Tolerance of Fruit of Different Tomato Cultivars to Soft Rot

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ABSTRACT

Tomato cultivars differ in their tolerance to soft rot caused by *Erwinia aroideae*. Two to three times as many mature green Walter tomatoes were rotted 3 and 7 days after wound inoculation as were those of Florida MH-1 or Homestead-24. However, all inoculated fruit eventually rotted. Exposure of the fruit for 5 days to 45 F before inoculation greatly increased the susceptibility of all fruit to soft rot, but did not eliminate the differences among varieties. Increasing the inoculum level from 10^5 bacteria/ml to 10^7 bacteria/ml approximately doubled the amount of decay noted 3 and 7 days after inoculation.

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Additional key words: chilling injury, inheritance.

One of the major problems associated with the development of a successful mechanical harvest system for fresh market tomatoes has been the large amount of mechanical damage to the fruit (4). This problem has been reduced considerably by the development and use of jointless tomato lines. However, mechanical damage of the fruit of even jointless lines during harvest has continued to be a major problem. The effect of injuries on the amount of fruit decay which occurs later cannot be assessed until significant numbers of mechanically harvested fruit have been processed through packinghouses. These injuries could present a major problem for postharvest handling, as all fruit, whether healthy or rotted, pass through the harvester. If rotted fruit were present in the field prior to harvest, contamination of injuries on most fruit would be virtually assured unless some means of complete sanitation can be devised.

One of the most destructive postharvest decays of tomato fruit has been soft rot caused by *Erwinia carotovora* (L. R. Jones) Holland (*Pectobacterium carotovora* Waldee). L. R. Jones (8) reported as early as 1901 that soft rot bacteria did not penetrate the intact surface of vegetables, but rather gained entrance through wounds or surface cracks. In addition, green fruit apparently rotted more rapidly than ripe fruit. In 1924, Wingard (16), working with the non-gas forming variant of *E. carotovora* (*E. aroideae*) substantiated Jones' report that ripe fruit were not so susceptible to soft rot as were green fruit, and found that bacteria infected stem and blossom scars as well as surface cracks. A more recent report reaffirmed that ripe fruit were more tolerant of soft rot than green fruit, and also determined that pink fruit were more tolerant than green fruit (14).

Soft rot incidence on fresh market vegetables has been reduced through the use of antibiotics (15), through sanitation aided by the use of hypochlorite ion or chloramines (5, 11, 15), and by the use of low temperature during storage and transit (5, 15). At the present time, antibiotics cannot be used for postharvest treatments because of FDA regulations. The usefulness of chlorine compounds has been limited, presumably because the active agent acts on the surface of wounds or other organic matter as well as on the bacteria (5). Use of chlorine compounds will, nevertheless, reduce the amount of inoculum present in the wash water and thus, the amount of decay (11). Fruit of all tomato varieties are sensitive to extreme chilling, although some are more tolerant than others (2, 13). In addition, chilling was found to decrease the tolerance of tomato fruit to soft rot and to Alternaria rot (11). Consequently, use of low temperatures during postharvest handling has been limited.

Production of fresh market tomato varieties which possess tolerance to postharvest fruit decays has not been considered to any extent. Tomatoes tolerant to late blight have been tested for resistance to buckeye rot caused by *Phytophthora parasitica* var. *terrestris* (6). Wingard (16) inoculated mature green fruit of six different tomato varieties with *E. aroideae*. All inoculated fruit were rotted within 7 days, and Wingard concluded that no varietal differences existed. Varietal differences in the incidence of Alternaria stem end decay in chilled tomatoes have been reported (13). Further studies established that the cultivar Grothen's Globe was more tolerant to Alternaria rot than was Manapal (12).

Hollis & Goss (7) reported highly significant varietal differences in susceptibility of potato tubers to *E. carotovora*. Rutabaga and turnip varieties have been reported to differ in susceptibility to a soft rot epiphytotic in the field (10). However, no attempt was made to provide uniform predisposing factors such as hail damage, insect wounds, etc. Early publications have referred to differences in susceptibility of potato varieties to *Erwinia atroseptica* (9). Field tolerance, however, was not correlated with tolerance as determined in the laboratory. In addition, the tolerance of the tuber or seed piece of a given variety gave no indication about the tolerance of the stem of that variety.

In the following study, three tomato varieties, Walter, Homestead-24, and Florida MH-1, were tested for tolerance to soft rot. Walter and Homestead-24 were selected because they were standard varieties and were substantially different in reaction to fruit decay following chilling during the spring of 1970 (2). Florida MH-1 was selected for the test because it was the first machine-harvest, fresh-market tomato line to be released for commercial use (3).

MATERIALS AND METHODS.—Mature green fruit from the varieties Florida MH-1, Homestead-24, and Walter were harvested from three different areas of Florida during the winter and spring seasons of 1971. In two of the three areas, the three varieties were grown in the same field using the same cultural conditions. In the other area, the varieties were grown in adjacent fields by the same grower. After each of four harvests, 90 mature green fruit from each variety were selected for uniform size, maturity, and freedom from surface blemishes or wounds, swabbed with 10% commercial chlorine bleach, and placed on fiberglass trays so that each tray contained 10 fruit of each variety. An additional 90 fruit were chilled for 5 days at 45 F, then treated as above.

The bacterium used was originally isolated from a tomato fruit showing a typical soft rot lesion. The isolate, derived from a single colony, was maintained in sterile distilled water suspensions in screw cap vials stored at 4 C until required for starting nutrient broth cultures. The broth cultures were grown at 30 C for 24 hr in an incubator-shaker. Bacteria were centrifuged from the culture, resuspended in sterile saline buffered to pH 7.0 (0.8 g NaCl, 0.2 g Na_2HPO_4, and 0.2 g KH_2PO_4 to 1 liter with distilled H_2O), and repelleted. The washed bacterial pellet was suspended in sterile buffered saline and adjusted to 50% T (transmittance) at 600 nm. This provided an approximate concentration of 10^8 bacteria/ml. From this stock suspension, a dilution series of 10^7, 10^6, and 10^5 bacteria/ml buffered saline was prepared.

Subsequent tests on the bacterium used indicated that it was gram-negative; motile by peritrichous flagella; indole positive; H_2S negative; KCN positive; and lysine decarboxylase negative; that it reduced nitrate; produced acid but no gas in Kligler's iron agar (fermented glucose and lactose), with mannitol, or with rhamnose; liquefied gelatin; grew in Koser's citrate; but did not utilize sorbitol or dulcitol. This organism would best fit *Erwinia aroideae* of Bergey's Seventh Edition (1).

A cork mounted on a metal transfer needle pierced with four straight-pins served as the wounding instrument. Depth of the four wounds was ca. 2-mm. The base of the cork served as a stop so that all wounds were the same depth. The instrument was dipped in a bacterial suspension before each wounding, and each fruit was inoculated in four areas with a total of 16 punctures. The sequence of inoculation was such that at each concentration of bacteria, the wounding of two fruit of one variety was followed by wounding of two fruit of the next variety until 10 fruit of each variety were inoculated. This sequence served as one replicate of the three replicate experiment. Fruit which had been chilled were inoculated in the same manner. All wounded fruit were stored at 70 F and 90% relative humidity. Fruit with lesions were removed and recorded at 48-hr intervals. Dates when surviving fruit turned pink, then ripe, were also recorded.

RESULTS.—The criterion used for measuring tolerance to soft rot was a comparison of the number of fruit rotting (having at least one soft rot lesion) out of each 10-fruit replicate at various intervals after inoculation. Fruit which were inoculated immediately after harvest generally did not visibly begin rotting until 3 days after inoculation, whereas those which were chilled began 2 days after inoculation (Table 1). Duncan's multiple range test was applied to the data. Transformation of zero (no rot) or 100 (all rotted) was not done. By chance, some of the comparisons were made with data which had few, or no, zero or 100 values. Significance of the differences between the means in the latter appeared no different from situations where zero or 100 values had been included.

If maintained for a sufficient time, all inoculated fruit eventually rotted, starting at the wound. However, the numbers of rotted fruit, 3 and 7 days after inoculation, showed significant or highly significant differences among varieties. The differences of the means of Walter (when compared with Florida MH-1 and Homestead-24) were either significant or highly significant. The differences among Florida MH-1 and Homestead-24 were not significant. Similar results from tests of significance were obtained using the means of the number of fruit that had rotted 7 days after inoculation. By 14 days after inoculation, virtually all Walter fruit had rotted at all three inoculum concentrations. However, 28 and 34% of Homestead-24 fruit remained healthy at the 10^6 and 10^5 inoculum levels, respectively.

Although none of the fruit was pink or ripe at the time of inoculation, the majority of fruit of all varieties were either ripe or pink by the time soft rot lesions had developed. An average of 46, 40, and 49% of Walter fruit which had rotted by 14 days after wound inoculation with needles dipped in 10^7, 10^6, and 10^5 bacteria/ml, respectively, were ripe before soft rot developed. Corresponding values for Florida MH-1 were 48, 78, and 73, whereas Homestead-24 had 53, 67, and 73%, respectively. Percentages of fruit which had been red-ripe for 4 days or longer before soft rot lesions had developed were 7, 10, and 19%, respectively, for Walter. Corresponding values for Florida MH-1 were 17, 32, and 27%; Homestead-24 had 10, 18, and 16%, respectively. Most fruit required 4 days to turn from pink or breaking to red ripe. Soft rot lesions developed much more rapidly, advancing from just being visible to involving more than one half of the fruit in 2 days.

DISCUSSION.—Tolerance to soft rot as expressed herein was based upon the ability of the fruit to tolerate the presence of soft rot bacteria for a given period of time. Each fruit of each variety was given a similar wound. Thus, the tolerance of a cultivar to mechanical damage could not have been a factor in the tolerance of that cultivar to the soft rot disease. Tolerance to mechanical damage would, however, be

TABLE 1. Effect of inoculum concentration and chilling (Ch) on bacterial soft rot in three tomato cultivars

		Percentage rotted fruit[a]							
		Days after inoculation							
		2		3		7		14	
Variety	Inoculum concn (bacteria/ml)	Ch[b]	Not ch	Ch	Not ch	Ch	Not ch	Ch	Not ch
Walter	10^7	97	–[c]	98	60	100	52	–	98
	10^6	83	–	83	40	88	36	–	92
	10^5	74	–	74	28	78	29	–	86
Florida MH-1	10^7	67	–	74	30	79	44	–	94
	10^6	46	–	47	12	49	21	–	92
	10^5	31	–	34	6	38	16	–	80
Homestead-24	10^7	49	–	57	12	77	96	–	96
	10^6	32	–	36	3	53	21	–	72
	10^5	34	–	31	1	36	16	–	66

[a] Average of nine replicates with 10 fruit inoculated in four places for each replicate.
[b] Stored at 45 F for 5 days before inoculation.
[c] – = No rot until 3 days after inoculation.

a factor in the incidence of soft rot in a commercial situation.

Fruit of Florida MH-1 and Homestead-24 possessed higher tolerance to soft rot than did those of Walter. The differences among the treatment means were significant at the 95 and/or 99% level for all comparisons among Walter and Florida MH-1 or Homestead-24, 3 and 7 days after inoculation. Since most fruit of both Florida MH-1 and Homestead-24 rotted by 14 days, the delay in the appearance of soft rot was only 11 days. As an appearance of soft rot of tomatoes during transit could result in severe secondary spread of the disease, a delay in the onset of the disease would be important. Delayed expression of soft rot would not necessarily mean that large numbers of contaminated fruit would be salvaged, but would mean that fruit developing soft rot at the later stages in handling could be culled before secondary spread occurred. In addition, up to 32% of the total number of fruit rotting were ripe at least 4 days before the rot occurred. These fruit probably would have been successfully marketed and consumed without any visual evidence of soft rot or noticeable deterioration of fruit quality.

At least three different reports have indicated that ripe fruit were more tolerant to soft rot than were green fruit (8, 14, 16). Although the fruit in this study were green when inoculated, a great majority (78% of Florida MH-1 inoculated with needles dipped in 10^6 bacteria/ml) were ripe when soft rot symptoms first appeared. Comparisons of the tolerance to soft rot of green, pink, and ripe fruit of the three cultivars in this report are currently under way.

The varietal differences in tolerance to soft rot were not altered by exposure of the fruit to 45 F for 5 days. There was, however, a marked decrease in the tolerance of all three cultivars following the low temperature exposure. Decreased tolerance to fruit decays in tomato has been linked previously to chilling injury (11, 13, 17). However, chilling injury as expressed by increased incidence of Alternaria rot (13) or failure to ripen properly along with pitting of the surface of the fruit (17) did not occur after a 5-day exposure to 45 F.

To successfully market machine-harvested tomatoes, all methods for reducing postharvest rot will be required. This will be especially true when rotted fruit are present in the field before harvest. The usual methods of reducing postharvest rot may be modified according to the level of tolerance of fruit of the cultivars grown. Either an increase in the tolerance of fruit to mechanical injury or to postharvest rot will reduce the need for complete sanitation. On the other hand, environmental and entomological conditions which increase the amount of soft rot present in the field prior to mechanical harvest could prevent successful marketing of any but the most disease-tolerant cultivars.

The possibility that tolerance to soft rot may be inherited was suggested by comparison of the pedigree of the susceptible Walter and the tolerant Florida MH-1, as the latter was a selection from a cross between Walter and Heinz 3. The former is a fresh market tomato, whereas the latter is a processing type which has been in part selected for tolerance to fruit rots. The tolerance of Florida MH-1 to soft rot could well be an expression of the fruit decay tolerance of the Heinz 3 parent.

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