unless the plants were infected prior to planting. If the plants were inoculated immediately after planting, severe symptoms ensued but no yield reduction occurred.

To alleviate disease it is essential to 1) raise the pH of the container mix and of the field soil to at least 6.3, 2) prevent wounding of the crowns of the transplants, 3) use only disease-free transplants, and 4) fumigate the field (3). A combination of disease-free, nonwounded transplants, and fumigated fields of pH 6.5-7.0 should result in excellent disease control and maximum yields.

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DOES THE INITIAL CONDITION OF THE TRANSPLANTS AFFECT TOMATO GROWTH AND DEVELOPMENT?

D. I. LESKOVAR AND D. J. CANTLIFFE
Vegetable Crops Department, IFAS, University of Florida
Gainesville, FL 32611

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Abstract. **Growth changes in response to transplant handling, storage and age were evaluated in tomato (*Lycopersicon esculentum* Mill cv. Sunny). Transplants, 45-days old, were stored in trays (Not Pulled) or packed in boxes (Pulled) for 8 days at 5 and 15C. Pulled transplants had higher shoot growth than Not Pulled transplants. Also, 35-day old Not Pulled and Pulled transplants were stored at 20/28C for 3 days. Not Pulled transplants yielded more extra large fruit than Pulled transplants. Experiments were conducted in the spring and fall to evaluate transplant age (2 to 6 weeks old). In the spring, growth was similar for 4, 5 and 6 week-old transplants. Four and five-week old transplants produced the most early large fruit yield, but 4-week old transplants produced greater total yield than 6-week old transplants. In the fall, yields were similar among 2- to 5-week-old transplants.**

In Florida, fresh market tomatoes are established in the field by direct seeding or by using containerized transplants. Transplants are generally shipped directly to growers in the trays used for growing the transplants. Field establishment normally occurs between 1 to 3 days, and in some cases up to 7 days, after plant arrival. Transplants shipped out of Florida are hand-pulled from the tray, packed in boxes, and transported at approximately 14C in refrigerated trucks. Field establishment may be delayed from 1 to 7 days depending on weather conditions at planting site and distance to market.

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Transplant age at shipping depends on the grower's preference. Growers in the northern U.S. prefer tomato transplants that are at least six-weeks old and 12 to 15 cm in height. Growers in Florida prefer transplants that are 5 or 6-weeks old and 10 cm in height.

Studies on shipping containers, storage time and temperature, and plant age have been reported for bareroot and containerized tomato transplants (8,10,11,12,15). Storage at 10 to 13C for less than 10 days was recommended for tomato plants (4). Fruit yield was reduced when bareroot tomato transplants were packed at 1250 plants/crate compared to 1000 plants/crate (11).

Plant performance after initial transplanting, depends also on the physiological age of the transplants. Enhanced yield was reported using 3- to 5-week-old bareroot transplants as compared to 7- and 9-week-old transplants, respectively (8). Transplant size expressed as height, leaf area or shoot weight, when measured in the greenhouse, generally is larger for older than for younger transplants (15). In those previous studies (8,15), however, shoot and root growth changes that occur during transplant storage and subsequent to planting were not considered.

In these studies, the effects of (a) transplant handling on shoot and root growth changes during extended-low temperature storage, (b) transplant handling on early growth and yield after reduced-ambient storage, and (c) transplant age on plant growth and yield of tomato transplants were investigated.

Materials and Methods

Extended storage (Experiment 1) 'Sunny' Tomato plants were grown for 45 days at Speedling Inc., Bushnell, Fla. using their flotation system. Speedling polystyrene trays with 200 inverted pyramid cells of 2.5 cm x 7.2 cm (side length x depth; 18 cm^3) were used. Greenhouse transplant production practices were standard proprietary procedures of Speedling Inc. (3). Handling treatments were: (a) transplants that were kept directly in trays and packed in boxes (Not Pulled) and (b) transplants that were hand-pul-