EFFECT OF CERTAIN ENVIRONMENTAL CONDITIONS ON THE PREVALENCE OF OPHIOBOLUS GRAMINIS IN THE SOIL[1]

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INTRODUCTION

Investigations of fungi and bacteria in soil have shown that the type and number are affected greatly by environment. The effect of environmental factors on the prevalence of soil-borne parasites has received but little attention, in contrast to the extensive studies of the environmental factors affecting the behavior of parasitic organisms in pure culture or in tests of pathogenicity. In the case of soil-borne parasites, information on the behavior in infested soils under various conditions is more important than that on the causal organisms in pure culture.

The experiments reported here were made to determine whether certain environmental conditions, particularly temperature, moisture, and compactness of the soil, favored the retention of *Ophiobolus graminis* Sacc., the parasite that causes take-all of wheat, in naturally infested uncropped soils. For comparison, a few experiments on the tolerance of this organism to extreme temperatures were conducted in pure culture.

EXPERIMENTAL METHODS

In the studies of *Ophiobolus graminis* in pure culture, low temperatures were obtained by both outdoor exposure and artificial refrigeration. Cultures of *O. graminis* were grown on potato-dextrose agar in test tubes. Certain of these cultures were kept in an ordinary thermograph shelter, and others were buried at progressive depths in the soil, where they were exposed to decreasing extremes of temperature. The temperatures were measured with maximum and minimum thermometers and a thermograph. At various intervals during the winter transfers were made to find out whether the fungus was viable.

The thermal death point of *Ophiobolus graminis* growing on potato-dextrose agar was determined by the standard method employed by bacteriologists, with modifications for fungi.

In the tests of infested soils the samples were exposed to various temperatures by outdoor exposure in flats, in the greenhouse in flats and metal pans, and in a freezing chamber in flats; or they were stored in a deep cave in cans. Soil samples described as "moist" were maintained at approximately 60 percent of the maximum water-

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holding capacity, while the dry samples were completely air-dried. Looseness of the soil was maintained by occasional stirring, and compactness by thorough tamping while in a moist condition.

The severity of take-all lesions on Kanred wheat grown in the greenhouse was used as an indication of the presence and extent of infestation in a given sample of soil. The method has been described previously.[2]

EXPERIMENTAL RESULTS

EFFECT OF EXTREME TEMPERATURES ON OPHIOBOLUS GRAMINIS IN PURE CULTURE

Davis [3] showed that *Ophiobolus graminis* grows best at about 23° to 24° C. At 4° growth was exceedingly slight, while at 36° it was checked entirely. The fact that the fungus grows only slightly at 4° C. (39.2° F.) suggested the experiments to determine whether the winter cold in Kansas might not only check its growth but possibly kill it. These experiments were conducted during the winter of 1925–26 and 1926–27.

All the cultures were viable at the end of both winters. The weekly maximum and minimum temperatures in the instrument house, given in table 1, show that the organisms survived temperatures as low as −2° F. Cultures of the fungus also were subjected to repeated alternations of temperature ranging from 70° to as low as −20°. None of the exposures, shown in table 2, affected the viability of the fungus.

Determinations of the thermal death point of *Ophiobolus graminis* showed that both the microhyphae and the macrohyphae were killed when exposed for 10 minutes at 122° F. (50° C.). The fungus remained viable after exposure for 10, 20, and 30 minutes to a temperature of 113° F. (45° C.). Cultures exposed 30 minutes recovered more slowly than those exposed for shorter periods.

TABLE 1.—*Weekly minimum and maximum outdoor temperatures during winter months of 1926 and 1927 when cultures of Ophiobolus graminis were stored outdoors at Manhattan, Kans.*

Year	Month	Experiment No.	Temperature							
			First week		Second week		Third week		Fourth week	
			Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
			° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
1926	January	1					54	3	52	0
1926	February	1	56	24	63	20	59	1	68	28
1926	March	1	58	14	70	14	78	20		
1926	December	2			55	−1	48	12	57	16
1927	January	2	64	16	48	−2	36	9	64	14
1927	February	2	62	30	52	5	72	7	70	23
1927	March	2	66	9	68	25	77	23	66	25
1927	April	2	77	30						

[2] FELLOWS, HURLEY, and FICKE, C. H. SOIL INFESTATION BY OPHIOBOLUS GRAMINIS AND ITS SPREAD. Jour. Agr. Res. 58: 505–519, illus. 1939.

[3] DAVIS, RAY J. STUDIES ON OPHIOBOLUS GRAMINIS SACC. AND THE TAKE-ALL DISEASE OF WHEAT. Jour. Agr. Res. 31: 801–825, illus. 1925.

TABLE 2.—*Time and temperature of exposure in a freezing chamber of pure cultures of Ophiobolus graminis*

Period of freezing		Temperature			Period of freezing		Temperature		
Date	Duration	Minimum	Maximum	Mean	Date	Duration	Minimum	Maximum	Mean
1926	*Hours*	*° F.*	*° F.*	*° F.*	*1927*	*Hours*	*° F.*	*° F.*	*° F.*
Dec. 3–4	5.0	[1] −13	10.4	−8.7	Jan. 6–7	16.5	[1]−13.0	30.0	9.5
Dec. 7–8	29.0	[1]−20.2	15.8	−1.1	Jan. 8–15	81.0	[2]−11.2	30.2	9.0
Dec. 9–10	20.5	[1]−16.6	21.2	−1.3	Jan. 18–22	38.0	[2]−7.6	30.2	7.8
Dec. 11–12	2.0	[1]−16.6	−4.0	−11.3	Jan. 31	9.0	[1]−5.8	22.1	4.1
Dec. 13–14	5.5	[1]−13.9	1.4	−5.9	Feb. 10–11	16.5	[2]−5.8	26.6	−.4
Dec. 16–17	25.0	[1]−12.1	21.2	−6.1	Feb. 14–15	11.5	[2]−7.6	−.4	−2.9
Dec. 20–21	9.5	[1]−9 4	10.4	−1.8	Feb. 17	8.5	[2]−2.2	23.0	6.3
					Feb. 19	7.0	[1]−.4	24.8	6.3

[1] Cultures were held at a temperature of approximately 70° F. during the intervals between freezing.
[2] Cultures kept below freezing while the freezing chamber was not operating.

EFFECT OF EXTREME TEMPERATURES AND DROUGHT ON OPHIOBOLUS GRAMINIS IN SOIL

Numerous experiments were conducted in several years to determine whether summer heat and drought would reduce the quantity of *Ophiobolus graminis* in infested soil in the field. These experiments were made by comparing the relative abundance of the fungus in the upper soil layers with that in the deeper layers, which had been subjected to less heat and drought.

The severity tests with Kanred wheat showed that the fungus was reduced somewhat during the summer in the upper 2-inch stratum, but the difference in the abundance of the organism between this stratum and lower depths down to 10 inches was too small to be of practical importance. All the soil strata studied retained sufficient infestation to produce severely diseased wheat plants.

Infested soils were exposed to more severe conditions in the greenhouse. In 1929, 1931, and 1932, soil from infested spots in the field was taken to the greenhouse in the spring, spread in 1-inch layers in shallow pans, and exposed unshaded and without watering until the latter part of October. In 1932 the tests were duplicated with soil samples placed in an elevated position outdoors, where they were protected from the rain but exposed to the sun during the summer. Control samples were stored in a cool cave. The soils were tested for infestation during the winter following the exposure. The results are given in table 3, and temperatures of the soil samples exposed outdoors in 1932 are shown in figure 1. The temperatures of the soil samples stored in the greenhouse are not given, but they were much lower than those of the samples exposed outdoors.

All the soil samples exposed to heat and drought retained enough infestation to produce severely diseased plants, but in three of the four tests the infestation was reduced to some extent. The experiment performed in 1931 showed that soil kept in the greenhouse had more infestation than the control. However, in this experiment the severity rating was high, and when plants are very severely diseased it is difficult to make fine distinctions. Consequently, the apparent difference may not be very significant

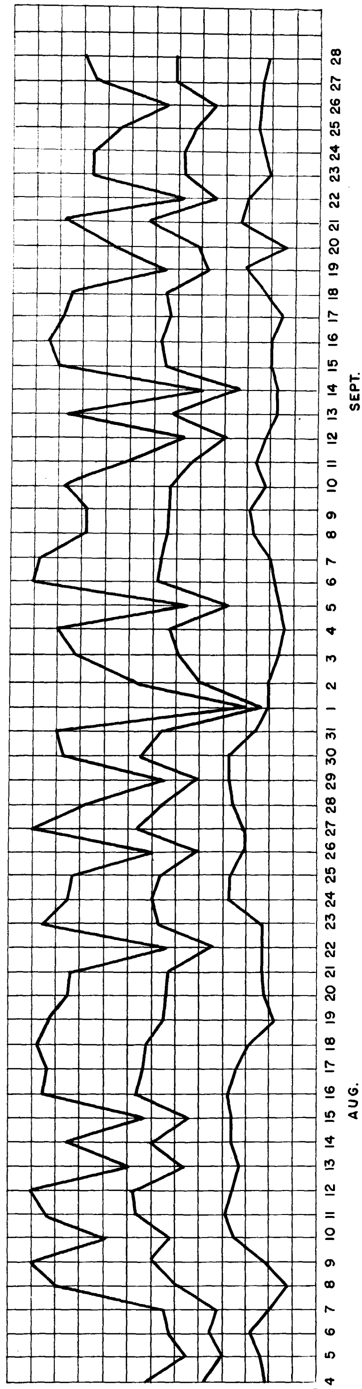

FIGURE 1.—Maximum, minimum, and average daily temperatures of a layer of infested soil 1 inch thick exposed outdoors during August and September 1932.

TABLE 3.—*Severity of take-all on wheat plants grown in the greenhouse in infested soil that had been dried in the greenhouse or outdoors, Manhattan, Kans., 1929-32*

Soil treatment and year	Tests	Plants	Average height of plants	Plants tillering	Culms		Plants dead	Plants having diseased—			Roots retained	Average severity of lesions on—			Severity rating
					Number	Heading		Crowns	Culms	Roots		Crowns	Culms	Roots	
Dried in greenhouse:	*No.*	*No.*	*In.*	*Pct.*		*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	
1929	6	105	25.5	48.2	195	9.5	36.1	45.4	25.9	42.1	78.0	67.5	60.0	66.7	20.8
1931	8	70	17.5	27.1	92	8.6	40.0	100.0	96.1	99.7	20.1	90.7	76.8	92.1	148.5
1932	8	59	23.8	13.8	65	35.6	14.8	100.0	32.1	99.6	54.0	69.8	52.4	67.0	48.8
Average[1] and total	22	234	22.2	29.7	352	17.5	30.3	81.8	51.3	80.4	50.7	76.6	63.0	75.5	72.7
Dried outdoors:															
1932	6	55	22.8	50.9	101	44.5	34.5	64.5	48.8	64.1	57.4	77.8	61.8	85.3	38.3
Controls: [2]															
Infested soil:															
1929	6	111	20.2	7.2	124	23.3	28.8	84.9	55.5	79.6	48.3	87.0	74.4	81.4	66.6
1931	9	70	16.2	31.4	118	16.1	44.2	100.0	82.4	98.9	23.5	90.0	67.1	83.2	115.1
1932	4	33	19.5	21.2	40	12.5	6.0	100.0	52.4	99.6	45.0	84.0	36.5	78.0	63.2
Average [1] and total	19	214	18.5	19.9	232	17.5	26.5	94.9	63.4	92.7	38.9	87.0	59.3	80.8	80.4
Sterilized soil:															
1929	6	90	28.4	30.0	140	59.2	0	0	0	0	100.0	0	0	0	0
1931	10	86	30.6	82.5	249	53.8	0	0	0	0	100.0	0	0	0	0
1932	6	54	30.8	98.1	218	72.0	0	0	0	0	100.0	0	0	0	0
Average [1] and total	22	230	29.9	70.2	607	61.6	0	0	0	0	100.0	0	0	0	0

[1] Simple averages.
[2] Soil collected from the same spot but not exposed to heat and drought

Infested soil exposed alternately to growing and freezing temperatures under conditions identical with those of the organism in pure culture showed no reduction of the disease on wheat plants subsequently grown in the soil. Thus, alternate freezing and thawing did not injure the organism in either soil or pure culture. The temperature records are shown in table 2.

In an experiment in which *Ophiobolus graminis* was grown in pure culture it had a thermal death point of 122° F. (50° C.) when exposed for 10 minutes. In another experiment in soil it was not killed at temperatures that ranged from 140° to 160° F. for more than an hour on each of several days. The fact that the macrohyphae on infected plants are much coarser and their walls thicker than in pure culture may explain this difference.

EFFECT OF TEMPERATURE, MOISTURE CONTENT, AND COMPACTNESS OF SOIL ON VIABILITY OF OPHIOBOLUS GRAMINIS

The effect of exposure conditions on *Ophiobolus graminis* either in the absence or in the presence of the host should be reflected later on wheat plants grown in the soil.

The three environmental factors most likely to affect soil flora in the field are moisture, temperature, and compactness or tilth. Accordingly soil from infested spots in the field was exposed for various lengths of time to eight combinations of these three factors. These

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combinations were: (1) moist, cool, compact; (2) dry, cool, compact; (3) moist, cool, loose; (4) dry, cool, loose; (5) moist, warm, compact; (6) dry, warm, compact; (7) moist, warm, loose; and (8) dry, warm, loose.

The two temperature conditions were obtained by storing one set of soil samples in a deep cave and the other in the greenhouse. The temperature in the cave averaged 37.5° F. and was always above freezing during subzero weather, and in the summer it averaged 71.5°, never going above 72°. The greenhouse temperature was fairly uniform during the winter, with an average of 70.2°, and was variable during the summer but averaged 83.6°. The average maximum daily temperature in June was 97.1°, in July 110.7°, and in August 102.5°. The dry compact samples were so thoroughly puddled and hard at the end of the storage period that a hammer was required to pulverize

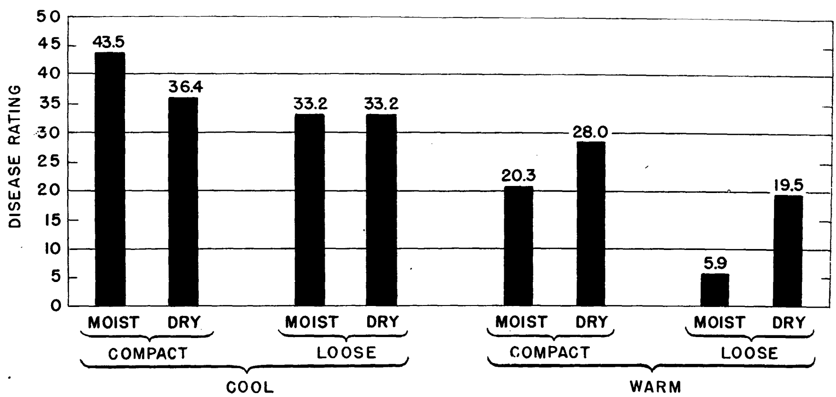

FIGURE 2.—Average severity ratings of take-all on wheat plants grown in the greenhouse in infested soil stored previously under different conditions of moisture, temperature, and compactness, at Manhattan, Kans., 1930–36. (Data in table 4.)

them. The dry samples were air-dried. Water was applied to the moist samples from time to time. At the end of the storage period all of the soil samples were brought to favorable tilth and moisture, and wheat was grown in them in the greenhouse.

This experiment was conducted four times during the period from 1930 to 1936. For a given experiment all the soil was taken from the same infested spot in the field and was well mixed. Tests for infestation in the first experiment were on plants grown in soil stored for 230 days; in the second experiment, 338 days; in the third, 777 days; and in the fourth, 608 days.

The data on the severity of take-all on the wheat plants grown in the greenhouse in the various soil samples are given in table 4, and the average severity ratings are shown graphically in figure 2. The data in table 4 are summarized in table 5 to show the effects of the environmental factors considered separately and in combinations of two. The relative importance of the factors is indicated by averages and totals from the combinations into which they entered. The severity ratings shown in table 5 are presented graphically in figure 3.

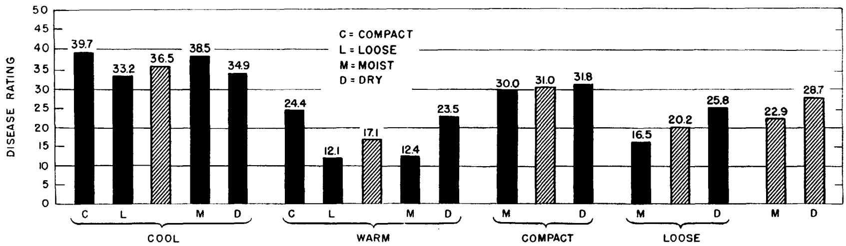

FIGURE 3.—Disease-severity ratings showing the relative effect of single and double environmental factors on the retention of *Ophiobolus graminis* in stored infested soil. The hatched columns represent weighted averages for each single factor. (Data in table 5.)

Under the conditions of the experiments the storage temperature had more effect on the viability of *Ophiobolus graminis* in infested soil than had any other factor. Cool temperature favored the fungus regardless of the other factors. Warm soil combined with other factors in any manner retained less infestation than any similar combination with a cool soil.

TABLE 4.—*Severity of take-all on wheat plants grown in the greenhouse in infested soil previously stored under different conditions of moisture, temperature, and compactness, Manhattan, Kans., 1930–36*

[The length of storage in the various experiments was as follows: No. 1, 230 days; No. 2, 338 days; No. 3, 777 days; and No. 4, 608 days]

Condition of soil in storage	Experiment No.	Tests	Plants	Average height of plants	Plants tillering	Culms			Plants dead	Plants having diseased—			Roots retained	Average severity of lesions on—			Severity rating
						Number	Heading	Average number per tillering plant		Crowns	Culms	Roots		Crowns	Culms	Roots	
		Number	*Number*	*Inches*	*Percent*		*Percent*		*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
Cool, compact:																	
Moist	1	4	36	37.2	68.9	99	43.4	----	0	25.5	15.8	25.4	90.7	58.3	11.6	43.5	10.9
	2	5	46	11.4	43.4	69	0	2.15	36.9	100.0	87.1	99.7	15.2	80.9	44.2	98.3	143.8
	3	5	58	24.0	29.3	81	27.1	2.35	0	100.0	24.5	89.0	49.0	60.4	9.6	70.0	37.9
	4	6	47	16.3	29.7	69	5.7	2.56	12.7	100.0	77.3	98.8	50.8	79.8	45.0	75.0	58.8
Average and total	----	20	187	22.2	42.8	318	19.0	----	12.4	81.3	51.1	78.2	51.4	69.8	27.6	71.7	[1] 43.5
Dry	1	3	27	34.3	44.4	59	16.9	----	14.8	100.0	88.8	95.3	35.3	79.6	67.3	84.2	71.2
	2	6	58	17.0	58.6	108	5.0	2.47	37.9	100.0	98.1	99.9	19.7	92.3	70.0	95.3	109.4
	3	5	61	24.4	32.7	88	31.8	2.35	1.6	58.5	4.4	52.4	86.0	50.1	68.3	31.2	15.0
	4	6	52	27.3	21.1	68	66.1	2.45	3.8	16.6	7.4	15.8	91.6	47.7	43.7	75.0	8.1
Average and total	----	20	198	25.7	39.2	323	29.9	----	14.5	68.7	49.6	65.8	58.1	67.4	62.3	71.4	[1] 36.4
Cool, loose:																	
Moist	1	3	28	35.5	50.0	52	17.3	----	0	16.6	0	6.1	99.1	16.5	0	37.7	4.4
	2	5	56	16.4	28.5	78	2.5	2.37	19.6	100.0	76.0	97.5	18.5	78.5	53.6	89.7	136.5
	3	4	40	23.0	47.5	62	30.6	2.15	0	100.0	0	84.7	74.0	60.1	0	56.7	21.8
	4	6	51	14.3	19.6	61	0	2.00	15.6	100 0	58.8	98.1	62.5	75.4	39.8	58.3	52.1
Average and total	----	18	175	22.3	36.4	253	12.6	----	8.8	79.1	33.7	72.1	63.5	57.6	23.3	60.6	[1] 33.2
Dry	1	2	21	39.0	66.6	67	26.8	----	0	20.5	0	2.0	100.0	9.0	0	32.3	3.3
	2	5	46	20.6	52.1	84	9.5	2.58	10.2	100.0	87.1	99.4	41.2	74.3	41.2	78.8	61.7
	3	4	46	19.2	17.3	55	21.0	2.12	2.1	100.0	16.3	94.5	52.9	76.1	11.4	60.1	42.3
	4	6	50	17.1	8.0	54	25.9	2.00	18.0	93.9	65.3	90.3	56.6	72.0	49.5	75.0	51.8
Average and total	----	17	163	23.9	36.0	260	20.8	----	7.5	78.6	42.1	71.5	62.6	57.8	25.5	61.5	[1] 33.2

Warm, compact:																	
Moist	1	4	37	40.0	72.9	159	26.4	--------	0	0	0	.2	100.0	0	0	35.0	1.1
	2	5	52	10.4	34.6	76	0	2.22	38.4	100.0	85.9	99.9	25.9	83.6	62.8	89.4	124.0
	3	5	52	37.2	44.2	88	64.7	2.60	0	25.0	7.5	20.1	90.1	40.0	18.3	56.1	8.6
	4	6	55	21.0	34.5	82	26.8	2.42	1.8	50.0	16.6	49.1	76.6	75.0	23.8	68.7	18.9
Average and total	--------	20	196	27.1	46.5	405	29.8	--------	10.0	43.7	27.5	42.3	73.1	49.6	26.2	62.3	[1] 20.3
Dry	1	2	15	27.5	60.0	31	22.5	--------	20.0	81.2	50.0	52.2	53.8	62.0	86.4	71.5	37.0
	2	6	60	15.1	65.0	136	13.2	2.94	33.3	100.0	91.8	100.0	21.3	74.5	64.8	93.3	85.6
	3	5	60	29.0	36.6	91	57.1	2.40	0	42.0	0	16.1	94.6	36.3	0	30.3	7.8
	4	6	42	26.1	42.8	64	28.1	2.22	0	57.7	26.4	39.6	84.4	34.0	42.5	59.2	13.8
Average and total	--------	19	177	24.4	51.1	322	30.2	--------	13.3	70.2	42.0	51.9	63.5	51.7	48.4	63.5	[1] 28.0
Warm, loose:																	
Moist	1	3	33	39.3	60.6	90	52.2	--------	0	0	0	0	100.0	0	0	0	0
	2	5	39	18.0	100.0	182	24.7	4.66	7.6	74.2	42.5	73.0	50.9	66.2	57.6	62.9	27.5
	3	3	33	33.0	15.1	39	87.1	2.20	0	5.5	0	.6	100.0	5.0	0	2.0	−.8
	4	6	50	23.8	30.0	78	26.8	2.84	0	0	0	Trace	100.0	0	0	0	−25.6
Average and total	--------	17	155	28.5	51.4	389	47.7	--------	1.9	19.9	10.6	18.4	87.7	17.8	14.4	16.2	[1] 5.9
Dry	1	3	29	41.6	79.3	104	31.5	--------	0	30.0	3.3	22.1	90.6	7.7	75.0	59.6	8.7
	2	5	48	16.8	56.2	95	17.8	2.74	35.4	100.0	83.3	99.8	27.3	93.6	75.8	89.3	83.2
	3	3	32	32.0	34.3	45	66.6	2.18	0	18.1	0	2.0	100.0	2.0	0	2.0	1.5
	4	5	41	22.2	26.8	59	30.5	2.63	0	54.5	32.4	44.8	80.0	61.4	30.0	59.7	19.1
Average and total	--------	16	150	28.1	49.1	303	36.6	--------	8.8	50.6	29.7	42.1	74.4	48.6	45.2	52.6	[1] 19.5

[1] Calculated from averages, not an average of severity ratings. For method see footnote 2, p. 724.

TABLE 5.—*Summary of data from table 4 to show the weighted average influence of single environmental factors and of two environmental factors on the prevalence of Ophiobolus graminis in infested soil*

Condition of soil in storage	Tests	Plants	Average height of plants	Plants tillering	Culms		Plants dead	Plants having diseased—			Roots retained	Average severity of lesions on—			Final severity rating
					Number	Heading		Crowns	Culms	Roots		Crowns	Culms	Roots	
	Number	*Number*	*Inches*	*Percent*		*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
Single environmental factor: [1]															
Cool	75	723	23.5	38.2	1,154	20.5	10.8	76.9	44.1	71.9	58.9	63.1	34.6	66.3	36.5
Warm	72	678	27.0	49.5	1,419	36.0	8.5	46.1	27.4	38.6	74.6	42.0	33.5	48.6	17.1
Compact	79	758	24.8	44.5	1,368	27.3	12.5	65.9	42.5	59.5	61.5	59.7	41.1	67.2	31.0
Loose	68	643	25.7	43.2	1,205	29.4	6.7	57.0	29.0	51.0	72.0	45.4	27.1	47.7	20.2
Moist	75	713	25.0	43.9	1,305	27.2	8.2	56.0	30.7	52.7	68.9	48.7	22.8	52.7	22.9
Dry	72	688	25.5	43.8	1,208	29.3	11.0	67.0	40.8	57.8	64.6	56.5	45.3	62.2	28.7
The two environmental factors: [2]															
Cool:															
Compact	40	385	23.9	40.3	641	24.0	13.4	75.0	50.3	72.0	54.7	68.6	44.9	71.5	39.7
Loose	35	338	23.1	36.2	513	16.7	8.1	78.8	37.9	71.8	63.0	57.7	24.4	61.0	33.2
Moist	38	362	22.2	28.9	571	15.3	10.8	80.2	42.4	75.1	57.4	63.7	25.4	66.1	38.5
Dry	37	361	24.8	37.6	585	25.3	11.0	73.6	45.8	68.6	60.3	62.6	43.9	66.4	34.9
Warm:															
Compact	39	373	25.7	43.8	727	29.8	11.6	56.9	34.7	47.1	68.3	50.6	37.3	67.9	24.4
Loose	33	305	28.3	50.2	692	42.1	5.3	35.2	20.1	30.2	81.0	33.2	29.8	34.4	12.1
Moist	37	351	27.8	48.9	794	38.5	5.9	31.8	19.0	30.3	80.4	33.7	20.3	39.2	12.4
Dry	35	327	26.2	50.1	625	33.4	11.0	60.4	35.8	47.0	68.9	50.1	46.8	58.0	23.5
Compact:															
Moist	40	383	24.6	44.0	723	24.2	11.2	62.5	39.3	60.2	62.2	59.7	26.9	67.0	30.0
Dry	39	375	25.0	45.1	645	30.0	13.9	69.4	45.8	58.8	60.8	59.0	55.3	67.4	31.8
Loose:															
Moist	35	330	25.4	43.9	642	30.1	5.3	49.5	22.1	45.2	75.6	37.7	18.8	38.4	16.5
Dry	33	313	26.0	42.5	563	28.7	8.1	69.6	35.4	56.8	68.5	53.2	35.3	57.0	25.8

[1] Averages and totals derived from all the combinations into which the following single factor entered.
[2] Averages and totals derived from all the combinations into which the following combinations of two factors entered.

Both moisture and compactness modified the effect of temperature on the prevalence of *Ophiobolus graminis* in infested soil. When the infested soil was cool and loose, moisture appeared to be of little importance, because the plants grown in the cool loose soil that had been stored in either a dry or a moist condition had equal disease ratings. A compact warm soil retained more of the fungus in a viable state than a loose one. The addition of moisture to warm soil, either loose or compact, tended to rid the soil of infestation. However, the effect of moisture was greater when the soil was loose.

The individual experiments are all in agreement in indicating that temperature is the most important factor influencing the retention of the parasite in the soil. Some of the results of experiment 1, however, are at variance with those of other experiments with regard to moisture and compactness. This is due perhaps to the fact that the soil in experiment 1 was stored for a much shorter period than in the other experiments.

Infestation did not increase under any condition of storage. In experiments 2, 3, and 4 additional soil was taken to the greenhouse at the time the soil was collected, and wheat was sown at once in order to compare the disease produced initially with that after the soils had been stored. Since the highest retention of infestation was shown to have occurred in the soils stored in a cool condition, this group is used for comparison with the initial infestation in table 6. It is evident that even cool uncropped soil lost some infestation, as might be expected, since Sewell and Melchers [4] have shown that rotation of crops is an aid in controlling the take-all disease.

TABLE 6.—*Comparison of the presence of Ophiobolus graminis in portions of the same infested soil sample, one portion fresh and the other stored*

Experiment No.	Severity rating					
	Stored soil					Fresh soil
	Cool, compact		Cool, loose		Average	
	Moist	Dry	Moist	Dry		
2	143.8	109.4	136.5	61.7	112.8	115.1
3	37.9	15.0	21.8	42.3	29.2	63.2
4	58.8	8.1	52.1	51.8	42.7	93.6
Average	80.1	44.1	70.1	51.9	61.5	90.6

DISCUSSION

The soil is a common medium for many micro-organisms. The interactions of these organisms may be mutually deleterious, helpful, or neutral. Consequently the results obtained in studies of the effect of soil environment on a single organism are difficult to interpret because of the likelihood of indirect effects of other organisms. Thus the results with *Ophiobolus graminis* just described might have been different if the infested soil had contained a somewhat different microflora.

[4] SEWELL, M. C., and MELCHERS, L. E. THE EFFECT OF ROTATION AND TILLAGE ON FOOT-ROT OF WHEAT IN KANSAS, 1920–1924. Amer. Soc. Agron. Jour. 16: 768-771, illus. 1924.

Aside from the effect of a varying microflora, the effect on the parasite of fluctuations of temperature and moisture within a single year or season should not be great when the infested soil is cropped to a susceptible plant, because an abundance of the host during the growing season provides an opportunity for growth of the fungus to offset the effects of adverse weather conditions. However, there might be a gradual reduction of the organism during a cycle of dry, hot years, or an accelerated accumulation during a cool, moist cycle.

It would seem that adverse weather conditions should have the maximum effect on the fungus in infested soil planted to a nonsusceptible crop. Under these conditions hot weather should reduce infestation, the fungus might not be rehabilitated even though cool weather occurred later, and infestation would diminish from year to year.

SUMMARY

Ophiobolus graminis Sacc., the parasite causing take-all of wheat, when in pure culture was not killed by the winter temperatures occurring in Kansas, nor was it affected by repeated abrupt alternations of growing and subfreezing temperatures. The thermal death point of both microhyphae and macrohyphae was about 122° F. (50° C.).

In naturally infested soil the fungus survived temperatures as high as 160° F. (71° C.). High temperatures and drought in the summer reduced the infestation in infested soils only slightly. The abundance of the fungus in infested soils was not reduced by repeated alternations from growing to subfreezing temperatures.

The abundance of the parasite in infested soil was reduced in different degrees by different combinations of moisture, temperature, and compactness of the soil during storage. However, the fungus remained viable in either moist or dry infested soil stored in a warm greenhouse as long as 777 days. In general, cool soil tended to retain the fungus longer than warm soil. The fungus was reduced most in a warm, loose, moist soil, and least in a cool, compact, moist soil.