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EXPERIMENTS ON THE CONTROL OF TOMATO YELLOWS
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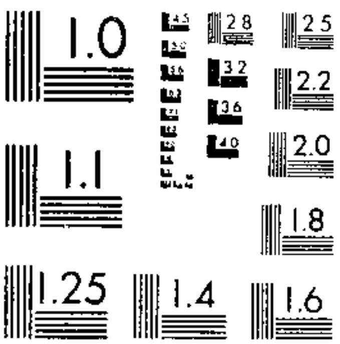
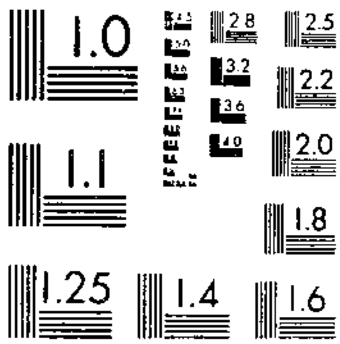


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A



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NATIONAL BUREAU OF STANDARDS-1963-A

TECHNICAL BULLETIN No. 189 JULY, 1930

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EXPERIMENTS ON THE CONTROL OF TOMATO YELLOWS

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INTRODUCTION

In 1926 McKay and Dykstra (*23*)[2] reported certain experiments which indicated that tomato yellows (western yellow blight)[3] is a virus disease etiologically identical with curly top of sugar beets and that, like the latter, it is transmitted by viruliferous beet leaf hoppers (*Eutettix tenellus* Baker). Subsequent work by Shapovalov (*36*) and Severin (*31*) confirmed the results of McKay and Dykstra. (Pl. 1.) Repeated plantings of seeds from the diseased and healthy plants, made by various workers, gave no proof that tomato yellows is transmitted with the seed. Prior to the discovery of the cause of the disease, much of the work with control measures was of a haphazard nature. Yet some more or less positive results were obtained, which may be of interest from the practical as well as the theoretical viewpoint. In particular, efforts were made to alter the environment in such a way as to create conditions favorable to the host and unfavorable to the disease. Among other measures tried were the application of sprays and dusts, variations in soil management and in the time of planting, care in handling seedlings, and the development of resistant varieties.

[1] Eubanks Carsner, of the Office of Sugar Plants, Bureau of Plant Industry, and J. W. Lesley, of the University of California, read the manuscript and offered a number of suggestions which greatly improved the text. Acknowledgment is also made of the cooperation of the University of California in providing, at the citrus experiment station at Riverside, the facilities for some of the work herein reported.

[2] Italic numbers in parentheses refer to Literature Cited, p. 21.

[3] The name "tomato yellows" is now being more generally used in place of western yellow blight and various other synonyms (*37*).

The greater part of the field work described in this bulletin was conducted at two places—the citrus experiment station of the University of California, at Riverside, and the United States Cotton Field Station at Shafter, Calif.

ALTERATION OF THE ENVIRONMENT

Although in the past workers were at variance regarding the etiology of the disease, many of them agreed that environmental conditions have a decided effect on the development and the severity of yellows. Close observers could not fail to note that the most severe attacks of yellows are accompanied by intense sunlight and high temperature, and that any factor which tends to moderate these adverse conditions also brings about a reduction in the percentage of plants diseased.

Henderson (*13*) as long ago as 1906 observed that while in unprotected fields yellows developed on 80 per cent or more of the plants, not more than 25 per cent of the plants among large apple trees were infected; and in one field where the plants were, in addition, protected from west winds, no yellows occurred. He tried artificial shading, using corn plants, open-top boxes, and V-shaped board protectors. When small V-shaped protectors were used, the disease was still abundant, affecting in some instances as many as 64 per cent of the plants, but the use of large ones reduced the infection to 23 per cent; the use of open-top boxes reduced it to 29 per cent; and the use of corn reduced it to 33 per cent. Where no protection was given yellows occurred on 80 to 90 per cent of the plants. Plants grown from seeds directly in the field (not transplanted) showed about 25 per cent infection.

Humphrey (*15*), while considering it as probable that the disease was induced primarily by one or more root-destroying fungi, believed that its effects are augmented by such external factors as temperature, rapid loss of water from the leaves, and excessive intensity of sunlight. In his experiments with individual glass-covered boxes placed over each tomato hill, the reduction of the disease obtained by this method was probably due to the exclusion of insects and to shading. The boxes measured 12 inches on each side and had wooden sides and glass tops. The glass covers were removed when the plants were 6 inches high or more, but the sides were left in position for the entire season. With this arrangement an experimental plot at Clarkston, Wash., showed only 3 per cent of the disease, whereas in the neighborhood it ranged from 4 to 93 per cent. In another plot at Pullman, Wash., all protected plants were healthy, while neighboring fields were affected to the extent of 45 per cent.

McKay (*22*) reported that some growers had considerable success in holding the disease in check by the use of natural or artificial windbreaks, such as hedges or brush fences.

Shapovalov (*34*, *35*) showed that a striking correlation exists between the regional as well as the seasonal prevalence of yellows on the one hand and such climatic factors as tend to increase the evaporating power of the air on the other. He shaded a certain number of plants by means of muslin tents constructed over portions of rows in his plots at Riverside, Calif., with the result that during a severe infection in 1924 the disease was reduced to less than 12 per cent, as compared with 41 per cent in unshaded rows. Shapovalov and Beecher (*38*) noticed on several occasions that tomato fields or portions of the fields located in orchards were, as a rule, less affected by yellows than those exposed to the full sunlight. Severin (*31*) also observed in 1926 that "tomatoes grown along a fence in the shade of eucalyptus trees were, with few exceptions, healthy, while every plant exposed to sunshine was diseased." Rosa (*26*) believed that shading protected tomato plants from yellows.

Similar beneficial effects of reducing the intensity of sunlight were noted also in connection with the work on curly top of sugar beets (*1*, *2*, *7*, *8*, *42*).

REDUCED SUNLIGHT

Shaded tomato plants show a smaller percentage of yellows than do unshaded plants for two reasons. In the first place, they are protected to a certain degree from the invasion of the insects. As pointed out by Severin (*31, p. 268*), "the leaf hopper is a sunshine-loving insect and usually will not enter the shade if its food and breeding plants are favorable." However, the writers' experiments show (*39*) that when plants are artificially inoculated with the curly-top virus by means of viruliferous beet leaf hoppers and then distributed among chambers differing with respect to the light conditions, the amount of yellows is reduced in proportion to shading. In an experiment with such different habitats, where the total daily light intensity was determined by means of the uranyl acetate-oxalic acid method (*3*), the results shown in Table 1 were obtained.

TABLE 1.—*Effect of light on development of tomato yellows*

Type of chamber covering	Percentage of direct sunlight	Number of inoculated plants	Number of affected plants
Heavy muslin	8	12	3
Light cheesecloth	47	12	4
2 layers of window glass	60	12	5
1 layer of window glass	71	12	6
Frame as above (no glass)	87	12	9

It appears, therefore, that shading not only protects tomato plants from the insect virus carriers, but also is unfavorable to the subsequent development of the disease.

It is well known that ordinary glass transmits only a part of the ultra-violet rays of sunlight. However, the data given in Table 1 indicate that the reduction in the number of cases of yellows in this trial was due to the reduced intensity of light rather than to its changed quality. This conclusion is further corroborated by the results of another experiment conducted in the open field at Shafter, Calif., in 1926. In order to reduce or cut off entirely a portion of the ultra-violet rays of sunlight, 22 tomato plants were roofed over with the thin glass (mentioned in Table 1) set in a continuous framework built over this section of the row, allowing free access of air on sides and ends, but protecting the plants from direct sunlight except in the early morning and toward sunset. In a near-by row 22 other plants were provided with a similar frame but without glass. At the end of the season only 3 plants remained healthy in each of these two groups of plants. The shorter wave ultra-violet of sunlight apparently was not a factor in hastening the diseased condition.

During the same summer a number of pruned tomato vines were observed in a small lath house at Shafter. They showed no infection at first, but during June they developed several cases of yellows. Since a good deal of disease had appeared in the field by this time (92 per cent of the total number of plants being diseased by June 15), it is evident that the lath house exerted some influence in delaying either the infection or the onset of the disease, or both.

SHADING WITH TALL-GROWING PLANTS

In view of the unquestionably beneficial results derived from shading in controlling tomato yellows, further trials seemed desirable in order to establish definitely its practical value to the grower and to develop the most efficient and economical methods of supplying the necessary shade to the plants. Experiments with this object in view were conducted by the writers at Shafter, Calif., where natural infection is very severe almost every year. It seemed especially desirable to learn whether any of the tall-growing economic crop plants could be profitably substituted for artificial shading materials when planted in alternate rows.

Four such crops were tried in 1926—cotton, sesbania, milo maize, and sunflower. Rows were laid out north and south, and the tomato and the shade-crop seeds were planted on the same day (April 1), the shade crop being only 12 inches west of each of the tomato rows. Only the sunflower plants showed a rapid rate of growth, and in five weeks from the time of planting they were throwing shade on the young tomato plants after 2 p. m. The other crops grew rather slowly, and the tomatoes in adjoining rows developed a large percentage of the disease before they obtained any benefit from shading. Sunflowers gave a satisfactory protection from the disease and reduced it to less than one-half of that in the check-rows, but because of their proximity to the tomatoes the growth of the latter was checked very strikingly. However, the sunflowers died prematurely about July 1 (probably from an insufficient water supply). As a result of there no longer being any competition for food by the sunflowers, the tomatoes developed very rapidly and produced a large crop late in the season. (Pl. 2, A.) A little over 7 per cent of additional cases of yellows were noted after July 1.

The experiment with sunflowers was repeated in 1927, and a sweet-corn plot was added, but other shade crops were omitted because of previous unsatisfactory results. The benefit from shading in this experiment was, in the main, the same as in 1926. A much better growth of tomatoes was obtained by planting the shade crop 36 inches away from the tomato rows on their west side. In order to get the

A diseased and a healthy tomato plant in the same hill. The darker plant on the right is healthy, and the lighter one on the left is affected with yellows. The disease was transmitted by means of viruliferous *Eutettix tenellus* previously fed on beets affected with early top

A, The sunflower plot at Shafter, Calif., in 1926. The photograph shows this plot after the sunflowers had died and the stalks were removed. B, the sunflower plot at Shafter, Calif., in 1927. The part in the foreground shows a section of the checkrows, immediately following it is a portion protected by the sunflowers until July 1, and beyond it and to the left is another portion with the sunflowers still standing best results from shading the young tomato plants, sunflower seeds were planted the last of February, or 38 days in advance of tomato seeds (planted April 6). Five weeks after the tomato seeds were planted the plants were shaded by the sunflowers after 2 p. m. On the same date the corn shade did not reach the tomato plants until after 3.45 p. m. About July 1, sunflowers were removed from one-half of each row. Nearly 7 per cent of additional yellows developed in these half rows thereafter. (Pl. 2, B.)

The shading experiment with sunflowers was again repeated at Shafter in 1928. Of the shade crops only the sunflower was retained. This time the sunflower seeds were planted on February 2 in rows running in the same direction as before, but 9 feet apart instead of 7 as in 1926 or 8 as in 1927. Tomato seeds were planted on March 15 and 16 in rows 4 feet east and 5 feet west of each of the sunflower rows. The shade reached the tomato plants at about 2 p. m. on March 16, six weeks after the seed was planted. The infection with yellows in 1928 was very slight at Shafter and throughout California. Most of the disease in the Shafter plots developed before any benefit from shading with sunflowers was secured. The results of the 3-year experiments with shading by means of tall crops are given in Table 2.

TABLE 2.—*Effect of shading with crops on the amount of tomato yellows, Shafter, Calif.*

Shade crop and duration of shading	Percentage of plants infected with yellows		
	1926	1927	1928
Sunflower:			
Up to July 1 only	26.0	35.2	12.7
The entire season—			
In portions where sunflowers were removed on July 1	33.3	41.0	
In portions where sunflowers remained the entire season		37.9	12.7
Sesbania, during the entire season	98.1		
Cotton, during the entire season	97.4		
Milo, during the entire season	82.1		
Sweet corn, during the entire season		78.0	
Unshaded rows, during the entire season	99.7	80.7	14.2

DURATION OF SHADING

The results given in Table 2 indicate very clearly that shading materials may be dispensed with about July 1. The writers' observations at Shafter show that as a rule tomato yellows in that section reaches three-fourths of its seasonal total during the second week of June and that nearly all of the remaining fourth develops prior to July 1.

Table 3 gives a summary of seasonal developments for three successive years. This abatement in the spread of the disease is thought to be due in part to the cessation of flights of the beet leaf hoppers and in part probably to the age of the plants. These points are discussed more in detail elsewhere in this bulletin under Time of Planting.

TABLE 3.—*Seasonal progress of tomato yellows at Shafter, Calif.*

Items of comparison	1926	1927	1928
Total number of plants under observation	1,417	800	675
Number at the beginning of the season:			
Date	May 14	May 13	May 16
Number of cases to date	139	37	15
Percentage of season's total to date	10.9	6.4	17.6
Number at the end of May:			
Date	May 28	May 20	--------
Number of cases to date	688	242	--------
Percentage of season's total to date	53.9	42.0	--------
Number in early or middle June:			
Date	June 4	June 13	June 6
Number of cases to date	928	420	62
Percentage of season's total to date	72.7	74.5	72.9
Number at the end of June:			
Date	June 28	June 28	June 22
Number of cases to date	1,254	549	81
Percentage of season's total to date	98.2	95.3	95.3
Number at the end of the season:			
Date	Aug. 24	July 29	Aug. 8
Number of cases to date	1,277	576	85
Percentage of season's total to date	100	100	100

SHADING WITH MUSLIN TENTS

Besides the shade crops, one row in 1926 was shaded by a heavy muslin wall, 3 feet high, placed immediately on the west side of the row. Three of the 33 plants in this row survived throughout the season; thus 90.9 per cent were infected with yellows, as compared

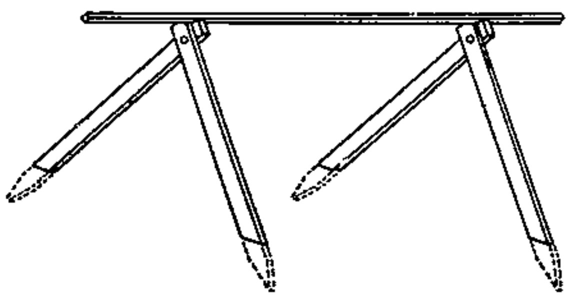


FIGURE 1.—A knockdown frame for shading rows of tomatoes

with 99.7 in the checkrows. A more efficient method of cloth shading consists in building low tents over the entire rows. In the 1924 experiment at Riverside the frames for such tents were built of laths and were very satisfactory for one season, but it did not seem practicable to save many of the used laths for another season. At Shafter in 1927 the frames previously used for the test with glass covers were adapted for the construction of muslin cages. The results were satisfactory. (Pl. 3, A.)

Finally a rather simple frame that can be used a number of years was evolved. It may be built of inverted V's from strips of lumber about 4 feet long, three-fourths of an inch thick, and 3 inches wide, sharpened at one end for inserting into the soil, and with a bolt hole near the other end for bolting the pieces at the top. (Fig. 1.) One of the inverted V's is set over each plant, and a ridgepole of 1-inch strip is run along the top. Two widths of cloth may be sewed together lengthwise and then spread over the framework and fastened here and there to the outer sides with tacks. The cloth and the frame may be removed at the end of June and saved for another year. Muslin of 50 meshes to the inch is satisfactory, but a heavier material may be used if durability is desired.

On the basis of the writers' trials, it would seem that this method may be satisfactory under certain conditions, particularly for small-sized patches in areas of severe infestation. The results obtained with this form of shading in 1927 and 1928 were as follows:

	1927	1928
Percentage of plants infected with yellows, in rows shaded by tents	10.8	3.0
Percentage of plants infected with yellows in unshaded rows	80.7	14.2

If these tents are made insect proof, a still better control may be obtained. One such closed cage was used over 20 plants in 1927. Only one plant contracted the disease, which probably came through the cloth when the plant became so large that it pressed tightly on the muslin. No additional cases of the disease developed after the cage was removed on July 1. (Pl. 3, B.) A serious disadvantage of this closed cage is that the setting of the fruit is somewhat delayed. This unfavorable effect may possibly be overcome by the use of more loosely woven textiles, such as tobacco cloths, which would permit more air movement through the inclosure. In experiments with control of aster yellows transmitted by *Cicadula sexnotata* Fall., which is only slightly larger than *Eutettix tenellus*, Jones and Riker (*19*) reported satisfactory results from a cloth having 22 threads to the inch, while Kunkel (*20*) obtained a reduction of yellows from 80 per cent to 20 per cent by shielding plants with fences built of wire screen having only 18 meshes to the inch.

The question may be raised as to whether the economic gain secured through this means of protection justifies the expense connected with it. As the trials at Shafter show, the tent shading may save about three-fourths of the stand. The cost of the tents prepared for these experiments naturally was higher than it would have been for a large grower, because in this case the materials were bought in small quantities. The quantities of lumber and muslin necessary to cover 1 acre will depend somewhat on the spacing used, especially between the rows. If tomatoes are planted 6 feet apart each way, 1,200 plants will cover 1 acre. To build the tents illustrated in Figure 1 to cover this number of plants will require 3,000 board feet of lumber and 4,800 yards of muslin. Assuming that the price of lumber is 4 cents a foot and the price of muslin 10 cents a yard, the total cost of these materials per acre will be $600. To this should be added the cost of bolts, about $25 or $30 per acre. Although the material may serve for a number of years, it is evident that for the majority of sections where yellows does not occur with regular severity, the mean annual expenditure for tents may still be too great to be profitable, unless tomatoes bring unusually high prices. The protection afforded by sunflowers or a similar tall-growing crop is more nearly within the reach of the average grower.

SHADING WITH LOW AND DENSELY GROWING PLANTS

The effect of a dense growth of weeds on the development of yellows is also of interest in connection with shading. Several observers (*1, 2, 39*) noticed that very weedy beet fields showed a much smaller amount of curly top and produced a fair crop, whereas clean-cultivated fields suffered severe loss. As the leaf hoppers apparently prefer a warm, open, sunny location to close heavy vegetation covering the ground, it may be possible that the dense vegetation is less frequently invaded by the insects, and a smaller amount of disease would naturally result. The dense foliage may, of course, exert other influences, as on soil moisture and soil temperature.

To test the effect of low, dense vegetation, buckwheat was planted in 1928 in drills about 1 foot apart in a small tomato plot at the time of setting the plants (April 16 and May 20). A second plot had cowpeas broadcast March 20, and the tomatoes set on the same dates as in the buckwheat plot. The seasonal progress of yellows is given in Table 4.

TABLE 4.—*Prevalence of yellows in tomato plants in dense growth of buckwheat and cowpeas*

Intercrop	April planting		May planting		Plantings, both plots		
	Total number of plants	Number of diseased plants	Total number of plants	Number of diseased plants	Total number of plants	Number of diseased plants	Percentage of diseased plants
Checks (tomatoes only)	57	10	59	17	116	27	23.3
Buckwheat	54	5	55	9	109	14	12.8
Cowpeas	56	2	51	1	107	3	2.8

As the buckwheat in the late plot was small until the latter part of May (during the period of greatest infection), this may help to explain the nearly double infection as compared with that in the earlier planting where the buckwheat was in full bloom and from 12 to 15 inches high by June 1. In both early and late plantings the buckwheat was able to reduce the infection by about 50 per cent. However, the tomatoes were rather pale and not very vigorous as a result of the intercrop of buckwheat. Among the cowpeas the tomato vines were almost completely submerged and smothered, in spite of the cowpeas having been thinned out, and the resulting tomato vines were very weak and spindling, with almost no fruit. Apparently the cowpeas prevented the infection. As the 1928 season was marked by an unusually small percentage of yellows, it is doubtful whether this protection would be as effective in a season of severe infestation.

It is a well-known fact that seedlings left in the seed bed are seldom seriously affected by yellows. Dense growth in this case again appears to be the main factor. However, if continuous rows of seedlings are grown in the field, with a wide spacing between the rows (6 feet or more), they may be no less affected in years of severe outbreaks than are plants set out individually in the regular way. An experiment conducted at Shafter in 1926 indicates this. Two such continuous rows were planted, each containing several hundred plants. At the end of the summer only seven plants remained unaffected, while all the others had died from yellows.

In the Northwest, among some growers, there is a practice of setting more than one plant in each hill in order to have as nearly a normal stand as possible in spite of the loss from the disease. It is obvious that this measure can be of no assistance during seasons when the amount of yellows approaches 100 per cent, but it might bring the desired results with a smaller infection. A double number of plants set two plants to a hill with only 50 per cent of the disease may be expected to give a much-improved stand. However, even better results, with respect to the vigor of plants and yield, might possibly be obtained by setting the same number of plants individually with half the usual spacing in the row.

SPRAYING AND DUSTING

The purpose of spraying or dusting in the case of tomato yellows may be threefold. It may be done to destroy the leaf hoppers, to repel them, or to enable the plant to resist the infection. It is doubtful whether the use of insecticides on tomatoes for the first of these purposes will ever be practicable, since there are so many natural hosts of *Eutettix tenellus*, both wild and cultivated (*4*, *7*, *27*, *30*, *32*). More tangible results may be expected from repellents and protective sprays and dusts, although thus far there has been but little encouragement along this line.

Severin (*28*, *33*) tried nicotine-sulphate dust, but the results were unsatisfactory. However, Schwing, as reported by Haring (*10*), found that a heavy application of nicodust destroyed hoppers on beets where the hoppers were actually hit. Carsner and Stahl (*7*) used several insecticides as well as repellents in both liquid and dust form, but no benefit worthy of consideration resulted. More recently Carter (*8*) conducted experiments with a view to enabling sugar-beet plants to resist the effect of the curly-top virus after it has been introduced into the plants. He had plants sprayed with lampblack, zinc oxide, and lime, as well as unsprayed plants for checks. Plants sprayed with lampblack, a light-absorbing pigment which screens off a considerable portion of the sun's spectrum, suffered more than unsprayed beets. Plants sprayed with zinc oxide, a light-reflecting pigment but one with severe reduction in the shorter end of the spectrum, were slightly worse off than unsprayed beets. Only the plants sprayed with lime, a light-reflecting pigment which does not interfere to any considerable extent with the shorter waves, showed an increased resistance to curly top.

Similar tests were made also with tomatoes in the plots at Shafter during the summer of 1926. Various sprays were tried in studying two possible effects on the plants—the chemical effect and the shading effect due to absorption or reflection of incident light. All spray applications were made with a knapsack sprayer during the last week in May, when infection is usually very severe and general and the progress of the disease rapid. The sprays were repeated in 6 to 10 days, and plants in all stages of yellows were used.

As iron salts have proved beneficial in certain types of chlorosis, ferrous sulphate was applied in solutions varying from 2 to 6 per cent, alone and in conjunction with ammonium sulphate, to form a less readily oxidized iron compound. There appeared to be no beneficial effect either in improving the color of the plants or in retarding the advance of the disease, and the 4 and 6 per cent solutions burned the foliage considerably. This negative result was not surprising, as the yellowing of the foliage may have been due to other causes, such as an excessive accumulation of sucrose and reducing sugars, which Rosa (*25*) found to occur in the diseased plants, rather than to a deficiency of iron in the leaves. This excess of carbohydrates may have been responsible for the upsetting of the chlorophyll mechanism. In this case iron sprays could be of no benefit.

With a view to changing both the quantity and the quality of the light received by the tomato leaves, other sprays were tried. Certain sulphides having a metallic luster are known to have a high reflecting power for ultra-violet light (*9*). In an attempt to cut down the ultra-violet rays of the sunlight reaching the leaves, finely ground iron pyrites was applied as a spray. At first the leaves showed a deep-green color following the application, but the progress of the disease was neither stopped nor retarded.

In the dry air of the San Joaquin Valley of California the heat and sunlight are intense in June. As the heat rays are known to penetrate moist air much less readily than dry air, and as the orange and red portions of the spectrum are thought to have great influence in the process of photosynthesis, it seemed desirable to reduce the intensity of light penetrating the leaves and at the same time to cut off a large portion of the orange, red, and infra-red rays by placing some reflecting or absorbing substance on the foliage. Heavy coatings of calcium carbonate, magnesium carbonate, and hydrated lime, in the proportion of ½ to 1 pound of powder to a gallon of water, were applied in spray form. Although these applications were without effect in checking the disease, the green of the foliage seemed to disappear less rapidly than in the unsprayed diseased plants.

The only spray that gave any indication of retarding the disease was a solution of 2 per cent ferrous sulphate with enough hydrated lime to make the solution alkaline; that is, a sort of "iron Bordeaux." This gave an orange-colored deposit on the leaves. However, only a slowing down of the disease was apparent, and this was not great enough to be of any value where the infection was severe.

In May, 1927, 4–4–50 Bordeaux was tried, to see if it would show some repellent action on the insects, as in the case of the potato leaf hopper, or possibly show a screening action on the light. The results were negative. Eleven cases of yellows developed among the 52 sprayed plants (21 per cent), as compared with 15 cases among 65 unsprayed ones (23 per cent).

SOIL MANAGEMENT

At the time when yellows was thought to be caused by certain soil fungi, crop rotation and the disinfection of seed beds were considered advisable by some (*22*). Others observed that there is no apparent correlation between the amount of the disease and the supposed contamination of the soil, and that even on new sagebrush land the infection may run as high as 100 per cent (*11*, *15*). While thus the crop-rotation idea failed to find much support among the students of tomato yellows, soil conditions were regarded as of by no means slight significance. The fact that the disease is more severe in hot and dry regions, or where the loss of moisture is higher, forced upon many the thought that the losses may be reduced by increasing the supply of water to the plants. Some trials and observations seemed to confirm this belief. Also, indications were found that an abundant supply of humus in the soil, or well-fertilized soils, helped to check the development of the disease. This was first pointed out by Huntley (*16*), although he stated that lack of manure and humus in the soil had not proved to be the cause of the trouble.

Henderson (*13*) concluded that—

> plants set in good soil, well watered and cultivated, and protected from too hot sun by close planting and shading, and from severe winds by orchards, corn, or other means, will give very little blight.

The disease became very general by July 1 in the field where he had his trials in 1904, with the exception of the part "which had been submerged by the rise of the river" soon after setting. In two rows of another patch, which were "cleared of weeds, heavily limed and manured, and finally spaded up and put in prime condition, only one plant was blighted" out of 48, while the remainder of the plot showed many diseased plants. He also tried commercial fertilizers, but no definite beneficial results were derived (*12*).

McKay (*22*) advocated an abundant supply of moisture, a liberal use of barnyard manure, and good cultivation as important factors that tend to reduce the losses from yellows.

Thornber (*41*) reported a distinct gain from the application of manure. In his experiments at Clarkston, Wash., manure was applied in the trenches, covered with several inches of soil, and the tomatoes set over the manure. None of the 400 plants so treated developed yellows, whereas about 90 per cent of the 400 or so plants in an adjacent unmanured plot showed symptoms of the disease.

Smith (*40*) found no benefit from the application of sulphur or lime.

Sulphur tests were conducted by the writers for two years on a small scale at Shafter. In 1927 sulphur was applied at the rate of 400 pounds per acre in shallow furrows and harrowed in. No reduction in the disease was obtained from this application. In 1928 a second application at the rate of 800 pounds per acre was made to the same plot by broadcasting and was harrowed in before the tomatoes were planted. On this plot in 1928, 16 out of 116 plants, or 13.8 per cent, developed yellows, while on the untreated adjoining area 27 out of 116 plants, or 23.3 per cent, became diseased.

IRRIGATION AND FERTILIZATION

Experiments with irrigation, cultivation, and fertilizers were conducted by Shapovalov (*34*). In his irrigation experiment in 1922 during a serious outbreak of yellows, the disease practically ceased to develop after four weekly applications of water in a portion of a commercial field at Wineville, Calif. At the same time, in another portion of the field which had been irrigated only once the disease continued to develop for four additional weeks, with the result that about 10 per cent more of the plants became affected during the period of the experiment in this plot than in the wetter plot. During the next two years his experiments were repeated more carefully at another place in conjunction with different frequencies of cultivation, and the available soil moisture was measured by the porous porcelain soil points of Livingston and Koketsu. In 1923, when the attack of yellows was very slight, it seemed as if the disease had a tendency to be more prevalent on drier plots, thus corroborating the results of the 1922 experiment; but in 1924, with a very severe outbreak of yellows, no correlation could be seen between the amount of the disease and the available soil moisture as measured by the soil points. Only the plot fertilized with ammonium sulphate at the rate of 200 pounds to the acre showed a slight reduction in the percentage of yellows. It should be noted, however, that the results obtained with frequent irrigation in 1922 are not quite comparable with those secured in the next two seasons, since they were conducted in different localities and on different types of soil.

The writers tried various fertilizers and lime in 1925, when yellows was as severe as in 1924, and again in 1926, when there was a moderate attack of the disease. The plot treated with lime showed considerably less yellows than the check in 1925, but there was no significant difference in 1926. Other treatments, as Table 5 shows, did not seem to have any effect on the disease. All plots were adjacent.

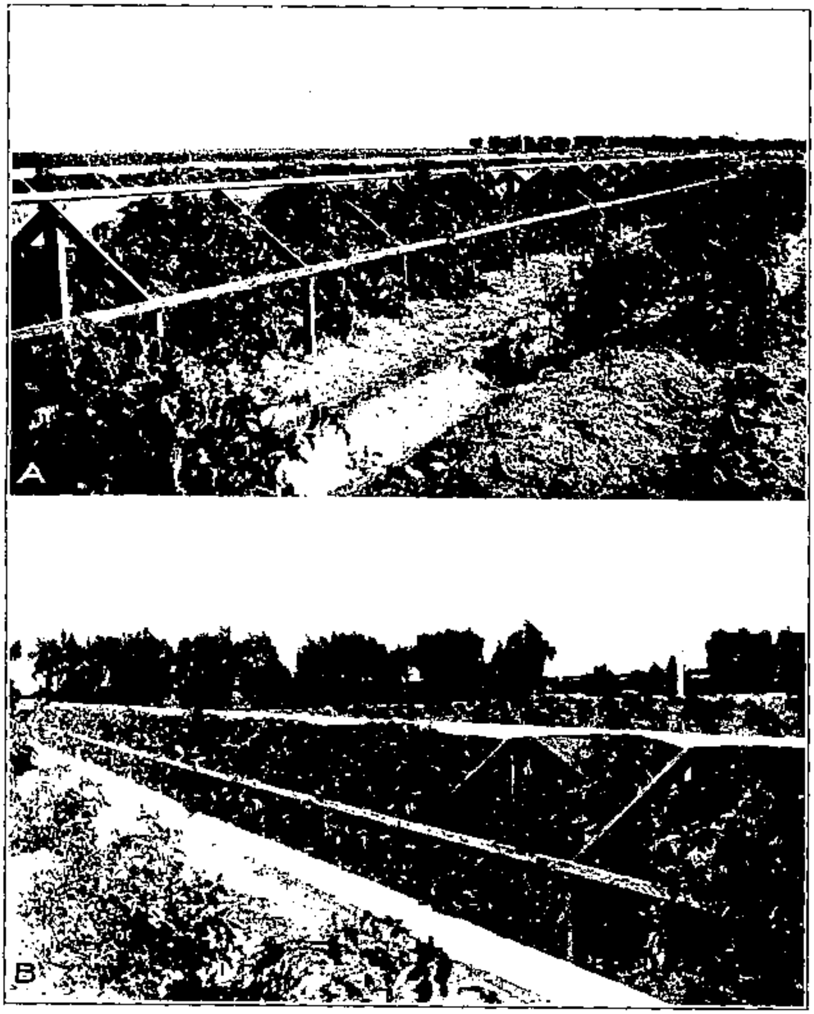
TABLE 5.—*Tomato yellows on differently fertilized plots at Riverside, Calif., in 1925 and 1926*

Treatment	1925			1926		
	Total number of plants	Number of plants affected	Percentage of plants affected	Total number of plants	Number of plants affected	Percentage of plants affected
Check	125	54	43.2	177	25	14.1
Air-slaked lime, 3,000 pounds to the acre	88	21	23.9	214	24	11.2
Ammonium sulphate, 400 pounds to the acre	85	36	42.4	223	47	21.1
Superphosphate, 428 pounds to the acre	79	35	44.3			
Potassium sulphate, 160 pounds to the acre	78	30	38.5			
Complete fertilizer, 8-6-8	81	33	40.7	212	39	18.4

Irrigation water was supplied as needed; that is, once in three or four weeks. It is possible that with a more abundant supply of water the effect of the fertilizers might have been more pronounced. Shapovalov's unpublished notes on his 1924 fertilizer trials show that the percentage of yellows was smaller on wetter fertilized plots than on drier fertilized plots. (Table 6.)

TABLE 6.—*Tomato yellows on plots fertilized with ammonium sulphate at the rate of 200 pounds per acre, Riverside, Calif., 1924*

Treatment	Total number of plants	Number of plants affected	Percentage of plants affected
Irrigation once in 4 weeks:			
Fertilized plants	99	39	39.4
Plants in unfertilized ends of same rows	135	63	46.7
Irrigation once in 2 weeks:			
Fertilized plants	98	35	35.7
Plants in unfertilized ends of same rows	153	67	43.8
Irrigation every week:			
Fertilized plants	113	37	32.7
Plants in unfertilized ends of same rows	161	57	35.4
Total number of fertilized plants	310	111	35.8
Total number of plants in unfertilized ends of rows	449	187	41.6



A, Tomatoes grown under a loosely covered muslin tent until July 1 at Shafter, Calif., in 1927. The cloth is removed to show the general vigor of the shaded plants as compared with those unshaded, mostly diseased, and of smaller size; photographed about July 1; B, tomatoes grown in a closed muslin cage until July 1, 1927. The plants completely filled the frame. A part of the unprotected row to the left, planted at the same time as the shaded plants, shows the general condition of the checkrows

A, Surviving plants in a seed bed at Riverside, Calif. They were planted in March and April and never irrigated. No yellows developed in this plot of seedlings; B, a Riverside (Calif.), plot of 1925, showing the relative size and vigor of untransplanted seedlings grown directly in the field (larger plants in the background) and the same seedlings transplanted (smaller plants in the foreground) 26 days after transplanting

The ammonium-sulphate plot which was irrigated once in four weeks (Table 6) may be compared with the ammonium-sulphate plot (Table 5) which was not irrigated. A decrease of 7 per cent in the amount of yellows is to be noted in 1924, as compared with the respective check plants, but practically no decrease is seen in 1925, while in the 1926 plot there was an even greater amount of the disease than in the check. The plot irrigated every week showed a decrease of nearly 3 per cent compared with the respective check. It is to be noted that the unfertilized ends of the rows also show progressively less disease in the more frequently irrigated plots.

SOIL DRYNESS AND PREIRRIGATION

There are indications that if the soil is kept very dry, practically at the point at which plants wilt, the development of yellows may be retarded.

At Riverside, in 1924, a seed plot was planted on a virgin desert soil adjacent to a tomato field, prior to the cessation of spring rains, and was not irrigated thereafter. A number of plants died from dryness, but none showed symptoms of yellows. A few even survived the unfavorable conditions and showed recovery in the fall. (Pl. 4, A.) During the same season the adjacent tomato field showed 35 to 45 per cent of the disease.

Additional tests along similar lines were made with regularly planted tomato plots at Shafter in 1927 and 1928. The plot which was to be kept dry was flooded before it was planted. Seeds were planted directly in the field about the middle of March, and the ground was irrigated a few times, until the young plants became established, or about the middle of May. Then the dry plot was not irrigated again until the plants showed wilting, which was 9 to 10 weeks after the previous irrigation. In the meantime the check rows were irrigated every 7 to 10 days. After about the middle of July both the dry and the regular plots were irrigated at necessary intervals. As is shown in Table 7, the 1927 dry plot had considerably less yellows than the check plots. In 1928, when the disease was very much less severe, no benefit from either form of irrigation was evident.

TABLE 7.—*Effect of extreme soil dryness on the development of tomato yellows*

Location	Percentage of plants infected with yellows	
	1927	1928
Dry plot at Shafter	61.7	15.9
Check on the west side	84.6	13.6
Check on the east side	91.0	17.4

GREEN MANURING

To determine the effect of introducing organic matter into the soil and producing more vigorous plants, experiments with green manuring were conducted by the writers at Shafter. *Melilotus indica* was used as a green-manure crop on the same plots for two seasons.

being planted about October 10 each year. The first crop was plowed under about April 1, 1927, well after full bloom, when the growth was very heavy. The second crop was turned under about February 10, 1928, at a much earlier stage of growth and before blossoming. The tomato vines of 1927 were greatly stimulated in growth on the cover-cropped areas, but the effect was less striking in 1928. As regards yellows, the results, considering only the manured and unmanured areas, are shown in Table 8. These figures do not point to cover crops as a means of producing plants vigorous enough to withstand the infection to any marked degree.

TABLE 8.—*Effect of green manuring on tomato yellows*

Year	Plot	Plants in cover crop area			Plants in bare area		
		Total number	Number infected	Percentage infected	Total number	Number infected	Percentage infected
1927	A	182	37	20.3	180	40	22.2
1927	B	141	45	31.9	139	50	36.0
1928	A	153	14	9.1	139	11	7.9
1928	B	158	7	4.4	157	10	6.4

GREEN MANURE WITH LIME AND FERTILIZERS

Tests by Rosa (*24*) and by Hepler and Kraybill (*14*) have shown phosphate fertilizers to be very effectual in stimulating the early growth of tomato plants. As it was known that plants in the more advanced stage of growth are less susceptible to yellows, it was thought desirable to test the effect of readily available phosphates. Superphosphate (18 per cent), at the rate of 600 pounds per acre, and steamed bone meal, superphosphate with hydrated lime (1,000 pounds per acre), and a complete 4–10–1½ fertilizer were used so as to give quantities of phosphoric acid equal to that in the superphosphate. These applications were made to certain rows in plot A (referred to in Table 8) in October, 1926, before seeding the cover crop of melilotus. The subsequent plowing of the land in April, 1927, naturally redistributed the fertilizers, so that the results in 1927 were neither very reliable nor clean-cut. The great variation in amount of disease even in the checkrows (6 to 40 per cent) made the results very indefinite. The cover-crop area showed an average of 20.3 per cent of yellows where phosphates had been applied and 26 per cent in the checks. The area without cover crop showed an average of 22.2 per cent of disease where phosphates had been applied, as compared with 18.7 per cent in the checks.

An additional fall application to a portion of plot A of 1,200 pounds per acre of 18 per cent superphosphate for the 1928 crop was of no benefit in the reduction of yellows, either directly or indirectly, through the cover crop.

The effect of the hydrated lime applied in the late summer of 1926 at the rate of 1,000 pounds per acre to half of plot B, referred to in Table 8, could be more readily determined than in the case of the phosphate fertilizers of plot A, where the quantities were small and distribution was upset by subsequent plowing.

While the larger amount of yellows in plot B in 1927 may be accounted for in part by the plants being about seven weeks younger than those in plot A, and hence more susceptible to the disease (see Table 10), there still appears to have been some benefit from lime, but only in conjunction with the green manure, as Table 9 indicates.

TABLE 9.—*Effect of green manure and lime on tomato yellows*

Year and treatment of plot B	Plants in cover-crop area			Plants in bare area		
	Total number	Number infected	Percentage infected	Total number	Number infected	Percentage infected
1927:						
Limed	69	18	26.1	73	27	37.0
Unlimed	72	27	37.5	66	23	34.8
1928:						
Limed	78	1	1.3	77	2	2.6
Unlimed	80	6	7.5	80	8	10.0

In 1928, while the number of diseased plants was small, the limed area again showed less yellows, the influence apparently extending through the unmanured area as well, which was not the case in 1927. The above figures are more or less in line with those previously obtained at Riverside (Table 5), although they can not be regarded as conclusive.

In other experiments diseased plants were subjected to different soil treatments, to study the possibility of recovery. In 1926 at Shafter plants in various stages of yellows were transferred (with roots) from the field to 5-gallon cans. The soil in these cans received applications of $NaCl$, KCl, $CaCl_2$, $FeCl_3$, $FeSO_4$, KH_2PO_4, $NH_4H_2PO_4$, $Ca(NO_3)_2$, or $NaNO_3$. Although three weeks later the plants were nearly dead from lack of water, the green color of the stems in some cases where a chloride had been used, especially KCl, suggested some improvement. Other cans received manure or manure with $CaCO_3$ and $NaNO_3$. The plants in the soil receiving $CaCO_3$ and $NaNO_3$ survived somewhat longer than the others.

In other somewhat similar tests made at Riverside in the summer of 1926, diseased plants from the field were transplanted to 10-inch pots, the soil receiving the following treatments: Gypsum, gypsum with compost, hydrated lime (about one-half per cent), lime with compost, and chopped alfalfa top mulch. While the healthy plants continued to grow in most cases, none of the diseased plants showed any sign of recovery.

Other tests with diseased and healthy rooted plants and cuttings grown in various very dilute solutions gave little information. In solutions of $FeSO_4$, iron pyrophosphate, $MnSO_4$, and $NaCl$ the plants promptly died. Diseased cuttings in solutions of $Ca(NO_3)_2$, $CaCl_2$, $MgSO_4$, K_2SO_4, KNO_3, K_2HPO_4, $NH_4H_2PO_4$, and a complete nutrient solution developed no rootlets, except in tap-water checks, but even there they were short lived. The greenhouse was very hot, and all cuttings decayed rapidly. Only the $Ca(NO_3)_2$ and $CaCl_2$ solutions suggested any trace of beneficial effect on the cuttings.

TIME OF PLANTING

It appears to be a definitely established fact, as far as sugar beets are concerned, that a crop planted early, between December 1 and March 1, under California conditions except in the fog belt, will not suffer from curly top as much as a later-planted crop (*2, 7, 29, 32*). The main point emphasized in this connection is that the beets should attain a vigorous growth before the leaf hoppers move into the cultivated areas. Similar but less definite observations have been made by the previous workers with respect to the time of transplanting tomatoes. The growing season in this case, of course, is different, but the principle involved appears to be the same.

As in the case of sugar beets, it is essential, from the viewpoint of minimizing the yellows infection, not to have young plants exposed to the leaf hoppers during their migration. Yaw (*44*) noted that when new plants are planted in June in place of those affected with yellows they almost never show the disease. In this case the transplanting is done after the main flight of the hoppers. In the writers' own work at Shafter in 1927, of the 117 seedlings set out on May 27 and 28, 26 or 22.2 per cent developed into plants having yellows, while of the 267 transplanted on June 13 only 19 or 7.1 per cent were affected. As explained by Severin (*31, p. 267*), "After a large flight occurs the adults are generally distributed on all green vegetation," and "the insects are often found on unsuitable food plants," such as tomatoes, but later on "the hoppers congregate on their most favorable food and breeding plants." Only the late-shipping crop of tomatoes can be planted in June and July. The canning crop and especially the early shipping crop require a much earlier planting. However, there are but few localities in the west (the Coachella and the Imperial Valleys) where tomato plants are set out early enough to develop into large and vigorous plants before the onslaught of the insects and thus be less susceptible to the disease.

Ball (*2*) and Carsner and Stahl (*7*) found that beets become less easily infected as they grow older. The writers' inoculation experiments show that the same is true also in regard to tomatoes. Plants of different ages were inoculated in different years and in different localities, and in each case younger plants appeared to be more susceptible and developed symptoms in a shorter time than did older plants, as may be seen from Table 10. In these experiments seeds were sown directly in the field, and later the seedlings were thinned out to one or two plants in the hill. Only one plant in each hill was inoculated. When more than one series of inoculations was made during the season each time an equal number of plants in each age group was used.

TABLE 10.—*Relation of age of tomato plants to susceptibility to yellows*

Location	Time of seeding	Number of inoculated plants	Number of plants infected	Percentage of plants infected
Riverside, Calif.	Mar. 15, 1927	54	36	66.7
Do.	Apr. 16, 1927	54	52	96.3
Do.	Mar. 2, 1928	36	10	27.7
Do.	May 15, 1928	36	26	72.2
El Centro, Calif.	Jan. 11, 1928	24	9	37.5
Do.	Feb. 14, 1928	23	15	65.2

Another test was made in regard to the relation between different times of transplanting and natural infection in a year when yellows was very serious. The results are in line with those obtained with artificial inoculations, as reported in Table 10. Five transplantings were made showing that plantings before and after the month of May were less affected than plantings made about the time of the flight of the leaf hoppers. (Table 11.) This trial was conducted at Riverside, Calif.

TABLE 11.—*Relation of time of transplanting tomato plants to susceptibility to yellows at Riverside, Calif., in 1925*

Date of transplanting	Total number of plants	Number of plants infected	Percentage of plants infected
Apr. 27	108	33	30.6
May 20	125	54	43.2
June 15	89	20	22.5
July 3	82	26	31.7
Aug. 6	74	3	4.0

From this data it appears possible to avoid some of the losses from tomato yellows by manipulating the time of planting whenever practicable. Late-shipping crops in California as a rule are only very slightly affected by this disease. They are not planted much before July 1. It is the early crop that needs special attention. By planting it as early as the frost permits, under certain conditions some of the infection may be avoided. The best results are obtained, however, when the crop is planted early and some form of shading provided, as is shown by the results obtained at Shafter and discussed in connection with shading.

Since the relative prevalence of beet leaf hoppers in an area in a given season depends on the number of insects going into hibernation, the quantity of winter-food plants, and the climatic conditions, the study of these factors has made it possible to predict the severity of the hopper infestation prior to planting time. When such forecasts are available, growers may be able to avoid planting susceptible crops in years expected to have serious outbreaks of the disease. Forecasts issued by Walter Carter, of the Bureau of Entomology, United States Department of Agriculture, during the last few years for an area in southern Idaho were used extensively in connection with beet plantings. No application of such data has yet been made for the purpose of avoiding tomato yellows.

Although certain natural enemies of *Eutettix tenellus* are known to exist, the beet leaf hoppers do not appear to be seriously affected by their presence. Therefore forecasts are not likely to be substantially offset by this factor. Also, as yet, there is no strong evidence that a biological method of control of this insect is practicable.

METHODS OF HANDLING SEEDLINGS

Before the discovery of the true nature of yellows many scientific workers as well as practical men were strongly of the opinion that the extent and the severity of the disease depended to a large degree on root injuries. Such injuries as those resulting from unfavorable physical soil conditions, the use of implements, or carelessness in transplanting were held to be accountable. Often infected plants were removed with their roots from a shallow soil with underlying hardpan or "plowsole," and the twisted and deformed roots were shown as an indisputable proof of the cause of the diseased conditions. Never were sufficient numbers of healthy plants in the same field examined to show whether these had normal roots or not. The injury inflicted in transplanting was considered to be especially serious. It was thought in this connection that plants grown from seeds directly in the field would not suffer as much from yellows as the transplanted ones. Henderson (*12, 13*) conducted tests in Idaho (near Lewiston) in 1905 and 1906 to prove this. In 1905 only 6 per cent of his seedlings (planted May 12 and later) were affected, while 60 per cent of the transplanted plants (set June 9 to 11) were diseased. In 1906 the respective percentages were 25 and over 80. This time the seedlings were planted about May 7 and the transplants set out May 20 and 21. Henderson also found that repotting and careful transplanting with little damage to the roots was without effect. It is quite possible that the type of roots formed was of much greater importance than the presence or absence of injuries. Untransplanted tomatoes, as a rule, "develop a deep tap root, which gives them an advantage under dry-farming conditions" (*26, p. 16*). At Riverside, in 1925, transplants remained for several weeks distinctly behind the corresponding untransplanted seedlings in vigor and amount of growth (Pl. 4, B), but this difference became gradually obliterated toward the end of the season. Indications are that the benefit from seeding directly in the field may depend somewhat upon the time of seeding and transplanting. An experiment conducted by the writers suggests this possibility. This experiment comprised a total of 520 untransplanted seedlings and 478 transplants. The untransplanted February and April seedlings showed slightly more yellows than did transplants from the same lots, while the untransplanted March seedlings showed less than half the disease found in the corresponding transplants, but May and June seedlings had again more yellows than the transplants made from them. (Table 12.)

TABLE 12.—*Comparative effect of direct seeding and transplanting on amount of yellows in tomatoes at Riverside, Calif., 1925*

Date of seeding	Percentage of seedlings having yellows	Date of transplanting	Percentage of transplants having yellows
Feb. 5	31.9	Apr. 27	30.6
Mar. 2	20.0	May 20	43.2
Apr. 3	24.2	June 15	22.5
May 1	36.3	July 3	31.7
June 5	7.8	Aug. 6	4.0

Unless tomato plants are raised in individual pots there is bound to be some root injury in transplanting. Differences in the degree of these injuries can hardly be a factor determining the percentage of yellows. Henderson's tests in 1905 seem to support this. The tomato plant forms adventitious roots very readily and immediately after setting, even when practically no original roots are left. On May 20, 1925, the writers planted 72 plants at Riverside with roots entirely trimmed off, and these developed into fine and vigorous plants with 25 per cent having yellows, whereas 125 plants set out in the usual way with roots attached had 43.2 per cent of the plants which showed the disease. It is not to be thought necessarily that this difference was due to the trimming of roots, as there may have been other factors at work; but the results of the experiment at least fail to support the idea that plants deprived of roots are more subject to yellows.

It had often been stated that deep planting can avert a great deal of loss from yellows, but there have been no clear-cut experimental data proving this contention. The writers tried both deep and shallow planting at Riverside in 1924 and 1925, with no significant benefit from deep planting. Large plants were used in these experiments, and those intended to be set deep were planted in holes 12 inches deep, while in shallow planting they were set only slightly deeper than they stood in the seed bed. There was also an intermediate planting in 1924 about 6 inches in depth. The results are given in Table 13.

TABLE 13.—*Effect of depth of planting on susceptibility of tomatoes to yellows at Riverside, Calif.*

Year	Plants in shallow planting			Plants in medium-deep planting			Plants in deep planting		
	Total number	Number infected	Percentage infected	Total number	Number infected	Percentage infected	Total number	Number infected	Percentage infected
1924	62	8	12.9	62	12	19.4	48	6	12.5
1925	66	17	25.8				64	20	31.2

DEVELOPMENT OF RESISTANT VARIETIES

Vavilov (*43*) pointed out that the chance of finding resistant varieties is smaller when the specialization of a parasite on genera and species of hosts is feeble. This might discourage the efforts to seek resistance to the curly-top virus, which has so many hosts, both wild and cultivated, belonging to different genera and families. Nevertheless, a very definite and marked resistance has been found in beans (*6*, *32*) and sugar beets (*7*), particularly in the latter, as demonstrated by the recent work of Carsner (*5*). The work with tomatoes has so far been less successful, though it is clearly established that certain varieties are far less susceptible than others. The results of earlier trials were either negative or indefinite (*11*, *12*, *17*, *22*).

The Idaho Agricultural Experiment Station was the first to give an encouraging report along this line of work up to 1924 (*18*). In all, 73 varieties and selections were tried. It was found that Dwarf Champion and some selections from the John Baer tomato possess a definite resistance. Only one strain of Dwarf Champion showed 74 per cent of yellows, the remainder being affected within the limits of 38 to 58 per cent, while in commercial strains the disease ranged between 58 and 100 per cent.

A painstaking and elaborate study of resistance to yellows in various tomato varieties was made by Lesley (*21*) and is being continued. He has made a great number of selections from, and crosses of, the most promising varieties. He finds that not only Dwarf Champion but other dwarf-type varieties show a certain degree of resistance to yellows. It is pointed out in this connection that—

> the resistant character of the dwarfs behaves as a recessive and appears to depend upon the gene for dwarf or possibly on a gene or genes more or less closely linked with it (*21*).

However, Red Pear, which is not a dwarf variety, is likewise resistant in about the same degree. This may indicate that the resistance is genetically of more than one kind and that it is possible by crossing to breed a variety with increased resistance to the disease. The results of Lesley's more recent (unpublished) studies seem to justify this expectation. So far, however, it has been possible to notice the difference in the resistance only under the conditions of a moderate attack of yellows when checks showed not over 50 or 60 per cent of the disease. Under much more severe conditions, when 90 to 100 per cent of check plants are infected, this difference is practically obliterated. As shown by the tests under a moderate attack in the field, the resistant strains and varieties were at least 25 per cent less susceptible to yellows. Later on, artificial inoculations were made by means of viruliferous *Eutettix tenellus*, and similar results were obtained.

SUMMARY AND CONCLUSIONS

Tomato yellows is a virus disease, is not seed borne, and its spread in the field is due exclusively to an insect carrier, the beet leaf hopper, *Eutettix tenellus* Baker.

Highly effective and economical control measures for the disease have not yet been found.

No sprays or dusts that were tried with the object of destroying or repelling the insect proved to be of sufficient value to deserve recommendation.

Measures intended to increase the vigor of the plant are of but slight benefit. However, in localities where the menace of the epidemic is great, these measures should not be neglected. Deep root formation should be encouraged; planting seeds directly in the field may be found preferable in some sections. The plants should not be overwatered during the vegetative growth. The soil should contain considerable quantities of organic matter derived either from cover cropping or from stable manure.

The time of planting may be varied in certain localities to advantage, and the occurrence of yellows may be slightly decreased if planting is done earlier or later. The purpose of the variation of planting time may be either to have plants as large as possible before the flight of the beet leaf hoppers begins or to dodge this flight.

The greatest benefit so far has been obtained with temporary muslin tents which protect the plants from the insect invasion and create conditions less favorable for the development of the disease.

With the summer crop this protection is of primary value during the first period of growth, or until about the end of June. This measure can not be generally recommended because of its relatively high cost. It may be resorted to where outbreaks of yellows as a rule are severe and the prices of tomatoes are high.

The use of a tall-growing plant for shading in place of the muslin tents also is of considerable benefit, though not as great as that of the tents. It may be adopted in those sections where conditions do not warrant quite as high an expenditure as the erection of tents entails.

The development of highly resistant varieties may be the ultimate solution of the problem. There appears to be a definite though not very strong resistance in certain varieties. This resistance seems to be insufficient to enable the plants to survive under the conditions most favorable to yellows.

While the work of breeding new varieties is being continued, the growing of now-available moderately resistant varieties with the aid of tents or shade crops suggests itself as the best temporary safeguard for the sections subject to regular severe outbreaks of yellows.

LITERATURE CITED

(1) BALL, E. D.
1909. THE LEAFHOPPERS OF THE SUGAR BEET AND THEIR RELATION TO THE "CURLY-LEAF" CONDITION. U. S. Dept. Agr., Bur. Ent. Bul. 66: 33–52, illus.

(2) ———
1917. THE BEET LEAFHOPPER AND THE CURLY-LEAF DISEASE THAT IT TRANSMITS. Utah Agr. Expt. Sta. Bul. 155, 56 p., illus.

(3) BEECHER, F. S.
1928. MEASUREMENTS OF TOTAL DAILY SUNLIGHT INTENSITY WITH REFERENCE TO THE ECOLOGY OF PLANT DISEASES. (Abstract) Phytopathology 18: 951.

(4) CARSNER, E.
1919. SUSCEPTIBILITY OF VARIOUS PLANTS TO CURLY-TOP OF SUGAR BEETS. Phytopathology 9: [413]–421, illus.

(5) ———
1926. RESISTANCE IN SUGAR BEETS TO CURLY-TOP. U. S. Dept. Agr. Circ. 388, 8 p., illus.

(6) ———
1926. SUSCEPTIBILITY OF THE BEAN TO THE VIRUS OF SUGAR-BEET CURLY TOP. Jour. Agr. Research 33: 345–348, illus.

(7) ——— and STAHL, C. F.
1924. STUDIES ON CURLY-TOP DISEASE OF THE SUGAR BEET. Jour. Agr. Research 28: 297–320, illus.

(8) CARTER, W.
1929. ECOLOGICAL STUDIES OF CURLY-TOP OF SUGAR BEETS. Phytopathology 19: 467–477, illus.

(9) COBLENTZ, W. W., and HUGHES, C. W.
1924. REFLECTING POWER OF SOME METALS AND SULPHIDES. U. S. Dept. Com., Bur. Standards Sci. Paper 19: [576]–585, illus. (Sci. Paper 493).

(10) HARING, C. M.
1922. THE BEET LEAFHOPPER, EUTETTIX TENELLA BAKER. Calif. Agr. Expt. Sta. Ann. Rpt. 1920–21: 41–42.

(11) HENDERSON, L. F.
1905. DEPARTMENT OF BOTANY. TOMATO BLIGHT. Idaho Agr. Expt. Sta. Rpt. 1904: [27]–32.

(12) ———
1906. INCOMPLETE EXPERIMENTS FOR 1905. TOMATO BLIGHT. Idaho Agr. Expt. Sta. Ann. Rpt. 1905: [14]–22.

(13) ———
1907. EXPERIMENTS FOR WESTERN BLIGHT CONTINUED. Idaho Agr. Expt. Sta. Ann. Rpt. 1906: 25–28.

(14) HEPLER, J. R., and KRAYBILL, H. R.
1925. EFFECT OF PHOSPHORUS UPON THE YIELD AND TIME OF MATURITY OF THE TOMATO. N. H. Agr. Expt. Sta. Tech. Bul. 28, 43 p., illus.

(15) HUMPHREY, H. B.
1914. STUDIES ON THE RELATION OF CERTAIN SPECIES OF FUSARIUM TO THE TOMATO BLIGHT OF THE PACIFIC NORTHWEST. Wash. Agr. Expt. Sta. Bul. 115, 22 p., illus.

(16) HUNTLEY, F. A.
1902. TOMATO CULTURE. Idaho Agr. Expt. Sta. Bul. 34, p. [108]–117, illus.

(17) IDDINGS, E. J.
1921. WORK AND PROGRESS OF THE AGRICULTURAL EXPERIMENT STATION FOR THE YEAR ENDED DECEMBER 31, 1920. Idaho Agr. Expt. Sta. Bul. 122, 64 p., illus.

(18) ———
1925. WORK AND PROGRESS OF THE AGRICULTURAL EXPERIMENT STATION FOR THE YEAR ENDED DECEMBER 31, 1924. Idaho Agr. Expt. Sta. Bul. 135, 53 p.

(19) JONES, L. R., and RIKER, R. S.
1929. PROGRESS WITH THE CONTROL OF ASTER WILT AND YELLOWS. (Abstract) Phytopathology 19: 101.

(20) KUNKEL, L. O.
1929. WIRE-SCREEN FENCES FOR THE CONTROL OF ASTER YELLOWS. (Abstract) Phytopathology 19: 100.

(21) LESLEY, J. W.
1926. A STUDY OF RESISTANCE TO WESTERN YELLOW BLIGHT OF TOMATO VARIETIES. Hilgardia 2: [47]–66, illus.

(22) MCKAY, M. B.
1921. WESTERN YELLOW TOMATO BLIGHT. Oreg. Agr. Expt. Sta. Crop Pest and Hort. Rpt. (1915–20) 3: [174]–178, illus.

(23) ——— and DYKSTRA, T. P.
1927. SUGAR BEET CURLY-TOP VIRUS, THE CAUSE OF WESTERN YELLOW TOMATO BLIGHT. (Abstract) Phytopathology 17: 39.

(24) ROSA, J. T., JR.
1920. PROFITABLE TOMATO FERTILIZERS. Missouri Agr. Expt. Sta. Bul. 169, 12 p., illus.

(25) ———
1927. CHEMICAL CHANGES ACCOMPANYING THE WESTERN YELLOW BLIGHT OF TOMATO. Plant Physiol. 2: 163–169.

(26) ———
1928. TOMATO PRODUCTION IN CALIFORNIA. Calif. Agr. Expt. Sta. Circ. 263, 40 p., illus.

(27) SEVERIN, H. H. P.
1919. THE BEET LEAFHOPPER. A REPORT ON INVESTIGATIONS INTO ITS OCCURRENCE IN CALIFORNIA. Facts About Sugar 8: 130–131, 150–151, 170–171, 190–191, 210–211, 230–231, illus.

(28) ———
1922. CONTROL OF THE LEAFHOPPER. IS IT ECONOMICALLY A HOPELESS PROBLEM IN CALIFORNIA? Facts About Sugar 14: 312–313, 332–333.

(29) ———
1923. INVESTIGATIONS OF BEET LEAFHOPPER (EUTETTIX TENELLA BAKER) IN SALINAS VALLEY OF CALIFORNIA. Jour. Econ. Ent. 16: 479–485.

(30) ———
1927. CROPS NATURALLY INFECTED WITH SUGAR BEET CURLY-TOP. Science (n. s.) 66: 137–138.

(31) ———
1928. TRANSMISSION OF TOMATO YELLOWS, OR CURLY-TOP OF THE SUGAR BEET, BY EUTETTIX TENELLUS (BAKER). Hilgardia 3: [251]–274, illus.

(32) ——— and HENDERSON, C. F.
1928. SOME HOST PLANTS OF CURLY-TOP. Hilgardia 3: [339]–392, illus.

(33) ——— HARTUNG, W. J., SCHWING, E. A., and THOMAS, W. W.
1921. EXPERIMENTS WITH A DUSTING MACHINE TO CONTROL THE BEET LEAFHOPPER (EUTETTIX TENELLA BAKER) WITH NICOTINE DUST. Jour. Econ. Ent. 14: 405–410, illus.

(34) SHAPOVALOV, M.
1925. ECOLOGICAL ASPECTS OF A PATHOLOGICAL PROBLEM (WESTERN YELLOW BLIGHT OF TOMATOES). Ecology 6: 241–259, illus.

(35) ———
1925. HIGH EVAPORATION: A PRECURSOR AND A CONCOMITANT OF WESTERN YELLOW TOMATO BLIGHT. Phytopathology 15: [470]–478, illus.

(36) ———
1927. INOCULATION EXPERIMENTS WITH WESTERN YELLOW TOMATO BLIGHT IN RELATION TO ENVIRONMENTAL CONDITIONS. (Abstract) Phytopathology 17: 723.

(37) ———
1928. YELLOWS, A SERIOUS DISEASE OF TOMATOES. U. S. Dept. Agr. Misc. Pub. 13, 4 p.

(38) ——— and BEECHER, F. S.
1926. MENACE OF WESTERN YELLOW TOMATO BLIGHT. Pacific Rural Press 111: 365, 371.

(39) ——— and BEECHER, F. S.
1928. THE DEVELOPMENT OF TOMATO YELLOWS UNDER DIFFERENT LIGHT CONDITIONS. (Abstract) Phytopathology 18: 950.

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

(41) THORNBER, W. S.
1912. WESTERN TOMATO BLIGHT. Better Fruit 6 (11): 14.

(42) TOWNSEND, C. O.
1908. CURLY-TOP, A DISEASE OF THE SUGAR BEET. U. S. Dept. Agr., Bur. Plant Indus. Bul. 122, 37 p., illus.

(43) VAVILOV, N.
1919. IMMUNITY OF PLANTS TO INFECTIOUS DISEASES. Izv. Petrovsk. Selsk. Khoz. Akad. (Ann. Acad. Agron. Petrovsk.) 1918, 239 p., illus. [In Russian. English resumé p. [221]–239.]

(44) YAW, F. L.
1924. REPORT ON SURVEY OF THE CANNING TOMATO INDUSTRY WITH SUGGESTIONS FOR IMPROVEMENT. Calif. Agr. Expt. Sta. Circ. 280, 30 p., illus.

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