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The Tipblight Disease of Tomato

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INTRODUCTION

THE name tipblight† has been given to a "new" tomato disease typically developed in those counties of Southern Oregon where tomatoes are grown for canneries. The name was suggested by the very noticeable blighting and blackening of the terminal shoots that superficially resemble both early blight (caused by the fungus *Macrosporium solani*) and bacterial canker (caused by *Bacterium michiganense)*. This tipblight, however, is in no way related to either of these diseases. It is a virus disease. As a virus disease it falls within the general group of plant diseases typified by such terms or names as "mosaic," "crinkle," "streak," "curly top," and "spotted wilt." Tipblight has frequently so reduced yields that neither the growers nor the canners have been able to meet their obligations. The present bulletin describes the disease, its distribution, infectiousness, means of spread, and certain facts about the causal virus that are considered necessary for discussing methods of control.

The research on which this bulletin is based was carried out both at the Southern Oregon Branch Experiment Station at Talent, Oregon, and at the Central Experiment Station at Corvallis, Oregon. The results of a four-year field and laboratory study are herein summarized for the benefit of tomato growers.

HISTORY AND DISTRIBUTION

The date of the first occurrence of tipblight in Southern Oregon has not been determined, but we do know that it has been there since 1931. The first survey of the disease was made in 1932. Since then comprehensive surveys of the disease have been made in practically every locality of the state where tomatoes are grown for market or canning purposes. These localities include Josephine, Jackson, Douglas, Marion, Umatilla, Multnomah, Lane, Benton, and Hood River counties. From this survey, and from tests on distribution made by planting small plots of tomatoes known to be susceptible to the disease at intervals between Corvallis and Medford, it has been shown that the disease has been confined to Jackson and Josephine counties. There is only one record of the disease in Josephine County; it was found there in 1936. The disease is not seed borne. The narrow range of this disease within the state, therefore, relates to certain local factors in these counties. What these factors may be is suggested in the section on how this disease overwinters.

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* This bulletin is based on the thesis of the junior author presented to the faculty of the Oregon State College in part fulfillment of the requirements for the degree of Doctor of Philosophy and on field and laboratory investigations by the senior author. The authors are greatly indebted to Mr. F. C. Reimer, Superintendent of the Southern Oregon Branch Station, who furnished both a place to work and special plantings of tomatoes to meet the requirements.

† McWhorter, F. P. and Milbrath, J. A., 1934. The interpretation of Oregon tipblight on a basis of causal virus. Abs. Phytopath. 25:897-898.

ECONOMIC IMPORTANCE

The economic importance of tipblight is potentially great because blighted plants either die or else yield only unmarketable fruits. The loss, therefore, is directly proportionate to the percentage of plants infected. In 1932, 1933, and 1934 the percentages of infection were high, amounting to about 20 per cent of the crop; in 1935 it was much lower; in 1936 there was only a trace of the disease; in 1937 it increased noticeably over the preceding year. The statement that as much as 20 per cent of the crop may

Figure 1. Characteristic appearance of large plant diseased with tipblight.

be destroyed does not properly emphasize the local importance of the disease, as individual growers lose proportionately far more than the percentage loss of the region. Thus, for example, in 1933 a few growers had every plant infected and lost every tomato, while other growers lost only a few. The reason for this localization of the disease has not yet been explained, but this scattering of infection must be considered when computing its economic significance.

THE CAUSAL AGENT

As stated above, tipblight is caused by a virus. The scope of this circular* does not permit a detailed discussion of the long series of tests

* These factors will be discussed in a technical paper by the junior author.

whereby this has been proved and the properties of the virus have been established. A short discussion of some of the properties of the virus is given to facilitate understanding the nature of the disease.

It was easily shown by direct microscopical examination that no visible germ of fungous or bacterial nature was associated with the prominent foliage symptoms. The absence of a visible germ and the presence of ex-

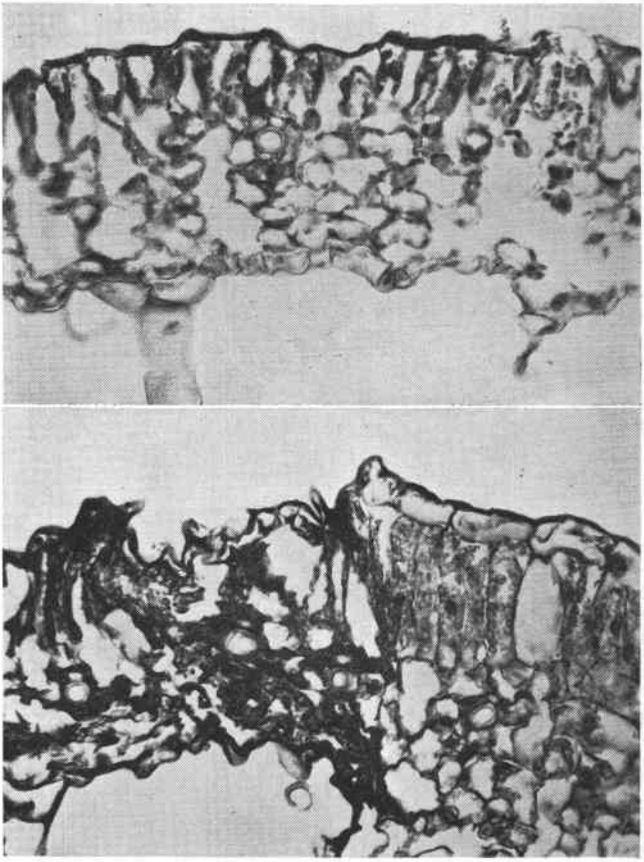

Figure 2. Photomicrographs of very thin cross sections of tomato leaves showing the effects of spotted wilt and tipblight viruses. Above: The spotted-wilt virus destroys only the epidermal area; this shallow kill is responsible for the "bronzing" appearance. Below: Tipblight spots are localized but result from the killing of the tissue from one side of the leaf to the other.

treme tissue modifications within diseased stems and leaves pointed to an invisible virus as the probable cause. Preliminary attempts to transfer the disease from tomato plant to tomato plant were failures. It was later learned that this was because the virus is very difficult to transmit, a fact in turn related to what may be termed the fragile nature of the virus. It has not been isolated as visible crystals, but has been studied as a component of the juice from diseased plants. It has the lowest thermal death point—i.e., resistance to heating—of any known virus, being destroyed by 10 minutes heating at 41.5 degrees C. It is inactivated quickly by exposure to air. At room temperatures infectious juice loses its potency within 60 minutes. The virus can be transmitted experimentally from diseased to healthy tomato plants by grafting and by using an abrasive such as carborundum* to introduce it into the leaf tissues. Other methods have failed. Even the highly efficient carborundum method fails with this virus unless the infectious juice is extracted from recently infected plants and rubbed into vigorous plants. The virus is not seed borne but can be disseminated by certain species of thrips.

The symptoms of the disease—i.e., the effects of the virus—on Indiana Canner and other varieties of tomato are described below. These effects somewhat resemble the appearances induced by the viruses that cause tomato streak, but they are very different from those caused by the virus responsible for spotted wilt. Tipblight is easily distinguished from streak by great differences in the properties of the viruses. It differs significantly from spotted wilt in its effects on the foliage of tomato plants and also in its properties; the virus of tipblight is more destructive. The fundamental difference between the effects of the viruses of tipblight and spotted wilt is shown in Figure 2. The bronzing of spotted wilt results because the virus produces notable effects only in the epidermis of the leaf. Note the dead epidermal layer (indicated as black crushed cells) shown in Figure 2. The lower figure (2) shows a section of a black spot area in a leaf infected with tipblight. Observe that a limited area of the leaf is killed from the upper to the lower surface, the necrotic area not being confined to the epidermis. Other differences between the two viruses, including the responses of nontomato test plants, will be discussed in a technical paper by the junior author.

SYMPTOMS

Indiana Canner, the tomato that has been grown in Jackson County more than any other variety, was selected for special study. The symptoms on this variety have been determined from field observations as well as experimental inoculations. It seems advisable, therefore, to divide the discussion of how tipblight affects tomato plants into two sections, the first of which deals with Indiana Canner. The second section describes how other varieties which could be grown may also succumb to the disease.

Symptoms on Indiana Canner. The most prominent symptom of tipblight in this variety is the pronounced blighting and blackening of the terminal shoots of affected plants. The blackening suggests the effects produced by fire blight on pears, but the pear disease is in no way related to this tomato trouble. The dead tips of diseased tomato plants stand upright above the living foliage in a very characteristic manner. These dead portions consist of black patches and brown streaks that later bleach to a silver gray. If the stems are cut open it will be noticed that they are hollow and that the pith of the tip region has been rearranged into scattered patches with conspicuous air pockets in between. The tissues of affected

* Rawlins, T. E. and Tompkins, C. M., 1934. The use of carborundum as an abrasive in plant-virus inoculations. Abs. Phytopath. 25:1147.

stems and tips appear dry; a significant difference between tipblight and bacterial canker, a disease which it superficially resembles. The leaves of affected shoots become spotted with either a few large black spots or else many small ones. These spots are round, somewhat zonate, and always black, being truly necrotic—that is, formed by the killing of the leaf cells included within the area of the spot. They extend through the leaf and are equally visible on either side of the leaf (Figure 2). As these spots increase in size they tend to coalesce unless the leaf withers before this can take place. The delicate bronzing and the ring-spot patterns characteristic of spotted wilt are never produced by the virus responsible for tipblight.*

The development of the disease follows a very definite course. Six to eight days after the plant has been inoculated with the causal virus, a black lesion (or lesions) appears in the part of the leaf where inoculation was effected. This initial lesion is followed two to five days later by black streaks which originate on the stem at the base of the inoculated leaf; such streaks continue to appear upward toward the tip of the branch. As the disease (literally the virus) progresses up the stem, tiny black spots form on both sides of the leaves. These spots enlarge within a day or two into the characteristic leaf effects described above. If the affected plant is small, it will die within approximately 14 days after the virus has been introduced. If a larger plant becomes infected the erect succulent branches arising from the central portion of the plant wither first; the procumbent lateral branches succumb last. Under natural field conditions the virus is carried from plant to plant by insects. When virus is introduced by an insect, black spots called "local lesions" always form at the point of entry. Then the virus either remains localized at the points of entry or becomes distributed within the plant and brings about the destruction of the plant as described above.

An interesting experiment and one of considerable diagnostic value can be made by removing the apparently healthy leaves occurring immediately below noticeably infected leaves on a diseased shoot and floating them for about twenty hours in a pan of water. If the disease is tipblight, the leaves will become speckled with characteristic greenish-black spots. This procedure is feasible under field conditions and may be used as a positive test to differentiate this disease from bacterial canker.

The fruits of affected plants show signs of the disease in all stages of development from the forming of the fruit-spur to maturity. If the infection becomes noticeable while flowers are opening, lesions may occur on the fruit spur and calyx, causing the flower alone to blight, or else the entire fruit spur. The development of small fruits is arrested and their normally green surfaces become discolored by brown spots that develop within the fruit and form no definite pattern. Fruits that have attained a diameter of slightly more than an inch before effects of the causal virus become apparent, do not continue to increase in size but immediately begin to ripen abnormally. Such fruits soften and become variegated with blotches or rings of yellow, orange, and red. The larger fruits tend to ripen unevenly, often turning red on one side only. The seeds remain undeveloped in the smaller fruits but develop normally in larger fruits. Similar mottling of fruit is caused by other virus diseases of tomato, including spotted wilt. See Figure 3.

* Occasionally both spotted wilt and tipblight attack the same plant. The appearance of such plants eventually assumes more tipblight than spotted wilt characters. The viruses from such a plant may be separated.

As stated above the pith of the plant is destroyed and hollow stems result. This same weakening effect follows into the root system as the vitality of the plant is weakened and top growth dries down. The underground portions break open and are invaded by saprophytic fungi. When small plants are infected, browning of the roots accompanies the progressive dying of the plant.

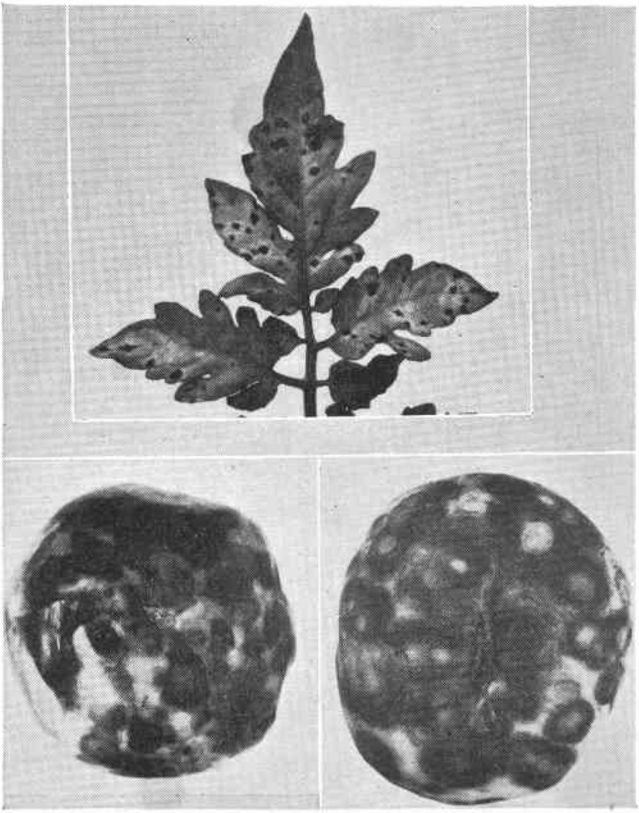

Figure 3. Leaf and fruit symptoms of tipblight on Indiana Canner.

Symptoms on tomato varieties other than Indiana Canner. We have successfully inoculated many varieties of tomatoes, including some of supposedly unusual genetic constitution, such as Red Plum, Red Peach, Dwarf Champion, Yellow Pear, and Red Pear. Among the more usual canning types (other than Indiana Canner) tipblight has been transmitted to Pritchard, Bonnie Best, Wayahead, Earlianna, Morton Stone, Santa Clara Canner, and San Jose Canner. In field test plots, natural infection has been observed on Stone, Penn State, Columbia, Glory, Early Santa Clara Canner, Marglobe, Beefsteak, Break of Day, Success, Matchless, and Norton. The symptoms are of the same general type on all these varieties, but there is some varietal variation in the form and size of the spots. Usually they are intensely black and margined with leaf-green as described above, but the spots on the varieties Yellow Pear, Wayahead, and Red Pear develop first as black rings, green within; later they blacken throughout. The spots are large on Pritchard, Wayahead, and Bozeman; small on Santa Clara, Dwarf Champion, and Red Peach; intermediate on the others. In every case the tissue is rapidly killed within the leaf throughout the area indicated by the spot.

DEVELOPMENT DURING A SEASON

Tipblight may be found in the tomato fields of the Rogue River Valley during the latter part of June, but it does not become abundant until July and August. The progress of the disease in certain fields was followed during the summers of 1934 and 1935.

Beginning July 12, 1934, a field of 944 plants was charted to show (1) the date each plant became noticeably infected, (2) the location of these plants in the field, and (3) the total number of plants infected. Records of the condition of each plant were made at intervals of about 7 to 14 days. When the chart was started (July 12) 188 plants were already infected. The appearance of these indicated that an important dissemination of the virus had taken place between June 15 and July 1. Eventually 388 plants in this field developed tipblight. An analysis of this record shows the spread of the disease was greater during July than during August. During 1935 a similar plot of tomatoes containing 1,150 plants was charted. The first notation that year, made on July 1, shows only two plants diseased, indicating that dissemination of the disease was taking place later than the previous year. The record for 1935 shows that a relatively rapid spread took place around July 15 and continued until early in August. The disease had practically ceased spreading by the middle of August. This variation of the rate of dissemination at intervals during a season seems directly related to the development and maturity of the tomato plants. The records on these two fields are shown in Table 1.

Table 1. PROGRESSIVE DEVELOPMENT OF TIPBLIGHT IN EXPERIMENTAL PLOTS.

Period ending	Number of plants infected		Number of plants infected during preceding interval		Percentage of plants infected	
	1934	1935	1934	1935	1934	1935
					Per cent	*Per cent*
July 1	......	2	......	2	......	.17
July 15	188	......	188	......	19.9	......
August 1	318	21	130	19	33.7	1.8
August 15	355	69	37	48	37.6	6.0
August 22	371	101	16	32	39.3	8.8
September 10	388	128	17	27	41.1	11.1

The amount of the disease present and the dissemination of the disease are directly influenced by the abundance of its insect carriers and by the availability of the weed hosts of the insects. These factors likewise influence the seasonal development of the disease. From the records mentioned above and from observations made during 1936 and 1937, when there was much less tipblight, it seems likely that spread is greatest during

July. These observations suggest the possibility of biological control of the disease by reduction of the thrips populations in the vicinity of the fields.

HOW TIPBLIGHT IS SPREAD

The extreme difficulty encountered in obtaining artificial spread of tipblight by mechanical means precludes the possibility of its being carried from plant to plant during the course of planting and cultivation. In this feature, it differs greatly from the mosaic disease of tomato, which is distributed with unbelievable ease by merely touching plants. Natural dissemination seemed, therefore, to depend on some insect carrier. A study of the insects present in fields where tipblight occurs was therefore made.

The insects commonly present include flea beetles, at least six species of leaf hoppers, two species of aphids, and two species of thrips. By comparing fields where tipblight was abundant with fields where it was absent, it was possible to observe what kind of insect seemed associated with the blight. Thus it was shown that there was some correlation between the prevalence of thrips and the amount of disease. Counts of insects made during different years, moreover, showed a direct correlation between the abundance of tipblight and the abundance of thrips. The high temperatures that prevail in Southern Oregon made it very difficult to conduct field tests with several species of insects to determine their ability to transmit the disease. They died shortly after they were confined in cages. Because of the local difficulties involved in insect transmission studies and because thrips seemed a likely carrier, a special study was made of thrips.

There are two species of thrips commonly present in the fields where tipblight occurs. Professor J. R. Watson of the University of California identified these as *Frankliniella moultoni* and *Thrips tabaci*. The *tabaci* species was especially numerous on tomato plants, weeds, and other plants in the vicinity. In every field where tipblight was destructive, the characteristic feeding marks of the thrips were abundant on the leaves.

In 1935 thrips were transferred from naturally infected tipblight plants to 31 healthy tomato plants by confining three to five thrips on the leaves of each plant. Black local lesions developed on the exposed leaves of 13 of the 31 plants. These plants were rather large for inoculation studies, but five of the thirteen later developed characteristic (systemic) symptoms of tipblight.

This virus disease does not lend itself readily to insect studies. Several attempts were made to establish colonies of thrips on diseased tomato plants, but these were destroyed by the virus in two to three days and the insect had little chance to feed before the plants were dead. Nonviruliferous* insects placed on tipblighted plants for twenty-four hours and then tested on healthy plants have failed to transmit the virus. It has been impossible to place nonviruliferous thrips on tomato plants affected with tipblight disease, and thus establish a colony of viruliferous insects. It was necessary, therefore, to find a plant that could withstand the virus better than tomatoes and could also serve as a food-host for thrips, so that they could feed long enough to become infective. Nasturtium plants proved well adapted for this purpose. Five nasturtiums were inoculated with tipblight virus and covered with cloth cages. When tipblight symptoms de-

* Term used to designate an insect that is potentially able to carry a virus but is known to be "clean" or free from the virus.

veloped, non-virus-bearing thrips that were thought to be *Thrips tabaci* were introduced into cages and allowed to colonize on the nasturtium plants. Thrips from these plants were transferred to 65 tomato test plants; 7 of these plants became infected with tipblight. A sample of these insects was sent to Professor Watson, who later identified what had been thought to be the common *tabaci* species as a mixture of three species, namely *Anaphothrips obscurus, Frankliniella occidentalis,* and *F. moultoni.* It was then too late to repeat the experiment, an unfortunate circumstance as the species *tabaci* also may have been present but was missed in taking the sample for identification.

From the foregoing and other experiments, it is concluded that thrips are able to transmit tipblight and that they are important factors in accounting for the spread and distribution of the disease in Southern Oregon. Although other species of insects may be able to transmit tipblight, *Thrips tobaci* is the only species of insect prevalent enough in the tomato fields to account for the rapid spread of tipblight.

HOW TIPBLIGHT OVERWINTERS

Tipblight virus is unable to resist aging, high temperatures, and dilution in water. This fact precludes the possibility of its overwintering in the soil either as a free virus or as a component of tomato debris. This conclusion was confirmed by several tests carried out under field conditions. The climate in Southern Oregon prevents tomato plants from overwintering outdoors and serving as carryover plants for the virus. It is not seed borne in tomato seed, and it is unlikely that it overwinters in thrips. It appears therefore that overwintering must be accomplished either in some weed host or in greenhouse plantings of tomatoes. The latter hypothesis seems improbable since we have never found the disease in commmercial plantings of greenhouse tomatoes. It seems very likely that the disease originated from some weed host and is perpetuated in some weed or weeds. This may account for the narrow distribution of the disease in this state. Unfortunately, the high temperature prevailing in Southern Oregon during the summer months has made it difficult to test the virus content of local weeds by the direct method of transferring juices from suspected plants to tomato, but it has been proved that some of them can serve as virus bearers.

The weeds of the region may be divided into groups on two bases; namely, length of life and preference as to place of growth. The length-of-life grouping includes annuals, biennials, and perennials; the place-of-growth grouping includes irrigation-ditch-bank plants, and open-field plants, especially those that thrive within tomato fields. Table 2 shows the more common of these weeds and their grouping on the foregoing bases.

The possibility of these weeds serving as reservoirs for the virus was determined by inoculating seedlings of each kind (as indicated in Table 2)* with virus-bearing juice from diseased tomatoes. As it was not feasible to use thrips to transfer the virus, these inoculations were made by the carborundum method. The possibility and probability of tipblight overwintering on weed hosts have been shown, but the actual overwintering under field conditions has not been demonstrated. Nevertheless the relationship is so probable that clean culture in and near tomato plantings is recom-

* This table is taken from the doctor's thesis by the junior author.

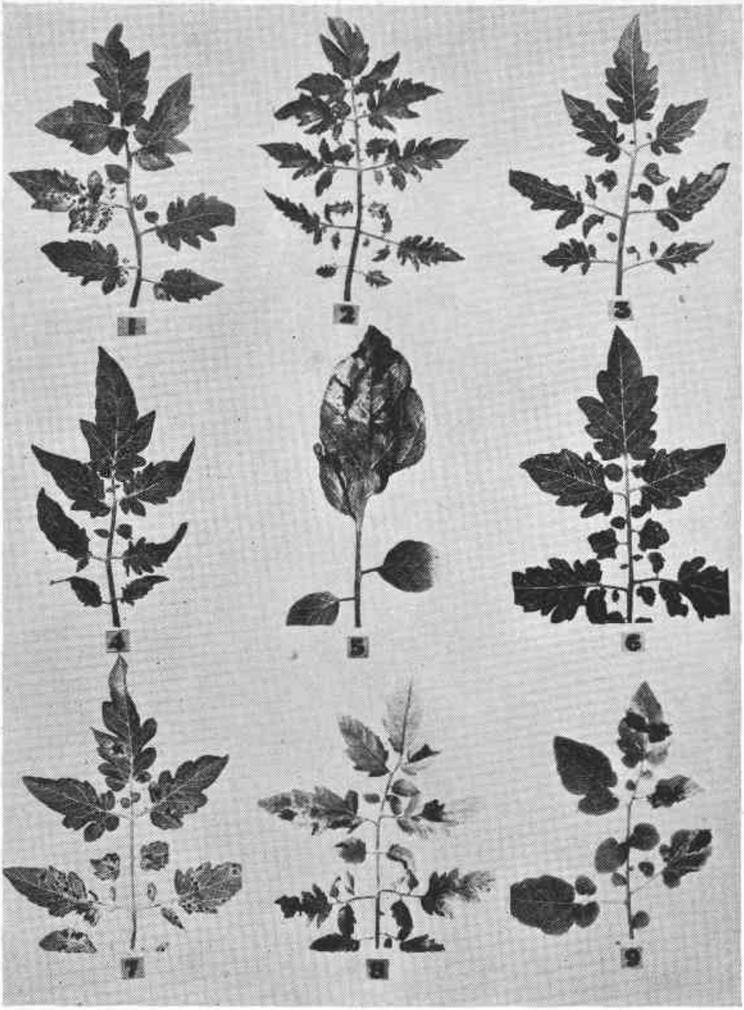

Figure 4. Effect of tipblight on leaves of different tomato varieties.

1. Dwarf Champion—lesions small, numerous, and with considerable yellowing about the margins.
2. Red Peach—lesions small, numerous, and with only a slight tendency to yellow about the margins.
3. Red Pear—lesions medium in size and number; lesions tend to form at first as circles, later becoming solid.
4. Dwarf Yellow Prince—lesions small, numerous; no yellowing about the margins.
5. Wayahead—lesions large and spreading; considerable yellowing in advanced stages.
6. Yellow Pear—lesions medium in size, numerous; decided tendency to form as black circular lesions.
7. Red Plum—lesions small and numerous; very slight tendency to yellow about the margins.
8. Bozeman—lesions very large and few in number.
9. Red Currant—lesions very large, produced only on the inoculated leaf, rarely becoming secondary.

mended without hesitation as a factor in eliminating tipblight from commercial fields.

Table 2. SUMMARY OF DATA OF WEED-HOST STUDIES.

	Taxonomy	Location		Inoculation studies		
Common names	Scientific names	Tomato fields	Waste land	Inoculated	Positive	Negative
Annuals						
Nightshade	Solanum nigrum	....	....	10	10	0
Jimson weed	Datura stramonium	....	....	35	19	16
Pigweed	Amaranthus retroflexus	....	....	12	10*	2
Lamb's quarter	Chenopodium album	....	....	0	0	0
Tumble weed	Amaranthus graecizans	....	....	0	0	0
Biennials						
Wild lettuce	Sonchus oleraceus	....	....	0	0	0
Chinese lettuce	Lactuca scariola	....	....	14	14	0
Moth mullein	Verbascum blattaria	....	....	0	0	0
Bull thistle	Cirsium lanceolatum	....	....	8	6*	2
Chinese weed	Malva rotundifolia	....	....	12	10*	2
Garden parsnip	Pastinaca sativa	....	....	5	0	5
Perennials						
Chicory	Cichorium intybus	....	....	4	4*	0
Nettle	Urtica holosericea	....	....	7	0	7
Plantain	Plantago lanceolata	....	....	6	0	6
Horehound	Marrubium vulgare	....	....	8	3*	5
Sagebrush	Artemisia heterophyla	....	....	9	0	9
Catnip	Nepeta cataria	....	....	3	1	2
Morning-glory	Convolvulus spp.	....	....	10	7*	3
Indian hemp	Apocynum cannabinum	....	....	0	0	0
Wild cucumber	Echinocystis oreganus	....	....	0	0	0
Goldenrod	Solidago elongata	....	....	0	0	0
Goldenrod	Solidago occidentalis	....	....	0	0	0
Yellow dock	Rumex crispus	....	....	5	0	5

* Local lesions only symptom produced.

As stated above, tipblight is not seed borne. During this investigation seeds have been saved from infected plants with the expectancy that the resulting plants would be readily susceptible to the disease. Plants from these proved susceptible, but in no instance was evidence found that the virus carried over in the seed. As a special test of this point, 100 such seedlings were grown in cages for nine weeks to protect them from insects. No indication of seed transmission was obtained.

CONTROL

As tipblight is a virus disease, direct control by spraying, dusting, or by using special fertilizers is at present impossible. Complete control can be ultimately achieved only by the development of resistant varieties. A special study of this important means of combating tipblight is being made by Superintendent F. C. Reimer at the Southern Oregon Branch Experiment Station. The development of a desirable tomato variety truly resistant to a virus is difficult and requires a long time. Superintendent Reimer has been making selections since 1932. Some progress has been made in the isolation and development of strains showing greater resistance to this disease under field conditions than the Indiana Baltimore, from which these selections were developed. This work is being continued to obtain increased resistance to tipblight and earlier maturity of the fruit. In the meantime it may be possible to combat the disease to some extent by indirect control measures included in the following program for tomato diseases generally encountered along with tipblight:

1. Use seed that has been cleaned by the fermentation method rather than the new mechanical cleaning methods. Seed that has been subjected to fermentation is far less likely to harbor the bacteria responsible for canker. Tipblight is not seed borne.

2. Use every precaution to prevent contamination of seedlings with tobacco viruses such as mosaic and streak. At transplanting time, it is equally important that the handlers of plants keep their hands thoroughly washed and refrain from the use of tobacco while transplanting. Such viruses sometimes produce effects resembling tipblight.

3. Clean culture seems advisable. This includes removal of weeds both from the field proper and from fence areas. Both experimental and circumstantial evidence indicates that tipblight may over-winter in weeds.

4. The removal of plants that first develop the tipblight disease is advised. Tipblight, unlike common mosaic, cannot be transferred by touch. If diseased plants are removed and destroyed early in the season, chances for further infection may be lessened; the original weed source, however, would still remain. Rogued plants should be taken entirely away from the planted area so that thrips will not have a chance to leave the diseased plants and migrate to healthy ones.

5. If the thrips that carry the disease could be completely controlled, tipblight could be eliminated.

6. Certain locations that are known to be particularly susceptible to inroads of tipblight should be avoided. Likewise seed beds should be located in areas where tipblight does not occur frequently. Studies on the control of this disease are being continued. When these are concluded, a full discussion of control measures will be made available to tomato growers.

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