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DIVISION OF PLANT PATHOLOGY AND PHYSIOLOGY

WILTS OF THE WATERMELON AND RELATED CROPS

(Fusarium Wilts of Cucurbits)

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‡In cooperation with School of Agriculture, A. & M. College of Texas.
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BULLETIN NO. 260. FEBRUARY, 1920.

WILTS OF THE WATERMELON AND RELATED CROPS

(Fusarium Wilts of Cucurbits.)

BY

J. J. TAUBENHAUS.

Watermelons constitute an important agricultural crop in Texas and are grown mainly in light sandy soil. The United States census estimated the area devoted to watermelons in Texas in 1910 as 18,466 acres, with a value of $539,313. Since then the acreage has increased at least 20 per cent. Of late, Texas watermelon growers, especially those in Waller County, experienced considerable difficulty in producing a normal crop. The failure was due primarily to several important fungous diseases. A conservative estimate may place the money losses from these diseases at not less than 20 per cent. of the total crop in the State. This does not take into consideration the waste from diseases of squashes, cashaws, pumpkins, cucumbers, and cantaloupes, which are of no little economic concern.

Of the many diseases which affect watermelons and other cucurbits in Texas, the Fusarium wilts are by far the most important. Watermelon wilt especially is not only prevalent in Texas, but according to Orton(15) it is also found from Maryland to Florida, in Alabama, Iowa, Oklahoma, California, and Oregon. On account of its economic importance, investigations were begun in 1916. The results obtained, and here presented, deal with studies on the Fusarium wilts of watermelons and related crops. The other diseases of cucurbits are now being studied and the results obtained will be presented in a later publication of the Texas Agricultural Experiment Station. The field experiments on this project were carried out at the Prairie View Normal School and grateful acknowledgment is due to the authorities of that institution and especially to Professors Waller and Ed Williams for whole-hearted assistance and cooperation. The writer was also assisted by different laboratory helpers, who, because of the war, did not remain long enough with the work. In this connection, however, mention should be made of the valuable assistance rendered by Mr. Albert Johnson, formerly a graduate student of the Texas Agricultural and Mechanical College and now captain in the U. S. army.

HISTORICAL.

The investigation of the Fusarium wilt of watermelon received first attention from Dr. Erwin Smith(21), who in 1899 devoted considerable study to it. However, Dr. Smith's claim that the fungus *Necosmospora* *vasinfecta* was the perfect or ascus stage of *Fusarium vasinfectum,* originally described by Atkinson(1) as causing a wilt disease of cotton was the cause of much confusion. At first no one seemed to question these results, as they were accepted by most workers, among whom may be mentioned Martin(14), Stuckey(24), and others. Of those to challenge the validity of Dr. Smith's conclusions was Higgins(12), who showed that *Fusarium vasinfectum* Atk. and *Necosmospora vasinfecta* (Atk.) Ew. Sm. were not genetically related. Furthermore, Higgins(12) has shown that the watermelon fungus referred to by Dr. Smith as *Necosmospora vasinfecta* var. *niveum* was really a distinct species, to be referred to as *Fusarium niveum* Ew. Sm. Later, Butler(2), Delacroix(6), and Wollenweber(25), like Higgins, also proved that *Necosmospora vasinfecta* was not in any way related to the *Fusarium vasinfectum* or to any other pathogenic Fusaria.

PRESENT WORK.

It was already mentioned previously that Fusarium wilt is one of the serious drawbacks to profitable watermelon culture in Texas. This is also true with the squash and the cashaw, which suffer from a serious Fusarium wilt, but this wilt, as will be shown later, is caused by a Fusarium which is distinct from the fungus that causes wilt of the watermelon. The scope of the present work attempted to answer the following points relative to wilt diseases of cucurbits and other crops:

(1) Is *Necosmospora vasinfecta* the ascus (winter-resting spore stage) stage of *Fusarium vasinfectum* which causes a wilt of cotton?

(2) Is *Fusarium niveum* the conidial or summer fruiting stage of *Necosmospora vasinfecta* or is it a distinct species?

(3) Is *Fusarium vasinfectum* the cause of watermelon wilt?*

(4) Is the Fusarium wilt of squash and cashaw similar to or distinct from the Fusarium wilt of the watermelon?

(5) Is *Fusarium niveum* in any way related to the wilts of cotton, okra, cowpea, Irish potato, tomato, cabbage, or sweet pea?

(6) Is watermelon wilt induced by more than one species of Fusarium?

(7) Are cotton and okra wilts induced by the same fungus, *Fusarium vasinfectum?*

(8) What is the life history of the watermelon wilt fungus?

(9) What is the effect of soil temperature on the prevalence of the watermelon wilt?

METHOD OF PROCEDURE.

In order to definitely establish the above points, three series of experiments were planned, namely: (1) Field tests; (2) greenhouse experiments; (3) laboratory technic.

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*See also Taubenhaus, J. J. Diseases of truck crops: 244-246, 1918. (E. P. Dutton Co., New York.)

A. FIELD TESTS.

As previously mentioned, the field work was carried out at the Prairie View Normal College during four consecutive seasons. The above place was chosen because of the severity of cucurbit wilts there. Field tests were also carried out on the farms of Messrs. Garret and Robinson, to whom grateful mention is here due.

At Prairie View College, the field tests were planned as follows:

(a) One-half acre of watermelon "sick" soil, designated as plot A (chosen because watermelons had died badly there), was planted to watermelon, squash, cashaw, pumpkin, cucumber, cantaloupe, gourd, citron, cotton, cowpea, okra, and Irish potato, all being arranged in the order as shown in Table 1. Plot A was set aside as a permanent watermelon "sick" field in order to study the watermelon wilt and its relationship to the wilts of the other hosts mentioned in Table 1.

(b) One-half acre designated as plot B was chosen because of the fact that squashes and cashaws had died there for a number of years. This plot was planted to squash, cashaw, watermelon, gourd, cucumber, cantaloupe, cowpea, cotton, okra, and Irish potato. The arrangement of these hosts was made as indicated in Table 2. The object here was to determine whether or not the wilts of the squash and cashaw were the same as the wilt of watermelon, or if possibly related to the wilts of the other hosts indicated in Table 1.

(c) One-half acre designated as plot C was chosen because of its being virgin land and was planted to watermelons for the first time in 1916. This field was a pasture for a large number of years and was, as far as known, never planted to watermelons. Plot C was divided in equal halves, one part of which was fertilized with manure and the other half with commercial fertilizers. At the end of the summer season all the old watermelon vines and fruit culls in both parts of the plot were turned under with the plow (see Table 3). The object in plot C was to determine how many years it would take for a supposedly virgin land to become infected with watermelon wilt.

(d) One acre of watermelon "sick" soil designated as plot D was divided into three equal parts. One part was devoted to watermelon, the second to oats and cowpeas, the third to corn, a basis for a three-year rotation being thus formed. The object of this field (see Table 4) was to determine the effect of a three-year rotation on the control of watermelon wilt on sick soil.

(e) One acre of virgin land designated as plot E was divided in the same way as in D (see Table 5). The object in this plot was to determine whether a three-year rotation practiced on a virgin land would keep out watermelon wilt indefinitely.

(f) One-half acre of virgin land designated as plot F was planted to cucumber and cantaloupe, in which was also intermingled watermelon, squash, gourd, and cashaw. The object in this plot was to determine what would be the effect of growing various cucurbits on the same land and which of the cucurbit diseases would be common to all.

As no wilt appeared, further mention of this plot will, therefore, be omitted in this bulletin.

(g) One acre of wilt-infected watermelon land designated as plot G was planted to various varieties of watermelons. This was done in order to determine the existence, if any, of resistant varieties.

(h) One acre of wilt-infected squash land designated as plot H was planted to various varieties of squash, pumpkin, gourd, cantaloupe, and cucumbers so as to determine the presence, if any, of resistant varieties.

(i) One acre designated as plot I at the Robinson farm (in which cowpeas died badly from Fusarium wilt and okra only slightly), was planted to cowpeas, okra, cotton, squash, gourd, cashaw, watermelon, tomato, and cabbage. The object in this plot was to determine the relationship, if any, of the cowpea and okra wilts to the other hosts grown there. The experiments in plots A to I were carried on during 1916, 1917, 1918, and 1919 and the results obtained follow:

Table 1.—Watermelon sick field.

Host	1916	1917	1918	1919
Squash	100% healthy	100% healthy	1-10 of 1% killed**	½ of 1% killed**
Cotton	100% healthy	100% healthy	100% healthy	100% healthy
Cowpeas	100% healthy	100% healthy	100% healthy	100% healthy
Watermelon	97% killed*	94% killed*	98% killed*	96% killed*
Cucumber	100% healthy	100% healthy	100% healthy	100% healthy
Watermelon	92% killed*	90% killed*	92% killed*	99% killed*
Cantaloupe	100% healthy	100% healthy	100% healthy	100% healthy
Okra	100% healthy	100% healthy	100% healthy	100% healthy
Gourd	100% healthy	100% healthy	100% healthy	100% healthy
Watermelon	98% killed*	97% killed*	90% killed*	92% killed*
Citron	100% healthy	100% healthy	100% healthy	100% healthy
Pumpkin	100% healthy	100% healthy	100% healthy	100% healthy
Cotton	100% healthy	100% healthy	100% healthy	100% healthy
Watermelon	79% killed*	89% killed*	91% killed*	98% killed*
Okra	100% healthy	100% healthy	100% healthy	100% healthy
Citron	100% healthy	100% healthy	100% healthy	100% healthy
Cashaw	100% healthy	100% healthy	½ of 1% killed**	½ of 1% killed**
Watermelon	95% killed*	92% killed*	97% killed	96% killed
Irish potato	100% healthy	100% healthy	100% healthy	100% healthy
Tomato	100% healthy	100% healthy	100% healthy	100% healthy

EFFECT OF A SICK SOIL ON WATERMELONS.

In studying Table 1, it will be seen that during four seasons' trials, watermelons persistently died from Fusarium wilt on a watermelon sick soil. During 1916 and 1917 none of the squash, cucumber, cantaloupe, gourd, citron, pumpkin, cashaw or any of the other hosts mentioned in Table 1 were affected in any way by the watermelon wilt. This, from a practical consideration, proved conclusively that the wilt-producing fungus in the watermelon sick soil was responsible for the dying of the watermelons in that land. During 1918 and 1919, however, a slight per cent. of the squash and cashaw died from a Fusarium wilt which upon isolation proved to be different from the Fusarium wilt of water-

*The fungi isolated from the dead watermelon plants corresponded to Fusarium niveum, F. citrulli and F. poolensis.

**The fungus isolated from the dead squash and cashaw was identical with Fusarium cucurbitae.

melon but identical with the organism of squash wilt. In this case the Fusarium of the squash and cashaw was evidently introduced from the squash-wilt-infected land to the watermelon sick soil.

Table 2.—Squash, Fusarium sick soil.

Host	1916	1917	1918	1919
Squash	78% killed*	82% killed*	77% killed*	90% killed*
Cotton	100% healthy	100% helathy	100% healthy	100% healthy
Squash	81% killed*	92% killed*	78% killed*	91% killed*
Cowpeas	100% healthy	100% healthy	100% healthy	100% healthy
Watermelons	100% healthy	100% healthy	100% healthy	100% healthy
Gourd	100% healthy	100% healthy	100% healthy	100% healthy
Cotton	100% healthy	100% healthy	100% healthy	100% healthy
Watermelons	100% healthy	100% healthy	1 plant died**	3 plants died**
Cowpeas	100% healthy	100% healthy	100% healthy	100% healthy
Pumpkin	100% healthy	100% healthy	100% healthy	100% healthy
Cucumber	100% healthy	100% healthy	100% healthy	100% healthy
Watermelons	100% healthy	100% healthy	100% healthy	2 plants died**
Okra	100% healthy	100% healthy	100% healthy	2 plants died**
Cashaw	69% killed*	81% killed*	82% killed*	96% killed*
Cantaloupe	100% healthy	100% healthy	100% healthy	100% healthy
Cashaw	72% killed*	77% killed*	73% killed*	92% killed*
Irish Potatoes	100% healthy	100% healthy	100% healthy	100% healthy
Tomatoes	100% healthy	100% healthy	100% healthy	100% healthy

EFFECT OF A SICK SOIL ON THE SQUASH AND CASHAW.

In studying Table 2, we find that during the four seasons' trials, both the squash and the cashaw which grew on a sick soil persistently died from a Fusarium wilt which only attacked these two hosts. However, in this same field, neither the watermelon, the cucumber, the cantaloupe, the pumpkin, the gourd, or any other of the hosts mentioned in Table 2 was affected by the squash and cashaw wilt. This conclusively proves that the wilt of the squash and cashaw is in no way related to the watermelon wilt. During 1916, 1917, and 1918 the watermelons in field B remained healthy. However, in 1919 a very small number of watermelon plants died from the typical watermelon wilt.† In this case, evidently, the watermelon wilt fungus was eventually introduced in the wilt-infected squash field. From the results obtained in plots A and B it is evident that it is practically safe to grow squashes and cashaws in the same field where watermelons die from watermelon Fusarium wilt. The same is true also in growing watermelons in a wilt-infected squash land.

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*The fungus isolated from the dead squash and cashaw plants was identical with Fusarium cucurbitae.

**The fungus isolated from the dead watermelon plants was identical with F. niveum.

†Isolation cultures yielded *Fusarium niveum* which upon inoculation into healthy watermelon seedlings caused them to die.

Table 3.—Virgin soil planted in Tom Watson watermelon.

Cultural treatment	1916	1917	1918	1919
Manure alone.—Old vines and culls worked under at end of season.	100% healthy....	1 plant died from Fusarium wilt	½ of 1% died from Fusarium wilt	8% died from Fusarium wilt
Fertilizer alone.—Old vines and culls worked under at end of season.	100% healthy....	100% healthy....	2 plants died from Fusarium wilt	½ of 1% died from Fusarium wilt

MODE OF INFECTION OF VIRGIN LANDS.

In studying Table 3, it will be noticed that on a virgin land where manure was applied and where watermelons were grown there for four consecutive seasons, only one diseased watermelon appeared during the second season in 1917. During the third year the wilt increased to one-half of one per cent., and the fourth year, in 1919, the wilt was prevalent to the extent of 8 per cent. On the other hand, where fertilizer alone was applied to a virgin land, two watermelon plants died from wilt during the third summer in 1918 and only one-half of one per cent. during the fourth season in 1919. This, then, indicates that manure favors earlier infection and the more rapid spread of the watermelon wilt in a virgin land than is the case where commercial fertilizers alone are used. It is further evident from Table 3 that continuous cropping of watermelons on a virgin land will soon introduce the Fusarium wilt. If the practice of continuous growing of watermelons on that land is persisted, that land will become sick to and unfit for watermelons. This fact has actually happened in many counties (especially Waller County), where, in numerous instances, watermelons were grown consecutively on the same land for twenty years or more. This resulted in the wholesale infection of the land, thus making watermelon culture precarious and unprofitable.

Table 4.—Watermelon Fusarium sick soil, 3 year rotation.

1917	1917	1917
1-3 acre in corn. Goodcrop.	1-3 acre in oats and cowpeas. Good crops.	1-3 acre in watermelons. 93% killed by Fusarium wilt.
1918	1918	1918
1-3 acre in watermelons. 40% died from Fusarium wilt.	1-3 acre in corn. Good crop.	1-3 acre in oats and cowpeas. Good crops.
1919	1919	1919
1-3 acre oats and cowpeas. Good crops.	1-3 acre in watermelons.*	1-3 acre in corn. Good crop.

*In May 20, 1919, a careful count showed 23% watermelon plants died from watermelon wilt. By June 10, 1919, and owing to excessive rains most of the watermelon plants were drowned out (see also Fig. 9). This made it impossible to complete the year's work in that plot.

EFFECT OF ROTATION ON SICK LAND.

In studying Table 4, it is seen that a three-year rotation on a badly infected watermelon sick soil was instrumental in reducing the wilt the third season from 93 to 40 per cent., and the fourth season to 30 per cent. Unfortunately, however, during the fourth season (the summer of 1919) the heavy rains during May and June (see Fig. 9) drowned out the field the latter part of the season, so that complete data could not be obtained. It was evident, however, that a three-year rotation considerably reduced the amount of wilt on infected land.

Table 5.—Virgin land, 3 year rotation.

1917	1918	1919
1-3 acre in corn. Good crop.	1-3 acre in oats and cowpeas. Good crops.	1-3 acre in watermelon. Good crop, no Fusarium wilt.
1917	1918	1919
1-3 acre in watermelon. Good crop, no Fusarium wilt.	1-3 acre in corn. Good crops.	1-3 acre in oats and cowpeas. Good crops.
1917	1918	1919
1-3 acre in oats and cowpeas.	1-3 acre in watermelons.	1-3 acre in corn.

EFFECT OF ROTATION ON HEALTHY VIRGIN LAND.

In studying Table 5, one sees that on a virgin land, where a three-year rotation has been practiced, no watermelon wilt appeared during the third season's culture. This clearly and forcibly brings out the necessity of (1) using virgin lands for watermelons, and (2) of practicing on that land a definite system of rotation in order to keep out the wilt.

VARIETAL RESISTANCE IN WATERMELONS.

In studying Table 6, which is self-explanatory, it will be seen that of the twenty varieties of watermelons tested, none showed complete resistance. Furthermore, but very few came in the class B, while most of them were over 90 per cent. susceptible to wilt (see Fig. 1a). Similar results were obtained by Orton(16), who tried out 100 American and Russian varieties and not any of them proved to be resistant. It is probable, however, that through selection of individual resistant hills, a resistant strain may be developed. Because of the dry seasons of 1917 and 1918 the selected hills in the field failed to produce fruit. Selections of resistant hills were made, however, during the season of 1919 and enough seed saved for future work. It is probable that by crossing any of the watermelon varieties with the citron, which is immune to wilt, one may obtain a resistant strain more expeditiously. This was actually done by Orton(16), who crossed the citron with the Georgia Rattlesnake. This strain tested out at Prairie View, Texas, proved to be 100 per cent. resistant but of little value because of its thick rind and spherical shape. The average watermelon growers in Texas prefer

Table 6.—Resistance of watermelon varieties to Fusarium wilt.

Name of variety	Nature of growth	Shape of melon	Average weight of melon	Consistancy of rind	Texture of meat.	Flavor	Shipping qualities	Resistance to disease
Golden Sweet	Scant	Long to round mixed	25 lbs.	Very brittle and thin.	Coarse	Extra sweet	Poor	C*
Ice Cream or Peerless	Rank	Long	24 lbs.	Brittle and thin	Fine, better than Watson.	Good	Poor	C
Shaker Blue	Rank	Round	35 lbs.	Solid and medium thick.	Coarse	Poor	Good	C
Triumph	Rank	Round	25, 28 lbs.	Very solid and thick	Coarse	Poor, not sweet	Good	C
Florida	Rank	Long	28 lbs.	Very solid and thick	Good	Good	Good	C
Striped Gypsy	Rank	Round	20, 25 lbs.	Very solid and thick	Coarse	Citron flavor	Excellent	C
McIver	Rank	Long, Tom Watson shape.	25, 30 lbs.	Solid and medium thin	Fine texture	Good	Good	C
The Dixie	Rank	Short and long	20, 25 lbs.	Very solid but thin	Very coarse	Poor	Good	C
Sweetheart	Rank	Round	35, 40 lbs.	Very solid and thick	Very coarse	Medium sweet	Good	C
Icing or Ice Rind	Rank	Round	20, 25 lbs.	Brittle and thin	Fair	Very sweet	Poor	C
Fordhook	Rank	Long to round	25, 28 lbs.	Very solid and thick	Good	Good	Good	C
Sugarstick	Rank	Long	18, 20 lbs.	Very solid but thin	Fair	Fair	Good	C
Cuban Queen	Rank	Round	30, 35 lbs.	Very tough and thick.	Medium	Fair	Good	C
Mammoth	Rank	Long to round	25 lbs.	Very solid and thick	Fair	Poor	Good	B
Cole's Early	Rank	Round	25, 30 lbs.	Solid and thick	Fine	Fine	Good	C
Kolb's Gem or American	Rank	Round	25 30 lbs.	Very solid and thick	Coarse	Fair	Good	B
Kleckley Sweet	Rank	Long	30, 35 lbs.	Brittle, very thin	Fine	Fine	Poor	C
Tom Watson	Rank	Long	30, 50 lbs.	Solid and thin	Fine	Fine	Good	B
Alabama Sweet	Rank	Long	30, 35 lbs.	Very solid and thin	Medium	Very sweet	Good	C
Holbert Honey	Rank	Long	30, 35 lbs.	Very brittle, very thin	Fine	Extra sweet	Very poor.	C

*A—100% resistant. B—Over 60% infected. C—Over 90% infected.

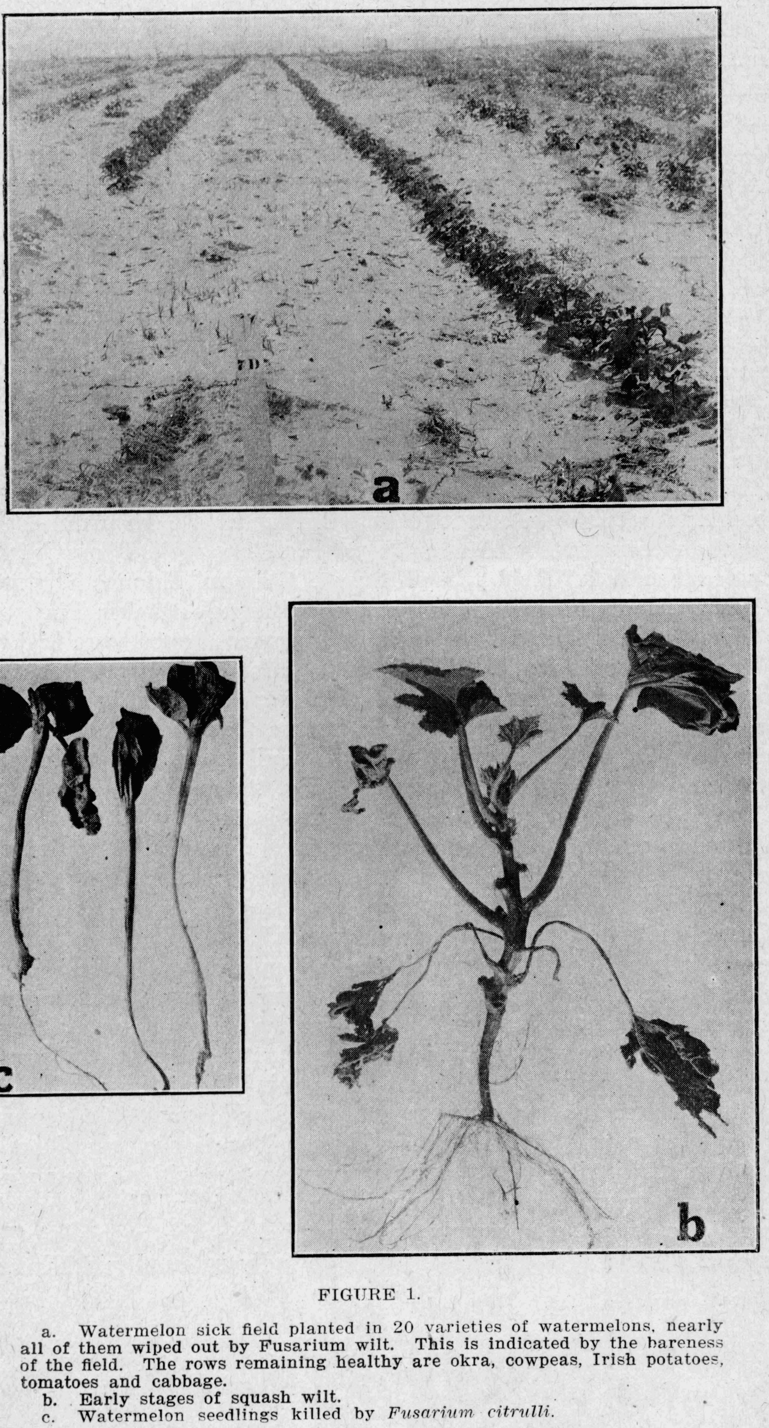


FIGURE 1.

a. Watermelon sick field planted in 20 varieties of watermelons, nearly all of them wiped out by Fusarium wilt. This is indicated by the bareness of the field. The rows remaining healthy are okra, cowpeas, Irish potatoes, tomatoes and cabbage.
b. Early stages of squash wilt.
c. Watermelon seedlings killed by *Fusarium citrulli.*

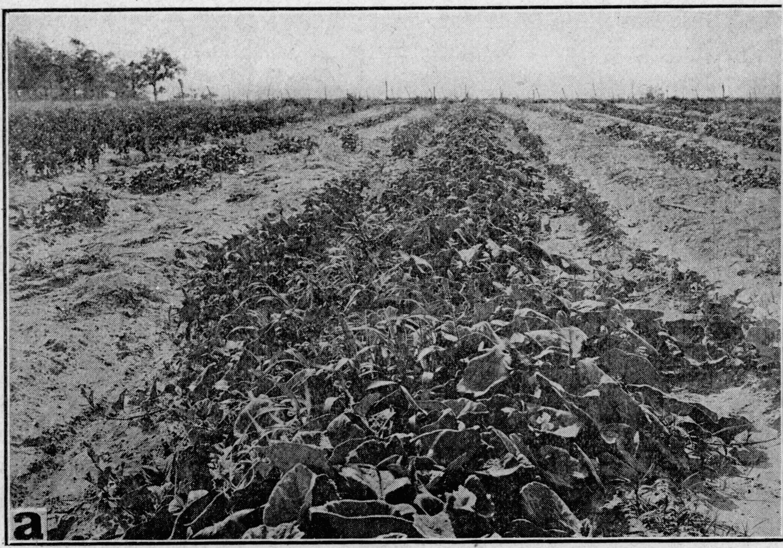
the Tom Watson variety; hence it might be crossed with the citron to obtain quality and resistance. This is planned to be carried out by us in the future. It is true that there are many watermelon varieties which are far superior in flavor to the Tom Watson; however, the latter variety has been well introduced, and, besides, it is a good shipper and is packed economically in the cars when shipped long distances.

VARIETAL RESISTANCE IN OTHER CUCURBITS.

Of the many squash varieties tested, the Mammoth White Bush, Yellow Summer Crookneck, New Giant Summer Crookneck, Long White Marrow, and the Boston Marrow seem to possess considerable resistance. Of the other squash varieties tested which were practically 100 per cent. susceptible to wilt may be mentioned the Early White Scalloped Bush, "Bush" Fordhook, New Red or Golden Hubbard, Chicago Warted Hubbard, Mammoth Chili, Essex Hybrid, Mammoth Whale, Delicious, Delicate, Pike's Peak, Yellow Pathy Pan, and Mammoth Yellow Bush.

It is worthy of note that of the seven varieties of pumpkin tested all showed to be highly resistant to Fusarium wilt. Of the varieties tested may be mentioned Big Tom or Imported Large Field Pumpkin, Large Cheese Kentucky Field, Small Sugar, Genuine Mammoth, Burpee's Golden Oblong, Japanese Pumpkin, and Burpee's Quaker Pie.

Like the pumpkin, all the varieties of gourds tested were highly resistant to Fusarium wilt. This is the case for the cultivated as well as for the ornamental varieties. In Texas there seems to be an inherent prejudice against eating gourds. It is true that because of unpleasant taste most of the edible varieties are not well suited for cooking; however, the variety "Sugar Through" (Fig. 2a and b) obtained from Burpee's Seed Company proved not only resistant to wilt but also highly adapted to cooking and when prepared properly, cannot be distinguished in taste from any of the superior varieties of squashes, pumpkins, or cashaws. In fact, the domestic science department of Praivie View Normal College cooked the "Sugar Through" gourd in various ways and served it to many visitors and to the students without their being told what it was. The dish was relished as though it were pumpkin, squash, or cashaw. "Sugar Through" gourd was also cooked by several farmers as well as by the writer at his home without telling what it was and the fruit was consumed and taken for squash. Furthermore, this gourd is well adapted for canning purposes as well as for pies. On account of the prolific nature of the "Sugar Through" variety of gourd and the size of its fruit, it could take an important place with the pumpkin or any other cucurbit both as a food for humans and for stock. This variety is, therefore, strongly recommended to the people of Texas, especially in localities where the land is badly infected with Fusarium wilt.



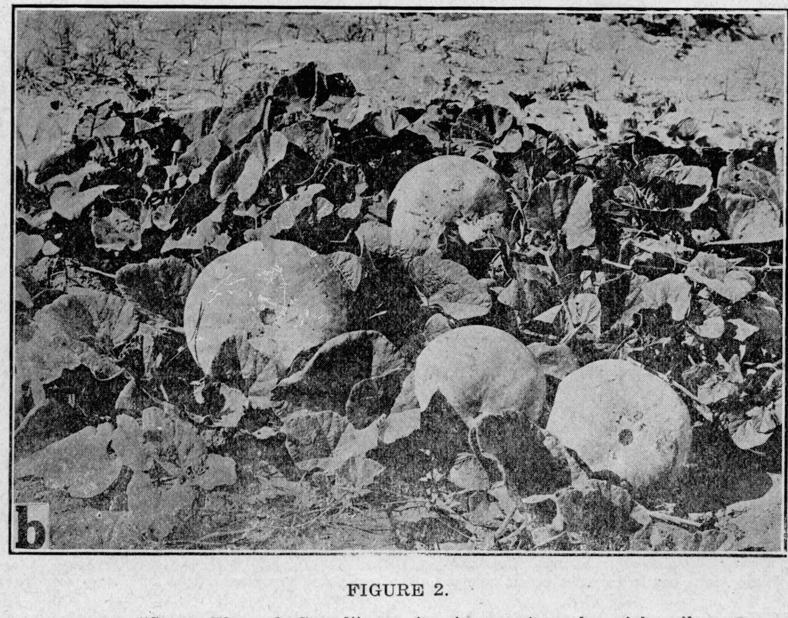


FIGURE 2.

a. "Sugar Through Gourd" growing in a watermelon sick soil.
b. "Sugar Through Gourd" growing in a squash sick soil, exhibiting in both cases 100 per cent resistance.

In addition to the "Sugar Through" gourd the following varieties of gourd have been tested and proved entirely immune to Fusarium wilt: White Egg, Dipper, Dish Cloth or Chuffa, Orange, Apple, Spoon, and Calabash.

Four seasons of field trials seem to indicate that the cucumber is not host to the Fusarium wilts which attack the watermelon or the squash. Cucumbers are frequently subject to the same bacterial blight (*Bacillus tracheiphilus* Ew. Sm.) which affects cantaloupes. Cultures made from freshly wilted cucumber plants yielded in most cases a pure growth of *B. tracheiphilus.* On the other hand various Fusaria were often isolated from infected cucumber plants which had wilted and died long since. These fungi resembled in no way the pathogenic Fusaria of the watermelon and squash wilts. Furthermore, cucumbers grown in infected squash or watermelon sick soil remained healthy during the entire season. The same also holds true for the cantaloupe (Fig. 3a), which in Texas is frequently wiped out not by Fusarium wilt but by bacterial blight (*Bacillus tracheiphilus*) or by *Sclerotium rolfsii* Sacc. Stone(23) reports a serious vascular disease of greenhouse cucumbers and attributes it to a species of Fusarium. It is probable, however, that he either dealt with a new disease or with bacterial blight (*Bacillus tracheiphilus*), and that the Fusarium was only a secondary invader. Lewis(13) reports the following Fusaria to cause a rot on cucumber fruit: *Fusarium orthoceras, F. reticulatum,* and *F. argillaceum.* In Texas, however, we have not met with any of these Fusaria on the cucumber.

Table 7.—Cowpea Fusarium sick soil, Robertson's farm.

Host	1916	1917	1918	1919
Cowpea	79% killed*	76% killed*	83% killed*	86% killed*
Squash	100% healthy	100% healthy	100% healthy	100% healthy
Cotton	100% healthy	100% healthy	100% healthy	100% healthy
Cowpea	82% killed*	79% killed*	76% killed*	82% killed*
Okra	38% killed*	33% killed*	20% killed*	29% killed**
Cotton	100% healthy	100% healthy	100% healthy	100% healthy
Watermelon	100% healthy	100% healthy	100% healthy	100% healthy
Squash	100% healthy	100% healthy	100% healthy	100% healthy
Cashaw	100% healthy	100% healthy	100% healthy	100% healthy
Cowpea	81% killed*	78% killed*	83% killed*	91% killed*
Okra	22% killed**	36% killed**	24% killed**	18% killed**
Cotton	100% healthy	100% healthy	100% healthy	100% healthy
Watermelon	100% healthy	100% healthy	100% healthy	100% healthy
Okra	10% killed**	36% killed*	29% killed**	21% killed**

A NEW OKRA WILT.

In studying Table 7 it will be seen that cowpeas (var. Lady Finger), died badly in the field from *Fusarium tracheiphila*† during the seasons of 1916, 1917, 1918, and 1919. On the other hand, the same wilt did

*Isolations made from infected cowpea plants yielded pure cultures of *Fusarium tracheiphila.*

**Isolations made from infected okra plants yielded not *Fusarium vasinfectum,* but *F. malvacearum.*

†Proved by isolation cultures and artificial inoculation on healthy cowpea plants in the laboratory.

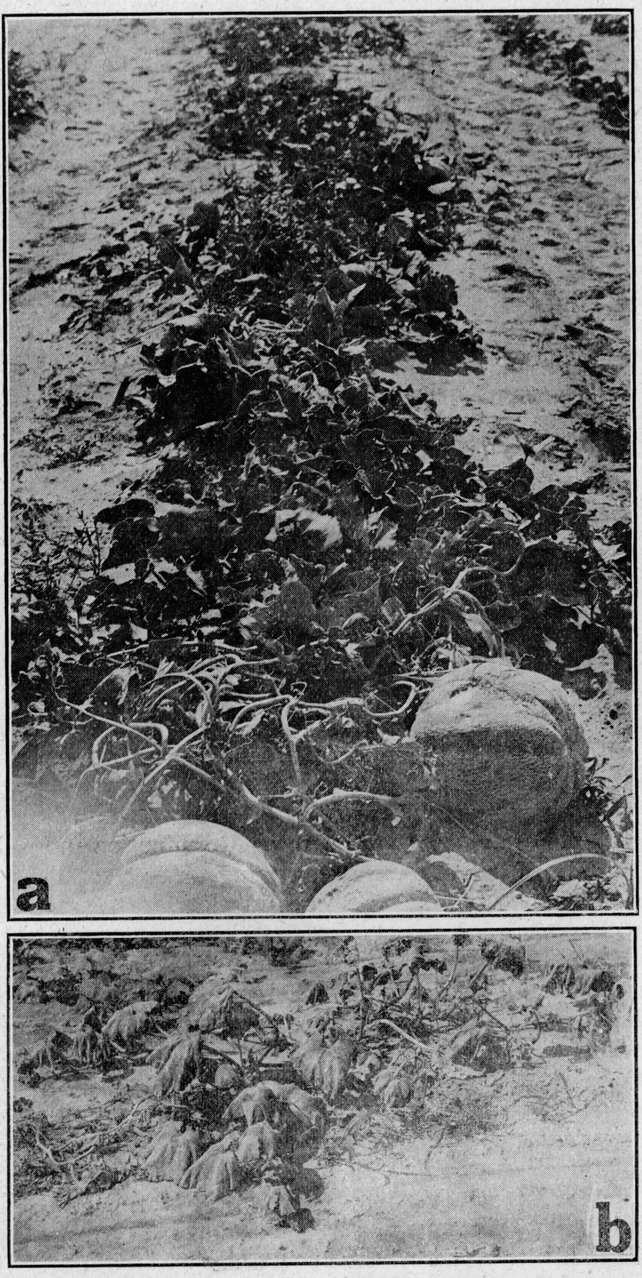


FIGURE 3.

a. Row of cantaloupes growing in a squash sick field, resistant 100 per cent.

b. Squash plant dying from Fusarium wilt in same field as a.

not attack the squash, the watermelon, the cashaw, the cotton, the tomato, the cabbage which were planted during the four seasons in the sick cowpea field. However, the only other crop which was dying from a Fusarium wilt was the okra. This was observed during the summer seasons of 1916, 1917, 1918, and 1919. It should be noticed that the Fusarium wilt which killed the okra at the Robertson farm did not affect the cotton. From experiments referred to later (p. 20), it will be seen that this okra wilt is different from the common wilt of okra and as proved by Carpenter(4) is attributed to *Fusarium vasinfectum,* which also attacks the cotton. As will be seen on page 20 the okra wilt at the Robertson farm was found to be induced by an apparently new species of Fusarium, which for convenience was named *Fusarium malvacearum,* Taub. No attempt has as yet been made to determine the prevalence and distribution of this new okra wilt in Texas.

B. GREENHOUSE EXPERIMENTS.

In connection with, and in order to duplicate the field experiments, a large series of tests were started in the greenhouse during 1917 and 1918. The experiments were arranged as follows:

EXPERIMENT 1.

One bench, one-half of which was filled with sick soil, brought from a watermelon sick field from Prairie View, Texas, was designated as plot 1. The other half of the bench which was separated by a solid partition was filled with sick soil taken from a sick squash field from Prairie View, Texas, and designated as plot 2. Both of these plots were planted with seeds* of watermelon, squash, pumpkin, okra, gourd, and cowpeas. The seeds were planted in rows, 100 to a row. Germination proceeded normally within six to twelve days after sowing. After ten days growth, 80 per cent of the watermelon seedlings in plot 1 died from Fusarium wilt (Fig. 4b). On the other hand, all the other hosts in this plot remained healthy. In plot 2, 65 per cent. of the squash plants died from Fusarium wilt (Fig. 4a) while the watermelon and the other hosts remained healthy. This test, carried out for two years, practically yielded similar results, thus proving that the watermelon sick soil contained Fusarium of watermelon wilt which killed the watermelon, but none of the other cucurbits or the okra or cowpea. Likewise, the squash sick soil which was infected with Fusarium wilt was killing the squash only, but none of the other cucurbits nor the okra and cowpea. In order to definitely determine whether the watermelon and squash seedlings in plots 1 and 2 were killed by Fusaria, isolation cultures were made of freshly wilted plants of both hosts, using all the known aseptic rules. Pure cultures of Fusaria were obtained from both the wilted watermelon seedlings from plot 1 and from the squash seedlings from plot 2. The

*Before planting, the seeds were soaked for one minute in a 1-2000 corrosive sublimate solution, then rinsed in sterilized water.

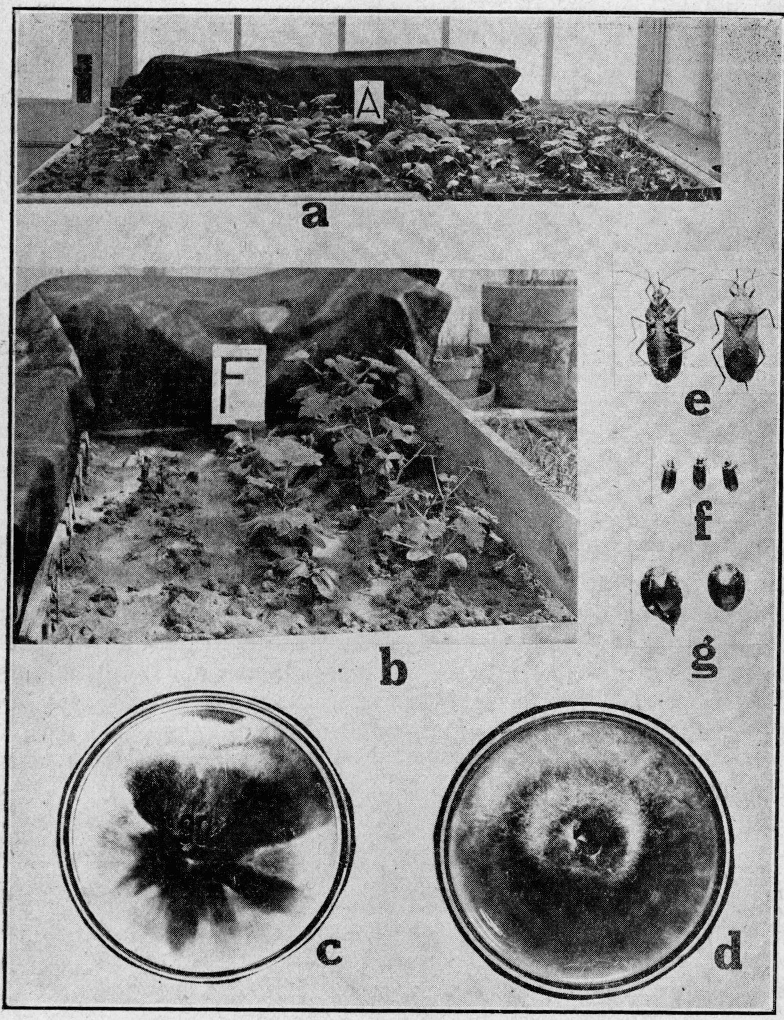


FIGURE 4.

a. Squash sick soil in the greenhouse, to the right and middle only, squash plants die from Fusarium wilt; to the left, watermelon plants remain healthy.
b. Watermelon sick soil in the greenhouse, to the right squash plants remain healthy; to the left, watermelon seedlings badly die from Fusarium wilt.
c. Plate culture of *F. citrulli* on potato agar.
d. Plate culture of *F. niveum* on potato agar.
e. Squash bug. f. Cucumber striped beetle. g. Lady bug. (e. to g., all carriers of watermelon and squash wilt.)

pure culture of Fusarium obtained from the watermelon seedlings was then inoculated in sterilized soil which was planted to healthy disinfected watermelon seed. Likewise the pure culture of Fusarium originally isolated from the squash wilted seedlings of plot 2 was inoculated in the pots with sterilized soil and planted to squash. Within fifteen days the watermelon seedlings and later during blossoming the squash plants were killed by their respective Fusaria inoculated in the pots. In each case, whenever infection became apparent the causal organisms were recovered again.

EXPERIMENT 2. ARTIFICIAL SOIL INFECTION.

Healthy soil was secured and filled in ten 5-inch pots, both soil and pots being twice steam sterilized for two hours at 20 lbs. pressure. Three pots of these were inoculated* with a pure culture of Fusarium obtained from a wilting watermelon stem and two were left as checks. These five pots were then planted with healthy disinfected squash seeds. Of the remaining five pots, three were inoculated with a pure culture of Fusarium which was originally isolated from wilted squash plants and two were left as checks. These five pots were then planted with healthy disinfected seed of watermelon. The seedlings in the ten pots all germinated and both squash and watermelon plants grew and remained healthy during four months in the greenhouse without ever exhibiting signs of wilt. On the other hand, watermelon seedlings soon wilted when healthy watermelon seeds were planted in the pots inoculated with watermelon Fusarium. From these experiments it was conclusively proved that both squash and watermelon wilts are distinct and that it is possible to grow healthy watermelons in a squash sick land provided the watermelon Fusarium is kept out. Likewise, it is possible to grow healthy squash in a sick watermelon field provided the squash Fusarium is kept out.

EXPERIMENT 3. PATHOGENICITY OF FUSARIA STUDIED.

To further prove the pathogenicity of the Fusaria here considered, 264 5-inch pots were filled with good watermelon soil which was shipped in from Prairie View. The pots and soil were sterilized in the autoclave for three hours at 15 lbs. pressure. This was done twice with an interval of two days so as to make sure that any microorganisms that might be in the soil were killed. To further make certain of the absence of microorganisms, isolations were made from the soil, the method used being indicated on page 25. No growth whatever appeared from the platings of the steamed soil, proving that no microorganisms remained alive there. The 264 pots were then divided into eleven series, nine of which were inoculated with eight distinct species of Fusaria. The eleventh series was used as a check. Three pots were used for each species

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*The method of inoculation consisted in introducing in the soil pure cultures of solution, then rinsed in sterilized water.

of Fusarium, making a total of 240 inoculated pots and 24 of checks. The following organisms were used for inoculation: *F. niveum, F. citrulli,* and *F. poolensis,* all three of which were isolated from diseased watermelon plants; *F. cucurbitae* was originally isolated from diseased squash plants; *F. vasinfectum* was isolated from diseased cotton plants; *F. malvacearum* (Fig. 8g). from diseased okra plants from Robertson's farm; *F. tracheiphila* was isolated from cowpea; *F. conglutinans* was isolated from diseased cabbage plants; *F. lycopersici* was isolated from diseased tomato plants; *F. lathyri* from diseased sweet pea plants. The method of inoculation consisted in breaking up in sterilized water young five-days-old cultures of each particular Fusarium and then worked in with the soil. After inoculation, the pots were allowed to stand two days, after which time every pot in all the series, including the checks, was planted alike with five seeds of each of watermelon, squash, cotton, okra, cowpea, tomatoes, cabbage, and sweet pea (Fig. 5a and c). The results of these experiments are indicated in Table 8, which is self-explanatory. It is thus seen that pure cultures of *F. niveum, F. citrulli* and *F. poolensis* were all capable of producing a wilt disease of watermelon. None of these organisms, however, were capable of producing a wilt on squash, cotton, okra, cowpea, tomato, cabbage, or sweet pea. Likewise, *F. cucurbitae,** originally isolated from the squash, was only capable of infecting the squash and the cashaw, but none of the other hosts, as shown in Table 8. The same was also true for *F. vasinfectum,* which has proved to be parasitic on the cotton and the okra only. Furthermore, *F. malvacearum,* originally isolated from okra plants, proved to be a weak parasite on okra but was unable to infect cotton or any of the other hosts indicated in Table 8. In a further study of Table 8, it will be seen that *F. tracheiphila* is parasitic on the cowpea only, *F. conglutinans* parasitic on the cabbage only, *F. lycopersici* parasitic on the tomato and *F. lathyri* parasitic on the sweet pea only.

Table 8.—Greenhouse pot inoculations.†

Pot Series No.	Species and Strain No.	Host Used	Period of incubation (days)	Percentage of dying
No. 1, including 24 pots..	Fusarium niveum, 107‡	Watermelon.....	10	82
	do**..............	Squash..........	0	0
	do**..............	Cotton..........	0	0
	do**..............	Okra............	0	0
	do**..............	Cowpea..........	0	0
	do................	Tomatoes........	0	0
	do**..............	Cabbage.........	0	0
	do**..............	Sweetpea........	0	0

**Fusarium cucurbitae* seems to be distinct and different from *F. helianthi, F. reticulatum,* and *F. culmorum,* which Lewis (13) reported to produce a rot on squash fruit.

†Representing results of average of two years experiments.

‡Fusarium citrulli and F. poolensis of pot series No. 2 and 3 behaved like F. niveum, that is, they produced disease on watermelon, but not on squash. cotton, okra, cowpea, tomato, cabbage or sweet peas.

**No infection took place when fungus was placed in soil, nor when abrasian was made on stem end or on roots and not even when fungus mycelium was inserted in stems or roots.

Table 8.—(Continued).

Pot Series No.	Species and Strain No.	Host Used.	Period of incubation (days)	Percentage of dying
No. 4, including 24 pots..	F. cucurbitae, 103......	Squash..........	41	67
	do**..............	Watermelon.....	0	0
	do**..............	Okra...........	0	0
	do**..............	Cotton..........	0	0
	do**..............	Cowpea.........	0	0
	do**..............	Tomato.........	0	0
	do**..............	Cabbage........	0	0
	do**..............	Sweet pea.......	0	0
No. 5, including 24 pots..	F. vasinfectum, 101*....	Cotton..........	32	78
	do**..............	Okra...........	40	62
	do**..............	Watermelon.....	0	0
	do**..............	Squash..........	0	0
	do**..............	Cowpea.........	0	0
	do**..............	Tomato.........	0	0
	do**..............	Cabbage........	0	0
	do**..............	Sweet pea.......	0	0
No. 6, including 24 pots..	F. malvacearum, 102*...	Okra...........	14	57
	do**..............	Cotton..........	0	0
	do**..............	Watermelon.....	0	0
	do**..............	Squash..........	0	0
	do**..............	Cowpea.........	0	0
	do**..............	Tomato.........	0	0
	do**..............	Cabbage........	0	0
	do**..............	Sweet pea.......	0	0
No. 7, including 24 pots..	F. tracheiphila, 103.....	Cowpea.........	24	83
	do...............	Okra...........	0	0
	do...............	Cotton..........	0	0
	do...............	Tomato.........	0	0
	do...............	Cabbage........	0	0
	do...............	Watermelon.....	0	0
	do...............	Sweet pea.......	0	0
	do...............	Squash..........	0	0
No. 8, including 24 pots..	F. conglutinans, 100....	Cabbage........	15	75
	do...............	Tomato.........	0	0
	do...............	Cowpea.........	0	0
	do...............	Okra...........	0	0
	do...............	Cotton..........	0	0
	do...............	Watermelon.....	0	0
	do...............	Squash..........	0	0
	do...............	Sweet pea.......	0	0
No. 9, including 24 pots..	F. lycopersici, 111*.....	Tomato.........	37	48
	do...............	Cabbage........	0	0
	do...............	Cowpea.........	0	0
	do...............	Okra...........	0	0
	do...............	Cotton..........	0	0
	do...............	Watermelon.....	0	0
	do...............	Squash..........	0	0
	do...............	Sweet pea.......	0	0
No. 10, including 24 pots.	F. lathyri	Sweet pea.......	12	79
	do...............	Tomato.........	0	0
	do...............	Cabbage........	0	0
	do...............	Cowpea.........	0	0
	do...............	Okra...........	0	0
	do...............	Cotton..........	0	0
	do...............	Watermelon.....	0	0
	do...............	Squash..........	0	0
No. 11, including 24 pots.	Check................	Watermelon.....	No inoculation.	All healthy
	do...............	Squash..........	do....	do
	do...............	Cotton..........	do....	do
	do...............	Okra...........	do....	do
	do...............	Cowpea.........	do....	do
	do...............	Tomato.........	do....	do
	do...............	Cabbage........	do....	do
	do...............	Sweet pea.......	do....	do

*No infection took place when fungus was inoculated in the soil, but only through abrasian at the stem end or in the roots.

**No infection took place when fungus was placed in soil, nor when abrasian was made on stem end or on roots and not even when fungus mycelium was inserted in stems or roots.

As a result of these soil inoculations it was thought that the reason perhaps certain hosts, as indicated in Table 8, were susceptible only to certain specific Fusaria, was probably due to the fact that the inoculum was put in the soil without injuring the roots of the hosts. Accordingly, and after a period of six weeks, the various hosts which did not become susceptible to infection by the Fusaria, as shown in Table 8, were bruised at the stem ends and roots. This was done by scratching deeply with a sterilized knife and yet no infection took place, thus further proving that certain Fusaria can attack only specific hosts and no others and this restriction to host is not necessarily influenced by wounds. Not being content with the above results we planned another experiment, as follows: Thirty-two 5-inch pots were filled with sandy loam soil and

Table 9.—Greenhouse pot experiments.*

Series and pot No.	Kind of Host planted in pots	No. pot	Kind of Fungus inoculated	Result of inoculation
A. 1, 2, 3, 4	Watermelon	1	Fusarium niveum	50% dead**
		2	F. cucurbitae	All healthy
		3	F. vasinfectum	All healthy
		4	Check	All healthy
B. 5, 6, 7, 8	Squash	5	F. cucurbitae	28% dead**
		6	F. niveum	All healthy
		7	F. vasinfectum	All healthy
		8	Check	All healthy
C. 9, 10, 11, 12	Cotton	9	F. vasinfectum	41% dead**
		10	F niveum	All healthy
		11	F. cucurbitae	All healthy
		12	Check	All healthy
D. 13, 14, 15, 16	Okra	13	F. Vasinfectum	18% dead**
		14	F. malvacearum	9% dead**
		15	F. niveum	All healthy
		16	Check	All healthy
E. 17, 18, 19, 20	Cowpea	17	F. niveum	All healthy
		18	F. tracheiphila	81% dead**
		19	F. Vasinfectum	All healthy
		20	Check	All healthy
F. 21, 22, 23, 24	Tomato	21	F. lycopersici	73% dead**
		22	F. niveum	All healthy
		23	F vasinfectum	All healthy
		24	Check	All healthy
G. 25, 26, 27, 28	Cabbage	25	F conglutinans	95% dead**
		26	F. niveum	All healthy
		27	F. vasinfectum	All healthy
		28	Check	All healthy
H. 29, 30, 31, 32	Sweet pea	29	F. lathyri	30% dead**
		30	F. niveum	All healthy
		31	F. vasinfectum	All healthy
		32	Check	All healthy

steam sterilized as indicated on page 18. The pots were then divided in eight series, each series consisting of four pots. The pots in each series were planted as indicated in Table 9, ten seeds being used to each pot. The seeds in all the pots came up regularly and the plants were allowed to grow undisturbed for ten weeks. The pots in this experiment were all watered with sterilized water to prevent accidental in-

*Average results of two years experiments.

**The fungus was recovered from the infected plants.

FIGURE 5.

a. From left to right—pot 100 inoculated with *Fusarium conglutinans* in which cabbage seedlings are dying while other hosts remain healthy. Pot 106 inoculated with *F. citrulli,* all watermelon seedlings dying, but other hosts remain healthy. Third pot with no number, inoculated with *F. niveum,* watermelon seedlings dying, all other hosts healthy. Pot 111 inoculated with *F. lycopersici,* tomato plants wilting, all other hosts remaining healthy.

b. Four series of pots in the greenhouse, first row at bottom. Pots 105 and 106 inoculated with *F. citrulli,* all watermelon seedlings dying. Pot 107 inoculated with *F. niveum,* and pot 114 inoculated with *F. poolensis,* watermelon seedlings dying in both. Second row, pot 100 inoculated with *F. conglutinans,* pot 101 inoculated with *F. tracheiphila,* pot 102 inoculated with *F. vasinfectum,* pot 103 inoculated with *F. oxysporum.* Third row, pot 104 inoculated with Fusarium from cucumber fruit, pots 108 and 109 inoculated with Fusarium from blossom end rot of watermelon fruit, pot 110 check, no inoculation. Fourth row on top, pot 112A and 111 inoculated with *F. malvacearum.* Notice watermelon seedlings are all healthy in the upper three rows.

c. Six pots all inoculated with *F. lycopersici.* Notice that tomato plants in last pot to the left are all wilting and have lost most of their foliage; on the other hand, the squash, cowpea, watermelon, pumpkin, and cabbage planted in the other pots are all healthy.

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fection. At the end of ten weeks the plants in each pot were inoculated with Fusarium fungi as indicated in Table 9, the customary check being allowed to each series. The method of inoculation consisted in inserting a copious amount of young, actively growing mycelium at the base of the healthy host through a wound made with a sterilized scalpel. Sterilized moistened cotton was then applied around the inoculated area and covered with the sterilized soil from the pot and kept damp for two days without, however, placing it under bell jars. The results of these inoculations are shown in Table 9, which is self-explanatory and which further substantiates the results recorded in Table 8.

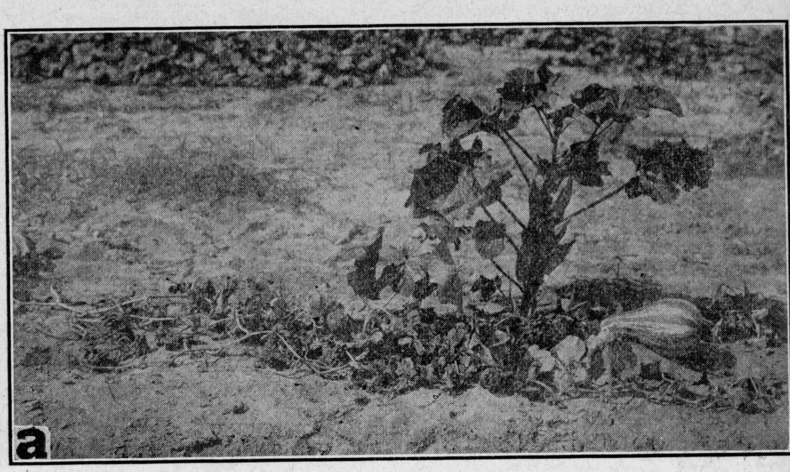
In order to determine whether the species of Fusaria recorded in Table 9 are pathogenic to tubers of Irish potatoes, the following experiments were tried: Healthy Irish Cobbler potatoes were secured, carefully washed and dipped for one minute in a solution of one part corrosive sublimate in two thousand parts of water. After this treatment the tubers were rinsed in sterile water to remove all traces of the disinfectant. The potatoes were then divided into series of three each and in each series two tubers were inoculated with a Fusarium species and the third one left as a check. The Fusaria used in this experiment were: *F. niveum*, *F. malvacearum*, *F. cucurbitae*, *F. lycopersici*, *F. conglutinans*, *F. lathyri*, and *F. oxysporum*. In thirty days after inoculation, *F. oxysporum* produced a slight rot while all the others failed to cause any infection.

C. LABORATORY EXPERIMENTS.

In connection with field and greenhouse studies of plant pathogens it is, of course, necessary to carry on laboratory experiments. These consisted in: (1) Isolation work; (2) culture work; (3) life history, physiological and morphological studies of the organisms under observation.

ISOLATIONS.

Experiments have already been referred to on page 18, where actual inoculations were carried out in the greenhouse with pure cultures of the organisms here studied. The sources of isolation of these Fusaria were also indicated on page 18. The method of isolation was as follows: Wilted seedlings or vines were cut with sharp scissors into small pieces



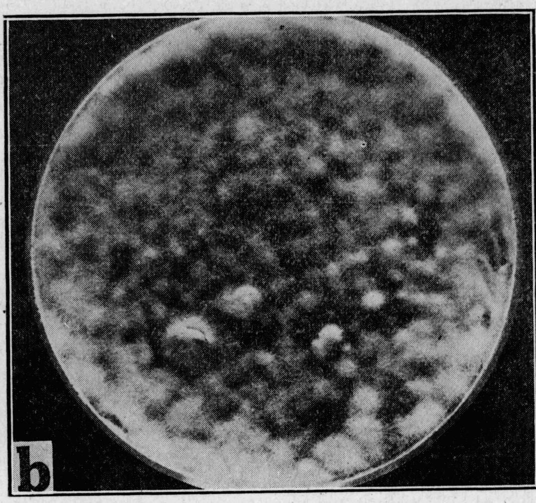


FIGURE 6.

a. Healthy okra plant growing in same hill of wilted squash plant in field.
b. Plate culture of isolation of *F. cucurbitae* from wilted squash vine.

about one-eighth of an inch in length. These pieces of plant tissue were then rinsed in distilled water, dropped in a test tube and disinfected for one-half minute in a solution containing equal parts of 1-1000 mercuric chloride and 50 per cent. alcohol. The bichloride solution was poured off and the plant material rinsed five times in sterile water to wash off all traces of the disinfectant. With this method of isolation each host was, of course, done separately. Tubes with agar medium were melted and cooled down to the proper temperature. With a flamed and cooled forceps a piece of the plant material was placed at the mouth of the tube and thoroughly crushed with the forceps and then shaken up with the media. The content of the entire tube was then poured in a sterile petri dish and allowed to cool. In order to keep out contamination from bacteria, a drop of 5 per cent. lactic acid was added to each petri plate. As soon as growth appeared, transfers were made to slants in tubes and the resulting pure growth was used for inoculation or study. More than five thousand platings were made from these various hosts here mentioned and in the majority of cases a pure culture of Fusarium was obtained from tissue of wilted watermelon or squash plants, thus showing the association of the Fusarium with the wilt. The pathogenicity of these Fusaria was already shown in Tables 8 and 9.

SOIL ISOLATIONS.

It has been previously stated that Fusaria growths were isolated from tissue of wilted roots or vines. It further became necessary to determine whether or not the Fusaria-wilt-producing fungi also live in the soil. Accordingly isolation cultures were made from sick watermelon and squash soils at the following depths: one, three, six, nine, twelve, twenty-four, thirty-six and forty-eight inches. The method of isolation was as follows: One gram of sick soil was placed in a sterilized eight-ounce baby bottle, to which was added 50 c.c. of sterilized water equivalent to 1/50. The bottle was corked with a flamed stopper and shaken with an electric-revolving apparatus for thirty minutes. Then with a sterile pipette 1 c.c. of the 1/50 solution was taken out and placed in another sterilized baby bottle which contained 20 c.c. of sterilized water. This was equivalent to 1/1000, that is, one gram of soil in 1/1000 c.c. of water. Again with a sterile pipette, 1 c.c. of the original 1/50 was now put in a baby bottle which contained 200 c.c. of sterile water, making it equivalent to 1/100, that is, 1 gram of soil to 1/100 c.c. of water. Platings were now made by adding 1 c.c. of the 1/100 dilution to tubes of melted media and then pouring it in a sterile petri dish. Similarly, the same was done by adding 1 c.c. of the 1/1000 dilution of melted agar and poured in sterile petri dishes to which was added a drop of 5 per cent. lactic acid to inhibit bacterial growth. The plates from 1/100 dilution were marked A and those from 1/1000, B. Over 1000 soil isolation plates were made. No attention or counts were made of any other growth except Fusaria. As soon as the latter appeared they were transferred to slants and simultaneously the pathogenicity of some of these organisms tested by inoculating them in pots of sterile soil and planted with squash or watermelon as the case might be. From these isolations it was determined that wilt-producing Fusaria from a watermelon sick soil are very abundant to a depth of the first to the twelfth inch. However, the number of Fusaria colonies decreased with a depth below twelve inches. Finally, at forty-eight inches deep the number of colonies was about 60 per cent. less than in the first twelve inches of soil. The strains of Fusaria isolated from a depth of forty-eight inches were as virulent upon watermelon seedlings as those from the upper twelve inches. Isolations of the same depths as for sick watermelon soil were also made for Fusarium squash sick soil with nearly similar results.

CULTURE WORK.

Anyone who has worked with Fusaria will appreciate the difficulty and the dilemma in which one finds himself when trying to identify these organisms. With our present meager knowledge of the Fusarium group one is at sea when it comes to classifying or describing new species. At times one is inclined to believe that such an undertaking is a hopeless task. The writer agrees with Sherbakoff(20) that it is useless to try out many culture media for Fusaria fungi. Of the large variety of media tried those adapted in our work were, therefore, few and consisted of potato plugs, cornmeal, and rice agar. The results of the culture work on the Fusaria here studied are shown in Table 10. From the above Table (see also Fig. 8a to j) it is seen that *Fusarium citrulli* and *F. malvacearum* belong to the type Discolor, whereas *F. niveum* and *F. poolensis* are of the Elegans type. The characteristics of the other Fusaria are also indicated in Table 10, which is self-explanatory. As to odor, Carpenter(3), Cromwell(5), and Woolénweber(25) state that *F. vasinfectum, F. tracheiphila, F. lycopersici* and *F. niveum* produce none. In our work on steamed rice, it was found that this was not always the case. *F. niveum* and *F. conglutinans* always produced an odor of ripe banana, *F. citrulli* and *F. cucurbitae* an odor of strong alcohol, *F. tracheiphila* an odor of slight fermentation and later of rotting cabbage, *F. lycopersici* medium lilac. It is therefore very doubtful if odor is of any taxonomic value in determining species of Fusaria. Frequently a culture seems to have no odor; however, as soon as the mycelium in the test tube or flask is slightly disturbed, its odor is at once liberated. The odor is usually strongest when the culture is seven to ten days old, but gradually disappears and is completely gone with age. In our work and as found by others, rice is the best medium for determining color (Fig. 7a to g). However, the latter can only be studied in young cultures, as color, like odor, generally disappears with age. Some species impart a strong color, which becomes permanent. The color of *F. poolensis,* for instance, which is a deep blue, does not change though the cultures become very old. Usually with the disappearance of the color, there is a large amount of water of condensation formed on

Table 10.—Characteristics of Fusaria studied.

Species	Sclerotia	Sporodochia	Pionnotes	Chlamydospores	Macroconidia 3 septate	Macroconidia 4–5 septate	Type	Odor	Parasitism
Fusarium niveum	Large, green to blue.	Numerous	Reduced	Intercalary and terminal.	Up to 60% 25-55x 3.50-5u.	Up to 15% 45-60x 3.5-5.2u.	Elegans	Ripe banana	Watermelon wilt.
Fusarium citrulli n. sp	Entire surface of media becomes mass f blue sclerotia.	Numerous purple color.	Perfect	Terminal	Few or none	5 septate up to 80% 50-80x 3-4.5u.	Discolor	Medium lilac	Wilt of watermelon seedlings.
Fusarium poolensis n. sp.	None	Abortive blue	Abortive	Intercalary and terminal.	Abortive	Up to 2% 32-35x 2.5-3u.	Elegans	Strong lilac	Watermelon wilt.
Fusarium cucurbitae n. sp.	None	None	None	Abundant, terminal and intercallary.	Up to 100% 30-80x 2-3u.	Few 45-85x 2.2-3 5u.	Elegans	Strong alcohol.	Squash wilt.
Fusarium oxysporum	Blue sclerotia	Many	Reduced	Terminal and intercallary.	Up to 100% 23-48x 3.25-4.5u.	5 to 15% 40-53x 3.5-5u.	Elegans	Slight lilac	Potato wilt.
Fusarium vasinfectum.	Blue gray	Numerous	Perfect	Intercallary and terminal.	Up to 100% 23-46x 3.4-5u.	Up to 25% 34-56x 3-5u.	Elegans	Strong lilac	Cotton wilt
Fusarium vasinfectum.	Blue gray	Numerous	Perfect	Intercallary and terminal.	Up to 100% 23-46x 3.14-5u.	Up to 25% 34-56x 3-5u.	Elegans	Strong lilac	Okra wilt
Fusarium malvacearum n. sp.	Abortive	Abortive	Perfect	Intercallary and terminal.	Scarce	5-6 septate up to 100% 25-40x 4-6u.	Discolor	Strong lilac	Okra wilt, weak parasite.
Fusarium tracheiphila.	Green and flesh colored.	Few to none.	None	Intercallary and termina .	23.6-40x 3.5-4u	28-48x 3-4.5u	Elegans	Slight fermentation to rotten cabbage.	Cowpea wilt.
Fusarium conglutinans.	Absent	Absent	Absent	Terminal	In majority 35-55x 2.5-3.3u.	Rare	Elegans	Ripe banana	Cabbageyellows or wilt.
Fusarium lycopersici.	Flesh colored	Numerous	Perfect	Intercallary and terminal.	Up to 50% 30-48x 3.5-5u.	Few 45-58x 3.5-5u.	Elegans	Medium lilac	Tomato wilt, sleeping sickness.
Fusarium lathyri.	Abortive	Abortive to numerous.	Perfect	Mostly terminal.	Up to 100% 15.8x 4.2-30.8x5.6u.	Few 20-38.5x 4.5-5u.	Martiella	Strong lilac	Sweet pea wilt.

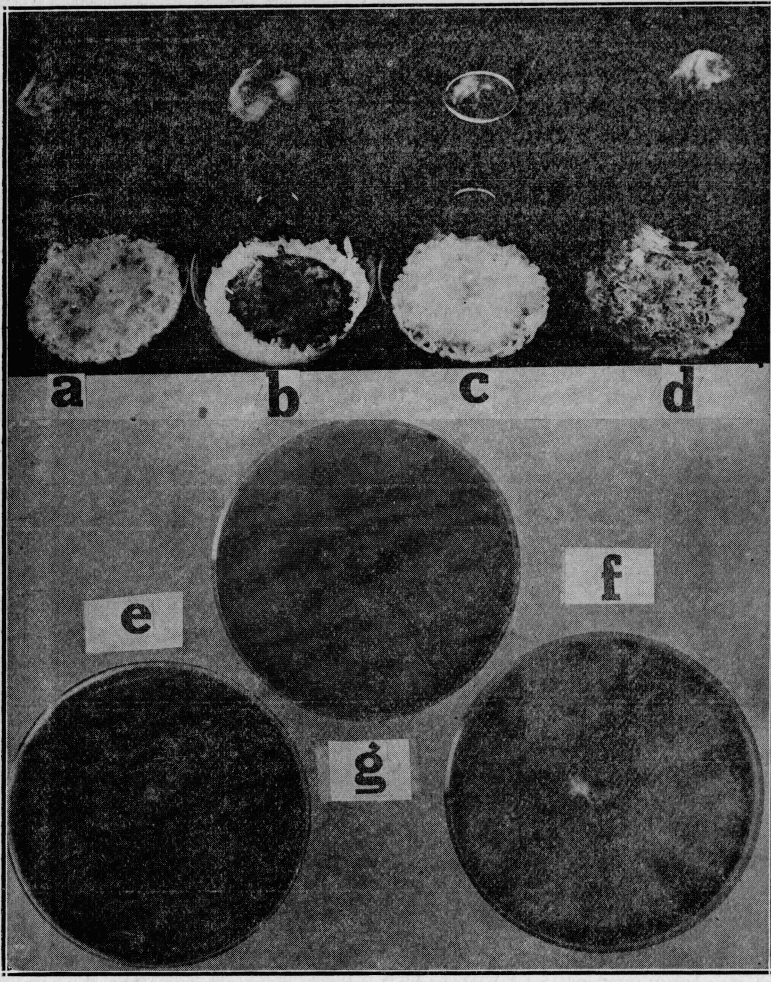


FIGURE 7.

a to d—Flask cultures on rice. a. *Fusarium vasinfectum*. b. *F. citrulli*. c. *F. niveum*. d. *F. poolensis*.
e to g—Plate cultures rice agar. e. *F. poolensis*. f. *F. niveum*. g. *F. citrulli*.

the sides of the glass as well as on the surface of the mycelium and later the entire medium becomes soft, the mycelium disintegrates, and the whole mass becomes bathed in a clear vinegar liquid.

LIFE HISTORY.

In order to determine the life history of *Fusarium niveum* and *Fusarium cucurbitae* and if possible to discover an ascagenous stage, a large number of dead watermelon and squash vines were collected during June, 1917 and 1918, and each placed separately in a heap in the field and exposed to weather conditions at Prairie View. Similarly, wilt-infected watermelons and squash vines were placed in wire cages and exposed to weather conditions in the writer's home garden. Cultures were then made every month from the above material. These monthly cultures were started in July, 1917, and in July, 1918, and were continued during August, September, October, November, December, January, February, March, April, and May for these two years. In each case, no difficulty was experienced in isolating Fusaria from the watermelon and squash vines from July to December. However, after January the vines were partially decayed and it became very difficult to obtain a satisfactory pure growth. This was especially true with the vines set in a heap in the field, although less so with the vines put away in wire cages. It should be added that the wire cages were set in the garden, exposed to the weather, lying on broken pieces of brick to insure drainage and prevent decay. Drops of 5 per cent. lactic acid added to the media helped in part to exclude large numbers of bacteria. Fusaria obtained from wintered-over wilted watermelon and squash vines, respectively, were then inoculated into sterilized pots and soil, which were separately planted in watermelon and squash seed. In no case did the Fusarium isolated from wintered watermelon vines fail to infect watermelon seedlings. The same was also true for the Fusarium isolated from wintered-over squash vines thus proving definitely that the vines from wilted watermelons or squash help to carry over winter the Fusaria wilts of these hosts. When we realize that the average farmer, after picking his melons, abandons his fields until spring, we can readily see that the old watermelon and squash vines, especially in diseased fields, should offer the most favorable means of carrying over from season to season the Fusaria which produce wilts. Likewise, many watermelon growers, after picking the melons turn the field over to cattle. This, no doubt, is a good practice only in healthy fields, as in this case the cattle eat up all vines and culls, at the same time fertilizing the land. On infected land such a practice, however, is objectionable, as the cattle in roaming about actually help to spread the disease by carrying on their hoofs some of the infected soil particles. It is also likely that the wilt organisms may pass unharmed through the digestive tract, as the cattle feed on the diseased vines. Experiments to determine this were not carried out. Harter and Jones (11) suggest this as a possibility when cattle feed on wilt (*Fusarium conglutinans*)

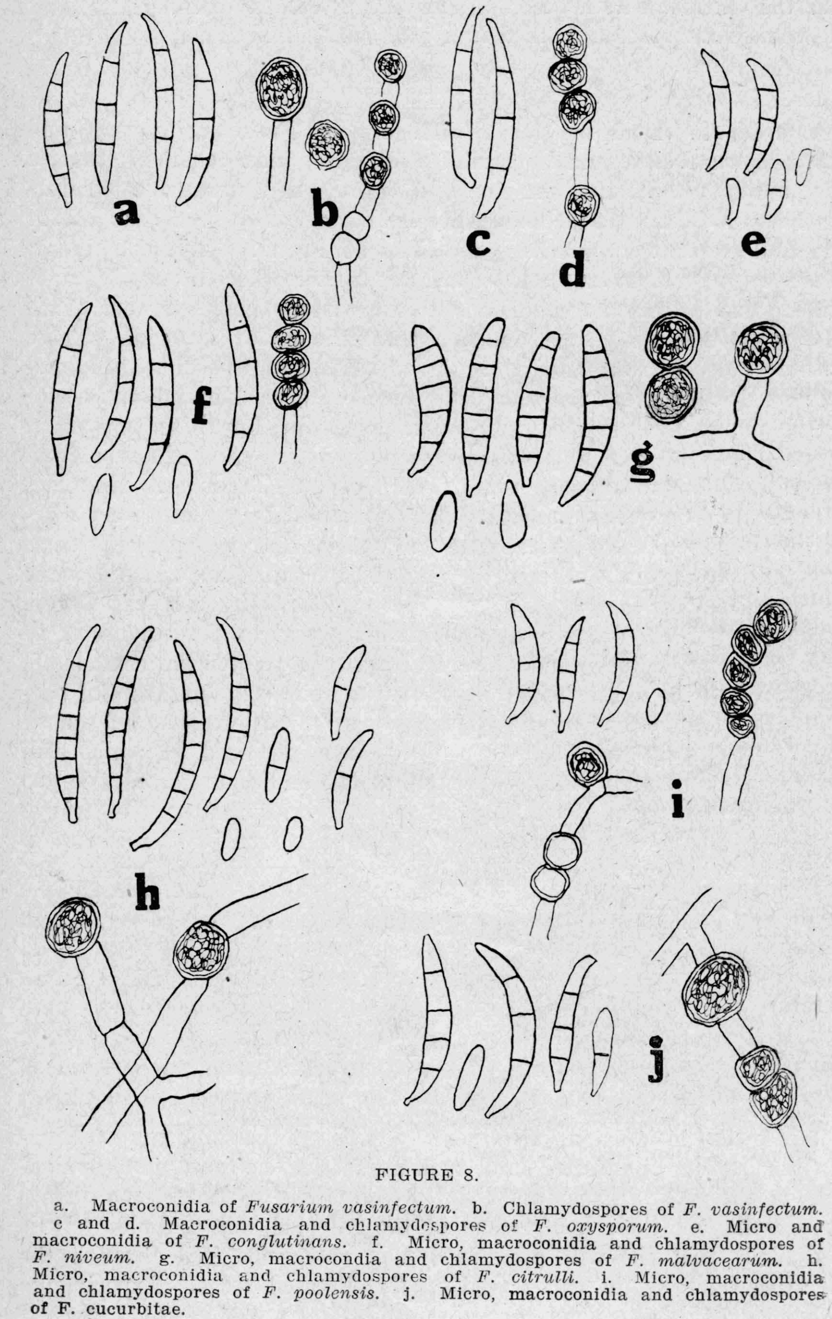


FIGURE 8.

a. Macroconidia of *Fusarium vasinfectum*. b. Chlamydospores of *F. vasinfectum*. c and d. Macroconidia and chlamydospores of *F. oxysporum*. e. Micro and macroconidia of *F. conglutinans*. f. Micro, macroconidia and chlamydospores of *F. niveum*. g. Micro, macrocondia and chlamydospores of *F. malvacearum*. h. Micro, macroconidia and chlamydospores of *F. citrulli*. i. Micro, macroconidia and chlamydospores of *F. poolensis*. j. Micro, macroconidia and chlamydospores of F. cucurbitae.

infected cabbage. As far as possible infected watermelon or squash vines should not be turned under but should be destroyed. This, of course, will involve extra cost and labor, but no progressive grower will consider this an obstacle, especially so where the farm depends to a large extent on the success of the watermelon as a cash crop.

To further prove that Fusarium wilt of the watermelon is carried over with infected vines which are plowed under, the following experiment was tried: Several 5-inch pots were filled with good watermelon soil and twice sterilized in the autoclave for three hours under 15 lbs. pressure. When the soil was cooled, several watermelon vines coming from a hill known to be killed by Fusarium and proved so through culture isolation, were worked in the sterilized soil and then covered with a layer of paraffin. These pots were then placed outdoors, at College Station to pass the winter over in the open. Early in the spring, these pots were taken into the laboratory, the paraffin cover removed, and healthy watermelon seeds which were first disinfected for one-half minute in a solution of bichloride of mercury of the same strength as described on page 16 were planted in the pots. The seed had germinated normally but after eight days started to wilt. Isolation cultures were made from these wilted seedlings and a Fusarium which corresponded to *F. niveum* was also isolated from the soil of these pots. Both strains of Fusaria when reinoculated into sterilized soil planted with watermelon seeds produced the typical wilt. This proved that wilted watermelon plants when worked in the soil will help to infect it. It should be added that at no time was an ascogenous stage discovered on wintered-over infected watermelon or squash vines. Neither have we been able to find the *Necosmospora vasinfecta* stage on any of the cucurbits studied.

TEMPERATURE STUDIES.

It is generally conceded that temperature studies both of the air and of the soil are important factors in favoring or retarding the spread of certain important disease-producing organisms which are carried over in the soil. Gilman(10) has shown the important relationship of temperature to cabbage wilt (*Fusarium conglutinans*). Likewise Johnson and Hartman(9) have demonstrated that soil temperature is the most important factor in determining the extent of the root rot (*Thielavia basicola*) of tobacco In our present work on cucurbit diseases it was necessary to determine whether or not there exists any relationship between outdoor temperature of the air and that of the soil to the Fusarium wilt of cucurbits. It was also necessary to determine the possible effect of these temperatures on the life history of the cucurbit wilt-producing Fusaria. Hence, especially built soil thermometers were secured from the Henry Green Company of Brooklyn, New York. These thermometers were placed in the soil to a depth of 1, 3, 6, 12, 24, 36, and 48 inches. They were installed in a typical watermelon soil at Prairie View. The thermometers were stuck in the soil in a straight row and at a foot and a half distance from each other. The parts protruding above ground were protected by a cage, the walls of which consisted of loose ordinary chicken wire. This was done in order to prevent the breaking of the instruments by the field workers or by possible roaming animals. The soil around these instruments was carefully hoed, and this was done each time the field was cultivated. An outdoor thermometer was also hung up on the outside of the cage and readings were taken three times daily, that is, 7 a. m., 12 m., and 5 p. m. These readings started April 20, 1918, and are still being taken. It is expected that these soil temperature studies will be further continued for at least ten to fifteen years. It is believed that soil temperature data will be of importance not only to interpret occurrence of plant diseases, but it will also be of value to the agronomist, horticulturist, and to the practical trucker. It is unfortunate that facilities were lacking for recording soil-moisture data in connection with the soil-temperature readings.

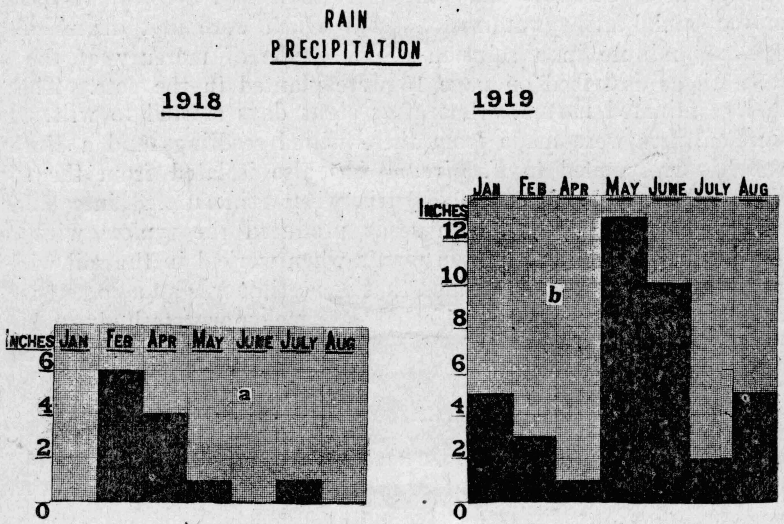


FIGURE 9.

a. Monthly rainfall for 1918. b. Monthly rainfall for 1919.

No records were kept of the rainfall at Prairie View. These data, however, were obtained from the chief of the U. S. Weather Bureau, to whom credit is here given. In referring to Figure 9a and b one will see that the rainfall data for 1918 and 1919 are recorded for Hempstead, a town about four miles distant from Prairie View, and both in Waller county. In studying Figure 10 we see that the outside temperature as well as the temperature as indicated by the thermometers of one and three inch under the soil fluctuate for April, 1919, but fluctuate equally. However, on the other hand, the temperatures as indicated by the twelve, twenty-four, thirty-six, and forty-eight-inch thermometers remained fairly uniform. It is further seen that the temperatures of the deeper thermometers, especially the

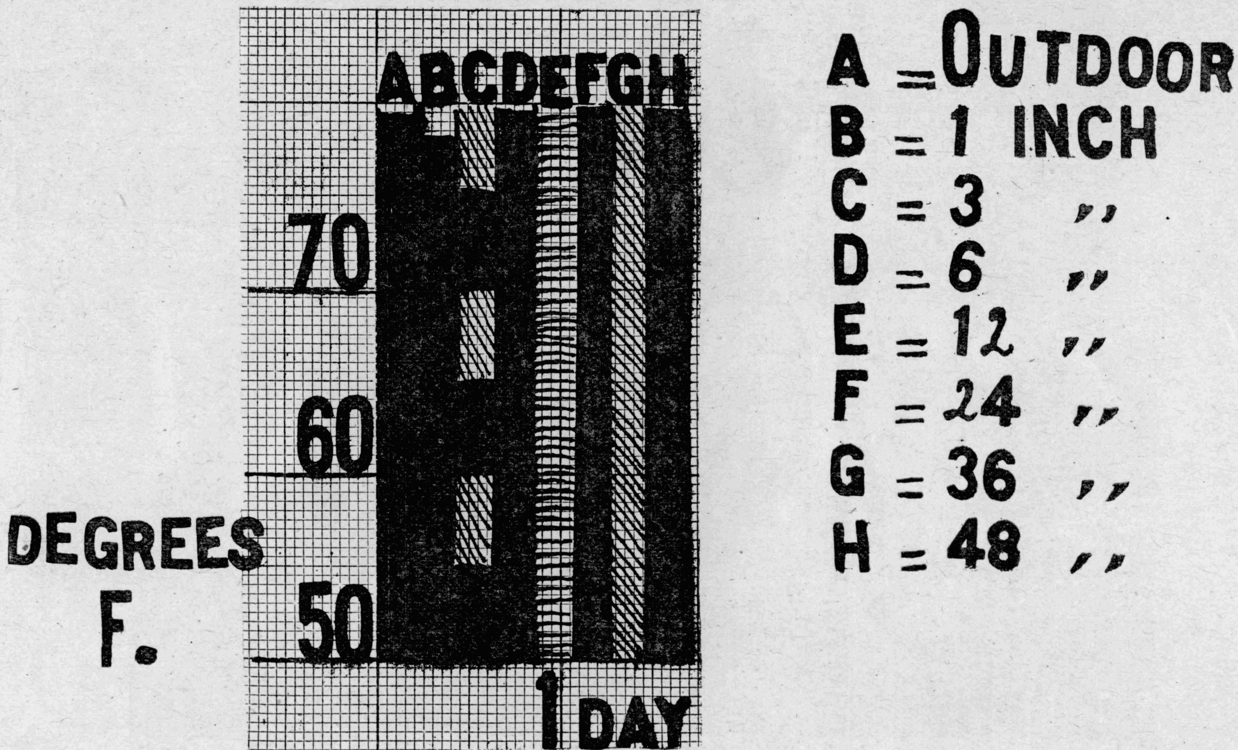


FIGURE 9a.

Sample explaining soil temperature readings for one day in each Figure 10, 11 and 12. A to H representing temperature readings, numbers representing degree F. Each column represents an average temperature of three readings per day.

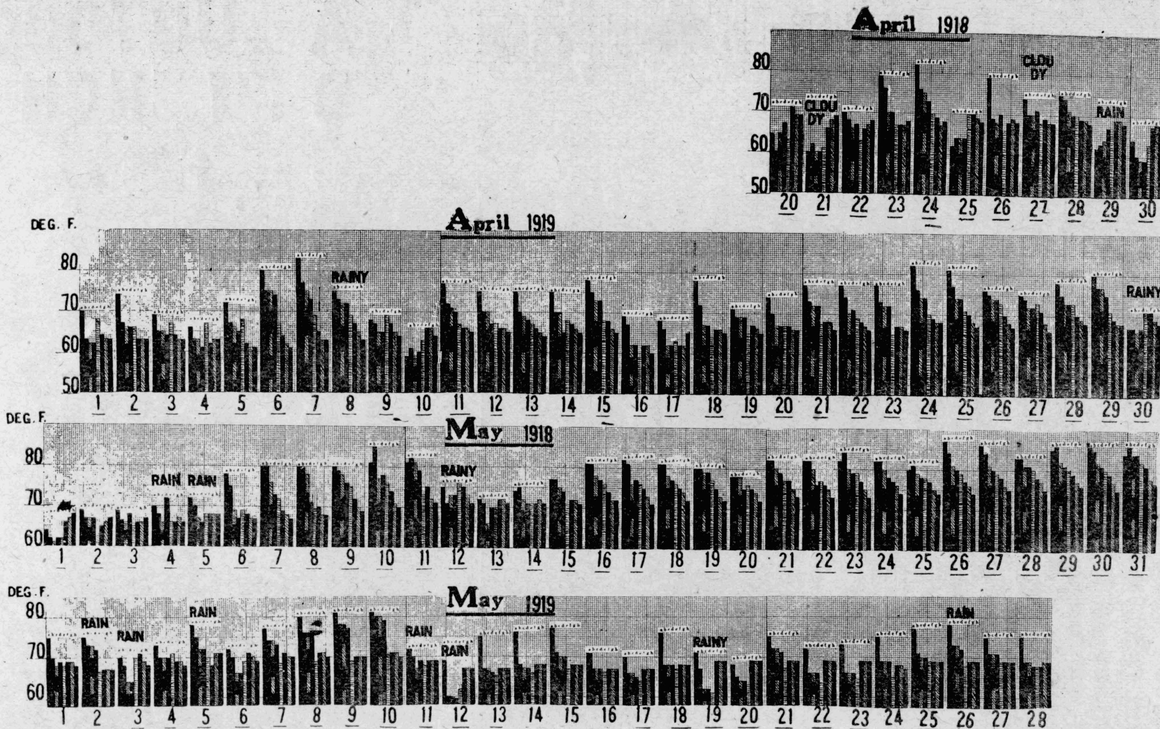


FIGURE 10.

Soil temperature studies for April and May of 1918 and 1919 at Prairie View, Texas.

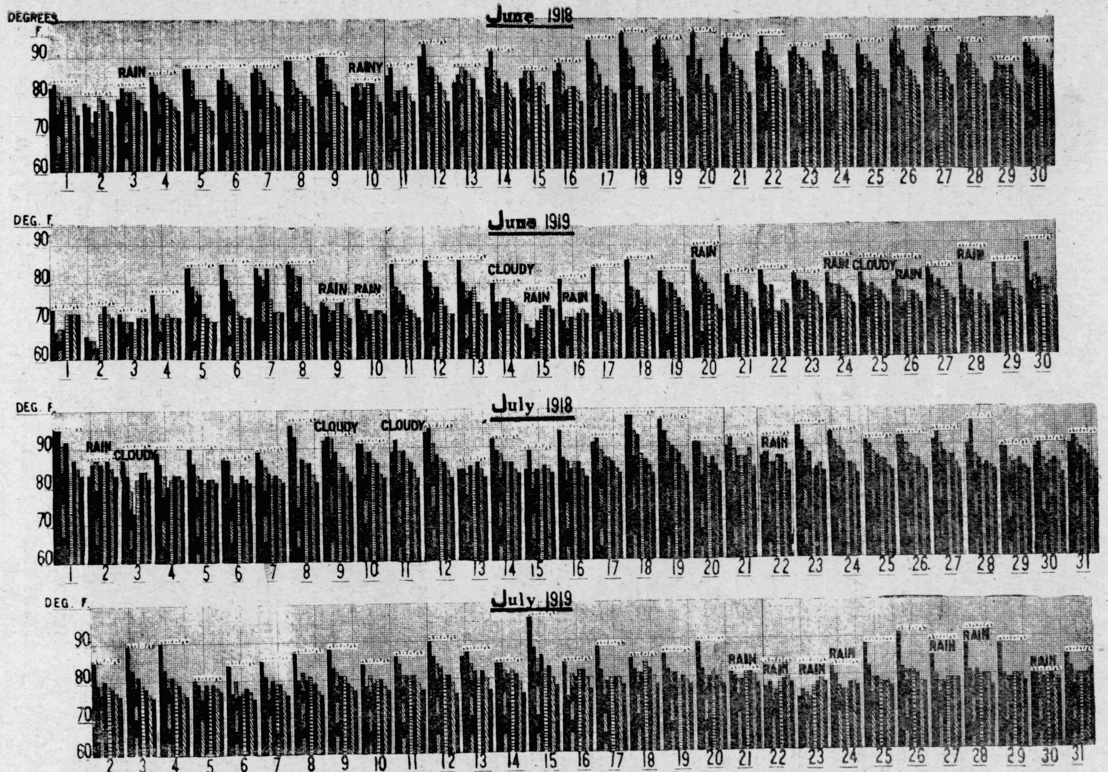


FIGURE 11.

Soil temperature studies for June and July, 1918 and 1919, at Prairie View, Texas.

twenty-four, thirty-six, and forty-eight-inch, did not go below 55 or above 70 degrees F. The same was practically true for April, 1919. In further studying Figure 10 we see both in May, 1918, and 1919 the deeper temperatures gradually rose to almost 70 degrees F. and fluctuated very little above or below. On the other hand, the temperature indicated by the three and six-inch thermometers fluctuated more or less closely with the rise or fall of the outside temperature. Rainy days would frequently cool off the temperature of the outside as well as the temperature of the one, three, and six-inch thermometers, whereas the temperature of the twelve to forty-eight-inch thermometers would remain more or less constant. Again referring to Figures 9 and 11 we see that May, 1918, was a very dry month; whereas May, 1919, had considerable rainfall. This was also true of June, 1918, which was exceedingly dry, and June, 1919, which was very wet. It became, therefore, evident that in a dry month such as June, 1918, the deeper temperatures, especially those of the twelve, twenty-four, thirty-six, and forty-eight-inch thermometers would practically remain constant at 80 degrees F. or a little above. In June, 1919, with considerable rainfall, the deeper temperatures, although remaining constant, were considerably lower, i. e., 70 degrees F. or slightly above, a difference of about ten degrees. The same was practically true of August, 1918, and 1919 (see Figs. 9 and 12).

No temperature data are available for January, 1918, since the readings were started only on April 20 of that year. However, in studying Figure 12 for January, 1919, we see that the outside temperature as well as the temperature indicated by one, three, and six-inch thermometers fluctuated considerably and this depended on the outside temperature. However, the deeper temperatures, especially those from twelve to forty-eight inches, remained more or less constant at 55 to 60 degrees F. Furthermore, during the coldest days in January, 1919, the temperature of the one, three, and six-inch thermometers never went down to the freezing point and the temperatures of the deeper thermometers remained high enough to maintain the activities of soil organisms in these depths (see Table 11). In Figure 12, for February, 1919, we also see that that month was considerably warmer than January, and the outside temperature as well as the temperature of the three and six-inch thermometers fluctuated much more than it did during January, 1919. However, the temperatures from the twelve to forty-eight-inch thermometers remained more or less constant at 50 to 55 degrees F., thus permitting microorganism activities in the deeper strata of the soil. Further interpretation of Figures 10 to 12 will be referred to under life history, as well as soil isolation studies. Figure 13 will be interpreted under the discussion of the prevalence and spread of wilt. It is to be observed from the foregoing discussions that the deeper temperatures remain more or less constant and that during the coldest months of January and February during 1919 in Waller county the temperature did not drop low enough to interfere with soil microorganism activities.

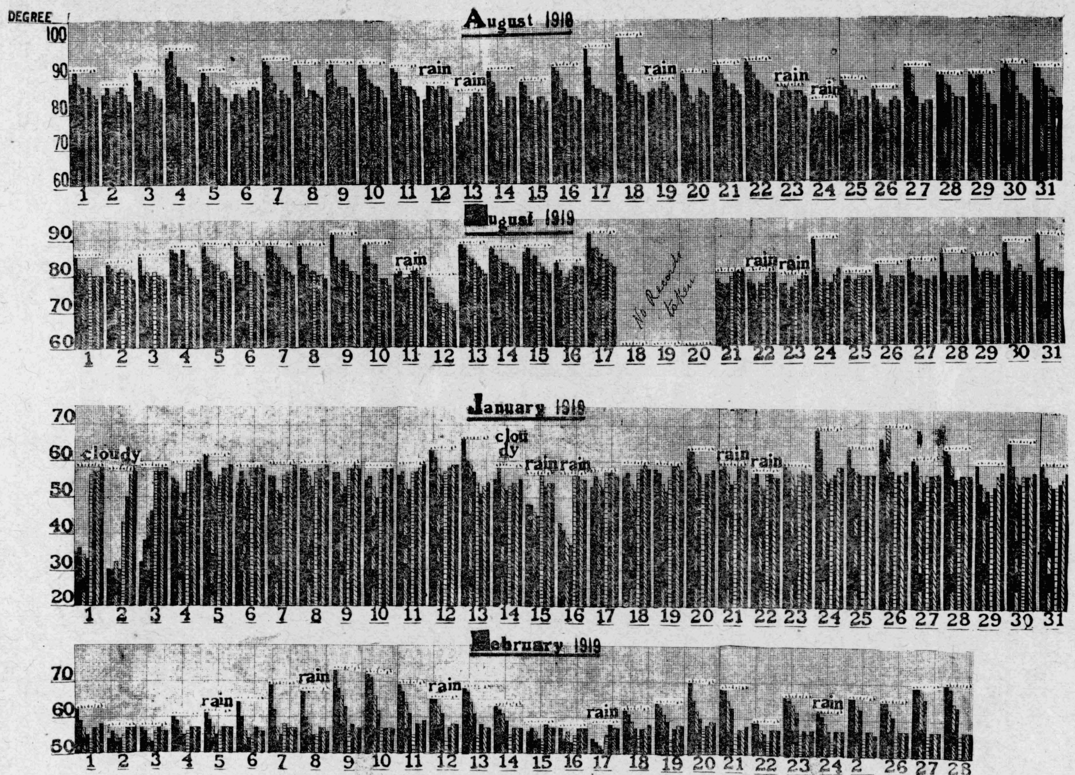


FIGURE 12.

Soil temperature studies for August, 1918 and 1919, January and February, 1919, at Prairie View, Texas.

Furthermore, the deeper temperatures are not greatly influenced by slight outdoor changes during the same season. A rise or fall in degrees of the deeper soil temperatures is, however, noticed if the outdoor temperature rises or falls for a considerable length of time or by the occurrence of at least a six-inch rainfall. From this and reference to Table 11 it is quite evident why cucurbit Fusaria in the soil are prac-

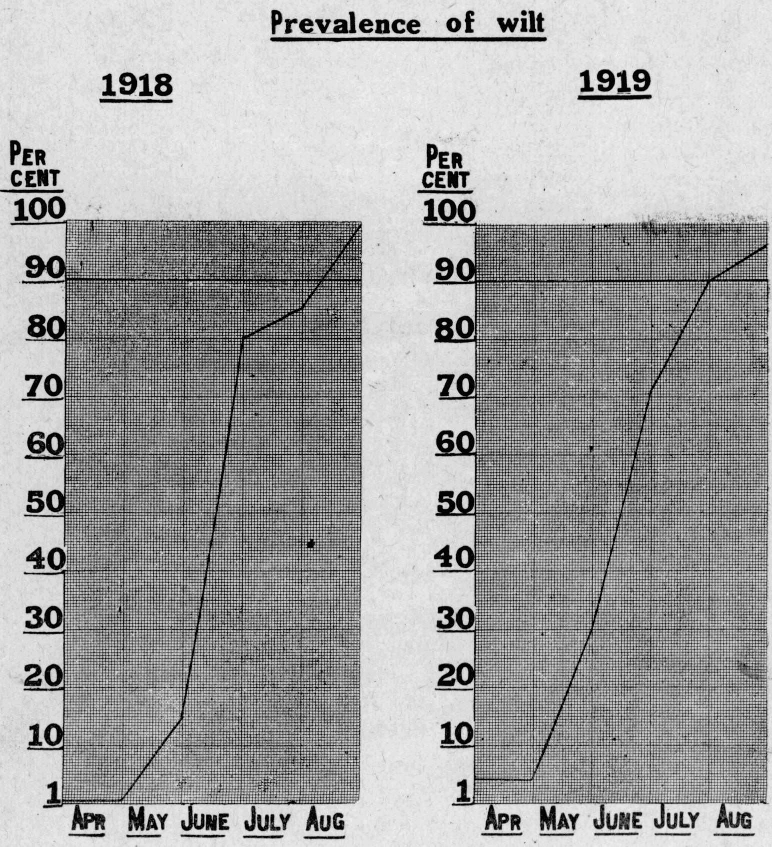


FIGURE 13.

Prevalence of Fusarium wilt of watermelon during 1918 and 1919.

tically active during the entire year since the soil temperatures during the coldest month of the year remain fairly constant at 50 to 60 degrees F. It becomes plain that if watermelon vines and culls are plowed under in a watermelon "sick" soil, the wilt-producing Fusaria will be furnished with food to live on during the following year even though the field is planted to a crop other than watermelons.

HIBERNATION OF WATERMELON FUSARIA IN THE FIELD.

It has been shown that both *Fusarium niveum* and *F. cucurbitae* are carried over from season to season with dead watermelon and squash plants, respectively. In the course of our investigations we have been able to prove that the above Fusaria are also carried over from year to year in the soil. For this purpose, monthly soil isolations were made of a sick watermelon field during 1918 and 1919. The method of isolation was already described on page 25. Cultures were made from the soil at depths of one, three, six, twelve, twenty-four, thirty-six, and forty-eight inches. This was done for the purpose of comparing these studies with the data obtained on soil temperatures at corresponding depths (see Figs. 10 to 12). The counts of the isolation of Fusarium colonies are shown in Table 11. No counts were made of organisms other than Fusaria. Bacteria were eliminated by adding one drop of 5 per cent. lactic acid to each plate.

The soil samples were drawn within an area four feet square to eliminate possible soil differences. Samples of the various depths were each laid on a clean cloth, mixed with a sterilized spatula, placed in sterilized jars, brought to the laboratory and cultured the same day. The medium employed was Czapek's synthetic solution agar, which was made as follows:

$MgSO_4$	0.50 gm.
K_2HPO_4	1.00 gm.
KCl	0.50 gm.
$FeSO_4$	0.01 gm.
$NaNO_3$	2.00 gm.
Cane sugar	30.00 gm.
Distilled water	1000.00 c.c.
Agar	15.00 gm.

In studying Table 11 one will see that the watermelon sick soil contained a far larger amount of Fusaria than a so-called healthy watermelon soil. Furthermore, in the sick soil *F. niveum* actually predominated and its pathogenicity was verified through actual inoculations. Table 11 further reveals the fact that colonies of the soil Fusaria and especially in the watermelon sick soil were fairly abundant in numbers during January and February, the coldest months in 1919. It is further apparent that great numbers of Fusaria were present in all the depths studied during the months of greater rainfall. For this reason a larger number of Fusaria colonies were found per gram of air-dried soil in January, 1919, than in February of the same year. (For graphic illustration of amount of rainfall see Fig. 9.) The same was also true for April, 1918, which had a greater precipitation than April, 1919. The reverse was the case for May, 1918, with a precipitation of six inches, whereas the precipitation in 1919 of the same month was thirteen inches. Here, of course, the Fusaria were more numerous. The same was apparent for June, July, and August of 1918 and 1919, as shown in Table

Table 11.—**Fusaria colonies per gram air dry watermelon sick soil in depths of.†**

Month	1 inch deep	3 inches deep	6 inches deep	12 inches deep	24 inches deep	36 inches deep	48 inches deep	Healthy soil 1 inch deep
Jan., 1919	**2,600,000	1,600,000	903,562	803,700	500,710	290,000	**169,990	*209,000
Feb., 1919	2,000,000	900,970	771,930	499,768	390,901	260,000	100,561	193,002
April, 1918	10,699,000	7,930,000	5,009,000	3,679,000	1,965,000	886,901	760,900	798,306
April, 1919	7,500,000	4,633,000	2,100,000	1,000,000	991,000	781,555	304,000	553,401
May, 1918	**8,000,000	5,661,000	3,000,000	1,201,000	960,446	295,000	168,000	*389,000
May, 1919	10,793,000	8,029,000	5,600,000	3,921,000	2,111,000	865,000	675,651	869,990
June, 1918	12,000,000	9,001,601	6,751,000	4,000,000	2,301,000	900,699	300,000	323 000
June, 1919	17,009,000	16,000,000	12,301,000	9,735,000	7,220,000	1,003,000	800,710	991,000
July, 1918	16,751,000	12,000,780	10,000,000	8,000,603	5,003,000	993,136	500,000	734,000
July, 1919	17,860,000	13,000,000	10,601,000	8,723,591	5,000,000	960,000	560,000	761,000
Aug., 1918	10,500,000	9,000,000	5,000,000	4,009,650	700,890	325,000	300,000	300,000
Aug., 1919	**16,000,000	14,580,000	9,000,000	7,000,000	1,008,000	900.768	871 000	*600,000

†No counts were made of the fungi other than *Fusaria* in the plates.
*Fungi identified as *Fusarium solani* (Mart.) Ap. and Wr., *F. oxysporum* Schl., *F. caudatum* Wr.
**Fungi identified as *Fusarum niveum* Ew. Sm. and *F. oxysporum*.

11 and Figure 9. It seems, therefore, that the prevalence of Fusaria in sandy soils, both in diseased and healthy fields, is directly influenced by the prevalence of soil moisture brought about by greater precipitation.

CONDITIONS FAVORING WILT INFECTION.

There seems no doubt but that numerous biting insects (Fig. 4e to g) in the field, especially the cucumber-striped beetle, plays an important part in starting infection and in disseminating the Fusarium wilts of watermelon and other cucurbits. This beetle usually feeds on the very young seedlings, biting into the cotyledons and into the young stems, thereby opening the way to infection. Numerous striped cucumber beetles (*Diabrotica vittata* Fab.) were collected alive from the watermelon sick field at Prairie View and placed in sterilized test tubes that were plugged with sterilized cotton. These were brought to the laboratory, taken out with sterilized forceps and allowed to crawl on a sterile-poured plate containing potato agar. In three to four days a Fusarium as well as several other fungi appeared on the tracks where the beetles were crawling. This Fusarium growth was purified, then transferred to slants, and inoculated into sterilized soil in pots which were planted with healthy watermelon seeds. The young seedlings later wilted in these pots and the Fusarium fungus was reisolated, proving definitely that the striped-cucumber beetle is one of the carriers of Fusarium which causes wilt in watermelon. Striped-cucumber beetles as well as a large lady beetle (*Epilachma borealis* Fab.) were also collected from a sick squash field at Prairie View and treated in the same way as the striped beetle collected in the watermelon sick field with the same results, namely: that these insects which feed on squash plants were active carriers of the Fusarium squash wilt fungus. Many of the collected striped beetles from the watermelon sick field were let loose in a wired cage containing healthy watermelon plants which grew in a sterilized soil in pots. The striped beetles immediately started to feed on the plants, and after three days wilting began where these beetles were allowed to feed. The check plants which were allowed to be fed on by the beetles collected at College Station from rose plants did not show any evidences of wilt but the plants were finally destroyed by the beetles as a result of the feeding. This showed conclusively that the striped cucumber beetle, as well as other insects, may carry the cucurbit Fusaria wilts from plant to plant.

There seems to be no evidences as yet that these insects carry the causal organisms of the watermelon or squash wilts internally in their bodies. Numerous striped cucumber beetles were collected in a diseased watermelon field as they were feeding on young watermelon seedlings. These insects were then placed in a sterilized test tube and brought to the laboratory and disinfected; for methods employed, see page 25. Each beetle was then crushed up in a tube of melted and properly-cooled agar and poured into sterilized petri dishes. Over fifty plates were made but no fungus growth appeared. This seems to indicate,—

although not very conclusively,—that the striped beetle does not carry the causal organism internally in its body.

EFFECT OF SOIL TEMPERATURE AND MOISTURE ON THE OCCURRENCE OF WILT.

It has already been pointed out that the increase in Fusaria in the soil is governed, all things being equal, by the greater abundance of moisture in that soil. In referring to Figure 9 and Table 11 one will see that a larger number of Fusaria colonies in the soil were actually found during the months of greater rainfall. This is true not only in the summer but also during the winter months. The prevalence of Fusarium wilts of cucurbits does not seem to follow the same general lines; that is, the greatest amount of disease is found during June, July, and August, when the temperature is the highest. Moisture does not seem to be an absolute necessity since the wilts are slightly more severe in a dry season (see Fig. 13). However, it should be added that in a dry season infected plants linger but little. In a wet season the infected plants remain alive a much longer period and frequently even during the entire growing season. The untrained eye will, therefore, be apt to overlook the disease. In both cases, however, the yields in a sick field are reduced 50 to 100 per cent. It seems, therefore, that the severity of cucurbit wilts goes hand in hand with the highest favorable soil temperature for the host. This seems why wilt is worse during June, July, and August because at that time the soil temperatures are highest and these temperatures are also best for the fullest development of the host in the field.

SYMPTOMS OF WATERMELON WILT.

The field symptoms of the watermelon wilt are manifested by a gradual wilting of the cotyledons and young leaflets of the seedlings. This is especially true with seedling infection in the field by *Fusarium citrulli* (Fig. 1c), and *F. poolensis*. *F. niveum* also attacks young seedlings but it is more frequently associated with the wilting of older plants. Infection may start at an early age but the diseased plant will apparently keep on growing, this being especially true during wet weather. In dry weather, however, the leaves of the affected plants begin to wilt, gradually resume their turgidity over night, wilt again the next morning, and in two to three days the affected plant usually dies (Figs. 14a and b and 15a and b). Frequently the disease is confined to one or two vines of the plant, in which case the infected vine wilts while the others in the same hill remain healthy. Here the causal fungus is confined only to the vascular bundles of the wilted vines. Later, however, infection spreads from the roots to the other vines of the plant. Contrary to the wilts of some other crops, an example of which is the cabbage which sheds its leaves, the foliage of dead watermelon vines does not drop off but remains clinging to the plant. The causal fungus is found in both the vascular bundles of the roots, stems, and petioles, which become more or less yellowed to browned. Isolation cultures were made from a large number of wilted plants and *Fusarium niveum* was obtained from any part of the roots, stems, petioles, and leaf veins. The causal fungus was also isolated from the tip ends of the longest

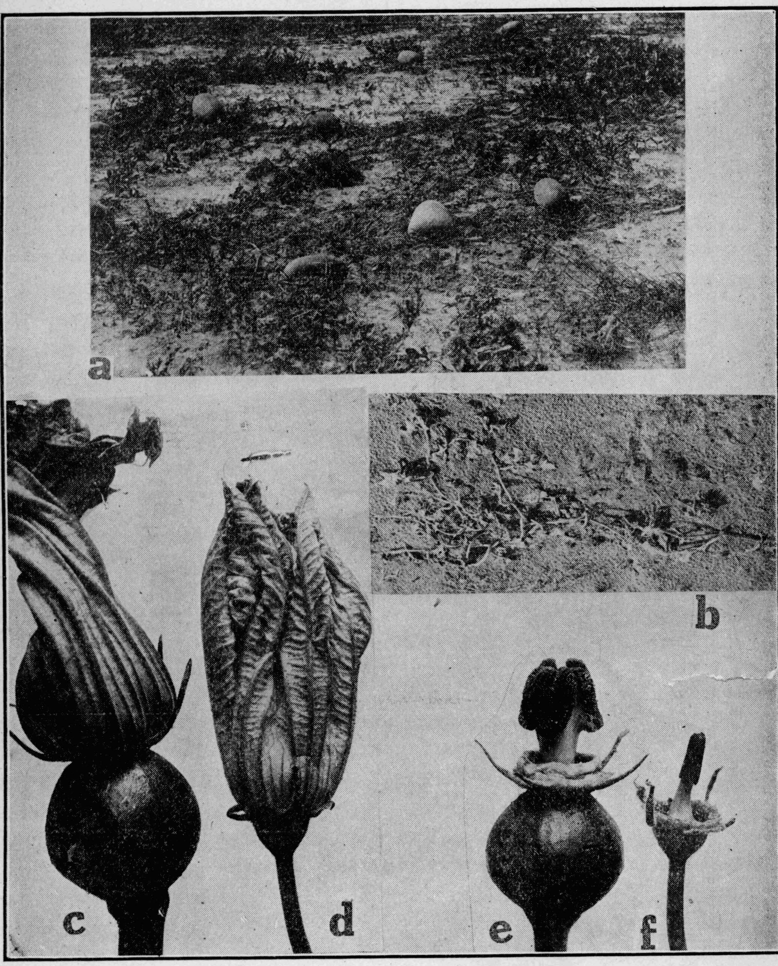


FIGURE 14.

a. Watermelon field badly affected with Fusarium wilt. b. Watermelon plant wilted by Fusarium. c. and e. Female blossom of the squash. d. and f. Male blossoms of the squash.

vines of infected plants, but never from the watermelon fruit which often manages to ripen and produce seed. Numerous plantings of seeds taken from melons of infected plants were planted in pots with sterilized soil yielded 100 per cent. healthy plants. The symptoms of squash wilt (Figs. 1b, 3b, and 6a) are identical with that of the watermelon, except that the disease is not serious during the seedling stage but is more confined to the older plants, becoming evident during blossoming.

PATHOLOGICAL MORPHOLOGY.

The Fusarium of watermelon and this is true of the Fusarium of squash is confined solely to the fibro-vascular bundles of all of the parts of the affected plant, the fruit apparently being an exception. As is well known, the fibro-vascular bundles are the conducting tubes through which water and soluble mineral food are brought up by the roots from the soil to the stems, leaves, and fruit. The Fusarium, in clogging these vessels, naturally shuts off the upward flow of this liquid and thereby causes the affected plant to wilt. Hence it is not uncommon to see watermelon plants wilt although there may be an abundance of moisture in the soil. In cutting open, either lengthwise or crosswise, one will notice that the vascular bundles of the stem of a diseased plant are more or less yellowed to slightly browned, whereas the vascular system of a stem of a healthy plant is greenish and its general color is not much differentiated from the color of the other tissue. If a wilted vine is cut open and placed in a covered tumbler, the Fusarium fungus will, within twenty-four hours, be seen to grow out from the cut ends of the vines as a white cottony growth. This is not the case with healthy vines when similarly treated. This simple test may be utilized by every grower to determine the presence of Fusarium wilt.

METHODS OF CONTROL.

From the foregoing discussion and a reference to Table 3, it becomes evident that growing watermelons on the same land for a number of years will eventually infect it with Fusarium wilts. This is also true of other cucurbits such as squash and cashaw. Wherever watermelons form a basis for an economic crop, care should be taken to prevent the infection of the land with Fusarium wilt. This means that a definite system of rotation should be worked out; the kind, however, will depend on the location and the inclinations of the grower himself. The point to keep in mind is not to grow watermelons more than once or twice on the same land without following it with other crops for at least two to three other years. In this way only will the grower keep his land free from disease and at the same time succeed in producing a profit-watermelon crop. In cases where land has already become slightly or badly infected with wilt, it should at once be given a rest from watermelons for several years, since the longer the crop will be grown on that land the more unfit it is likely to become for watermelons. Orton(17) even recommends that infected soils should be given a rest for ten to twelve years. It is fortunate indeed that Fusarium wilt of watermelon is confined only to that crop; hence any other economic crop may be grown on a diseased watermelon land.

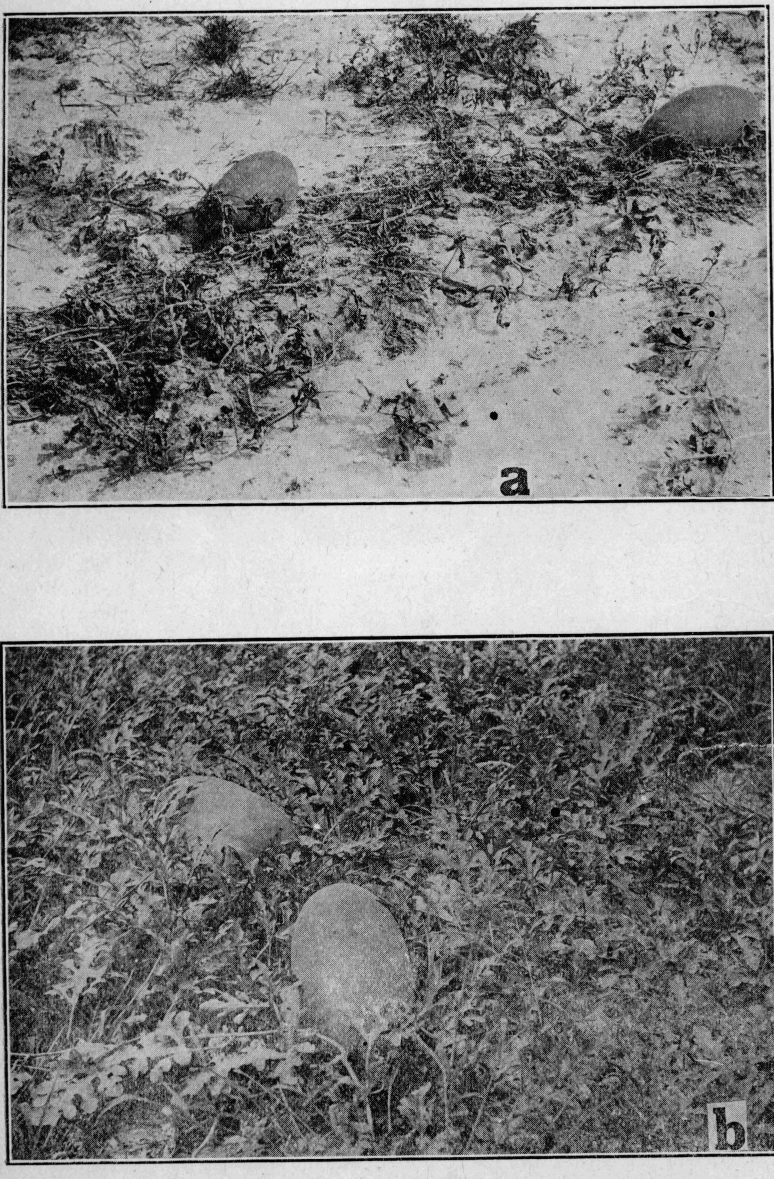


FIGURE 15.

a. Watermelon hill killed by Fusarium. b. Healthy hill for comparison.

Spraying for watermelon wilt is of no value, since, as already shown, the disease only works in the interior of the fibro-vascular or water-conducting bundles of the roots, stems, petioles, and even veins of the

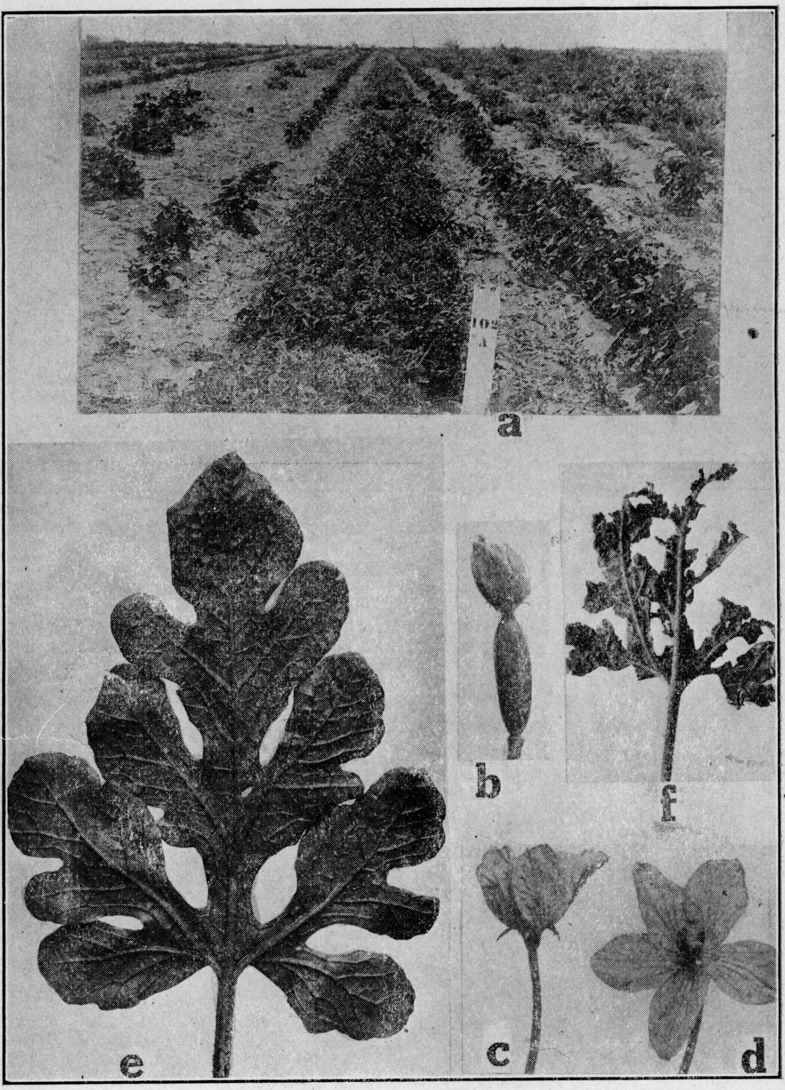


FIGURE 16.

a. Center row, citron, 100 per cent. resistant, growing in a watermelon sick field. b. Female blossom of watermelons. c. and d. Male blossoms of watermelons. e. Healthy watermelon leaf. f. Watermelon leaf burned by 4-4-50 Bordeaux.

leaves. Spraying, however, will be of value in protecting the crop from various leaf spots. This is especially desirable during a wet year but will be of little value in a season with a minimum of rainfall. The

4-4-50 Bordeaux mixture formula as is generally recommended for other crops should never be used for watermelons, squashes, or for any other of the cucurbits. Watermelon leaves, as well as the leaves of other cucurbits, are sensitive and delicate and are easily burned (Fig. 16e and f) from the application of strong Bordeaux. The safest application as worked out from our investigations is a 3-8-50 Bordeaux mixture. Even this weak formula slightly burns the foliage, especially when the plants are young. However, it was found that when a still weaker solution is used that the fungicide loses its effectiveness in controlling leaf spots; hence, where spraying is absolutely necessary the slight injury to the foliage when plants are still young is less serious than when the plants are unsprayed and the foliage allowed to be destroyed by the leaf spots.

PROBLEMS UNSOLVED.

In the present work a discussion was given only of the results of our investigations on Fusarium wilt of watermelons and related cucurbit hosts. The Division of Plant Pathology and Physiology of the Texas Agricultural Experiment Station is now further investigating:

(1) The various leaf spots of the watermelon which destroy the foliage. The disease produced by these leaf spots is commonly known as burning or firing.

(2) Blossom end rot.

(3) Blossom drop.

(4) Diseases of the cucumber, cantaloupe, squash, and other cucurbits.

It may be already stated that one form of blossom drop is but a natural phenomenon. In carefully watching the watermelon blossoms (Fig. 16b to d) as they appear during the season one will see that the watermelon plant produces over 90 per cent. male blossoms and only about 10 per cent. or less female blossoms, the two sexes being formed separately in distinct male and female blossoms on the same plant. The male blossoms (see Fig. 16c and d) usually drop off after their pollen has matured, whereas the female blossoms (Fig. 16b) cling to the vine, although only two or three marketable watermelons mature to a hill. In a dry season the plants yield on an average not more than two to three female blossoms while all the others are male blossoms which, as already stated, drop off after their usefulness has been completed. It is this drop of male blossoms which often alarms the growers, as they believe that the shedding of the flowers means ruin to the crop. The same is also true for the squash blossoms (see Fig. 14c to f).

SUMMARY.

A summary of the results of the investigations on the Fusarium wilts of cucurbits in Texas here presented may be stated as follows:

(1) Fusarium wilt of watermelon is caused by three distinct species of Fusaria, namely: *F. niveum*, *F. citrulli*, and *F. poolensis*.

(2) The Fusaria of the watermelon wilt can only attack the watermelon but no other cucurbit hosts.

(3) The Fusarium wilt of squash and cashaw is caused by a distinct species, namely: *F. cucurbitae*. This fungus attacks no other host except the two previously named.

(4) Neither the watermelon nor the squash and cashaw Fusaria are able to attack other hosts such as cotton, okra, cowpea, potato, tomato, or any other plants.

(5) *Fusarium niveum* of watermelon wilt is a distinct species and is not related to *F. vasinfectum* of the cotton and okra.

(6) *Fusarium vasinfectum* is in no way related to *Necosmospora vasinfecta.*

(7) *Necosmospora vasinfecta* is a saprophyte and is rarely found in Texas.

(8) *Fusarium vasinfectum* attacks the cotton and the okra only.

(9) *Fusarium malvacearum* has proved to be a weak parasite on okra, capable of producing a wilt, but does not affect the cotton.

(10) *Fusarium tracheiphila* produces a wilt on the cowpea only.

(11) *Fusarium oxysporum* produces a wilt on the potato only.

(12) *Fusarium lycopersici* produces a wilt on the tomato only.

(13) *Fusarium conglutinans* produces a wilt on the cabbage only.

(14) *Fusarium lathyri* produces a wilt on the sweet pea only.

(15) It is doubtful whether *Fusarium niveum* of watermelon can attack ginseng plants as stated by Reed(18). From Reed's description he has not been working with pure cultures.

(16) It is apparent that neither the cucumber nor the cantaloupe is subject to the same wilt as the watermelon or the squash. In Texas, cucumber and cantaloupe wilts are caused directly by *Bacillus tracheiphillum.* A Fusarium is often isolated from wilted cucumber or cantaloupe but this Fusarium is only a secondary invader and apparently only a saprophyte.

(17) Planting watermelons on the same land for a number of years will eventually infect it with Fusarium wilt and if this practice is continued long enough the soil will be rendered unfit for watermelons. The same is also true for the squash.

(18) A three-year rotation on a badly infected watermelon land seems to be quite helpful in reducing the amount of the disease although it does not completely eradicate the Fusarium fungus in that land.

(19) Gourds have proved to be immune to either the watermelon or the squash Fusarium wilts.

(20) The "Sugar Through" is a variety of gourd which excels all the other gourds in its edible and economic value. In lands where squash wilt is very severe, the "Sugar Through" may well take its place both for its resistance to disease and its great productiveness.

(21) Spraying for Fusarium wilts is not recommended because the disease only works in the interior of the water vessels of the infected plants. Spraying with 3-8-50 Bordeaux is, however, recommended for the control of leaf spots.

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