

853
Circular 809

UNIVERSITY OF ILLINOIS
AGRICULTURE LIBRARY



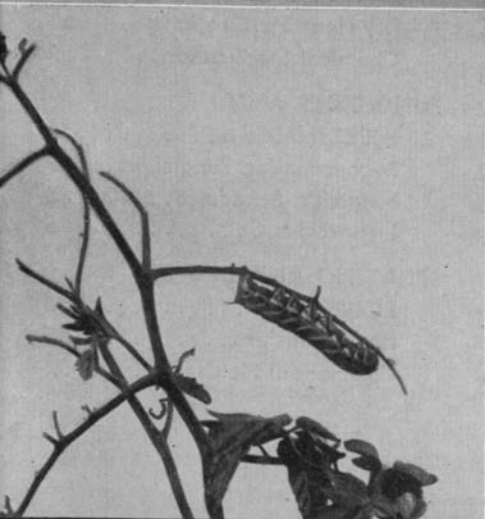
CIRCULATING COPY
AGRICULTURE LIBRARY

TOMATO DISEASES

and

INSECT PESTS

Identification
and Control



LIBRARY
OCT 1 1919

UNIVERSITY OF ILLINOIS · COLLEGE OF AGRICULTURE
Extension Service in Agriculture and Home Economics
in cooperation with ILLINOIS NATURAL HISTORY SURVEY

CONTENTS

	PAGE		PAGE
GENERAL CONTROL			
MEASURES	3	Tomato Fruitworms	39
TOMATO DISEASES	5	Colorado Potato Beetles	41
Damping-Off	5	Garden Slugs	41
Collar Rot	6	Cutworms	42
Hollow Stem	7	Aphids or Plant Lice	43
Mosaic Diseases	7	Whiteflies	44
Streak Diseases	11	Nematodes or Eelworms	44
Bacterial Wilt	12	Symphylids	46
Leaf Roll	13	Mites	46
Bacterial Canker	14	Cloudy Spot of Tomato Fruit	47
Fusarium Wilt	17	SEED TREATMENT	48
Verticillium Wilt	19	Eradicative Seed	
Gray Leaf Spot	20	Treatments	48
Early Blight	21	Protective Seed	
Septoria Leaf Spot	23	Treatments	49
Bacterial Spot	25	SOIL STERILIZATION	50
Leaf Mold	25	Steam Sterilization	51
Late Blight	27	Dry-Heat Sterilization	52
Buckeye Rot	28	Chemical Sterilization	52
Blossom-End Rot	29	FUNGICIDES AND	
Botrytis Fruit Rot	31	INSECTICIDES	53
Anthracnose	32	Recommended Fungicides	53
Minor Fruit Rots	33	Fungicide Schedules	54
Injury from 2,4-D	33	Insecticides	55
TOMATO INSECTS AND		SPRAYING AND DUSTING	
THEIR CONTROL	36	EQUIPMENT	56
Flea Beetles	37	Home Gardens	56
Tomato Hornworms	38	Commercial Fields	57

*(This circular is a revision of Circular 683
of the same title.)*

IR 6e
no. 809
cop. 5

Tomato Diseases and Insect Pests: Identification and Control

By M. B. LINN and W. H. LUCKMANN¹

TOMATOES now rank as one of the most important truck and garden crops in Illinois. Although they are grown largely for market and canning, sizable plantings can be found in practically every home garden.

Like most crops, the tomato is subject to a number of diseases and is attacked by several insects. While not all cause serious losses, there are a number that require definite attention if the crop is to be grown with profit. The information given in this circular is designed for home gardeners, commercial tomato growers, cannery fieldmen, and all others interested in growing tomatoes.

GENERAL CONTROL MEASURES

In addition to specific control measures for specific troubles, there are several general practices that all tomato growers should follow to keep losses from diseases and insects at a minimum:

Select disease-free seed. Saving the seed from only healthy plants and fruit will eliminate many crop losses and much soil contamination that would otherwise occur. Certified seed is of considerable value, for it comes from fields certified by state inspection agencies as being free from bacterial canker and certain other seed-borne diseases.

Treat seed. Regardless of the origin of the seed it should be given an eradicant treatment to insure freedom from disease organisms. Unless the eradicant is one of the very few that serve also as protectants, the seed should be given a protective treatment as well. This will reduce losses from seed decay and damping-off in the seedbed.

Plant on clean soil. Many serious field troubles start from infested soil in the seedbed. Disease-free soil that has not grown

¹ M. B. LINN, Professor of Plant Pathology, and W. H. LUCKMANN, Associate Entomologist, Illinois Natural History Survey.

tomatoes, potatoes, eggplants, okra, or peppers should preferably be used. If this is not possible, the soil should be sterilized.

See that seedbeds are well ventilated. Good ventilation of seedbeds, along with proper spacing and watering of seedlings, will help to prevent seedling diseases.

Use only healthy transplants. Diseases and insects are often introduced into gardens and fields on transplants. If you have to buy plants, insist that they be free from these pests. Do not select plants with spots on the leaves, brown lesions on the stems, or knots on the roots if healthy-appearing plants are available.

Ventilate southern-grown plants as soon as received. If you use southern-grown plants, take a few bundles from each hamper or basket on arrival. This will let the air circulate more freely around all the plants and will help to prevent diseases. Ventilation is especially important when high temperatures or rains delay setting the plants in the field. (If you dip the roots in water, be careful to see that the stems and leaves are kept dry.)

Pay close attention to sanitation. It is much easier, more effective, and less costly to prevent heavy losses from plant pests than it is to control them once they have become established. If you have a small garden where a long rotation is not practical, pull up and destroy all plants that die during the growing season. Do not place these plants on the compost pile, or the disease or insects that killed them may be returned to the garden soil. If you have a large garden or a commercial field, it is advisable to plow under deeply all plant refuse. Also, destroy all weeds within or near the tomato plantings since they often harbor certain diseases and insects during the winter.

Rotate crops. Most growers have learned by experience that planting the same crop on the same land year after year becomes unprofitable. *Once every three years is often enough to plant tomatoes on the same land.* Do not rotate them with potatoes, eggplants, okra, or peppers.

Keep out of field when plants are wet. Don't walk through the field or cultivate it when the plants are wet with dew or rain. This is very important in preventing the spread of such diseases as gray leaf spot, early blight, late blight, and Septoria leaf spot.

Watch for first signs of diseases and insect pests. Apply

proper sprays or dusts promptly. To control diseases satisfactorily, it is usually necessary to apply fungicides *before* the diseases appear.

TOMATO DISEASES

Tomato diseases are caused by fungi, bacteria, viruses, or unfavorable environmental conditions.

Fungi and *bacteria* are microscopic plants which depend upon green plants such as tomatoes for their food. They enter the tomato plant either through wounds or through the unbroken epidermis. Once inside the plants, they may cause spotting of the leaves or fruit; rotting of the stem, fruit, or roots; and often wilting and death of the entire plant. Fungi and bacteria may overwinter on old tomato vines and fruits, on weeds of the tomato family, and on tomato seed.

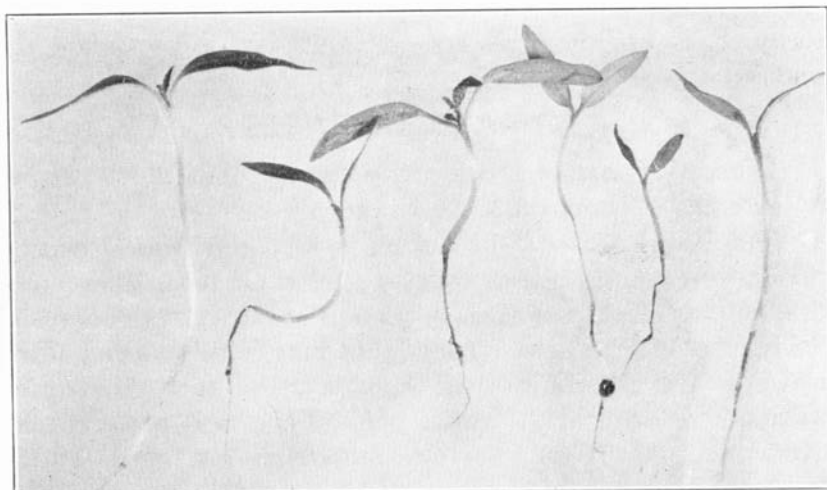
Viruses are infectious substances too small to be seen with the ordinary microscope although their presence can be demonstrated in several ways. Some tomato viruses are highly infectious, that is, easily transmitted from diseased to healthy plants by mere contact. Other viruses are not so easily spread and are transmitted only through the feeding and subsequent plant-to-plant movement of certain insects.

Diseases due to *unfavorable environmental conditions* are sometimes called noninfectious or nonparasitic diseases because they do not spread from one plant to another. Some of the conditions which may cause these troubles are too much or too little soil moisture and nutrients, and temperatures above or below the optimum for growth of the tomato plant.

On the following pages, diseases are discussed in the approximate order in which they appear during an average growing season. Although they may not always appear in the sequence given here, it is believed that an arrangement based on seasonal appearance will help to some extent in diagnosing the diseases.

Damping-Off

Damping-off is common wherever tomato seedlings are grown. Any one of several soil fungi may cause this trouble. There are two types: pre-emergence and post-emergence. The latter type is the one most commonly associated with the term "damping-off."



All these tomato seedlings except the one on the left show injury typical of post-emergence damping-off. Note the shriveled stems of the affected seedlings as compared with the healthy plant. (Fig. 1)

In *pre-emergence damping-off* the seed rots in the soil or the seedling dies before it emerges. In *post-emergence damping-off* the seedling topples over after it has emerged from the soil but while it is still small and succulent. The plant collapses because the stem tissues at or near the ground level become soft and water-soaked (Fig. 1).

Damp, cloudy weather, poor ventilation, and overcrowding and overwatering of the seedlings form ideal conditions for this disease.

Control. Soil sterilization (page 50) is one way to control both pre-emergence and post-emergence damping-off in the hotbed, cold-frame, or greenhouse flat. Seed treatment with a protective fungicide such as Phygon, Orthocide, Arasan, or Semesan (page 49) is also advisable even if the soil has been sterilized. This measure is particularly effective against seed rot and helps somewhat to control the post-emergence type of the disease.

Sometimes post-emergence damping-off can be stopped by sprinkling the soil with a Semesan suspension — 1 ounce of the powder in 3 gallons of water. Apply at the rate of 1 quart to 10 square feet of soil. Fixed-copper, ziram, captan, dichlone, or zineb sprays (page 54) help to prevent post-emergence damping-off.

Collar Rot

This disease, which differs in appearance from damping-off in that the affected stem tissues are somewhat hard and brittle instead of soft and water-soaked, is discussed under "Early Blight" (page 21).

Hollow Stem

A noninfectious disease, hollow stem may occur in almost any stage of tomato-plant development. However, if care is used in producing and selecting seedlings, this disease will be of little importance.

Control. Do not use spindly transplants. This is the most important single measure for preventing losses from hollow stem. Seedlings should be properly hardened-off before they are set in the field and should not be transplanted into dry soil.

Avoid overcrowding, overwatering, and overfertilization with nitrogen. These factors, either singly or together, may contribute to the appearance of hollow stem. Too little sunlight may also be a contributory factor.

Mosaic Diseases

Mosaic diseases are the most common tomato troubles encountered under Illinois conditions. In fact, most tomato plantings have some degree of mosaic infection before the growing season is over. The seriousness of these diseases is not often recognized, however, for their symptoms are sometimes inconspicuous and the damage they do is usually ascribed to some other cause.

At least three mosaic diseases of tomato are known to occur in Illinois: common mosaic, aucuba mosaic, and cucumber mosaic. Common and aucuba mosaics are caused by two strains of the common tobacco-mosaic virus, which also attacks a large number of weeds and economic plants. Cucumber mosaic in tomato is due to a virus which also infects plants of the cucumber family as well as spinach, celery, pepper, and a wide variety of weeds and flowers.

Common mosaic. Mottled areas of light and dark green in the leaves are the most characteristic symptom of this disease. The dark green areas usually appear somewhat raised and puckered (Fig. 2). The young leaves at the tips of the growing branches tend to be bunched and to unfold unevenly. Plants affected in the early stage of growth are usually stunted and have a yellowish cast.

Ordinarily the fruit does not show any marked disfiguration. Both number and size of fruit are reduced, however, resulting in lowered yields. If infections occur before or during transplanting to the field, the yield may be reduced by as much as 50 percent.

The common-mosaic virus is so extremely infectious that a person can transmit it merely by touching a healthy tomato plant after having touched an affected plant. Transplanting, cultivating, weeding, and attacks by insects (*see* aphids, page 43) are possible ways of spreading the virus. Greenhouse infections may often be correlated with hand operations such as pruning and tying the plant.

Since the virus will live for several years in dried leaves and stems, it may be spread to growing plants from the remains of the previous

Leaves of plants affected with common mosaic show light and dark green mottling. Dark areas are usually raised and puckered. (Fig. 2)



Yellow mottling of the leaves is characteristic of aucuba mosaic. Mottling of the fruit may often accompany these symptoms on the leaves. (Fig. 3)



crop. This method of transmission does not appear to be important in field-grown tomatoes but may be responsible for some infections in greenhouse crops, especially where one crop is followed almost immediately by another.

Certain ornamental plants and perennial weeds such as zinnia, snapdragon, phlox, petunia, ground cherry, and horsenettle are sometimes infected by the virus and may serve as sources of early infections in the greenhouse, seedbed, and field.

Often mosaic infections in tomatoes originate from the use of tobacco in one form or another by the grower or his helpers. As already mentioned, the virus causing tomato mosaic is a strain of the common tobacco-mosaic virus; it affects tobacco in much the same way that it affects tomatoes. It is not killed in most tobacco-manufacturing processes and hence is present in a virulent form in most kinds and brands of chewing and smoking tobacco.

The common-mosaic virus is rarely seed-borne except in freshly extracted seed. For that reason seed-transmission of the virus is probably of little importance in either commercial or home-garden tomato production.

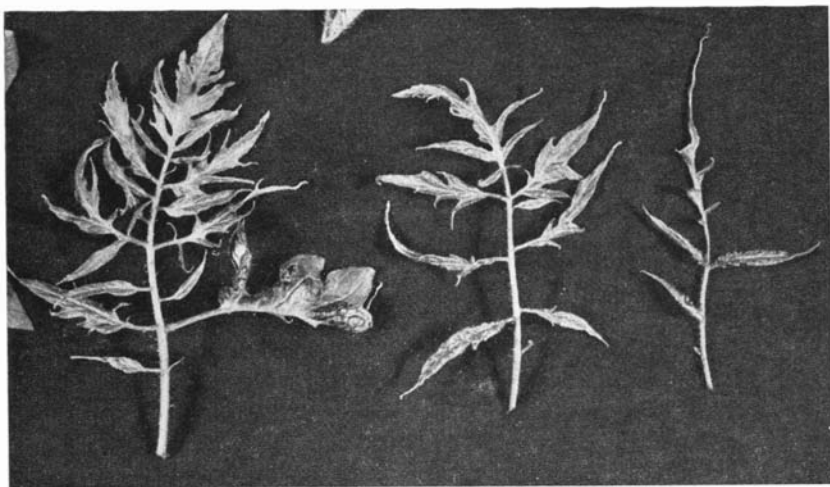
Aucuba mosaic. This disease causes a striking yellow mottling of the leaves (Fig. 3) and sometimes yellowing and even bleaching of the upper parts of the stems and branches. The fruit may be mottled—light and dark green when immature, and yellow and red when ripe—and generally unacceptable for marketing.

The aucuba-mosaic virus is introduced and spread among tomato plants in much the same way as the common-mosaic virus, except that the aucuba virus is not quite so easily transmitted by contact and, so far as is known, is not spread by insects.

Cucumber mosaic. Tomato plants affected with this disease in the early stages of growth are yellowed, bushy, and considerably stunted. Although the leaves may show a mottling suggestive of common mosaic, the most pronounced symptom is the "shoe-string" appearance of the leaves. Sometimes the leaves are so distorted that very little remains of the leaf blade but the midrib (Fig. 4). Severely affected plants produce but few fruit, and these are usually smaller than the fruit from healthy plants.

The number of cultivated and wild plants susceptible to the cucumber-mosaic virus is larger than the number susceptible to the common- and aucuba-mosaic viruses put together. The virus overwinters in the roots of certain perennial weeds such as pokeweed, catnip, and milkweed. At least five species of aphids, as well as the striped and spotted cucumber beetles, are capable of transmitting the virus from the overwintering weed hosts to the tomato.

The cucumber-mosaic virus is not transmitted in tomato seed, is



These three leaves show types of abnormal growth caused by the cucumber-mosaic virus. Often there is little left except the midrib. (Fig. 4)

not easily transmitted to tomatoes by rubbing or handling the plants, and does not persist in the soil or on the hands of those working with infected plants.

Control of mosaic diseases. Eradicate all perennial weeds from the seedbed, garden, field, greenhouse, and the area around the greenhouse. It is especially important to get rid of ground cherry, horseweed, milkweed, catnip, and pokeweed.

If you have been working with plants of any kind or have been using tobacco in any form, wash your hands in soap and water or in a solution of trisodium phosphate to inactivate any viruses before handling tomato seedlings and transplants. Insist that all your helpers do likewise. If you are operating a greenhouse, you might display prominent signs over the entrances to the tomato houses, saying "Visitors are asked not to touch the plants." This would help to prevent virus infections without giving offense to anyone.

Do not grow tomatoes in the garden or field next to crops such as potatoes, cucumber, tobacco, and related plants which are likely to carry viruses capable of infecting tomatoes. If possible, tomato plants should not be grown in seedbeds or sections of greenhouses used for flower production.

Do not plant cucumbers and melons next to greenhouses in which a fall or spring crop of tomatoes is to be grown; otherwise, virus-bearing aphids and cucumber beetles may move into the greenhouse as the cucumbers and melons mature.

Fumigate, spray, or dust greenhouses at frequent intervals to con-

trol aphids (page 43). This measure is particularly worth while if begun in the fall before freezing weather has caused insects to move into the greenhouse from out-of-doors. Aphid control is important also in preventing the spread of mosaic diseases after they have become established on a few plants in the greenhouse.

Streak Diseases

Two kinds of streak diseases are found in Illinois: single-virus streak, which occurs mostly in greenhouse tomato crops; and double-virus streak, which affects both greenhouse and field plantings.

Single-virus streak, as the name indicates, is caused by a single virus, which is closely related to the virus causing common mosaic. However, the only symptom the two diseases have in common is a more or less distinct mottling of the leaves.

Under conditions not well understood, tomato plants infected with this streak virus develop brown streaks on the stems and petioles (leaf stalks). Small, irregular, dark brown spots appear on the leaves. *The pith or central stem tissue shows a brownish discoloration.*

Fruit are often marked with slightly sunken, brown rings about $\frac{1}{2}$ inch in diameter. They may not, however, display any symptoms.

Double-virus streak is the result of a double infection with (1) the common-mosaic virus and (2) the so-called latent potato virus. This latent virus occurs in plants of many potato varieties grown in this

During the early stages of double-virus streak, leaves of a diseased plant may wither and die. Later the fruit is also affected, showing small, greasy, brown areas of irregular shape.

(Fig. 5)



country, but doesn't produce marked symptoms on potatoes. When it occurs alone in the tomato plant, it causes only a very mild mottling of the leaves. However, when a tomato plant already infected with the common-mosaic virus becomes infected with the latent virus, then double-virus streak develops. Serious damage may follow early-season infections.

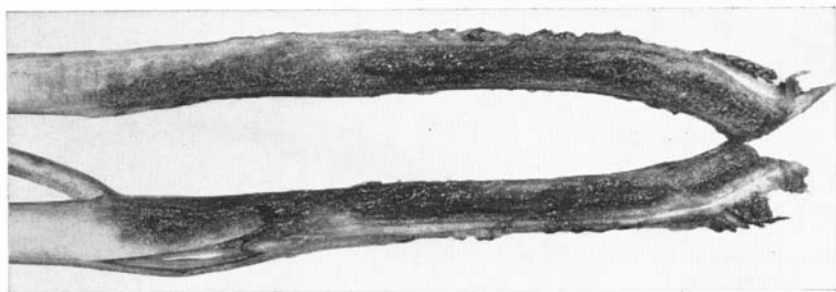
Like common mosaic and single-virus streak, this disease is characterized by mottling of the leaves. Small, grayish-brown dead spots develop on the leaves along with the mottling. The leaves may wither and die in the early stage of the disease (Fig. 5). *The pith is not discolored as it is in plants affected with single-virus streak*, but many narrow, dark brown streaks appear on the stems and leaf petioles. Fruit is marked with small, irregular, greasy, brown patches $\frac{1}{8}$ to $\frac{3}{8}$ inch in diameter.

Control of streak diseases. Since the common-mosaic virus helps to cause double-virus streak, the same general precautions that are given for control of mosaic diseases should be followed. It is particularly important not to plant tomatoes next to potatoes in the garden or field. After handling potato tubers or vines be sure to wash your hands with soap and water or a trisodium phosphate solution before working around or handling tomato plants. Do not permit the use of tobacco around the tomato plants.

Affected plants should be promptly removed from the greenhouse. This measure, however, may be of little value if the disease is well distributed throughout the planting.

Bacterial Wilt

This disease, caused by *Pseudomonas solanacearum*, can be found occasionally in Illinois fields set with southern-grown plants. Losses from this trouble are slight for the state as a whole.



One characteristic of bacterial wilt is the water-soaked, brownish streak that can be observed in the central part of the stem when the stem is split lengthwise. (Fig. 6)

Affected plants wilt rather rapidly and soon die. There is no spotting or yellowing of the leaves. If the stem is cut lengthwise near the ground level, a water-soaked or brownish discoloration of the pith or central tissue can be observed (Fig. 6). A slimy ooze appears if the cut stem is squeezed. This is one way to distinguish the disease from *Fusarium* and *Verticillium* wilts. Cavities form in the pith in the later stages of the disease.

Control. The causal bacteria are spread from diseased to healthy plants and from field to field by drainage water following rains. For this reason infected plants, if relatively few, should be removed from the field at once. Do not replace them with healthy plants, for they also are likely to become infected. If a field shows a relatively high percentage of infection, do not grow tomatoes there for four or five years. Instead, use it for crops that are not susceptible, such as small grains, legumes, and corn. Under any circumstance, do not rotate tomatoes with potatoes, peppers, or eggplants.

Leaf Roll

A nonparasitic disease, leaf roll is widespread in Illinois in some years. It generally follows extended periods of wet weather and is most likely to occur on plants in poorly drained soils. It has also been observed after close cultivation and extremely close pruning.

The rolling generally starts on the lower leaves and proceeds upward until, in some instances, almost all the leaves are affected (Fig. 7). In severe cases the rolled leaves are somewhat thickened and tend to rattle when the plant is shaken. Ordinarily, affected plants

As the name "leaf roll" suggests, this disease is characterized by rolling of the leaves. Lower leaves are usually affected first. Close cultivation and pruning may bring on this disease. (Fig. 7)



bear a normal or near-normal crop of fruit. But sometimes the plants may lose one-third to one-half of their leaves, with a corresponding loss in fruit quality and yield. This defoliation is most severe on staked tomatoes. The conditions causing plants to lose their leaves are not entirely understood, but heavy rains and winds, which whip and riddle the older rolled leaves, may be partly responsible.

Control. To lessen damage from leaf roll, choose well-drained areas for tomatoes, particularly if you are growing them in a garden. Do not cultivate deeply near the plants. Where leaf roll is an annual problem, it may be necessary to stop staking tomatoes.

Bacterial Canker

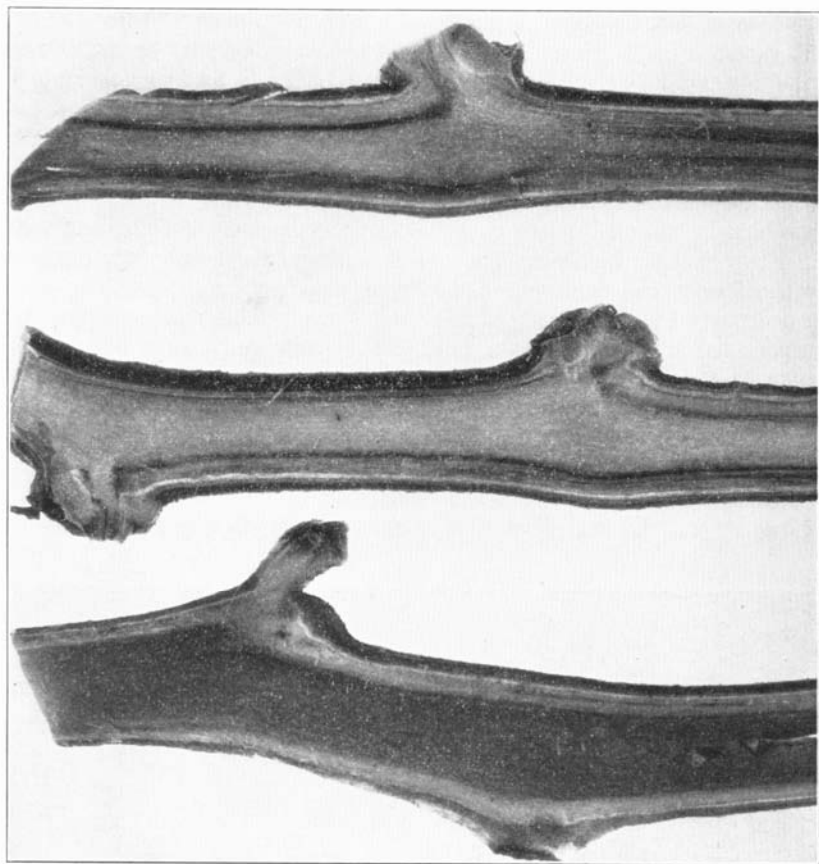
At one time bacterial canker was one of the most destructive tomato diseases in greenhouse and field plantings in Illinois. In recent years losses from this disease have been slight, principally because of the increased use of certified and treated tomato seed by southern plant growers. However, growers who save their own seed and ignore control measures can expect to suffer losses from canker if weather conditions favor its development.

The disease is caused by a bacterium, *Corynebacterium michiganense*, which, so far as is known, attacks only the tomato. First symptoms are usually drooping of the lower leaves and curling of the

leaflets. Soon wilting becomes pronounced, progressing from the bottom of the plant upward. Later, the leaves wilt and die, but the petioles usually remain green and firm. They are very hard to remove from the main stem, thus differing from the petioles of plants affected by *Fusarium* and *Verticillium* wilts. This characteristic aids materially in field diagnosis of bacterial canker. Individual stalks may



One or two stalks of a plant may die as a result of infection with bacterial canker, while the rest of the plant still seems to be free of the disease. (Fig. 8)



Discolorations typical of bacterial canker (*bottom*), *Verticillium* wilt (*middle*), and *Fusarium* wilt (*top*) are shown by these stems that have been slit lengthwise to reveal these abnormalities. Bacterial canker causes lines of creamy white, yellow, or yellowish brown near the edges. The discoloration is usually lighter than in the other two diseases. (Fig. 9)

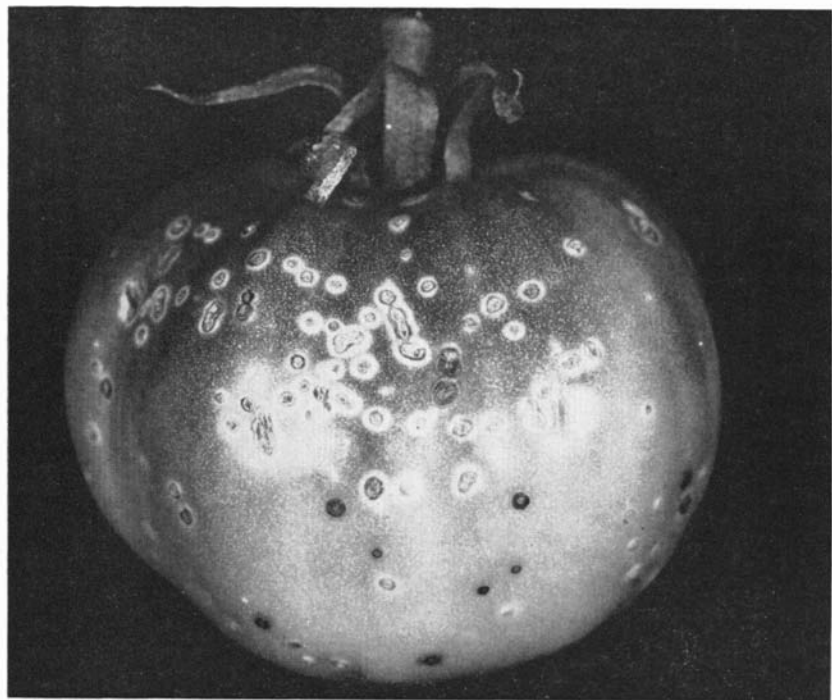
be killed early with the rest of the plant appearing healthy for some time (Fig. 8).

Yellowish to yellow-brown streaks usually appear on the stems of infected plants. If an infected stem is cut lengthwise, lines of creamy white, yellow, or yellowish brown can be seen close to the edge on one or both sides (Fig. 9). These are due to the presence of the causal bacteria in the water-conducting tubes and their subsequent spread to adjacent tissues. The discoloration is generally much lighter than that typical of *Fusarium* or *Verticillium* wilt.

Two distinct types of fruit infections result from this disease: (1) internal infection and (2) external infection, or fruit spot. Internal infection, which occurs through the vascular (food- and water-conducting) channels of the plant, is by far the more important. The discolored tissue typical of the disease may often be traced directly through an infected plant into its fruit and seeds. This type of fruit infection does not affect materially the marketability of the fruit, but it is largely responsible for outbreaks of the disease the following year.

Fruit spot, or bird's-eye spot, as it is often called, is a very common form of bacterial canker under Illinois weather conditions. The spots appear as tiny light dots which soon show a rough brownish center surrounded by a white halo (Fig. 10). Fruits may have only a few spots or they may be literally covered with them. The most serious aspect of this infection is its effect upon the market value of the fruit.

The causal bacteria are transmitted on and in the seed and on seedlings from diseased seed or infested soil. Wind, rain, and cultural practices account for local spread once the bacteria are established in plants or soil. Exactly how long the organism will live in the soil has



Fruit spot (bird's-eye spot) first appears as tiny light dots. These soon enlarge, with rough brownish spots appearing in the center. (Fig. 10)

not yet been determined, but it has sometimes been known to survive for at least two and one-half years.

Control. Bacterial canker furnishes an outstanding example of the importance of using clean, disease-free seed. Never save seed from fields known to have bacterial canker. If you buy seed, it will be well worth while to get only certified seed since such seed is usually canker-free. If you use non-certified seed of unknown origin, give it an eradicative seed treatment (page 48). Sterilize the seedbed soil (page 50) if it is not known to be free from the disease, or else replace it with soil that has not grown tomatoes.

If soil is known to be infested with canker, the best thing to do is to grow other crops for at least three years before planting tomatoes again. In small gardens where three-year rotations are not practical, pulling up and destroying tomato vines after the crop is harvested will help to control bacterial canker.

Fusarium Wilt

Fusarium wilt is still one of the most prevalent field and greenhouse diseases of tomatoes in Illinois despite the fact that several desirable resistant varieties have been available for some time. These varieties have made it possible to continue growing tomatoes on about 4,000 acres of wilt-infested soil in Illinois. Without them, Fusarium wilt would undoubtedly be the most damaging tomato disease in this state. It is present in all important tomato-growing regions of the United States, but does its greatest damage in the southern states and in northern states during excessively hot seasons.



Pronounced yellowing of individual leaves is characteristic of the beginning stages of Fusarium wilt. A single leaf may turn yellow first, with the discoloration spreading over the entire plant. After a leaf turns yellow, a slight touch will make it drop from the stem. (Fig. 11)

The disease is caused by a soil fungus (*Fusarium oxysporum* f. *lycopersici*) which enters the roots, and, like the bacterial canker organism, does its damage by growing in the food and water channels of the plant. It is believed that a toxic substance secreted by the fungus causes the wilting and death of the plant.

Many growers know this wilt disease as "yellows" because of the characteristic yellow color of infected plants (Fig. 11). The first symptom of the disease is the yellowing of a single leaf or a slight wilting and drooping of the lower leaves. If a section of the stem close to the base of the plant is examined now or later, a distinct brown discoloration of the water- and food-conducting channels may be seen (Fig. 9).

As the disease becomes more acute, wilting and yellowing become progressively worse until finally the entire plant wilts and dies. In damp weather the pinkish-white growth of the causal fungus may be seen in wounds or on leaf scars of plants killed or severely infected by the wilt organism. A black-rot condition in the small side roots is typical of this disease.

Shortly after a petiole and the leaflets on it become infected and yellowed, they will drop from the main stem with a mere touch. Petioles of plants infected by bacterial canker (page 14) seldom turn yellow and are very difficult to remove from the main stem. This fact aids materially in telling these diseases apart under field conditions.

The first symptoms of *Fusarium* wilt generally appear about the time of bloom or shortly after the set of the crown-cluster fruit, although the infection may occur any time during the life of the growing plant. The disease is favored by hot weather, and the high summer temperatures common in Illinois cause infections to progress very rapidly. Growth and reproduction of wilt are most active when the soil temperature is between 82° and 84° F. Plants sometimes die within 2 to 4 weeks after the first symptoms appear.

Fusarium wilt is introduced into a new area in or on the seed, by seedlings grown in infested soil, by dust and rain storms, and on farm implements. Seed is often considered responsible for introducing the disease into widely separated areas, while the other methods account largely for local spread. Seedbed infections commonly result in severe losses. Seedlings grown on infested soil usually do not show the disease until after they have been transplanted for some time. Thus it is important that the seedbed soil be sterilized unless it is known to be disease-free.

Once the wilt fungus becomes established in the soil, it generally persists there for many years, making any reasonable rotation worthless.

Control. The usual control of *Fusarium* wilt is to grow immune, resistant, or tolerant varieties, several of which are now available.

Immune varieties are seldom, if ever, affected by wilt. Resistant or tolerant varieties are not affected when soil temperatures are below 70° F.

Immune, red-fruited varieties tested in Illinois and found to be worthy of trial by canners, commercial growers, and home gardeners are: Boone, Brookston, Kokomo, and Manalucie. Others less extensively tested that may be acceptable are: Indark, Kopiah, Manalee, Fortune, Chesapeake, and Wiltmaster. Sunray is an orange-yellow-fruited, wilt-immune variety. Wilt-resistant or tolerant varieties are: Rutgers, Garden State, Pritchard, Marglobe, Break O'Day, Queens, and several others. Rutgers and Garden State are perhaps the most popular varieties grown in Illinois for processing, fresh market, and home garden use. Michigan State Forcing (red), Ohio W-R 3 Globe (pink), and W-R 7 are wilt-resistant varieties often used by greenhouse growers. A promising, resistant, red-fruited variety is Michigan-Ohio Hybrid which originated from a cross between Michigan State Forcing and Ohio W-R Globe. Another red greenhouse variety, Tippecanoe, developed by Purdue University, is said to have high resistance to wilt.

If the wilt fungus is known to be present in greenhouse soils, resistant varieties should be used and the soil should be sterilized (page 50).

Tomatoes should not be grown on the same ground oftener than once in three or four years since a light infestation of wilt can be greatly increased by too-frequent cropping with tomatoes. It is advisable also to pull up and destroy wilt-affected tomato plants in small plantings at the end of the season.

Certified seed is less likely to carry the wilt fungus than uncertified seed. If you use home-saved seed, be sure that the fruit for this seed comes only from plants completely free from wilt.

Verticillium Wilt

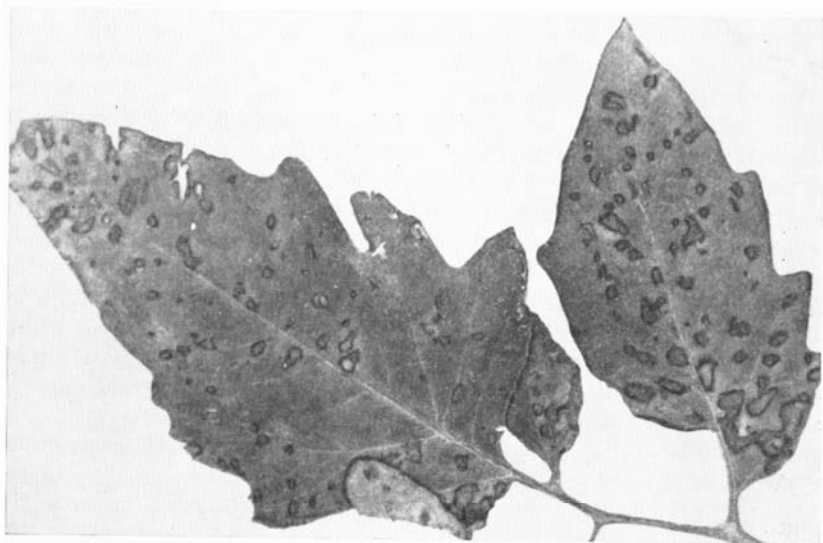
The symptoms of this disease are almost identical to those of Fusarium wilt (Figs. 9 and 11) and the two ordinarily cannot be distinguished except by laboratory examinations. Verticillium wilt is caused by a soil fungus (*Verticillium albo-atrum*) which also attacks pepper, eggplant, potato, and a wide variety of other plants. The causal fungus may be carried at times on or in the seed, which may account for its introduction into widely separated areas. Verticillium wilt, unlike Fusarium wilt, thrives best under cool moist conditions and therefore is more serious in the northern states and Canada than in the southern states.

Control. No resistant varieties suitable for growing in Illinois have been developed, but otherwise control measures are the same as those described for Fusarium wilt. If the disease becomes established in the

seedbed or greenhouse, the soil must be sterilized if tomatoes are to be grown profitably. Do not plant tomatoes in fields where eggplant, pepper, and okra have been grown, especially if these were affected by wilt.

Gray Leaf Spot

Gray leaf spot, caused by the fungus *Stemphylium solani*,¹ is a comparatively new disease of tomatoes in Illinois. Although it may have been present in slight amounts before 1949, it did not occur in



The brownish-black spots characteristic of gray leaf spot may grow to $\frac{3}{16}$ inch in diameter. As they grow, they become shiny and glazed. Later they dry out, often splitting as they do so. (Fig. 12)

epidemic proportions until then. That year it caused severe defoliation in several fields in Vermilion county. This disease is potentially more destructive than either early blight (page 21) or Septoria leaf spot (page 23), because severe infections occur earlier in the season and the fungus spreads more rapidly from lower to upper leaves. Warm, wet weather hastens the spread of the fungus and its subsequent penetration of the leaves.

Gray leaf spot is limited to the foliage and stems; no lesions develop on the fruit. Small, brownish-black spots, either irregular or circular in outline, are the first symptoms on the leaves (Fig. 12). The spots grow larger, $\frac{3}{16}$ inch usually being the maximum diameter. Often

¹ A new species of *Stemphylium* has been reported recently on tomatoes in Florida.

they cover most of the total leaf surface, the tip quarter being especially spotted and browned. Lesions on the petioles and upper parts of the stems are elongated and brown.

The spots on the leaves become shiny and glazed as they enlarge, resembling somewhat those of bacterial spot (page 25). After the spots start to dry out, they often crack from side to side. The central part may break out entirely, giving a shot-hole appearance to the leaf. Usually the leaf is quite yellowed at this time. Soon the entire leaf wilts, dies, and falls off the stem.

The gray leaf spot fungus apparently can overwinter easily on tomato-plant refuse. It has been reported in Florida on eggplant and pepper and on three species of weeds belonging to the tomato family. Several other weeds related to tomato were inoculated artificially and found to be susceptible. Gray leaf spot infections have been seen on horsenettle (*Solanum carolinense*) growing in Illinois tomato fields affected by the disease.

Control. Eradicative seed treatment (page 48), soil sterilization (page 50), three- or four-year rotations, and spraying or dusting with fungicides (page 53) in the seedbed and field are recommended as preventive measures against gray leaf spot. Zineb and maneb are effective if applications are made before the disease appears and if leaves and stems are well covered. Ziram fungicides are comparatively poor in controlling gray leaf spot.

Early Blight

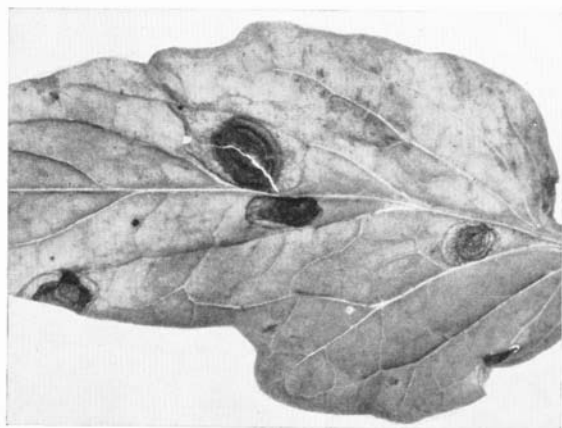
Early blight, caused by a fungus (*Alternaria solani*), may occur as a collar rot, a stem canker, a leaf spot, or a fruit spot.

Collar rot is characterized by large, brown, slightly sunken, irregular lesions on the stems of seedlings and transplants at or slightly above the ground level (Fig. 13). Similar but smaller *stem cankers* may develop for a considerable distance above the ground level. Plants so affected are apt to die or be unproductive if set in the field.

Seedlings and transplants affected with collar rot show large, brown lesions at the level of the ground or slightly above it. Other early-blight lesions (stem cankers) may appear farther up on the stem. (Fig. 13)



The *leaf-spot* stage can be distinguished by irregular, brown spots which are often marked with concentric rings or ridges giving a "target-board" effect to the spots (Fig. 14). Occasional spots may be almost $\frac{1}{2}$ inch in diameter. Abundant rainfall and high temperatures may result in severe leaf infections and loss of much of the foliage. Often so many leaves are lost that there is considerable sunscalding of the fruits. The result is usually off-quality conditions in the fruit, such as flabbiness, cracking, orange instead of red color, and off-flavors. The susceptibility of the fruit to anthracnose is increased. Lesions may also occur on the flower stems and cause the blossoms to drop.



Early-blight infections on leaves often look like target boards because of the concentric brown rings. Leaves affected in this way commonly drop from the plant.

(Fig. 14)

Fruit spots caused by early blight are dark, sunken, and leathery, occurring at the stem end. The fungus often completely covers these affected areas, appearing as a brown moldy growth marked with concentric rings like those on the leaves. The fruit may drop prematurely from the vines.

Control. Eradicative seed treatments (page 48) and seedbed sterilization (page 50) should be used to prevent seedling infections. Provide ample ventilation and avoid overwatering and overcrowding of the seedlings. Discard any transplants with cankers on the stem. Plants should not be held in the seedbed for any length of time after they have reached the proper stage for transplanting. Nor should southern-grown plants be held in storage any longer than absolutely necessary after they are received.

General sanitation in the garden and field will help to prevent infection. Ground cherry, horsetail, night shade, and other weeds related to the tomato should be eradicated from tomato plantings. In commercial fields it helps to cut up vines with a disk and plow them under deeply in fall or early spring.

Spraying or dusting the plants in the seedbed and field with ziram, maneb, zineb, captan, or fixed-copper fungicides (page 50) will help in controlling early blight. However, this practice is likely to be profitable only if started before the disease appears.

Septoria Leaf Spot

Septoria leaf spot is most severe during rainy seasons and in fields where plants are crowded and bearing a heavy fruit load. It is caused by the fungus *Septoria lycopersici*. Although the disease is most serious under field conditions, damage may occur in the seedbed. The lower leaves of seedlings may become severely spotted if held too long before transplanting to the field.

As a general rule, the disease is slow in getting started and is not much in evidence before the first or middle of July, or not until the plants have begun to set fruits. Small gray spots, with tiny black specks in the center and with black or brown borders, are the first evidence of the disease. They may remain small or may grow to about $\frac{1}{8}$ inch in diameter (Fig. 15). The lower leaves are attacked first.

Frequent showers and air temperatures of from 60° to 80° F. bring about favorable conditions for the spread and development of the fungus. Under these conditions, infections spread rapidly with a progressive loss of foliage until only a few leaves are left at the tip of the stem or branch. The fungus may also attack the stems, leaf petioles, blossoms, and fruit stems. Fruit spotting is seldom of any importance,

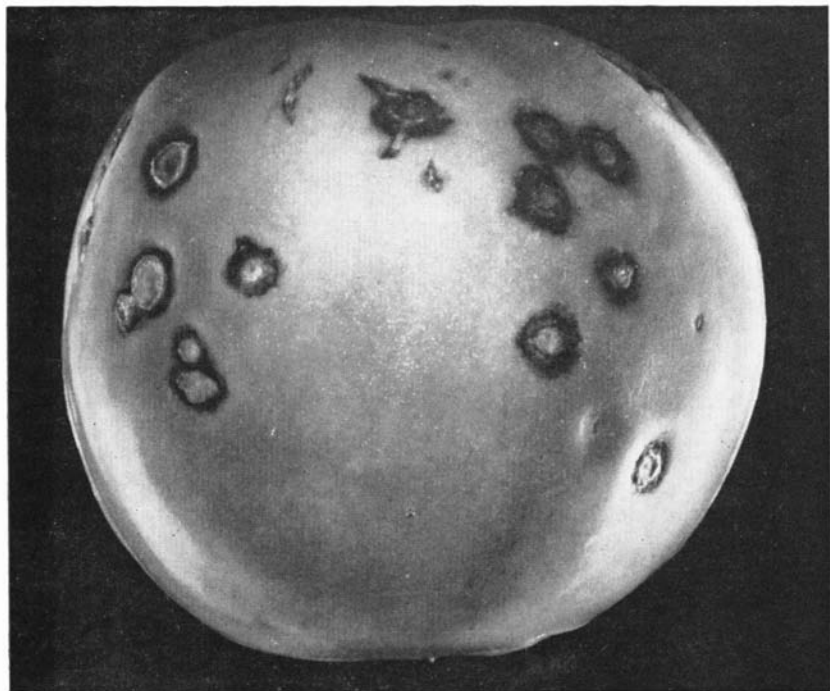


First symptoms of Septoria leaf spot are small gray spots with black dots in the center and with black or brown edges. These spots may become as large as $\frac{1}{8}$ inch in diameter. (Fig. 15)

but, as with early blight, fruits on plants defoliated by *Septoria* leaf spot are apt to be of poor quality and very susceptible to anthracnose.

Summer infections of *Septoria* leaf spot originate from infected seed, from the remains of old plants left in the field from the previous year, or from infected weeds such as horsenettle, ground cherry, nightshade, and Jimson weed. The fungus is spread by splashing rains and on the hands and clothing of those working with plants wet with dew or rain.

Control. The control measures given for early blight (page 22) apply in general to the control of *Septoria* leaf spot. These are eradicated seed treatments, seedbed sterilization, proper cultural practices, general sanitation, weed control, and spraying or dusting with fungicides. In general this disease is more difficult to control with fungicides than is early blight. Good control is almost impossible if fungicides are not applied until after the disease appears. Fixed-copper, maneb, and zineb fungicides (page 54) appear to be somewhat more effective against this disease than other kinds of fungicides.



Lesions caused by bacterial spot are first raised; later they sink and have a scab-like appearance. In Illinois these spots are the most serious part of this disease. (Fig. 16)

Bacterial Spot

Bacterial spot is widely distributed in Illinois. It is particularly serious in warm seasons with frequent or heavy dews. The disease is common on pepper as a leaf and fruit spot, as well as on the tomato.

Leaf spots appear as small, water-soaked areas which later turn brownish-black. The spots are somewhat irregular in outline and have a greasy appearance on the upper surface. Several lesions may cause a leaflet to turn yellow. Lesions may also occur on the flower stems and cause the blossoms to drop. Spots on the fruit first appear as small, black, raised "pimples" which are surrounded by water-soaked areas. Later the raised portion sinks, forming a cavity and typical scab lesions (Fig. 16). The development of these spots on the fruit and flower stems is the most serious aspect of the disease in Illinois.

The bacterium causing the disease is *Xanthomonas vesicatoria*. Bacteria overwinter on the seed and probably on occasion in the soil.

Control. Eradicative seed treatments (page 48) will rid the seed of any scab bacteria. Seedbed sterilization (page 50) may also be of some help in reducing losses. Spraying the plants in the seedbed and field with streptomycin, an antibiotic, has given good control over bacterial spot in Florida. Five applications of streptomycin at a concentration of 200 p.p.m. (parts per million) gave excellent results in seedbeds. In the field, five applications at 400 p.p.m. and three at 200 p.p.m. at 4 to 5 day intervals controlled the disease even after it was established throughout the field. Spraying or dusting with fixed-copper fungicides (page 54) is also effective. There is some evidence from the Florida tests that streptomycin and fixed coppers in a combination spray are more effective than either one alone. Rotation with crops other than peppers is recommended.

Leaf Mold

Leaf mold, caused by the fungus *Cladosporium fulvum*, is principally a greenhouse trouble although on occasion it may develop in the garden or field. All above-ground parts of the plant may be affected, but generally the greatest damage occurs to the leaves. The fruit itself is rarely attacked.

Yellowish or light green spots on the upper side of infected leaves are the first evidence of the disease. The lower surfaces of these patches are often covered with a grayish-purple moldy growth (Fig. 17).

When humidity is high, the fungus develops rapidly on the foliage. It is spread from plant to plant by watering and air currents, and through contact of the leaves. Infections usually progress from the lower leaves upward. If control measures are not practiced, the entire plant may be affected, and the crop greatly reduced.

Control. Adequate ventilation and temperatures of at least 60° to



The undersides of leaves affected with leaf mold often show patches of a grayish-purple moldy growth. On the upper sides, yellowish or light green spots correspond to the moldy patches. (Fig. 17)

65° F. throughout the growing season will lessen damage in the greenhouse. At night keep the temperature of the greenhouse higher than that outdoors. This will reduce the amount of moisture that forms on the leaves and thus help to control the disease, since moisture is essential for the growth of the mold fungus. If leaf mold becomes serious, some night heating may be needed as late as the middle of June and as early in the fall as the first of September. The control obtained in this way will more than pay for the additional heating. If at all possible avoid syringing the plants with water.

Mold-resistant varieties for greenhouses have been developed, including Improved Bay State and Waltham Mold-Proof Forcing, which are red-fruited varieties, and Globelle, a pink-fruited variety. Improved Bay State and Waltham Mold-Proof are the only ones with a high degree of resistance to all known strains of the leaf mold fungus.

Spraying or dusting with zineb or fixed-copper fungicides (page 54) will help to prevent leaf-mold infections in the field but may be of little value in the greenhouse.

Late blight first appears as dark brown water-soaked areas on leaves and stems. Often a pale green band surrounds the brown spot on the leaf. (Fig. 18)



Late Blight

The fungus (*Phytophthora infestans*) that causes the late-blight disease of potatoes is also responsible for late blight in tomatoes. This disease was not serious on tomatoes in Illinois until 1945 (according to available records of the past 30 years). Since that time it has appeared every year in some areas. When conditions are extremely favorable for infection (temperatures between 50° and 70° F., plus high humidity or rainfall) and where protective fungicides have not been applied, the disease may spread throughout a large tomato field in a few days' time, killing the vines and rotting all green and ripe fruit.

First symptoms of late blight are irregularly shaped, dark brown, water-soaked areas on the stems and leaves (Fig. 18). A pale green band of tissue usually surrounds the affected area on the leaf. The grayish, moldy growth of the fungus may be found on the underside of these spots. Severely affected plants look as if they have been killed by frost.

Fruit rotting usually starts at or near the stem end and soon spreads over the entire fruit (Fig. 19). Rotted areas are greenish-black with a rather firm but slightly wrinkled surface. Under moist conditions the growth of the fungus may be apparent on the surface of affected fruits.

Infections on tomatoes originate for the most part from imported tomato plants, from nearby potato fields, or from infected greenhouse tomatoes. After infection begins, it is spread by the microscopic spores or seeds of the fungus. These are produced by the hundreds on each individual spot and may be carried for some distance by air currents. Since a new crop of spores is produced every two or three days under



Late blight attacks both green and ripe fruit. Rotted areas are greenish-black and somewhat wrinkled, though firm. (Fig. 19)

favorable conditions, a single blighted tomato or potato plant may give rise to a tremendous number of infections in a field.

Control. Zineb, maneb, or fixed-copper fungicides (page 54) will control late blight satisfactorily, particularly if they are applied before the disease becomes scattered throughout the planting.

Tomatoes should not be planted in the field following potatoes, nor should these crops be planted in adjacent fields.

Buckeye Rot

Buckeye rot, caused by a fungus (*Phytophthora parasitica*), occurs on either green or ripe fruit and is most common in poorly drained fields during warm, wet weather. It may also attack eggplant and pepper fruit.

The rot appears as a greenish to brownish water-soaked spot near the blossom end of the fruit where it is in contact with the soil. The rotted area enlarges rapidly in warm weather until one-half or more of the fruit is covered. When the rot develops slowly, definite zonations or dark concentric rings appear in the decayed area (Fig. 20). In wet weather the grayish-white fungus growth may develop on the rotted fruit.

Control. Good drainage is particularly important in preventing

These tomatoes indicate how "buck-eye rot" gets its name. Infection starts as a greenish to brownish spot near the blossom end and enlarges rapidly in warm weather. (Fig. 20)

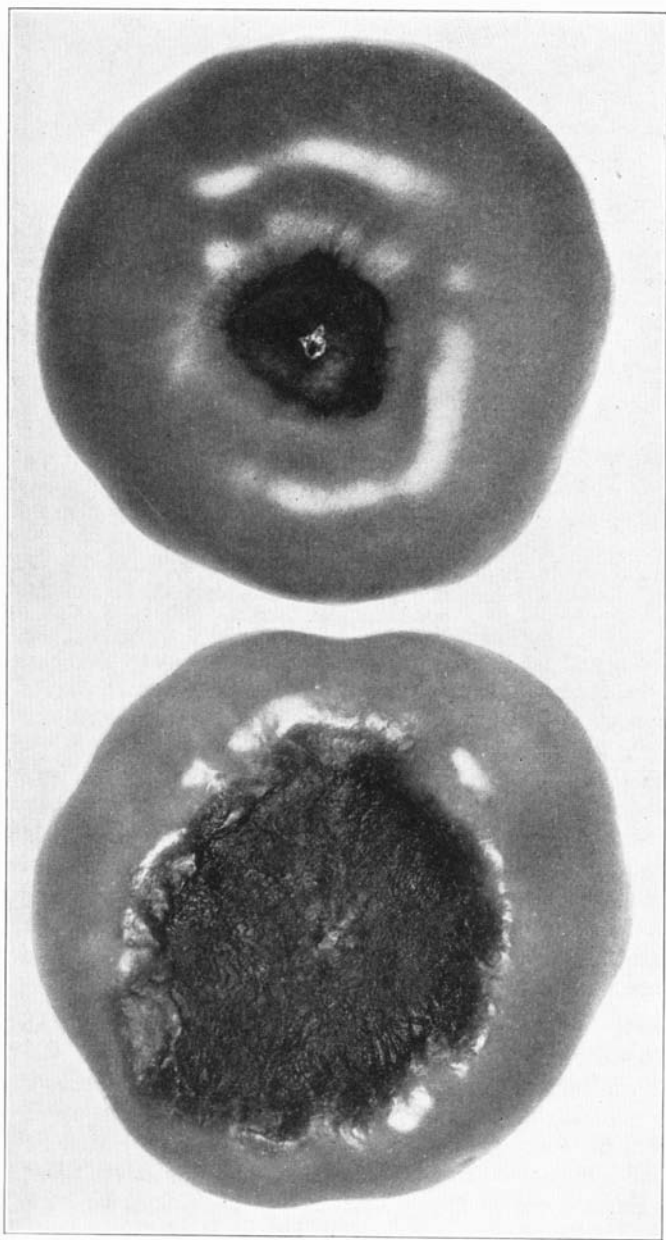


losses. A three-year rotation with crops other than eggplants or peppers will also help to control the disease. Staking plants in the garden will help considerably by keeping the fruits from touching the soil. Spraying or dusting with a fixed-copper fungicide (page 54) will help to protect the fruits against infection.

Blossom-End Rot

Blossom-end rot is a noninfectious disease caused by a deficiency of calcium. It is usually more severe on staked tomato plants than on those that are not and is worse in some seasons than in others. Conditions that favor blossom-end rot also favor leaf roll (page 13). Although the disease may appear at any stage of fruit growth, the fruit seems most susceptible when it is one-half to two-thirds mature. A small water-soaked spot around or near the blossom end is the first symptom of the disease. Later the spot enlarges, soon becoming sunken, brown, and leathery (Fig. 21). In severe cases it may involve more than half the affected fruit. It is very common for secondary fungi and bacteria to attack fruit affected with blossom-end rot and thus cause further rotting.

Control. In the greenhouse and garden, the disease can be prevented to some extent by maintaining a uniform supply of soil moisture and by avoiding the use of excessive amounts of ammonia or nitrated nitrogen and highly soluble potassium salts. A light application of dolomitic limestone, gypsum, superphosphate, or hydrated lime should be worked into the soil to a depth of 4 to 6 inches before planting. The Florida Experiment Station suggests that a calcium chloride solution (4 pounds of 95-percent material or 5 pounds of 78-percent dissolved in 100 gallons of water) be sprayed on the leaves when blossom-end rot is first noted or when it is anticipated. Such sprays should be used during periods of most rapid growth. In Illinois commercial and home



Blossom-end rot is just starting on the top tomato. As the rot spreads it becomes sunken and leathery, as on the bottom tomato. (Fig. 21)

gardens, gardeners might try calcium chloride sprays on an experimental basis, beginning when the first fruits are the size of golf balls and continuing at weekly intervals until 3 or 4 applications have been made. Prolonged, periodic applications of this chemical may cause marginal leaf burn.

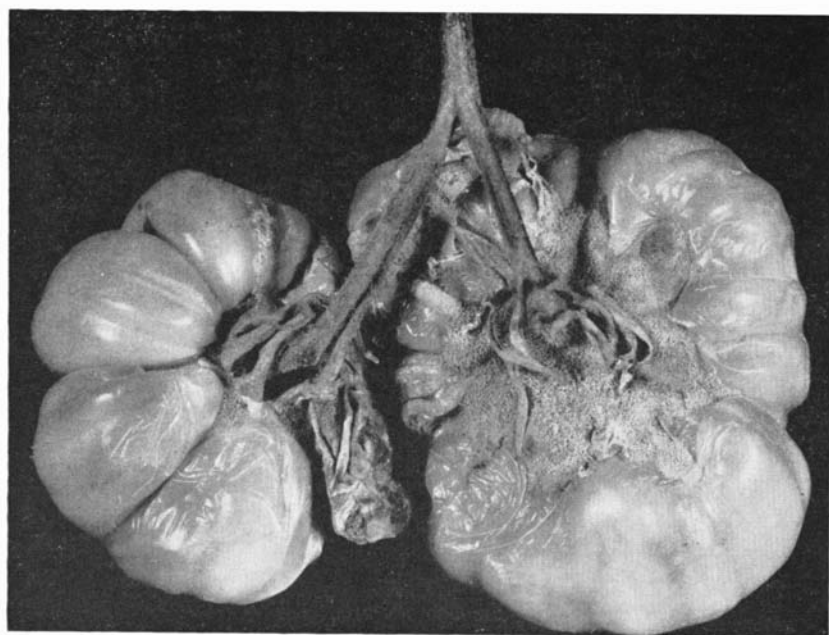
Botrytis Fruit Rot

Severe losses occur in greenhouse crops some years as a result of Botrytis fruit rot (caused by the fungus *Botrytis* sp.). Damp, cloudy weather appears to be very favorable for outbreaks of the disease. Syringing the plant with water and jarring the plant to insure pollination loosen tremendous numbers of the spores (seeds) of the fungus into the air. These spores are then carried by air currents to other plants.

The disease first appears as a small, water-soaked spot near the stem end of the green fruit. The infection spreads rapidly, and ultimately most, if not all, of the fruit may be affected (Fig. 22). The diseased area is covered with a grayish, powdery, moldy growth composed of countless fungus spores.

Although infection is most evident on the fruit, the main stem, the flowers, and the fruit stalks may also be affected at times.

Control. Measures for the control of this disease are essentially



A grayish, powdery, moldy growth covers diseased areas of tomatoes affected with botrytis fruit rot. (Fig. 22)

the same as those for leaf mold (page 25). It is particularly important to avoid syringing the plants.

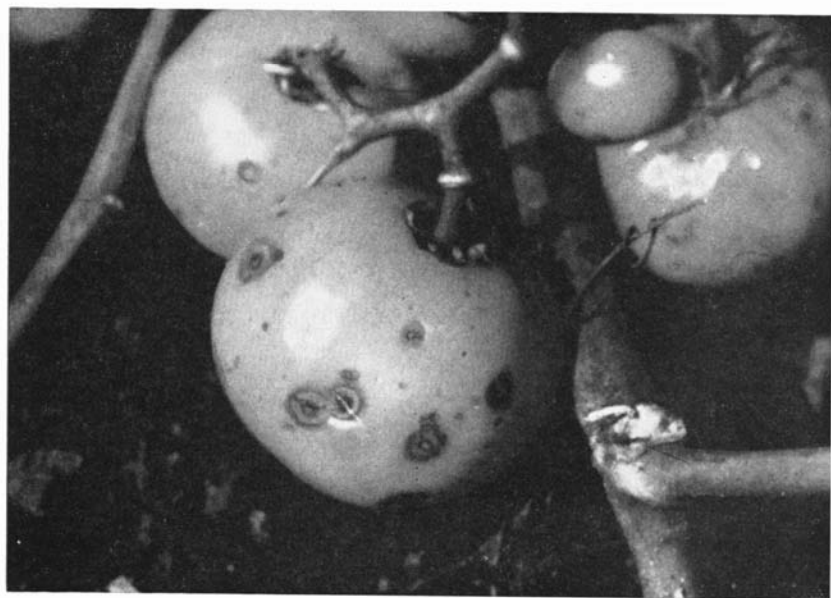
Carefully picking diseased fruits and removing them from the greenhouse may help somewhat to keep losses at a minimum, particularly if this is done when the disease first appears.

Spraying or dusting with fixed-copper compounds (page 54) may help prevent infection, but cannot be relied upon exclusively.

Anthracnose

Anthracnose, or ripe rot, caused by the fungus *Colletotrichum phomoides*, is the most widespread and destructive tomato fruit rot in Illinois. It appears to be most common on plants growing in poorly drained and infertile soils, and on plants which have lost much of their foliage from disease or other causes. The causal fungus can overwinter in soil debris and, as recent experiments at the New York (Geneva) Station have shown, it can spread from infected leaves to nearby fruit.

Although many infections probably take place when the fruit is still green, the disease is not evident until the fruit is ripe or nearly ripe. Then it appears as small, slightly sunken, circular, water-soaked spots (Fig. 23), which enlarge rapidly in warm weather. The center of each spot becomes darkened and in moist weather may turn pink. These rotted areas are commonly marked with concentric rings. The whole fruit may be almost completely covered with anthracnose spots in a matter of 24 hours or so after picking if conditions are favorable.



Anthracnose becomes evident when fruit is ripe or nearly ripe, making its appearance as small, round, slightly sunken, water-soaked spots. (Fig. 23)

Control. Some of the losses from anthracnose can be avoided if adequate soil fertility is maintained and if the soil is well-drained. A four- or five-year rotation will also help control the disease.

In the home garden, all ripe fruit should be harvested at each picking. If it is left in the field, it will decay and serve as sources of infection for the remaining fruit. This measure is probably impractical for larger plantings.

Results of recent experiments show that ziram, captan, maneb, dichlone, and zineb fungicides (page 54) have considerable value as protectants against anthracnose infections. These fungicides are effective only when application is started early in the season. The fixed-copper fungicides are not very effective in control of anthracnose.

Minor Fruit Rots

Several minor rots may damage the tomato fruit in the field or, in the case of "green wraps," during shipment to market. Many different species of fungi and bacteria are responsible for such rots. They commonly infect the fruits through insect-feeding punctures, growth cracks, or mechanical injuries. Some of these organisms cause a distinct odor of fermentation. One of the most common types is a soft, watery rot which makes the diseased fruit resemble bags of water hanging on the vine.

These fruit rots appear to be least severe on plants growing in well-drained soil. They are generally most prevalent during and after periods of excessive rainfall.

Control. Grow tomatoes in well-drained soil. Use care to avoid injuring fruits that are picked and wrapped for shipment while they are still green. Spraying or dusting with fixed-copper fungicides may aid in controlling some of these rots.

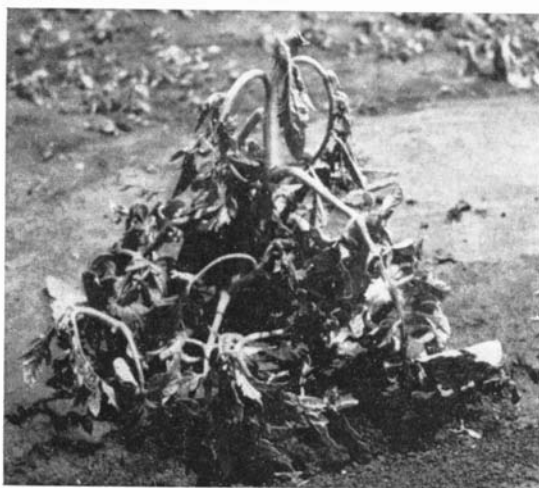
Injury from 2,4-D¹

The weed-killing chemical 2,4-D has caused serious damage in Illinois to tomato and other susceptible kinds of plants, such as grapes (wild and cultivated), melons, sweet potatoes, beans, roses, dogwood and redbud trees. Weedkillers such as 2,4-D are quickly absorbed by the leaves and transported throughout the plant. Only a trace of the chemical is needed to kill susceptible plants. Unfortunately, 2,4-D is unable to differentiate between broadleaf weeds and crop plants. The active ingredient may be carried by air currents and cause injury at a distance of $\frac{1}{2}$ mile or more from the sprayed area. Dust formulations may be carried for several miles. Contaminated sprayers and

¹The herbicide commonly known as 2,4-D is 2,4-dichlorophenoxyacetic acid. The herbicides 2,4,5-T and MCPA may also severely injure crop plants and cause symptoms similar to those of 2,4-D injury. The herbicide 2,4,5-T is 2,4,5-trichlorophenoxyacetic acid and MCPA is 2-methyl-4-chlorophenoxyacetic acid. This discussion applies equally to injury from any of these herbicides.

pesticide containers may also be responsible for injury, particularly in home gardens.

Tomato plants in all stages of growth are susceptible to injury from 2,4-D. The degree of injury is directly proportional to the concentration of chemical to which the plant is exposed. At high concentrations when the spray is applied directly to the plant, the first symptoms can usually be seen within 3 to 4 hours. The upper part of the stem becomes twisted and the petioles (leaf stalks) bend downward (Fig. 24). The entire plant may die within a week. If the plant



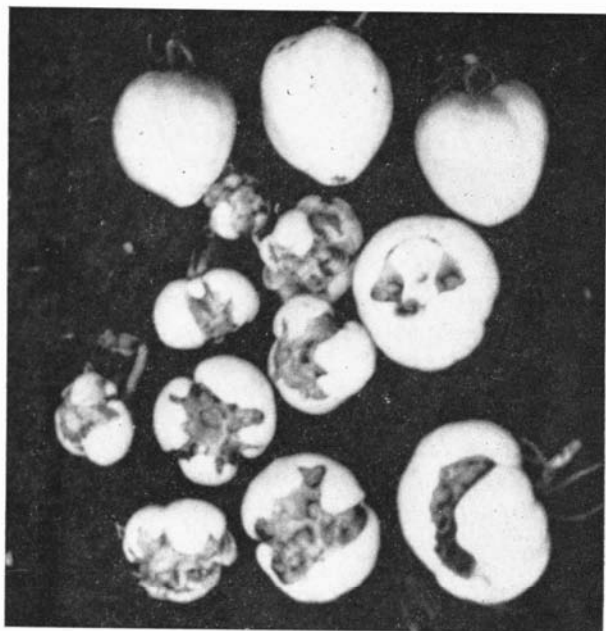
This tomato plant was sprayed directly with 2,4-D at a concentration used for weed control. The symptoms of injury — drooping and twisting of the upper part of the stem and leaf stalks — appeared 24 hours after it was sprayed. (Fig. 24)

survives, the new vine growth is apt to be severely stunted, the stem may split open near the ground, and adventitious roots develop on the side branches above ground. Root growth is severely restricted. There is extensive dropping of flowers. Any fruit that is green at the time of spraying is likely to become heart-shaped or to crack open. (Fig. 25).

At lighter concentrations where the fumes or spray mist has drifted several hundred feet before settling on the tomato plant, the first symptoms may not become apparent until 5 or 10 days after spraying or until new leaves have expanded. The leaflets have wavy or frilled margins (Fig. 26), and the veins are lighter and more prominent than usual. The tips of the leaflets tend to be drawn out to a fine point. Fruit may ripen prematurely. The amount of blossom drop and of heart-shaped fruit may be considerable but depends on the concentration of 2,4-D to which the plant has been exposed. At distances of $\frac{1}{2}$ mile or more from the sprayed area, the only observable symptom may be a slight distortion to the leaflets.

To determine whether 2,4-D has caused economic loss to tomatoes, several factors that may bring about similar effects must be evaluated.

The cracks in these tomatoes are the result of injury by direct spraying with 2,4-D. The three heart-shaped fruit at the top developed on plants injured by 2,4-D mist. (Fig. 25)



Upper part of a tomato plant as it looked several days after it was exposed to 2,4-D mist. The wavy margins and drawn out tips of the leaflets are typical symptoms of 2,4-D injury. (Fig. 26)

When fruit-setting compounds¹ are sprayed over the entire plant, they may produce symptoms of injury on the leaves that are indistinguishable from those caused by 2,4-D. Too little or too much nitrogen in the soil, night temperatures below 55° F., or day temperatures above 90° F. may cause tomato flowers to drop. Diseases such as early blight, Septoria leaf spot, and bacterial spot that cause lesions on the pedicels (flower stalks) may bring about flower drop and poor fruit set. A diagnosis of 2,4-D injury can often be confirmed by finding symptoms on weeds growing in or around damaged tomato fields.

Prevention of injury. Do not use the high volatile 2,4-D esters unless you thoroughly understand the hazards involved and are willing to take the necessary precautions. They are especially hazardous to use around the home where there is danger of the fumes drifting and damaging nearby susceptible ornamental plants and vegetables. Damaging fumes may rise from weeds or grass for as long as 3 days after they have been sprayed with high volatile ester 2,4-D. This is less likely to happen with low volatile ester or amine forms of 2,4-D. Look for "low volatile," "low volatility," or "LV," or "amine" on the label. Do not use any kind of 2,4-D, including low-volatile ester, amine, or other salt formulations within 1/2 mile of a tomato planting.

Low gallonage sprayers that apply 2,4-D as a fine, concentrated mist are more likely to cause drift and subsequent crop damage than those that deliver the chemical as a coarser, less concentrated spray. Agricultural engineers suggest that flooding-type flat-fan nozzles (Spraying Systems 1/8K 1, 1/8K 1.5, 1/8K 2, and 1/8K 3 or their equivalents) be used for weed control near susceptible crops instead of the conventional flat-fan types. The flooding types produce a coarser spray and still give adequate coverage of broadleaf weeds.

It is best to have a sprayer solely for applying 2,4-D and another for applying fungicides, since it is exceedingly difficult to remove all of the residue from a 2,4-D contaminated sprayer. Buy fungicides and insecticides only in factory-sealed packages and never in used containers that may have been contaminated with 2,4-D.

TOMATO INSECTS AND THEIR CONTROL

Flea beetles, tomato worms, cutworms, and aphids or plant lice are the most important of the insects attacking tomatoes. In the greenhouse, the tomato may also be attacked by whiteflies, nematodes, and symphylids. Garden slugs frequently damage ripening tomato fruit.

All the tomato insects are more or less general feeders, at-

¹ Chemicals such as para-chlorophenoxyacetic acid and beta-naphthoxyacetic acid are sometimes sprayed on individual flower clusters to induce fruit set under unfavorable environmental conditions.

tacking potatoes, eggplants, peppers, and such weeds as ground cherry, horsenettle, and buffalo bur. Preventing these plants from becoming heavily infested with insects is often a great help in reducing injury to tomatoes.

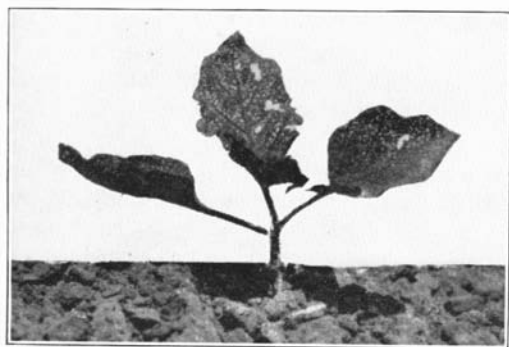
Insects attack the tomato in a number of ways. They may eat the foliage and fruit, destroy the roots, suck sap from the plants, or transmit harmful disease organisms. The type of injury depends largely upon the feeding habits of the insect.

In general, insects may be divided into two classes according to their feeding habits: (1) chewing insects, such as the tomato worms and flea beetles, and (2) sucking insects, such as aphids and whiteflies. *Chewing insects* eat away parts of the plant and are usually controlled by a stomach poison. *Sucking insects* secure their food by piercing the plant with their needle-like beaks and sucking out the sap. For their control, a contact poison is most effective. Stomach poisons are of no value against sucking insects on plants.

Flea Beetles

Several species of flea beetles attack tomatoes. Most important are the potato and eggplant flea beetles.¹ Adult insects are about $\frac{1}{16}$ inch long, brownish-black to black, and very active when disturbed.

Injury. Usually injury to the tomato is most severe during the early growing season. Leaves of badly injured plants are so full of small holes where the beetles have fed that they look as if they have been peppered with fine shot (Fig. 27). The margins of these feeding punctures usually dry out and cause the death of an entire leaf. The young of flea beetles attack the roots and lower stems of some crops, but they are not of much importance on tomatoes.



Flea beetles feed on the leaves of plants, leaving many small holes. This eggplant shows typical injury. Tomato leaves eaten by these insects have the same appearance. (Fig. 27)

¹ *Epitrix cucumeris* (Harr.) and *Epitrix fuscula* Crotch.

Life history and habits. Flea beetles spend the winter in the adult stage under trash and rubbish in or near the tomato field. In the spring they emerge and feed for a while upon wild host plants and later upon the tomato and other cultivated crops. They lay their eggs in the soil around plants that they feed on. After a few days, small white or yellowish-white larvae hatch from the eggs and start feeding upon the roots. One or two generations are produced each year.

Control. Closely watch young tomato plants, especially after they are transplanted, and apply control measures upon the first sign of injury. DDT at 1 pound per acre either as a dust or spray (page 55), is effective *if the plants are thoroughly covered*. Beetles quickly find the untreated parts of a plant and start feeding on them.

Tomato Hornworms

Largest and best known of the tomato insects are the tomato hornworms¹ (Fig. 28). These worms when fully grown are 3 to 4 inches long; are green to brown in color, with diagonal white stripes along the sides; and have a prominent horn on the rear end of the body.

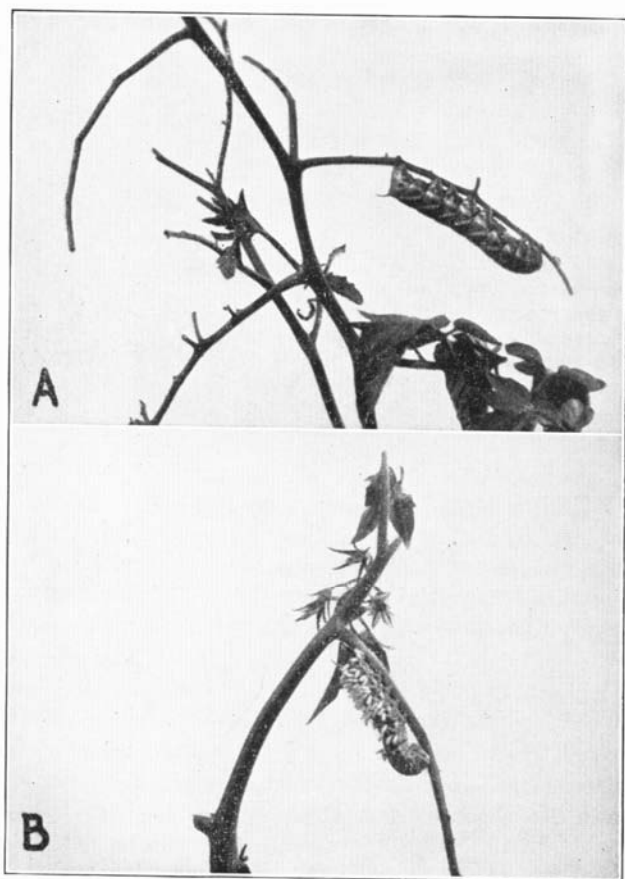
Injury. Hornworms are ravenous feeders. During the two or three weeks they spend on tomato plants, they consume large quantities of foliage and occasionally attack the fruits. Injury usually becomes apparent about the middle of the summer and continues until the end of the growing season unless the worms are controlled.

Life history and habits. Hornworms spend the winter as dark-brown, inactive pupae (cocoons) several inches below the soil surface. In the spring they emerge as large, dark gray hawk moths. These are often seen hovering over petunia, Jimson weed, and other flowers from which they sip nectar. They lay greenish-yellow eggs on the underside of tomato leaves. It takes about a week for the eggs to hatch and about 3 weeks for the worms to become full grown. At least a full first and a partial second generation occur during the growing season.

Control. Hand-picking is an effective way to rid a small garden of hornworms, but is not practicable where tomatoes are grown on a large scale. In large plantings, hornworms can be controlled by applications of 2 pounds of TDE, 3 pounds of toxaphene, or $\frac{1}{3}$ pound of endrin per acre as dusts or sprays (page 55).

During most seasons hornworms are held in check by tiny wasp parasites that feed within the bodies of the hornworms and kill the worms before they mature. Parasitized hornworms can be recognized by the white cocoons of parasites attached to their backs (Fig. 28). They should not be disturbed if hand-picking is used as a control measure. If undisturbed the parasites will emerge from the cocoons and attack other hornworms.

¹ *Protoparce quinquemaculata* (Haw.) and *P. sexta* (Johan.).



Hornworms can practically strip a plant of its leaves (A). They are held in check by tiny wasp parasites. Hornworms with parasite cocoons on their backs (B) should not be destroyed, since the hornworms will do no more feeding and the parasites emerging from the cocoons will attack other hornworms. (Fig. 28)

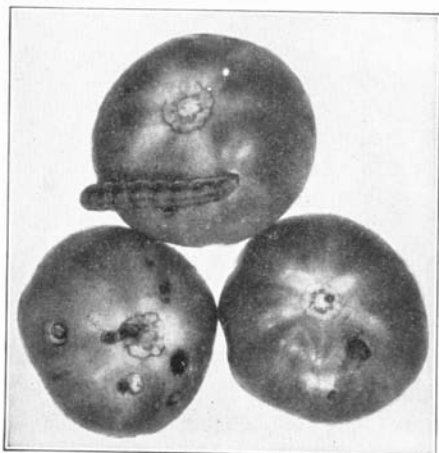
Tomato Fruitworms

By far the most destructive of the tomato fruitworms is the corn earworm.¹ This insect is often referred to simply as the tomato fruitworm, although the general classification of tomato fruitworms includes several species of cutworms as well. The corn earworm ranges in color from a flesh pink to green or dark brown, with darker stripes running the length of the body. Full-grown worms are usually about $1\frac{1}{2}$ inches long.

¹ *Heliothis zea* (Boddie).

Injuries on these tomatoes are typical of the damage done by the corn earworm. The fruit is ruined by the feeding of these worms. They may attack the fruit at any stage of its development.

(Fig. 29)



Injury. Unlike hornworms, corn earworms feed mainly on tomato fruit, attacking fruit of all sizes. They do not confine their feeding to single fruits, but move from one to another, destroying much more than they consume. Damage to the tomato crop (Fig. 29) is greatest when the moths are abundant and the supply of green corn silk is more or less limited. In northern Illinois the greatest injury occurs during the latter part of the growing season.

Cutworms sometimes attack tomato fruit, but ordinarily do not do much damage.

Life history and habits. The corn earworm does not often overwinter north of the Ohio river. To the south it spends the winter 2 to 6 inches beneath the soil surface as a brown pupa. The moth which emerges in the spring has a wingspread of about 1½ inches. The wings are dark straw to grayish-brown.

The moths lay their eggs on the fresh silks and tassels of corn, on tomato plants and eggplants, and on other host plants, both wild and cultivated. It takes five to seven days for the eggs to hatch. The worms feed for three weeks or more before becoming full-grown. During this time each worm injures several fruits. Pupation takes place in the ground soon after the worms become mature.

None of the pupae developing in the late fall are able to survive the cold winter in central and northern Illinois. Migrating moths are responsible for the initial tomato fruitworm infestation each year in the northern two-thirds of the state.

Control. Regular dusting or spraying of tomatoes for control of the corn earworm or tomato fruitworm is not necessary in northern Illinois until late in the season in years when the insect is abundant in field and sweet corn. However, this insect is damaging in southern Illinois almost every year. Where tomatoes are regularly attacked by

fruitworms, early and thorough treatment is essential for tomatoes free of worms.

Make applications of 1 pound of DDT or 1 pound of TDE as dust or spray at weekly intervals beginning at first fruit set. Either may be combined with fungicides used in the regular spray schedule, thus saving the expense of a separate application. When spraying is infrequent or when it begins after some damage is evident, use 3 pounds of DDT or TDE, or 6 pounds of toxaphene per acre.

Cutworms attacking tomato fruits can also be controlled in this manner.

Colorado Potato Beetles

The Colorado potato beetle¹ is an oval, hard-shelled insect about $\frac{3}{8}$ inch long, with alternate black and yellow stripes on the wing covers. The full-grown young are sluggish, soft-bodied, humpbacked grubs. They are red with two rows of black spots on each side of the body and are about the same size as the adult beetles.

Injury. This beetle is a typical chewing insect. Although it is primarily a pest of other crops, it often attacks tomatoes. Both the adults and larvae feed on the foliage and if they are numerous may completely strip the plants.

Life history and habits. The Colorado potato beetle overwinters in the adult stage several inches below the surface of the soil. The beetles come out of the soil in the spring to feed and lay cylindrical, orange-yellow eggs. The eggs are deposited in groups of 5 or more on the undersides of the leaves. It takes 4 to 9 days for the eggs to hatch and about 3 weeks for the grubs to become full-grown. These full-grown grubs then descend into the soil, make a spherical cell, and transform to the pupal stage. After 5 to 10 days, the adult beetles appear, feed for several days, and lay eggs for the second generation. Two generations occur annually.

Control. The Colorado potato beetle can be easily controlled by DDT dusts or sprays (page 55). The insecticide should be applied when the beetles or grubs are first noticed. One or two treatments should eliminate both the adults and larvae.

Garden Slugs

Several species of slugs attack tomatoes. Their presence is easily detected by the shiny trails of slime they leave in their paths. These slimy, repulsive creatures resemble snails in general appearance. They range in color from gray to dark blue and are 1 to 3 inches long.

Injury. Slugs are most troublesome during seasons when there is a great deal of moisture. They rasp out holes in the foliage and fruit of tomato plants, the principal injury being to the ripening fruit. Blemishes and decay are common on tomatoes that have been attacked.

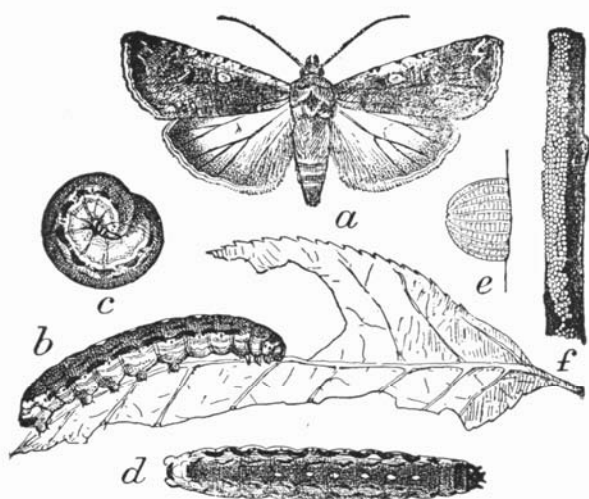
¹ *Leptinotarsa decemlineata* (Say).

Life history and habits. Slugs lay their eggs in clusters in moist soil or other protected places. These hatch in three weeks or more, depending upon the weather. Development depends largely upon food and living conditions. Slugs are said to live for several years.

Control. Metaldehyde is recommended for the control of garden slugs. Follow the manufacturer's directions in the use of this material. An application of hydrated lime may afford some protection.

Cutworms

Most growers are familiar with cutworms and the damage they do. Several species of these plump, well-fed worms (Fig. 30) damage tomatoes. Although they vary considerably in habits and appearance,



Newly hatched cutworms are usually darker and more hairy than mature ones. After feeding for about a month they become full grown (b, c, d). Then they change into pupae (cocoon), and remain in this stage about two weeks. Emergings as moths (a), they are ready to lay eggs (e, egg much enlarged; f, egg mass) to start a new generation.

(Fig. 30)

they are usually gray to brown or black in color and are from $1\frac{1}{2}$ to 2 inches long when full-grown.

Injury. Cutworms are ordinarily most troublesome during the early spring, doing their damage in the hotbed or in the field and garden soon after transplanting. They may cut the plants off at or near the ground level, feed on the foliage or fruit, or destroy the roots. The cutting off of the young plants is usually the most noticeable injury.

Life history and habits. Most of the common cutworms pass the winter in the worm stage. They may be found hibernating in the soil, clumps of grass, or other protected places. Feeding begins early in the spring and continues until the worms become full-grown. Pupation takes place underground. Adult moths emerge during late spring and commence laying eggs shortly thereafter. Eggs are laid on the ground,

and on the stems of weeds, grasses, or other plants. Most of the common cutworms have but one generation a year.

Control. Clean cultivation of crops that precede tomatoes is of considerable importance in cutworm control. Sod or weedy ground upon which tomatoes are to be grown the following year should be plowed during late summer or early fall and kept clean in order to keep cutworm moths from laying eggs.

In a small garden, cutworms can be collected by hand. Young plants can be protected by pressing tin or cardboard cylinders into the soil around the plants, or by wrapping the stem with a 4-inch collar of paper at transplanting time. One-half teaspoon of granular dieldrin or heptachlor worked into the soil about the base of the plant will protect the newly transplanted plants.

Sprays or dusts of $\frac{1}{2}$ pound of dieldrin, 1 pound of heptachlor, or 2 pounds toxaphene per acre will successfully control cutworms that attack plants above the ground. Treating the above ground portion of the plant will not control the black cutworm and others that feed underground. For these insects, the insecticide must be worked into the soil around the base of the plant. Land that is known to be infested with cutworms should be treated with insecticide several days before the tomatoes are transplanted into the field.

Aphids or Plant Lice

Aphids, or plant lice,¹ are small, soft-bodied insects that secure their food by sucking sap from the plants. They are about $\frac{1}{8}$ inch or less in length, and vary in color from solid pink to dark green. Both winged and wingless adults may appear on the same plant.

Injury. Aphids are seldom numerous enough on tomatoes to kill the plants. They may, however, stunt the plants and injure the fruit clusters enough to reduce yields. They also transmit virus diseases of tomatoes.

Aphids prefer the shaded parts of a plant, but may be found on exposed blossom clusters and growing tips. They feed entirely on juices extracted from plants with their small, piercing mouth parts.

Whether grown in the greenhouse or out-of-doors, tomatoes should be carefully watched for aphid infestation and promptly and thoroughly treated if the insects are abundant enough to cause damage.

Life history and habits. The potato aphid, which is commonly found on tomato plants, spends the winter in the egg stage on rose bushes. During the summer winged females are produced that migrate back to tomato, potato, and other plants, where they feed and reproduce. Both winged and wingless females occur, each capable of giving birth to as many as 50 young over a period of two weeks. Ten days to three weeks are required for the young to reach the adult stage.

¹ *Macrosiphum solanifolii* (Ashm.) and other species.

During the fall, winged females migrate back to the rose, where a generation of wingless egg-laying females is produced. Several generations are produced each year.

Control. Aphids can be controlled on tomato plants by a thorough application of either 2 pints of 40-percent nicotine or 1 pound of malathion dust or spray (page 56). Nicotine should be applied only when the temperature is above 70° F. One-half pound of parathion per acre is also effective on tomato aphids. Avoid overdosing with this insecticide as it may injure tomato plants.

Whiteflies

Greenhouse tomatoes are sometimes infested with tiny, powdery-white insects, known as whiteflies,¹ that swarm off the plants when disturbed. The adults, which may be seen at rest on the underside of infested leaves, are about $\frac{1}{16}$ inch long and have four wings. The young, also found on the underside of leaves, are very small, oval, scale-like creatures, light green in color.

Injury. Injury from this pest is common on tomatoes and other greenhouse crops. Both adults and young suck sap from the plants. If the infestation is very heavy, the plants become stunted and unproductive. The young excrete a sticky substance which covers foliage or fruit and supports a growth of black fungus.

Life history and habits. All stages of whitefly may be found at any time in an infested greenhouse. The eggs, which hatch in 10 to 14 days, are deposited on the underside of leaves. After hatching, the nymphs attach themselves and begin sucking sap from the plants. They are then oval-shaped, motionless, and light green. About two weeks from the time of hatching, adults emerge and begin at once to lay eggs.

Control. Whiteflies can be controlled by an application of 1 pound of malathion dust or spray per acre. Malathion applied in the form of a 10-percent aerosol at a dosage of 1 pound to 50,000 cubic feet is also effective. *While applying aerosol in a greenhouse, be sure to protect yourself by wearing a mask recommended to absorb the insecticide.*

Nematodes or Eelworms

Root-knot of tomato is caused by microscopic nematodes,² or eelworms. In Illinois these pests cause most trouble in the greenhouse, but may attack tomatoes in the field, especially if the young plants were grown in infested soil.

Injury. These very small white worms bore into the roots of tomato and other crops, causing characteristic knots or swellings, as shown in Fig. 31. This abnormal growth of the roots prevents the

¹ *Trialeurodes vaporariorum* (Westw.)

² Species of *Meloidogyne* Goeldi.

normal transportation of water and food materials, causing the plants to become stunted and eventually to die. If tomatoes are wilting or dying prematurely, a few plants should be dug up and the roots examined for this trouble.

Control. Every precaution should be taken to prevent infestation in houses that are free of this pest. Before planting, thoroughly sterilize infested soil, benches, and walks, preferably with steam (page 51).

If steam is not available, certain chemicals can be used to sterilize nematode-infested soil. These are (1) methyl bromide—ethylene dichloride-carbon tetrachloride, (2) ethylene dibromide, (3) methyl



An extreme case of root swelling and distortion caused by the root-knot nematode. Affected plants become stunted and eventually die. (Fig. 31)

bromide in xylene, (4) "D-D" mixture (dichloro-propane and dichloropropene), and (5) chloropicrin. Follow the directions of the manufacturer in the use of these materials.

Field or garden soil that is known to be infested should not be planted to tomatoes or other susceptible crops.

Symphylids

Symphylids¹ are primarily greenhouse pests in this state. Tomatoes cannot be grown successfully in houses where the soil is infested with these insects. They are white, centipede-like creatures, about $\frac{1}{4}$ inch long when full-grown, and may be found to a depth of 3 feet in the ground.

Injury. By eating off the young roots, these tiny creatures cause plants to become badly stunted and finally die. They may also attack the larger roots and underground parts of the stem, making them warty and tough.

Life history and habits. Throughout the year an infested greenhouse will contain symphylids in all stages of development. They spend their entire life below the soil surface. Usually they lay their eggs, which are almost invisible to the naked eye, several inches below the surface. It takes 4 to 6 weeks for symphylids to complete their development from egg to adult.

Control. Prevention is better than cure, for once an infestation has become well established in a greenhouse, it is hard to clean up. Symphylids are most easily controlled in raised benches, though even this is difficult. All symphylids and eggs in raised benches can be killed by steam sterilization if this is properly done. In ground benches, steam sterilization will kill all symphylids in the upper part of the soil. Since some of the eggs and adults survive in the lower subsoil, sterilization will have to be repeated each year in order to prevent serious injury. Walks, as well as benches, must be treated.

Infestation is sure to occur again in sterilized benches if infested soil is brought in from the outside or other parts of the greenhouse. Lindane gives good control of symphylids. Use 5 ounces of 25-percent lindane wettable powder in 50 gallons of water and apply the mixture to 1,000 square feet. Additional watering will aid penetration of the chemical into the soil.

Mites

Spider mites and tomato russet mites are sometimes troublesome in commercial plantings. Malathion at 1 pound and kelthane or parathion at $\frac{1}{2}$ pound per acre give good control of spider mites. Sulfur is very effective against tomato russet mites. Use either 10 pounds of wettable sulfur or 30 pounds of sulfur dust per acre. Parathion or kelthane can also be used to control russet mites.

¹ *Scutigera immaculata* (Newp.).

Cloudy Spot of Tomato Fruit

Cloudy spot of tomato fruit is one of the most common troubles reported from Illinois home gardens. It is most common from late July or early August until the end of the season when activity and feeding of the stink bugs stop. Although these bugs may be so few in number as to go unnoticed, only a very few are necessary to cause cloudy spots on most tomatoes in the home garden.

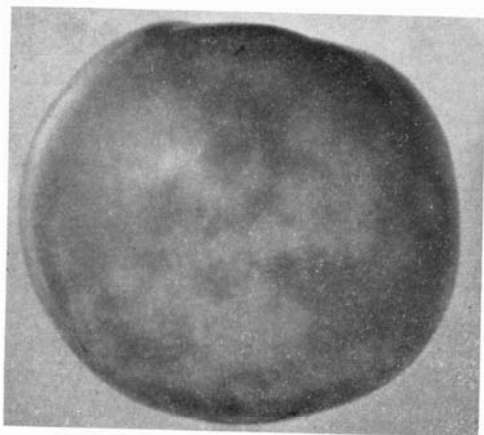
Injury. The injuries appear on the green fruit as whitish areas with indistinct borders. Isolated spots may be from 1/16- to 1/2-inch or so in diameter, or the spots may run together and involve a large portion of the fruit surface (Fig. 32). On ripe fruit the spots are light yellow. If the skin is peeled back, the discolored area is seen to consist of shiny, somewhat spongy masses of tissue that do not extend deeply into the fruit. The processor, however, must cut these areas out to get whole canned tomatoes of top quality.

Life history. The stink bug overwinters as an adult in debris along fence rows and ditch banks. The adults leave hibernation in early spring to feed and lay eggs in weeds or weedy areas. The bugs, hatched from the eggs, suck plant juices and become full grown in 4 to 6 weeks. In Illinois 3 or 4 generations are probably produced each year.

Control. Stink bugs are difficult to control. Weedy areas, such as fence rows and ditch banks, are homes of these insects. Spray weedy areas near commercial gardens with 1 pound of DDT or 2 pounds of toxaphene in 100 gallons of water. In commercial gardens while the tomatoes are still small, apply 3/4 pound of actual DDT or 2 pounds of toxaphene in enough water to cover the foliage thoroughly. Wash all fruit before use.

Spray weedy areas near home gardens with 4 tablespoons of 25-percent DDT emulsifiable concentrate in 1 gallon of water. Spray the foliage of tomato plants thoroughly with 3 teaspoons of 25-percent emulsifiable concentrate. Wash fruit before use.

The feeding of stink bugs caused the indistinct whitish or yellowish areas on this tomato. (Fig. 32)



SEED TREATMENT

Tomato seed treatments are of two types: *Eradicative seed treatment*, which destroys disease-producing fungi and bacteria carried with the seed; and *protective seed treatment*, which coats or "galvanizes" the seed coat, thus protecting the seed against decay and damping-off caused by soil organisms. Both types of treatment are important in producing disease-free tomato plants. Since very few seed-treating materials will serve as both eradicants and protectants, it is usually advisable to follow the eradivative treatment with a protective treatment.

Eradicative Seed Treatments

Hot water, bichloride of mercury, or New Improved Ceresan can be used for eradivative treatment. Hot-water treatment will eliminate most internal and external seed-borne disease organisms; the other two materials will disinfest only the surface of the seed. Bichloride of mercury is available at any drug store, is relatively easy to use, and is therefore especially recommended for the home gardener. New Improved Ceresan can be bought at most seed and farm-supply stores.

Hot-water treatment. Put the seed in a loosely woven cotton bag, filling not more than half the bag. Then soak the seed for 25 minutes in hot water held at 122° F. It is very important that water be kept at this temperature. If it gets even 2 or 3 degrees hotter, the seed may be injured. For this reason, an accurate thermometer is essential.

For best results the volume of water should be at least five times the volume of the seed. When the seed bag is first put in the water it should be worked with the fingers to make sure that all seeds are

CAUTION — All the chemicals used for seed treatment are injurious to man and animals when taken internally. Some may cause severe skin irritations if allowed to accumulate. Every precaution should be taken to avoid inhaling them. Wear a dust mask or respirator if large quantities of seed are being treated with dusts. Wash exposed skin surfaces at frequent intervals with soap and water. When finished with treatment pour all chemical solutions down the drain or pour out in such a way that they will soak into the ground.

wetted and that all air is out of the bag. After treatment pour out the seed in a thin layer on paper or screens in a warm but not hot place. When the seed is thoroughly dry (24 to 36 hours after treatment) it should have a *protective* treatment.

Bichloride of mercury treatment. This material (also known as mercuric chloride and corrosive sublimate) can be bought in the form of blue tablets or as a crystalline powder. It is mixed with water in a non-metallic container at the rate of 1 to 2000. One tablet in 1 quart of water or $\frac{1}{8}$ ounce of the powder in $7\frac{1}{2}$ quarts of water will give the right proportions. First completely dissolve the chemical in a small amount of boiling water; then add as much cold water as is needed. There should be at least 1 gallon of solution for each pound of seed.

Put the seed in a cotton bag and soak it in the solution for 5 minutes. Remove the seed from the solution, let it drain for a few seconds, wash it in several changes of water, and spread it out in a thin layer to dry. After the seed is thoroughly dry, it should be given a *protective* treatment. A bichloride of mercury solution should be used for only one lot of seed and then discarded.

This material is a **DEADLY POISON**. Before using, read carefully the precautions on page 48.

New Improved Ceresan treatment. Add this dust to the seed at the rate of $\frac{1}{2}$ of 1 percent by weight. This is equivalent to approximately 1 teaspoonful to 1 pound of seed or 4 ounces to 50 pounds of seed. Shake together the seed and chemical in a closed container such as a fruit jar, lard can, or rotating drum until each seed is coated. Before using the seed, store it for at least 2 or 3 weeks in a cloth bag in order to insure disinfestation by the volatile fumes of the chemical. *A protective treatment is not necessary.*

Like bichloride of mercury, this material is a **DEADLY POISON**. Precautions are given on page 48.

Protective Seed Treatments

Phygon Seed Protectant (dichlone), Orthocide 75 (captan 75), Arasan (thiram), and Semesan have given the best results in Illinois as protectants against seed decay and damping-off. Most seed and farm-supply stores carry one or more of these materials. Recommended rate of application for Phygon, Orthocide 75, and Arasan is 1 level teaspoonful to 1 pound of seed, or 3 ounces to 50 pounds of seed. That for Semesan and Cuprocide is $\frac{1}{2}$ level teaspoonful to 1 pound of seed or $1\frac{1}{2}$ ounces to 50 pounds of seed. Combinations of a fungicide and an insecticide may be purchased.

The method of treatment is the same as that given for New Improved Ceresan except that it is not necessary to store the seed after treatment. The seed can be sown at once or stored for some time if

kept dry and in a container that will permit some air circulation. Any excess fungicide remaining after treatment can be screened off and used again.

SOIL STERILIZATION

When properly done, sterilization of the soil is one of the most effective ways of controlling soil-borne diseases, nematodes, insects, and weeds. The two means most commonly employed are: (1) heat sterilization with steam or dry heat and (2) chemical sterilization with formaldehyde or chloropicrin.

Certain precautions must be taken, regardless of the method used, if soil sterilization is to be effective:

The soil must be friable (easily crumbled) so that the heat or the chemical can penetrate the largest particles.

The soil must not be too wet. The higher the water content of the soil, the longer it takes to steam-sterilize it. Also, excessive water may dilute sterilizing chemicals to the point where they no longer will be effective.

Soil temperatures should be 60° or higher for most effective chemical sterilization and for rapid escape of the residual gases after sterilization is complete.

Barnyard manure, other humus material, and sand must be added before sterilization. Soil may be reinfested with disease organisms if these materials are applied after it has been sterilized.

Recontamination of sterilized areas should be avoided. If possible, set aside a complete set of tools (rakes, hoes, etc.) for use only in these areas. Otherwise, dip them in a 1-to-20 formaldehyde solution after each use in contaminated soil and before use in sterilized soils. Do not transplant seedlings and other plants from unsterilized into sterilized soil. This practice is almost sure to result in recontamination of the treated soil.

After sterilizing soil with steam it is a good practice to wait a week or ten days before seeding or planting. In the meantime the soil should be watered thoroughly once or twice. If this is not done, some difficulty may result in germinating seeds or growing plants.

Steam Sterilization

This is probably the best way to rid the indoor seedbed and hot-house of soil-borne plant pests and weeds. Any one of several methods may be used. Regardless of the method, the temperature of the soil farthest removed from the steam inlet should be kept at 180° F. for at least one hour. The temperature can be determined by inserting thermometers into the soil at various depths. In ground beds, it will usually suffice to raise the temperature at the surface of the soil to 180° F. provided the soil is well loosened beforehand. The process may be considered complete when a medium-size potato, buried about 3 inches under the surface of the soil, is well cooked. Efficiency of the sterilization can be increased by covering the soil with heavy plastic, canvas, sisalkraft paper, or burlap.

Underground tile method. Tile lines for draining soil in the greenhouse can also be used for steaming, provided they are close enough together, are not sunken out of line, or are not filled in places with soil. Best results have been obtained by using 4-inch tiles laid in parallel lines 24 inches apart and at a depth of about 15 inches in the soil. Pipes from the boiler are connected to the tile lines.

Underground pipe method. Essentially the same as the tile method, this method is especially adapted to raised benches although it may be used in ground beds. The piping should be 1½ to 2 inches in diameter and bored with ⅜-inch holes about a foot apart.

In benches, lay piping, holes down, about 1 inch from the bottom and 15 inches apart. If placed in the ground, the piping should be about 15 inches deep and about 18 inches apart. The piping may be installed as a permanent fixture, but most growers prefer to remove it after each sterilization so that it won't deteriorate so fast. To make pipes easy to take out, fasten wires at 15- or 20-foot intervals when the lines are being laid. The wires should extend far enough above the surface of the soil that they can easily be caught hold of.

Aboveground pipe method. This method is probably less expensive and less time-consuming than any other. It is simply a matter of laying metal downspouting (rain pipe) on top of the soil and leading steam directly from the boiler line into the pipe. Usually small holes are drilled alternately on opposite sides of the downspouting. Since no two steam systems are exactly the same, the only way to determine the exact size and spacing of holes is through trial. As a rule, the nearer the holes are to the steam inlet, the larger or the closer together they must be. In some installations the holes in the spouting are ¼ inch in diameter, from 18 to 24 inches apart near the steam inlet, and as much as 36 inches apart at the opposite end. This system also works well if the downspouting is not drilled but is laid down with a small space left between sections.

Ordinarily, it is best to cover not more than 100 linear feet of

bench or bed space at a time. To accomplish this most conveniently, lead the steam into a T-coupling at the center of the bed — just above the soil surface — and then into two 50-foot downspouting pipes. When the pipes are in position on top of the soil, cover soil and pipes with canvas or sisalkraft paper, tacking or weighting it down along the edges of the bench. The temperature and time interval are the same as for other steam-sterilizing methods.

Inverted pan method. This method is especially suitable for sterilizing soil in benches and flats. It may also be used on ground beds if the area to be treated is small and the soil well-loosened before treatment. The pan may be any desired shape in order to fit a bench or ground area of given width, but should not be more than 24 square feet. It should be at least 8 inches deep. Before steaming, press the pan firmly into position. It may be necessary to weight the pan down to hold it in place.

A flexible hose connects the pan to the steam line. The hose fitting and intake should preferably be at the end of the pan. Temperature and timing are the same as for other steam-sterilization methods.

Dry-Heat Sterilization

This method, while very effective, is suitable only when small amounts of soil are to be sterilized. It is especially recommended for use by the home gardener.

Moisten the soil until it tends to cling together when squeezed in the hand. Then put it in a small flat or a similar container not over 4 or 5 inches deep, and bury a small potato, about 1½ inches in diameter, in the center. Put the soil and container into a low-heat oven held at about 200° F. and heat until the potato is well cooked. The soil will have been sterilized sufficiently when this point is reached.

Chemical Sterilization

There are times when steaming or other heat treatments are not practical. Under these circumstances, growers may resort to formaldehyde, chloropicrin (tear gas), or other chemicals (see page 44, under "Nematodes" for additional names). Formaldehyde has been shown to be very effective in controlling soil-borne tomato diseases. However, it will not kill nematodes or most weed seeds. Chloropicrin has not been tested extensively in Illinois, and results of the tests thus far have been somewhat erratic. In some sections of the country, however, it apparently has given excellent control of soil-borne diseases, insects, nematodes, and weeds.

Directions for the use of formaldehyde are given below. Follow the directions of the manufacturer when using any of the other chemicals.

Formaldehyde. Mix 1 gallon of 38 to 40 percent (commercial) formaldehyde in 24 gallons of water. Apply to the spaded and pul-

verized soil with a sprinkling can at the rate of 1 quart to each square foot, then cover the soil with canvas or paper. After 48 hours remove the cover and allow the formaldehyde fumes to escape. The soil may be worked with a fork to hasten the drying process. Do not put seeds or plants in the treated soil for 10 days or two weeks after treatment, or not until all formaldehyde fumes have left the soil. Formaldehyde should never be used in greenhouses where plants are growing, for the fumes are likely to cause injury.

CAUTION — Chemical soil fumigants often are irritating to the membranes of the mouth, eyes, nose, and throat. Therefore, exercise extreme care when using them. Take care not to spill any of the liquid chemicals on hands or clothing. If this should happen, wipe it off the skin promptly or remove affected garment at once.

FUNGICIDES AND INSECTICIDES

Several fungicides and insecticides are suitable for the control of diseases and insects on tomatoes. These materials can be used profitably only if (1) a spray or dust is selected that is known to control the disease or insect concerned, (2) the plants are uniformly covered, and (3) applications are properly timed.

Most fungicides and insecticides can be combined and applied in one operation, thus saving considerable time and labor. When combining pesticides, use the same proportions as if they were to be applied separately.

Spraying gives better control of tomato diseases and insects than dusting. Dusting has a place, however, when outbreaks of disease and insects threaten and large acreages must be covered rather quickly.

Recommended Fungicides

Recommendations for fungicides are based on results of experiments at the Illinois Agricultural Experiment Station and at stations in other states. It is likely that these recommendations will be changed somewhat from year to year as new and more effective fungicides and schedules are developed and are tested under commercial conditions. The fungicides listed are compatible with most organic insecticides. None of these, however, except fixed coppers, should be mixed with calcium arsenate suspensions. Regardless of what fungicide is used, read carefully the "Caution" on page 56 before mixing and using.

Fixed coppers have largely taken the place of bordeaux mixture because they are less apt to cause plant injury and are easier to prepare. They can be purchased ready to mix with water for spraying or in a form suitable for dusting. Fixed coppers, which are sold under various trade names, include such forms as basic copper sulfates, basic copper chlorides, copper oxychlorides, cuprous oxides, and copper hydroxides.

Zineb is the common name given to organic fungicides, such as Dithane Z-78 and Parzate, which contain zinc ethylene bisdithiocarbamate. It can be made in the spray tank by mixing nabam (disodium ethylene bisdithiocarbamate, as in Dithane D-14 or Parzate Liquid) with powdered zinc sulfate in water. Zineb prepared in this way is equal to, if not better than, the preparation made by mixing Dithane Z-78 or Parzate powder with water.

Maneb is the common name applied to fungicides, such as Manzate and Dithane M-22, which contain manganous ethylene bisdithiocarbamate. Maneb can be made in the spray tank by mixing nabam with powdered manganous sulfate in water.

Ziram is the common name for organic fungicides, such as Zerlate, Karbam white, and Corozate, which contain zinc dimethyl dithiocarbamate.

Dichlone is the common name given to fungicides, such as Phygon-XL and Phygon Seed Protectant, which contain 2, 3-dichloro-1, 4-naphthoquinone.

Captan is the common name applied to fungicides such as Orthocide 50W, Captan 50W, Orthocide 75, and Stauffer 75-W, which contain N-(trichloromethylthio)-4-cyclohexene-1, 2-dicarboximide.

Fungicide Schedules

If home-grown plants are used, they should be given one or two applications of ziram, fixed copper, dichlone, captan, or zineb while in the seedbed. Likewise, direct-seeded fields should be sprayed or dusted before blocking and thinning. Fungicides applied at this time give protection against collar rot, anthracnose, and early stages of various leaf-spot diseases. The fixed-copper fungicides should not be applied immediately before or after seedlings or plants are transplanted.

If late blight or leaf-spot diseases appear before flower development, another treatment with fixed copper, maneb, or zineb may be needed.

A regular spray schedule for tomatoes in the field should begin between two and three weeks after the first crown-cluster flowers appear. At least four or five applications at 10-day intervals will be necessary, with the exact number depending on weather conditions.

More than five may be needed if the weather is cool and rainy, and if late blight is present in the field or general vicinity.

Dosage. For home gardens, use 1 level tablespoonful of maneb or dichlone, 2 of zineb or ziram, and 3 of fixed copper or captan in each gallon of water. For use on tomatoes for the fresh market or for processing, follow exactly the directions given on the label of the container.

Insecticides

DDT is effective against several insect pests but it must be used carefully on tomatoes because there is danger of injuring young plants. It is available as a dust, and as emulsion concentrates and wettable powders for spraying.

To save the expense of a separate application, DDT may be mixed with any commonly used fungicide or pesticide *except* those containing lime, such as bordeaux mixture or nicotine sprays or dusts. It may be used as follows:

Dust

3-percent DDT

Apply 50 pounds an acre
— or —

5-percent DDT

Apply 30 pounds an acre

Spray

50-percent wettable DDT

Use 2 pounds in 100 gallons water an acre
— or —

25-percent emulsifiable DDT

Use 2 quarts in 100 gallons water an acre

TDE, formerly called Rhothane, will control tomato hornworms and tomato fruitworms. It is sold as emulsion concentrates and wettable powders for spraying. The residues of TDE are less toxic than those of DDT, but it must be used according to the manufacturer's directions. The spray should be prepared as follows:

50-percent wettable TDE

Use 2 pounds in 100 gallons of water an acre

— or —

25-percent emulsifiable TDE

Use 2 quarts in 100 gallons of water an acre

Parathion is a relatively new insecticide. Although highly effective against aphids it is a **DEADLY POISON** and should not be used where a safer material will give reasonably satisfactory control. If you use this material, be sure that you know and enforce the proper precautions. **When applying parathion, wear a good respirator or dust mask and protective clothing. Bathe or shower as soon as possible after using this material. The home gardener should not use this material. Do not apply parathion to tomatoes within 15 days of harvest.**

Nicotine is effective against aphids, but has little other place in

tomato-insect control. Forty-percent nicotine sulfate is the commonly used form. Nicotine is poisonous to humans and therefore should be handled with extreme care. It may be used as follows:

Dust

40-percent nicotine sulfate

Mix 3 pints with 50 pounds hydrated lime and apply 30-40 pounds an acre

Spray

40-percent nicotine sulfate

Use 3 pints with 9 pounds soap in 150 gallons water an acre

Malathion, a new phosphate insecticide, is very effective against aphids and mites. It is a very safe material to handle. For necessary precautions and dosage rates on tomatoes, follow the manufacturer's directions printed on the label.

Dieldrin, heptachlor, and toxaphene act as contact and stomach poisons. These chemicals are chlorinated hydrocarbons and control many vegetable insects very effectively. They are now available in granules, as well as in the regular dusts, wettable powders, and spray formulations.

CAUTION — All the chemicals used for spraying and dusting are injurious to man and animals when taken internally. Some may cause severe skin irritations if allowed to accumulate. Every precaution should be taken to avoid inhaling them. Wash exposed skin surfaces at frequent intervals with soap and water. Bathe or shower and change clothes after applying insecticides or fungicides. Zineb is inflammable.

To avoid dangers from handling and using these chemicals and to make sure no hazardous residues remain on tomatoes, the directions of the manufacturer should be READ, UNDERSTOOD, AND CAREFULLY FOLLOWED.

SPRAYING AND DUSTING EQUIPMENT

Home Gardens

Manually operated sprayers and dusters are suitable for use in the home garden, where only a relatively small number of plants are grown. Regardless of the type, a sprayer or duster should have enough force to drive the insecticide or fungicide into the center of the plant.

A coarse, driving spray may give better coverage of the fruit and inside leaves than a fine, mist-like spray. Frequent agitation of the spray suspensions will be necessary to prevent the pesticides from settling out. Home gardeners will find that prepared mixtures containing insecticide and fungicide are usually available at local pesticide

stores. These products are quite effective and are easy to use. The new granular insecticides in 1-pound containers are particularly adaptable for use in the home garden to control soil insects.

For the home gardener who needs a small amount of spray, a table of measurements is given below. This table shows how the recommendations given in this circular can be adjusted for preparing small amounts of spray.

Suppose you want to make a gallon of DDT spray for flea beetles. First look up flea beetles on page 37 and write down the dosage of DDT recommended per acre (1 pound). Then read the label on the container of the insecticide you have bought and turn to the table below. If you have bought 25-percent DDT wettable powder, use 2 tablespoons in 1 gallon of water. If you have bought a liquid DDT (called emulsifiable concentrate) containing 2 pounds of DDT per gallon, use 4 teaspoons of the liquid DDT in 1 gallon of water.

Measurements for Small Quantities of Spray

(Based on 1 pound of active insecticide in 100 gallons of water per acre)

Type of formulation	Amount of insecticide needed in		
	25 gallons of water	5 gallons of water	1 gallon of water
Wettable powder			
15 percent.....	1½ lb.	16½ Tb.	10 tsp.
25 percent.....	1 lb.	10 Tb.	2 Tb.
50 percent.....	½ lb.	5 Tb.	1 Tb.
Emulsifiable concentrate, per gallon			
1½ lb.....	2½ c.	8 Tb.	5 tsp.
2 lb.....	1 pt.	6 Tb.	4 tsp.
5 lb.....	¾ c.	2½ Tb.	1½ tsp.

All measurements are standard and level.

No adjustment of dust formulas is necessary for home gardens. However, thorough coverage with dusts, as with sprays, is desirable.

Commercial Fields

High-pressure sprayers. Most of the large spray-machinery companies make large-volume, high-pressure sprayers which are satisfactory for applying fungicides or insecticides in commercial fields. These sprayers cover as many as 10 rows on one trip across the field (Fig. 33).

In order to use conventional sprayers, some growers have adopted a spacing of 5½ to 6 feet between rows, with the plants 2½ to 3 feet apart in the rows. These distances provide not only room for wheeled equipment but also more space for pickers to walk and place hampers.

Regardless of the type of power-driven, wheeled sprayer employed, certain details must not be overlooked. The *nozzle disc* should be at least a No. 5 (hole with a diameter of 5/64 inch). Although discs smaller



A wide boom is needed on high-pressure sprayers used for tomatoes. This will keep down vine damage and also permit coverage of a maximum number of acres in a day. The sprayer pictured will cover 9 rows. (Fig. 33)

than No. 5 make pressures easier to maintain, they break up the spray stream into such a fine mist that part of it drifts away and the remainder wets only the outside leaves of the plant. There should be at least three nozzles to each row. *Pressures* in the spray lines should be at least 200 but not over 500 pounds to the square inch. *Speed of operation* should not exceed 3 or 4 miles an hour. Proper *gallage* can be obtained by regulation of pressure, speed, disc size, and number of nozzles to the row. It is usually necessary to experiment with each sprayer to find the proper regulation.

Vine lifters are not essential equipment but if put on the tractor wheels will prevent a certain amount of vine damage. *Proper mixing* of fungicides or insecticides in the spray tank is necessary for good control of diseases and insects. The tank should not be more than half full when the pesticide is added. It is advisable to make a thin paste of the fungicide with water in a pail before pouring it into the tank. After thorough mixing in the tank, which means running the sprayer agitator for at least one minute, the rest of the water is added and agitation continued for another minute or two before spraying is started.

Low-gallage, mist-concentrate sprayers. These sprayers have a high-speed, motor-driven propeller which blows water droplets containing fungicides to the plants (Fig. 34). Since the water-fungicide suspension is deposited on leaves and fruit in droplets instead of in a continuous film, the concentration of the fungicide is usually increased.

Thus if 3 pounds of a fungicide in 160 gallons of water is applied per acre with a conventional, high-gallonage sprayer, then the concentration must be increased in the low-gallonage sprayer to $2 \times$ (3 pounds in 80 gallons), $4 \times$ (3 pounds in 40 gallons), or $8 \times$ (3 pounds in 20 gallons) in order to achieve comparable disease control. The amount of water used per acre will depend on pump and nozzle capacity, as well as speed.

This type of sprayer is lighter in weight and covers a wider swath than the high-pressure sprayer. Spray-deposit tests indicate that fairly uniform coverage of foliage and fruit can be obtained if these sprayers are carefully operated.

Dusters. Power dusters for use on tomatoes should have two or three outlets to the row and should discharge equal quantities of dust from each outlet. New types of dusters have been developed which put out the same amount of dust regardless of whether the dust hopper is full or one-fourth full. Fungicidal dusts should be applied at the rate of at least 50 pounds to the acre if conventional ground equipment is used. Dew does not have to be present but if the wind is strong enough to prevent complete coverage, dusting operations should be suspended.

Airplanes. Airplanes have been used in some instances for applying fungicides and insecticides to tomatoes. Airplane dusting may be of considerable value in combatting late blight where large acreages have to be covered in a short time. The fungicide dosage should be between 60 and 70 pounds to the acre. The application of liquid fungicides to tomatoes by airplanes cannot be recommended at present.



This mist-concentrate sprayer will cover 20 or more rows of tomatoes in one round trip across a field. Sprayers of this type carry less water than high-pressure sprayers and thus are lighter in weight.

(Fig. 34)

How to Send Diseased Plants for Identification

If a disease appears in your tomatoes that you can't diagnose from the information in this circular, you may send a specimen from the diseased plant to the Department of Plant Pathology, University of Illinois, Urbana, Illinois.

Select representative samples of the diseased material you want identified and, if possible, a sample of similar material from a healthy plant. Send plenty of material. A small specimen often fails to show a sufficient range of symptoms to make accurate identification possible.

Leaves. Press flat between several sheets of newspaper or paper toweling, place between two layers of cardboard, and mail in an envelope. Do not moisten the paper or the plant.

Fruit. Send fresh fruit showing symptoms. Do not send fleshy fruit in advanced stages of decay. Wrap separately in paper toweling or newspaper and pack in a strong cardboard box. Do not pack in foil, moistened paper, cotton, or a plastic bag.

Roots, stems, or entire plants. Wrap moistened paper toweling tightly around roots. Wrap stems or entire plants in dry paper. Do not moisten tops of plants. Mail in a strong cardboard box.

If possible, mail all specimens so that they reach the University later than a Thursday. Specimens that lie in the post office over a weekend are likely to spoil. Since letters and specimens mailed separately are apt not to arrive at the same time, a letter should be enclosed with the specimen or attached to the package. The letter should give the variety of the plant involved, a description of the disease, weather, and soil conditions, and the kind and amount of fertilizers, fungicides, insecticides, and other chemicals that may have been applied to the soil or plants. Don't forget your return address.