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TOMATO LATE-BLIGHT ROT, A SERIOUS TRANSIT AND MARKET DISEASE

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INTRODUCTION

Although the disease of tomatoes known as late blight has been reported periodically from various parts of the country since it was first recorded by Thaxter¹ in Connecticut in 1890, it was not known to be of serious economic importance as a transit and market disease until 1906. At this time Smith² stated that the tomato fields of La Habra and other southern California districts were completely destroyed by the blight. Although the disease was reported as serious in various localized areas, particularly in Virginia, West Virginia, and Pennsylvania, during the 20-year period from 1906 to 1926, tomatoes in California were not severely affected. In the early winter of 1926, however, an outbreak of late blight caused considerable damage in California, and during the following two years (1927 and 1928) tomatoes were seriously affected in those regions where the temperature and moisture conditions favored the development of the disease.

DESCRIPTION

The organism that causes late blight of tomatoes is thought to be the same as, or at least very similar to, the one causing late blight of potatoes (*Phytophthora infestans* (Mont.) DBy.); the symptoms produced on the tomato and potato plants are very much alike. Sometimes the vines are completely killed, and the field appears as if a heavy frost had occurred. (Fig. 1.) Large water-soaked, greenish brown to black blotches are produced on the leaves, and during moist weather an abundance of fine white downy mildew is formed on the under side of the affected leaves. This mildew is

¹ THAXTER, R. DISEASES OF TOMATOES. Conn. Agr. Expt. Sta. Rpt. 1890:95-96. 1891.

² SMITH, R. E. TOMATO DISEASES IN CALIFORNIA. Calif. Agr. Expt. (State.) Bul. 175, 16 p., illus. 1906.

the mycelium of the fungus, which bears thousands of spores, and it is by means of these that the fungus is scattered throughout the field. The brownish water-soaked areas are also found on the stems under favorable growing conditions. Following heavy fogs the mildew is often quite prominent, as shown in Figure 2.

Tomato fruits are apparently susceptible to attack by this fungus during all stages of their development. Small tomatoes less than 1 inch in diameter often become completely decayed while hanging on the vines (fig. 3), and fruits of larger size showing all stages of decay are readily found in the field during epidemics of the disease. In practically all instances the fruit decay starts at the stem scar and progresses down through the tissues, producing a watery brown breakdown of the internal as well as of the external tissues. The first visible symptom of decay on the fruit is a small greenish brown

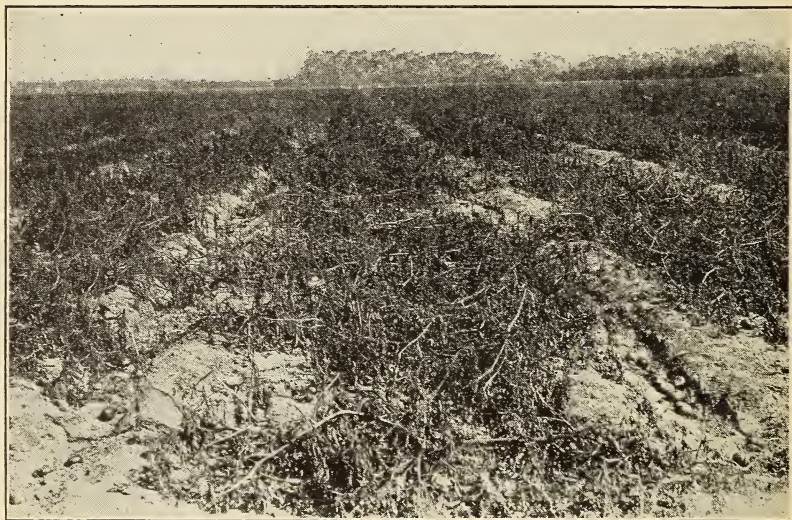


FIGURE 1.—A field of tomatoes badly infested with late blight

blotch less than one-fourth of an inch in diameter at the edge of the stem scar. Pressure applied by moving the thumb over the blotch toward the scar causes drops of a watery liquid to come out at the edge of the scar. As the decay progresses the tissues become more water-soaked, and there is a change in the color of the spot from greenish brown to brown without any definite markings and generally without visible evidence of the fungus. (Fig. 4.) If the decay is well advanced and the fruits are in a moist, well-protected place, the fungus develops on the surface of the decaying tissues as a fine white mildew. (Fig. 5.)

Lesions that develop during transit under the humid conditions within the car and under the protection of the wrapper generally show as greenish brown water-soaked blotches with a fine white mildew which is especially prominent over the stem scar. (Fig. 6.)

GEOGRAPHIC DISTRIBUTION AND ECONOMIC IMPORTANCE

Tomato late blight has been reported from scattered States during the years 1919 to 1929,³ but it reached serious economic importance in only a few. The greatest losses during the years from 1919 to 1924, inclusive, were sustained by Virginia and West Virginia, where in moist seasons and in the mountainous regions they sometimes averaged 5 to 8 per cent. In some fields 100 per cent infection occurred. The disease was reported in three successive years (1919 to 1921) from North Carolina, where it was destructive in the mountainous sections above 3,000 feet. It was occasionally reported from Delaware, Maine, New Jersey, Ohio, Florida, and Pennsylvania. In the last-named State and in New York when the disease occurred it seemed correlated with an epidemic of late blight on potatoes. No blight was reported from any State in 1925 and since that year the disease has reached economic importance only in California.

In seasons of serious late-blight infection there is great financial loss due to the decay of the fruit as well as to the destruction of the vines. This is illustrated by the following statistics concerning the tomato crop of California, the most important tomato-shipping State troubled with late blight. Smith⁴ reported that in 1906 the shipments from the southern California districts were reduced from 3,000 crates per day to practically nothing. In the epidemic of 1927 the yields in Ventura, Orange, and Los Angeles Counties were greatly reduced. The fields near the coast where fogs were heavy and frequent showed a higher percentage of infection than those farther inland where fogs were less common and the temperature generally much higher. In some fields the infection was as high as 100 per cent. In one 1,000-acre ranch the tomatoes were so badly affected that the fruit was not even picked.

In 1928 the blight was of less economic importance than in 1927, although even in that year some growers suffered severe losses. For example, one 75-acre field in Ventura County, which under normal conditions should have produced 50 cars of marketable tomatoes, yielded only 8 cars. At a conservative estimate of \$1,000 per car, the loss would have amounted to \$42,000.⁵

Of the 310 cars of California tomatoes inspected at terminal markets during 1927⁶ by the Bureau of Agricultural Economics, 118

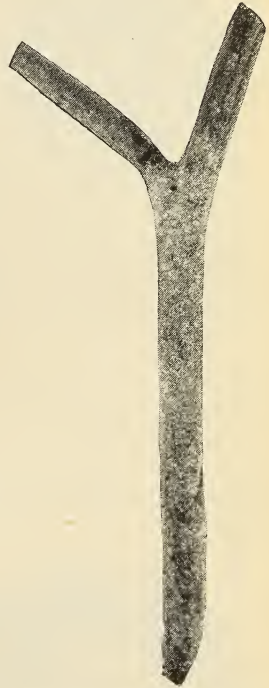


FIGURE 2.—Late-blight lesion on a tomato stem, showing an abundance of mycelium and spores (mildew) covering the surface

³ U. S. DEPARTMENT OF AGRICULTURE, BUREAU OF PLANT INDUSTRY. Plant Disease Reporter, Sup. 2, 10, 16, 22, 26, 34, 41, 43, 54, 61, and 68. 1919-1929.

⁴ SMITH, R. E. Op. cit. (See footnote 2.)

⁵ Since this circular was submitted for publication late-blight rot has appeared in epidemic form in the tomato crop of the lower Rio Grande valley of Texas during May, 1931.

⁶ Data compiled under the direction of F. C. Meier from food-products inspection certificates of the Bureau of Agricultural Economics.

showed tomato late-blight rot, averaging 30.6 per cent. The range was from less than 5 per cent to 100 per cent in a few cases. Table 1 shows the percentage of decay in 50 of these cars selected at random.

The following year 268 cars of California tomatoes were inspected. Late-blight rot was found in 52; of these 16 showed less than 5 per cent decay; 28 showed from 5 to 25 per cent; 7 cars showed 25 per cent and over; and 1 car had more than 50 per cent of decay. The average for the 52 cars was 11.9 per cent.

TABLE 1.—*Late-blight rot in carload lots of California tomatoes in 1927*

[The average for the 50 carloads picked at random was 33.6 per cent]

From—	To—	Date received	Percentage of decay
Los Angeles, Calif.	Chicago, Ill.	Oct. 14	20
Do.	do.	Nov. 1	15
Do.	do.	Nov. 5	40
Do.	do.	do.	45
Do.	Memphis, Tenn.	Nov. 7	10
Do.	Chicago, Ill.	do.	40
Do.	Detroit, Mich.	do.	15
Do.	do.	do.	12
Do.	Hartford, Conn.	Nov. 8	7
Do.	Baltimore, Md.	do.	30
Do.	Chicago, Ill.	do.	15
Do.	do.	do.	70
Do.	Detroit, Mich.	Nov. 9	20
Do.	Chicago, Ill.	Nov. 10	80
Do.	do.	Nov. 11	15
Do.	New York, N. Y.	do.	20
Do.	do.	do.	85
Do.	New Orleans, La.	Nov. 12	50
Do.	Chicago, Ill.	do.	60
Do.	Fort Worth, Tex.	Nov. 14	7
Do.	New York, N. Y.	do.	11
Do.	Chicago, Ill.	do.	6
Do.	do.	Nov. 16	8
Do.	Atlanta, Ga.	do.	10
Do.	Chicago, Ill.	do.	8
Do.	do.	Nov. 17	65
Do.	do.	do.	12
Do.	Dallas, Tex.	Nov. 18	35
Do.	Chicago, Ill.	do.	28
Do.	do.	do.	25
Do.	do.	Nov. 19	30
Do.	do.	do.	35
Do.	do.	do.	30
Do.	do.	Nov. 21	16
Do.	Milwaukee, Wis.	Nov. 22	30
Do.	Dallas, Tex.	do.	32
Do.	do.	do.	35
La Mesa, Calif.	Chicago, Ill.	do.	30
Do.	do.	do.	28
Los Angeles, Calif.	do.	Nov. 25	50
Do.	New Orleans, La.	do.	35
Do.	Detroit, Mich.	Nov. 26	30
Do.	Atlanta, Ga.	Nov. 28	60
La Mesa, Calif.	Chicago, Ill.	do.	85
Do.	do.	do.	75
Do.	do.	do.	70
Do.	do.	do.	70
Ontario, Calif.	New York, N. Y.	Nov. 29	55
Brentwood, Calif.	Memphis, Tenn.	Dec. 2	15
Vista, Calif.	St. Louis, Mo.	Dec. 19	5

RELATION TO WEATHER CONDITIONS

The amount of damage caused by late blight is directly related to weather conditions. When temperature and moisture are favorable for the development of the late-blight fungus, it is one of the most destructive decay-producing organisms known. Most serious losses are sustained during wet seasons when the nights are cool (50° to 60°

F.) and the days moderately warm (60° to 75°). A mean daily temperature above 75° checks the disease. The spores of the fungus are killed in a few days during dry weather when the temperature reaches 80° or above. Consequently, in regions where the temperature is high and the air dry for the greater part of the time, late blight is not an important disease. It is more prevalent in regions



FIGURE 3.—Immature tomatoes, showing advanced stages of late-blight rot

of high altitude, such as the mountainous sections of Virginia and West Virginia, and in coastal regions, such as southern California, where fogs and rains are frequent.

Unfortunately, a great part of the fall crop of tomatoes in California is grown in regions almost ideal for the development and spread of late blight. Heavy fogs are common, and the temperature ranges

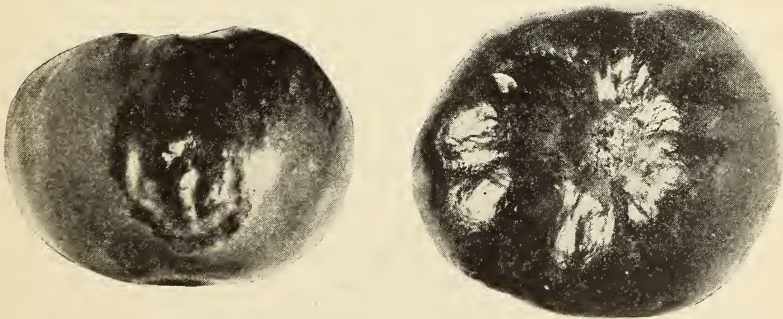


FIGURE 4.—Advanced stage of tomato late-blight rot, showing its spread from a stem scar

between 50° and 75° F. for a great part of the tomato-growing season. The heavy infection of 1906 was reported by Smith as occurring during a period of warm days and cool nights following heavy November rains. Cool weather with frequent rains and fogs prevailed during the years 1926 to 1928 when the other serious epidemics

occurred. In 1929, however, when the weather was warm and dry and there was no fog, late blight was not found even in fields that had been completely destroyed by this disease the previous year.

DEVELOPMENT IN TRANSIT ⁷

Test shipments sent from Oxnard and Fullerton, Calif., to Chicago, Ill., during October and November, 1928, were used to determine the rate of development of the late-blight decay. Tomatoes were carefully selected for typical late-blight lesions and for freedom from secondary organisms. The lesions found at the shipping point were outlined with India ink, and the fruits were then wrapped and packed according to commercial practice. Some healthy tomatoes were packed with the diseased ones in an attempt to ascertain whether the disease would spread to healthy fruits in transit. The lugs thus shipped were examined and the lesions remeasured at Chicago after six days in transit. In obtaining the data discussed below, only those lesions that were free from contaminating organisms were considered.



FIGURE 5.—Tomato late-blight rot as it occurs on fruit in moist, well-protected places. The surface of the fruit is covered with a great abundance of mycelium and spores (mildew) of the causal fungus

In 559 lesions measured the average increase in diameter during the 6-day transit period was $1\frac{1}{2}$ inches. In the case of three lugs which arrived in four days, 301 lesions showed an average increase in diameter of slightly over 1 inch. These tomatoes were held at room temperature for two days, during which time the increase was $\frac{1}{4}$ inch, making a total increase of $1\frac{1}{4}$ inches in diameter in six days. The average daily growth was greater during the first four days than in the last two days. These data, together with other observations, indicate that there was a retardation in the rate of decay with the increase in the size of the lesion,

regardless of maturity. In fruits that were green on arrival, lesions less than 1 inch in diameter at shipping point showed an average increase in diameter of $1\frac{3}{4}$ inches during the 6-day transit period. Lesions from 1 to 2 inches in diameter increased about $1\frac{1}{2}$ inches, whereas those larger than 2 inches increased only 1 inch. There were also indications of a decrease in rate of decay with increase in maturity. Lesions on fruit green on arrival showed an increase in diameter of $1\frac{1}{2}$ inches, whereas the decayed areas on fruit ripe on arrival had advanced only 1 inch in diameter during six days in transit.

During favorable weather conditions tomatoes harvested from fields showing blight were subject to heavy decay in transit, even though the fruit showed no evidences of disease at the shipping point.

⁷ The writers are greatly indebted to various members of the Federal-State inspection force of California, and to numerous growers and packers who kindly cooperated in this work.

Apparently the fungus had entered the tomatoes through the stem scar but had not developed enough to produce decay that was evident on the surface of the fruit. In a test shipment from Oxnard, Calif., in October, 1928, a lug of tomatoes harvested from an infested field but carefully selected for freedom from any evidence of decay, was sent to the Chicago laboratory. After a 6-day transit period, 8.7 per cent showed late-blight lesions averaging 2 inches in diameter. In a lug of tomatoes commercially graded and packed that were harvested from an infested field at Fullerton, Calif., 41 lesions developed in transit to Chicago. These lesions, practically all of which developed at the stem scar, occurred on 32 per cent of the fruits and averaged $1\frac{1}{2}$ inches in diameter.

Three lugs of tomatoes were shipped from Oxnard, Calif., to Chicago, Ill., to determine the amount of spread of decay in transit. For this purpose 163 healthy fruits from a field showing no blight were wrapped and packed among tomatoes showing well-advanced late-blight decay. On arrival in Chicago after six days in transit, four of these healthy fruits showed infection at the stem scar. The average size of the lesions thus developed was 2 inches in diameter.

Observations in the field, in the packing house, at the receiving market, and in the following inoculation experiments uphold the contention of those writers who state that infection does not take place through an unbroken skin. In one experiment decayed pulp from a blight-affected tomato fruit was placed on the uninjured surfaces of 40 healthy green tomatoes, which were then wrapped and held at 60° to 70° F. for one week. No infection occurred.

The tomatoes in one lug selected from a disease-free field at Oxnard, Calif., were inoculated by inserting a piece of decayed pulp into a small knife wound made on the side of each fruit. These tomatoes were then wrapped and shipped by express to Chicago, where, after six days in transit, examination showed 55 per cent infection with late-blight rot. The lesions averaged five-eighths of an inch in diameter.

Decayed pulp from a tomato affected with late-blight rot and the mycelium and spores of the causal fungus proved equally effective as inoculum when placed on the stem scar. In an experiment in which 48 healthy tomatoes were inoculated by placing a small piece of decaying pulp on the surface of the stem scar without wounding, 33 developed typical late-blight decay within one week. The lesions extended out from the center of the stem scar for from $\frac{1}{4}$ to $1\frac{1}{2}$ inches. The average diameter of the affected areas was 1 inch.

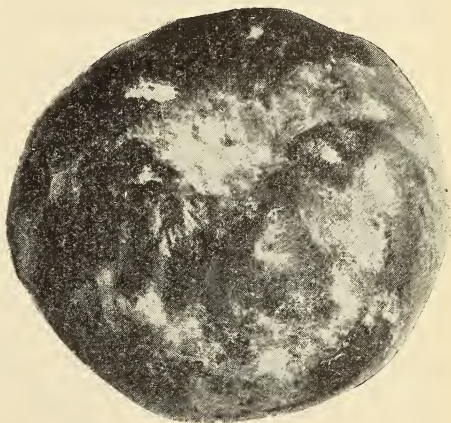


FIGURE 6.—Advanced stage of tomato late-blight rot as developed during transit. White mycelium of the fungus is usually prominent over the stem scar

The amount of late-blight rot that develops in tomatoes during transit varies with the severity of the vine infection and the weather conditions just previous to harvesting the fruit. Tomatoes picked from dry vines after three or four days of dry weather are much less likely to show decay than those picked from the same vines after a few days of foggy weather. The moist condition of the vines not only favors the production of spores of the fungus but also favors their germination and the entrance of the fungus into the fruit. Table 2 shows the amount of development of late-blight rot in transit in eight cars of California tomatoes that may be taken as fairly representative of the range of conditions found in the October and November crop of 1928. It will be noted that tomatoes picked from relatively dry fields or from fields having slight late-blight infection of the vines showed only a slight amount of development of decay during transit, whereas fruit that was harvested following wet-weather conditions or from vines severely infected with late blight generally showed a high percentage of decay on arrival at market.

TABLE 2.—*Development of late-blight rot during transit in eight cars of California tomatoes shipped in 1928*

Date of shipping-point inspection	Percentage of decay	Date of receiving-market inspection	Percentage of decay	Remarks
Oct. 4	17	Oct. 15	30	Stock from moist, badly blighted field. Shipping-point inspection made after car had stood on track 3 days.
Oct. 5	0	do	.5	Stock dry. Little blight in field.
Oct. 17	3	Oct. 28	23	Fruit from vines severely affected with late blight. Decay ranged from 10 to 50 per cent on arrival.
Oct. 19	.5	Oct. 29	6	Arrived at Atlanta under refrigeration, top doorway 43°, bottom 38° F. Decay in advanced stages.
Oct. 30	0	Nov. 12	1	Few infected plants in field.
Oct. 31	1	Nov. 14	22	Stock from moist vines, blight evident. Decay in advanced stages on arrival.
Nov. 2	0	do	13	Vines showed blight.
Do	0	do	2	Vines slightly affected, conditions generally unfavorable for spore production by the fungus.

CONTROL MEASURES

The experience gained from shipments of tomatoes from California fields where late blight appeared during the fall of 1927 indicated that it would be unwise to continue shipping tomatoes from fields showing any blight. Before the seriousness of this disease as a factor in the transportation and marketing of tomatoes was understood, many cars of tomatoes harvested from fields showing a slight amount of blight were packed and shipped without the shippers realizing the danger involved. Some of these cars showed as high as 95 per cent decay on arrival at the eastern markets, and in many cars it was not unusual to find almost half of the tomatoes infected. The fear of losing not only the tomatoes but the money paid for handling, packing, and freight charges caused many growers to abandon fields as soon as the blight appeared in the 1928 crop.

To determine the practicability of saving the tomatoes from such infested fields, which otherwise would not be harvested, the following treating experiment was conducted. To make the test as severe as possible, tomatoes were harvested from a field in which all the plants were blighted. From one-half to two-thirds of the vines were badly decayed, and the leaves and stems showed a great abundance of

mildew. The vines had been wet by heavy fogs for two successive days previous to harvesting the tomatoes used in this experiment. Under these conditions it would seem that an abundance of spores and mycelium should have been available for infecting the fruit. Seven lugs of tomatoes were harvested from this field and sorted carefully twice to be sure of eliminating all tomatoes showing the slightest signs of infection. Four of the lugs of tomatoes were then treated by immersing them in a solution of 1 part commercial formaldehyde to 300 parts water. Table 3 shows the plan of this experiment and the results obtained.

TABLE 3.—Results of an experiment to control tomato late-blight rot by treating the fruits

Box	Number of fruits	Treatment	Temperature of solution	Time (minutes)	Percentage of blight after—	
					5 days	10 days
No. 1.....	138	Formaldehyde, 1 to 300.....	60	2	4.3	5.8
No. 2.....	129	.....do.....	60	2	12.4	13.2
No. 3.....	154	.....do.....	90	2	8.0	8.0
No. 4.....	83	.....do.....	60	5	7.2	9.6
No. 5.....	140	Water only.....	60	2	8.0	17.1
No. 6.....	123	None.....	.....	.....	17.0	26.0
No. 7.....	128	.....do.....	.....	.....	11.7	21.8

From this experiment it will be seen that tomatoes harvested and treated under the conditions mentioned can not be disinfected sufficiently to prevent decay from developing during the first five days after treatment. Since other observations have indicated that it takes about five days for lesions to become apparent after infection has taken place, it is evident that the decay showing up during the first five days is the result of previous infection. Only spores and mycelium still on the surface could be reached by surface disinfection, and it is in the killing of these spores that the beneficial results obtained from treating fruit in disinfecting solutions is shown. This probably explains the marked reduction in the amount of decay that developed between the fifth and tenth days in the case of the treated fruit. Of the 504 treated tomatoes which developed an average of 8 per cent decay during the first five days, only five additional tomatoes showed decay at the end of 10 days. Thus there was an increase of only 1 per cent, whereas the 391 untreated tomatoes which showed 12 per cent decay at the end of 5 days showed 21 per cent after 10 days, an increase of 9 per cent during the second 5-day period as contrasted with an increase of scarcely 1 per cent during the same time in the treated stock.

Since this experiment was conducted under conditions most favorable for the development of late-blight rot and yet a considerable degree of control was obtained, it would seem that it might be profitable under certain conditions to harvest tomatoes from blighted fields provided the stock was disinfected after picking and then left for four or five days before sorting and packing for shipment. As a rule, however, this procedure would be rather impractical, and the expense of equipment and treatment would scarcely be justified unless a large acreage was involved or other uses could be found for the equipment in seasons when late blight was not prevalent.

For the control of late blight of tomatoes in the field it is recommended that a thorough spray program be worked out in cooperation

with the local county agricultural agent. Good results have been obtained in most instances by the use of 4-4-50 Bordeaux mixture and some of the copper dusts, in a spray or dust schedule similar to that practiced in controlling late blight of potatoes. Variation in weather conditions in the different tomato-growing regions, however, makes it advisable for local investigators to determine the need for spraying, the kind of spray to be used, and the time of application.

SUMMARY AND CONCLUSIONS

Late blight is a serious field, transit, and market disease of tomatoes that not only destroys the vines but also causes decay of both green and ripe fruits as well.

The seriousness of this disease is dependent upon weather conditions. Cool nights (50° to 60° F.) and moderately warm days (60° to 75°) during seasons when there is an abundance of atmospheric moisture (fogs or rain) are especially favorable for the development of late blight. Dry, hot weather is very unfavorable for its development, consequently late blight is never important in regions having such weather conditions.

Affected plants show large greenish brown to black water-soaked blotches on the leaves and stems. Under moist conditions a fine white mildew is prominent on the surface of the affected areas.

Fruits are susceptible to decay by late blight during all stages of their development. In practically all instances the decay starts at the stem scar and produces a watery, greenish brown to brown breakdown of the internal as well as the external tissues.

After the fungus gets into the stem scar, about five days are usually required for the decay to become visible. Infections through wounds elsewhere on the fruit produce visible decay much sooner.

Lesions present on the fruit at shipping time increase from 1 to 1½ inches in diameter during six days in transit.

Tomatoes harvested from blighted fields but showing no decay at time of shipment may develop spots varying from 1 to 1½ inches in diameter during a 6-day transit period.

Spread of the disease from decaying fruit to healthy fruit during transit is rare. Such new spots as have been observed to develop by contact during transit were mainly at the stem end of the tomatoes and were about 2 inches in diameter.

Artificial infection of tomato fruits by means of mycelium, spores, and pulp from tomatoes decaying with late-blight rot is readily accomplished through the stem scar and through wounds elsewhere on the fruits.

A shipment of tomatoes harvested from plants showing an appreciable amount of late blight is certain to show some decay by the time it reaches the market.

The amount of rot developing during transit and marketing in stock harvested from blighted fields may be greatly reduced by immersing the tomatoes for two minutes in a disinfecting solution (1 part formaldehyde to 300 parts of water), then allowing them to stand for four or five days before sorting and packing for shipment. This treatment is impractical for most tomato-growing regions, because of the expense for necessary equipment.

Late blight may be kept under control in the fields if a thorough spraying program is followed. Best results are generally obtained by use of 4-4-50 Bordeaux mixture or some of the copper dusts.

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