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DEVELOPMENT OF PHOMA ROT OF TOMATOES IN TRANSIT AND IN STORAGE

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INTRODUCTION

Phoma destructiva Plowr. not only causes a blight of the vines and fruits of the tomato (*Lycopersicon esculentum* Mill.) in the field but is responsible for very heavy losses after the tomatoes leave the packing sheds. Small stem-scar infections or small infections arising through growth cracks, insect wounds, or bruises often escape detection in the packing sheds and continue to develop while the tomatoes are en route to the market or are held in the ripening rooms. Judged by observation on the markets and the inspection certificates issued by the Food Products Inspection Service of the Bureau of Agricultural Economics, United States Department of Agriculture, phoma rot ranks as second only to rhizopus rot and in some years is more serious than the latter in causing spoilage of tomatoes in transit.

Phoma rot has been reported from all of the important tomato-growing States, but is especially serious on tomatoes from Florida. During the years 1924–25 to 1927–28, 5,776 shipments of tomatoes were inspected at destination. As most of these were car-lot units, and as 1,368 of the inspected car lots[2] originated in Florida, the shipments from that State comprised about 23.7 percent of the total number of tomato inspections (table 1). During this period approximately 13.4 percent of all the cars inspected contained tomatoes infected with phoma rot, and 27.9 percent of all the car lots from

[1] In cooperation with the University of Chicago.

[2] Figures for calendar year. Since only a few cars were shipped during November and December in the 4 years under consideration, the error in percentage is negligible. Destination inspections of Florida tomato shipments during these years equaled 38.5 percent of the Florida shipping-point inspections and 4.6 percent of all Florida tomato shipments.

Florida showed this disease. While only 23.7 percent of the total number of car lots inspected came from Florida, 49.4 percent of the car lots that showed phoma rot at destination came from that State.

TABLE 1.—*Phoma rot in tomato shipments (car-lot units) from Florida as compared with that in total number of tomato shipments in the United States from 1924 to 1928* [1]

Year	Shipments inspected at destination			Inspected shipments showing phoma rot		
	Total	Car lots from Florida		Total	Car lots from Florida	
	Number	*Number*	*Percent* [2]	*Number* [2]	*Number*	*Percent*
1924–25	1,126	426	37.8	246	192	78
1925–26	1,175	206	17.5	104	32	30.8
1926–27	1,725	371	21.5	249	66	26.5
1927–28	1,750	365	20.9	179	91	52.3
Total	5,776	1,368	23.7	778	381	49.0

[1] Shown by food-products inspection certificates of the Bureau of Agricu ltural Economics, U. S. Department of Agriculture.
[2] Approximate.

The following average percentages of phoma rot were reported in phoma-infected car lots of tomatoes from Florida inspected at destination during these years: 9.6 in 1925, 5.5 in 1926, 3.7 in 1927, and 11.7 in 1928, or an average of 8.7 for the 4 years. The percentages of infected fruits in the various shipments ranged from less than 1 to 85. Stevens and Nance [3] give total percentages of phoma rot of tomatoes for these years (averaging all Florida car lots inspected at destination) as 4.7 in 1925, 1.4 in 1926, 1.0 in 1927, and 2.9 in 1928, and state that losses from phoma rot are decidedly higher in Florida than in any other State. Of all the Florida tomato shipments inspected at destination in 1934, 30.8 percent contained fruits infected with phoma rot.

TEST SHIPMENTS FROM FLORIDA

Because of the repeated occurrence and economic importance of phoma rot, questions frequently arise as to the amount of development in transit on fruits that seem free from this rot at the time of packing and the relationship of development in transit to that in storage. With the object of answering some of these questions, the following observations were made on test shipments from Florida.

SHIPMENTS IN 1925–27

During the years 1925–27, 12 test crates of tomatoes apparently free from phoma rot were shipped by express from Florida to Chicago, and 2 crates were included in a commercial shipment to New York. No record was made of temperatures in transit, but neither heat nor refrigeration was added in either case. All tomatoes were wrapped and packed in standard six-basket crates. At the receiving points the percentage of phoma rot was noted and the lesions were

[3] STEVENS, N. E., and NANCE, N. W. SPOILAGE OF TOMATOES IN TRANSIT, AS SHOWN BY INSPECTION CERTIFICATES, 1922 TO 1930. U. S. Dept. Agr. Circ. 245, 4 pp. 1932.

measured before and after a 7-day storage period. The results are shown in table 2. The transit periods ranged from 4 to 7 days, with an average of about 5½ days. As the average actual daily increase in diameter of the pure phoma lesions during transit and storage was 0.137 cm, the theoretical average size was 1.92 cm after 7 days in transit and 1 week in storage. It may be noted that this figure is almost twice that given later for the comparable average diameter in the case of the 1934 test shipments.

Part of this difference in lesion diameter is due to the fact that in 1927 the tomatoes in one crate were of more mature stock than the ordinary commercial run and were entirely ripe on arrival. The phoma lesions present on these tomatoes were much larger on arrival, averaging 1.09 cm in diameter, than those in other shipments. In the same year the average diameter of lesions on regular commercially mature tomatoes on arrival was 0.53 cm. As the transit period in both cases was 5 days, the daily growth rate in transit of the lesions on the riper tomatoes was just twice that on the less mature ones. The faster rate of growth on ripe tomatoes as compared with those in the green and turning stages is further illustrated by the 1934 figures.

TABLE 2.—*Phoma rot in tomatoes shipped from Florida to Chicago and New York, 1925–27*

Year	Test crates	Phoma rot present		Average diameter of pure phoma lesions	
		On arrival	After 7 days' storage	On arrival	After 7 days' storage
	Number	*Percent*	*Percent*	*Cm*	*Cm*
1925	5	3.8	11.4	0.48	1.39
1926	3	5.0	6.0	.77	1.60
1927	[1] 6	1.4	1.5	1.05	2.35
Average		[2] 3.4	6.3	.77	1.78

[1] Including 1 crate of fruit that was entirely ripe on arrival.
[2] Average transit period about 5½ days.

Yet, even omitting the values for the lot of ripe tomatoes just mentioned, the average size of the lesions for the years 1925–27 was larger than that for 1934, for the average daily growth rate of the remaining lesions was 0.09 cm during transit and 0.13 cm during storage, giving a theoretical average diameter of 0.63 cm at the end of a 7-day transit period and of 1.54 cm after an additional week in storage. However, these tomatoes were shipped in April and May, whereas those shipped in 1934 arrived in late January and were therefore cooler when packed in the cars and were exposed to much cooler weather in transit. Both lots were ripened at a room temperature which fluctuated between 66° and 76° F. Since the optimum temperature for development of phoma rot on ripening fruits under transit and storage conditions is 70° to 75°,[4] it is obvious that, considering the temperature factor alone, the growth

[4] NIGHTINGALE, A. A., and RAMSEY, G. B. TEMPERATURE STUDIES ON SOME TOMATO PATHOGENS. (Unpublished manuscript.)

rate in transit in 1934 would be less than in 1925–27. This accounts, partially at least, for the difference in size of lesions upon arrival. Of course, since there is actually much variation in the stage of maturity of "commercially mature" tomatoes, it is not possible to eliminate variations in rate of development of phoma rot lesions due to variations in degree of ripeness of any two lots of tomatoes. There are always some fruits that are ripe on arrival, and in any year the lesions that are largest on arrival will be found on these fruits.

In addition to the pure phoma lesions, there were some spots that yielded in culture *Alternaria*, bacteria, or *Fusarium* associated with the *Phoma*. *Alternaria tomato* (Cke.) Brinkman [5] was present as the causal organism of nailhead lesions that were present at the time of shipping, the *Phoma* gaining entrance through these lesions. The average size of such lesions after transit and storage was no larger than that of pure phoma lesions. On the other hand, the *Fusarium* species were contaminants, appearing in phoma lesions quite late in the ripening-storage period, and in practically every case were associated with phoma rot that had developed in a bruise or about a wound. Such lesions, firm and dark colored at first, developed more rapidly and became softer and more water-soaked as the decay progressed. The final break-down of the tomato was more rapid than in the case of phoma rot alone. *Rhizopus* also occurred as a secondary organism following phoma rot, and the subsequent break-down was so rapid that the tomatoes had to be discarded at once.

Bacteria were isolated only from those phoma lesions which occurred around a wound or which had well-developed pycnidia. It was quite evident that the bacteria were able to gain entrance through the epidermal ruptures made by the phoma pycnidia. In lesions contaminated with bacteria, the rate of lesion development during storage of ripe or ripening fruits was greater than that of comparable pure phoma lesions during storage; the tissues soon softened and the fruit broke down and wet the wraps, the bacteria and phoma spores spreading to other tomatoes and playing a part in the development of new lesions in scars and wounds if the contaminated fruits were held sufficiently long in storage under humid conditions.

Usually there is little or no spread of phoma rot from one tomato to another in transit and storage, but in the case of some of the test tomatoes held for 7 to 20 days a few new lesions developed in insect or sand pricks, nailhead lesions, bruises, or cracks that had been in contact with other sporulating lesions. Under the conditions of these tests the atmosphere was not sufficiently humid to permit much spread of spores from one tomato to another unless bacteria or other contaminants caused soft rot resulting in the breaking down of the fruit, or unless the phoma lesion grew to sufficient size to crack and allow the juices to carry spores from one tomato to another. Even then, as previously reported by other investigators,[6]

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[5] BRINKMAN, A. DE ROODNEUZEN-ZIEKTE VAN PHASEOLUS VULGARIS L. VEROORZAAKT DOOR PLEOSPORA HERBARUM (PERS.) RBH. [Thesis, 86 pp.] Amsterdam. 1931.

[6] JAMIESON, C. O. PHOMA DESTRUCTIVA, THE CAUSE OF A FRUIT ROT OF THE TOMATO. Jour. Agr. Research 4: 1–20, illus. 1915.

a wound was found necessary for infection. In commercial practice tomatoes are usually held under conditions that do not favor the spread of the disease in the ripening rooms. Rosenbaum [7] found that spores of *Phoma* were sometimes produced in abundance within the wrappers but that the fungus rarely penetrated the wrapper.

However, many new lesions may develop in the ripening rooms as a result of delay in the appearance of field infections. Table 2 shows the percentage of new lesions developing in storage during the years 1925–27. It will be noted that the percentage of phoma rot after storage was almost double that present on arrival. A few of these new lesions were evidently due to infection in storage, as just described, but the great majority were due to infection in the field, which did not show at the end of a 4- or 5-day transit period but appeared very early in storage. On tomatoes that were 6 to 7 days en route, practically all lesions developing in storage were visible on arrival. In many instances the infection was almost imperceptible until the tomato approached ripening. If the tomatoes ripen before such lesions increase greatly in size they may be marketed before the fungus has done more than cause a blemish, and such small lesions on ripe fruits are therefore of little commercial significance.

The frequent delay in the appearance of shipping-point infections is in keeping with the results of Porte,[8] who found that most of the phoma infections that developed on test tomatoes during a storage period of 14 days after arrival at Florida packing sheds must have originated in the field, since the average percentage of phoma infections on uninoculated controls was 32 percent, whereas the average percentage of infections occurring in the tomatoes sprayed with phoma spores was only 39.3 percent. He found that during development under conditions prevailing in Florida tomato fields, *Phoma* could become sufficiently embedded in the tissues of the stem end of many apparently unblemished tomatoes to enable it to produce macroscopic lesions as the fruit ripened.

SHIPMENTS IN 1934

A more detailed study was made of the four crates of tomatoes shipped from Florida in 1934. This "mature green" stock was wrapped and packed in 6-basket crates in the usual manner and shipped to Chicago in a commercial car of tomatoes. The tomatoes in the test crates had been carefully selected for freedom from disease and were examined for phoma rot at Chicago 7 days after the shipping date. Lesions were found on 33.8 percent of the tomatoes, an average of 2.5 spots per fruit. The lesions were measured, and the tomatoes were then held for 4 days in a ripening room with a temperature range of 66° to 76° F., after which they were removed for the purpose of remeasuring the lesions. Some were cultured to check diagnosis and the others were returned to the ripening room for another 3 days, at the conclusion of which final measurements and isolations were made.

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[7] ROSENBAUM, J. THE ORIGIN AND SPREAD OF TOMATO FRUIT ROTS IN TRANSIT. Phytopathology 8: 572–580, illus. 1918.

[8] PORTE, W. S. NOTES ON THE CONTROL OF TRANSIT AND STORAGE DECAYS OF TOMATOES BY THE USE OF CHEMICAL WASHES. Phytopathology 24: 1304–1312. 1934.

All lesions showed evidence that the fungus had entered through the stem scar or through some injury. About 47 percent of the lesions resulted from stem-scar invasions, 41 percent followed shoulder bruises, and the rest occurred around growth cracks, checks, and abrasions. The high percentage of stem-scar lesions is of interest, since it is these lesions that are most likely to escape detection in the packing sheds. The greatest number of lesions showing delayed development and appearing after the tomatoes have reached the ripening rooms also occur at the stem scar. Such infections will always prove a serious factor in the marketing losses of tomatoes as long as phoma rot occurs in fields of susceptible tomatoes, for Porte [9] found that an impressive number (11.5 percent) of the lesions developed despite the best of the 21 washing treatments tested (formaldehyde).

No new spots developed during the 7-day ripening period in 1934, but those already present, with few exceptions, continued to enlarge. The average initial diameter was 0.38 cm; the diameter after the first 4 days of storage was 0.68 cm, and after 7 days in the ripening room the lesions averaged 1 cm. It may be noticed, therefore, that the daily growth rate increased with the ripening of the fruits, being about 0.07 cm per day during the first storage period, and 0.10 cm during the last 3 days of storage. This may be further illustrated by the average increase in diameter in the ripening room, for during these 7 days the lesions on fruits that were green at the beginning of storage made a gain of 0.33 cm, those on the turning tomatoes made a 0.47-cm gain, and those on the ripe fruits increased 0.71 cm. Although 21 percent of the fruits were still green on arrival and 28 percent were just turning, after 4 days in the ripening room only 2 percent remained green and there were only 17 percent turning. By the end of the week all but one of the fruits were ripe. Since the commercial ripening of tomatoes during the winter months occurs for the most part after the tomatoes have arrived at the receiving markets, it is obvious that phoma lesions already present will develop more rapidly in storage than they did in transit.

On arrival in Chicago, i. e., 7 days after shipping date, the spots varied from very early stages, 0.10 cm in diameter, to large lesions 1.75 cm in diameter. Since the tomatoes had been selected for freedom from disease, there was a lower percentage of large spots than might be expected in a commercial shipment. On arrival only 5.3 percent of the pure phoma lesions were over 1 cm in diameter, 16 percent were between one-half and 1 cm, and 78.7 percent were less than one-half cm. About 38 percent of the total number of lesions present had little commercial significance, since they were less than one-half cm in diameter and occurred on ripe fruits. In addition to the pure phoma lesions there were some lesions (about 2 percent of the total number) that contained *Alternaria solani* (Ell. and Mart.) Jones and Grout as well as *Phoma*. These were all on ripe fruits and averaged 0.98 cm in diameter on arrival and 1.94 cm after 4 days in storage. A few of the pure phoma lesions in the 1934 shipments and some of those found in the previous shipments were equally large. From the standpoint of economic loss, *Alternaria*

[9] PORTE, W. S. See footnote 8.

species are less important as secondary organisms in phoma lesions than are *Rhizopus*, *Fusarium*, and bacteria.

Green, turning, and ripe fruits showed equal numbers of phoma rot lesions. On arrival 51 percent of the fruits were ripe and bore 51.7 percent of the lesions; 28 percent of the fruits were just turning color and bore 27.6 percent of the lesions; and the remainder of the lesions (20.7 percent) were on the 21 percent of green fruits. Although the number of lesions seemed to bear no relationship to the maturity of the fruit, the size of the lesions did, as might be expected from the increased growth rate on riper tomatoes. Only in the case of the smallest lesions (less than 0.5 cm in diameter) was the distribution fairly uniform, 23 percent occurring on green fruits, 29 percent on turning fruits, and 48 percent on ripe fruits. Of the largest lesions (1 cm or more in diameter), 76 percent occurred on the ripe tomatoes and the remaining 24 percent occurred on turning fruits. None as large as 1 cm and only two larger than 0.6 cm in diameter were found on green tomatoes. Of the total number of lesions, ranging between 0.5 and 1.0 cm in diameter, 15.7 percent were on green fruits, 23.5 percent on turning fruits, and 60.8 percent on ripe ones. At the time of arrival the average diameter of the lesions was 0.28 cm on green fruits, 0.32 cm on turning fruits, and 0.46 cm on ripe fruits.

Pycnidia developed in the larger lesions on ripe fruits. No pycnidia were found on green tomatoes, and on turning tomatoes only three lesions had well-developed fruiting bodies. On arrival 2.4 percent of the lesions bore pycnidia; these lesions averaged 1.5 cm in diameter. After 4 days in the ripening room an additional 9.5 percent of the lesions had well-developed pycnidia and had reached an average diameter of 1.5 cm. It is obvious, then, that unless some of the fruits in a lug are ripe and have phoma lesions that have already attained considerable size there will be no spread of the disease from one tomato to another by means of spores. However, even if conditions do not favor the spread of pycnidiospores in transit and storage, the pycnidia offer ingress to faster developing rot-producing organisms; therefore the presence of pycnidia not only increases the unsightliness of the fruits but is a menace to the keeping quality of the tomatoes. Tomatoes with small firm phoma lesions, if marketed before other organisms enter, are not entirely worthless.

SUMMARY

Phoma rot is one of the most important causes of loss of tomatoes in transit and storage and has been reported from all of the important tomato-growing States. It has been most serious in shipments originating in Florida; of the total number of cars inspected at destination during the years 1924–28 and found to contain tomatoes infected with phoma rot, about half were from Florida. The percentages of infected fruits in the various shipments ranged from less than 1 to 85.

In four different seasons (1925–27 and 1934) 18 test crates of "mature green" tomatoes, wrapped and packed in the usual manner, were shipped from Florida, 16 to Chicago, and 2 to New York. Some of the crates were sent by express; the others were included in commercial car-lot shipments of tomatoes.

Though selected for freedom from disease at the time of packing in Florida, 33.8 percent of the tomatoes in the 1934 shipment showed phoma rot on arrival at Chicago 7 days later. The lesions ranged in diameter from 0.10 to 1.75 cm; 47 percent originated at the stem scar, 41 percent in shoulder bruises, and the remainder in other wounds or injuries.

About 38 percent of the total number of lesions present in 1934 had little commercial significance, since they were less than 0.5 cm in diameter and occurred on ripe fruits which could still be marketed.

Lesions occurred on green as well as on ripe tomatoes. Although the number of lesions seemed to bear no relationship to the maturity of the fruit, the size of the lesions did. Of the largest lesions 1 cm or more in diameter, 76 percent occurred on ripe fruits and the remainder on turning fruits. Only two lesions larger than 0.6 cm were found on green tomatoes.

The rot developed more rapidly on ripe tomatoes than on green ones. The daily growth rate of the lesions increased with the ripening of the tomatoes; consequently the size of the lesions increased more rapidly in storage than in transit. Rapid development occurred in transit when more mature fruits were shipped.

The rate of development of the lesions also varied with the temperature to which the tomatoes were exposed. Commercially mature tomatoes shipped late in January (1934) had lesions averaging 0.38 cm in diameter on arrival, whereas those shipped in April and May (1925–27) had lesions averaging almost twice the size in a comparable time.

Practically all of the spots developing in storage were already visible at the end of a 6- or 7-day transit period, although many of those at the stem scars would have passed unnoticed in the packing sheds. Fruits that were seemingly free from phoma rot, on arrival after 4 or 5 days in transit often bore imperceptible infections which developed visible lesions as the fruit ripened.

A few new lesions developed about stem scars or in injured areas as a result of the spread of pycnidiospores on fruits held 7 to 20 days in storage. Under ordinary commercial ripening-room conditions there would be little spread of the disease from one tomato to another.

Pycnidia occurred in the larger lesions on ripe tomatoes, but none was found on those that were green. By rupturing the epidermis of the tomato, pycnidia offer ingress to faster developing decay-producing organisms such as bacteria, and species of *Fusarium* and *Alternaria*.

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