AMERICAN, EGYPTIAN, AND INDIAN COTTON-WILT FUSARIA

Their Pathogenicity and Relationship To Other Wilt Fusaria

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AMERICAN, EGYPTIAN, AND INDIAN COTTON-WILT FUSARIA: THEIR PATHOGENICITY AND RELATIONSHIP TO OTHER WILT FUSARIA

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Introduction

The early work on the *Fusarium* (*Fusarium oxysporum* f. *vasinfectum* (Atk.) Snyder & Hansen or *F. vasinfectum* Atk.) that causes the wilt disease of cotton (*Gossypium hirsutum* L.) was begun by the writers when it was generally believed that the wilt fusaria were rather specific in pathogenicity (*25*, *29*).[1] The investigations led to the discovery that the United States cotton-wilt *Fusarium* caused wilt of cotton, okra (*Hibiscus esculentus* L.) alfalfa (*Medicago sativa* L.) (*6*), burley tobacco (*Nicotinia tabacum* L.), the Chinese lantern plant (*Physalis alkekengi* L.) (*11*), and a slight wilt of a weed (*Cessia tora* L.) (*1*, *8*).

The isolates of the United States cotton-wilt *Fusarium* used in the early experiments probably belonged to race 1, as this race is widespread. Another race (race 2), which has been reported recently from only a few locations (*10*), caused wilt of the hosts susceptible to race 1 and, in addition, caused wilt of flue-cured tobacco and of Yelredo soybean (*Glycine max* (L.) Merrill). The results suggested that perhaps other wilt fusaria also were less specific in pathogenicity. For this reason an effort was made to determine the host ranges of numerous wilt fusaria and to find interrelationships through common hosts. As the United States cotton-wilt *Fusarium* lacked host specificity and showed a wide host range, it was possible that the Egyptian and Indian cotton-wilt fusaria would also show similar interrelationships.

This bulletin discusses the pathogenicity of the United States, Egyptian, and Indian cotton-wilt fusaria on cotton and other plants; the reaction of American upland, Egyptian, Indian, and several wild cottons to the wilt fusaria from other plants; and the attempts to find isolates of the United States cotton-wilt *Fusarium* that might show differential pathogenicity for varieties of cotton, and, therefore, be classed as races. Certain aspects of the wilt-nematode complex, which were interpreted by some workers as indicative of pathogenic races of the wilt fungus, are included.

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[1] Italic numbers in parentheses refer to Literature Cited, p. 17.

Review of Literature

The discovery that the United States cotton-wilt *Fusarium* not only caused wilt of upland cotton but also caused wilt of burley tobacco (*1*, *8*, *24*), alfalfa (*6*), and slight wilt of *Cassia tora* L. (*8*) led to numerous other inoculations. When it was found that certain cotton isolates also caused wilt of flue-cured tobacco and the Yelredo soybean, but most of them did not, those isolates causing only wilt of cotton were designated race 1 and those causing wilt of cotton, flue-cured tobacco, and Yelredo soybean were designated race 2 (*10*). Another *Fusarium* that caused severe wilt of *Cassia tora* in the southeastern United States (*5*, *6*) was different from the cotton *Fusarium*, races 1 and 2, for it was highly pathogenic on *Cassia tora* and only slightly so on cotton and Kentucky 5 burley tobacco, but like races 1 and 2 of the cotton *Fusarium*, it was highly pathogenic on alfalfa. Yet another *Fusarium*, causing wilt of alfalfa, differed from those attacking cotton and *Cassia tora*, as it was nonpathogenic on cotton, *Cassia tora*, soybean, and burley and flue-cured tobaccos (*6*). Although the fusaria from cotton, *Cassia tora*, and alfalfa had different host ranges, they were related by having a common host, alfalfa. Recently (*11*), another common host for the wilt fusaria of United States cotton, races 1 and 2; *Cassia tora;* and sweetpotato, race 2, has been found in *Physalis alkekengi* L., the winter cherry, or Chinese lantern plant.

Races 1 and 2 of the United States *Fusarium* were identified because of selective pathogenicity for such unrelated hosts as cotton, flue-cured tobacco, and Yelredo soybean. However, the possibility that races of this *Fusarium* with selective pathogenicity for varieties of upland cotton might exist has been investigated by the writers and others. Sherbakoff (*22*) inoculated four varieties of cotton with five *Fusarium* isolates. He noted considerable differences in virulence among them but "no specialization of any of the isolates in regard to their pathogenicity to the varieties of cotton." Cralley (*14*) inoculated a susceptible and a resistant variety with 80 separate *Fusarium* isolates, but failed to find races. Barker and Sherbakoff (*12*) made a survey of many wilt-infested fields throughout the Cotton Belt. They mentioned the possibility of physiologic races, but concluded that their existence was not substantiated by these observations.

Evans (*15*) first noted that American cottons were resistant in the wilt fields of India. This observation has been substantiated by others (*19*, *20*, *21*). Fahmy (*16*, *17*) reported three races of the cotton-wilt *Fusarium*, using the entire species of American upland (*Gossypium hirsutum*), Egyptian (*G. barbadense*), and Indian cottons (*G. arboreum*, *G. herbaceum*) as the differential hosts and not certain varieties within the species. Thus, in this separation, the varieties within a species would react similarly to each race. Fahmy's results indicated rather clearly that weakly pathogenic isolates of the United States fungus were used in the investigation, as they produced no or only slight disease symptoms on several highly susceptible upland varieties and the susceptible Sakel variety. It appeared, therefore, that more virulent *Fusarium* isolates and a wider range of cotton varieties should be used to establish the races more precisely. Mundkur (*21*) concluded that the Indian strain of the cotton-wilt fungus was a distinct physiologic race that was unable to attack American cotton and that the American strain was unable to attack Indian cotton. However, preliminary experiments by the present writers indicated that the American strain could attack Indian cotton. Kulkarni (*20*) also believed that there was physiologic specialization in the cotton-wilt *Fusarium* from these three countries.

Material and Methods

Fresh cultures of the United States, Egyptian, and Indian cotton-wilt fusaria were collected, as well as viable seed of a number of varieties of cotton of the following species: *Gossypium hirsutum* L. (American Upland); *G. barbadense* L. (Egyptian); *G. arboreum* L. and *G. herbaceum* L. (Indian); and the wild cottons, *G. thurberi* Tod. and *G. anomalum* Wawra & Peyritsch. The classification of cotton is that of Hutchinson and coworkers (*18*). A list of some of the varieties used in this study and their source are given in table 12, Appendix. Variety is used to include variety, type, or breeding line.

Several methods of growing and inoculating plants have been used (*2*, *3*). In recent years, the plants have been grown in steamed sand in 2-gallon glazed pots with a 2-cm. hole laterally at the bottom for drainage. Seed were planted evenly spaced in a circle 1 inch from the periphery. Formerly, young plants of tobacco, tomato, sweet-potato, and occasionally other crops were inoculated by dipping the roots in the fungus inoculum and then setting 5 to 8 of them in a circle in the pot. At present, the transplanted plants, except sweet-potato, usually are allowed to become well established in the pots before being inoculated in the same manner as those plants seeded directly in the pot. The nutrient solution described by Armstrong (*2*) was used for growing the plants.

Monoconidial isolates, derived chiefly from microspores, were the source of the inoculum except where the corresponding mass cultures were tested for comparison. The isolates were maintained on slants of potato-dextrose agar. One milliliter of the fungus suspension, which was prepared by pouring sterile water on a fresh agar-slant culture and loosening spores and mycelium with a sterile needle, was added to 500 ml. of culture medium that had been sterilized in a 2-liter flask plugged with cotton. The medium consisted of sucrose or glucose, 2 percent; $MgSO_4$, 0.003 M; KCl, 0.022 M; KH_2PO_4, 0.008 M;[2] $Ca(NO_3)_2$, 0.0356 M;[2] and $FeCl_3$, $MnSO_4$, $ZnSO_4$, 0.2 p.p.m. of each cation. The fungus was cultured for 72 hours at 28° C., and the flask was shaken several times daily to keep the mycelium well dispersed.

The inoculation procedure was as follows: Roots of the plants were cut on one side by pressing into the moist sand to a depth of 1½ inches either an inverted Buchner funnel placed in the center of the pot or a large test tube placed close to the stalks of the plants. Then 500 ml. of the inoculum was poured into the depression, the roots were covered with sand, and water was sprinkled over the surface to settle the sand. The same procedure was used for the second inoculation a week later. This is essentially the method described by Tharp (*27*).

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[2] Misprint in (*3*, *p. 809*), where these salts were given as 0.1008 M and 0.1035 M, respectively.

The inoculations were generally performed in the late afternoon, and by the following morning the plants were usually able to remain in the sunlight without protection. There was never any evidence that staling products, with toxic effects on the plants, had accumulated in the solution. The inoculation method seemed to provide optimum conditions for wilt development, so that the pathogenic potential of the pathogen could be determined.

During the experiments, the usual precautions were taken to prevent accidental contaminations. All necessary glassware and instruments were sterilized, and sterilized rubber gloves were worn when making the inoculations for each isolate. Uninoculated plants of the varieties being tested were included in each series of experiments. Reisolations of fusaria were made from diseased plants in the cross-inoculation experiments by plating surface-sterilized stem sections on water agar. Inoculations were made on the appropriate host to establish the identity of these isolates.

Both external and internal symptoms of wilt were noted, but only the percentages of plants showing external symptoms have been given in the tables. Plants were removed from the pots when they were severely diseased. When an experiment was terminated, those that showed no external symptoms were cut diagonally 1 to 2 inches above the soil line, and also vertically, if there was discoloration, to note its extent. These plants were graded on a scale of 0, 1, 2, 3, according to the degree of discoloration. These data were omitted from the tables, as they seemed to be of minor importance in defining the host relationships.

Results of Inoculation of Varieties of Cotton of 5 Species With Races 1 and 2 of the United States Cotton-Wilt Fusarium

Races 1 and 2 of the United States *Fusarium* have been identified because of selective pathogenicity for such unrelated hosts as cotton, tobacco, and the Yelredo soybean. These races could not be separated by their pathogenicity on 21 resistant or susceptible varieties[3] of *Gossypium hirsutum*, 8 of *G. barbadense*, and the resistant wild cotton *G. thurberi*. The varieties of *G. hirsutum* in these tests were Acala, Coker 100 Wilt, Deltapine, Empire P45-19, Hopi, Hurley Special Rowden, Stonewilt, Super Seven, White Gold Wilt, and various breeding lines of Coker 100 Wilt, Empire, and Marett's W/R. The varieties of *G. barbadense* were Amsak, Ashmouni, Bryan, Pima 32, Sakel, Sakha 4, Seabrook sea-island, and Tanguis. Two to fourteen different isolates of both races 1 and 2 were used in these inoculations, except for the variety Rowden, where 77 of race 1 and 14 of race 2 were involved. The isolates of race 1 were from Alabama, Arkansas, Georgia, North Carolina, Oklahoma, South Carolina, and Tennessee.

In additional tests, 4 varieties of *G. arboreum*, Garo Hill, New Million Dollar, K–1, and Okinawa; and 1 of *G. herbaceum*, G. A. 26, gave the same reactions to some isolates of race 1 and race 2.

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[3] Variety will be used to include variety, type, or breeding line. See table 12 for additional information.

Results of Inoculation of 2 Varieties of Upland Cotton With Isolates of Fusarium From Wilt-Nematode Sites

Observations have been made by the senior author since 1928 that wilt-resistant varieties of cotton were resistant in some wilt-infested fields but occasionally were seriously damaged in others. It has long been thought that the severity of cotton wilt is increased by the presence of the root-knot nematodes (*Meloidogyne* spp.) in the soil. More recently, the nematodes that do not cause gall formation—the meadow (*Pratylenchus* spp.), sting (*Belonolaimus gracilis*), and reinform (*Rotylenchulus reniformis*) nematodes have also been associated with unusual losses from the wilt disease.

The severe damage to cotton in some wilt-infested fields, where no root-knot galls were found suggested that new and perhaps more virulent races of the cotton-wilt *Fusarium* might be involved. A collection of wilt fusaria from a field where wilt-resistant varieties and breeding lines were destroyed over an area of about one-half acre were collected (field 1) by the writers. No root-knot galls were found on plants in this field, but more recently the soil has been found to be infested with the non-gall-forming sting nematode. Fungus isolates were also made from plants in another field (field 2) infested with the root-knot nematodes in which were grown some of the same wilt-resistant varieties as in field 1, as well as 13 other resistant varieties and a susceptible variety as a check. Only about 10 percent of the plants of the resistant varieties showed external symptoms of wilt in field 2.

Two varieties of cotton, the susceptible Coker 100 and the wilt-resistant Dixie Triumph 12, were inoculated with the *Fusarium* isolates from the two fields. In these early experiments, plants were grown in solution culture (*2*) or in 2-gallon stoneware pots containing sterilized soil to which cultures of the fungus isolates on a wheat-oats mixture were added in the proportion of 1 part to 40 by weight (*9*). As no significant differences in the data with the two methods were apparent, the results are combined in table 1. Isolates of high virulence were obtained from plants in both fields. Isolates 2 and 4 from field 2, where only the susceptible variety was killed to an appreciable extent, were as pathogenic as isolates 7 and 8 from field 1, where all resistant plants were killed in a large area. Isolates 3 and 5 from field 2 were less virulent than the preceding ones, but variations in pathogenicity and also in cultural characters can be found in *Fusarium* isolates from cotton (*9*, *28*) and other crop plants. Furthermore, the virulence of an isolate apparently was not related to the degree of resistance of the host from which it came; i.e., isolates 1 to 4 from a susceptible variety and isolates 5 to 8 from resistant varieties. It seemed reasonable to conclude, therefore, that the killing of plants in field 1 was due not to a more virulent parasite or a new race but probably to a complex of environmental factors in this field.

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TABLE 1.—*Percentage of plants of a susceptible (Coker 100) and a resistant variety (Dixie Triumph 12) of cotton with external and internal symptoms of wilt, after inoculation with 8 Fusarium-wilt isolates from fields 1 and 2*

Fungus isolate No.[1]	Variety	Plants	External symptoms of wilt	Internal symptoms of wilt
		Number	*Percent*	*Percent*
1	Coker 100	106	63.2	85.8
	Dixie Triumph 12	107	59.8	83.2
2	Coker 100	105	94.3	97.1
	Dixie Triumph 12	108	30.6	74.1
3	Coker 100	126	30.2	50.8
	Dixie Triumph 12	95	11.6	37.9
4	Coker 100	105	82.8	89.5
	Dixie Triumph 12	81	50.6	85.2
5	Coker 100	112	25.0	37.5
	Dixie Triumph 12	102	15.7	34.3
6	Coker 100	99	51.5	79.8
	Dixie Triumph 12	97	26.8	42.3
7	Coker 100	115	80.9	93.0
	Dixie Triumph 12	87	39.1	72.4
8	Coker 100	118	74.6	88.1
	Dixie Triumph 12	110	39.1	68.2

[1] Isolates 1 to 6, inclusive, from field with little wilting of resistant varieties (field 2); 7 to 8 from field where all varieties were killed in ½-acre spot (field 1). Isolates 1 to 4 are from susceptible variety; 5 to 8 from resistant varieties.

Results of Inoculation of Cotton and Other Plants With the United States Race 1, Egyptian, and Indian Cotton-Wilt Fusaria

Some varieties in the following tests wilted with all the cotton fusaria, but others showed no external symptoms of disease. For the separation of the races, there were varieties that showed pronounced differences in their reaction to the wilt fusaria, as well as many that showed intermediate reactions. In this study a close comparison of varieties was not sought. To simplify the results, therefore, if 50 percent or more of the plants of a variety showed external symptoms of wilt, it was considered susceptible; if less than 50 percent showed external symptoms, it was considered resistant.

Gossypium arboreum

Few seed of some varieties of *Gossypium arboreum* and *G. herbaceum* were available, and repetitions of tests with these varieties could not be made. However, familiarity with the testing method on a wide range of hosts, the use of isolates of known pathogenicity, and the consistency of tests that could be repeated substantiated the results of those tests with a small number of plants. Since K–1 produced seed in the greenhouse, repetitions of tests with this variety could be made. Some plants of this variety were killed in practically every test with the numerous isolates of the United States fungus, race 1, yet more than half of the plants showed no symptoms of disease (table 2). Lines resistant to the United States fungus could probably be developed with ease from the K–1 variety. It was also highly resistant to the Egyptian *Fusarium*, as few plants were seriously affected by this fungus. If wilting of 50 percent or more of the plants is considered susceptibility, only 2 of the 12 varieties of *G. arboreum* were susceptible to the United States fungus, while 4 and 6, respectively, were susceptible to the Egyptian and Indian fusaria. The varieties Nanking, New Million Dollar, Okinawa, and Red Leaf were highly resistant to all three of the cotton-wilt fusaria.

TABLE 2.—*Gossypium arboreum: Percentage of plants with external symptoms of wilt, inoculated with 5 fusaria*

Variety	United States of America cotton *Fusarium*, race 1		Egyptian cotton *Fusarium*		Indian cotton *Fusarium*		*Cassia tora Fusarium*		Alfalfa *Fusarium*	
	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Chinese R. Spotless	17	17.6	10	0	11	45.4	------	------	------	------
Dhulia 2	18	55.6	10	70.0	12	91.7	------	------	------	------
Garorani #6	22	18.2	11	0	4	25.0	------	------	------	------
Garo Hill	176	40.3	19	15.8	8	100	37	[1] 24.3	13	0
K-1	838	40.7	235	19.6	392	87.7	20	0	13	0
Nanking	13	0	10	0	10	0	23	0	17	0
New Million Dollar	174	6.9	20	0	19	0	21	0	------	------
Okinawa	150	0	9	0	11	0	42	0	------	------
Recessive	14	71.4	7	70.0	9	88.9	20	0	------	------
Red Leaf	8	0	10	0	10	0	18	0	------	------
Rozi	28	0	15	93.3	13	100	------	------	------	------
Sanguineum	24	16.7	9	100	7	100	12	0	------	------

[1] Stunting, chief symptom.

Gossypium barbadense

Most of the 14 varieties of *Gossypium barbadense* were susceptible to either or both of the United States and the Egyptian fusaria, but most of them were resistant to the Indian *Fusarium* (table 3). Only Bryan, Pima 14–7–11, and Yuma showed more than 50 percent wilting when inoculated with the Indian fungus, and Triple Hallmark × Red Stem F_1 was almost in the same class. Furthermore, these varieties were susceptible to all the cotton-wilt fusaria; on the other hand, Ashmouni was resistant to all of them, especially so to those from Egypt and India. Seabrook sea-island was by far the most resistant of all the commercial varieties grown in the United States that have been inoculated with the United States fungus. Lack of seed prevented further testing of this variety.

Gossypium herbaceum

Few seed of the varieties of *Gossypium herbaceum* were available. Kumpta was resistant to all the cotton-wilt fusaria and Wagad 8 was susceptible to all; Vijay, showing only slight symptoms, was also resistant to all isolates (table 4).

TABLE 3.—*Gossypium barbadense: Percentage of plants with external symptoms of wilt, inoculated with 5 fusaria*

Variety	United States of America cotton *Fusarium*, race 1		Egyptian cotton *Fusarium*		Indian cotton *Fusarium*		*Cassia tora Fusarium*		Alfalfa *Fusarium*	
	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Amsak	184	48.9	94	97.9	83	9.6	16	0	12	0
Amsak F_{13}	131	67.9	50	76.0	102	4.9	—	—	—	—
Ashmouni	163	29.4	9	0	10	0	19	[1] 5.3	14	0
Bryan 12-7-1 #1B	57	100	52	88.5	65	67.7	11	0	11	0
Giza 12	83	42.2	40	67.5	86	5.8	—	—	—	—
Pima 14-7-11	44	81.8	56	89.3	118	53.4	15	0	—	—
Pima 32	219	81.3	170	53.5	119	5.9	21	0	—	—
Pima 51	35	37.1	11	100	10	0	—	—	—	—
Sakel	123	92.7	202	89.1	20	0	30	0	13	0
Sakha 4	175	93.1	58	86.2	58	0	21	[2] 4.8	—	—
Sea-island, Seabrook	117	6.8	—	—	—	—	—	—	—	—
Tanguis	129	73.6	9	0	8	0	17	0	—	—
Triple Hallmark × Red Stem F_1	50	82.0	58	93.1	91	48.3	—	—	—	—
Yuma	131	77.9	50	98.0	179	53.1	10	0	—	—

[1] 1 stunted plant; internal discoloration.
[2] Slightly affected in 1 plant.

TABLE 4.—*Gossypium herbaceum: Percentage of plants with external symptoms of wilt, inoculated with 5 fusaria*

Variety	United States of America cotton *Fusarium*, race 1		Egyptian cotton *Fusarium*		Indian cotton *Fusarium*		*Cassia tora Fusarium*		Alfalfa *Fusarium*	
	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
G. A. 26	83	90.4	10	10.0	9	55.6	11	[2] 63.6	—	—
Kumpta	17	35.3	10	0	11	0	—	—	14	0
Vasudeva (resistant)	6	[1] 50.0	—	—	5	0	6	0	—	—
Vasudeva (susceptible)	5	100	—	—	7	85.9	7	0	—	—
Vijay	19	[1] 52.6	9	0	9	[1] 11.1	—	—	—	—
Wagad 8	10	80.0	4	100	9	77.8	—	—	—	—

[1] Slight symptoms only.
[2] Slow wilt in only a few leaves.

Gossypium hirsutum

In *Gossypium hirsutum*, only a few varieties with appreciable differences in genetic characters, such as Acala, Hopi, and Rowden, were selected from the large number available for testing. Opinions differ concerning the classification of Haitian (*G. hirsutum* var. *marie-galante*), and little is known about the CO–2 and CO–4 varieties that came from India. The most striking feature of the results in table 5 was the high resistance of all varieties, except one line of Haitian, to the Egyptian and Indian fusaria. Only a few seed of three lines of Haitian were received. Ten plants of CB1086 A–1, when inoculated with the Egyptian *Fusarium* gave 70 percent wilt. Plants of the other two numbers proved highly resistant to both the Egyptian and Indian fusaria, although all three were very susceptible to the United States fungus. Inability to obtain more seed made it impossible to follow the intriguing possibility that one line (CB1086 A–1) of *G. hirsutum* var. *marie-galante* was susceptible to the Egyptian *Fusarium* while two other lines (CB1086 and CB1086 A–2) were very resistant.

At different times numerous wilt-resistant varieties of upland cotton have been tested in the greenhouse, and generally the results have been comparable to those for Coker 100 Wilt, White Gold Wilt, and Empire P45–19 in table 5. Under conditions for optimum wilt development, relatively few plants of these varieties were killed and the overall severity of the disease was not so great as with the very susceptible Acala, Hopi, and Rowden. In a field plot that was heavily infested with the wilt *Fusarium*, as judged by the high mortality of the susceptible variety Rowden, about 10 percent of the resistant varieties were killed and relatively few others showed severe external symptoms of wilt.

TABLE 5.—*Gossypium hirsutum: Percentage of plants with external symptoms of wilt, inoculated with 5 fusaria*

Variety	United States of America cotton *Fusarium*, race 1		Egyptian cotton *Fusarium*		Indian cotton *Fusarium*		*Cassia tora Fusarium*		Alfalfa *Fusarium*	
	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Acala	211	95.7	10	0	10	0	22	22.7	13	0
CO-2 [1]	21	95.2								
CO-4 [1]	27	85.2								
Coker 100 Wilt	189	83.1	10	0	10	0				
Empire P45-19	115	59.1	9	0	10	0				
Haitian	[2] 75	78.7	[3] 10	70	[2] 37	0				
			[4] 40	0						
Hopi	178	99.4	9	0	10	0	19	47.4	13	0
King 82	46	97.8	10	0	10	0				
Rowden, Hurley Special	1,864	93.4	10	0			370	26.5	42	0
Stonewilt	82	84.1	10	0	10	0				
White Gold Wilt	37	78.4	10	0	10	0				

[1] CO-2 and CO-4 are varieties from India.
[2] Three breeding lines, CB1086, CB1086A-1, and CB1086A-2.
[3] CB1086A-1 only.
[4] Two lines, CB1086 and CB1086A-2.

Wild Cottons

Seed of nine species of wild cottons were obtained, but only those of *Gossypium anomalum* and *G. thurberi* were viable.

Gossypium anomalum was very susceptible to all three of the wilt fusaria, and *G. thurberi* possessed high resistance approaching immunity (table 6). Three of the 95 plants of *G. thurberi* inoculated with the United States fungus showed slight but definite leaf symptons of wilt, and the discolored vascular tissue could be traced to the affected lower leaves.

Okra

The pathogenicity of the United States *Fusarium* on okra (*Hibiscus esculentus* L.) has been reported (*8*, *13*, *26*). Since the first report by the writers, 22 additional cotton-wilt islolates have been tested; the results are given in table 7. Isolates of both races 1 and 2 were equally pathogenic. Others (*16*, *17*, *20*) have reported that the Egyptian and Indian fusaria were nonpathogenic on okra, which was confirmed by the results reported herein.

Alfalfa

Since the fusaria from United States cotton and from *Cassia tora* caused wilt of alfalfa but were different from the alfalfa-wilt *Fusarium* (*6*), the pathogenicity of the Egyptian and Indian cotton fusaria on alfalfa was investigated. These fusaria from foreign cottons were nonpathogenic on alfalfa (table 7).

TABLE 6.—*Wild cottons: Percentage of plants with external symptoms of wilt, inoculated with 5 fusaria*

Species	United States of America cotton *Fusarium*, race 1		Egyptian cotton *Fusarium*		Indian cotton *Fusarium*		*Cassia tora Fusarium*		Alfalfa *Fusarium*	
	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Gossypium anomalum	12	100	9	100	8	100	5	0	20	0
Gossypium thurberi	95	3.2	15	0	11	0	19	0	10	0

TABLE 7.—*Alfalfa, Cassia, and okra: Percentage of plants with symptoms of wilt, inoculated with 5 fusaria*

Species and variety	United States of America cotton *Fusarium*, race 1		Egyptian cotton *Fusarium*		Indian cotton *Fusarium*		*Cassia tora Fusarium*		Alfalfa *Fusarium*	
	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms	Plants	External symptoms
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Alfalfa, Kansas Common	291	75.3	32	0	27	0	205	81.0	94	71.3
Cassia tora	773	7.2	17	0	20	0	760	95.1	46	0
Okra, Clemson Spineless	255	93.7	10	0	10	0	20	0	10	0

Cassia tora

The inoculations of *Cassia tora* with the United States cotton-wilt isolates gave variable results. No external symptoms of wilt appeared in any plant in numerous experiments, while in others an appreciable number of plants were affected. The results in table 7 represent inoculations with 52 different isolates of the United States cotton *Fusarium;* 30 of these isolates produced no external symptoms of wilt, but external symptoms were produced by 17 isolates on 1 to 20 percent of the plants, by 4 isolates on 21 to 50 percent of the plants, and by 1 isolate on 61 percent of the plants. Vascular discoloration of varying intensities was evident in 35 percent of the plants showing no external symptoms of wilt. The Egyptian and Indian cotton-wilt fusaria produced no symptoms of wilt on *C. tora.*

Other Plants

Plants of the genera, species, or varieties listed below were grown in pots of sand and inoculated with each of one or more isolates of the Egyptian, Indian, and United States cotton, race 1, wilt fusaria. There were 5 plants of sweetpotato, and 10 or more of all other plants per pot. No external symptoms of wilt appeared on any of the plants even after inoculation with a heavy mass of inoculum. Furthermore, with most plants, vascular discoloration was present in such few instances that it was probably of no significance. The plants inoculated were as follows: Aster (*Callistephus chinensis* (L.) Cass.) var. Early Heavenly Blue; bean (*Phaseolus vulgaris* L.) var. Mexican Pink; beet (*Beta vulgaris* L.) var. sugar beet, G.W. 359; cabbage (*Brassica oleracea* var. *capitata* L.) var. Copenhagen Market; carnation (*Dianthus caryophyllus* L.) var. Orion or Apollo; celery (*Apium graveolens* L. var. *dulce* DC.) var. Golden Self-blanching; cowpea (*Vigna sinensis* (Torner) Savi) vars. Lady Finger and California Blackeye 5; cucumber (*Cucumis sativus* L.) var. Palmetto; dill (*Anethum graveolens* L.) ; *Hibiscus cannabinus* L.; mimosa (*Albizzia julibrissin* Durazz.) ; muskmelon (*Cucumis melo* L.) var. Honey Rock; garden pea (*Pisum sativum* L.) var. Thos. Laxton; radish (*Raphanus sativus* L.) var. Long White Icicle; sesame (*Sesamum indicum* L. var. Criollo; spinach (*Spinacia oleracea* L.) var. Bloomsdale Savoy-leaved; stock (*Matthiola incana* (L.) R.Br.) var. 10-Weeks Bright Pink; sumac (*Rhus typhina* L.); sweetpotato (*Ipomoea batatas* (L.) Lam.) var. Porto Rico; sweet william (*Dianthus barbatus* L.) var. Giant Pure White; tomato (*Lycopersicon esculentum* Mill.). var. Bonny Best; wallflower (*Cheiranthus cheiri* L.) annual, single, mixed; watermelon (*Citrullus vulgaris* Schrad.) var. Garrison.

In addition to the plants above, the Egyptian and Indian fusaria were used to inoculate the Yelredo, L.Z., and Mammoth Yellow varieties of soybeans and the Egyptian fungus was used to inoculate Gold Dollar flue-cured and Kentucky 5 burley tobacco (*Nicotiana tabacum* L.) as well as *N. glauca* Graham and *N. rustica* L. There were no external symptoms of wilt in any case.

Results of Inoculation of Cotton With Wilt Fusaria From Other Plants

Alfalfa-Wilt *Fusarium*

Although alfalfa was a common host for the wilt fusaria from alfalfa, United States cotton, and *Cassia tora*, the alfalfa fungus was more restricted in its host range than were the other two, for it was nonpathogenic on *C. tora* and okra (table 7) and on all varieties of cotton (tables 2 to 6).

Cassia-Wilt *Fusarium*

The wilt *Fusarium* first obtained from affected *Cassia tora* plants growing in a cottonfield was the cotton-wilt fungus (*8*). Later, another wilt *Fusarium*, which was obtained from severely diseased plants of *C. tora* in South Carolina, Georgia, and Florida, was a highly virulent pathogen on this host (table 7) and was designated the *Cassia*-wilt *Fusarium* until its relationship to other wilt fusaria has been established. This fungus was usually weakly pathogenic on upland cotton, although some isolates failed to produce any external symptoms of wilt on susceptible varieties. However, two of the numerous isolates of the *Cassia* fungus caused mild to severe symptoms, with a few plants killed, on 70 and 72 percent of Rowden cotton plants. All isolates tended to become less pathogenic on cotton after they had been growing for a time on ordinary media, such as potato-dextrose agar.

Most varieties of *Gossypium arboreum*, *G. barbadense*, and *G. herbaceum* were practically immune to the *Cassia* fungus (tables 2, 3, 4). Only one variety of *G. arboreum*, Garo Hill, showed any external systems and this was chiefly a stunting effect. Symptoms developed slowly in G.A. 26 (*G. herbaceum*) and consisted of yellowing and finally necrosis of leaf areas in only a few leaves per plant. The apparently greater susceptibility of Hopi (*G. hirsutum*) may be due to the use of one of the more virulent isolates (table 5). In three tests, the *Cassia*-wilt *Fusarium* produced considerable vascular discoloration in okra but no external systems of disease (table 7). Like the United States cotton-wilt fungus (*6*), it was a virulent pathogen on alfalfa (table 7).

Wilt Fusaria From Other Plants

When the wilt fusaria from each of the following plants was used to inoculate 10 or more plants of Hurley Special Rowden cotton that was growing in pots, no external systems of wilt were produced: Asparagus; aster; bean; beet; cabbage, race 1; celery; cowpea, races 1, 2, and 3; cucumber; *Dianthus;* mimosa, race 1; muskmelon; pea, races 1 and 2; radish (cabbage race 2); sesame; spinach; stock (cabbage race 3); sumac; sweetpotato, races 1 and 2; tomato, races 1 and 2; and watermelon. Sakel and K–1 varieties of cotton were inoculated with the wilt fusaria from aster; beet; celery; *Dianthus;* tomato, race 2; and stock, all of which were nonpathogenic. In addition, the wilt fusaria from mimosa, race 1, and sesame also produced no external symptoms of wilt on Sakel cotton.

Discussion

When Fahmy (*16*, *17*) differentiated three races of the cotton-wilt *Fusarium*, he stated that the American *Fusarium* was pathogenic on some American upland varieties, weakly so on Egyptian varieties, and nonpathogenic on Indian varieties; that the Indian *Fusarium* was pathogenic on some Indian varieties but not on Egyptian or American upland varieties; and that the Egyptian *Fusarium* was pathogenic on Egyptian and some Indian varieties, but weakly so on some upland varieties. Table 8 gives his general classification, as well as one based on results reported in this bulletin. The difference in these classifications can probably be explained by the use of more virulent isolates and a wider selection of cotton varieties by the authors. Apparently the isolates of the United States *Fusarium* used by Fahmy were weakly pathogenic, since he observed only a low percentage of wilt on susceptible varieties of upland and Sakel cotton.

TABLE 8.—*Differentiation of the cotton-wilt fusaria into pathogenic races*

Classification	*Fusarium* isolated from cotton from—	Wilt reaction of [1]—		
		American upland cottons	Egyptian cottons	Indian cottons
Fahmy	United States	*S*	*W*	*R*.
	Egypt	*W*	*S*	*S*.
	India	*R*	*R*	*S*.
Armstrong & Armstrong	United States	*S*	*S*	*S*.
	Egypt	*R*	*S*	*S*.
	India	*R*	*S*	*S*.

[1] *S*=susceptible; *W*=weak; and *R*=resistant.

In pot tests in India, Mundkur (*21*) observed no wilting when a recently introduced susceptible variety of cotton from the United States and an Indo-American variety were inoculated with a United States cotton-wilt isolate from Arkansas. The use of a nonvirulent isolate probably accounted for these negative results. In tests conducted in the United States where an Indian variety of cotton growing in an acidic sandy soil from a United States cottonfield was inoculated with the Indian fungus, a rather low percentage of wilt was obtained. Mundkur (*21*) interpreted this as an attenuation of the Indian *Fusarium* due to this type of soil, which differed from the heavy alkaline soil in India where wilt was a problem. Most isolates of the United States fungus used in the investigations reported herein have come from acidic sandy soils, but several isolates that were highly virulent were from a soil of pH 7.7 in Oklahoma. Furthermore, even though all American, Indian, and Egyptian varieties of cotton were grown in sand watered with a nutrient solution of pH 5.6, high percentages of wilt were obtained with susceptible varieties if virulent cultures were used in the inoculations. Resistant varieties also were not less resistant by growth in this medium. A gradual or abrupt loss of pathogenicity of *Fusarium*-wilt cultures when maintained on ordinary laboratory media is so common, but apparently not appreciated and checked by many workers, that some results in the literature need interpretation on this basis.

The results of the present investigation indicated that the number of *Fusarium*-wilt races that could be identified depended upon which cotton varieties were selected. If the following varieties were used, Dhulia 2 and Recessive from *Gossypium arboreum;* Bryan, Pima 14–7–11, and Yuma from *G. barbadense;* and Wagad 8 from *G. herbaceum*—all of which were susceptible to all the cotton-wilt fusaria—there would be no separation of races. If, however, seven varieties were selected from four species, as listed in table 9, the United States fungus would differ from the others, because it alone was pathogenic on the Rowden variety of *G. hirsutum*. The conclusion then would be that there were two physiologic races. If other varieties of the four species of *Gossypium* were selected (table 10), three physiologic races would be evident. Only the two varieties, Rozi and Sakel, would have to be inoculated, since the United States fungus caused wilt of only Sakel, the Indian fungus of only Rozi, and the Egyptian fungus of both varieties. There were other combinations of only two varieties that would separate the races, as for example, Rozi with Amsak F_{13}, Sakha 4, or Pima 32. Also, Sanguineum could be substituted for Rozi in all cases (tables 2, 3, 4, and 5).

TABLE 9.—*Differentiation of the cotton-wilt fusaria into 2 pathogenic races, due to the selection of varieties*

Fusarium isolated from cotton from—	Isolates used	Wilt reaction of [1]—						
		G. hirsutum, Var. Rowden	*G. arboreum*		*G. herbaceum*		*G. barbadense*	
			Var. Nanking	Var. Recessive	Var. Kumpta	Var. Vijay	Var. Yuma	Var. Ashmouni
	Number							
United States of America	18	*S*	*R*	*S*	*W*	*R* [2]	*S*	*W*
India	2	*R*	*R*	*S*	*R*	*R* [2]	*S*	*R*
Egypt	1	*R*	*R*	*S*	*R*	*R*	*S*	*R*

[1] *S*=susceptible, or wilted plants over 50 percent; *R*=resistant, or no wilted plants; *W*=weak, or wilted plants less than 50 percent.
[2] Slight symptoms in a few leaves.

TABLE 10.—*Differentiation of the cotton-wilt fusaria into 3 pathogenic races; the separation can be made by using only the varieties Rozi and Sakel*

Fusarium isolated from cotton from—	Wilt reaction of [1]—						
	G. hirsutum, var. Acala	*G. arboreum*		*G. herbaceum*		*G. barbadense*	
		Var. Rozi	Var. Dhulia 2	Var. G.A. 26	Var. Kumpta	Var. Tanguis	Var. Sakel
United States of America	*S*	*R*	*S*	*S*	*W*	*S*	*S*
India	*R*	*S*	*S*	*S*	*R*	*R*	*R*
Egypt	*R*	*S*	*S*	*R*	*R*	*R*	*S*

[1] *S*=susceptible, or wilted plants over 50 percent; *R*=resistant or no wilted plants; *W*=weak, or wilted plants less than 50 percent.

These results showed that the cotton-wilt fusaria from the United States, Egypt, and India were distinct physiologic races and that they were separated on the reactions of varieties in the species rather than the entire species, as suggested by Fahmy. The only general statement that could be made regarding an entire species of *Gossypium* as the differential host was that the commercial varieties of *G. hirsutum* in the experiments were not susceptible to either the Egyptian or the Indian *Fusarium*. Since not all the varieties in any one of the other species reacted alike to each race, no generalization could be made about these entire species as differential hosts.

The United States cotton-wilt *Fusarium* also differed from the others by its pathogenicity on hosts other than cotton. Alfalfa, *Cassia tora*, *Physalis alkekengi*, Yelredo soybean, okra, and Kentucky 5 burley and Gold Dollar flue-cured tobaccos were not susceptible to the Egyptian and Indian cotton-wilt fusaria. The recent discovery that races 1 and 2 of the United States *Fusarium* were virulent pathogens on *P. alkekengi*, but the Egyptian and Indian fusaria were not, showed other differences in pathogenicity. Furthermore, the Egyptian and Indian cotton-wilt fusaria did not seem to be related to a group of wilt fusaria in the United States as was the American fungus. One part of this complex group was composed of the following physiologic races that were related by having Kentucky burley tobacco as a common host: (1) Cotton *Fusarium*, race 1, nonpathogenic on sweetpotato and flue-cured tobacco (*7*, *24*); (2) cotton *Fusarium*, race 2, pathogenic on flue-cured tobacco but not on sweetpotato (*10*); (3) sweetpotato *Fusarium*, race 1, nonpathogenic on flue-cured tobacco and cotton (*7*, *24*); (4) sweetpotato *Fusarium*, race 2, pathogenic on flue-cured tobacco but not on cotton (*7*, *24*).

As noted above, flue-cured tobacco was a differential host for the two races of the United States cotton *Fusarium* and also for the two races of the sweetpotato *Fusarium*; it was a common host for race 2 of each, thus establishing another relationship of the cotton and sweetpotato fusaria. *P. alkekengi* (*11*), on the other hand, was not a differential host for the two races of the cotton *Fusarium*, since it was highly susceptible to both. However, like flue-cured tobacco, it distinguished the races of the sweetpotato *Fusarium*, for race 2 was highly pathogenic but race 1 was only mildly so.

In another part of this group, the relationship of the United States cotton *Fusarium*, race 2, and the cowpea *Fusarium*, race 1, was shown by Yelredo soybean as the common host. However, none of the races of the cowpea fungus caused wilt of cotton (*4*, *23*), nor did those of the United States cotton fungus cause wilt of cowpeas.

In pathogenicity, the *Cassia*-wilt *Fusarium* and the United States cotton-wilt *Fusarium* showed an unusual reciprocal relationship that has not been encountered with other wilt fusaria. Generally, the *Cassia* fungus was weakly virulent on upland cotton, the United States cotton fungus was weakly virulent on *Cassia tora*, and each was highly virulent on its principal host. The pathogenicity of the United States cotton isolates was quite variable on *C. tora*, with no differences in the races being evident. Some isolates caused mild external symptoms of wilt on less than 50 percent of the plants, but occasionally one caused external symptoms on more plants with a few severely affected, and still other isolates were nonpathogenic. Isolates of the *Cassia*-wilt *Fusarium* showed the same wide range of pathogenicity on upland cotton. The *Cassia* fungus, however, produced no symptoms of wilt on most of the Egyptian and Indian cottons nor did the wilt fusaria from these cottons produce symptoms on *C. tora*. The United States cotton *Fusarium* and the *Fusarium* on *C. tora*, however, were equally pathogenic on alfalfa. *Physalis alkekengi* was another host on which it was impossible to distinguish the United States cotton- and the *Cassia*-wilt fusaria, thus giving additional evidence of their close relationship. *P. alkekengi* was of further significance as it was the first common host to be reported for the *Cassia*-wilt *Fusarium* and race 2 of the sweetpotato *Fusarium*.

The complicated interrelationships of these wilt fusaria showed the inadequacies of a rigid "formae" system of classification based on the concept of narrowly limited host specialization in the parasitism of fusaria of the section Elegans. The names of the cotton-wilt *Fusarium* are given in the two current systems (*25*, *29*).

The four races of the cotton-wilt *Fusarium* were differentiated by the susceptibility or resistance of plants in the families Malvaceae, Solanaceae, and Leguminosae. A separation into three races was made by the inoculation of only two varieties of cotton, a variety in *G. arboreum* or *G. herbaceum*, the other in *G. barbadense*, but for the differentiation of the two races of the United States cotton-wilt *Fusarium* either flue-cured tobacco or Yelredo soybean was needed.

The separation of the races of the *Fusarium* causing wilt of cotton on the basis of their selective pathogenicity is given in table 11.

TABLE 11.—*Fusarium races causing wilt of cotton separated on the basis of their selective pathogenicity*

Fusarium races and source	Pathogenicity	
	Caused wilt of—	Did not cause wilt of—
Race 1 from the United States.	Some varieties of cotton in the 4 cultivated species (*G. arboreum*, *G. barbadense*, *G. herbaceum*, and *G. hirsutum*) and the wild cotton *G. anomalum*. Also, alfalfa (*Medicago sativa*), okra (*Hibiscus esculentus*), burley tobacco (*Nicotiana tabacum*), *Physalis aklekengi*, weak on *Cassia tora*.	Flue-cured tobacco (*N. tabacum*) or Yelredo soybean (*Glycine max*).
Race 2 from the United States.	Same species and varieties as race 1; also flue-cured tobacco and Yelredo soybean.	
Race 3 from Egypt	Some varieties in only 3 of the cultivated species (*G. arboreum*, *G. barbadense*, *G. herbaceum*) and the wild cotton *G. anomalum*.	Varieties of *G. hirsutum* or of alfalfa, okra, burley or flue-cured tobaccos, *Physalis alkekengi*, *Cassia tora*.
Race 4 from India	Same species as race 3, except for differential varieties in the 3 species of cultivated cotton.	Do.

Summary

The cotton-wilt fusaria from the United States, Egypt, and India were used to inoculate cultivated varieties, types, and breeding lines of *Gossypium arboreum*, *G. barbadense*, *G. herbaceum*, and *G. hirsutum;* the wild cottons, *G. anomalum*, and *G. thurberi;* and numerous other species of plants. With varieties of cotton as differential hosts, three races of the cotton-wilt fusaria were identified, the United States, the Egyptian, and the Indian. Since there were varieties in *G. arboreum*, *G. barbadense*, and *G. herbaceum* that were susceptible to all the cotton-wilt fusaria, the determination of physiologic races on the basis of varieties of an entire species was invalid. With these susceptible varieties, no separation of races could be made. The number of races that could be identified depended upon which varieties were selected. A selection of seven other varieties, as in table 9, showed two races, but the selection of only two varieties, Rozi (*G. arboreum*) and Sakel (*G. barbadense*) showed that there were three races, since the United States fungus caused wilt of only Sakel, the Indian fungus of only Rozi, and the Egyptian fungus of both varieties. Other combinations of two varieties would also separate the three races. The only generalization that could be made concerning an entire species of *Gossypium* as a differential host was that the commercial varieties of G. *hirsutum* that were tested were not susceptible to either the Egyptian or the Indian *Fusarium*.

Attempts to find physiologic races of the United States cotton-wilt *Fusarium* on the basis of differential pathogenicity for varieties of cotton were unsuccessful. However, two races of the United States cotton *Fusarium* were identified by differences in pathogenicity on Yelredo soybean and flue-cured tobacco. The most commonly occurring race, designated as race 1, did not cause wilt of soybean and tobacco as did race 2, which probably is restricted in its distribution.

Unlike races 1 and 2 of the United States *Fusarium*, the Egyptian and Indian fusaria did not cause wilt of alfalfa, burley tobacco, okra, and *Physalis alkekengi*, as well as a slight wilt of *Cassia tora*, nor did they cause wilt of Yelredo soybean and flue-cured tobacco, like race 2 of the United States fungus.

The interrelationships of the United States cotton-wilt fusaria with those from alfalfa, *C. tora*, sweetpotato, and cowpea are discussed. Common hosts for some of the various races were found in plants of such diverse relationships as Yelredo soybean, flue-cured tobacco, burley tobacco, alfalfa, okra, *C. tora*, and *P. alkekengi*.

The *Fusarium* causing wilt of the world cottons comprises four races: Races 1 and 2 from the United States, race 3 from Egypt, and race 4 from India.

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Appendix

TABLE 12.—*Varieties, types, and breeding lines of cotton used in the comparisons of the United States, Egyptian, and Indian cotton-wilt fusaria*

(Identifcation of variety and breeding line furnished by donors)

Species and variety	Breeding line or identification	Donor
Gossypium arboreum		
Chinese R. Spotless	*G. arboreum* race *sinense*	C. V. Subramanian.
Dhulia 2	*G. arboreum* race *bengalense*	Do.
Dominant Red Leaf	Dominant anthocyan factors	Thomas Kerr.
Gaorani #6	*G. arboreum* race *indicum*	S. G. Stevens.
Garo Hill	*G. arboreum* f. *cernuum*	Thomas Kerr.
Do		S. G. Stevens.
K–1	*G. arboreum* race *indicum*	C. V. Subramanian.
Nanking	*G. arboreum* f. *indicum* var. Nanking	Thomas Kerr.
New Million Dollar	*G. aboreum* race *sinense*	C. V. Subramanian.
Do	*G. aboreum* race *sinense*	H. D. Loden.
Okinawa		Thomas Kerr.
Do		S. G. Stevens.
Recessive	No anthocyan of any sort	Thomas Kerr.
Rozi	*G. arboreum* race *indicum*	C. V. Subramanian.
Gossypium barbadense		
Amsak F_{13}		R. H. Peebles.
Amsak F_{13}	S.P. 1948	Do.
Amsak	Sac. 1944	Do.
Amsak	S.P. 1050, inbreeding not continuous	Do.
Ashmouni		Do.
Bryan 12–7–1 #1B	S.P. 1948	Do.
Giza 12 × Am × Ash F_4 10–84		Do.
Giza 12 × Am × Ash F_6 10–84	S.P. 1950	Do.
Pima 14–7–11 P. 24	S.P. 1948	Do.
Pima 32 EP × Giza 7–51–32	1948 crop	Do.
Pima 32	1950 crop	Do.
Pima 51		Do.
Sakel		Do.
Sakel	29th inbred generation	Do.
Sakha 4 from Egypt	1940 selfed	Do.
Sea Island–Seabrook		W. H. Jenkins.
Tanguis (Peru) CB 1329		Do.
Tanguis (Peru) CB 1698		Do.
Tanguis (Peru) CB 1699		Do.
Triple Hallmark × Red Stem 2127		R. H. Peebles.
Triple Hallmark × Red Stem F_1	S.P. 1945	Do.
Yuma P 20	S.P. 1948	Do.
Yuma P 22	S.P. 1950	Do.
Gossypium herbaceum		
G. A. 26	*G. herbaceum* race *wightianum*	C. V. Subramanian.
Kumpta	*G. herbaceum* race *wightianum*	Do.
Resistant		R. S. Vasudeva.
Susceptible		Do.
Vijay	*G. herbaceum* race *wightianum*	C. V. Subramanian.
Wagad	*G. herbaceum* race *wightianum*	Do.
Gossypium hirsutum		
Acala (Oklahoma)		L. A. Brinkerhoff.
CO–2	*G. hirsutum* race *latifolium* (type Cambodia).	C. V. Subramanian.
CO–4	*G. hirsutum* race *indicum*	Do.
Coker 100 Wilt		Coker's Pedigreed Seed Co.
Empire P45-19		W. W. Ballard.
Haitian C. B. 1086, 1086A–1, 1086A–2.		W. H. Jenkins.
Hopi (Sac.)		R. H. Peebles.
Hurley Special Rowden No. 10		H. C. Hurley & Son and Bill Cunningham's Feed and Seed.
King 82 (2423)		R. H. Peebles.
Stonewilt, Strain 7		W. W. Wannamaker Seed Co.
White Gold Wilt		Marett Seed Co.

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