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TEXAS AGRICULTURAL EXPERIMENT STATION

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COLLEGE STATION, BRAZOS COUNTY, TEXAS

BULLETIN NO. 343 JULY, 1926

DIVISION OF PLANT PATHOLOGY AND PHYSIOLOGY

STUDIES OF A NEW FUSARIUM WILT OF SPINACH IN TEXAS

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†As of June 30, 1926.
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***In cooperation with the School of Agriculture.

SYNOPSIS

Spinach is an important truck crop in Texas, and is grown mostly as a winter crop. A new spinach wilt has been under observation for several years. This trouble causes serious losses, especially on spinach which matures during the late spring or early summer. At first it was thought that this disease as it affects spinach in Texas was the same as the one occurring in Idaho. However, as indicated in this Bulletin, this disease was found to be hitherto undescribed, and is caused by a fungus, Fusarium solani, which is commonly found on decayed tubers of Irish potatoes. The cause of the disease was definitely established by inoculating healthy spinach with pure cultures of Fusarium solani from spinach and Irish potatoes. It was shown that this disease has a definite relationship to soil temperatures, becoming worse as the temperatures of the air and soil increase. The causal organism was studied and comparisons were made with the Fusarium spinaciae which causes a spinach wilt in Idaho. The two organisms were found to be distinct, and both pathogenic to spinach. Practically all varieties of spinach are susceptible to this wilt except the New Zealand spinach, which was found to be wholly resistant not only to wilt but also to high temperatures and is, therefore, well adapted to summer weather conditions. Control methods would consist in not planting this crop on land previously devoted to spinach or Irish potatoes, but if possible to have it follow some graminaceous crop.

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BULLETIN No. 343 JULY, 1926

STUDIES OF A NEW FUSARIUM WILT OF SPINACH IN TEXAS

BY

J. J. TAUBENHAUS

INTRODUCTION

For the last five years the writer has studied a serious disease of spinach as it occurs in many parts of Texas. The trouble was first found by the writer in 1921 at College Station. Cultures made from roots of infected plants yielded in nearly every case a pure culture of a Fusarium. Hungerford (2) in 1923 called attention to a Fusarium wilt of spinach in Idaho. He submitted the organism to Dr. Sherbakoff, who pronounced it a new species of Fusarium, which he named *Fusarium spinaciae*. In 1924 the author (7) made brief mention of the spinach wilt as it occurs in Texas. The present bulletin sets forth the results of our studies on this disease, which was found to be different from the one occurring in Idaho.

DISTRIBUTION OF THE DISEASE IN TEXAS

After this new disease had been found on spinach grown at College Station, a careful survey by the writer revealed its presence in numerous parts of Brazos County, where spinach is generally grown on a small scale in home gardens. It was also found in East Texas, notably in Smith County in the vicinity of Tyler, and in Cherokee County around Jacksonville and Alto. The disease was also found in abundance in the spinach districts of South Texas around San Antonio, Laredo, Dilley, Carrizo Springs, Crystal City, Big Wells, Asherton, Eagle Pass, and in the lower Rio Grande Valley in the vicinities of Harlingen, Mercedes, Weslaco, Edinburg, McAllen, Pharr, Brownsville, and around Corpus Christi and Robstown. It is probably prevalent wherever spinach is grown in Texas and possibly in other spinach-growing states.

ECONOMIC IMPORTANCE

The main commercial spinach crop of Texas is grown in South Texas. The seed is sown in the early and late fall and the crop harvested from January to the latter part of March. This is of interest on account of the fact that the disease does not seem to cause severe damage on early spinach. The economic importance of the disease is shown by estimates made by the writer which place the losses from Fusarium wilt at 2 to 10 per cent of the early crop, and 20 to 70 per cent of the late plantings. The disease has been found on virgin land on all types of soils. However, the greatest damage occurs on old land devoted to spinach for a succession of years.

SYMPTOMS

The disease is very characteristic and resembles a typical wilt. Infected plants first attract attention by their stunted and dwarfed condition. As the season advances, such plants turn pale, the lower leaves wilt, and gradually die. Affected plants may be readily pulled out from the ground without much difficulty. The roots of such plants are of a pale dead color accompanied by a loss in turgor. When cut open crosswise or lengthwise the interior tissue appears brown in color.

The spread of the disease becomes more pronounced with the approach of warm weather, when the soil temperature rises. At that time healthy, vigorous plants suddenly become infected and wilt. This will be referred to later.

The Fusarium wilt of spinach is frequently mistaken by growers for damage caused by the onion maggot. With the latter, however, the chief injury is in the center of the plant though the outside leaves turn yellow and may even wilt. By cutting into such affected plants, one or more maggots may be found in the rotted center. Not infrequently the maggot injury opens the way to infection by Fusarium wilt. In Texas, spinach is also found to be attacked by a Rhizoctonia, which causes numerous deep, dark lesions on the roots, and this results in a stunting of the plant. Like maggot injury, Rhizoctonia root rot frequently opens the way to infection by Fusarium wilt, thus materially shortening the life of the plant.

Table 1. Isolations from Field-Infected Spinach.

Source of Infected Spinach	Date	Parts of Plant Cultured	Number of Plate Cultures Made	Percentage of Plates Showing Fusarium	Pathogenicity of Fusarium Established
College Station, Texas	April 28, 1924	Roots.......	298	94	Yes, on spinach
College Station, Texas	April 29, 1924	Leaf petioles.	115	0	
College Station, Texas	April 29, 1924	Leaf veins...	49	0	
College Station, Texas	June 16, 1924	Seed stalks..	98	0	
College Station, Texas	April 30, 1925	Roots	70	90	Yes, on spinach
College Station, Texas	April 30, 1925	Leaf petioles.	72	0	
Laredo, Texas.......	May 2, 1924	Roots.......	207	98	Yes, on spinach
Laredo, Texas........	May 3, 1924	Leaf petioles.	93	0	
Laredo, Texas.......	May 3, 1924	Leaf veins...	57	0	
Crystal City, Texas..	April 26, 1924	Roots.......	206	80	Yes, on spinach
Crystal City, Texas..	April 27, 1924	Leaf petioles.	105	0	
Crystal City, Texas..	April 27, 1924	Leaf veins...	97	0	

PARTS OF PLANT AFFECTED

To determine the parts of the plant affected, diseased spinach plants were secured from three separate sections of this State, namely, College Station, Laredo, and Crystal City. Cultures were made from the roots, petioles, leaves, leaf veins, and seed stalks. The method of isolation was as follows: Affected material was thoroughly washed in running tap water to remove adhering particles of soil, and then cut up into small pieces about one-eighth of an inch in length. These were then dropped in a test tube and immersed one-half to one minute

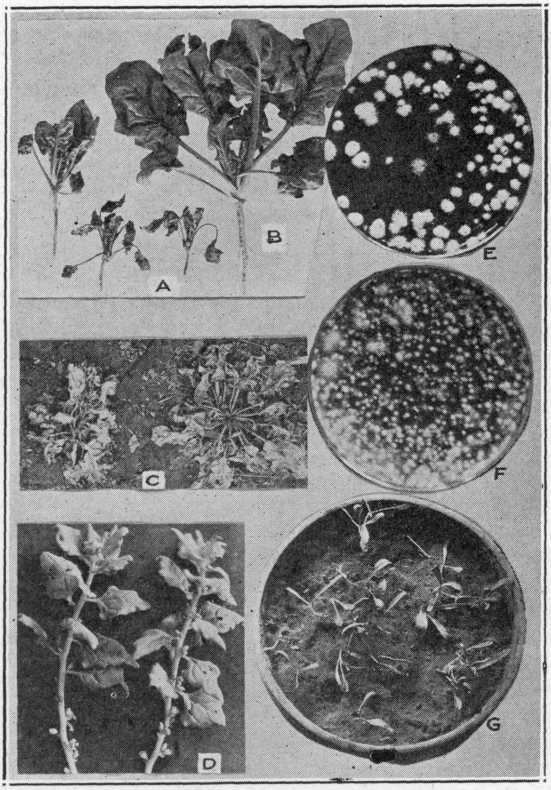

Figure 1.

a. Early infected plants as they are commonly met with in the field showing wilting and stunted condition. b. Normal healthy plant of same age for comparison. c. Mature spinach plants suddenly wilting and showing collapsed condition. d. Two branches of New Zealand spinach, which is wholly resistant to the wilt disease. e. Practically a pure culture of *Fusarium solani* isolated from roots of infected spinach grown in the field. g. Spinach seedlings artificially infected with *Fusarium solani* showing wilting. f. Practically a pure culture of *Fusarium solani* recovered from artificially infected seedlings shown in g.

in a solution made up of equal parts of 1:1000 mercuric chloride and 50 per cent alcohol. The material was rinsed five times in sterile water to remove all traces of the disinfectant. Individual pieces of the tissue were taken out aseptically, placed in a tube which contained melted but properly cooled agar, and crushed with sterile forceps. The agar containing the crushed tissue was poured from the tube into a sterile Petri dish. In order to keep out contamination from bacteria, a drop of a 5 per cent lactic acid was added to each Petri dish. As soon as growth appeared transfers were made to slants of agar tubes and the resulting pure growth was used for inoculation or study. It is seen in Table 1 that the causal organism was recovered from the roots only of affected spinach plants. This was true not only of specimens secured locally, but also from other parts of Texas. From this it would seem that in Texas the Fusarium wilt of spinach is entirely a root trouble. Hungerford (2) does not state whether in Idaho spinach wilt infects any of the parts of the plant above ground, although he points out that *Fusarium spinaciae* is an organism which invades the vascular system of the spinach root. The Fusarium here described, on the other hand, is found to invade not only the vascular bundles but other tissues of the root as well. A further study of the Texas spinach Fusarium brought out the fact that it is identical with *F. solani.*

EVIDENCES THAT FUSARIUM SOLANI IS THE CAUSE OF THE DISEASE

In order to determine the pathogenicity of this organism, pure cultures were secured from infected spinach grown in various parts of Texas. Likewise, a tube culture of *F. solani* from decayed Irish potatoes was secured from Dr. Sherbakoff from Tennessee and a tube culture of *F. spinaciae* from Professor Hungerford from Idaho. These strains were tested as to their pathogenicity on spinach. The method of inoculation was as follows: 8-inch pots were filled with a good sandy loam. The pots and soil were sterilized for four hours at 20 pounds steam pressure. After properly cooling, the soil in the pots was inoculated with a ten-day tube culture of Fusarium, which grew in tube slants of oatmeal agar. The entire content of the tube was broken up in sterilized water and worked in the soil in the pot, and allowed to stand undisturbed for one week. This was intended to permit the organism to grow and thoroughly invade the inoculated soil, which was then planted with spinach seed. After germination, the spinach plants were watched for the appearance of disease, and the causal organism recovered from the plants. Checks were also used in which the pots and soil were sterilized but not inoculated with any organism. From Table 2 it is seen that whenever *Fusarium solani* is isolated from spinach roots it is pathogenic to spinach. The symptoms of the artificially infected plants appeared identical with those of naturally infected spinach. Table 2 further indicates that *Fusarium solani* obtained from Irish potatoes from Tennessee was likewise pathogenic to spinach. From these experiments it is evident that *Fusarium solani* is the cause of the spinach wilt disease in Texas.

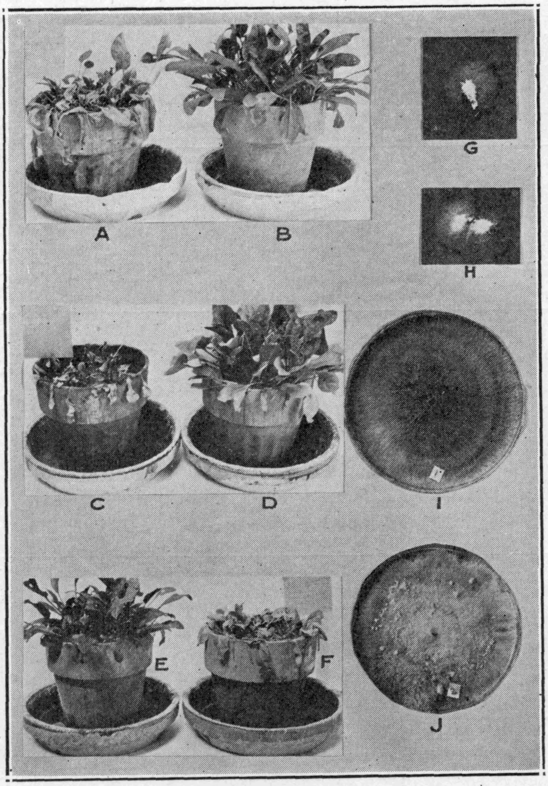

Figure 2.

a. Spinach seedlings artificially infected with *Fusarium spinaciae* from Idaho. b. Healthy check, uninoculated. c. Spinach seedlings artificially inoculated with *Fusarium solani* from spinach. d. Check, healthy, uninoculated. f. Spinach seedlings artificially inoculated with *Fusarium solani* from decayed tubers of Irish potatoes from Idaho. e. Check, healthy, uninoculated. g. Portion of spinach root artificially inoculated with *Fusarium spinaciae* from Idaho, planted in a Petri dish of agar agar and showing Fusarium growth. h. Two sections of spinach roots artificially inoculated with *Fusarium solani* from spinach planted in Petri plates of agar agar showing Fusarium growth. i. Young Petri dish culture of *Fusarium solani* from spinach grown on potato agar and showing radial growth. j. A more advanced stage of *i*.

Table 2. Artificial Inoculations on Spinach.

Date of Inoculation	Source of Inoculum	Number of Pots Inoculated	Results and Date	Number of Reisolations from Roots of Artificially Inoculated Plants	Results and Date
Dec. 8, 1924	*Fusarium solani* from spinach roots from College Station, Texas.	6 Pots, 50 seedlings per pot	January 26, 1925, 65 per cent infection.	32	January 30, 1925. All plates show typical Fusarium.
Dec. 8, 1924	*F. solani* from spinach roots from Laredo, Texas.	5 Pots, 50 seedlings per pot	January 26, 1925, 78 per cent infection.	59	January 30, 1925. All plates show typical Fusarium.
Dec. 8, 1924	*F. solani* from spinach roots from Crystal City, Texas.	5 Pots, 50 seedlings per pot	January 30, 1925, 80 per cent infection.	37	February 2, 1925. All plates show typical Fusarium.
Dec. 8, 1924	Check. No inoculation.	4 Pots, 50 seedlings per pot	January 26, 1925, all healthy.		
Jan. 26, 1925	*F. solani* from spinach roots from College Station, Texas.	4 Pots, 50 seedlings per pot	March 30, 1925, 71 per cent infection.	40	April 5, 1925. All plates show typical Fusarium.
Jan. 26, 1925	*F. solani* from spinach roots from Laredo, Texas.	3 Pots, 50 seedlings per pot	March 30, 1925, 73 per cent infection.	22	April 5, 1925. All plates show typical Fusarium.
Jan. 26, 1925	*F. solàni* from spinach roots from Crystal City, Texas.	4 Pots, 50 seedlings per pot	March 30, 1925, 76 per cent infection.	12	April 5, 1925. All plates show typical Fusarium.
Jan. 26, 1925	Check. No inoculation.	2 Pots, 50 seedlings per pot	March 30, 1925. All healthy.		
Mar. 16, 1925	*F. solani* from spinach roots from College Station, Texas.	6 Pots, 50 seedlings per pot	May 8, 1925, 82 per cent infection.	47	May 12, 1925. All plates show typical Fusarium.
Jan. 26, 1925	*F. solani* from Irish potatoes from Tennessee.	8 Pots, 50 seedlings per pot	March 3, 1925, 70 per cent infection.	68	March 8, 1925. All plates show typical Fusarium.

Although not indicated in Table 2, artificial inoculations with *Fusarium spinaciae* showed that it is just as pathogenic to spinach, as is *Fusarium solani*. Results of these inoculations are shown in Fig. 2, a-h.

Fusarium solani, according to Sherbakoff (6), is usually found on rotted potato tubers and on decaying organic matter. It is surprising, therefore, to find that this organism is pathogenic to spinach. In a conversation with Dr. Sherbakoff, the writer understood him to say that he found *Fusarium solani* to be parasitic on plants other than the Irish potato.

In addition to establishing the pathogenicity of *Fusarium solani* as to spinach and Irish potatoes, it was also necessary to determine the virulency of these organisms on potato tubers. From Table 3, it is evident that *Fusarium solani,* whether isolated from spinach or from Irish potatoes, is pathogenic to Southern spring-grown Irish potatoes. However, infection was rather slight when inoculations were made on Northern-grown winter varieties.

Table 3. Artificial Inoculations on Irish Potatoes.

Date of Inoculation.	Source of Inoculum.	Source of Tubers Used	Number of Tubers Inoculated	Results and Date
Feb. 2, 1925	*Fusarium solani* from spinach roots from College Station, Texas.	Storage potatoes from Idaho. Variety unknown.	22	March 20, 1925. Sixty per cent of tubers show very slight infection around inoculated area, causing dry rot.
Feb. 2, 1925	*Fusarium solani* from Irish potatoes from Tennessee.	Storage potatoes from Idaho. Variety unknown.	18	March 20, 1925. 63 per cent of tubers show slight infection as above.
Feb. 2, 1925	Check. No inoculation.	Storage potatoes from Idaho. Variety unknown.	31	March 20, 1925. All healthy but one which was decayed by slimy soft rot.
Feb. 2, 1925	*Fusarium spinaciae* from spinach from Idaho.	Storage potatoes from Idaho. Variety unknown.	28	March 20, 1925. All healthy.
May 27, 1925	*Fusarium solani* from spinach roots from College Station, Texas.	Spring, Texas-grown Triumphs.	39	June 16, 1925. 100 per cent of tubers rotted throughout, causing soft decay.
May 27, 1925	*Fusarium solani* from Irish potatoes from Tennessee.	Spring, Texas-grown Triumphs.	32	June 16, 1925. 100 per cent of tubers rotted throughout as above.
May 27, 1925	Check. No inoculation.	Spring, Texas-grown Triumphs.	27	June 16, 1925. All healthy.
May 27, 1925	*Fusarium spinaciae* from spinach from Idaho.	Spring, Texas-grown Triumphs.	41	June 16, 1925. All healthy but two tubers decayed by slimy soft rot.
May 27, 1925	*Fusarium solani* from Irish potatoes from Virginia.	Spring, Texas-grown Triumphs.	25	June 16, 1925. 100 per cent of tubers rotted throughout, causing soft decay.

PHYSIOLOGY OF THE CAUSAL ORGANISM

To determine the possible relationship or differences between *Fusarium solani* and *Fusarium spinaciae,* the two organisms were grown on a variety of media in both Petri dishes and Erlenmeyer flasks. Best results were obtained with potato starch agar, steamed rice, and corn meal. It was found that *Fusarium solani* from Texas spinach and *Fusarium solani* from decayed tubers from Tennessee were practically identical on all media grown, but were distinct from *Fusarium spinaciae.* On potato starch agar in Erlenmeyer flasks, *Fusarium spinaciae* makes a flat, shiny, superficial growth with no discoloration of the substrata and possesses a strong fermenting odor (Figure 3, a). On the other hand, *Fusarium solani* makes a restricted, fluffy growth, with distinct browning of the substrata and no odor of fermentation. Similar conditions were also found on corn meal (Figure 3, b). When grown in Petri dishes on soft potato agar, *Fusarium solani* from Texas spinach and *Fusarium solani* from decayed potatoes are very much alike; that is, growth is radial and raised, whereas the *Fusarium spinaciae* growth is flat, restricted, glossy to dirty cream color (Figure 3, c, lower three plates). Perhaps the greatest differences appear when these organisms are grown in Petri dishes on hard potato agar. Here *Fusarium solani* from Texas spinach and *Fusarium solani* from decayed Irish potatoes are distinctly radial. With age, *Fusarium solani* from decayed potatoes produces pseudo-pionnotes in concentric rings, which did not appear in *F. solani* from Texas spinach (Figure 3, d). But this slight difference is not considered by the writer to be of sufficient justification to consider the Fusarium affecting Texas spinach a new variety of *F. solani.* On the other hand, *Fusarium spinaciae* on hard potato agar in Petri dishes maintains its flat, glossy characteristic growth (Figure 3, d). In Table 4, the salient differences of *Fusarium solani* and *F. spinaciae* are summarized. In this table it is seen that both *F. solani* and *F. spinaciae* have microconidia, the latter being slightly larger in *F. solani.* The macroconidia in both organisms are mostly three septate, but these are comparatively shorter in *F. solani.* Furthermore, chlamydospores in *F. solani* are from one to three septate and rough-surfaced, whereas in *F. spinaciae* they are slightly smaller, smooth and mostly zero septate. Neither *F. solani* nor *F. spinaciae* were found to produce sclerotia on the many media tried. Pionnotes are formed by *F. solani* and none with *F. spinaciae.* Sporodochia are formed on both organisms, although they are slightly larger in *F. solani.* As already stated, perhaps the greatest distinguishing characteristic between the two is the whitish or dirty cream, glossy, shiny growth of *Fusarium spinaciae* as contrasted with the superficial, raised, fluffy, white to olive, buff, greenish, blue color of *Fusarium solani.* In addition, *F. spinaciae* is characterized by a strong odor of fermentation on various starchy media and this is not the case with *F. solani.*

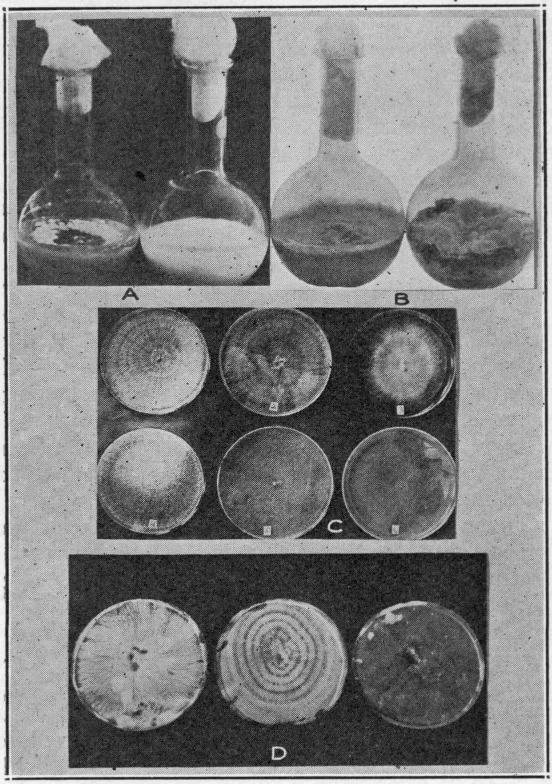

Figure 3.

a. To right, *Fusarium spinaciae* on potato starch. To left, *Fusarium solani* from spinach on potato starch. b. To right, *Fusarium solani* from spinach on corn meal. To left, *Fusarium spinaciae* on corn meal. c. Top row, to right, one plate *Fusarium spinaciae* on potato agar. To left, two plates of *Fusarium solani* from spinach on potato agar. Bottom row, to right, one plate *Fusarium spinaciae* on rice agar. To left, two plates *Fusarium solani* from spinach on rice agar. d. To right, one plate *Fusarium solani* from spinach on hard potato agar. Center plate, *Fusarium solani* from decayed Irish potatoes on hard potato agar. To left, one plate *Fusarium spinaciae* on hard potato agar.

Table 4. Salient Differences Between *Fusarium solani* and *F. spinaciae.*

Characteristics	*Fusarium solani* from Texas Spinach	*Fusarium spinaciae from* Idaho Spinach
Microconidia	Always present, zero septate 8x3–10.5 *u.*	Always present, zero septate 7.5x3–11.4 *u.*
Macroconidia	Mostly 3 septate, comparatively short 27–34x5.4–5.8 *u*, slightly or not pedicillate, rounded to slightly constricted at apex, 4 septate not very prevalent, 5 septate rare.	Mostly 3 septate, 27–45x4.5x6.4 *u* pedicillate, apex broader, but abruptly constricted, 4 to 5 septate infrequent to rare.
Chlamydospores	1–3 septate 5–11 *u*, terminal or intercalary, rough surfaced.	Mostly zero septate, mostly smooth, 5.5–18.6 *u.*
Sclerotia	None	None
Pionnotes	Numerous, bluish	None
Sporodochia	Frequent, larger than in *F. spinaciae.*	Small, whitish, and scarce to rare.
Color of mycelium	White to olive, buff to greenish blue.	In media, without sugar, white to dirty cream, or glossy. With sugar occasionally light lilac.
Odor of fermentation	None	On potato plugs, rice.

SUSCEPTIBILITY OF DIFFERENT VARIETIES OF SPINACH

Under field conditions practically every variety of spinach grown is subject to Fusarium wilt. On the other hand, there seems to exist sufficient evidence of individual resistance. Where the disease is very prevalent, one notices healthy individuals growing here and there next to many others which have died from the wilt. This resistance is especially apparent in the late season when the greatest number of the plants die as a result of the disease. No attempt was made to carry on any selection of these resistant individuals, although there seems to be great promise in that direction. In order to definitely determine the susceptibility or resistance of various spinach varieties to the wilt disease, seeds of as many varieties as could be secured were planted on badly infected land in the writer's home garden. The varieties tested were as follows: King of Denmark, Bloomsdale Savoy, Victoria, Improved Thick Leaved (Viroflay), and Long Season. None of these varieties, however, showed any more resistance than the other. On the other hand, New Zealand spinach (Tetragonia expansa) proved to be completely resistant. However, New Zealand spinach (Figure 1, d) is not a true spinach. New Zealand spinach is grown by truckers and sold to local markets in Texas. It is resistant not only to the Fusarium wilt, but it can also withstand a great deal of hot weather.

EFFECT OF TEMPERATURE ON SPINACH WILT

It is generally conceded that soil temperature is an important factor in either favoring or retarding the spread of certain plant diseases, the causal organism of which is soil-inhabiting. This has been demon-

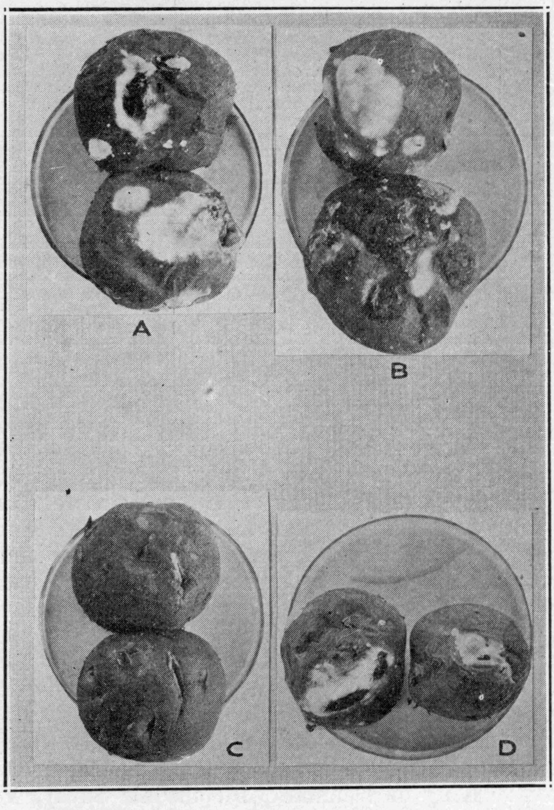

Figure 4.

a. Spring-grown Irish potatoes artificially inoculated with *Fusarium solani* from spinach. b. Spring-grown Irish potatoes artificially inoculated with *Fusarium solani* from decayed tubers of Irish potatoes from Tennessee. c. Spring-grown Irish potatoes inoculated with *Fusarium spinaciae* but remaining healthy. d. Spring-grown Irish potatoes inoculated with *Fusarium solani* from decayed Irish potatoes from Virginia.

strated by Gilman (1), Jones (4, 5), Johnson and Hartman (3), and many others. We have already mentioned the fact that the Fusarium wilt of spinach is more prevalent on late- than on early-planted spinach. This undoubtedly is due to the fact that the later plantings mature at a time of higher soil temperatures. In order to determine this more definitely, the outdoor temperatures of the soil of infected spinach land were studied. Soil temnerature studies were made in the writer's garden where spinach was known to suffer very badly from wilt. One thermometer was used to study the temperature of the air and two others were installed at depths ranging from two to four inches. Temperature readings were taken three times a day, namely, 7:00 a. m., 12:00 m., and 5:00 p. m. A careful check was also kept of the daily percentage of wilt, and records of the daily precipitation were secured from the Division of Entomology of the Texas Experiment Station. The spinach was planted in the middle of February and the soil temperature readings began March 18, 1925, and continued during April, May, and June. Table 5 and Figure 6 clearly show that the rise in percentage of spinach wilt goes hand in hand with a corresponding rise in both the air and soil temperatures.

It is interesting to note that in Webb County and in the Winter Garden District of Texas where spinach is grown on a commercial scale, the crop is planted during the fall months and harvested during the early spring. The later plantings are those to show greater losses from wilt. It appears from this that soil temperature is an important factor in the spread of the spinach wilt in Texas.

Table 5. Relation of Soil Temperature to Percentage of Fusarium Wilt, College Station, 1925.

Month	Outdoor			2 Inches			4 Inches			Monthly Precipitation Inches	Monthly Per Cent Wilt
	Extremes		Monthly Mean	Extremes		Monthly Mean	Extremes		Monthly Mean		
	Maximum	Minimum		Maximum	Minimum		Maximum	Minimum			
March	89	48	72.3	86	53	70.4	81	58	68.5	1.55	1
April	98	50	78.8	94	51	77.2	92	60	76.2	1.18	2
May	104	52	85.4	96	54	80.8	90	58	79.4	.12	15
June	110	74	93.8	102	80	89.3	98	72	86.4	1.62	63

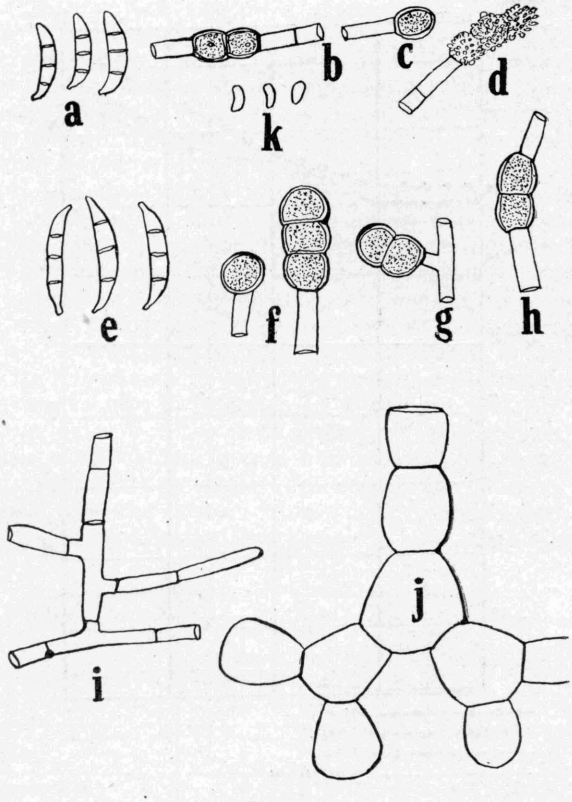

Figure 5.

a. Macrospores of *Fusarium solani* from spinach. b, c, and d. Chlamydospores of *Fusarium solani* from spinach. k. Microspores of *Fusarium solani* from spinach. e. Macrospores of *Fusarium spinaciae*. f, g, and h. Chlamydospores of *Fusarium spinaciae*. i and j. Mycelium of spinach Rhizoctonia.

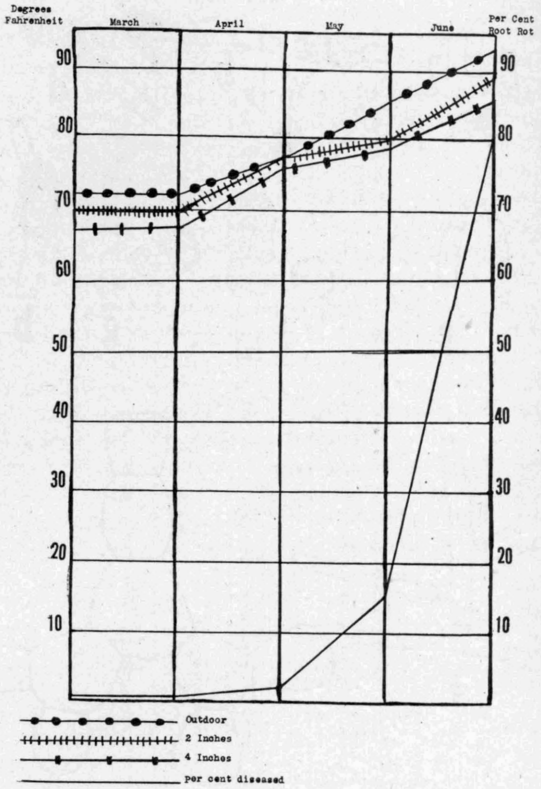

Figure 6.

Graph showing the relationship of average, mean outdoor temperature and soil temperatures of two and four inches depth for March, April, May, and June, 1925, and the relation to the percentage of Fusarium wilt during these months.

RHIZOCTONIA ASSOCIATED WITH FUSARIUM WILT

In our studies of the Fusarium wilt of spinach we frequently found Rhizoctonia root rot disease more or less serious. This trouble was manifested by typical cankered lesions, which were confined to the foot of the plant or its roots. In many cases the Rhizoctonia was associated with the Fusarium wilt. In other cases it was found independent of that disease. In either case, the Rhizoctonia was found to cripple seriously the root system and to inhibit the normal development of the plant. No studies were made to compare the Rhizoctonia of spinach with the same organism as it occurs on the Irish potato. Comparative studies were made of the spinach Rhizoctonia and a species of Rhizoctonia isolated from cotton seedlings affected with sore shin. When grown on sterilized rice the spinach Rhizoctonia was found to penetrate and to grow within the entire substratum, coloring it a distinct light brown. On the other hand, the cotton Rhizoctonia was found to grow superficially and did not color the substratum. Whether or not we are justified in considering both the spinach and cotton Rhizoctonia distinct from each other and from the Rhizoctonia of potatoes remains to be determined. At present, the spinach Rhizoctonia is mentioned only because of its importance in causing a serious root trouble and because of its opening the way to infection by Fusarium wilt.

In order to determine the pathogenicity of the spinach Rhizoctonia, spinach seeds were planted in pots and inoculations carried out as for the spinach Fusarium previously discussed. In referring to Table 6, it will be seen that the spinach Rhizoctonia is highly pathogenic, as it caused 100 per cent infection every time it was inoculated into sterilized soil.

Table 6. Rhizoctonia Inoculation on Spinach.

Date of Inoculation	Number of Pots Inoculated	Per Cent Germination of Spinach Seed	Date and Per Cent of Infection
March 11, 1924	8	93	April 15, 1924. 100
Check. No inoculation	4	100	April 18, 1924. All healthy.
October 3, 1924	6	84	November 15, 1924. 100
Check. No inoculation	3	99	Nov. 15, 1924. All healthy.

METHODS OF CONTROL

No definite methods of control have been worked out for either the Fusarium wilt or Rhizoctonia root rot of spinach. The growing commercial importance of spinach now demands attention to this problem. It has already been pointed out that the Fusarium wilt, especially, is more prevalent and serious on late-planted spinach; hence the chief method for spinach growers is to plant early enough to avoid the high soil temperatures. Frequently, however, late-planted spinach brings as good a price or even better than early-planted spinach. Late-planted spinach crop should not be planted on newly cleared land or land previously devoted to Irish potatoes. It would seem advisable to plant late spinach in South Texas after corn or sorghum. Furthermore, late-planted spinach should be given all possible care, especially in irrigation to prevent any setback, which favors infection.

SUMMARY

In 1921, a new spinach wilt was first found and reported by the writer at College Station, Texas. In 1923, Hungerford (2) reported a new spinach wilt in Idaho. Studies were made with a view of determining the cause of the spinach wilt in Texas and its possible identity with that of Idaho. A summary of our studies brings out the following salient features:

1. Spinach wilt in Texas is caused by the fungus *Fusarium solani,* which is ordinarily found on decayed tubers of Irish potatoes and also causes decay of spring-grown Irish potatoes.
2. The spinach wilt of Texas, although apparently similar in appearance to that of the Idaho spinach wilt, was found to be distinct from the latter, and prevalent in many parts of the State.
3. The disease is less severe on winter-grown spinach, but more serious on spinach planted in the early spring or late summer.
4. The symptoms of the spinach wilt are typical of a Fusarium of which the causal organism is confined to the root. Where infection occurs early, plants remain stunted and dwarfed. When older plants become affected, they seldom recover, but generally die within a few days. Frequently this disease may be mistaken for injury brought about by root maggots.
5. The causal organism of spinach wilt is confined to the roots. We have never been able to isolate the causal organism from any parts of the leaves, stems, or seed stalks.
6. *Fusarium solani* from Texas and *Fusarium spinaciae* from Idaho are both pathogenic to spinach, but the two organisms are very different when grown in pure culture on media rich in carbohydrates. All varieties of spinach are subject to spinach wilt in Texas, with the exception of New Zealand spinach, which is not a true spinach.
7. Soil temperature is an important controlling factor in the spread of the spinach wilt. Under Central Texas conditions the disease does not spread under the average outdoor temperatures of 72 degrees Fahrenheit, or of 70 degrees in the soil at a depth of two inches, or 68 degrees in the soil at a depth of four inches. The disease gradually increases with the increase of soil temperature above these temperatures.
8. In connection with the Fusarium wilt, a new Rhizoctonia root rot has been found and preliminary studies reported. The Rhizoctonia causes a serious root rot and it also opens the way to infection by Fusarium wilt. The spinach Rhizoctonia seems to be different from the Rhizoctonia which causes sore shin of cotton in Texas.

9. Control methods of Fusarium wilt would consist in not planting spinach during the months of high soil temperatures.

ACKNOWLEDGMENT

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