ROLE OF INSECTS IN THE DISTRIBUTION OF COTTON WILT CAUSED BY FUSARIUM VASINFECTUM [1]

By J. J. TAUBENHAUS, *chief, Division of Plant Pathology and Physiology, Texas Agricultural Experiment Station,* and L. DEAN CHRISTENSON, *field assistant, Division of Cotton Insect Investigations, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture*

INTRODUCTION

The methods of spread of cotton wilt caused by *Fusarium vasinfectum* Atk. have received considerable attention from investigators. It has long been suspected that insects frequently play a part in the local spread of cotton wilt. During 1933 and 1934 the writers sought to obtain definite information on the possibility of spread of wilt through the fecal pellets of insects that normally feed on the different parts of cotton plants known to be infected with fusarium wilt. Some attention was also given to spread of *F. vasinfectum* as adhering spores on the exterior parts of the body of cotton insects. The laboratory studies here reported were made at College Station, Tex. The field data were obtained in cotton fields near College Station, Beaumont, and Caldwell, Tex. Brief reports on this work appeared in 1933 and 1934.[2]

METHODS AND MATERIALS

The experiments were divided into three groups dealing with cotton insects feeding on (1) roots, (2) stems and leaves, and (3) bolls. The few species worked with were selected because of the ease with which they could be submitted to experimental conditions.

In the laboratory, field-collected insects were caged with portions of roots, stems, or leaves of cotton plants known to be infected with *Fusarium vasinfectum.* The fecal pellets from these insects were collected at least once a day and dried so that they would not quickly disintegrate when placed in fluids. Then they were surface-sterilized by being placed for 30 seconds in an aqueous solution containing, by weight, 0.05 percent mercuric chloride and 35 percent ethyl alcohol, and finally, after being rinsed three times in sterile water, they were planted in Petri plates on acidified potato-dextrose agar. In other tests, certain cotton insects were allowed to feed on normal cotton leaves that had been sprayed with a heavy suspension of spores of a pure culture of *F. vasinfectum.* The fecal pellets from such insects were collected each morning and cultured in the same manner. From time to time insects were dissected under aseptic conditions, and fecal pellets about to be defecated were extracted and cultured. In other tests, insects were permitted to feed on wilt-infected cotton material, and then, after prolonged surface sterilization, the entire insects were cultured on nutrient agar in Petri dishes.

[1] Received for publication July 8, 1936; issued Nov. 1, 1936. Contribution no. 291, Technical Series, Texas Agricultural Experiment Station.

[2] TAUBENHAUS, J. J., and CHRISTENSON, L. D. EFFECT OF INSECTS AND OTHER ANIMAL ORGANISMS ON THE SURVIVAL OF THE CAUSATIVE ORGANISM OF COTTON WILT, FUSARIUM VASINFECTUM. Tex. Agr. Expt. Sta. Ann. Rept. 46: 89-90. 1933.

——— and CHRISTENSON, L. D. INSECTS AS POSSIBLE DISTRIBUTING AGENTS OF COTTON WILT CAUSED BY FUSARIUM VASINFECTUM. (Abstract) Phytopathology 24: 839-840. 1934.

In field tests designed to determine whether cotton insects act as carriers of *Fusarium vasinfectum*, a number of insects were collected in wilt-infected fields. Where possible they were picked up with sterile forceps. To obtain very active species it was necessary to net them or bat them down with a swatter. Each individual thus secured was placed in a sterile vial plugged with cotton and brought to the laboratory, surface-sterilized, and then cultured, or fecal pellets about to be defecated were dissected out and cultured. Soil-inhabiting insects in wilt-infested cotton fields were collected by means of a Berlese funnel and then surface-sterilized and cultured.

Wherever possible, precautions were taken to prevent or minimize casual contamination of fecal pellets or insects to be cultured. All cages and vials were heat-sterilized before use. In experiments with white grubs the soil in which the insects were confined was heat-sterilized at intervals. Spore-covered leaves used for the leaf-feeding insects were suspended at the tip of vials to prevent falling fecal pellets from coming in contact with the leaf areas.

EFFECTIVENESS OF STERILIZATION METHOD

It was established early in these experiments that an aqueous solution containing, by weight, 0.05 percent mercuric chloride and 35 percent ethyl alcohol was effective in destroying the hyphae, chlamydospores, and the microspores as well as the macrospores of *Fusarium vasinfectum*. This solution, however, did not always spread uniformly over the entire surface of fecal pellets or of entire insects when these were characterized by deep sutures or by hirsute bodies or appendages.

Tests to determine the effectiveness of surface sterilization were made by covering entire insects and fecal pellets with a spore suspension of *Fusarium vasinfectum*. One lot each of larvae and fecal pellets of *Alabama argillacea* Hbn. thus treated was surface-sterilized with the mercuric chloride-alcohol solution with 100-percent effectiveness, while in a lot of grasshoppers similarly treated sterilization was only 74 percent effective. Results of the many experiments subsequently made, however, indicated that in the main this sterilization method was highly effective. Nevertheless, external sterilization alone was not relied on. The results were checked from time to time by culturing fecal pellets dissected out from the recta of insects under aseptic conditions.

IDENTITY AND PATHOGENICITY OF THE FUSARIA

All isolations of the fusaria in these experiments were finally grown in tubes on potato-dextrose agar or on sterilized rice. Morphologically, and in pure culture, the strains of *Fusarium* recovered from the fecal pellets or insects used in these tests could not be distinguished from typical *F. vasinfectum* isolated from the roots or stems of a naturally infected cotton plant. Many of these strains were identified by Dr. C. D. Sherbakoff, of the Tennessee Agricultural Experiment Station, as *F. vasinfectum*, but somewhat different from *F. vasinfectum* that affects cotton in Tennessee. Cotton seedlings were successfully inoculated with pure cultures of *F. vasinfectum* obtained from Sherbakoff. Successful inoculations were also made with strains of *Fusarium* recovered by the writers at College Station and Beaumont from insects that had fed on normally infected cotton

plants and from the fecal pellets of these insects. It is of interest to note that more than 80 percent of the fusaria recovered from the fecal pellets of the cotton insects used in these experiments were the same as or similar to *F. vasinfectum*. Other organisms recovered, particularly from the fecal pellets, were *F. semitectum* and various species of *Aspergillus*.

In November 1934 several thousand fecal pellets were collected from grasshoppers that had fed on cotton stems naturally infected with cotton wilt. These pellets were kept at room temperature, in a test tube plugged with cotton, and cultures were made of them from time to time. The percentage of pellets from which *F. vasinfectum* was recovered is shown in table 1. It will be noted that *F. vasinfectum* remained viable for at least 15 months.

TABLE 1.—*Viability of Fusarium vasinfectum in dried fecal pellets obtained November 1934 from grasshoppers fed on wilt-infected cotton stems*

Date cultured	Pellets cultured	Pellets from which *F. vasinfectum* was obtained	
	Number	*Number*	*Percent*
December 1934	160	147	91.9
April 1935	210	180	85.7
November 1935	117	93	79.5
March 1936	287	117	40.8

RECOVERY OF FUSARIUM VASINFECTUM FROM ROOT-FEEDING INSECTS

The root-feeding insects used included white grubs (*Phyllophaga crassissima* Blanch. and other unidentified species), wireworms, and numerous small insects usually included in the category of "smaller soil animals."

The white grubs were placed in soil cages and fed on portions of cotton roots infected with *Fusarium vasinfectum*. The fecal pellets were collected daily by soil sifting and cultured in the usual way. As shown in table 2, out of 239 fecal pellets cultured, 78, or 32.6 percent, yielded pure cultures of *F. vasinfectum*. Likewise, cultures were made of 17 entire white grubs that had been feeding on infected cotton roots, and 4, or 23.5 percent, yielded pure growth of *F. vasinfectum*.

TABLE 2.—*Petri-dish cultures of fecal pellets of white grubs (Phyllophaga crassissima and others) fed on portions of cotton roots infected with fusarium wilt*

Degree and type of feeding	Fecal pellets cultured	Cultures showing good growth of *Fusarium vasinfectum*	
	Number	*Number*	*Percent*
Slight to moderate surface grazing	17	1	5.9
	1	1	100.0
	16	16	100.0
	3	2	66.7
Moderate gouging	3	0	0.
	3	0	0.
	11	5	45.5
	12	0	0.
	12	8	66.7
	119	20	16.8
Copious gouging	17	17	100.0
	25	8	32.0
Total	239	78	32.6

A number of wireworms were placed in soil cages and permitted to feed on the roots of wilt-infected cotton plants. After feeding, they were surface-sterilized and the entire insects cultured. In not a single instance was *Fusarium vasinfectum* recovered.

Among the smaller soil animals worked with were the Collembola (including *Onychiurus fimetarius* (L.) Lubb., *Pseudosinella violenta* Fols., and *Entomobrya sabulicola* Mills [3]), a species of Japygidae, and coleopterous larvae. They were collected from the soil about the roots of wilted cotton plants and cultured with and without surface sterilization. Certain of the Collembola, having shown a marked avidity for mycelial growth of *Fusarium vasinfectum*, were fed for from 3 to 24 days on pure slant cultures of the cotton-wilt fungus. General collections of smaller insects obtained from the soil surrounding wilt-infected cotton roots were surface-sterilized and also cultured. The results are shown in table 3. It will be noted that, of all the specimens of Collembola cultured, only one (*P. violenta*), which was not surface-sterilized, yielded growth of *F. vasinfectum*. Growth of *F. vasinfectum* was obtained from two of four unidentified coleopterous larvae cultured. In cultures of approximately 1,000 smaller soil insects and other Arthropoda, 6 yielded growth of *F. vasinfectum*.

TABLE 3.—*Petri-dish cultures of smaller soil animals collected from soil under wilted cotton plants or fed upon pure cultures of Fusarium vasinfectum prior to culturing*

Species	Source or treatment of insects	Preparation for culturing	Insects cultured	Insects yielding growth of *Fusarium vasinfectum*	
			Number	*Number*	*Percent*
Onychiurus fimetarius	Soil under wilted plant	Not sterilized	(1)	0	
Pseudosinella violenta	do	do	7	1	14.3
	do	Washed and sterilized	17	0	
	Fed on *F. vasinfectum*	Washed in sterile water	4	0	
	do	Washed and sterilized	15	0	
Entomobrya sabulicola	Soil under wilted plant	do	2	0	
	Fed on *F. vasinfectum*	Not sterilized	7	0	
	do	Washed in sterile water	4	0	
	do	Washed and sterilized	18	0	
Japygidae	Soil under wilted plant	Not sterilized	5	0	
Coleopterous larvae	do	Washed and sterilized	4	2	50.0
Miscellaneous smaller soil animals, etc.[2]	do	do	[3] 1,000	6	.6

[1] Several.
[2] Composed of Collembola, Japygidae, Campodeidae, larval stages, etc. Other arthropods, such as Pauropoda, Symphyla, Diplopoda, Chilopoda, Acarina, Araneida, etc., were included.
[3] Approximate number.

RECOVERY OF FUSARIUM VASINFECTUM FROM STEM- AND LEAF-FEEDING INSECTS

The stem borer *Ataxia crypta* Say [4] is frequently found infesting dead stems of cotton plants in Texas and consuming tissues normally attacked by the cotton-wilt fungus. In feeding within cotton stems this insect usually expels considerable frass through a small hole maintained for the purpose. The frass falls to the ground or is blown away by the wind. A number of *A. crypta* were introduced into stems of cotton plants that had been killed by *Fusarium vasinfectum*. Nine entire larvae, fecal pellets, and frass were surface-

[3] Identified by J. W. Folsom, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.
[4] Identified by H. J. Reinhard, Texas Agricultural Experiment Station.

sterilized and cultured in the usual way. *F. vasinfectum* was recovered from the frass and from six of the nine entire larvae.

Among the grasshoppers [5] commonly found in wilt-infected cotton fields in Texas are the following: *Melanoplus differentialis* Thos., *M. mexicanus* Sauss., *M. femur-rubrum* Deg., *Encoptolophus texensis* Brun., *Spharagemon cristatum* Scudd., *Tomonotus aztecus* Sauss., *Chortophaga viridifasciata* var. *australior* Deg., *Schistocerca americana* Dru., *S. obscura* Fab., *Trimerotropis citrina* Scudd., and *Dissosteira carolina* L.

A number of grasshoppers of the species *Melanoplus femur-rubrum*, *M. differentialis*, and *Schistocerca obscura* and an unidentified miscellaneous group were caged and permitted to feed on the stems of wilt-infected cotton plants. The insects were forced to consume diseased tissues or starve, inasmuch as all foliage had been removed. The fecal pellets were collected each morning and cultured immediately after surface sterilization. As shown in table 4, 25 lots containing a total of 1,729 fecal pellets, were cultured. Pure growth of *F. vasinfectum* was recovered from 80 percent of these lots. In addition, four surface-sterilized adult grasshoppers were cultured, one of which produced a growth of *F. vasinfectum* originating at a point on a tarsus.

TABLE 4.—*Petri-dish cultures of fecal pellets of grasshoppers fed on portions of cotton stems infected with fusarium wilt*

Species	Fecal pellets cultured	Growth of *Fusarium vasinfectum* [1]
	Number	
Melanoplus differentialis	36	−
	59	+
	56	+
	42	−
	85	+
	50	−
	39	+
	51	+
	40	+
	49	+
	100	+
	100	+
	72	+
	149	+
	164	+
Melanoplus femur-rubrum	50	+
	205	+
Schistocerca obscura	18	+
	12	+
	44	+
Miscellaneous [2]	57	−
	46	−
	55	+
	100	+
	50	+
Total	1,729	5 −, 20 +

[1] + denotes positive growth of *F. vasinfectum*, − no growth.
[2] Chiefly *Melanoplus differentialis;* also *M. femur-rubrum* and unidentified nymphs.

During the season of 1934 field studies were made to determine the extent to which leaf-feeding insects in badly diseased cotton areas may act as carriers of cotton wilt. Grasshoppers, including all the

[5] Identified by the late A. N. Caudell, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

species mentioned above, were used in these experiments, because they are active fliers, are prevalent in wilt-infected cotton fields in Texas, and are also known to consume quantities of cotton-leaf tissue. Pure cultures of *Fusarium vasinfectum* were obtained from 22.2 percent of 419 grasshoppers collected near Caldwell, from 26.6 percent of 184 collected near College Station, and from 33.3 percent of 90 obtained near Beaumont. In the Caldwell field, from which data of a seasonal nature were obtained, 9.4 percent of the grasshoppers were found to carry the wilt fungus internally on July 24, 11.7 percent on August 7, 35.6 percent on September 4, 24.9 percent on September 27, and 29.5 percent on October 18. These statements apply only to those species of grasshopper for which positive results were obtained. Several other species that were present in the fields in smaller numbers were not tested.

There was no way of determining whether the number of grasshoppers acting as carriers of *Fusarium vasinfectum* was in direct ratio to the number of plants infected in the field. All fields in which surveys were made proved ultimately to have 75 percent or more of the plants diseased.

Larvae of *Alabama argillacea*, *Laphygma frugiperda* S. and A., and *Prodenia ornithogalli* Guen. obtained from nonwilt areas were placed in separate cages and fed on cotton leaves naturally infected with wilt. In addition, larvae of *Alabama* and *Prodenia* were fed on leaves that had been painted with a heavy suspension of spores of a pure culture of *Fusarium vasinfectum*. The fecal pellets and some of the entire insects were cultured in the usual way. As shown in table 5 and figure 1, typical *F. vasinfectum* was often recovered from the fecal pellets of the larvae and from some of the entire insects.

TABLE 5.—*Petri-dish cultures of fecal pellets and various stages of lepidopterous leaf-feeding insects*

Species	Kind of food consumed	Material	Cultures	Cultures showing good growth of *F. vasinfectum*	
			Number	*Number*	*Percent*
Laphygma frugiperda	Naturally infected cotton leaves.	Fecal pellets	5	0	0
			29	16	55.2
			40	0	0
			114	43	37.7
			8	8	100.0
Prodenia ornithogalli	---do	---do	1,826	559	30.6
	---do	Entire larvae	20	1	5.0
	Spore-covered cotton leaves.	Fecal pellets	52	29	55.8
Alabama argillacea	Naturally infected cotton leaves.	---do	768	615	80.0
	---do	Entire larvae	9	2	22.2
	Spore-covered cotton leaves.	Fecal pellets	202	202	100.0
	---do	Entire larvae	2	0	0
	---do	Prepupae	1	0	0
	---do	Pupae	10	1	10.0
	---do	Adults	4	0	0

Tests were made to determine whether the wilt organism could remain within *Alabama argillacea* during pupation and later be disseminated by the adult moth, which has exceptional migratory powers. This problem was attacked by determining the degree of completeness with which the alimentary tract was voided of viable fungus material through the elimination processes. Larvae were fed

for a time upon normal cotton leaves, then upon spore-painted leaves, and then once more upon normal leaves. Fecal pellets were cultured individually as defecated. No growth of *Fusarium vasinfectum* was obtained until approximately 26 minutes after spore-covered cotton leaves had been provided as food. All fecal pellets were then found to sponsor growth of the fungus until approximately 26 minutes from the time the second feeding on normal leaves had begun. Thereafter no growth of *F. vasinfectum* was obtained. In other tests larvae were allowed to feed on spore-covered cotton leaves and then starved for

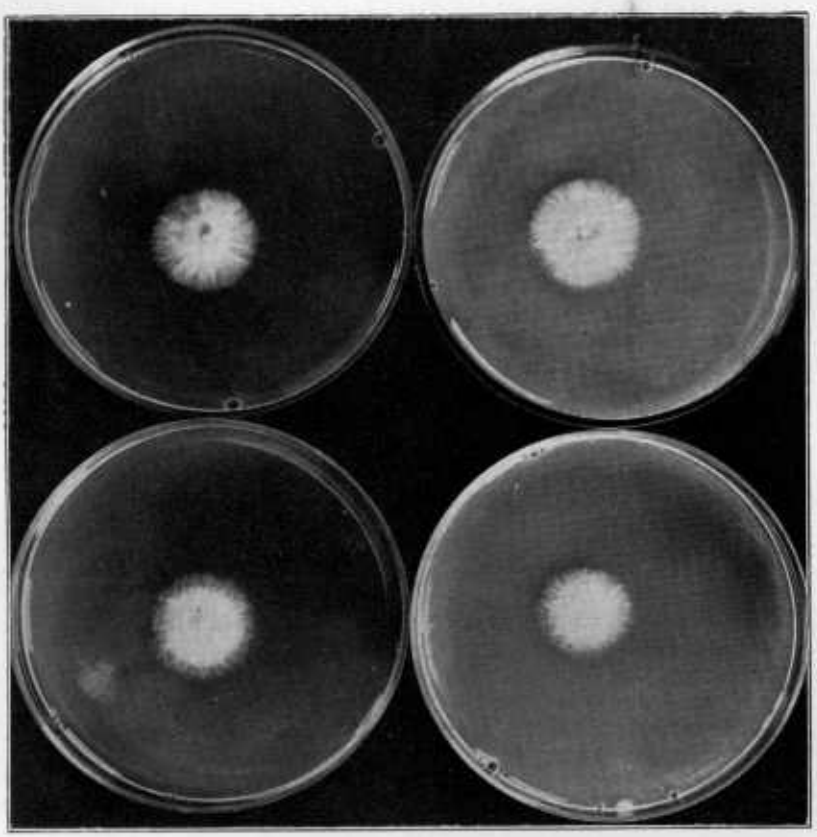

FIGURE 1.—Pure cultures of *Fusarium vasinfectum* recovered from individual fecal pellets of *Alabama argillacea* larvae that had been fed on cotton leaves painted with a suspension of the spores of *F. vasinfectum*.

from 1 to 4 days. These larvae were then dissected and their alimentary tracts aseptically removed and cultured. The results were always negative.

Similar tests were made with *Melanoplus differentialis* and *Schistocerca americana*, with the same results. In the case of *M. differentialis* no growth of *Fusarium vasinfectum* was obtained in cultures after approximately 45 minutes from the time the last spore-covered leaves had been eaten. For *S. americana* the period was 42 minutes (at 26.5° C.).

From these results it appears that the passage of *Fusarium vasinfectum* through the alimentary tracts of the insects used in these tests was relatively rapid.

This conclusion is substantiated by the results of cultures of pupae and adults of *Alabama argillacea*, the larvae of which had been fed upon spore-contaminated leaves for several days prior to pupation. In cultures of 49 of these pupae that had spun up in heavily inoculated leaves, only 2 yielded growth of *F. vasinfectum*. In cultures of 20 adults that were collected as they emerged from their pupal cases, no wilt fungus was obtained. There is little likelihood that the fungus is retained within *A. argillacea* in a viable state during pupation and formation of the imago.

RECOVERY OF FUSARIUM VASINFECTUM FROM BOLL-FEEDING INSECTS

Boll-feeding insects are usually numerous in cotton fields. Two types were worked with, the boll weevil (*Anthonomus grandis* Boh.) and the bollworm (*Heliothis obsoleta* Fab.). Only entire immature stages and adult boll weevils collected from within bolls on badly wilted cotton plants were cultured. Three out of ninety-five larvae, or 3.2 percent, 1 out of 30 pupae, or 3.3 percent, and 1 out of 61 adults, or 1.6 percent, yielded pure-culture growth of *Fusarium vasinfectum*. The results of these tests with the boll weevil are not considered as conclusive of the passage of viable fungus through the alimentary tract and need further verification. Fecal pellets from *H. obsoleta* larvae that had fed upon spore-covered involucral bracts and small bolls were cultured after external sterilization. Pure growth of *F. vasinfectum* was obtained from 60 percent of these.

DISSEMINATION OF FUSARIUM VASINFECTUM THROUGH EXTERNALLY ADHERING SPORES

Numerous tests were made to determine the ability of insects to spread the cotton-wilt fungus on their appendages. After being exposed to cotton stems bearing an abundance of sporodochia, such insects as *Anthonomus grandis* Boh., *Olla abdominalis* Say, *Jadera haematoloma* H. S., *Zelus cervicalis* Stål, *Nezara viridula* L., *Euschistus servus* Say, and others were found to start cultures of *Fusarium vasinfectum* where their feet were permitted to touch the surface of acidified agar in Petri dishes. Cultures of the appendages of insects captured in badly wilted cotton fields showed that many normally transport viable fungus in this manner.

DISCUSSION

This paper has indicated the possibility of insects spreading *Fusarium vasinfectum* through their fecal pellets. Such pellets may carry the fungus as bits of hyphae or spores, which are unaffected by brief surface sterilization with an aqueous solution containing, by weight, 0.05 percent mercuric chloride and 35 percent ethyl alcohol.

To check the reliability of the results, cultures were made of fecal pellets dissected from the recta under aseptic conditions, and typical growth of *Fusarium vasinfectum* was obtained from the following insects: *Schistocerca americana*, *Melanoplus differentialis*, *M. mexi-*

canus, *Chortophaga viridifasciata* var. *australior*, *Encoptolophus texensis*, *Trimerotropis citrina*, and *Spharagemon cristatum*.

That the results obtained are largely accurate is further indicated by the negative results obtained with certain soil-inhabiting insects. If the methods had allowed contaminations sufficient to account for the large percentage of positive results obtained in many experiments, one might expect that those tests which were habitually negative would also have been subject to the same degree of contamination and that positive results would have been intermixed with negative ones. The same logic applies to the test in which cultures were made of individual pellets, as these were defecated from larvae of *Alabama argillacea* and grasshoppers that had been fed successively upon wilt-free food, spore-covered food, and wilt-free food. If the positive results had originated in external contaminations, there would have been no such abrupt change in the positive or negative character of cultures.

Another test may be cited as an indication of the accuracy of the results. Living *Alabama argillacea* larvae, containing wilt fungus internally, were submerged in the sterilization fluid for 30 seconds. This exposure was found to be not immediately fatal. The larvae were then transferred with sterile forceps to sterile acid-agar plates, where they were left until they had defecated one or more fecal pellets. The insects were then removed and the plate was left for fungus development. All of a number of tests resulted positively. In every instance the growth of *Fusarium vasinfectum* originated with fecal pellets. That external sterilization was efficient is indicated by the fact that not a single growth of the wilt fungus resulted from contact of larvae with agar surfaces during their wanderings inside the Petri dishes.

The point of appearance of *Fusarium vasinfectum* in cultures also merits consideration. When entire insects were externally sterilized and cultured, growths of the wilt fungus most commonly made their appearance near the anus, and more rarely on appendages and external body parts.

Passage of the cotton-wilt fungus through the alimentary tract of the insects studied appears to have been relatively rapid. Swiftly flying insects could undoubtedly spread *Fusarium vasinfectum* from field to field through their fecal pellets, although the supply of fungus would be exhausted before they could cover great distances. Those insects that do carry wilt fungus internally are probably of importance in field-to-field spread, and in intensifying the infective element within a field. Each infective fecal pellet deposited is an additional source of fungus that may ultimately attack cotton plants. The fecal pellet itself provides sufficient nutrient material to enable the fungus to grow. The possibilities with respect to insects that serve as vehicles for externally adhering spores are almost unlimited.

It is worthy of note that those insects whose alimentary fluids had no immediate lethal effect on *Fusarium vasinfectum* are all phytophagous. Most of the insects that destroyed wilt fungus by eating it, particularly the Collembola, feed normally upon decaying organic matter and fungi. Indications are that the association between insects and the wilt fungus is entirely a mechanical one.

SUMMARY

The following cotton insects were caged and fed on roots, stems and leaves, or bolls of cotton plants infected with typical fusarium wilt: *Melanoplus femur-rubrum, M. differentialis, Schistocerca americana, S. obscura,* and other less abundant grasshoppers; the larval stages of *Alabama argillacea, Laphygma frugiperda,* and *Prodenia ornithogalli;* a number of species of white grubs; and the larval stage of *Ataxia crypta.* Viable *F. vasinfectum* was recovered from fecal pellets or entire insects cultured on potato-dextrose agar in Petri dishes. The wilt fungus could not be recovered from, and was apparently destroyed while passing through, the alimentary tract of wireworms, Collembola, and Japygidae.

Viable *Fusarium vasinfectum* was recovered from cultures of the entire insects or of fecal pellets dissected out from the recta of numerous species collected in badly wilted cotton fields in Texas. The following insects were found to act as natural carriers of the cotton wilt fungus: *Melanoplus differentialis, M. mexicanus, M. femur-rubrum, Encoptolophus texensis, Spharagemon cristatum, Tomonotus aztecus, Chortophaga viridifasciata* var. *australior, Schistocerca americana, S. obscura, Trimerotropis citrina,* and *Dissosteira carolina.* It still remains to be proved whether the boll weevil can act as a carrier of fusarium wilt of cotton.

Cotton seedlings were successfully inoculated with strains of *Fusarium* isolated from the alimentary tract of insects and with a pure culture of *F. vasinfectum* from infected cotton.

Fusarium vasinfectum has survived for 15 months in fecal pellets from grasshoppers fed on wilt-infected cotton stems and kept dry in the laboratory.

It is suggested that these results may help to explain the occasional finding of infected plants in areas where the disease does not ordinarily occur.