COLLAR ROT RESISTANCE IN TOMATOES[1]

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INTRODUCTION

The disease of tomato foliage caused by *Alternaria solani* (Ell. and Mart.) Jones and Grout and known as early blight occurs practically everywhere in the United States of America and in most other countries where tomatoes are grown. A tomato crop is seldom free of early blight, and losses caused by it are sometimes extremely high. Thus it is familiar to all commercial tomato growers. Since all varieties of tomatoes have appeared to be susceptible to early blight, the prospect of breeding resistant varieties has not appeared very hopeful. Control of the disease has usually been approached through changes in crop management and the application of fungicidal dusts and sprays.

The collar rot phase of *Alternaria solani* infection is generally less familiar to tomato growers. It consists of dark sunken lesions or cankers girdling the stems of young plants at or near the soil level.[2] It develops on plants in the seedbeds or coldframes, during shipment and after transplantation to the field, and on plants seeded directly in the field.[3 4] Many plants are killed, and many others break over at the weakened area of the stem, remain flat on the soil, and put out new roots above the collar lesion. These are able to survive but fail to develop into vigorous plants.

The collar rot phase of *Alternaria solani* infection of tomatoes has become increasingly important along with the practice of shipping tomato plants from Southern to Northern States. Only a comparatively few commercial varieties, such as Marglobe, Rutgers, Indiana Baltimore, John Baer, and Grothen Red Globe, are involved in this plant-shipping industry. Studies at the United States Regional Vegetable Breeding Laboratory, Charleston, S. C., show that these varieties so far as examined are highly susceptible to collar rot, whereas certain other varieties are outstandingly resistant. It appears, therefore, that the control of collar rot may be effectively approached through plant breeding.

The purpose of this paper is to record the collar rot reaction of a large number of tomato varieties and selections and to describe the methods by which it has been possible to determine varietal differences in resistance.

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[2] PRITCHARD, F. J., and PORTE, W. S. COLLAR-ROT OF TOMATO. Jour. Agr. Res. 21: 179–184, illus. 1921.

[3] THOMAS, H. R. COLLAR-ROT INFECTION ON DIRECT-SEEDED TOMATOES. U. S. Bur. Plant Indus., Plant Dis. Rptr. 24 (1): 8–10. 1940. [Processed.]

[4] THOMAS, H. R., and SAMSON, R. W. DISEASES OF CANNING TOMATOES IN INDIANA AND THE RELATION TO SOURCE OF TRANSPLANTS. U. S. Bur. Plant Indus., Plant Dis. Rptr. 22. 330–331. 1938. [Processed.]

MATERIALS AND METHODS

Tomato (*Lycopersicon esculentum* Mill.) plants were produced in flats in which they were allowed to grow for 4 weeks. During that time they were thinned to permit normal uniform growth. At the end of 4 weeks they were taken up, inoculated, and transplanted to greenhouse bench soil consisting of unused or sterilized compost. The fresh compost was fairly light, well-screened, and practically free of damping-off organisms, so that no complications with other organisms were encountered.

Inoculation consisted in dipping the tops, including the stems, of the seedlings in a water suspension of a macerated culture of *Alternaria solani*. The culture employed was the same strain as that used in early blight studies made prior to these on collar rot.[5] Roots were not immersed. Ten plants were dipped in the inoculum at a time. Plants were set immediately to a depth of about 3 inches in rows in the bench soil, furrows were made between rows, and water was applied in the furrows in such a way as not to wash any inoculum from the stems. Collar rot readings were made on the 7th and 14th days. Usually 100 percent collar rot infection developed on susceptible varieties within 7 days. Since the inoculated plants were not held in damp chambers but were kept on open benches at all times, the foliage infection was kept at a minimum and in fact developed scarcely at all.

The alternaria culture was grown in liter flasks of liquid medium[6] and was used when 3 to 4 weeks old. The entire culture was thoroughly macerated or broken into fine particles with the assistance of an electric homogenizer or blending apparatus.[7] The macerated culture was diluted to about four volumes with distilled water. Enough inoculum was prepared so that a fresh quantity could be used for each series of plants inoculated.

Final collar rot evaluations were made by (1) recording the number of survivors, (2) pulling the survivors, washing the stems free of soil, and recording the degree of collar infection, and (3) calculating the relative tolerance to collar rot. The index of tolerance was based on the following assignment of values: 0, plants killed; 25, plants alive but broken over at collar lesion; 50, plants with well-developed collar lesions but still erect; 75, collar lesions very shallow or with a definite tendency to heal; and 100, no collar lesions. Final rating of varieties thus took into account not only survival and freedom from collar rot but also the extent of development or severity of collar rot lesions and the apparent ability of some varieties to recover or heal after infection.

The high effectiveness of the technique was proved not only by visual observation but also by the high F value obtained in variance analysis (see table 1).

RESULTS OF COLLAR ROT INOCULATIONS

The varieties, accessions, and clonal selections listed in tables 1 and 2 are arranged in descending order of resistance to collar rot. Table

[5] ANDRUS, C. F., REYNARD, G. B., and WADE, B. L. RELATIVE RESISTANCE OF TOMATO VARIETIES, SELECTIONS, AND CROSSES TO DEFOLIATION BY ALTERNARIA AND STEMPHYLIUM. [U. S. Dept. Agr. Cir. 652.]

[6] The liquid medium consisted of 10 gm. of peptone, 0.5 gm. of monopotassium phosphate, 0.25 gm. of magnesium sulfate, 20 gm. of sucrose, and 1,000 cc. of distilled water.

[7] ANDRUS, C. F. PREPARATION OF INOCULUM WITH A MECHANICAL LIQUEFIER. Phytopathology (Phytopath. Note) 31: 566–567. 1941.

1 shows varietal ranks following variance analysis of one complete four-replicate experiment. Table 2 includes additional varieties tested for collar rot reaction but not in the replicated experiment. Some of the varieties listed as resistant or tolerant showed considerably less than 100 percent freedom from collar rot. This is because a few plants of those varieties actually bore collar rot lesions, but the lesions were superficial and contributed little to the disability of the plant. Several grades of collar rot injury following inoculation are shown in figures 1 and 2.

Most of the varieties listed as resistant or tolerant in table 1 are relatively unknown to tomato growers in this country. They are predominantly from continental Europe or England. Those of the greatest probable value for immediate adaptability are the English forcing varieties Ailsa Craig, Devon Surprize, and King George, and the Danish varieties Danish Extra Early and Danish Export—all medium-sized red tomatoes that have proved to be very productive in South Carolina. Other varieties listed as resistant or tolerant to collar rot in table 1 include Norduke, of high quality and reputedly resistant to fusarium wilt, at least in certain areas, and Riverside, one of the newer wilt-resistant varieties, which is useful principally as a canning tomato (figs. 1 and 2).

TABLE 1.—*Collar rot rating of 115 tomato varieties and selections based on a four-replicate inoculation with Alternaria solani*

Group and designation	Vegetable Breeding Laboratory accession No.	Source [1]	Rating [2]
Group 1 (resistant or tolerant):			
Semperfructifera	99	Europe	98
P. I.[3] 118787	812–M1	South America	96
P. I. 117228	795–M1	Asia	95
Erste Ernte	54	Europe	94
King George selection	207–M1	England	94
P. I. 119105	817–M1	South America	94
Targinnie Red Selection	6–02–M4	Australia	92
Laxtons Open Air [4]	82	England	92
Tomato No. 73	780	North America	92
P. I. 127467	1005–M1	Asia	92
King George	207	England	91
Danish Extra Early selection	30–M2	Europe	90
Devon Surprize	35	England	90
Soleil Levant	97	Europe	90
Ailsa Craig	211	England	90
Cherry	781	North America	90
P. I. 120273	836–M1	Asia	89
Dobbies Champion [4]	45	Scotland	88
Lycopersicon pimpinellifolium × Marglobe (F_5).	245–2–9–1–M1	U. S. Regional Vegetable Breeding Laboratory.	88
Danish Extra Early	30	Europe	87
Targinnie Red	6–7	Australia	86
Danish Export	31	Europe	85
P. I. 126913	384–M5	South America	85
P. I. 118789	814–M1	do	85
Targinnie Red selection	6–02–M5	Australia	82
Do	6–10–M1	do	82
P. I. 138628	1027–M1	Asia	80
Norduke	202	North America	78
Riverside	973	do	78
Cereza	34	South America	77
P. I. 134208	882–M2	Asia	77
Lucullus	80	Europe	75
P. I. 120260	829–M1	Asia	74
Essex Wonder	52	England	73
Danish Extra Early selection	30–M1	Europe	70
Lister Excelsior	2	North America	68
Prairiana	214	do	64

[1] The source mentioned represents the best information available to the authors. The actual locality of origin of many of the named varieties is obscure.

[2] Significant difference mean of 4=16.03 at 5 percent; 21.07 at 1 percent. F_s=41.41**.

[3] P. I. refers to accession numbers of the Division of Plant Exploration and Introduction.

[4] Probably not true to type.

TABLE 1.—*Collar rot rating of 115 tomato varieties and selections based on a four replicate inoculation with Alternaria solani*—Continued

Group and designation	Vegetable Breeding Laboratory accession No.	Source	Rating
Group 2 (susceptible or segregating):			
Targinnie Red selection	6-02-M8	Australia	59
Lycopersicon pimpinellifolium × Marglobe (F_4).	244-5-3-M3	U. S. Regional Vegetable Breeding Laboratory.	59
Lycopersicon pimpinellifolium	510-M3	South America	48
P. I. 79532 selection	7-010-2-M1	do	47
Lycopersicon peruvianum	543	do	45
Do	549	do	43
P. I. 79532 selection	8-M1	do	41
Victor Emanuel	108	Europe	41
Targinnie Red selection	6-02-S3	Australia	37
Lycopersicon pimpinellifolium	590-M3	South America	37
P. I. 79532 selection	7-013-5-M4	do	36
Gilbertiana	70-7	North America	33
P. I. 79532 selection	7-04	South America	32
Lycopersicon pimpinellifolium × Marglobe (F_4).	244-18-3-M1	U. S. Regional Vegetable Breeding Laboratory.	32
Lycopersicon peruvianum	537	South America	30
Lycopersicon pimpinellifolium × Marglobe (F_2).	575-M5	U. S. Regional Vegetable Breeding Laboratory.	30
P. I. 79532 selection	8-06-1	South America	23
Lycopersicon pimpinellifolium × Marglobe (F_5).	245-2-9-1-M3	U. S. Regional Vegetable Breeding Laboratory.	19
Bay State	571	North America	19
Group 3 (very susceptible):			
P. I. 79532 selection	8-13-M1	South America	15
Nystate	1035	North America	14
Lycopersicon pimpinellifolium × Marglobe (F_5).	244-2-7-3-M1	U. S. Regional Vegetable Breeding Laboratory.	13
Marglobe × *Lycopersicon pimpinellifolium* (F_5).	246-0-1-6-M1	do	13
Columbia	209	North America	12
Mingold	1040	do	11
Gulf State Market	222	do	9
Bounty	1046	do	8
Marglobe selection	9-01	do	5
Commercial Marglobe selection	10-02	do	5
Adelaide Dwarf	13	Australia	5
Express	50	do	5
Early Baltimore	201	North America	5
Marvel	217	do	5
Stone	235	do	5
Grothen Red Globe	238	do	5
Early Baltimore	1041	do	5
Riverside Favorite	85	Europe	4
Indiana Certified Marglobe	195	North America	4
Rutgers	200	do	4
Stokesdale	242a	do	4
Marglobe × Fiaschello (F_4)	254-0-2-M1	U. S. Regional Vegetable Breeding Laboratory.	4
John Baer	888	North America	4
Vetomold	970	do	4
Early Shipper	1038	do	4
Master Marglobe	228	do	3
Louisiana Gulf State	231	do	3
Fiaschello × Marglobe (F_4)	255-5-3-M2	U. S. Regional Vegetable Breeding Laboratory.	3
Essar	890	North America	3
Globelle	975	do	
Glovel	1031	do	3
Bred-Rite Marglobe	1033	do	3
Kilgores New "X"	1034	do	3
Fiaschello	56	Europe	2
San Marzano	128a	do	2
Pritchard	192	North America	2
Glovel	216	do	2
Marglobe × Fiaschello (F_5)	254-1-6-3-M1	U. S. Regional Vegetable Breeding Laboratory.	2
Do	254-5-3-M1	do	2
US23W(b20) selection	624-M1	North America	2
Do	624-M2	do	2
Do	624-M4	do	2
Pan America	889	do	2
Marhio	974	do	2
Valiant	241	do	1
Marglobe × *Lycopersicon pimpinellifolium* (F_5).	246-0-1-6-M3	U. S. Regional Vegetable Breeding Laboratory.	1
Fiaschello × Marglobe (F_5)	255-1-1-1-M1	do	1
Victor	971	North America	1
Essary	980	do	1

TABLE 1.—*Collar rot rating of 115 tomato varieties and selections based on a four-replicate inoculation with Alternaria solani*—Continued

Group and designation	Vegetable Breeding Laboratory accession No.	Source	Rating
Group 3 (very susceptible)—Continued.		North America	
Ponderosa	1029	do	1
Cuban Marglobe	1030	do	1
Crown selected Marglobe	1032	do	1
Break o' Day	197	do	0
Marvelosa	206	do	0
Cooper Special	223	do	0
Montgomery	234	do	0
Earliana	239a	do	0
McGee	1039	do	0
Early Santa Clara	1043	do	0

TABLE 2.—*Collar rot ratings of 42 tomato varieties and crosses not included in the analysis of variance*

Group and designation	Vegetable Breeding Laboratory accession No.	Source [1]	Rating
Group 1 (resistant or tolerant):			
P. I. 95558 × Targinnie Red	913-M1	U. S. Regional Vegetable Breeding Laboratory.	80
Group 2 (susceptible or segregating):			
Stoners M. P	95	Scotland	52
El Colono	37	South America	46
Heterosis	64	Europe	40
Trivetts Abundance	93	North America	36
Fillbasket	224	England	32
Bonny Best	243	North America	30
Group 3 (very susceptible):			
Everbearing	570	do	23
Chinaman × Marglobe (F_1)	225	do	22
Magnum Bonum	78	Europe	22
Browns Special	1042	North America	21
Red Cap	1036	do	21
Il Duce [2]	59	Europe	20
Everbearing Scarlet Globe	220	North America	20
Danmark	29	Europe	19
Sterling Castle	205	England	19
Marglobe × Chinaman (F_1)	226	U. S. Regional Vegetable Breeding Laboratory.	17
Chemin Early Red	16	Europe	16
Amarillo	68	South America	16
Kondine Red	63	England	15
Red Rock	236	North America	14
Original Pomona	118	Europe	13
Indefatigable	26	do	13
Up-to-Date	88	England	13
Rouge Grosse Native	127	Europe	12
Nicholsons Dallas	210	North America	12
Pearson	1044	do	11
Amwell	11	Europe	11
Earliest of All	38	North America	11
Radio	114	do	11
In Miscuglio	58	Europe	10
Pierrette	122	do	10
Louisiana Dixie	230	North America	9
Novato	72	Europe	9
Cameron Canada (Nova Scotia)	24	North America	8
Chinaman	227	do	8
Augusta	23	Europe	6
Burwood Prize	21	North America	5
Tuckswood	91	Europe	5
Marshalls Prolific	75	do	4
Market Wonder	76	do	4
Resista	111	do	4

[1] The actual locality of origin of many of the named varieties is obscure.
[2] Probably not true to type.

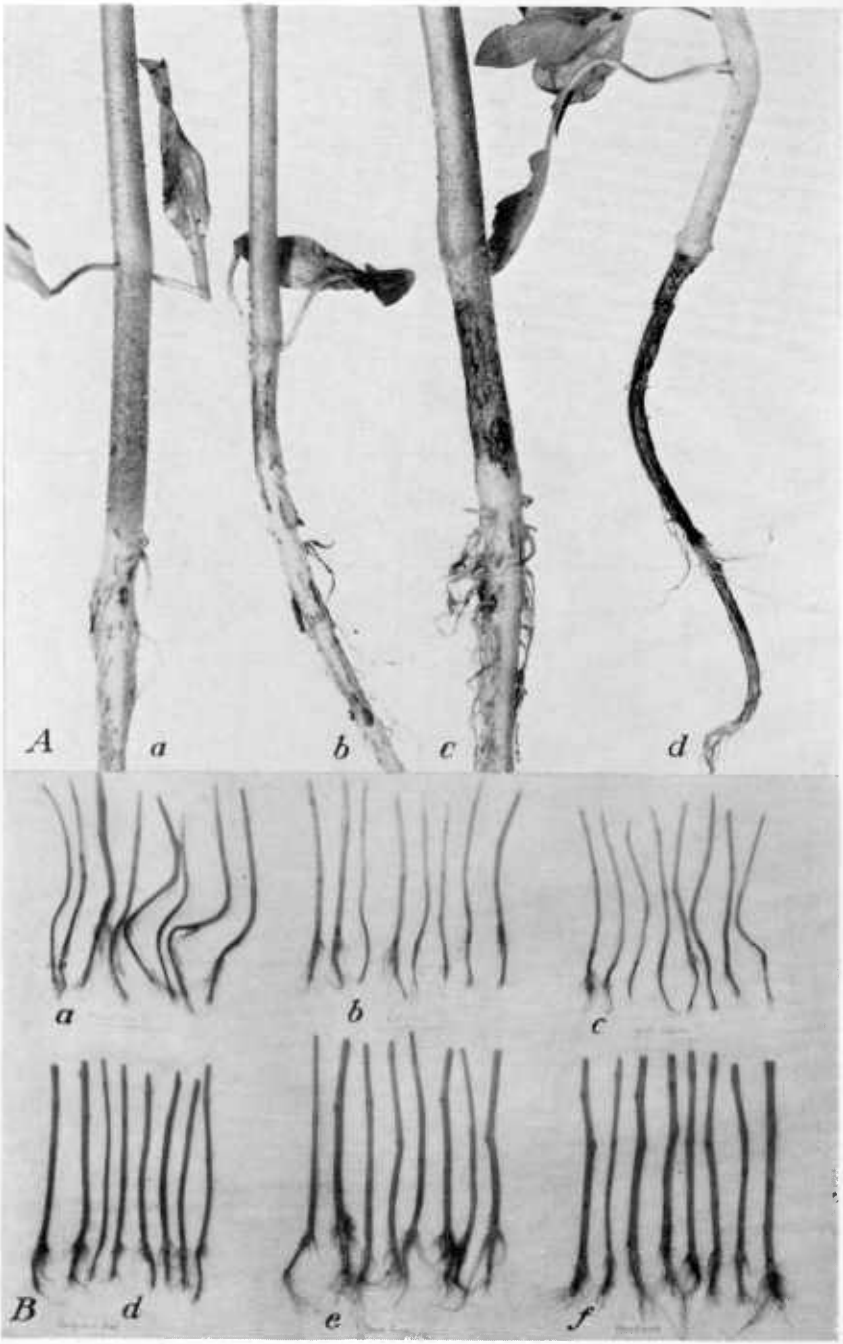

FIGURE 1.—*A*, Basal parts of inoculated tomato plants illustrating various collar rot ratings: *a*, 100 (no collar lesions); *b*, 75; *c*, 50; and *d*, 25. *B*, Reaction of three susceptible varieties: *a*, Marglobe; *b*, Rutgers; and *c*, Gulf State Market; and of three resistant or tolerant varieties: *d*, Targinnie Red; *e*, Devon Surprize; and *f*, Norduke. *A*, × 1; *B*, × ⅙.

Definite evidence of segregation for collar rot resistance is shown in the varieties Columbia, Prairiana, Gulf State Market, and Early Baltimore. The fact that different clonal selections by cuttings of

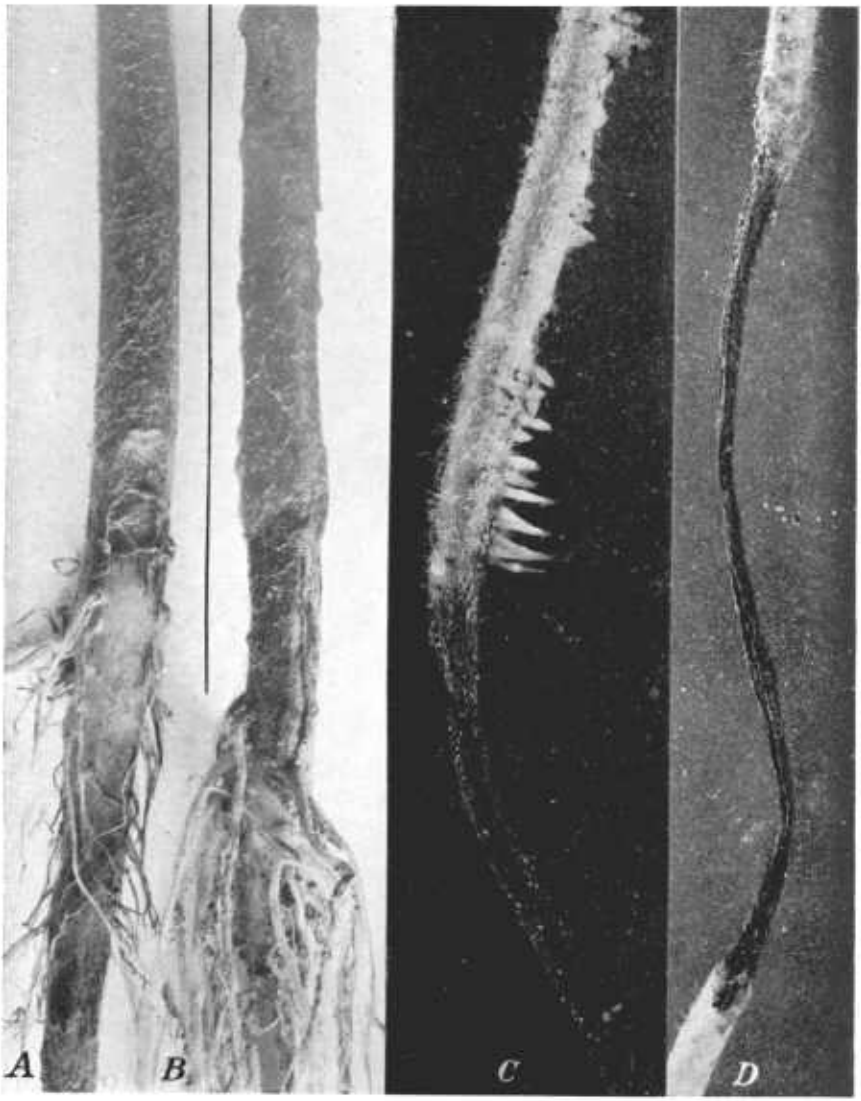

FIGURE 2.—Collar lesions of various types caused by *Alternaria solani*: *A*, Tolerant-reaction type; *B*, well-developed lesion showing a tendency to heal; *C*, severely infected collar with new roots developing above the lesion; *D*, severely infected collar without root development. All, × 3.

several varieties, such as Targinnie Red and Danish Extra Early, fall into separate reaction classes points to the desirability of making rigid selections for collar rot resistance in the segregating varieties. From the evidence available it seems probable that the varieties

Norduke, Prairiana, and Riverside, for example, could all be raised to the level of highly resistant varieties by clonal selection.

Several lines of *Lycopersicon pimpinellifolium* are listed among those segregating for collar rot resistance. The presence of factors for resistance to collar rot in *L. pimpinellifolium* is proved further by tomato No. 245–2–9–1–M1, which is a fifth-generation selection from an *L. pimpinellifolium*×Marglobe cross. Tomato No. 575–M5 is a sample from an F_2 population of a similar cross.

DISCUSSION

Although earlier studies have shown that all varieties are susceptible to leaf infection by *Alternaria solani*, significant degrees of lesser susceptibility were found.[8] Many of the varieties listed herein as resistant or tolerant to collar rot were among those found to be significantly less susceptible to alternaria leaf spot. It is believed that the method devised for evaluating resistance to collar rot is of definite value in the larger problem of developing resistance to *Alternaria solani*.

In application of the foregoing information to a solution of the current collar rot problem several interesting possibilities are suggested:

(1) Substitution of the collar rot resistant or tolerant varieties Riverside, Norduke, or Prairiana for the highly susceptible varieties now preferred might be practicable under certain conditions.

(2) The considerable evidence that many desirable varieties are heterogeneous and segregating for collar rot resistance suggests that direct selection might quickly yield resistant strains of the desirable type.

(3) A breeding program involving judicious crosses between collar rot resistant and the more desirable but susceptible varieties appears entirely practicable. Hybrids of Devon Surprize × Marglobe, Devon Surprize × Montgomery, and Targinnie Red×Montgomery are now available in the second generation.

SUMMARY

A method of dipping foliage of 4-week-old tomato seedlings in a water suspension of macerated *Alternaria solani* culture at the time of transplanting is described. The method produced 100 percent collar rot on the most susceptible varieties and 100 percent freedom from collar rot on the most resistant.

A large number of standard tomato varieties and clonal selections are rated according to collar rot reaction. Apparently complete resistance to collar rot was found in 23 varieties and accessions.

Collar rot resistance is correlated with lesser degrees of susceptibility to alternaria leaf spot, and the method of determining collar rot resistance should facilitate the breeding for resistance to defoliation in tomatoes.

[8] See footnote 5.