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TOMATO DISEASES IN TEXAS

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Texas Agricultural Experiment Station

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The symptoms, causes, and controls for 61 diseases and abnormalities of tomatoes in Texas are described. Information gained from research at Jacksonville is also added to the discussions of many of the diseases. Pictures are included to show symptoms of many diseases and abnormalities.

Good methods of managing hot beds to control damping-off and produce healthy, hardy seedlings are described.

Bacterial spot (nailhead rust) is the most destructive tomato disease in East Texas. Early blight, late blight, and Septoria blight damage tomato plants mainly by killing their leaves. Sprays and dusts to control these diseases are described.

Virus diseases of tomatoes include mosaic, fern leaf, curly top, and tip blight.

Southern blight is the most destructive of the diseases caused by soil-inhabiting parasites. Hence, its various symptoms are illustrated and its economic hosts are listed. Nematode root knot decreases the yield of tomato crops. Resistant varieties of tomatoes help to control Fusarium wilt.

Fruits on or near wet soil are likely to decay with soil rot, buckeye rot, southern blight, Rhizopus, or bacterial soft rot.

Unfavorable growing conditions cause growth cracks, sun injuries, blossom-end rot, puff, internal browning, catface, flower shedding, leaf roll, fertilizer yellowing, and root drowning.

General methods for controlling tomato diseases include sanitation, crop rotation, use of resistant varieties, and sprays or dusts.

This circular replaces Texas Agricultural Experiment Station Circular No. 82 entitled "Control of Tomato Diseases in the Seed Bed and Cold Frame," and Circular No. 86 entitled, "Common Diseases of Tomatoes."

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CIRCULAR NO. 113 NOVEMBER, 1946

TOMATO DISEASES IN TEXAS

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Texas is the leading tomato-shipping state in the United States. Tomatoes are grown in many counties and the acreage has increased from 9460 acres in 1924 to 83,600 acres in 1944, with an average of 46,490 acres per year from 1932 to 1941. Shipment of tomatoes from Texas increased from 6 carloads (from Cherokee county) in 1897 to 14,736 cars in 1945, and this total was almost equaled in 1946. Most of these tomatoes were green-wraps that sold for $900 to $3,000 per carload. Green-wrap tomatoes are those that are picked when they are mature in size but before they begin to turn red. They are washed, graded, waxed, wrapped in paper, packed in lugs containing 30 to 33 pounds of fruit each, and shipped to market in ventilated cars or trucks. The fruit ripens in transit or in buyers' storage rooms. Canneries use ripe tomatoes for juice or canned tomatoes, and many ripe tomatoes are also hauled from farms directly to grocery stores. In addition to the sale of tomato fruits, large quantities of tomato seedlings are trucked or shipped from plant farms in Texas to other states. Such seedlings are inspected for insects and diseases before shipment (15, 60).

Spring-crop tomatoes are grown especially in the areas near Harlingen, Mission, Falfurrias, Yoakum, Hallettsville, Livingston, Franklin, Jacksonville, Tyler, Edgewood, Avery, and DeKalb. Fall-crop tomatoes, maturing in November and December, are grown in the Lower Rio Grande Valley, the Winter Garden area, and near Laredo. Also, home gardens usually include some tomatoes. This extensive tomato industry in Texas has been concentrated in the areas listed due to favorable soil and climate. However, these same conditions favor many diseases that damage or destroy the crop. Diseases commonly decrease tomato yields from 10 to 50 percent, and for this reason, the sale of fruit often does not pay for fertilizer and labor expenses. The tomato has more than 200 diseases, many of which occur in Texas. Fortunately, research has discovered practical methods for controlling most tomato diseases. The purpose of this circular is to describe the symptoms and to give control measures for these diseases. It replaces Texas Agricultural Experiment Station Circulars 82 and 86. Additional information may be found in the literature references (10, 12, 40, 47, 53, 65, 71, 82).

KEY TO MAIN TOMATO DISEASES

			Page
A.	**Seedling diseases**		
1.	Brown cankers on lower stem or stems become thread-like and fall over	Damping-off	8
2.	Black or brown spots in leaflets	Early blight	25
		or Bacterial spot	21
		or Septoria blight	27
3.	Sunken black cankers in lower stem of plants in cold frame	Collar rot	25
B.	**Root and stem diseases**		
1.	Plants wilted, lower leaves dead; stems brown inside	Fusarium wilt	18
2.	Plants entirely wilted, white mold and decayed tissues at base of stem	Southern blight	13
3.	Swellings or knots 1/32 to 1/2 inch in diameter in roots	Root knot	16
4.	Black sunken cankers with rings in stem bark	Early blight	25
5.	Black streaks in woody part of stem; wilted leaves; exudate from cut base of stem	Bacterial wilt	20
6.	Tips of stems brown streaked and dead; pith brown	Tip blight	36
C.	**Leaf diseases**		
1.	Black spots 1/16 to 1/2 inch wide with concentric rings	Early blight	25
2.	Black or brown spots 1/16 to 1/8 (some are 1/4) inch wide	Bacterial spot	21
3.	Gray or tan spots 1/32 to 1/8 (some are 1/4) inch wide with black borders and black dots	Septoria blight	27
4.	Watersoaked spots 1/4 to 1 inch wide; leaflets and stems die quickly	Late blight	30
5.	Gray-green to brown moldy spots on lower sides of leaflets	Leaf mold	31
6.	Yellowish green mottling in leaflets, without mold	Mosaic	33
D.	**Fruit diseases**		
1.	Physiological abnormalities		
a.	Fruits partly angular and hollow	Puff	47
b.	Brown or black sunken spot in blossom end	Blossom-end rot	46
c.	Internal browning or decay of fruit	Core rot	50
d.	Fruits flattened, irregular, blossom end rough	Catface	50
2.	Bacterial diseases		
a.	White dots and brown cracked spots 1/16 to 1/4 inch wide in peel	Bacterial spot	21
b.	Brown spots with white rings 1/32 to 1/8 inch wide in peel	Bacterial canker	23
c.	Black dots 1/64 to 1/16 inch wide in peel	Bacterial speck	24
3.	Virus diseases		
a.	Light green spots in leaflets	Mosaic	33
b.	Brown rings and sunken brown bands in peel	Tip blight	36
c.	Large yellowish blotches in peel	Yellow mottling	33
4.	Fungus diseases		
a.	Sunken black spots with rings, 1/8 to 1/2 inch wide, often around stem	Early blight	25
b.	Large irregular dark brown areas with light brown bands	Buckeye rot	40
c.	Spots 1/8 to 2 inches wide with light and dark brown rings	Soil rot	40
d.	Soft rot with white mold and bodies like mustard seeds	Southern blight	13
e.	Brownish areas with uneven surface; firm rot	Late blight	30

CAUSES OF DISEASES

Plant diseases are caused by a number of agents, such as parasitic fungi, bacteria and nematodes; by viruses, and by abnormal environmental conditions (51, 73). Fungi and bacteria are responsible for most tomato diseases. Because these parasites are living organisms, their destructiveness depends to a large extent on temperature and moisture conditions prevailing in different seasons.

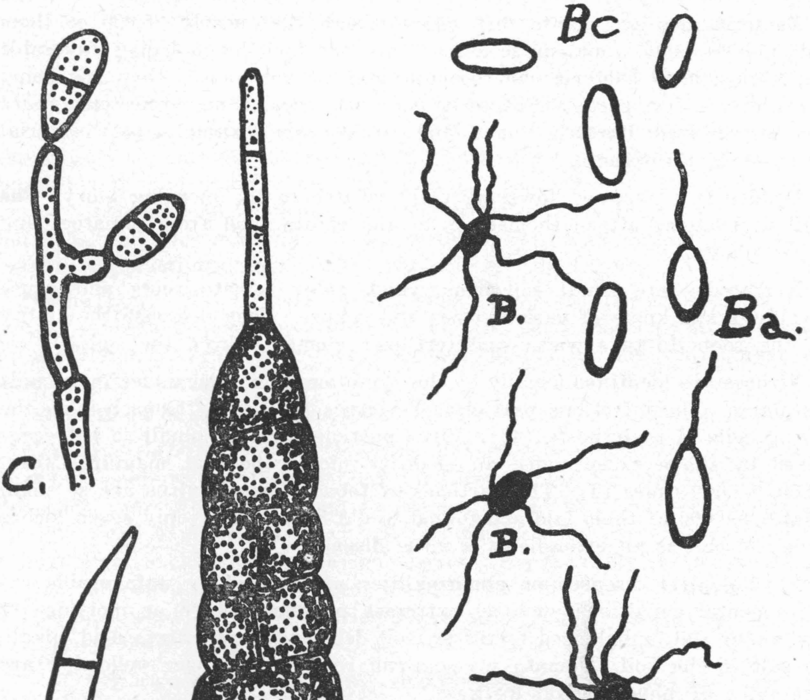

Figure 1. Examples of fungous spores and bacteria that cause tomato diseases. *A*, spore of Alternaria with its germ tube, *H*. *B*, bacteria with flagella (swimming appendages). *Ba*, bacteria with a single flagellum. *Bc*, bacteria without flagella. *C*, Cladosporium spores and mycelium (threads). *F*, Fusarium spore. These bodies can be seen only when greatly magnified. In this drawing the Alternaria spore is enlarged 700 times, Cladosporium and Fusarium are enlarged 1,000 times, and the bacteria are enlarged 5,000 times.

Fungi are plants most of which are so small that they can be recognized only with the aid of a magnifying glass or microscope. A good example of a fungus is the common gray mold with small black heads that grows on old bread. This same fungus also rots ripe tomatoes. Similar fungi cause other diseases of tomatoes. Some fungus spores and bacteria that cause diseases of tomatoes are illustrated with enlargement in Figure 1. Spores and bacteria may be carried short distances or hundreds of miles by wind, water, man, and animals.

Bacteria also are plants that are so small that nearly 25,000 of them laid side by side would make a row only one inch long. Under favorable conditions, most bacteria can reproduce themselves in less than one hour; therefore, a few parasitic bacteria can soon become numerous enough to be destructive. Bacterial spot and canker are examples of bacterial diseases of the tomato.

Dodder is a twining, flowering plant related to the morning glory. The yellowish stems attach themselves to and obtain food from tomatoes and other plants.

Nematodes are small eelworms which enter tomato roots and cause swellings and knots of various sizes and shapes. They decrease the ability of the roots to take water and fertilizer elements from the soil.

Viruses are identified usually by the symptoms that they cause in animals or plants. The infectious particles of viruses reproduce themselves in the living cells of their hosts (49). Virus particles are too small to be recognized by shape except with an electron microscope that magnifies them about 45,000 times (4). The particles of tobacco-mosaic virus are so small that 5,000,000 of them laid end to end would make a row only seven inches long. Mosaic is an example of a virus disease.

Physiological diseases or abnormalities are caused by unfavorable environmental conditions such as extremes of temperature or moisture of the air or soil, unbalanced fertilizer, soil deficiency, and excess acid, alkali, or salt in the soil. Tomato blossom-end rot and fertilizer yellowing are examples of physiological diseases.

DESCRIPTIONS OF DISEASES AND CONTROL METHODS

Damping-off of Seedlings

Poor stands of seedlings in hot beds usually are due to damping-off diseases that are caused mostly by species of fungi that live in the soil, especially *Pythium ultimum* and Rhizoctonia *(Corticium vagum)*. There are two stages of damping-off: seeds rot and seedlings decay before they appear above ground (pre-emergence damping-off), and seedlings die after they emerge (post-emergence damping-off). In this latter stage, the seedling stems become soft, constricted, thread-like, with or without browning, and fall over on the ground (Figure 2, D). Damped-off plants wither, decay, and soon disappear. Small patches or large areas of plants damp-off in hot beds, and sometimes nearly all of the seedlings die within a week. When seedlings survive damping-off, they may have the wire-stem symptom of hard, discolored stems (57).

Severity of damping-off depends to a large degree on the amount of light that the seedlings receive, and on the temperature and moisture content of the soil. Soil cooler than 70° F. favors injury by the damping-off fungi especially when the surface of the soil remains wet. Well drained soil is needed for tomato plants. Growing seedlings under sheets in hot beds and cold frames prevents the seedlings from receiving more than 100 to 300 foot-candles of direct sunlight intensity (normally around 10,000 f. c.). Therefore, they grow tender, spindly, and become starved, which makes them very susceptible to damping-off (Figure 2, A, B, D). In cold frames, seedlings often die because they are squeezed or dried during transplanting. More commonly, however, the young plants die because they had damping-off symptoms before they were set in the cold frame. Brown roots often are seen on seedlings when they are dug from hot beds, and such seedlings should be discarded. Damping-off fungi also may be destructively abundant in the soil of cold frames.

In the Lower Rio Grande Valley, tomato seed is planted in fields and brown cankers (caused by *Corticium vagum*) may develop in the bases of the stems. In rainy weather, the stem may bear the white layer of spores of the causal fungus.

Damping-off of seedlings may be avoided by using the following methods:

New or disinfected soil: A mixture of leaf-mold woods soil, well rotted barnyard manure, and commercial fertilizer should be put into the hot bed each year after the upper six inches of old soil has been removed. However, the expensive hot-bed soil can be used for three years if it is fumigated with chloropicrin tear gas each year, preferably early in October (7, 18, 38, 39), or is sterilized with steam (31), or hot water (11). Disinfested sand to which nutrients are added makes favorable soil for raising seedlings (11).

Seed treatment: Pre-emergence damping-off is controlled by chemical treatment of the seed (1, 21, 24, 27, 32, 53, 57). To use the dry method, dust the seeds thoroughly with Cuprocide (red or yellow cuprous oxide), Arasan, zinc oxide, or Ceresan at the rate of two-fifths ounce per pound of seed or one-fourth teaspoonful per ounce of seed. The seed and dust should be poured into a glass jar or can, the lid tightened, and the container shaken for a few minutes until the seed is well dusted. If several pounds of seed are to be dusted in one container, place a piece of tangled wire or rocks in the can to help mix the seed and dust.

The bacteria that cause nailhead rust are carried on tomato seed and can be killed by soaking the seed for 15 minutes in Semesan solution (one level tablespoonful per gallon of water), or the seed may be soaked for five minutes in a 0.033 percent solution of mecuric chloride (19 grains per gallon of water). For soaking, the seed should be tied loosely in a cheesecloth bag and stirred in the solution to remove all air bubbles which tend to prevent disinfection of some of the seeds by keeping them dry. Seed that is treated with mecuric chloride should be rinsed with water immediately after treatment. The wet seed should be spread on a cloth or paper to dry in a shady place out of the wind. Treated seed is preferably planted soon after treatment but may be stored by hanging in loose cloth bags.

Controlling post-emergence damping-off: In rainy, snowy, or freezing weather when the seedlings cannot be given enough sunshine, they sometimes begin to damp-off despite previous precautions. Then the seedlings should be sprinkled or sprayed with one of the following mixtures: (a) A suspension of 1 ounce of Semesan in 3 gallons of water to each 80 square feet of hot bed surface, repeated two or three times at five-day intervals as needed (21). In place of the Semesan, the same concentration of Basicop or similar copper chemical may be used (Table 3). These chemicals also help to control leaf diseases. Plants in cold frames should be sprayed twice with one of these copper chemicals at 10 and 20 days before setting the plants in the field.

Light: An abundance of sunlight offers the best control for post-emergence damping-off. Therefore, the sheets should be removed from hot beds and cold frames every day when the air is warmer than 40° F. and when there is no severe storm. This allows the seedlings to receive 1,000 to 10,000 foot-candles of light from the sky and to become very resistant to damping-off. They will also grow normally and strong enough to endure weather outdoors, and become frost resistant when they receive sufficient sunlight. Well-lighted seedlings have thick hairy stems with some purple color, and broad, dark green leaves (77). Drying of the surface soils helps to control damping-off, but extreme purpling of the stems indicates drouth injury. The seedlings should receive enough water to maintain good growth (Figure 2).

Warm soil: In most Texas areas, tomato seed for the spring crop is planted in hot beds in cool weather, therefore, it pays to warm the soil for proper germination and growth of the seedlings. Soil temperatures of 75° to 90° F. accelerate growth of seedlings and help them to avoid damping-off. Compost hot beds do not remain warm very long, and may become cold on frosty nights. Most farmers, therefore, prefer flue-heated hot beds. In clay land, flues can be made from trenches that are dug about six inches deep and ten inches wide in the bottom of the hot bed and covered with strong sheet metal. In sandy soil, stove pipes or tile make good flues. The flues should be about one foot deep near the furnace and five inches deep near the smoke stacks. Hot beds face the south to get maximum sunlight, and beds eight feet wide require two flues with a separate furnace for each. The flues should be in the front two-thirds of the bed. Old oil drums are preferred for furnaces, and green hardwood is desirable for a slow, long-lasting fire. A stovepipe suspended from the rafters at the back of the hot bed and connected to a separate furnace warms the air of a hot bed for frost protection. Some farmers set lighted lanterns in hot beds and cold frames on frosty nights, but there is danger of

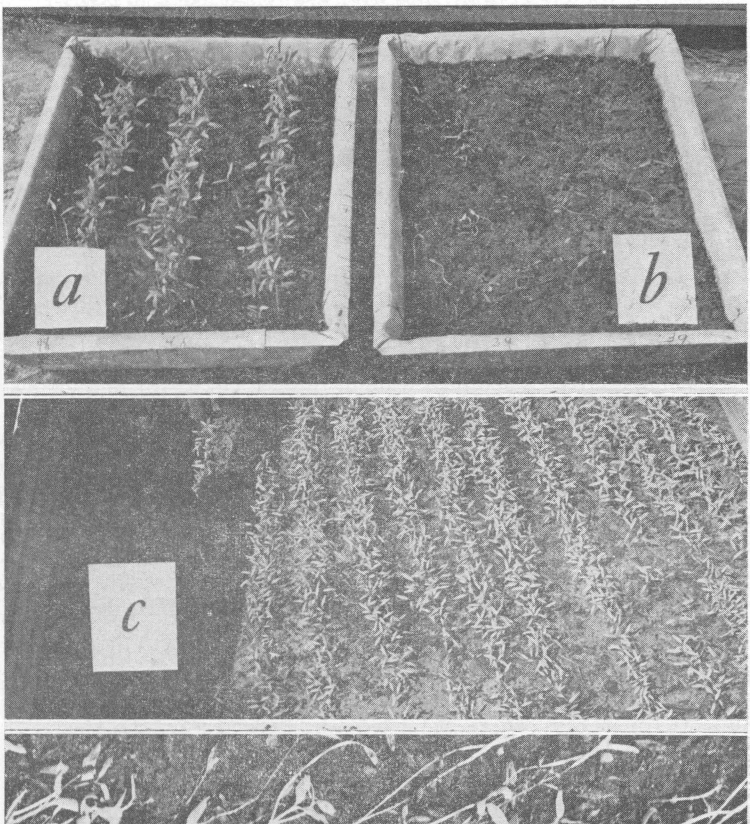

Figure 2. Damping-off of tomato seedlings was controlled (A) by Cuprocide seed treatment, in contrast to damping-off and disappearance of most of the seedlings from untreated seed (B). (C) Daily removal of sheets helped the seedlings to grow normally with the aid of sunlight. (D) Dim light let the seedlings grow weak, spindly, and easily killed by damping-off fungi.

burning the cloth sheets. If the air temperature is below freezing, water may be sprinkled on the sheets where it will freeze and protect the seedlings from frost. After a frost, sheets should not be removed until the air outside becomes warm, as frosty air on the moist warm seedlings might kill many of them suddenly. Electric heating cable in the soil of hot beds has been satisfactory, although very expensive. Cold frames are built with the ends at the north and south to admit maximum sunlight on the young plants.

White Leaf

Tomato seedlings that are grown under a sheet become so tender that they cannot endure cold or windy weather. The seed leaves turn nearly white when they are exposed to strong cold wind. When tomato plants are grown in a greenhouse and set outdoors, dry wind may cause white or tan areas about one-fourth to one inch wide in the leaflets. Browning of leaves is a symptom of serious injury to plants that is caused by dry wind on leaves that have been shaded too much. Some varieties of tomatoes, especially Marglobe, were only mildly injured which may indicate varietal resistance to wind injury in cold frames where other varieties were badly damaged (75). White and brown discoloration of leaves usually is avoided by growing hardy tomato plants with plenty of sunshine.

Killing of Leaves by Wind-blown Sand

Sand carried by strong north winds has been observed to kill most of the leaves on tomato plants set in rows near the north side of a shed but there was no injury to the plants in the other rows near the shed. The damage probably was increased where the wind was deflected by the shed.

Hard Stem

When a young tomato plant is stunted by drouth or cold, the stem loses much of its ability to grow in diameter. After such a plant resumes growth later in favorable weather, the stunted part of the stem remains hard, brittle, and slender while the new part of the stem above the injured portion becomes normally large and succulent. Strong wind may break the hardened part of the stem. Where many hard-stem plants occur in a field, it is desirable to plow soil over the hard parts of the stems.

Frost Injury

Complete freezing of leaves makes them wilt and become dry and brown or black soon after the ice melts in the tissues. Sometimes, only the tops of tomato plants freeze in a field. However, frost injury may be mild and damage only part of the tissues without killing the leaves. A frost may cause only light brown discoloration of the tops of tomato leaves that will remain alive. When tomato plants are grown without sheets in the day time in hot beds and cold frames, they become resistant to cold so that they can survive temperatures as cold as 28° F.

DISEASES CAUSED BY SOIL-INHABITING PARASITES

Southern Blight

Southern blight is a very destructive disease that is caused by a white fungus, *Sclerotium rolfsii,* which lives in the soil (Figure 3, B, Figure 4). In severe cases, most of the plants in a field are killed in the harvest season (Figure 3, A). The causal fungus is most destructive each year when the soil is warm and wet, and it attacks many kinds of crop plants (Table 1). The fungus rots the outer tissues at the base of stems about two inches above and below the soil surface (Figure 4). The leaves wilt and die suddenly within a day or two (Figure 3, A). In wet weather, the rotted part of the stem bears the white mold on which round fuzzy white bodies appear. These bodies soon become the round shiny brown or yellow sclerotia that resemble mustard seeds. The sclerotia are the reproductive bodies of this fungus. Southern blight often causes black streaks in the bases of the stems. When the soil becomes dry around the base of an infected plant, the white mold holds a ridge of sand one-eighth to one-fourth inch thick like a collar.

Besides killing the stems, the southern blight fungus rots the tomato fruits that touch the soil, sometimes causing severe loss. The decaying fruits bear large numbers of sclerotia (Figure 3, B; Figure 20, C). These sclerotia keep the fungus alive in dry, cold, or hot soil. They germinate in warm moist soil, and cause southern blight in crop plants. Reproduction of the fungus can be decreased by pulling up diseased tomato plants and carrying them out of the field, or at least turning the plants upside down to allow the roots to dry as soon as diseased plants are found.

How the fungus spreads: The fungus and its sclerotia are carried from one area to another in soil or infected plants. If this fungus is in the hot-bed or cold-frame soil, it is likely to be carried into the field with the plants. Muddy water containing the fungus can flow from an infested field over a lower field where the fungus may soon be found killing plants. Land often is infested with the southern blight fungus because peanuts grew in the fields. Peanuts are very susceptible to southern blight which rots the nuts and underground stems so that the nuts remain in the soil when the peanuts are dug (Figure 3, C). In fields where tomatoes have followed peanuts within three years, southern blight has killed 10 to 100 percent of the tomatoes. It is, therefore, advisable to avoid peanuts in crop rotation with tomatoes, peppers, or melons.

Control: Crop rotation to control southern blight should include cereal and grass crops that should be planted at a time to provide large plants during the warm rainy weather in May and June, or in September and October. Only the seedling stages of these plants are very susceptible to southern blight.

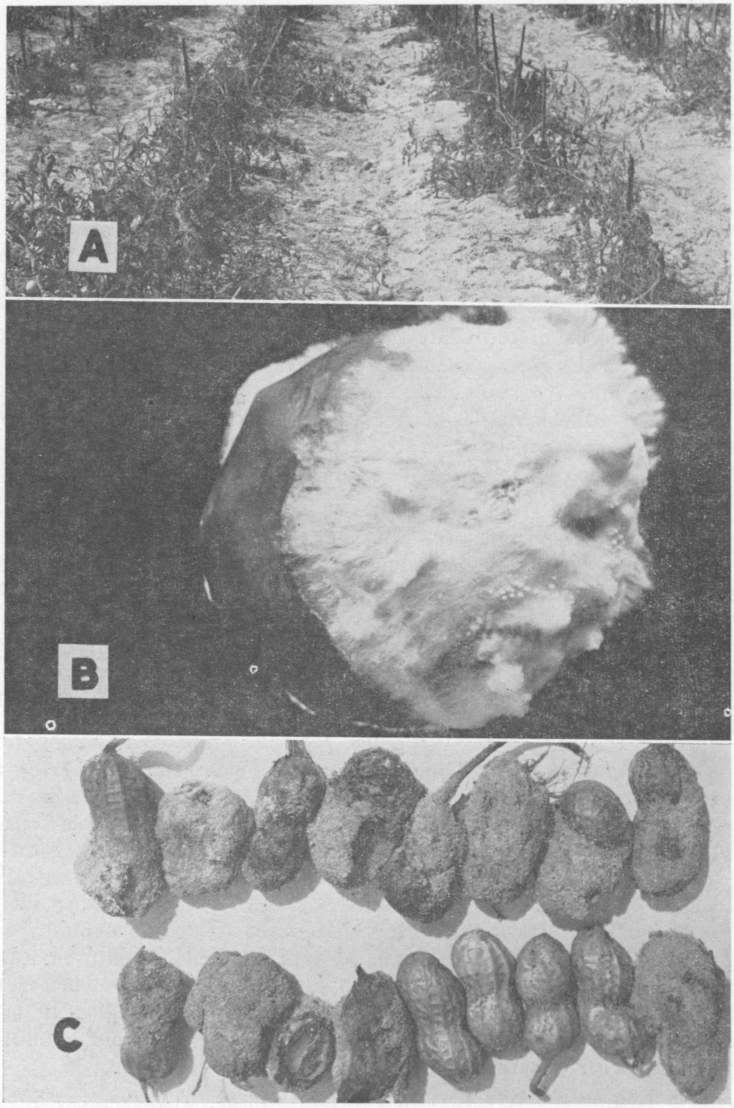

Figure 3. A. Southern blight killed nearly all of the tomato plants in this field where peanuts were rotted by the disease the preceding season. B. Decaying tomato fruit showing the white mold of the southern-blight fungus; the small round white bodies are immature sclerotia. C. Spanish peanuts mostly rotted by southern blight that frayed their stems and held cases of sand around many of the nuts.

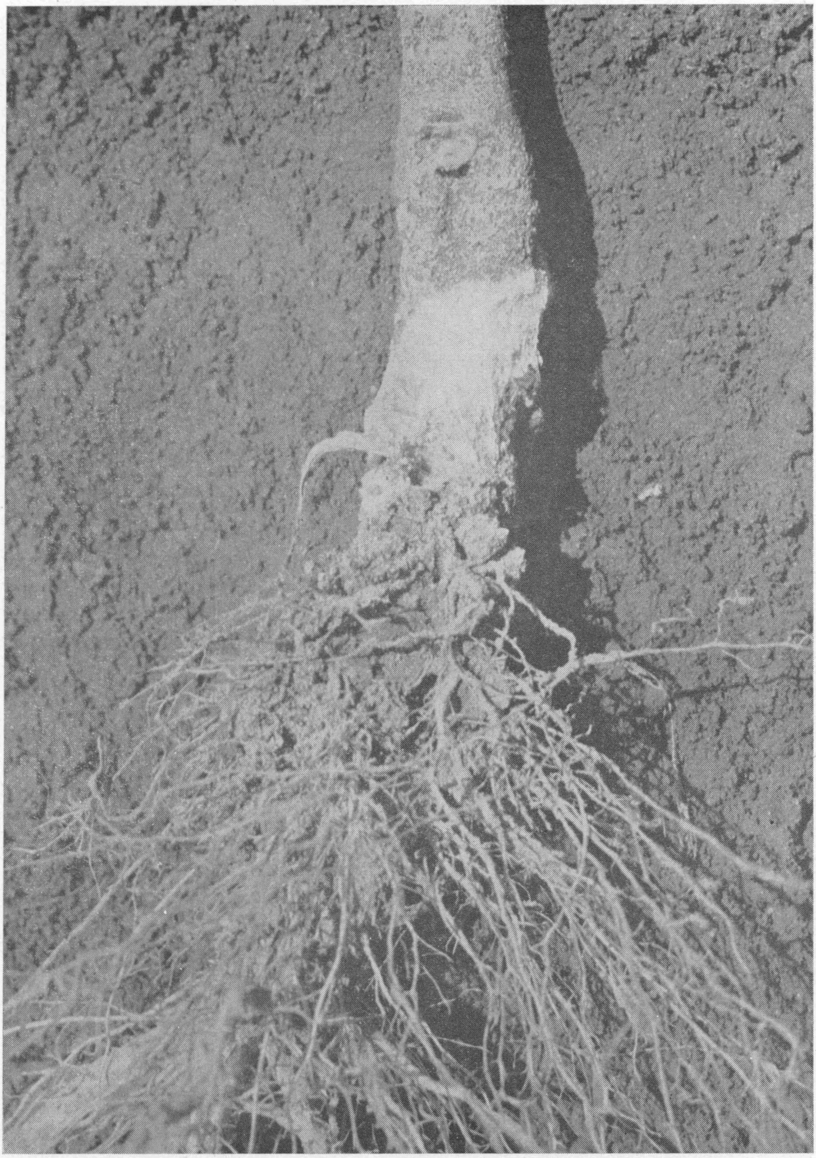

Figure 4. Southern blight of tomato showing the causal fungus (white mold) growing on base of stem. This was one of the last of the plants to die of southern blight in a two-acre field of tomatoes.

Table 1. Cultivated plants and weeds that are injured by southern blight*

Alfalfa	fig	radish
apple	flax	ragweed
banana	garlic	rice
barley	gladiolus	rose
bean	ground cherry (Physalis)	sorghum
beets	horseweed (Erigeron)	soybean
cabbage	iris	sugar cane
cantaloupe	lespedeza	sunflower
carrot	lettuce	sweet clover
castor bean	narcissus	strawberry
citrus	oats	sweet potato
clover	onion	tobacco
corn	peanut	tomato
cosmos	pea	turnip
cotton (young plants)	pepper	walnut (seedlings)
cone flower (Rudbeckia)	phlox	watermelon
crotalaria	pigweeds (Amaranthus)	wheat (young plants)
cucumber	potato	zinnia
eggplant	pumpkin	

**Sclerotium rolfsii* that causes this disease has more than 190 host plants (62).

Sclerotinia Stem Rot

Abundant white mold grows on the bases of tomato stems in rainy weather in the Lower Rio Grande Valley. This white mold (*Sclerotinia sclerotiorum*) rots the stems and kills the plants. Large black sclerotia of the fungus are produced by the white mold and keep the fungus alive in dry seasons. It rots the stems and fruits of many species of plants (74). This disease is best controlled by removing diseased plants from the field as soon as they can be found, and by rotation with cereal and grass crops, such as corn, sorghum, and sudan grass. Cotton also may be useful as a rotation crop.

Charcoal Rot

When spring-crop tomato plants are weakened by drouth, charcoal rot may attack the lower part of the stem (Table 2). The pith is usually entirely or partly destroyed. When the dead, dry stems are broken open, the interior looks gray or black due to the large number of black sclerotia each of which is about as large as a pin point. Charcoal rot is not likely to damage tomato plants in cool spring weather when they receive enough water, fertilizer, and proper cultivation. Charcoal rot is caused by a fungus, *Sclerotium bataticola*, that lives in the soil (88).

Nematode Root Knot

Dwarfed plants, yellowish to purplish discoloration of leaves, and premature death are above-ground symptoms of root knot caused by the roundworm or nematode (*Heterodera marioni*) (9). These are small parasitic worms 1/70 to 1/20 inch long that live in the soil and penetrate roots in which they cause swellings (Figure 5). These knots are enlargements of the root itself and they are unlike the nodules on the sides of legume roots that are caused by the beneficial nitrogen-fixing bacteria.

Figure 5. Large swelling and knots in tomato roots caused by root-knot nematodes. The knotted roots are unable to absorb water and fertilizer efficiently from the soil.

Root-knot nematodes attack more than 850 species of crop and wild plants in which they cause slight to severe damage to the roots. Few crops are immune to root knot, but some are resistant (6, 59). This is a debilitating disease that greatly decreases the yield and quality of farm crops and causes large annual losses. Root knot may be the most destructive disease of crop plants that grow in old cultivated sandy land in warm rainy climates (61).

Root knot nematodes require living roots for their food and are injured or killed by drying and exposure to sunshine. However, they survive from one year to another in undecayed roots in the soil even when the soil is dry to a depth of four feet in summer. These nematodes may move through sandy soil by their own effort as far as two feet per year. They usually are more destructive in sandy land than in clay land. Nematodes are spread by using diseased seedlings, by movement of infested soil on animals or machines, and in flowing water.

Control: The following precautions are profitable to take in controlling root-knot nematodes: Avoid setting any plants that show root knot, as they would be worthless, and nematodes from these plants would soon infest the soil of the field and make it unprofitable for cultivation of common cash crops (15). Soil free from nematodes should be used for hot beds and cold frames. Clean soil is so important in such cases that it justifies costly control methods, such as chloropicrin fumigation (18). New soil fumigants include Iscobrome, D-D Mixture, ethylene dibromide, and Dowfume. Tractor-drawn machines are available for fumigating large areas of soil (7, 38, 39).

Crop rotation is the most practical method for controlling root-knot nematodes in fields that are worth less than $500 per acre. The growing of sorghum, *Crotalaria spectabilis*, and velvet beans in succession for three years, with sufficient cultivation to control weeds, will greatly decrease the nematodes in the soil. For the following three years, Brabham or Iron cowpeas, corn, and sweet potatoes (Porto Rico, Big Stem Jersey, Red Jersey, Yellow Jersey, or Dixie Yam varieties) (23, 59), should be planted in succession. Nematodes are not likely to remain abundant in land that is occupied for five or more years by a properly-mowed Bermuda grass pasture. Many species of weeds have root knot, therefore, allowing weeds to grow on the land without cultivation does not control root knot satisfactorily (Table 2). The abundance of nematodes in soil can be decreased significantly by plowing the land three, five and seven inches deep in succession at about seven-day intervals in hot dry weather (19).

Fusarium Wilt

This common destructive wilt of tomatoes is caused by the fungus, *Fusarium oxysporum* f. *lycopersici*, that lives in the soil and attacks tomato roots (48). Even though it may cause disease in only a few roots of a plant early in the season, this fungus soon grows into the stems and causes downward curling, yellowing, and browning of the lower leaves followed by death of the plant (Figure 6). The leaf injury often appears first on only one side of a plant. Brown streaks in the woody parts of the lower stem and in the leaf petioles are the most reliable symptoms of Fusarium wilt. Sometimes the brown discoloration extends even into the fruits.

The wilt fungus attacks tomatoes of all ages, becoming especially destructive at fruiting time when the soil is moist and the temperature is about 82° to 88° F. Wilt is accordingly more serious in some seasons than in others. The fungus can live for many years in the soil and may be transported by wind, flowing water, or movement of soil. This species of Fusarium is often carried into new fields in infected tomato seedlings that became diseased in hot beds, cold frames, or seedling fields (60). In rainy weather, stems of plants killed by the Fusarium may bear a layer of pink spores of the fungus on their surface. Some strains of the fungus are more virulent than others, which increases the difficulty of developing resistant tomato varieties. Tomatoes and this wilt fungus are both favored by the same growing conditions. Marglobe (resistant) was most susceptible to wilt at a low soil-moisture level, while John Baer (susceptible variety) was most susceptible under higher soil-moisture conditions (54). Wilt usually is worse in slightly-acid soils than in alkaline soils. In fields that are badly infested with the fungus, only resistant varieties such as Marglobe and Rutgers live long enough to produce even a small crop of fruit (Figure 6). Root knot decreases the wilt resistance of Marglobe and Rutgers tomatoes (22, 76).

Figure 6. Stone tomatoes killed by Fusarium wilt, on right, compared with wilt-resistant Marglobe tomatoes, on left.

Susceptibility of varieties: Gulf State Market, Stone, Greater Baltimore, Bonny Best, John Baer, and Earliana varieties are very susceptible to Fusarium wilt. They usually are unprofitable in areas where much of the land contains the wilt fungus. Growing these or other susceptible varieties not only risks serious damage to the crop but also greatly increases the infestation of the soil with the wilt-causing fungus, making the land less profitable for tomato production for the next several years. Earlier publications give the relative resistance of 69 tomato varieties to Fusarium wilt (71, 76), under Texas conditions. Many varieties are resistant to wilt (28), especially Marglobe and Rutgers. New early hybrid tomatoes that are practically immune to the ordinary strains of the wilt fungus are being developed at the Tomato Disease Investigations Laboratory at Jacksonville.

Control of wilt: It is profitable to plant only resistant tomato varieties especially Marglobe or Rutgers in fields (76) or the later Pan America in home gardens. Grothen's Globe and Stokesdale are other resistant varieties for commercial fields. Diseases are avoided by using seed from healthy plants (State Certified Seed), and hot-bed and cold-frame soil that is free from the wilt fungus. By knowing the crop history of his land, a farmer can select a field that has not produced wilted tomatoes in the preceding 10 years. Then he may use a rotation in which tomatoes are planted no oftener than once in four years to keep the wilt fungus from becoming too abundant in the soil (Table 2). Fields in which as many as one-fourth of the plants show wilt symptoms should not be used to grow tomatoes within the next 10 years.

Verticillium Wilt

Another kind of tomato wilt is caused by a fungus named *Verticillium albo-atrum* that also lives in the soil. It wilts tomatoes in warm soil and also in soil that is too cool for Fusarium wilt (45). Tomato plants that are wilted by Verticillium show prominent black to brown discoloration of the woody tissues of the stems especially in the bases but also extending almost to the tops. This fungus makes black cankers where it enters roots. It attacks many kinds of crop plants including cotton, strawberries, eggplants, and some stone fruits, and it may become increasingly destructive year after year. Verticillium wilt has been found in some areas in Central and West Texas. Rotation with cereal crops helps to control this wilt. Riverside and Essar varieties of tomatoes are resistant to Verticillium wilt, but neither of these varieties yielded well at Jacksonville.

Bacterial Wilt

One of the soil-inhabiting bacteria *(Bacterium solanacearum)* attacks tomato roots, spreads into the base of the stems and causes black and brown discoloration of the woody tissues and pith. The base of the stem may appear dirty green at first and then become brown or black and shriveled. A few or all of the leaves may wilt within a day or two. Diseased plants are dwarfed and the leaves may wilt suddenly. When the base of a diseased stem is cut, a slimy exudate may be seen coming from the water tubes within a few minutes. This sticky ooze can be seen best with a magnifying glass. Bacterial wilt of tomatoes has been found in Cherokee and Gregg counties and there is danger that it may increase in abundance and destructiveness.

This bacterial disease attacks at least 106 species of plants including potatoes, tobacco, peanut, bean, soybean, pea, cowpea, nasturtium, castor bean, cotton, pepper, petunia, ground cherry, eggplant, and ragweed (13). Fields in which diseased plants have grown remain infested with the wilt bacteria during the next several years, making them unsuitable for susceptible crops. The bacteria are spread from plant to plant by potato beetles and other insects which should be controlled on tomato plants. Crop rotation helps to control bacterial wilt (Table 2).

BACTERIAL DISEASES OF FRUITS AND LEAVES

Bacterial Spot

Bacterial spot (locally called nailhead rust) is a very destructive disease of tomatoes in some areas where it damages or spoils many crops in rainy seasons. It is caused by a species of bacteria (*Bacterium vesicatorium*) (13) which makes circular or elongated brown spots 1/32 to 1/8 inch wide in the epidermis of stems and fruit pedicels (Figure 7, A). Similar brown to black spots develop in the leaves, often so abundantly that the leaflets are badly injured or killed (Figure 7, B). The spots often are sunken in the lower sides of the leaflets. Leaf spotting is associated with downward curling of leaves (Figure 7, B). Some varieties show browning of the margins of the leaflets as a prominent symptom of bacterial spot, but this symptom is rare in Marglobe and Rutgers tomatoes. The Pritchard variety is very susceptible to bacterial spot.

At first, this disease makes greenish-white translucent pimples in the peel of young fruits. As these pimples develop, they remain raised with greenish-white translucent margins and irregular flattened or sunken brown centers in which the epidermis soon breaks (Figure 8, right). Soon these spots become 1/20 to 1/3 inch wide and may coalesce to form even wider spots. The whitish margins disappear and the centers become dark brown with torn margins (5). Some spots have dark green borders (Figure 9, C). When half grown fruits become infected, the symptoms consist of small black spots or translucent pimples. Only small fruits are susceptible to infection so green-wrap fruits are immune.

The causal bacteria adhere to the seeds when they are removed from the fruits. These bacteria on the seeds infect the young seedlings, making black spots in the leaves in hot beds, cold frames, and fields. Splashing rain that is driven by strong winds in storms may carry the bacteria several feet away from diseased spots to healthy tissues which soon become infected and show diseased spots usually five to ten days later. Bacterial

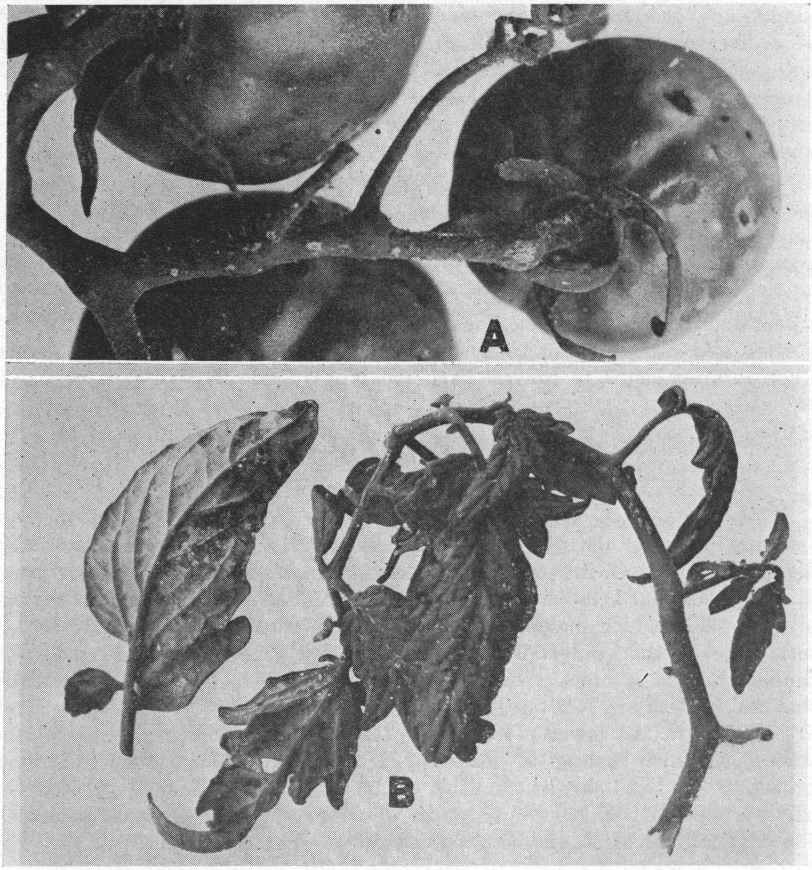

Figure 7. A. Brown cankers in epidermis of truss and brown spots with pale green borders in fruit peel caused by bacterial spot disease (nailhead rust) of tomato. B. Leaflet on left shows sunken brown spots in lower side caused by bacterial spot. Compound leaf on right is spotted and curled downward typically by bacterial spot.

infection is aided when rain makes watersoaked spots in leaves (30). Fields with nailhead rust often show spots on nearly all of the fruits which are thereby made nearly worthless. The spots show leakage as the fruits mature. Mildly affected fruits may be sold to canneries.

Control of bacterial spot: It pays to use only seed from healthy plants (State Certified Seed). If uncertified seed is used, it should be soaked in a solution of mercuric chloride (see page 9). The tomatoes should be sprayed or dusted thoroughly and often in hot bed, cold frame, and field with a copper fungicide (see page 60). There is increasing evidence that the nailhead-rust bacteria live from one season to the next in the soil or in old tomato-crop refuse. The bacteria can live on wheat roots and may live on roots of other plants (8). Farmers may allow tomato plants and weeds to grow in their hot beds all summer, and tomatoes may survive all winter in a place that is protected with tall weeds. Consequently, the bacteria may have a living host all winter. Sanitation and crop rotation are advisable in controlling bacterial spot. Bell pepper plants are also susceptible to bacterial spot disease. When nailhead rust is first found in a field on a small number of plants, these should be destroyed or removed from the field immediately to minimize the spread of bacteria. After this, the hands should be washed with soapy water before handling healthy tomato or pepper plants.

Bacterial Canker

Frequently, many tomato fruits in a field may be made worthless by spots of bacterial canker (also locally called nailhead rust). This disease is caused by a species of bacteria named *Aplanobacter michiganense* (13) that makes round flat snowy-white spots on the peel. When young, the spots can be rubbed off easily (5). These white spots later develop slightly raised, tan, cracked centers surrounded by flat snowy-white margins. The spots are about 1/16 of an inch wide (Figure 8, left). Only young fruits are susceptible to infection. When half-grown fruits become infected, only slightly raised tan cracks appear in the peel. The bacteria that cause this disease may be carried on the seed and infect the young seedlings. Infected young plants may develop yellow to brown streaks in the stem and leaf veins. Later the stem may crack open, forming cankers in which bacterial ooze appears. The top leaves may wilt on these cracked stems. Infected leaves show light green to gray spots between the veins. Control methods are the same as for bacterial spot.

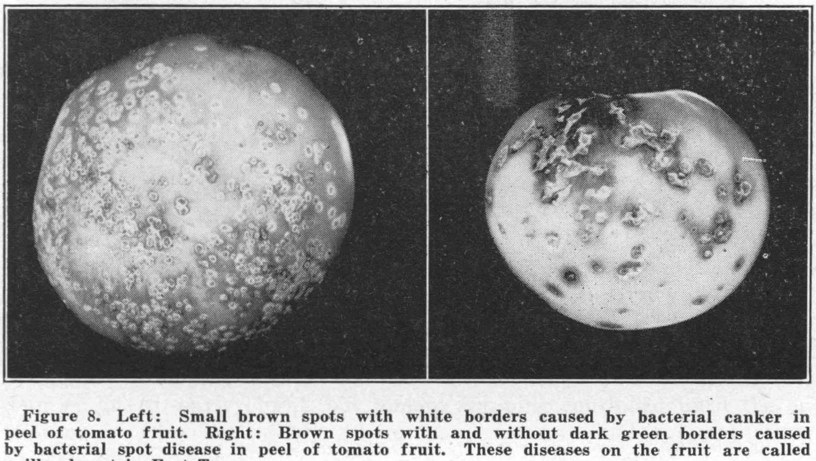

Figure 8. Left: Small brown spots with white borders caused by bacterial canker in peel of tomato fruit. Right: Brown spots with and without dark green borders caused by bacterial spot disease in peel of tomato fruit. These diseases on the fruit are called nailhead rust in East Texas.

Bacterial Speck

Bacterial speck (caused by *Bacterium punctulans*) is increasing in destructiveness in Texas. This disease causes black, sometimes sunken spots in the fruit peel (Figure 9, A, B). Prominently-speckled fruits are culled out in the green-wrap trade (5). The specks are black to dark brown and usually are smaller than 1/32 inch in width. They are round, flat, unbroken, and have distinct margins. The disease also causes small black specks, especially in the lower sides of leaves. Closely spaced specks may grow together causing large irregular yellow blotches in the leaves. The specks also occur on fruit stems and the leaves and stems of seedlings. Spread of the bacteria and control of the disease is the same as for bacterial spot.

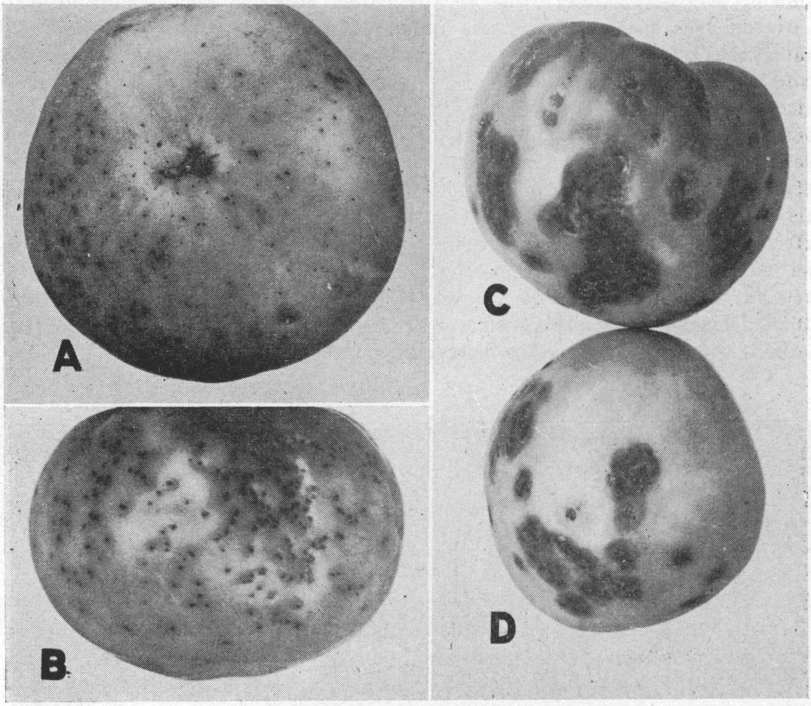

Figure 9. A, B. Small black spots without borders caused by bacterial speck disease in tomato peel; spots are sunken in "B". C. Dark green borders on brown cracked spots caused by bacterial spot disease in peel of tomato fruits.

FUNGUS DISEASES OF LEAVES, STEMS AND FRUITS

Nailhead Spot

Nailhead spot, caused by *Alternaria tomato*, is a disease that damages tomatoes in fields, transit, and storage (64). It causes small shallow gray to tan specks in the peel. Later, the specks become one-fourth to one-half of an inch in width. Such spots have black borders with whitish centers that may become black with spores of the causal fungus. The whitish center often has a black speck in the middle. Spots in the epidermis of the stems are circular, with tan centers, and are about one-fourth of an inch wide. Leaf spots are one-eighth to one-fourth inch in width, brown to black in color, and often have concentric lines resembling early blight. Marglobe variety is resistant to nailhead spot (10). Fungicidal sprays help to control this disease.

Early Blight

Early blight, caused by the fungus *Alternaria solani*, makes black spots in the leaves and stems of tomatoes in most fields. The leaf spots usually are 1/16 to 1/2 inch wide with concentric rings (Figure 10). Black spores (Figure 1) are produced in these spots. Long black cankers one-eighth of an inch to six inches in length, with concentric rings, are common in the surface of tomato stems (21). Other similar circular spots occur on the flower and fruit stems, and the fruits may have sunken black spots in their tops where the early blight fungus entered through the stems. Sunken circular spots may be found in the sides of tomato fruits in July.

Collar rot is a destructive stage of early blight (Figure 11). The sunken black cankers girdle the bases of the stems in the cold frames and fields. Collar rot has been known to canker the stems of a thousand plants in one cold frame, leaving many disconnected tops on the soil where they had rotted off. Some plants with collar rot were set in fields but they remained dwarfed. New hybrid tomatoes with resistance to collar rot are being developed by the U. S. Department of Agriculture.

Severe attacks of early blight early in the season result in the greatest damage to the crop. Loss of leaves decreases the production of food materials for the fruits which may also be injured by hot sunshine due to lack of shade. Usually early blight spots the leaves and stems and kills only the lower leaves before the end of the shipping season. However, an epidemic of this disease occurred in East Texas in 1941 (87). The plants still had three-fourths of their leaves on June 7 when they received a series of rains totaling 3.94 inches by June 16. By June 20 only one-tenth to one-fourth of the leaves remained on the plants in most fields and much of the fruit stopped growing and became sunburned due to lack of shade. The tomato shipping season was shortened one to two weeks in some counties due to early blight, but tomato shipping continued until the end of June in Cherokee county where many farmers had sprayed copper on their plants (81).

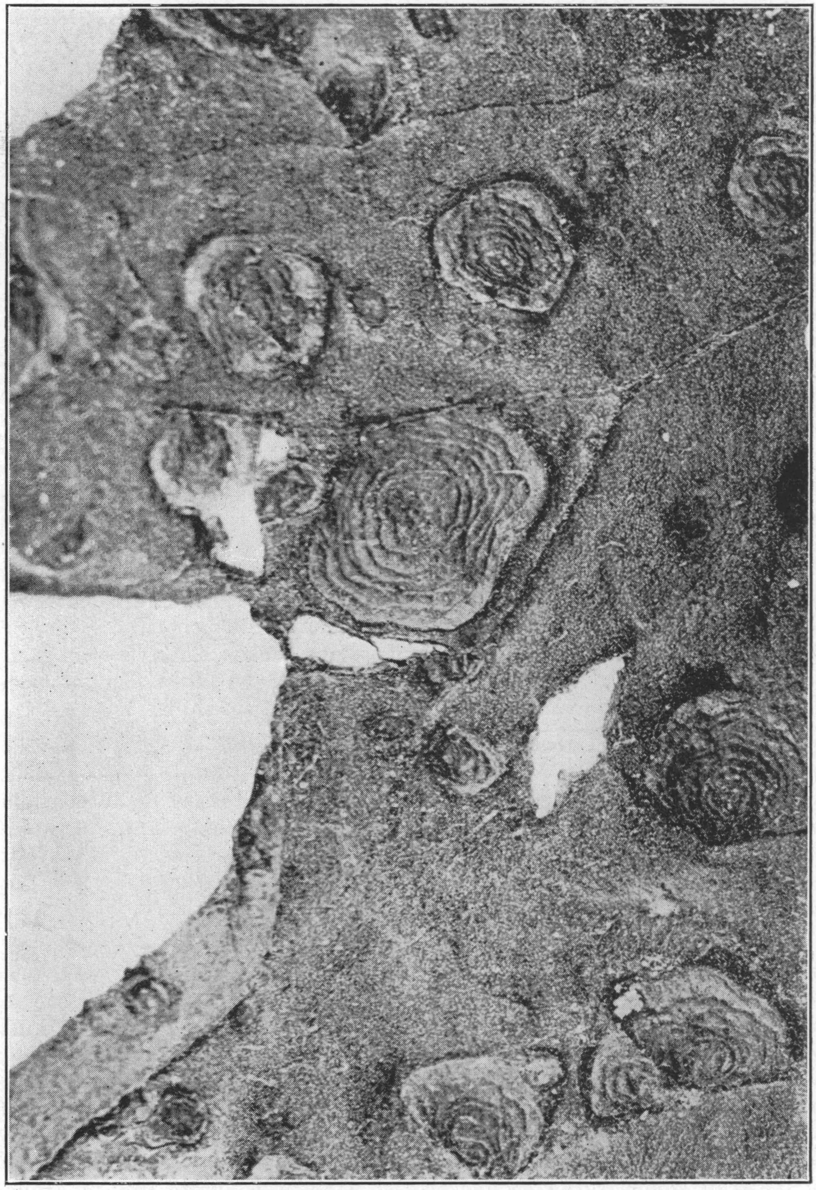

Figure 10. Black spots with concentric rings and lines caused by early blight disease in a tomato leaf. (Magnified three times.)

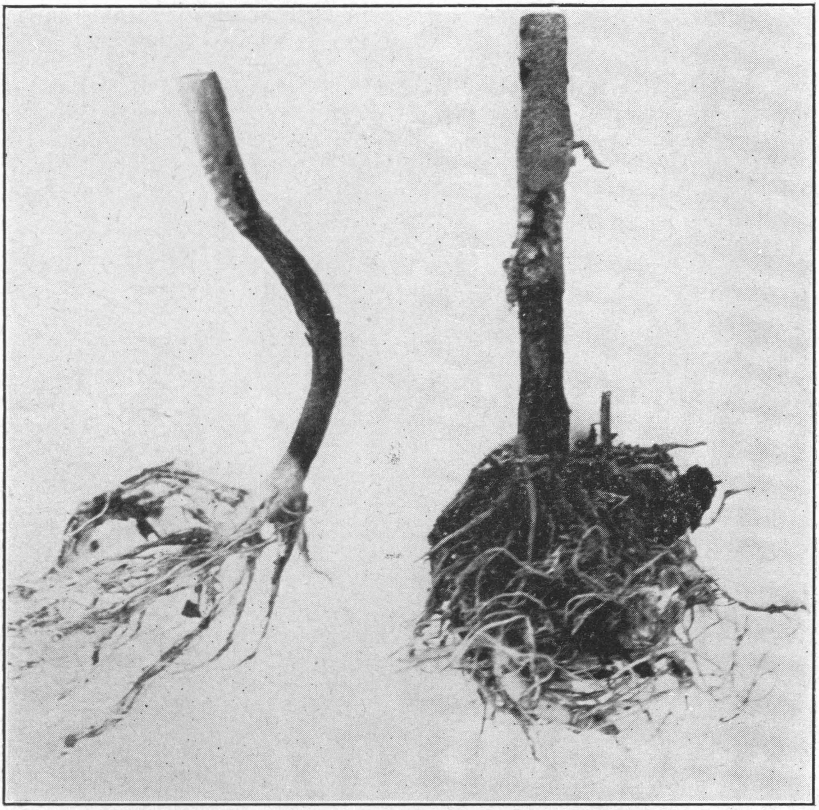

Figure 11. Collar-rot symptom of early blight consisting of sunken black cankers in bases of tomato stems in cold frame.

Control methods: Sprays and dusts control early blight (page 60) (44, 67). It is very important to prevent early blight from spotting the leaves and cankering the stems of the plants in the hot beds and cold frames as such damage decreases yields of fruit in the fields.

Septoria Blight

Spots 1/16 to 1/4 inch (usually 1/8 inch) wide with brown to black borders and black dots in the gray or tan centers are the symptoms caused by *Septoria lycopersici* (Figure 12). The black dots in the spots are fruiting bodies which discharge spores in rainy weather. Rain splatters these spores from the spots to healthy leaves that may show the infection in about a week, especially when temperatures are near 77° F. The spots may appear as numerous brown dots that kill the leaves quickly. The dead leaves hang on the stems. Septoria spots are also common on the stems, flower pedicels, and sometimes on the fruit of tomato plants.

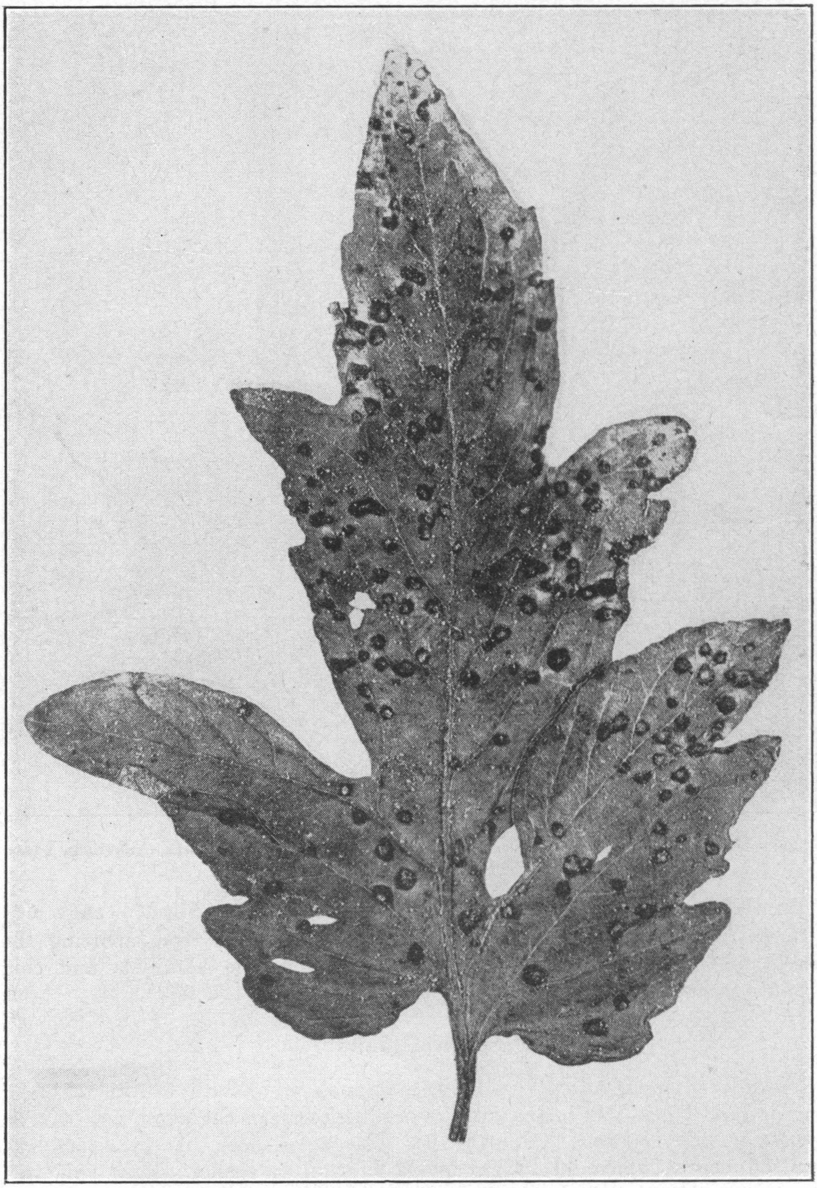

Figure 12. Spots with brown or black borders and gray or tan centers caused by Septoria blight in tomato leaf. (Magnified two times.)

Septoria blight was destructive at Jacksonville in 1936 but was absent in the drouthy season of 1937; it did not reappear abundantly until 1941, after which it became destructive again.

Control methods: Copper sprays and dusts control this disease (page 60). Septoria blight should be controlled in hot beds and cold frames, especially, because it often damages small plants, and infected plants grow slowly when set in fields. New hybrid tomatoes with resistance to Septoria blight are being developed by the U. S. Department of Agriculture.

Figure 13. A, B, C, D. Greenish-brown or black spots with whitish borders of spores caused by late blight disease in tomato leaflets. E. Tomato fruits with large areas rotted by late blight.

Late Blight

This is one of the most destructive of all plant diseases as it often destroys whole crops of tomatoes and potatoes in a week of cool (50° to 80° F.) rainy weather (55). Late blight is caused by the fungus, *Phytophthora infestans,* that causes large watersoaked greenish-brown or black spots in the leaves. During moist weather, the spots have white borders

Figure 14. Symptoms of late blight in tomato stems. A. Stem typically twisted and broken in a late-blight canker. B. Crack in late-blight canker in stem, and section of stem showing hollow center. C. Late-blight fungus killed the leaves, grew into the stem, and caused light brown stem cankers. D. New top grew on a tomato stem in warm weather after late blight had killed the old top. These figures were published first in Phytopathology (85).

of spores of the causal fungus on the lower sides of the leaf spots (Figure 13). The spots are one-eighth to one inch wide, without definite borders, and they kill the leaflets quickly. The spots become black in dry weather. Late blight causes a firm rot of tomato fruits, usually starting near the stem end. The peel in the affected area is slightly wrinkled and has a speckled or blotchy brownish-green color. The rotted spot lacks a definite margin, and may spread over one-third to one-half of a fruit within two days (42). Late blight makes light brown cankers that often girdle the stems and cause them to split open lengthwise. The stem may be twisted and broken in the region of the canker (Figure 14). The stem infection may extend into the roots.

Late blight is becoming increasingly destructive to southern spring-crop tomatoes (2, 17, 37). In March 1945, tomato plants with traces of late blight were brought from the Lower Rio Grande Valley to Jacksonville and set in fields. In the cool rainy weather, late blight killed most of these plants and the disease also spread to locally-grown plants in hot beds and cold frames (85). In areas where late blight is prevalent, care should be taken to locate tomatoes away from potato fields. Tomato fields should be sprayed very thoroughly and often (see page 60).

Leaf Mold

Yellowish-green blotches in the upper sides of leaflets accompanied by gray to greenish-brown moldy spots on the lower sides are the main symptoms of leaf mold caused by *Cladosporium fulvum* (Figure 15). The moldy patches are spores and sporophores and they may also occur on the upper sides of the leaflets. This disease sometimes occurs in fields during warm rainy weather. It is very destructive in greenhouses where good ventilation and temperatures near 80° to 90° F. are necessary to control the disease. Water should not be sprayed on the leaves in greenhouses. Globelle and Bay State varieties are resistant to certain races of the leaf mold fungus, but their fruits are too small for green-wrap tomatoes in Texas. Besides leaf spots, the disease also causes a stem-end rot of fruits and round black spots in the sides of fruits (42). Because the fungus survives on seeds, only seeds from healthy plants should be used. Copper sprays (Table 3) help to control leaf mold.

Gray Leaf Spot

Gray leaf spot is caused by a fungus, *Stemphylium solani*, that may become destructive. The leaf spots are round, 1/16 to 1/4 inch wide, and dark brown, gray, or black in color (63). The spots become shiny, glazed, and often have yellow borders. The centers of the spots crack and the leaf tissues may fall out leaving holes in the leaflets, or the whole leaflet may become yellow. Dead leaves usually fall off and the entire plant may be defoliated. Copper sprays (Table 3) control gray leaf spot.

Figure 15. Cladosporium leaf mold on lower side of tomato leaflet.

VIRUS DISEASES

Mosaic

Common tomato mosaic is caused by tobacco mosaic virus (Nicotiana virus 1) that causes mosaic of many species of plants (4, 26, 47). Tomato mosaic is recognized by a prominent, light green to yellowish mottling in the leaflets (Figure 16). Mottled leaves may show some raised dark green spots. The mottling becomes less distinct in hot weather. Mosaic decreases the size and yield of the fruit. The causal virus lives in the cells of the plants from which it is spread to healthy plants by the hands of the people who set out the seedlings and prune the tomatoes. Mottling appears in the inoculated plants within about two weeks.

There are two common sources of this virus: (a) It remains alive in ordinary smoking and chewing tobacco, and workmen using tobacco get the virus on their hands and inoculate tomatoes. Tomato farmers would profit by refraining from the use of tobacco while they are handling young tomato plants. (b) Perennial ground cherry (*Physalis heterophylla*) is a common weed that is often infected with this virus. Mottled ground cherry plants should be destroyed when they are found growing near tomatoes.

Yellow Mottling

Prominent yellow mottling of the leaflets and mottling of the fruits are symptoms of a mosaic disease that is caused by yellow tobacco mosaic virus (Nicotiana virus 1 C) (Figure 17, C). Mottled leaflets may be pale yellow or almost white with some green spots (47). Mottled fruits are refused at tomato packing sheds. Control measures are the same as for ordinary mosaic described above.

Mottle

In cool moist weather, tomato leaflets may show a dim mottling as the only symptom of the mottle disease that apparently causes little injury to the plants. Mottle is caused by the potato virus x (Solanum virus 1) that lives in most varieties of potatoes without causing visible symptoms.

Streak

Brown streaks in the epidermis of stems with brown areas in pith and cortex are symptoms of streak disease. The stems become brittle and brown spots may appear in the leaves and round sunken blotches may appear in the fruit peel. This kind of streak is caused by Lycopersicon virus 1). A few other viruses, or combinations of them, cause other kinds of streak symptoms. These viruses may also be carried on the hands, which should be washed with soapy water after handling a streak-diseased plant before touching healthy plants. Diseased plants should be destroyed as soon as they can be found.

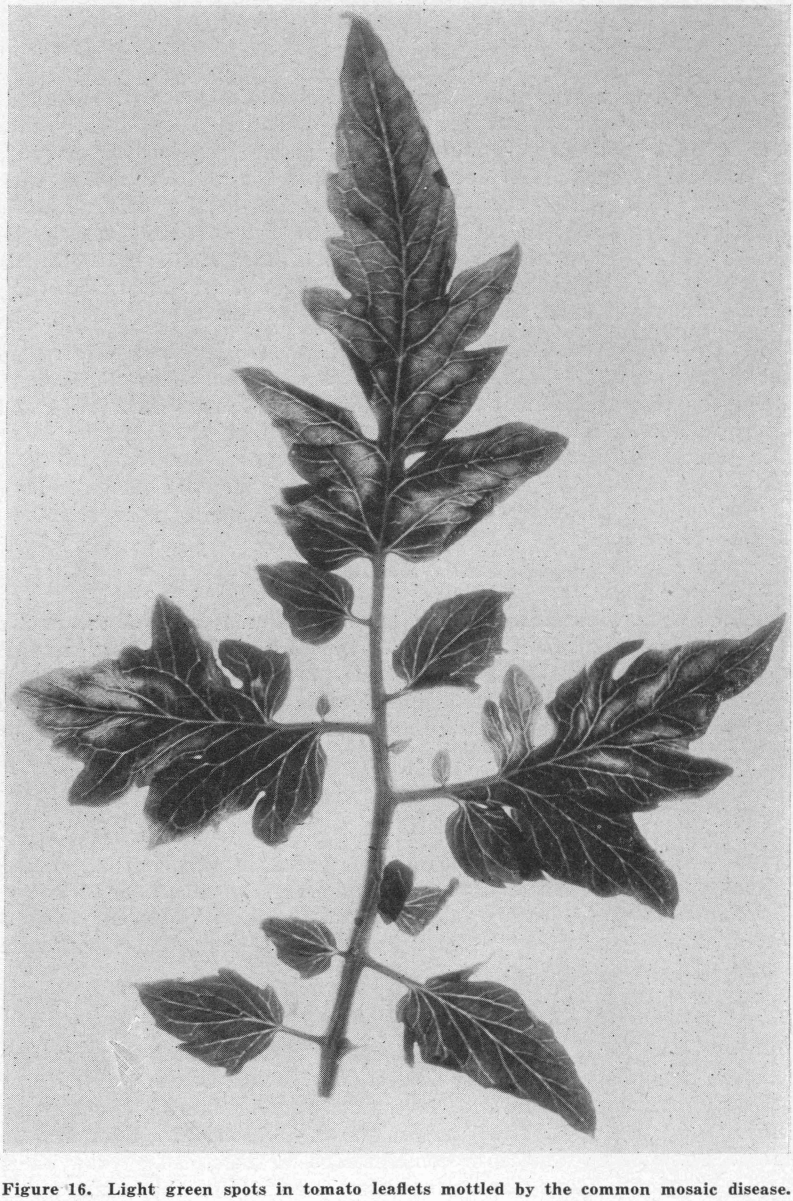

Figure 16. Light green spots in tomato leaflets mottled by the common mosaic disease.

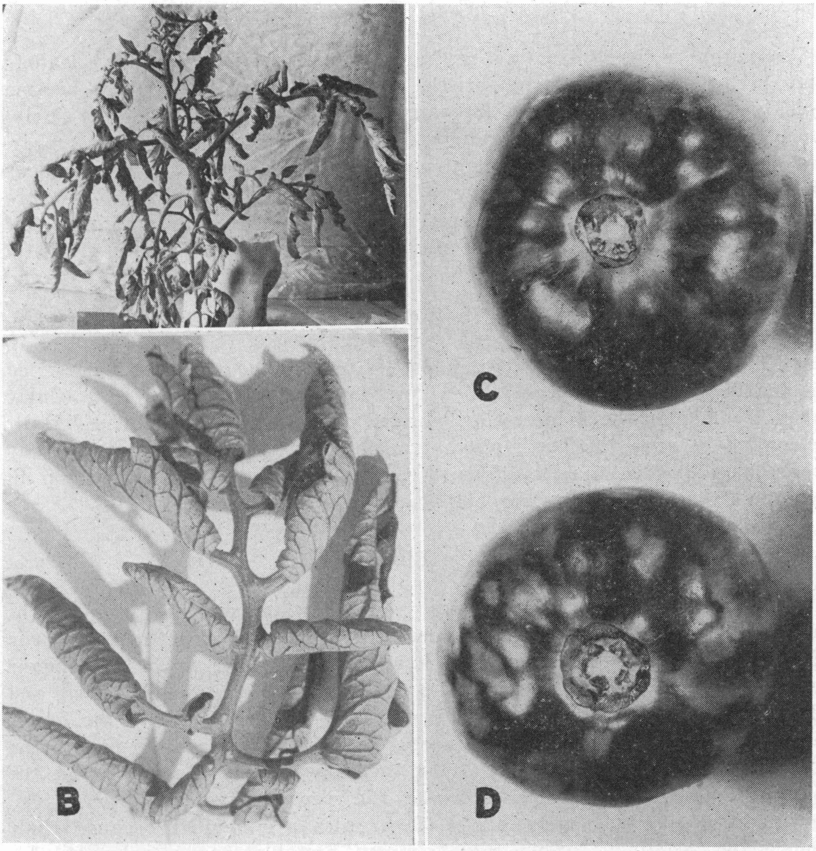

Figure 17. A, B. Extreme upward rolling of tomato leaflets caused by curly-top virus disease. C and D. Tomato fruits with mottling caused by the virus of yellow tobacco mosaic.

Fern Leaf

Leaflets are slender, narrow, and even thread-like when they have the fern leaf disease that is caused by the cucumber mosaic virus (Cucumis virus 1). Fern leaf may also be caused by Nicotiana virus 1. In extreme cases, only the midribs of leaflets remain (47, 71). The young leaves are small, twisted, and curled, while the old leaves are light green and may be rolled or folded. Diseased plants have few or no fruits. Aphids (plant lice) carry the virus from melons to many other species of plants. Control of fern leaf consists of removing diseased plants as soon as they are found, keeping tomato fields widely separated from fields of cucumber, squash, and cantaloupe, and spraying the plants to control aphids. Virus diseases are likely to become more serious on tomatoes.

Curly Top

Curly top is recognized by prominent upward rolling of the leaflets that become very crisp and brittle. Later, the leaflets usually become light green or yellow and develop purple veins (Figure 17, A, B). Curly-top plants are dwarfed and rigidly erect. As soon as the symptoms appear, the stems stop growing and they may become hollow. The fruit ripens regardless of size as though the plant had been cut off. Seeds mature poorly in such fruits. The roots decay and the plants die within a few weeks. Curly top spoiled about 1 percent of the plants in many fields in East Texas in 1940, but it usually is rare in this area.

The curly-top virus (Beta virus 1) also causes sugar beet curly top (47). The virus is carried by the beet leaf hopper insect that does not live in East Texas. It is presumed that in April 1940, the southwest wind carried the leafhoppers from range land a few hundred miles away (89). Curly top is common in the Winter Garden area and near El Paso. It is difficult to control because the leafhoppers transmit the curly-top virus to many kinds of plants in these regions. Removal of plants with curly top in and near tomato fields would help to control the disease.

Tip Blight

Blighting of the tops and young leaflets are symptoms of tip blight that is caused by the tip-blight virus, a form of the spotted-wilt virus (Lycopersicon virus 3). Round black spots 1/16 to 1/4 inch in diameter develop in the young leaflets and soon kill many of them. Brown and silvery-gray streaks appear in the epidermis of the tops of the stems several days before they die (Figure 18, B). Brown areas develop in the pith and water-conducting tissues in the upper parts of the stems, the center of which may become hollow as the stems shrivel (Figure 18, C). On diseased plants, nearly all of the fruits are spoiled because their peels show prominent brown rings, marks, and blotches (Figure 18, A). Some of these brown discolorations are sunken. Large areas of peel may be light brown. Inside the fruits, many tissues are brown or have brown borders. Empty brown or normal-colored cavities one-eighth to one inch long occur near the cores of many badly affected fruits that are one to two inches in diameter (Figure 19). Fruits stop growing when the brown discolorations appear. Large fruits may have only dim brown marks and may ripen unevenly. The small brown-marked fruits do not ripen but usually fall off when they are touched or their stems are shaken and the water-conducting tissues inside the fruit pedicels are brown. Many affected fruits show combined symptoms of both tip blight and blossom-end rot. Tip blight is transmitted by thrips and ornamental plants may be a source of the virus. Profitable control of tip blight may be obtained by applying sprays or dusts to control thrips, destroying tomato plants as soon as tip blight can be diagnosed, and destroying diseased ornamental plants (especially perennials) near farm houses.

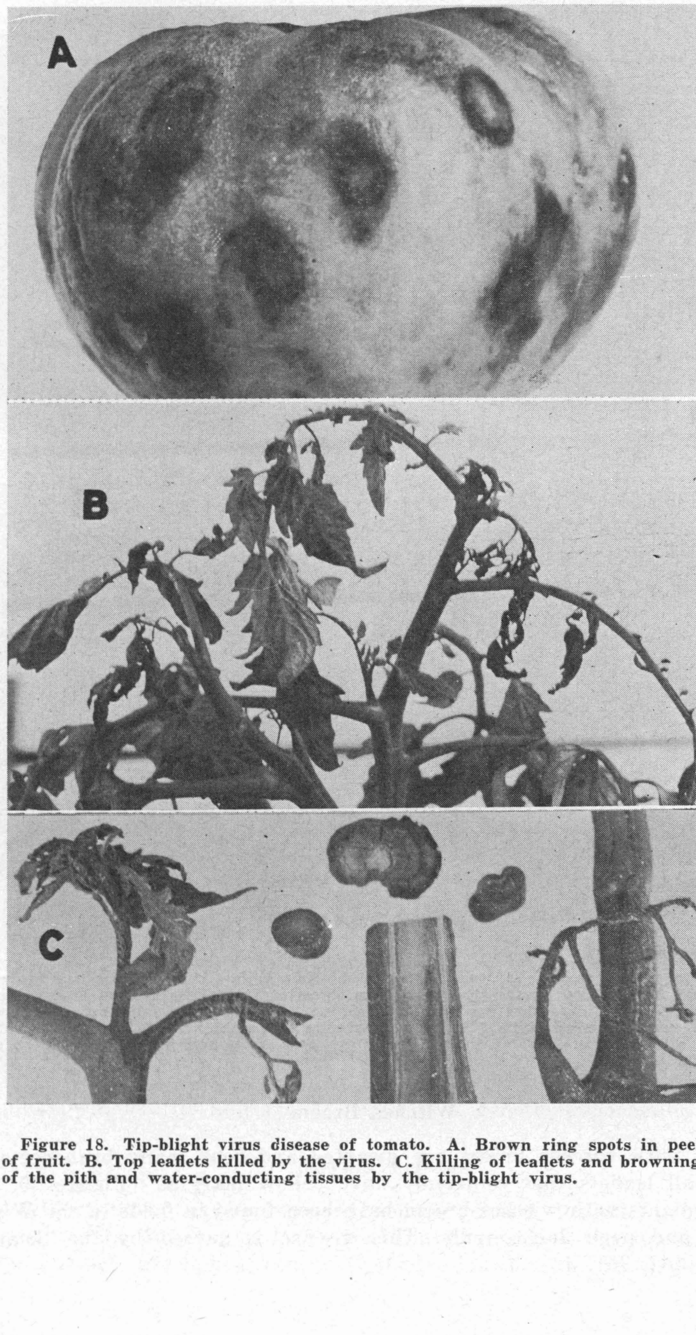

Figure 18. Tip-blight virus disease of tomato. A. Brown ring spots in peel of fruit. B. Top leaflets killed by the virus. C. Killing of leaflets and browning of the pith and water-conducting tissues by the tip-blight virus.

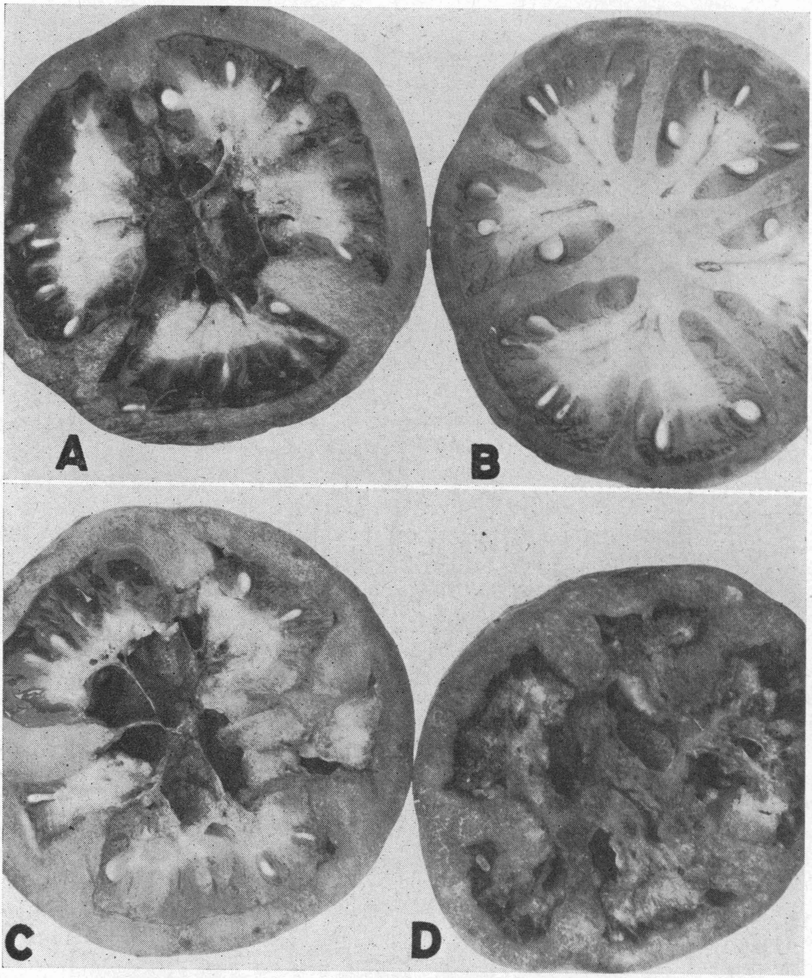

Figure 19. Cross sections of tomato fruits showing hollow core cavities and browned tissues that were caused by the tip-blight virus. Peel of fruits also showed brown marks. A, C. Large brown core cavities with browned tissues near them, and areas of brown tissues in outer walls of fruits. B. Browned tissues in center of each placenta to which seeds are attached. D. Most of tissues are brown and small hollow cavities may be seen near center of fruit.

Witches Broom

Plants with witches broom are dwarfed and bear many branches with very small leaflets that commonly have yellow margins (Figure 20, A). Tomato plants with witches broom have been found in fields in the Winter Garden and near Jacksonville. This disease is caused by the Solanum virus 15 (47, 70).

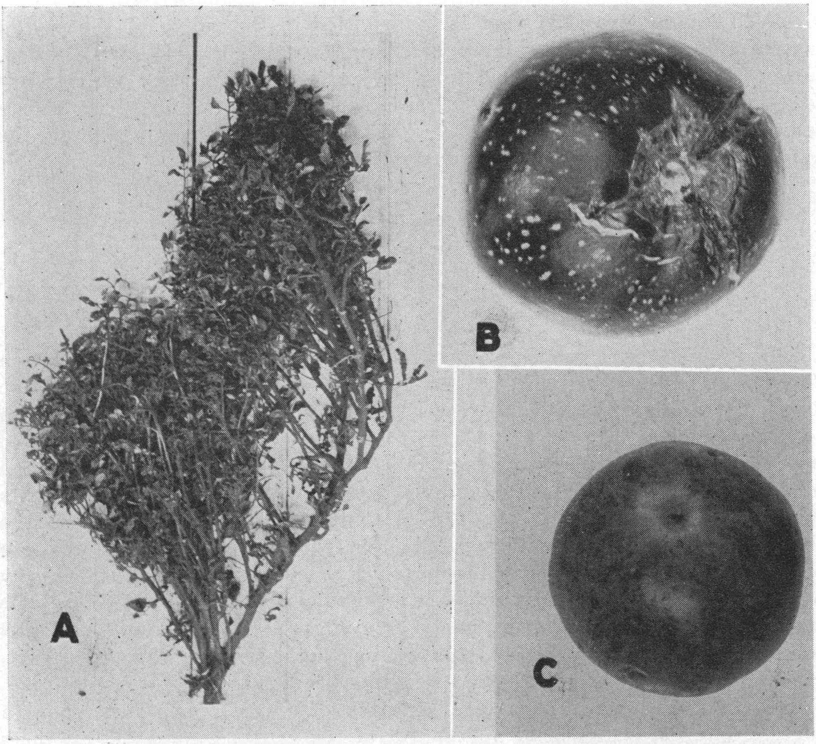

Figure 20. A. Witches broom, a virus disease of tomato, showing many small branches and leaves. B. Pits, pox, corky dots, or streaks in tomato fruit peel due to pox; this fruit also shows typical stem cracks. C. Mottled spots of dark green color in lighter green fruit peel, due to pox.

Fruit Pox

When affected with fruit pox, green tomato fruits show dark green spots or short streaks in the peel especially near the blossom end (Figure 20, C). These spots are 1/32 to 1/5 inch wide and are round, elongated, or irregular (29). Most of the spots may be in rows extending along the sides of the fruits. Some spots may join to form streaks. Many of the dark green spots become sunken corky pits (pox) with broken cuticle on the surface (Figure 20, B). Fruit pox has caused serious loss in the Winter Garden and is common in Cherokee county. The cause of fruit pox is unknown, but its appearance suggests a genetic abnormality (78).

Psyllid Yellows

Psyllid yellows causes upward rolling of old leaflets, puckering of young leaflets, purpling of leaf veins, and dwarfing of the plants. Diseased plants usually are light green. This disease is caused by the psyllid yellows virus (Solanum virus 18) that is transmitted in the saliva of the psyllid insects (43, 47). Psyllid yellows has been found in the Winter Garden, Lower Rio Grande Valley, and in Northwest Texas. Because the psyllids feed on potatoes also, fields of tomatoes and potatoes should be widely separated. Psyllid yellows can be controlled by killing or repelling the psyllids with sulphur sprays or dusts (35).

FRUIT ROTS CAUSED BY FUNGI AND BACTERIA THAT LIVE IN THE SOIL

Soil Rot

When green or ripe tomato fruits touch warm wet soil, they often develop Rhizoctonia soil rot, caused by *Corticum vagum.* This destructive disease is recognized by the alternating light brown and dark brown concentric rings (Figure 21, A). The rotted spots are one-fourth to two inches wide and circular or irregular in shape. The spots soon crack and brown mold with black sclerotia may develop in the cracks. Even fruits that are several inches above the ground may become infected by the fungus that is splashed with soil onto the fruits by rain. Rhizoctonia can penetrate the unbroken epidermis of fruits. It is most destructive in rainy weather when the top soil remains wet. Fruits that are infected in fields may show only traces of brown spots, or even no symptoms, but such fruits continue to rot in transit and storage, causing extensive damage. Hence, green fruits with brown spots are graded out at packing sheds (42). Fruits touching wet soil, and also bases of stems, sometimes show a surface layer of white mold and spores of the causal fungus. Many races of this fungus occur in soils and cause damping-off and stem-canker diseases of many crops. Staking and tying tomatoes to keep the fruits off the ground, and careful irrigation to keep the surface of the soil dry most of the time, help to control soil rot.

Buckeye Rot

Buckeye rot, caused by a fungus, *Phytophthora terrestria,* that lives in the soil, causes large irregular dark brown spots with green areas and darker brown rings (Figure 21, B). Borders of the spots may be water-soaked. The fungus enters fruits that touch the soil or those that have soil splashed onto them. This disease is serious especially in the Winter Garden area. Infected fruits from fields may show no symptoms or only little brown dots, but infections develop in transit and storage. Hence, spotted fruits are graded out at packing sheds. The control is the same as for soil rot (42).

Phoma Rot

Fruits with Phoma rot (caused by *Phoma destructiva*) show black sunken spots in which may be seen many black pimples bearing the spores

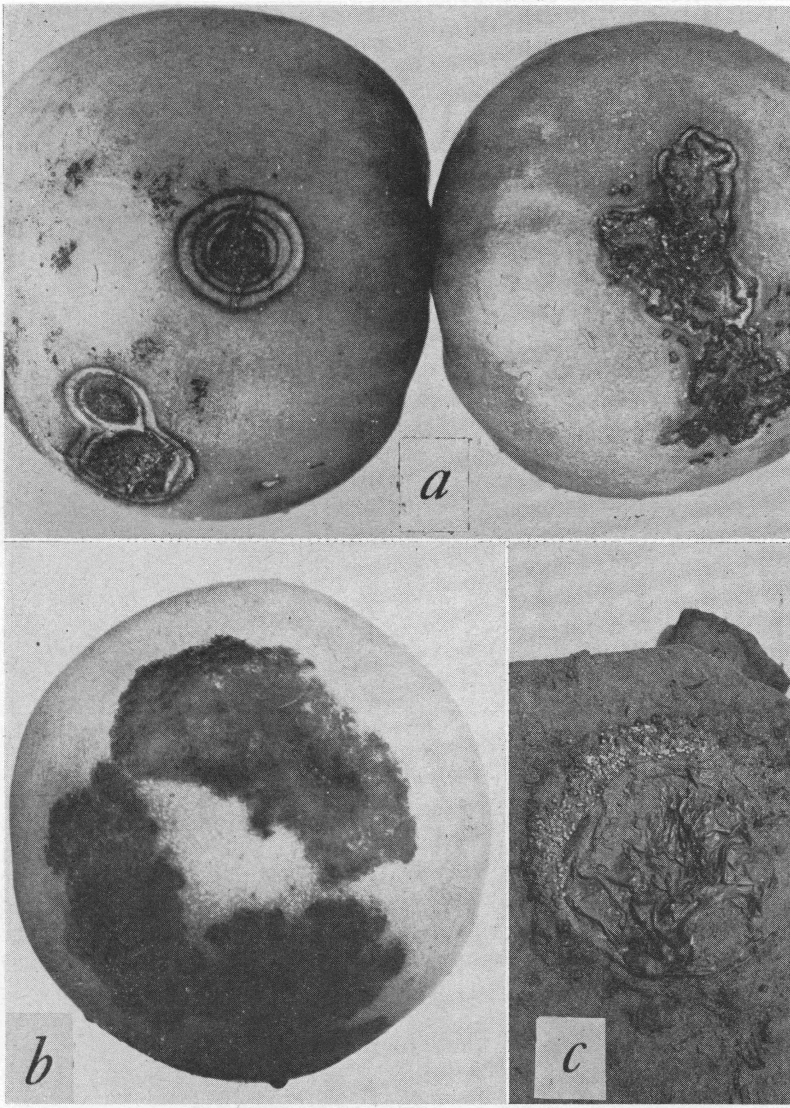

Figure 21. A. Brown and tan rings in sunken cracked spots caused by Rhizoctonia soil rot in two tomato fruits. B. Dark brown areas caused by buckeye rot of tomato. C. Block of sandy soil on which a tomato fruit rotted completely with southern blight, leaving only the peel and a ring of sclerotia of the causal fungus on the soil.

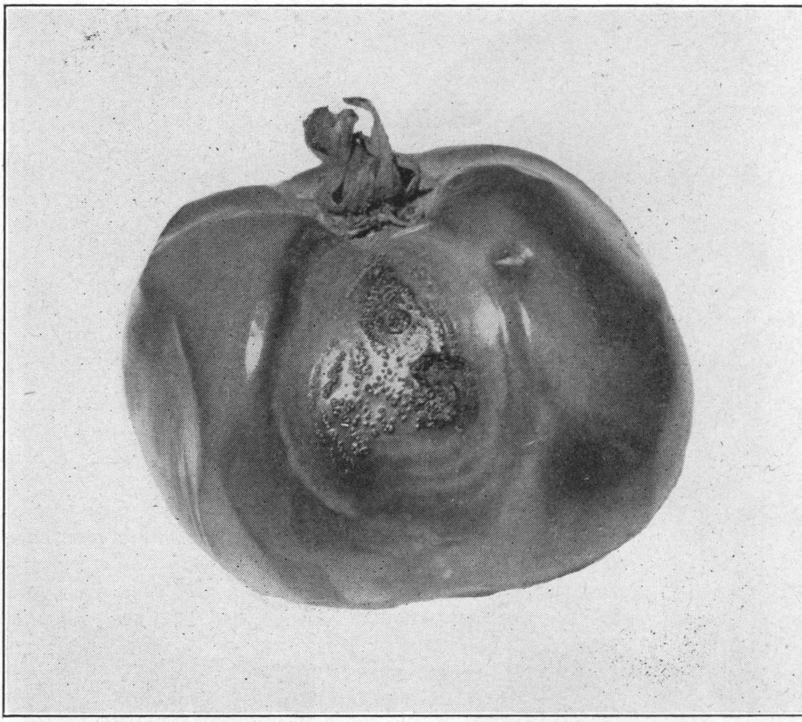

Figure 22. Phoma rot of tomato fruit showing sunken area with the black spore-bearing pimples of the causal fungus.

of the causal fungus (Figure 22). The fungus enters fruits through stem cracks or other wounds usually near the stem end. Brown to black spots in leaves and dark streaks and blotches in the epidermis of stems are other symptoms. Phoma rot is very destructive to fruits in transit and storage (58). Rotation of crops, use of certified seed, and spraying with copper compounds (Table 3) help to control Phoma rot. Careful grading at packing sheds is necessary to eliminate infected fruits.

Rhizopus Rot

Rhizopus rot is a watery soft decay of ripening fruits in warm rainy weather. It is caused by the mold, *Rhizopus nigricans*, that enters through wounds. The spots are blister-like areas at first but they enlarge rapidly and may rot the fruit within one day. Decaying fruits bear large masses of white or grayish mold with black dots of this bread-mold fungus that rots many kinds of fruits and vegetables. Rhizopus rot destroys tomatoes in transit and storage. This rot is controlled by avoiding wounds in handling the fruits and by maintaining well ventilated, cool storage (42).

Bacterial Soft Rot

A large percentage of the tomatoes that ripen during hot weather, as in East Texas fields in July, are spoiled by bacterial soft rot. This is the main cause of the rotting of green and pink fruits that are spread

Figure 23. Sack-rot disease (water-bags) of tomato fruits caused by bacteria. These fruits have rain-splashed sand on their surfaces.

out in the shade to ripen for canneries. Slightly sunken water-soaked spots with distinct margins develop in the surface of the fruits. A water-soaked margin remains after the center of the rotting area becomes opaque. In 3 to 10 days, the interior of the fruit decomposes into a watery, bad-smelling mass. When the peel is not cracked or injured by worms, the symptom of sack rot or water bag appears (Figure 23).

Bacterial soft rot is caused by *Bacillus aroideae* that also rots many other species of fruits and vegetables (42, 71). The bacteria enter the fruits mainly through stink bug punctures, growth cracks, and worm holes. Green and brown stink bugs and leaf-footed plant bugs are abundant in fields in East Texas. Fruits that are inoculated in fields continue to rot in transit and storage, where the bacteria enter other fruits through injuries in the peel. This disease is minimized by dusts or sprays, careful handling of fruits to avoid even sand scratches, and removal of rotting fruits.

ABNORMALITIES DUE TO UNFAVORABLE ENVIRONMENTAL CONDITIONS

Watersoaked Leaf Spots

Water droplets that are moving rapidly in a wind or from a garden hose may be forced inside tomato leaflets, causing watersoaked spots. Such spots may disappear in dry weather, or they may become brown dead spots. Watersoaked leaf spots can be avoided in hot beds and cold frames by watering the plants carefully and by covering them with sheets before thunderstorms (30).

Growth Cracks

Different symptoms of growth cracks result when the fruit swells or grows inside faster than the peel can grow or stretch, causing the cuticle to break as fine lines or deep cracks in the surface tissues of the fruit.

Stem cracks: Most varieties of tomato fruits crack in various ways especially when abundant rain follows periods of drouth as the fruits are attaining mature size and ripening (Figure 24, A, B and 20 B). Such fruits usually are cracked when they become red or pink in fields. As a result farmers hasten to pick green-wrap tomatoes before they crack. Marglobe and Rutgers fruits usually show radiate cracks in the stem ends (stem cracks) whereas Louisiana Red usually shows concentric cracks (10). Radiate cracks are 1/32 to 1/4 inch deep, 1/16 to 1/2 inch wide, and one-eighth to three inches long.

Blossom-end cracks: Wide cracks one to four inches long may cross the blossom-end of fruits without reaching the stem-ends. Trip-L-Crop variety showed this symptom.

Cuticle cracks: When hot weather follows abundant rains (from about June 20 to July 15 in East Texas), numerous cracks may form in the cuticle of fruit. At first they are clear and difficult to see but when the cracks deepen enough to permit drying of the epidermal cells, the cracks become black (Figure 24, C, D). As drying continues, areas one-eighth to one-half inch wide in the cracked cuticle become sunken and black, which almost spoils the market value of the fruits (84).

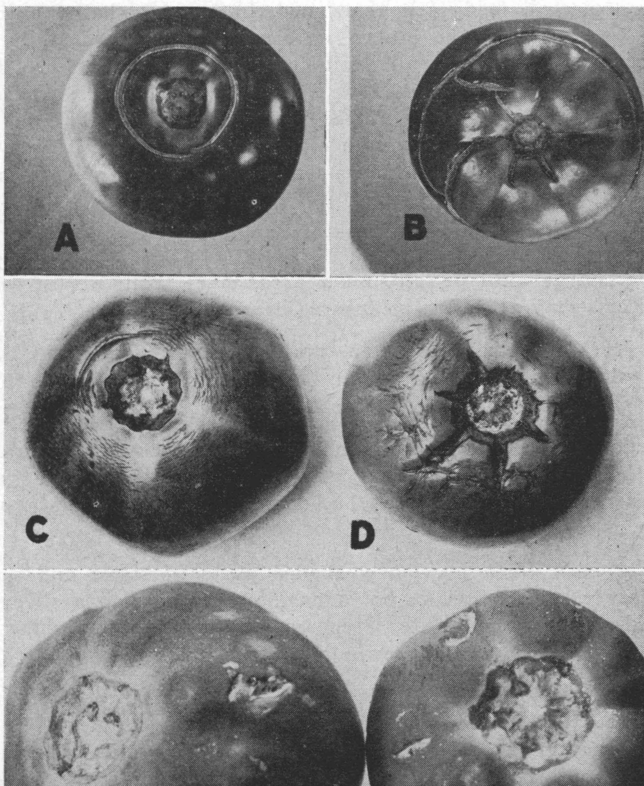

Figure 24. A. Ring crack in a tomato fruit. B. Tomato fruit with a ring crack and radiate stem cracks. C. Blackened cuticle cracks and a ring crack in peel of a tomato fruit. D. Black cuticle cracks and radiate stem cracks in a tomato fruit. E. Yellow bruised spots and broken spots in tomato fruits caused by hail stones.

Hail Injury

Small hail stones cause white, yellow, or brown sunken bruises one-eighth to one-half inch wide in the surface of tomato fruits. Larger hail stones break the peel and make deep holes in the sides of fruits (Figure 24, E). When hail breaks the stems so extensively that a profitable crop cannot be expected, fields are abandoned. In a single hail storm, all of the large tomatoes may be broken or blemished and spoiled for use as green-wrap fruits. Many small fruits may also be bruised by hail and the injury may persist for a few weeks. Ragged, papery margins on irregular cavities in the sides of the fruits distinguish old hail injuries from worm holes. Large fruits with only one or a few hail spots may be usable as ripe tomatoes but a serious amount of decay may be expected.

Various Types of Sun Injury

Sunburn: Large white or tan sunken areas make fruits almost worthless. Various molds may grow on the injured areas.

Brown freckles: Slightly sunken, brown freckles develop in the sides of ripe fruits exposed to the sun in July. The freckles are 1/16 to 1/4 inch wide in the peel of pink or ripe fruits.

Sun yellowing: Yellowing of the sunny side of green tomato fruits changes their appearance so that graders discard them. The yellowing accelerates ripening of the fruits but does not decrease their appearance or quality as ripe fruits.

Sun silvering: When previously shaded parts of stems and the lower sides of leaves are exposed to hot sunshine, they develop a silvery sheen as the epidermis becomes white. Stems can endure direct sunshine without injury only when they have grown in the sunshine.

Control of sun injury: Varieties such as Marglobe and Rutgers have heavy foliage that shades their fruits well. Tomatoes should be pruned only twice and their tops left on them so that they can shade the fruit. The plants should be sprayed or dusted to prevent defoliation by diseases and insect pests. Pickers should not turn the plants over and leave the previously shaded side exposed to the sunshine.

Blossom-end Rot

Blossom-end rot sometimes spoils half of the fruit in tomato fields (Table 4). The first external symptoms of blossom-end rot appear as abnormally dark green, watersoaked, or tan spots in the peel of the blossom-end (Figure 25, A, B, C). At first these spots are only in the peel but soon they enlarge and become sunken, brown, and leathery with distinct margins (Figure 27, right). These spots remain dry, shallow, and sunken unless they are invaded by molds that cover them with black or pink spores, or by soft-rot bacteria. The Buckeye State variety is so susceptible that the lower half or two-thirds of each fruit (even fruits only one-half to one inch in diameter) may be shriveled by blossom-end rot. Mild blossom-end rot may escape detection in the grading process and become more severe in transit and storage (42).

Causes of blossom-end rot: This abnormality develops when drouth follows a period of rainy weather while the green fruits are maturing (79). Blossom-end rot also develops in long periods of abundant rains. In drouths, plants transfer water from the fruits to leaves and this may kill some cells in the fruits. Continuous dry weather with enough soil moisture for slow growth of plants makes them resistant to blossom-end rot until rains appear. Nitrogenous fertilizers tend to increase the susceptibility of tomatoes to blossom-end rot especially if the soil is wet enough to stimulate development of succulent tissues with low resistance against drouth. The common practice of cutting off the tomato roots in cultivation decreases the absorption of water and fertilizer from the soil and may increase damage from blossom-end rot.

Control: Marglobe and Pritchard varieties are resistant to blossom-end rot while Rutgers is very susceptible. Sufficient calcium and phosphorus are needed to give to tomato plants their normal resistance to blossom-end rot (36, 41, 52, 79). Hence, only complete fertilizers containing superphosphate should be used for tomatoes, including the side-dressings. Enough superphosphate dissolves quickly in the water in the soil to provide tomatoes with the calcium and phosphorus that they require. Uniformity of water supply is improved by controlling weeds and keeping the soil crust broken between the tomato rows in the main growing and harvest seasons. Proper irrigation controls blossom-end rot in the Winter Garden area.

Puff or Pockets

Puffing of green tomatoes causes a large annual loss of the crop. Large air spaces under sunken areas in the fruit wall are symptoms of puff or "pop" (Figure 26). Badly affected fruits are partly angular in shape with flattened sides and a hollow "feel," and graders discard them. Puffed fruits are light in weight and their sides yield to slight pressure. When cut open, large cavities are noticed where tissues and seeds have failed to develop. When fruits ripen on plants, placental walls thicken and small cavities fill with juice, tending to obscure mild forms of puffing.

Poor pollination is a main cause of puffing. Fruits that begin growth in rainy weather may get only enough pollen to stimulate growth. One pollen grain is needed for each tomato seed, and when pollination is incomplete, whole locules may be seedless and grow hollow (16, 69). Hot dry weather can cause imperfect pollination of tomato flowers resulting in puffing. Other causes of puffing are unbalanced fertilizers, excess water in the soil, and temperatures that are too warm or too cool for best growth (16). Cherry tomatoes show little or no puffing while large globe varieties show the abnormality most frequently. Oblate varieties show

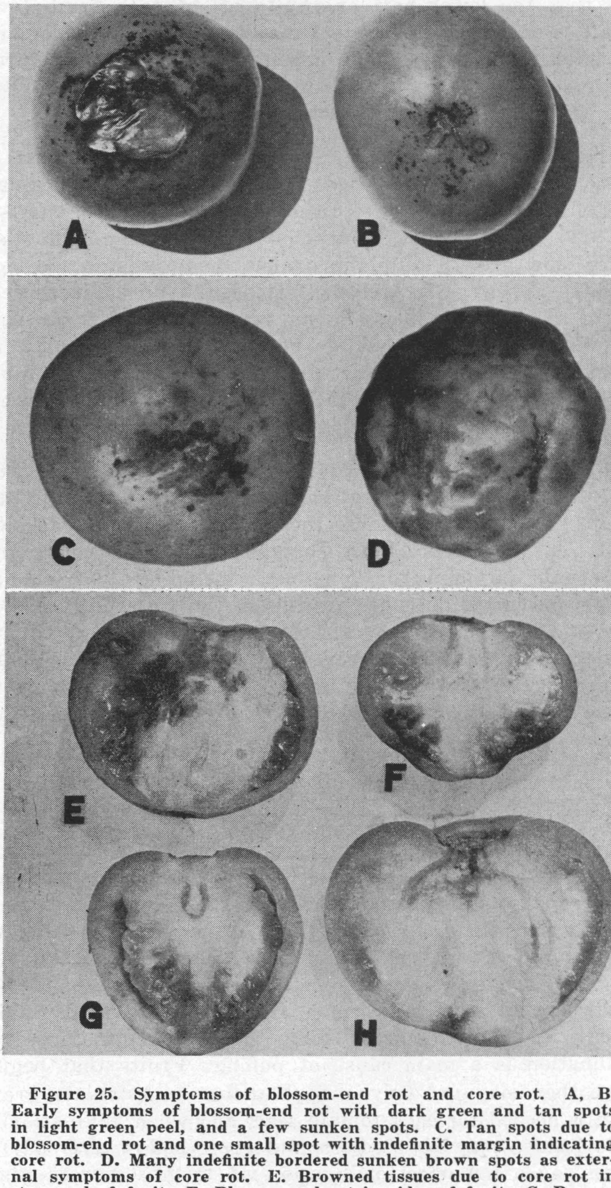

Figure 25. Symptoms of blossom-end rot and core rot. A, B. Early symptoms of blossom-end rot with dark green and tan spots in light green peel, and a few sunken spots. C. Tan spots due to blossom-end rot and one small spot with indefinite margin indicating core rot. D. Many indefinite bordered sunken brown spots as external symptoms of core rot. E. Browned tissues due to core rot in stem end of fruit. F. Blossom-end rot in sides of fruit. G. Browning of some tissues in fruit wall extending into deeper tissues near blossom-end. H. Browning of water tubes that extend inward from stem, and also early stage of blossom-end rot. Parts C to H were published in Phytopathology (79).

some resistance to puffing. Susceptibility to puffing is hereditary and it is regarded as a genetic weakness.

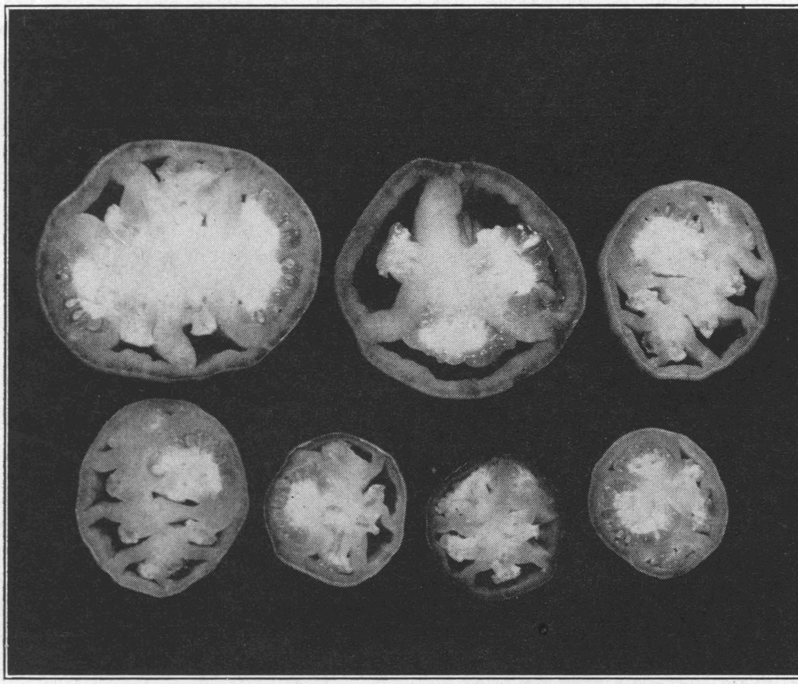

Figure 26. Cross-sections of puffed tomatoes.

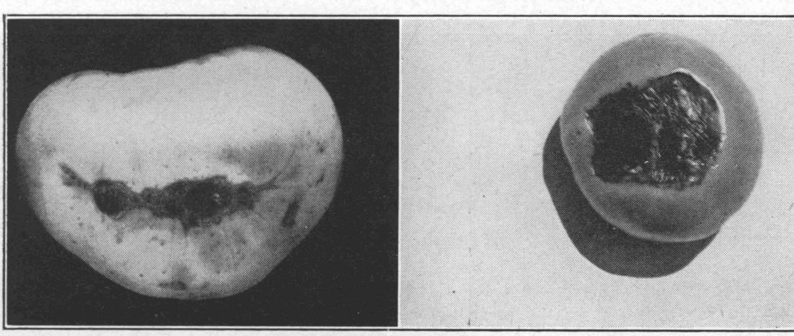

Figure 27. Catface (left) and blossom-end rot (right) of tomato fruits.

Internal Browning and Core Rot

When tomato fruits are cut open, browning of the water-conducting tissues is often seen to extend inward from the stem (Figure 25, H); similar discoloring of tissues may occur in the outer wall of the fruit (Figure 25, G, and 29), and in the core (Figure 28, right). Brown dots mark the ends of the browned vascular bundles in the white abscission disk at the stem end. In severe cases, indefinite-margined brown areas and sunken spots in the peel are symptoms of core rot or internal browning (Figure 25, C, D). Large green tomato fruits may show indistinct brown blotches in the peel, which in cross-section show browned water-conducting tissues in the outer wall (Figure 29).

These symptoms probably have the same cause as blossom-end rot. The browned tissues in the core may become hollow and black. In some cases, bacteria may decompose the affected tissues (Figure 28, left). Core rot and internal browning often are associated with puffed fruits, as was found in Rutgers and Stokesdale varieties. Core rot has been associated with periods of abundant rain in May and June (79).

Catface

Instead of showing only a small spot from the pistil scar, the blossom-end of fruits may show corky brown lines one-fourth to two inches in length, deep holes, or prominent brown corky irregular or rough areas (Figure 27, left). Some fruits are lobed and greatly distorted by catface especially when it is associated with internal fasciation. Small, smooth catface spots and lines are almost characteristic of large fruits of 5x5-lug size and larger, and they do not spoil the fruit for market. Prominent catface spots, especially those with deep holes, lower the market value of the fruit.

Some tomato varieties such as Rutgers and Gulf State Market have many catface fruits, as a genetic weakness, while Marglobe is resistant

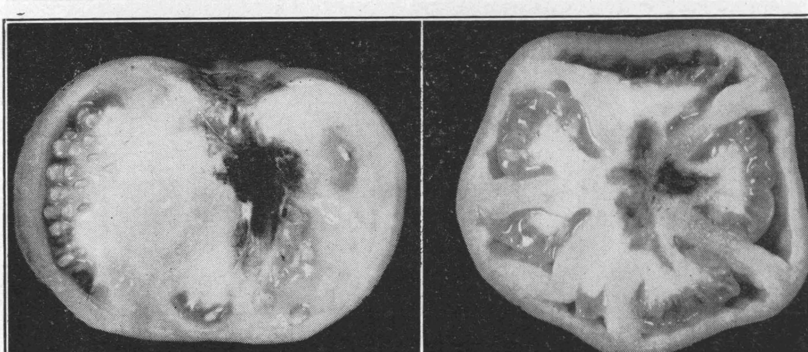

Figure 28. Core rot of tomato fruits. Left: Cavity rotted by bacteria. Right: Tissues browned by core rot that resembles blossom-end rot.

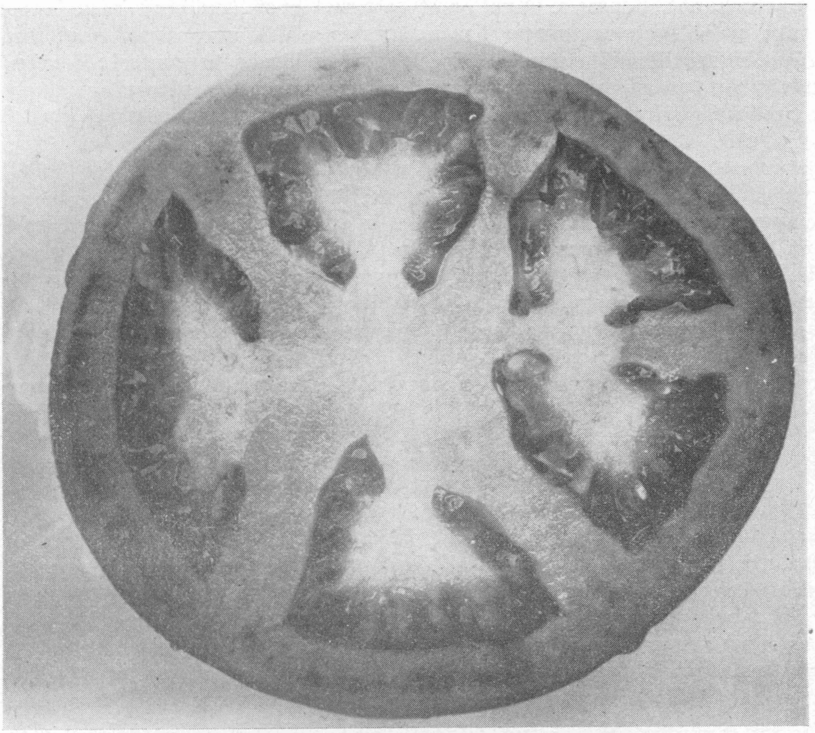

Figure 29. Groups of browned tissues in outer wall of tomato fruit, probably a symptom of one form of core rot.

to this abnormality (Table 4). Catface usually is most injurious to the two lower trusses of early fruit that mature in East Texas late in May and early in June. The first fruits formed by each plant are likely to have catface. Fruits that set and grow in dry cool weather in April and May are likely to develop catface or misshapen fruits (68).

Flower Shedding

Failure of pollination or fertilization of flowers in periods of abundant rains and hot drouths results in flower shedding. Due to improper development of flower parts, ordinary varieties of tomatoes do not set many fruits in hot dry weather. However, the Summerset and Porter varieties have the capacity to set fruit under such conditions. Too much nitrogen fertilizer in wet soil stimulates excess growth of stems from which the flowers are likely to fall off. Improper balance between nitrogen and carbohydrates within the plant may prevent fruit setting. Strong wind and blowing sand also may cause flower shedding.

Early blight, Septoria blight, and bacterial spot (nailhead rust) commonly make spots on young flower trusses which may cause shedding. This abnormality it minimized by sprays or dusts to control diseases, and by proper cultivation and fertilization, as healthy plants are likely to produce plenty of flowers in weather that favors fruit setting.

Leaf Roll

Upward rolling of the upper leaflets is the only symptom of leaf roll. Hot dry weather causes this symptom to develop in Blair Forcing and Lloyd Forcing varieties of tomatoes growing in fields (28). This physiological rolling of many upper leaflets is due to a genetic weakness in some varieties, and does not decrease their value in greenhouses. A similar milder abnormality consists of rolling of large bottom leaflets that touch hot dry soil, but apparently this does not injure the plants of common commercial varieties.

Short Internode Abnormality

Tomato plants affected with this trouble have short internodes and a very compact bunchy appearance with rigidly upright stems. Such plants are late in producing fruits and the fruits have relatively few seeds. Affected plants may have a small narrow opening in the top of the stem. Seeds from seven of the abnormal plants were tested in 1946, and six of the selections produced 55 all normal plants while the other selection had two of its three plants with the short internode abnormality. This abnormality has been identified only in the Rutgers variety and is serious in some areas. It may be due to unfavorable growing conditions.

Root Drowning

Loss of tomato plants due to root drowning was extensive in East Texas in the rainy springs of 1944, 1945, and 1946 (80). The tap roots of the plants became gray or black and decayed with an offensive odor within one to three days after the soil became saturated (Figure 30, C). The outer cortex of the roots decayed and sloughed off while the woody part of the tap roots and bases of the stems turned black or showed black streaks. Hot sunshine within three hours after flood rains may wilt and kill the top leaves while the lower leaves remain alive, but this is exceptional. Instead, the lower leaves usually turned brown and died. Badly injured plants died, but most of the plants survived by developing new roots in the upper few inches of soil (Figure 30, C). However, later growth of the tops was slow and the plants remained dwarfed (Figure 30, A, D). Purple veins in the leaflets and black streaks in the woody tissues in the lower part of the stem were late-season symptoms of this injury.

Root drowning occurred under the following conditions. Sandy loam soil that is one-half to four feet deep over a tight clay subsoil can absorb a few inches of rain and remain solid enough for cultivation as soon as rains cease. However, rains totaling six inches or more in a few days, and 24 to 36 inches in a spring season, overload the soil with water. Usually a firm crust one-half to four inches thick remains on top while the soil below is thin mud, like quicksand. Mud quickly flows into a post hole dug in such soil. Tamping the surface of such soil for a minute will make water rise to the surface and warns a farmer that cultivation should not be attempted. This condition is especially likely to occur near the base of sandy hills, because excess water soaks into the sandy soil of the hill and sinks to the top of the subsoil along which it flows or seeps slowly to the base of the hill. There the seep-water keeps the soil wet for one to three weeks after rains, even in hot dry weather.

Tomato root drowning probably is due both to suffocation of the roots and to toxic organic chemicals that are produced in warm wet soil. For

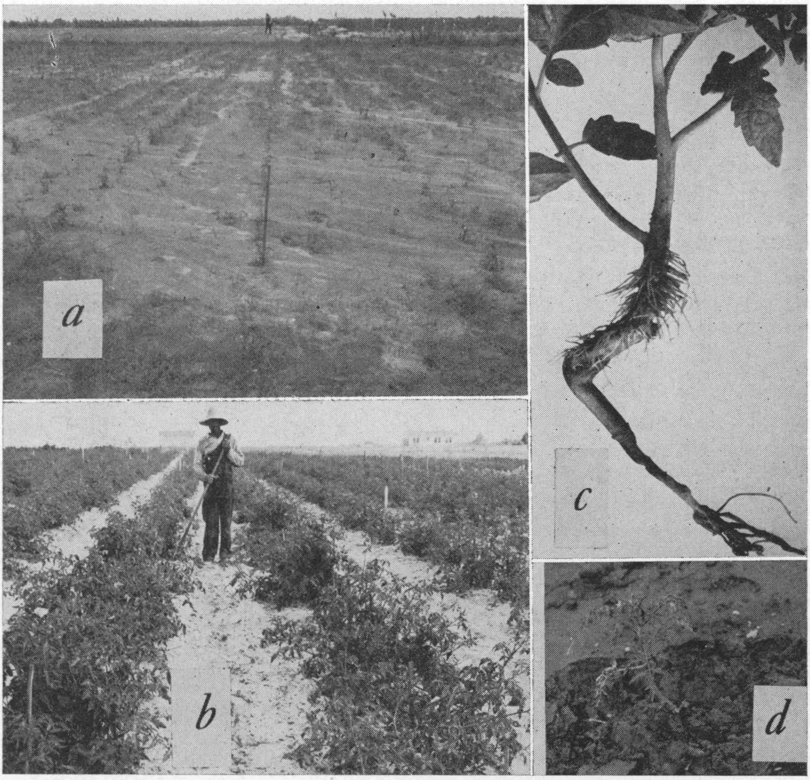

Figure 30. A. Dwarfing of tomato plants caused by drowning and decay of tap roots; sand bars were left by flowing water. B. This field (shown in upper right corner of "A") is about eight feet higher and was photographed on the same day, about six weeks after the six-inch rain; tomato plants grew well in this field. C. Excess water caused drowning of tap root but new crown roots kept this tomato plant alive. D. Sand bar excavated to show tomato plant that was dwarfed by root drowning; it had yellow leaves.

normal growth and continued life, tomato roots require much oxygen, but only low concentrations of oxygen can be expected in muddy sandy-loam soil (3, 14, 33, 34, 66). Excess water excludes air from the soil and favors the development of anaerobic microorganisms.

Control: Well drained land should be selected for tomatoes, but flood rains may saturate some soils where the slope of the subsoil is unknown. In fields that may become too wet, beds 8 to 24 inches high and 8 to 10 feet apart should be built with a plow. The ditches between the rows can be deepened and kept deep with a middle buster before the land becomes muddy. This makes a terrace of each row. Fertilizer should be distributed in the top of the terrace and later the plants should be set so that most of the roots are above the bottom of the ditches. By this method, tomatoes may be grown profitably on land that would be too wet under level or ordinary turning-plow cultivation (82). Where the sandy top soil is only six inches to one foot deep, some farmers plow or dig ditches between the tomato rows in muddy fields to drain the soil and decrease rotting of tomato roots. Drainage tile can be laid in very valuable land to carry away excess water.

Fertilizer Yellowing

Tomato leaves turn light green or yellow and the plants stop growing or even die when excessive amounts of commercial fertilizer (such as 6-10-7 or 5-10-5) are placed in the soil near the roots, especially when the soil is dry (Figure 31). The yellowed leaves turn brown unless the soil is watered abundantly soon enough. Moderately injured plants grow

Figure 31. Yellowing of tomato leaves caused by the use of too much commercial fertilizer in the red clay soil in dry weather.

normally when the soil becomes wet and mild fertilizer injury may not cause yellowing of the leaves. In extreme cases, abundant rain will not enable the plant to recover. Tomato roots often are injured by commercial fertilizer (especially sodium nitrate) distributed close to them, or unmixed in dry soil. In one field so treated, shedding of most of the flowers was the only symptom of injury.

Fertilizer yellowing is avoided by distributing 500 pounds or less of commercial fertilizer per acre in rows before transplanting time and mixing the fertilizer with the soil with an eight-inch buzzard-wing blade set level so that it will not lift the fertilizer out of the furrow. This is easily accomplished by mounting the buzzard-wing blade two inches behind and one inch below the delivery tube of the fertilizer drill. Side-dressing fertilizer should be mixed with the soil not closer than one foot from the tomato rows for the first application, and farther away for later applications. It is safe to use side-dressing fertilizer only when the soil is wet (82).

Mineral Deficiency Symptoms

Tomatoes must receive eleven mineral elements from the soil in order to grow normally (20). Complete commercial fertilizers are usually used to supply three of these (nitrogen, phosphorus, and potassium). Nitrogen deficiency causes yellowish green color of leaves and dwarfing of plants and is common in tomatoes after rain has leached much nitrogen from the soil.

Phosphorus deficiency causes purpling of tomato leaflets, especially the lower sides. It usually is avoided by adding the customary large amounts of phosphate fertilizer to the soil for raising tomatoes. However, phosphorus is removed by plants and lost by percolation and erosion.

Potassium deficiency causes the old leaves to become ashy gray-green with yellowish margins and yellowish-green and brown spots appear between the veins of younger leaflets. Severely affected leaflets become yellow or browned with brown veins and many leaflets die early. The stems are dwarfed and brittle and roots grow poorly and the fruit may ripen unevenly.

Calcium deficiency causes dwarfed, thick woody stems and abnormal roots. The top leaves become yellow while the lower leaves remain green. Affected plants may be slightly wilted. This abnormality is avoided by using plenty of superphosphate in the complete commercial fertilizer.

Iron deficiency affects tomatoes in calcareous (limy) and alkaline soils, causing the young tomato leaflets to become yellow. Stable manure mixed with the soil helps to control this abnormality.

Magnesium deficiency results in light green, yellow, and brown spots between the green veins of tomato leaflets, especially the old ones. Mixing magnesium limestone (dolomite) or other magnesium fertilizer into the soil avoids this abnormality.

Dodder

The yellow and brown thread-like vines on tomato plants are the stems of a parasitic flowering plant called dodder (*Cuscuta indecora*) (86) and perhaps other species (Figure 32). Various species of dodder grow on pepper, lespedeza, and many bushes and weeds. Dodder stems produce

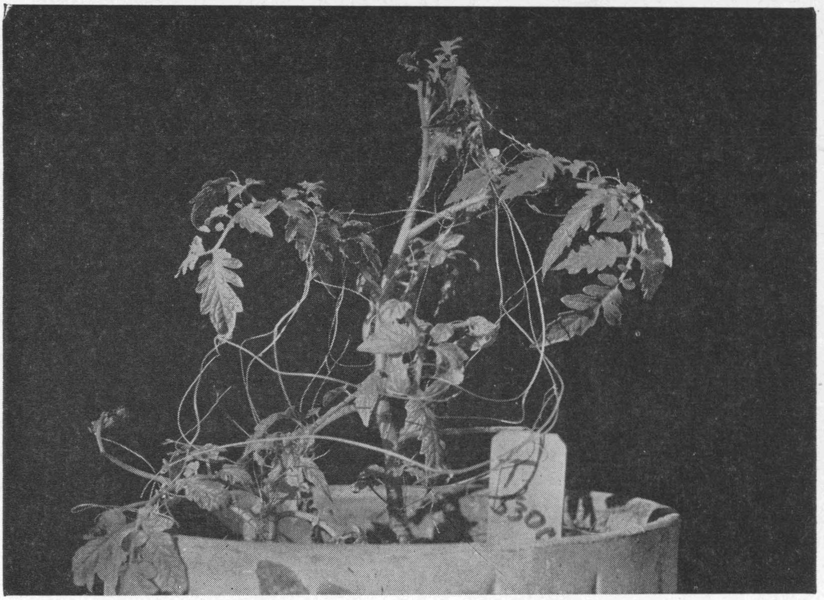

Figure 32. Yellow and brown stems of the dodder plant *(Cuscuta indecora)* **growing on a tomato plant.**

root-like structures that enter tomato stems and leaves from which they take food and water, causing a dwarfing disease. Dodder bears small whitish flowers that produce numerous seeds. Dodder stems grow from one host plant to another in cold frames and fields. Tomato plants with dodder should be destroyed before the dodder spreads to other plants or ripens its seeds (12).

GENERAL METHODS FOR CONTROLLING TOMATO DISEASES

Tomato and other green plants make their food and stored products by combining carbon dioxide from the air with water and minerals from the soil, with the aid of sunlight and the green chlorophyll in the leaves. Production of food and resulting crop profits, therefore, are decreased by any disease that decreases the amount of leaf surface on the plant or the conduction of water and mineral salts from the soil. Profitable production of tomatoes accordingly includes control of diseases in most fields nearly every year. Tomato diseases may be controlled by methods already described specifically for them and with further details given in this general section.

Sanitation

Many tomato parasites survive from one season to the next in dead plants, so the remains of the crop should be buried by deep plowing as soon as possible after harvesting. Care should be taken to avoid the movement of soil from infested fields to other fields on machinery, animals, or run-off water. Weeds should be controlled, not only because of competition with crops, but also because many viruses and the insects that carry them live on certain weed hosts.

Crop Rotation

Crop rotation involves santitation because properly rotated fields do not contain old tomato stems and roots. Root-knot nematodes and the fungi that cause wilts and southern blight can live in the soil for a few years or longer, especially where weeds are allowed to grow. Hence, tomato crops should not be planted oftener than once in five years in the same field. Although a tomato crop may show little damage from diseases in one season, continuing tomatoes in the same field for an additional year may help the parasites to multiply so abundantly in the soil that the field would be worthless for tomatoes for the next several years. Tomatoes are only one of the crops on well managed farms, so desirable

Table 2. Soil-inhabiting parasites causing diseases of farm crops, their main hosts, and resistant crops

Name of disease	Name of casual parasite	Host crops	Resistant crops
Nematode root knot	*Heterodera marioni*	Tomato, pepper, melons, peach, vegetables	*Crotalaria spectabilis,* sorghum, velvet bean
Nematode dwarfing	*Pratylenchus pratensis*	Corn, oats, and many other crops (50)	Late-planted, hot weather crops
Southern blight	*Sclerotium rolfsii*	Peanuts, tomatoes, peppers, vegetables	Cereals and grasses when planted in cool weather
Stem rot	*Sclerotinia sclerotiorum*	Tomato, potato, sunflower (74)	Cereal and grass crops
Bacterial wilt	*Bacterium solanacearum*	Tomato, potato, pepper, egg-plant, tobacco	Other crops
Verticillium wilt	*Verticillium albo-atrum*	Tomato, cotton, stone fruits	Cereal and grass crops
Tomato wilt	*Fusarium oxysporum f. lycopersici*	Tomato	Any other crop
Cabbage yellows	*Fusarium oxysporum f. conglutinans*	Cabbage, collards, cauliflower, turnip	Unrelated crops
Cotton wilt	*Fusarium oxysporum f. vasinfectum*	Cotton	Any other crop
Cowpea wilt	*Fusarium oxysporum f. tracheiphilum*	Cowpeas	Any other crop
Stem wilt or rot	*Fusarium oxysporum f. batatas*	Sweet potato (48)	Any other crop
Watermelon wilt	*Fusarium oxysporum f. niveum*	Watermelon, squash, cantaloupe, cucumber	Any other crop
Ashy stem blight and charcoal rot	*Macrophomina phaseoli* (*Sclerotium bataticola*)	Corn, sorghum, cowpea, bean, crotalaria, melons (88)	Cotton, velvet bean, resistant varieties of sorghum
Root rot	*Phymatotrichum omnivorum*	Cotton, sweet potato, and others (56)	Grass and cereal crops

fields can be selected for tomatoes each year. Carefully-planned crop rotations that decrease plant pests in the soil and provide soil building crops are necessary to maintain farms in profitable production (72). Many old cultivated fields already are infested with one or more of the soil-inhabiting parasites that cause root knot, wilt, and root rot of most farm crops. Control of these pests depends on selection of the right crops and the use of proper rotations. Farmers therefore need to keep a record of the parasites that are seriously abundant in their different fields (Table 2). A field may have two or more of the parasites at the same time, all of which should be identified and only crops that are resistant to them should be planted in the field for several years.

Disease Resistant Varieties

Diseases are best controlled by planting crops that are immune or resistant to them, and plant breeders are working successfully to develop such crops. Tomato varieties such as Marglobe and Rutgers resist Fusarium wilt, and new wilt-immune hybrids soon will be available. No commercially desirable tomato varieties are known to have valuable resistance to southern blight, bacterial wilt, or root knot.

Spraying and Dusting

Certain fungi, bacteria, and worms commonly damage or destroy tomato leaves and fruits. These pests increases in abundance in tomato fields so crop rotation helps to control them. However, they may be controlled more completely by sprays and dusts. Otherwise, disease and insect pests may decrease the yield of marketable tomatoes 25 to 100 percent in most unsprayed fields in nearly every year. Largest losses occur in seasons with enough rain to produce large crops of tomatoes.

Bacterial spot (nailhead rust), bacterial canker, bacterial speck, early blight, Septoria blight, and late blight are the main diseases to be controlled by sprays and dusts (81). Young plants in hot beds and cold frames should be protected with fungicides. It is easy and inexpensive to spray the young, closely spaced plants with copper chemicals to control these diseases before they become serious. Table 3 offers a choice of spray materials by their trade names. Any one of the first eight of the listed chemicals can be used at the rate of one ounce per 2 3/4 gallons of water in a hand sprayer.

Insect pests: Fruit worms, Colorado potato bettles (potato bugs), horn worms, blister beetles, garden fleahoppers, flea beetles, suck flies, aphids, and stink bugs are the main insect pests of tomatoes. The chewing insects are controlled by sprays or dusts containing calcium arsenate or lead arsenate. Blister beetles usually are repelled by calcium arsenate and they do not seriously injure sprayed fields. However, dusts or sprays with Kryocide or Cryolite are preferable for controlling blister beetles. Pyrocide 10 percent dust controls garden flea hoppers and green stink bugs fairly effectively. Black Leaf "40" spray controls "plant lice."

Spraying: Profitable control of diseases of leaves and fruits depends on following three important rules: (a) use the right chemicals, (b) use them soon enough and often enough, and (c) apply them thoroughly. Unsuccessful control of pests commonly results from failure to follow all three rules. Sprays are more effective than dusts when both are properly applied, and power sprayers are very profitable despite their cost and expense of operation. However, three-gallon sprayers are inefficient. The following precautions should be taken in controlling tomato diseases and insects.

Fungicides (described in Table 3) should be kept thoroughly mixed while they are being applied. Power sprayers have agitators that keep the spray materials well mixed. If the materials are not kept mixed, they will settle to the bottom of the tank or barrel and the spray will be too weak on part of the plants and too strong on the rest.

Spraying tomatoes in fields should start as soon as the plants show new growth in their tops. It is costly and hazardous to let any pest become established and abundant in a tomato field (Table 4). Sprays cannot cure diseased plants but they can help to keep them healthy.

All surfaces of the stems, leaves, and fruits should be covered by the sprays. Only thorough spraying gives good control of pests. This requires 50 to 200 gallons of spray liquid per acre, depending mainly on the size of the plants. It is better to spray the plants well while they are small so that fewer sprays will be necessary when the plants become large.

When sprays are applied at pressures of 150 to 200 pounds, the droplets are finest and they cover the plants much quicker, more thoroughly, and with less chemical than when the sprays are applied at low pressures (10 to 75 pounds).

Good control of fruit worms depends on applying the first spray when the first fruits are only one-fourth inch in diameter as the eggs usually hatch at this time. Each new flower truss must be sprayed to keep the worms out of the fruit. Sprays should be applied, therefore, about once a week until diseases have been controlled (Table 3). Lead arsenate or calcium arsenate should be used in the early sprays to control fruit worms and omitted from the later sprays (within 10 days before fruit picking starts and later).

To control diseases in rainy spring seasons, sprays should be applied every week from late March to early June. Protection is obtained only when the fungicide is on the plants *before* rains occur. When rain washes off the spray materials, the plants should be sprayed again as soon as possible. When drouths are so severe that there is no dew on the leaves, sprayings can be spaced 10 to 14 days apart depending on the need for worm control. In a dry season, three sprayings may protect a field from diseases whereas seven or more sprayings would be needed in a rainy season. Omitting even one spray in a rainy season may permit excessive damage from diseases (Table 4). Early infection of tomato plants results in greater loss than later infections. Early infestations with the nailhead-rust bacteria, for example, make it necessary for farmers to replant unsprayed tomato fields with other crops.

In spraying, the mist should be applied *sidewise* against the plants and also against the wind. Move the spray nozzle up and down beside the plant, and against and over each plant for a few seconds in order to cover the entire plant. Spraying downward onto a plant is a waste of material and time because the spray reaches only the tops of the leaves where the pests are usually absent, and where the first rain will wash off the material. Pests usually attack the lower sides of the leaves which, therefore, should be covered by the spray material.

Standard spray formula: 2 pounds of Spraycop mixed with 2 pounds of calcium arsenate in 50 gallons of water. Other copper chemicals, as listed in Table 3, may be used instead of Spraycop.

Some farmers prefer to use the 2 3/4-gallon hand sprayers, and they can be used best by the following method, remembering that useful spraying will require one to four barrelsfuls of water per acre of tomatoes: Fill the sprayer with water to the desired level about 4 inches from the top, pour the water into a 12-quart pail, mark the top of the water level on the pail with a pencil, measure one zinc-fruit-jar lid full of Copper-A Compound (or some other fungicide, see Table 3) into the water and add the same amount of lead arsenate. Stir the two powders into the water thoroughly with a paddle and pour this mixture through a cloth into the sprayer. Shake the sprayer every time it is pumped up.

Table 3. Concentrations of fungicidal sprays for tomatoes (a)

Copper fungicide (trade name) (b)	For plants up to 5 in. tall; tablespoonfuls for 2¾ gal. of water	For plants 6 in. or more tall	
		Tablespoonfuls for 2¾ gal. of water	Pounds for 50 gal. of water
Copper-A Compound (45% Cu)	4	6	2
Copper Oxychloride-Sulphate (55% Cu)	4	6	2
Basicop (52% Cu)	4	6	2
Microgel (50% Cu)	4	6	2
Tribasic Copper Sulphate (53% Cu)	4	6	2
Spraycop (29% Cu)	4	6	2
Copper King (about 50% Cu)	4	6	2
Basic Copper Arsenate (42% Cu)	4	6	2
Yellow Cuprocide (80% Cu)	4	6	1
Copper Hydro "40" (26 Cu)	8	12	4
Fungi Bordo (about 12% Cu)	12	18	8
Powdered Bordeaux (about 12% Cu)	12	18	8
Bordow (about 12% Cu)	12	18	8

(a) Any one of these fungicides or an equivalent compound may be used for spraying tomatoes. Also, home-made Bordeaux mixture may be used as described on page 61. To control fruit worms, horn worms, and potato beetles, the spray mixture should also contain lead arsenate or calcium arsenate at the rate of 2 pounds per 50 gallons of water, or 6 tablespoonfuls per 2 3/4 gallons of water (capacity of many small knapsack sprayers); no arsenate should be used after the largest fruits are 1 1/2 inches in diameter.

(b) It was not possible to test all of the chemicals that might be used for this purpose. Listing of these trade names does not constitute a recommendation or preference for them in comparison with any similar chemicals that are not listed. These chemicals contain fixed copper compounds such as basic copper sulphate, copper oxychloride, cuprous oxide, and copper hydroxide.

Preparing Bordeaux mixture: Home-made Bordeaux mixture costs less for chemicals, sticks to tomato leaves and fruits much better than many other fungicides, and is most effective in controlling bacterial spot (nail-head rust). The best quality of Bordeaux is made as follows:

Small amounts of Bordeaux mixture may be made by dissolving 3 teaspoonfuls of copper sulphate in 3 quarts of water in a glass, wooden, or earthenware container. In another container, stir 5 teaspoonfuls of hydrated lime into 1 quart of water. The copper solution is then poured with rapid stirring into the lime water, making one gallon of Bordeaux mixture.

For larger quantities: (a) dissolve 3 pounds of powdered copper sulphate (also known as blue vitriol or bluestone) in 25 gallons of water in a wooden barrel; (b) mix 3 pounds of fresh hydrated lime in 25 gallons of water in another barrel; (c) pour equal numbers of pailsful of the copper sulphate solution and lime suspension together into a third barrel and stir thoroughly. The mixture should be used while fresh and it should be well stirred during use. To control chewing insects such as fruit worms, mix 2 pounds of calcium arsenate or lead arsenate into each 50 gallons of Bordeaux mixture.

If a coarse crystal form of copper sulphate is used, dissolve it first in a few gallons of hot water, or by suspending the bluestone in a burlap bag so that the bottom of the bag touches the top of the water in the barrel and the bluestone will dissolve in a few hours. A convenient method is to make a stock solution of 1 pound of bluestone per gallon of water in a wooden, earthen, or glass container with a lid to prevent evaporation. To use this liquid, stir 3 gallons of this stock solution into 22 gallons of water in the copper-sulphate barrel mentioned above.

To make Bordeaux mixture in a power sprayer, fill the tank about two-thirds full of water, start the agitator, and pour in the right amount of stock copper sulphate solution. Wash the measured amount of dry hydrated lime through the strainer with a stream of water. Calcium arsenate is added last by washing it through the screen also, in filling the tank.

Bordeaux mixture deteriorates after it is mixed. Only the amount to be used in one day should be made at one time. Home-made Bordeaux mixture costs only about $1.80 for chemicals per 100 gallons, and it is more effective in controlling pests than the dry ready-made Bordeaux mixture that costs about $3.00 for enough of the powder to make 100 gallons of Bordeaux spray.

Dusting: Many farmers have dusted tomatoes profitably with a copper-calcium arsenate dust for several years, applying the dust to the plants in the hot bed, cold frame, and field. Dusting with a power machine ordinarily is more effective than spraying with a hand sprayer. Machine dusting is rapid, fairly effective, and low in labor cost in contrast to hand spraying that is slow, high in labor cost, and commonly ineffective because too small an amount of liquid is used per acre. Although dusting costs more for chemicals, the cost of labor is less than for spraying.

The fungicidal dust should be blown against all parts of the tomato plants and also against the wind. If there is too much wind, an excessive amount of dust will be wasted. Usually plants are dusted when there is little or no wind even if this requires dusting at night. Because tomato plants are hairy, the presence of dew is unnessary for dusting effectively, but dew helps to stick the dust onto plants. Most dusting is done early in the morning. Success in dusting depends much on finding windless hours for work without waiting longer than a week between dust applications. Other rules for dusting are the same as for spraying.

White Diamond No. 63 Vegetable Dust, Du Pont Potato Dust, Potato Copar, C-O-C-S Dust, and Chipman C. H.-C. Dust are valuable brands for tomatoes. The following formula for a home-made dust also is satisfactory: 2 1/2 pounds of Copper-A Compound, 4 pounds of calcium arsenate, and 13 1/2 pounds of Pyrax ABB. Loomkill talc may be substituted for the Pyrax ABB, or dusting sulphur may be used if a less expensive carrier is not available. Any one of the first eight copper compounds listed first in Table 3 may be used in place of the Copper-A Compound in a tomato dust. In mixing, put the three dusts into a large can such as a calcium-arsenate drum, also place a large piece of tangled wire or several rocks in the drum to insure thorough mixing, fasten the lid tightly, and roll the drum end-over-end and shake it sidewise for five minutes.

Benefits: Protecting tomatoes from diseases and insects is an essential part of crop production, the same as fertilization and cultivation of the crop. Unsprayed tomato fields often show losses or only small profits, especially in rainy seasons, because pests become numerous and damage or spoil the plants and blemish the fruits. Fruit worms are likely to be very numerous in dry seasons. When spraying or dusting of tomatoes is omitted, there is usually but little marketable fruit.

For a rainy season, seven sprays on a field would require about 600 gallons of liquid per acre and would cost about $9.00 for the Copper-A Compound and calcium arsenate used (Table 4). Labor is the main expense in spraying tomatoes; this item would cost about $30 per acre with a power sprayer and much more with a hand sprayer properly used. Spraying one acre of tomatoes with an ordinary 2 3/4-gallon sprayer requires 5 to 10 man-hours of hard labor for each satisfactory application. On account of the time involved, the spray may be too late on most of the crop for maximum effectiveness in controlling pests. In contrast, seven applications of dust per acre would require about 150 pounds of No. 63 dust costing about $15; but the cost for labor would be only about $5.00, as one man can dust an acre of tomatoes with a hand duster in one to two hours. Dusting is faster, more economical, and more effective with engine-driven dusters.

Protecting tomatoes from pests on the leaves and fruits avoids the loss of the cost of fertilizer, seedlings, and labor, such as is commonly experienced in unprotected fields. The value of the marketable fruit may be increased about $100 per acre or more when seasonal and market conditions are favorable, and when good fields of tomatoes produce gross incomes of $200 to $1,000 per acre. An increasingly large percentage of tomato farmers, therefore, have included spraying or dusting as a regular part of their method of raising tomatoes (Table 4).

Table 4. Control of bacterial spot of tomato by copper sprays; Rutgers variety, Jacksonville, 1946

Spray Material (a)	Number of		Marketable fruit			Bacterial spot	
	Plants	Rows (b)	Pounds picked	Pounds per acre (c)	Percent increase over checks	Number of spotted fruits per plant	Percent of checks
Calcium arsenate	405	6	555	6,820	0	6.67	100
Copper-A Compound	277	4	771	13,854	103	1.93	29
Microgel	288	4	770	13,311	95	1.67	25
Spraycop	275	4	708	12,813	88	.97	15
Bordeaux 3-3-50	270	4	681	12,555	84	1.09	16
Basicop	651	10	1,554	11,882	74	3.29	49
No. 63 Dust (4% Cu)	286	4	549	9,558	40	2.91	44
Zerlate (d)	281	4	541	9,582	40	4.61	69
Dithane (e)	285	4	494	8,627	26	4.68	70

a. All rows were sprayed or dusted with calcium arsenate plus the fungicides listed April 27, May 4, 16, and 24, and June 1 and 13. Omitting an application of fungicides from May 5 to 15 in very rainy weather permitted bacterial spot to become very destructive. There was a total of 10.96 inches of rain in May. Calcium arsenate is not a fungicide; the six rows sprayed with it alone are the checks.

b. The bacteria that cause bacterial spot were spread naturally by rain from the check rows and those sprayed with Dithane and Zerlate (no copper) onto the copper-sprayed rows, making control of bacterial spot disease very difficult and incomplete on the latter. The disease would have been controlled better if all of the rows had been sprayed with copper. Bacterial spot would probably have damaged the check rows worse if none of the rows had been sprayed with copper. In this test, spread of bacteria from the rows without copper sprays made control especially difficult on all of the rows treated with Copper-A Compound and No. 63 dust, 8/10 of the rows sprayed with Basicop, and half of the rows sprayed with Microgel, Spraycop, and Bordeaux 3-3-50. The other two rows sprayed with Bordeaux 3-3-50 remained almost free from bacterial spot.

c. Fruit yields were decreased by the hail storm on May 11 that spoiled an average of 1.4 fruits per plant. Averages of 0.46 fruits per plant had blossom-end rot, and 1.03 fruits per plant had severe catface. For example, 3,018 plants times 0.46 equals 1,388 fruits that were spoiled by blossom-end rot to which the Rutgers variety is susceptible.

d. Zerlate is zinc dimethyl dithiocarbamate.

e. Dithane is disodium ethylene bis-dithiocarbamate. The dithiocarbamates control some other diseases but were ineffective against bacterial spot in this test.

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