Survival of *Xanthomonas campestris* pv. *vesicatoria* in Florida on Tomato Crop Residue, Weeds, Seeds, and Volunteer Tomato Plants

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ABSTRACT

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Studies were undertaken to determine the ability of *Xanthomonas campestris* pv. *vesicatoria* to survive in Florida on crop residue, on or in plants of various weed species, in soil, on volunteer tomato plants and on tomato and pepper seed. In the crop residue studies, *X. c.* pv. *vesicatoria* was recovered from infected crop residue 6 mo after placing the residue in the field in December 1981 and 1982. When diseased crop tissue from spring crops (January–May) in Bradenton was placed in the field in May 1982 and June 1983, *X. c.* pv. *vesicatoria* was recovered after 3 mo and 6 wk, respectively. In summer survival tests done in Homestead (where diseased tissue was placed in the field 8 June 1982 and 7 June 1983) *X. c.* pv. *vesicatoria* was detected after 3 and 6 wk, respectively. In studies in which washings from plants of weed species were infiltrated into tomato plants, *X. c.* pv. *vesicatoria* was recovered from six weed species which included two solanaceous weeds, *Solanum americanum* and *Physalis pubescens*. However, only 11 of the 202 weed samples contained *X. c.* pv. *vesicatoria*. Volunteer tomato plants were found throughout the spring of 1982 following a fall (August–December) 1981 tomato crop. Volunteer plants had a high incidence of bacterial spot as late as July 1982. The use of sorghum as a cover crop enhanced development of volunteers, whereas periodic disking eliminated them. *X. c.* pv. *vesicatoria* was detected in one of 53 commercial pepper seedlots and in none of 293 commercial tomato seedlots. Tomato volunteers and crop residue are likely sources of primary inoculum, whereas tomato seeds and weeds appear to be questionable sources.

Bacterial spot of tomato and pepper which is incited by *Xanthomonas campestris* pv. *vesicatoria* (Doidge) Dye is one of the most devastating diseases of tomato and pepper in Florida. Fresh-market tomato production accounts for approximately 19,000 ha each year. Reported losses under heavy disease severity have been estimated to be as high as 52% as measured by weight losses of marketable fruit (25).

At best, control of this disease is marginal during the periods of high precipitation and high temperatures which occur routinely during the summer and sporadically throughout the year. The abundance of copper-resistant strains of *X. c.* pv. *vesicatoria* in Florida has made it more difficult to control this disease with sprays (20). It is essential to use an ethylene *bis*-dithiocarbamate compound in combination with copper compounds for reducing bacterial spot severity (6).

Since it is difficult to control bacterial leaf spot with foliar applications of chemicals once it becomes established, other control measures are needed to reduce disease losses. Prevention of the problem through exclusion of the bacterium is one possibility. To achieve this, it is necessary to determine the sources of inoculum. Often, bacteria are seedborne (1,2,5,15,18,21,23,27). Previously, researchers have reported the association of *X. c.* pv. *vesicatoria* with tomato and pepper seed (3,10,11) extracted with a mechanical seed extraction technique. However, current seed extraction from tomato fruit is not mechanical, but involves fermentation or acid extraction which supposedly eliminates bacterial pathogens. Consequently, there is controversy as to whether or not currently produced tomato seed is a source of inoculum.

Weeds, either as hosts or nonhosts, have been shown to serve as reservoirs of bacterial pathogens (4,9,16,19,21,28,29), which in turn may infect nearby crops susceptible to a particular organism.

Crop residue provides a means by which phytopathogenic bacteria overwinter and/or oversummer (12,21,24). Dead tomato stalks were important in the survival of *X. c.* pv. *vesicatoria* in Indiana and Nebraska (24,30).

Volunteer tomato plants were found to be a source of inoculum of *X. c.* pv. *vesicatoria* in Indiana (11,24). In those studies (11,24), *X. c.* pv. *vesicatoria* was detected readily on volunteer tomato plants grown in the spring from seed produced the previous year.

This study was undertaken to evaluate the role of crop residue, various weed species, volunteer tomato plants, and seeds in the

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season-to-season survival of *X. c.* pv. *vesicatoria* in the subtropical climate of Florida.

MATERIALS AND METHODS

Studies on host residue survival. Tomato foliage and stem tissue were collected from mature field-grown cultivar Sunny tomato plants severely affected by bacterial spot in field plots at Bradenton, FL. Collections of diseased leaf and stem tissue were made following fall crops for overwintering studies and following spring crops for oversummering studies. Approximately 35–40 g (fresh weight) of tissue was packed into 15 × 25 cm pouches made of fine-mesh (1-mm pores) nylon for assaying *X. c.* pv. *vesicatoria*.

The winter survival studies were conducted at Bradenton. Diseased tissue was collected 14 December 1981 and 15 December 1982 for the 1981–1982 and 1982–1983 overwintering studies, respectively. The nylon bags containing the diseased plant tissue were placed in a randomized complete block design consisting of four replications and three treatments in which the bags were placed either on the soil surface or buried at 15 or 30 cm.

In the spring of 1983, EauGallie fine sand at Bradenton was infested with *X. c.* pv. *vesicatoria* and assayed periodically for the presence of the bacterium. Inoculum was prepared by suspending in 0.01 M $MgSO_4 \cdot 7\ H_2O$ bacterial cells from a 48-hr culture of *X. c.* pv. *vesicatoria* grown on nutrient-yeast-dextrose agar. Viability of *X. c.* pv. *vesicatoria* in this suspension was not affected over a 2- to 3-hr period. The suspension was atomized onto batches of the soil rotating in a cement mixer and the amount was adjusted to approximately 10^8 colony-forming units (cfu) per gram. Infested soil was placed in 15-cm-diameter plastic pots that were buried in the soil in the field with the top of each pot approximately 2.5 cm above the soil surface.

The summer survival study was conducted at Bradenton and Homestead. Diseased tissue was collected, as described previously, on 21 May 1982 and 8 June 1983 at Bradenton, and 24 June 1982 and 6 June 1983 at Homestead. The test was set up in a randomized complete block design with four replications of two treatments in which the nylon bags were placed either on the soil surface or buried at 15 cm.

For assay purposes, one bag from each of the four replicates of each treatment was collected and placed individually in a flask containing 200 ml of a suspension of $CaCO_3$ (0.1%, w/v). All flasks were shaken vigorously for approximately 20 min. The infested soil was assayed by mixing 25 g of soil (wet weight) in 250 ml of the $CaCO_3$ suspension in a blender for 1 min. The resulting suspensions from tissue and soil were vacuum-infiltrated (14) into cultivar Walter tomato plants. Preliminary tests with pure cultures resulted in recovery from suspensions containing as few as 10 cfu/ml. The infiltrated plants were placed in the greenhouse and checked periodically for lesion development. Isolations from suspect lesions were made by triturating the lesion in deionized water and then streaking for individual colonies on nutrient-yeast-dextrose agar. Bacterial colonies suspected of being *X. c.* pv. *vesicatoria* were tested for Gram reaction (26), oxygen requirement (26), and utilization of mannose, arabinose, and dextrose (8,13,26). The suspect cultures were tested for pathogenicity by gently misting 4- to 5-wk-old cultivar Walter tomato plants with a suspension of each culture at approximately 10^8 cfu/ml (which was obtained by turbidimetric measurement with a spectrophotometer) and then placing the inoculated plants in polyethylene plastic bags. The inoculated plants were incubated at 28 C for 36 hr, then removed from the plastic bags, placed in the greenhouse, and rated for development of typical bacterial spot symptoms 14 days after inoculation.

Weed sampling for *X. c.* pv. *vesicatoria*. Weed samples were collected periodically from tomato fields currently in production and from tomato fields that were fallow. All fields had a history of bacterial spot. The weed samples (which consisted of four distinct plants of a particular species) were separated into root and shoot samples and assayed by washing the samples in 200 ml of the $CaCO_3$ suspension and then infiltrating the washings into tomato plants as previously described. Isolations were made from suspect lesions, and the suspect bacteria were characterized as described above.

Survey for volunteer tomato plants. Two surveys were completed, one in west-central Florida (Manatee and Hillsborough counties) and the other in southeast Florida (Dade County), both large production centers of fresh market tomatoes.

Nine tomato fields that had been in production the fall of 1982 were periodically surveyed in west-central Florida from March to July or August of 1983 for the presence of volunteer tomato plants (defined as plants arising either from germinating seeds or lateral shoots from surviving plant crowns of a preceding tomato crop). Plots (13.94 m^3) were established in each field. At frequent intervals during the survey period, the same locations were surveyed. The total number of volunteer tomato plants and the number of them infected with bacterial spot were determined in each plot. Fields were chosen in which various cultural practices were used following the fall crop. In two fields, sorghum was planted following the fall tomato crop. In four fields, rototilling or disking periodically was a routine practice, whereas in three fields the land was left untended following the fall crop. Periodically, isolations were made (as previously described) from lesions suspected of being incited by *X. c.* pv. *vesicatoria* and the bacterial isolates were characterized.

Five abandoned tomato fields (ranging from 16.2 to 32.4 ha in area) were identified in the southeast Florida area in early June 1980. Weed growth in all fields was already heavy at the beginning of the study. Volunteer tomato plants were monitored once or twice per week. In each field, population estimates were made by counting all volunteers in four 58-m^2 quadrats. During the first field visit, quadrats were established by selecting four sites randomly in the field, tossing a meter stick among the vegetation, and constructing a square (7.6 m on a side), using the orientation of the meter stick to align the left side of the square. In addition, the numbers of black nightshade (*Solanum americanum* L.) and other predominant weed species were recorded. The association of *X. c.* pv. *vesicatoria* with disease lesions on the volunteer plants was characterized periodically.

Seed detection of *X. c.* pv. *vesicatoria* from commercial seedlots. Preliminary tests were undertaken to determine the recovery of *X. c.* pv. *vesicatoria* from artificially infested seed. After rinsing cultivar Walter tomato seeds in tap water to remove acid and thiram (tetramethylthiuram disulfide), seeds were soaked in a 10^8 cfu/ml suspension of an *X. c.* pv. *vesicatoria* strain with induced resistance to streptomycin and rifampicin. Each seed contained between 667 and 3,333 cfu of *X. c.* pv. *vesicatoria* per milliliter. The infested seeds were added to healthy seeds to make a final concentration of 1, 10, or 100 infested seeds per 1,000 seeds. The seeds were immediately placed in sterile flasks, moistened, and the flasks were closed with aluminum foil over plastic foam stoppers to maintain high moisture. The seeds were incubated 7–10 days at room temperature until germination occurred. The resulting enriched seedlings were assayed by vigorously washing them in $CaCO_3$ suspension for 20 min and then infiltrating the washings into healthy tomato plants, and also by plating dilutions of the washings onto nutrient-yeast-dextrose agar supplemented with 50 μg/ml each of rifampicin and streptomycin and 100 μg/ml of cycloheximide.

Pepper and tomato seeds used in the transplant industries in Florida and Georgia were obtained from the Florida Department of Agriculture at Gainesville, FL, and the Georgia Department of Agriculture at Tifton, GA. Two hundred and ninety-three commercial tomato seedlots and 53 commercial pepper seedlots were assayed by the above assay procedure. Each sample consisted of at least 3 g of tomato seeds or 6 g of pepper seeds. Seven tomato seedlots tested had less than 3 g of seed available.

RESULTS

Vacuum infiltration efficiency. The bacterium was readily detected in solutions containing 10^1–10^2 cfu/ml whether in culture in 0.1% $CaCO_3$ suspension or in extract from seedling or soil suspensions as was previously observed with *P. syringae* pv. *tomato* (14). Plating of the extracts on a semiselective medium (22) was

ineffective because of the extensive number of contaminants on the enriched seedlings.

Crop residue studies. *X. c.* pv. *vesicatoria* was detected in the crop residue of a fall crop for approximately 6 mo (Table 1). In January and March, disease severity was greatest on plants infiltrated with washings from crop residue samples placed on the surface. However, when the crop residue was sampled in April or later, all treatments resulted in equally severe disease.

In summer survival studies, the bacterium was recovered for 74 days in the 1982 test and after approximately 35 days in the 1983 test (Table 2). The rate of recovery was equal in the two treatments; however, more disease was present on plants infiltrated with washings from crop residue placed on the soil surface than on plants infiltrated with washings from buried debris.

Epiphytic survival on weed species. During the sampling period, 44 plant species were assayed for the presence of *X. c.* pv. *vesicatoria*. The bacterium was detected on *S. americanum* (three samples), *Physalis pubescens* L. (three samples), *Ambrosia artemisifolia* L. (two samples), *Eclipta alba* L. (one sample), *Trifolium repens* L. (one sample), and *Eupatorium capillifolium* Watl. (one sample). Few bacterial lesions developed on tomato plants infiltrated with washings from these 10 samples, and the bacterium was only isolated from weeds located in fields currently in tomato production, or in fields where volunteer tomato plants were present. In no instance was *X. c.* pv. *vesicatoria* detected on weed samples in fields where tomatoes were not in production, or where volunteer tomato plants were not present in abundance.

Volunteer tomato plants. Tomato volunteers were observed consistently in the spring in fields in west-central Florida where sorghum was used as a cover crop (Table 3). Volunteers with bacterial spot were observed in those fields 12 July 1982 (field 2) and 17 August 1982 (field 1). The volunteers in field 1 were observed in close proximity to a current tomato crop. Where disking was a common practice, tomato volunteers reached the seedling stage in the spring, but were not observed 1–3 mo before the next crop. In fields 7–9, good sanitation and cultural practices were neglected. The plant beds and/or plastic mulch were not disked or burned. Volunteers with bacterial spot were readily observed on 9 July 1982. Volunteer populations declined in all cases as the season progressed.

In southeast Florida, substantial numbers of volunteer tomato plants were found in abandoned fields during the summer. Mean plant populations were as high as approximately $1/m^2$ in two of the five fields that were studied (Table 4). During the time that the fields were uncultivated, plant populations were stable and the mean number of volunteers per quadrat did not differ significantly ($P = 0.01$) in each field, based on sampling date. Once disking and other cultural practices were begun, volunteers were no longer found. In four fields, volunteers were found until late July, and in one case volunteers were still living on 13 August. Virtually all volunteer plants (95%) showed typical bacterial spot symptoms, and isolations, made periodically for confirmation, were positive for *X. c.* pv. *vesicatoria*.

Seed assay. Preliminary tests with infested seeds showed that *X. c.* pv. *vesicatoria* could be detected by the assay procedure when one infested tomato seed was placed with 999 healthy seeds. The recovery by this procedure was 67% in one test and 100% in a second test. In laboratory tests, bacterial populations increased between 40 and 80,000 times in treatments where infested seeds were incubated under high moisture conditions for 7 days compared to where seeds were assayed immediately after being infested. *X. c.* pv. *vesicatoria* was not detected in any of the 293 tomato seedlots, but it was detected in one pepper seedlot. However, upon retesting of that seedlot, the bacterium was not recovered.

DISCUSSION

Transmission of *X. c.* pv. *vesicatoria* in tomato and pepper seed has been studied previously (3,10,11,31). The original work on tomato was done by Gardner and Kendrick in 1921 (10,11). The extraction procedure used in that study was a mechanical method

TABLE 1. Recovery of *Xanthomonas campestris* pv. *vesicatoria* from naturally infected crop residue buried at two depths, or placed on the soil surface in the winter and spring of 1981–1982 and 1982–1983

	Sampling dates, 1981–1982[a]				Sampling dates, 1982–1983					
Treatment	19 Jan	25 Mar	9 Jun	20 Sept	17 Jan	4 Mar	4 Apr	6 May	27 Jun	3 Aug
Crop residue on soil surface	4[b] (5.0)	4 (5.0)[c]	2 (0.5)	0	4 (5.0)	4 (5)	4 (1.75)	4 (2.0)	2 (1)	0
Crop residue buried at 15 cm	4 (3.0)	4 (2.75)	3 (0.75)	0	4 (5.0)	4 (3)	4 (2.5)	4 (2.0)	0	0
Crop residue buried at 30 cm	4 (2.5)	4 (2.0)	2 (0.75)	0	4 (5.0)	4 (3)	4 (2.5)	3 (2.3)	0	0
Infested soil	...	...	...	...	0	0	0	0	ND	ND

[a] 1981–1982 test was begun 14 December 1981; 1982–1983 test was begun 15 December 1982.
[b] The number of replications (total of 4) from which *X. c.* pv. *vesicatoria* was isolated from crop residue.
[c] The value in parentheses represents the average bacterial spot severity rating of tomato plants infiltrated with washings from crop residue. The rating scale was: 0 = no lesions, 1 = 1–10, 2 = 10–50, 3 = 50–500, 4 = 500–1,000, and 5 = >1,000 lesions per plant. ND = not determined.

TABLE 2. Recovery of *Xanthomonas campestris* pv. *vesicatoria* from naturally infected crop residue buried or placed on the soil surface at two locations in Florida in the spring and summer of 1982 and 1983

	1982[a]							1983[b]							
	Homestead sampling dates			Bradenton sampling dates				Homestead sampling dates				Bradenton sampling dates			
Treatment	7 Jul	30 Jul	29 Aug	11 Jun	28 Jul	24 Aug	28 Sept	15 Jun	20 Jul	21 Aug	26 Sept	15 Jun	18 Jul	19 Aug	24 Sept
Crop residue on surface	4[c] (5)[d]	0	0	4 (5)	3 (1)	1 (2)	0	4 (5)	4 (2.25)	0	0	4 (5)	4 (4)	0	0
Crop residue buried at 15 cm	4 (1)	0	0	4 (3.3)	4 (1.5)	4 (1)	0	4 (5)	4 (1)	0	0	4 (5)	4 (1.5)	0	0

[a] In 1982, the Homestead and Bradenton studies were begun 8 June.
[b] In 1983, the Homestead study was begun 7 June, and the Bradenton study was begun 8 June.
[c] The number of replications (total of 4) from which *X. c.* pv. *vesicatoria* was isolated from crop residue.
[d] The value in parentheses represents the average severity rating for bacterial spot severity of tomato plants infiltrated with washings from crop residue. The rating scale was: 0 = no lesions, 1 = 1–10, 2 = 10–50, 3 = 50–500, 4 = 500–1,000, and 5 = >1,000 lesions per plant.

in which the spotted fruit was cut in two and the halves were rubbed over a screen. Methods currently used in commercial tomato operations include fermentation or acid extraction. These two methods reduce the degree of contamination of seed by fruit pulp. Chambers and Merriman (5) were able to isolate *P. syringae* pv. *tomato* from mechanically harvested tomato seed taken from infected fruit, but not from seed extracted by the fermentation or acid process. Since *X. c.* pv. *vesicatoria* was not recovered in any tomato seedlots and from only one pepper seedlot, our results indicate that infestation or infection by *X. c.* pv. *vesicatoria* in tomato seeds planted in Georgia and Florida appears to be at an extremely low level and might be unimportant in the epidemiology of the disease. However, in studies in which tomato fruits with extensive fruit spotting were collected, we were successful in isolating *X. c.* pv. *vesicatoria* from seed extracted by fermentation (J. B. Jones, R. G. McGuire, and R. E. Stall, *unpublished*). There is much more positive support that *P. s.* pv. *tomato* is seed transmitted (3,5,15,21,31). Since the detection procedure used in this study does not assay great quantities of seeds, it is possible that *X. c.* pv. *vesicatoria* is seed-transmitted at an extremely low level. Also, low population levels make the bacterium difficult to recover. For this reason, the enrichment technique was used.

Crop residue could be a means for *X. c.* pv. *vesicatoria* to overseason and serve as an inoculum source in successive crops. Peterson (24) was able to detect *X. c.* pv. *vesicatoria* in dead tomato stalks the following spring. According to Peterson (24), this was the major means of overwintering in Indiana since survival in the soil free of crop tissue was ephemeral. Our results on fall and winter crop residue and soil survival concur with his. In southeast Florida, however, the bacterium must be able to oversummer from winter crop to the next winter crop. Since the bacterium was not detected in August in diseased crop residue buried or placed on the soil surface the first of June in Homestead, the potential for residue of a previous winter crop to serve as an inoculum source for the next winter crop is highly unlikely.

The role of crop residue from a spring planting in the epidemiology of bacterial spot of the following fall crop in southeast Florida is conjecture. The bacterium was detected in some experiments as late as 24 August, but never in September after the diseased tissue had been buried in the field in May. It appears that the high soil and air temperatures reduced the survival potential of *X. c.* pv. *vesicatoria*. Similarly, the long-term survival of *P. s.* pv. *tomato* decreased as the soil temperature increased (21). *X. c.* pv. *vesicatoria*, like *P. s.* pv. *tomato*, does not appear to

TABLE 3. Periodic survey for tomato volunteers in spring 1982 fields in west-central Florida that had been in tomato production in fall 1981

Field	Survey date	Sites surveyed	Volunteers observed (no.)	Observed volunteers infected with XCV	Field practice
1	2[a]	8[b]	275	0	Sorghum was planted as cover crop.
	5	8	459	293	
	7	8	214	117	
	10	6	76	66	
	13	6	0	...	
	14	150	23	1	
	15	150	12	6	
2	1	7	419	116	Plastic mulch was removed from the plant beds, the field was disked once, and sorghum was planted as a cover crop.
	4	7	307	235	
	7	7	158	77	
	12	7	27	17	
3	1	8	313	3	Plastic mulch was removed from the plant beds, and the field was disked periodically.
	4	8	0	...	
	7	8	2	0	
	14	50	0	...	
4	1	7	0	...	Plastic mulch was removed from the plant beds, and the field was disked periodically.
	4	7	39	0	
	8	7	0	...	
	16	63	0	...	
5	3	8	0	...	Plastic mulch was removed from the plant beds, and the field was disked once.
	5	8	102	0	
	12	8	0	...	
	16	80	0	...	
6	6	9	18	18	Plastic mulch was removed from the plant beds, and the field was disked periodically. Volunteers were observed early in the season where disking had not been completed.
	9	9	18	4	
	11	9	0	...	
	13	9	0	...	
7	3	7	406	173	Plastic mulch was burned, but the field was not rototilled.
	6	7	405	282	
	8	7	410	126	
	11	7	51	46	
8	2	4	460	341	Plastic mulch was not burned, and the plant beds were still intact.
	5	4	244	151	
	8	4	164	47	
	11	4	14	8	
9	2	6	195	11	Plastic mulch was burned, but the field was not rototilled.
	5	6	228	54	
	8	6	174	56	
	11	6	13	5	

[a] Sampling dates: 1 = 16 March 1982; 2 = 17 March 1982; 3 = 22 March 1982; 4 = 6 April 1982; 5 = 9 April 1982; 6 = 13 April 1982; 7 = 12 May 1982; 8 = 14 May 1982; 9 = 18 May 1982; 10 = 18 June 1982; 11 = 9 July 1982; 12 = 12 July 1982; 14 = 6 August 1982; 15 = 17 August 1982; and 16 = 19 August 1982.

[b] Each survey site was approximately 3.05 × 4.5 m except in fields 7, 8, and 9 which had the original plant beds which were 30–60 m long and approximately 1.4 m wide.

TABLE 4. Last survival date and mean number of bacterial spot-infected oversummering volunteer tomato plants per quadrat in Dade County, Florida, in 1980

Field	Last date infected plants found	Plants per 58 m²[a]	
		Infected tomato	Black nightshade
A	23 July	38	3
B	30 July	4	0
C	25 July	19	0
D	25 July	56	0
E	13 August	64	3

[a] Data from four quadrats (7.6-m × 7.6-m) per commercial field. Analysis of variance showed no difference between mean numbers of plants in each field on different sampling dates.

oversummer in or on crop residue for long periods of time. However, if the bacterium survives only until June or early July, then the spring residue may serve as an excellent source of *X. c.* pv. *vesicatoria* for tomato transplant production, and consequently for the fall crops which begin in early to mid-August. Moreover, the crop residue from a fall crop could very well serve as an inoculum source for a spring crop in a field, or for a tomato transplant production site if the crop residue was in close proximity.

Epiphytic survival of *X. c.* pv. *vesicatoria* on weed species appears to be relatively unimportant in the epidemiology of bacterial spot of tomato. The detection of very low populations of *X. c.* pv. *vesicatoria* on only 11 of 203 weed samples (5%) from fields currently in tomato production or adjacent to tomato volunteers strongly suggests that weeds are a poor source of *X. c.* pv. *vesicatoria*. Additionally, McGuire and Jones (*unpublished*) inoculated several weed species including *S. americanum*, *A. artemesifolia*, and *E. alba* in the field with *X. c.* pv. *vesicatoria*. The bacterium was detected only after 2 weeks on *S. americanum*. From these results it appears that unlike several other bacterial plant diseases (9,16,29), weed species play a minor role in the epidemiology of bacterial spot of tomato. Previously, Laub and Stall (17) demonstrated that *Solanum nigrum* and *Physalis minima* were not hosts of *X. c.* pv. *vesicatoria*. Our results are supportive in that another *Solanum* sp. and another *Physalis* spp. were found not to be hosts of *X. c.* pv. *vesicatoria*.

Volunteer tomato plants probably are important in the epidemiology of *X. c.* pv. *vesicatoria* in Florida. In one field in southwest Florida (Homestead), infected volunteers were found 8 mo after the crop had been disked under. Thus, these volunteers were able to serve as a source of inoculum for a crop planted 1 yr after the previous one. Survival of infected volunteers until late July or early August, coupled with our experimental results showing survival of *X. c.* pv. *vesicatoria* for 2 mo in infected debris buried in Homestead soils, suggests a mechanism for local oversummering of the pathogen. Once new crops or weeds appear in September, *X. c.* pv. *vesicatoria* could colonize the rhizoplane (7,19) or phylloplane (9) of developing plants, where they could be a primary inoculum source for new tomato crops.

Failure to disk fields periodically throughout the off-season may allow substantial numbers of volunteers to survive. Using field E from Table 4 as an example, one location alone harbored 5,530–16,700 volunteer tomato plants (95% confidence limits of the mean). Undoubtedly, growers should destroy volunteer plants as a component of their total approach to control bacterial spot.

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