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COLLAR ROT OF TOMATOES

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Collar rot of tomatoes is a comparatively new disease in Colorado. It has appeared sporadically in the states of Delaware, New York, Vermont and New Jersey for a number of years, causing considerable damage in tomato fields. In Colorado it was first observed in the Arkansas Valley and the Grand Valley during the summer of 1931 on plants which had been shipped into the state as sets. Losses in stand in tomato fields in these areas were estimated at 20 percent.

Collar rot can be prevented from making another appearance in Colorado by sterilization of seedbeds and by the use of disease-free sets.

It is the purpose of this bulletin to describe this comparatively new tomato disease, explain its cause, the conditions which favor the disease, and to suggest practices and measures which should prevent its reappearance in Colorado.

Description

Collar rot is a disease which affects the stem of the tomato plant near the ground line. Diseased plants show dark, shrunken areas which in time may girdle the stem.

On Seedlings.—Seedlings in infected soil may show infection immediately following germination, and before they have emerged

Fig. 1.—Seedlings affected by collar rot.

from the soil. In experimental trials, out of 250 diseased seedlings which failed to emerge from the soil, all showed infection.

If such diseased seedlings are examined, brown shriveled spots may be found between the stem and root. Seedlings which are infected immediately following germination rarely appear above the soil line.

On the other hand, seedlings may emerge from the soil showing little or no infection, and only a careful stem examination will reveal the tiny brown spot which soon will develop into a severe collar rot. It is this obscurity of infection that so often leads the grower to believe that all plants are healthy.

Fig. 2.—A comparison of plants grown in infected (A) and uninfected (B) soils. In flat A are shown a few young plants growing in infected soil that have survived attack. In flat B, healthy plants growing in uninfected soil.

Seedlings appearing above the soil may be severely infected and may collapse in a few days, while others may persist for a long time (Figures 1 and 2).

On Young Plants.—Young plants which are infected by collar rot grow slowly, showing all signs of an unhealthy condition. The development of the lesion is very gradual, due to the hardening of stem tissues. The diseased region gradually girdles the plant forming a shrunken collar, hence the term "collar rot." (Figure 3.)

Diseased plants which may have been set out in the field, usually break off at the point of infection, due to wind or weight of stem and branches. (Figure 4.) This is perhaps the most devastating aspect of collar rot.

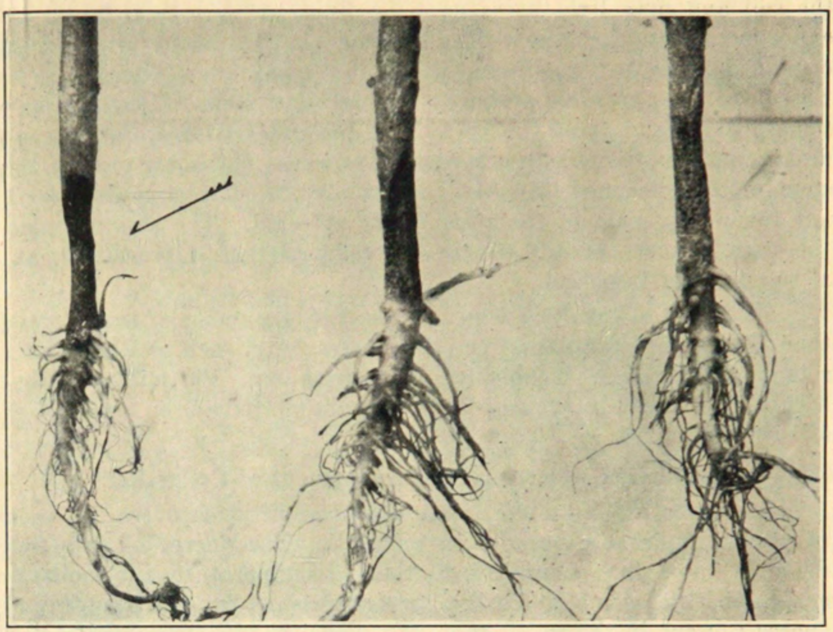

Fig. 3.—Collar rot on young tomato plants showing the way the disease girdles the stem.

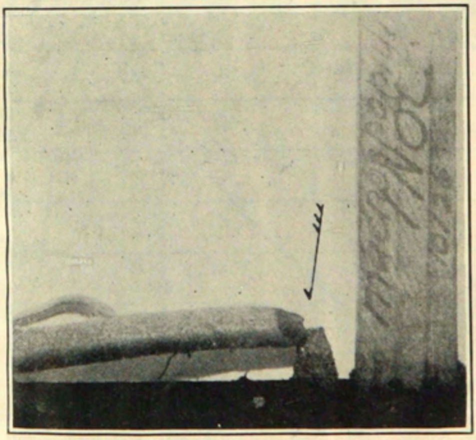

Fig. 4.—Final result of collar rot, the breaking off of the stem at the point of disease attack.

On Mature Plants.—Plants which survive breakage in the field usually persist, showing various degrees of wilting and discoloration. The diseased collar on the stem increases little in size, is dark brown and may be partly corked over. If the stems of these plants are split longitudinally, a black pith is often evident. The production of fruit on diseased plants is scant, fruits fail to attain a normal size, but show no signs of infection on skin or pulp.

The Cause of the Collar Rot Disease

Collar rot of tomatoes in Colorado is caused by a soil-borne fungus or mold called **Macrosporium solani.** This fungus grows thru the soil and may live there for some time. It has been found by experimentation that the thread-like mass of the mold growing on organic matter in the soil can attack the tomato stem and infect it. The infection threads puncture the succulent stem of the seedling tomato plant and force their way into the outer tissues of the stem, destroying this tissue as the fungus advances. The outer part of the stem, or the thickened bark-like portion may be completely destroyed, but the woody part of the stem is not affected. The result is that the stem becomes brittle and is so weakened that it readily breaks at the point of infection.

Collar rot of tomatoes may be caused by a number of molds other than **Macrosporium solani.** In other states fungi such as **Rhizoctonia solani, Verticillium lycopersici, Ascochyta** sp., **Verticillium albo-atrum, Alternaria solani** and **Phytophthora** sp. have been reported as causing collar rot.

Conditions Affecting the Development of Collar Rot

Soil infection studies indicate the possibility of severe infection of growing plants, especially in seedbeds. The degree of infection depends upon three factors, i. e., the soil temperature, the moisture content of the soil, and finally, the quantity of fungus threads and spores present in the soil.

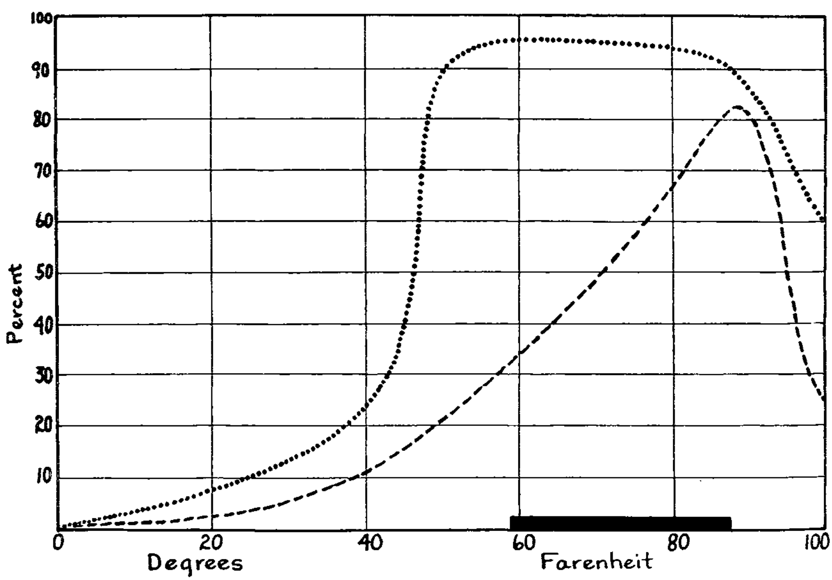

Fig. 5.—Graph showing the relationship of temperature to the growth and germination of the collar-rot fungus and to the growth of the tomato.

▬▬▬ Growth of the tomato

. . . . Spore germination of the fungus

- - - - - - - Growth of the fungus

The Relation of Temperature to the Disease.—The fungus causing collar rot grows within a wide range of soil temperature. It has been found that the organism will grow at a temperature as low as 37°F., and apparently thrives at as high a temperature as 96°F., producing infection within these limits, and growing most abundantly at temperatures approximating 75° to 78°F.

Tomatoes will not grow if the soil temperature falls below 57° to 59°F., and it has been found that the optimum or best soil temperature for tomatoes lies between 82° to 86°F.

This relation of temperature to the fungus growth and the growth of the tomato is illustrated in Figure 5.

In Figure 5 it will be seen that **Macrosporium solani,** causing collar rot of tomatoes, grows well and its spores germinate well at lower temperatures than those suitable for tomato growth. In the seedbed and in the field this is important, for the disease may gain headway when the young plants are in cold soil, and the fungus may advance in the stem tissues while the growth of the tomato is at a standstill. The lower temperatures of spring are more favorable to the disease and less favorable to the growth of the tomato.

The Relation of Moisture to Collar Rot.—Soil moisture sufficient to support germination and growth of the tomato has been found to be sufficient for severe seedling infection in infested soils.

In controlled experiments where the soil was held at two different temperatures and five different moisture contents, the following results were obtained:

Table 1.—Collar-rot infection at different soil-moisture contents and temperatures.

Soil temperature degrees F	Percentage of soil moisture	Percentage of infection
77	8	100
77	12	100
77	16	95
77	24	80
59	8	100
59	12	100
59	16	100
59	20	100
59	24	100

The above figures indicate that within a wide range of soil temperature and soil moisture, collar rot can cause damage to tomato seedlings when planted in infected soil. In other experiments, seedlings showed infection irrespective of soil-moisture content, altho an increase of the soil-moisture content brought about larger diseased areas on seedling stems.

In tests where transplants infected in the seedbed were set out in the field in wet and dry soil, it was observed that a greater number of plants recovered from the disease in the dry plot than in the wet.

In one experimental trial, 3-weeks-old infected plants were transplanted to two different field plots. Plot A was watered only at long intervals, while the soil in plot B was kept uniformly moist thruout the summer. Table 2 shows the result.

Table 2.—The relation of soil moisture to infection.

Variety	Percentage recovering in dry plot	Percentage recovering in wet plot
John Baer	57	0
Marglobe	44	15
Jewel	21	9

A comparison of results as shown in Table 2 indicates that a low soil-moisture content tends to check the development of collar-rot lesions. Recovery in each case was associated with a "corking" or healing over of the diseased part of the stem.

Soil Infection.—The quantity of the collar-rot organism in the soil plays an important part in the spread and the severity of attack by the disease.

This may be manifest in the seedbed where experiments have shown that if the soil is badly contaminated with **Macrosporium solani**, the germination is seriously affected.

Table 3.—Percentage of tomato-seed germination in infected soil.

Flat No.	Soil	Number of seeds planted	Percentage of germination
1	Inoculated	311	41
2	Inoculated	296	40
3	Inoculated	302	50
4	Inoculated	332	54
5	Sterile soil	317	88
6	Sterile soil	301	84
7	Sterile soil	272	83

The figures in Table 3 indicate that the collar-rot organism in the seedbed seriously cuts down germination as an average of 46 percent of the seedlings failed to emerge in the infested soil.

To determine further the relation between the amount of the fungus in the soil and infection by **Macrosporium solani,** other experimental trials were made. Masses of the fungus growing on barley kernels, and water suspensions of fungus spores were mixed in the soil as indicated in Table 4.

It is apparent from Table 4 that the more thoroly the fungus is mixed in the soil the higher the degree of infection.

Table 4.—The quantity of fungus and spores in the soil, relative to infection.

Flat No.	Type of inoculum	Percentage of infection
1	Ground mass culture in soil	57
2	Ground mass culture in soil	68
3	Unground mass culture in soil	14
4	Unground mass culture in soil	15
5	Unground mass culture poorly mixed in soil	4
6	Unground mass culture poorly mixed in soil	4
7	Spore suspension mixed with soil	0
8	Control—sterile soil	0

For further test of the relation of quantity and location of infecting material, greenhouse benches were planted to several varieties of tomatoes with masses of the fungus placed as shown in Table 5.

Table 5.—The quantity and position of the fungus in the soil relative to infection.

Row Nos.	Variety of tomato	Type of inoculum	Percentage of infection
1 and 4	Jewel	Mass culture above seed	34
2 and 5	John Baer	Mass culture mixed with seed	64
3 and 6	Jewel	Mass culture between rows	4
7 and 8	John Baer	Controls	0
9 and 10	Jewel	Controls	0

Table 5 shows a maximum infection of 64 percent where inoculum is mixed with tomato seed and a minimum infection of 4 percent where inoculum is sown in trenches between the plant rows.

Contact between the fungus and the young tomato stem is necessary for infection, and where the disease organism is sparsely distributed, chances of contact and resulting infection are greatly diminished. Spore suspensions of the fungus mixed in the soil cause little, if any infection. Apparently the fungus must be growing on organic matter in the soil and be in contact with the tomato stem to cause collar rot. The degree of collar-rot infection varies directly with the amount of the fungus and its dispersal in the soil.

Susceptibility of Tomatoes to Collar Rot

The seedling stage is not the only time tomatoes may be attacked by **Macrosporium solani.** The susceptible period of tomato plants extends from the time of germination to an age of approximately 3 weeks. An illustration of this is shown in Table 6, where healthy plants of varying ages were transplanted from clean soil to soil infested with the collar-rot organism. The plants were examined carefully 2 weeks later, with the results shown.

Maximum infection was obtained using 1-week-old transplants, infection gradually decreasing as the age of the plants increased to 3 weeks. Older plants showed decided resistance to collar rot. Micro-

Table 6.—The relation of age of the tomato plants to collar-rot attack.

Age of plants in weeks	Percentage of infection
6	0
5	0
4	0
3	18
2	32
1	55

scopic study of the stems of these plants indicated that the tissues undergo a thickening and hardening with age and can thus resist the penetration of the fungus.

Direct inoculations of the stems were made, placing the fungus at the ground line. Here the degree of infection was somewhat greater as shown in Table 7.

Table 7.—Results of inoculations on uninjured stems of plants of different ages. Examination made in 14 days.

Variety	Age of plants in weeks	Percentage of infection	Remarks
Early Detroit	6	77	Small lesions. Five cases superficial.
Marglobe	5	100	Small lesions. Six cases superficial.
Jewel	4	100	Lesions pronounced but not girdling.
John Baer	3	100	Lesions almost girdling stems.
Marglobe	2	100	Complete girdling of stem.
John Baer	1	100	Stems completely girdled and plants killed.

Altho conditions for the above study favored the causal fungus, it is apparent that severity of infection is largely dependent upon the age of the tomato plants.

It was also found that older plants grown slowly were less susceptible to collar rot than plants grown rapidly under favorable conditions. The organism more rapidly invades the tender, rapid-growing tissues while the slow-growing, tougher tissues resist attack.

Field Infection.—Trials were made to determine the possible spread of the organism in the field, to determine whether the disease might spread from plant to plant.

In these trials over a hundred plants were used in several rows, and in no instance did infection spread from a diseased plant to one that was healthy. It requires some time for the collar-rot organism to migrate thru the soil and the tomato sets reach a stage of maturity and resistance before the neighboring fungus can reach them.

Transplants were used from both clean and inoculated soils, and planted side by side, i. e., a healthy transplant between every two infected transplants. In a majority of cases it has been found that where plants have been transplanted deeply, roots have been devel-

Fig. 6.—Photograph showing the development of roots above the diseased portion following deep planting. It may be observed that the collar-rot lesions have not spread to any extent.

oped above the diseased portion (Figure 6.) This method of transplanting is suggested as a means of lowering collar-rot losses in the field.

Seed Treatments.—To test the possibility of seed treatment as a method of control, six flats containing inoculated soil were planted with tomato seed. Three of these lots of seed had been previously treated with three different dusts, Ceresan, Semesan Jr. and copper carbonate. After a period of 3 weeks the flats were examined and counts made. Table 8 gives the percentages of seed germination and infection in each flat.

Table 8.—The result of planting treated tomato seed in infected soil.

Treatments	Percentage of germination	Percentage of infection
Copper carbonate	92	65
Ceresan	31	51
Semesan Jr.	29	50
Control 1	61	56
Control 2	44	70
Control 3	37	64

In Table 8 the percentage of infection was determined on a basis of diseased and healthy plants which had passed the seedling stage. The fact that the causal organism hindered germination in all cases is quite apparent. Copper-carbonate dust stimulated germination to a marked degree, but collar-rot infection, however, was equally heavy in this flat. The mercuric dust treatments gave poor results, giving a low germination and no marked decrease in percentage of infection.

These results, altho by no means conclusive, indicate that the effectiveness of seed treatment as a method of control is questionable.

Recommendations for Control

Collar rot of tomatoes is a disease from which the plants seldom recover without seriously impairing growth and fruit production. Prevention then, rather than treatment, is the method of handling the disease. The following must be taken into consideration:

Seedbeds, if infected, should be treated in one of the following ways:

Removal of soil. Sterilization of all wood work with commercial formaldehyde (1 part formaldehyde to 50 parts water). Refill with clean soil.

Better yet, sterilize the soil in the seedbed. This is best accomplished by the use of steam. If there is no means of generating steam, the formaldehyde treatment may be used—one part of commercial formaldehyde to 50 parts of water. One-half to one and one-half gallons of this solution should be applied to each square foot of soil.

Another method is that of testing a square foot of soil to see how much water is necessary to saturate it, then adding a pint of formaldehyde to enough water to saturate from 6 to 10 square feet. The solution may be applied with a sprinkling can, the soil having first been loosened so that the solution can penetrate easily. After the bed has been wet down with the fungicide, it should be covered with boards or canvas for 12 hours.

Following the removal of the cover, the soil should be stirred several times to permit the fumes of formaldehyde to escape. Planting should not be made in the treated soil until 10 days or 2 weeks after the treatment.

Sprays, dusts and seed treatments are not of value in the control of collar rot.

Use clean stock. Plant deep. Any sets purchased by the grower should be carefully examined before planting. It is preferable for the grower to raise his own sets in disease-free soil.