SOIL-TEMPERATURE STUDIES ON FLORIDA CIGAR-WRAPPER TOBACCO [1]

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INTRODUCTION

Numerous studies have been made to determine the effect of temperature on the growth of certain varieties of tobacco (*Nicotiana tabacum* L.), and on the development of certain diseases of this host. Several workers have studied the relation between soil temperature and germination of tobacco seed. Kincaid (*8*)[2] found that the cardinal temperatures for the germination of Florida cigar-wrapper tobacco seeds are approximately 10°, 24°, and 34° C.

The extent to which the growth of tobacco plants is affected by soil temperature apparently has received little attention. Johnson and Hartman (*5*) reported that white burley plants grew very little at temperatures below 13° C., best at 29° or 31°, and poorly at 40°; they noted that at the optimum temperature the plants grew low and stocky with broad but rather pointed leaves, while at temperatures near the maximum the plants were tall and spindly with short and rounded leaves. Godfrey (*2*), who also experimented with white burley tobacco, reported that there was a uniform increase in growth at temperatures from 10° to 25°, and some growth at 38°, the highest temperature which he used.

The effect of soil temperature on the development of certain soil-borne diseases of tobacco, especially black root rot, has received considerable attention, as is shown in a review by Jones, Johnson, and Dickson (*7*). These writers have also presented a valuable discussion of the relation of soil temperature to plant disease, making further discussion of this subject unnecessary here.

Tisdale and Kelley (*10*) made observations on the relationship between soil temperature and the development of black shank caused by *Phytophthora parasitica* var. *nicotianae* Tucker. They reported that plants transplanted early remained free of the disease for a few weeks, until the mean daily temperature of the soil reached about 20° C., and that the temperature during the remainder of the season never rose too high for infection

The cardinal temperatures for the growth on culture media of a strain of the black shank *Phytophthora* isolated at the North Florida Experiment Station are approximately 8°, 30°, and 36° C., according to data reported by Tisdale and Kelley (*10*) and Tucker (*11*).

Black shank is the most important disease of tobacco in the district of northern Florida and southwestern Georgia where cigar-wrapper

[1] Received for publication May 13, 1935; issued December 1935.
[2] Reference is made by number (italic) to Literature Cited, p. 449.

tobacco is grown under shade. This disease was first identified in the United States by Tisdale (*9*) in 1922, and by breeding and selection he produced varieties of cigar-wrapper tobacco highly resistant to it.

The object of the investigation reported below was to determine the cardinal soil temperatures both for the development of the black shank disease and for the growth of Florida cigar-wrapper tobacco plants. Some observations were made on the relation of soil temperature to the development of black shank in the field.

APPARATUS, METHODS, AND MATERIALS

The apparatus used in these studies for the control of soil temperature was similar to that described by Camp and Walker (*1*). It consisted of eight compartments filled with water. Each compartment accommodated eight cans of soil, and the level of the water outside the cans was about the same as the level of the soil inside the

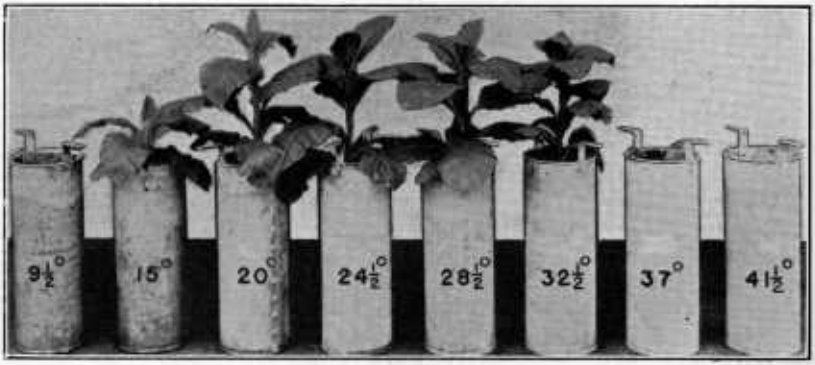

FIGURE 1.—Effect of constant soil temperatures (indicated on the cans) on the growth of tobacco plants of the Round Tip variety; see table 1, trial 2.

cans. An agitator in each compartment kept the water in continuous circulation. The compartment at one end of the apparatus was cooled by means of a thermostatically controlled refrigerator, and the compartment at the other end was heated by means of thermostatically controlled electric heaters of the immersion type. The other six compartments adjusted themselves to a series of intermediate temperatures, differing by 3° to 5°.

The cans (fig. 1), made of galvanized iron, were 8 inches in diameter and 22 inches deep, and had a capacity of about 4 gallons of soil. They were brought to equal tare by the addition of coarse gravel, and the same weight of moist soil was added to each.

The soil was a fine sandy loam having a pH value of about 5.2. The fertilizer used was composed of 100 pounds of cottonseed meal, 10 pounds of precipitated bone, and 15 pounds of sulphate of potash, and analyzed 8 percent NH_3, 8 percent P_2O_5, and 5 percent K_2O. It was applied at the rate of 5 ounces per 4-gallon can. Before the fertilized soil was used in these experiments, it was heated in an oven for about 6 hours at 60° to 70° C., or for about 2 hours at 80° to 90°, to destroy the black shank fungus and root knot nematodes.

The water-holding capacity of the soil was determined by the Hilgard (*4*) method, and the moisture content by drying samples in an oven at 105°. The initial water content of the soil in the different trials varied from 14 to 19 percent of the dry weight, or from 32 to 40 percent of the water-holding capacity. In the first two trials, the water content of the soil in the coldest compartment increased to about 25 percent of the dry weight as a result of the condensation of atmospheric moisture on the cold inner surface of the cans. However, the appearance of the plants in the cans was normal, and the difference in the moisture content of the soil was not believed to be of much importance. A 1-inch layer of coarsely granulated cork was added to the top of the soil after the plants had been transplanted, for the purpose of insulation.

The temperatures observed in the soil at a depth of 4 inches seldom varied more than 1° above or below the average temperatures reported in the tables. The mean daily temperature of the greenhouse in which the apparatus was located ranged from 23° C. in one trial conducted in midwinter to 29° C. in another trial conducted in early summer, and the daily range was generally between 10° and 15°. Conditions in the greenhouse during all trials were favorable for the growth of tobacco plants. The cans were weighed once a week, and sufficient tap water was added to the soil once or twice a week to restore them to their original weight, but no allowance was made for the weight of the plants.

The plants used in these experiments were of the variety No. 301, which is resistant, and Round Tip,[3] which is highly susceptible to black shank. No. 301 was developed at this station by Tisdale and Round Tip was developed in Connecticut by Hayes, East, and Beinhart and by Jones (*3*, *6*). Seed plants had been self-pollinated for several successive generations, and the seeds used were probably pure lines. The seedlings were grown in flats of sterilized soil. They were carefully selected for uniformity of size and color, and one seedling was transplanted to each can. The height of the plants at the time of transplanting was about 1½ inches.

THE CARDINAL SOIL TEMPERATURES FOR THE GROWTH OF TRANSPLANTED TOBACCO SEEDLINGS

Several trials were conducted to determine the cardinal soil temperatures for the growth of cigar-wrapper tobacco plants for a period of a few weeks after transplanting. These temperatures may be defined as follows: Minimum, the lowest temperature at which growth occurs; optimum, the temperature at which the most growth occurs; maximum, the highest temperature at which growth occurs.

A few days after the seedlings had been transplanted, the cans were placed in the tanks and brought to the various constant temperatures. After a certain period of growth, observations were made on the plants as follows: (1) Height from the soil to the terminal bud, (2) length of the longest leaf, (3) number of leaves longer than 1

[3] Both of these varieties may be classified under type 62,[4] which comprises southern shade tobacco grown for cigar wrappers.

[4] UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF AGRICULTURAL ECONOMICS. STANDARD GRADES FOR SOUTHERN SHADE TOBACCO (U. S. TYPE 62). 15 pp. 1933. [Mimeographed.]

inch, and (4) the green weight of the plants. Measurements of green weight were made only on the plants of No. 301; the Round Tip plants were used for the studies on black shank.

A preliminary trial was conducted with Round Tip plants to obtain an indication of the limits of temperature for growth. Because of

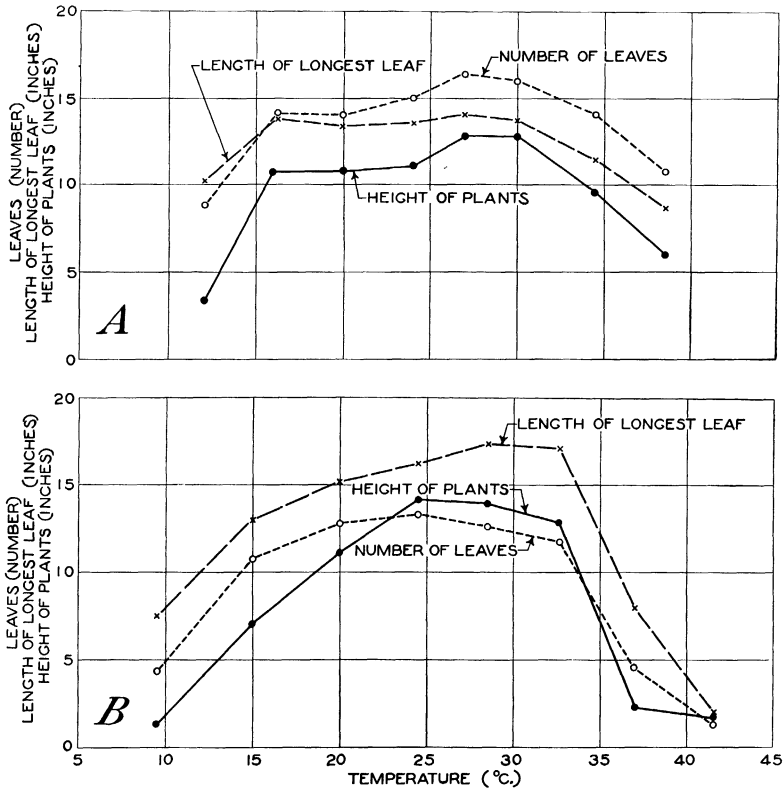

FIGURE 2.—Effect of various constant soil temperatures on the growth of tobacco plants of the Round Tip variety: *A*, Trial 1; *B*, trial 2.

mechanical difficulties incidental to the adjustment of the refrigerator, the control at the cold end of the apparatus was poor. However, it was evident from the results that the minimum was slightly below the lowest temperature used, 16° C. and below, and that the maximum was approximately 40°.

Three other trials with Round Tip and two trials with no. 301 plants were conducted. The average measurements of the plants in these five trials are given in table 1. The growth of Round Tip plants in trial 2 is shown in figure 1; the plants selected for the photograph were those which best illustrated the average measurements of

the plants grown in the respective compartments. The growth of the plants in trials 1, 2, 4, and 5 is shown graphically in figures 2 and 3.

These results indicate that the minimum temperature for growth of transplanted seedlings of both Round Tip and No. 301 is about 9° C.,

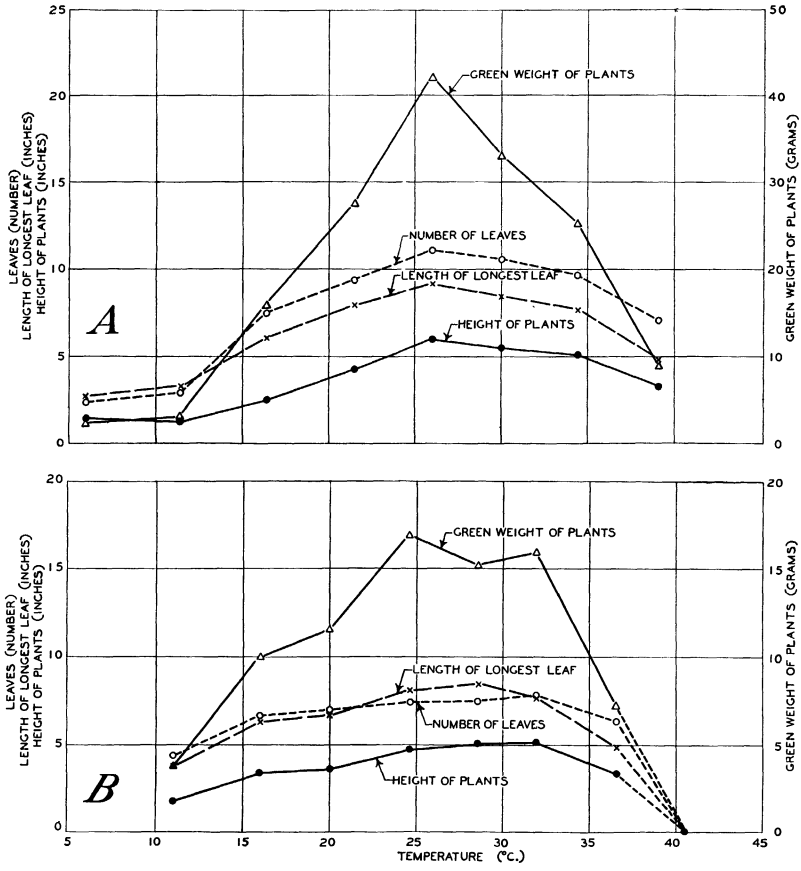

FIGURE 3.—Effect of various constant soil temperatures on the growth of tobacco plants of variety No. 301: *A*, Trial 4; *B*, trial 5.

and the maximum about 40°. The optimum was not very closely defined, because the best growth, as indicated by the measurements, was distributed over a range of temperatures from 24½° to 32°.

The minimum for the growth of transplanted seedlings corresponds closely to the minimum for the germination of seeds of No. 301 (*8*) but the optimum and maximum are somewhat higher.

TABLE 1.—*Effect of various constant soil temperatures on the growth of tobacco plants of the Round Tip and No. 301 varieties*

Trial no.	Variety	Period of observation	Soil temperature	Plants	Average height of plants	Average length of longest leaf	Average number of leaves	Average green weight per plant
		Days	° *C.*	*Number*	*Inches*	*Inches*		*Grams*
1	Round Tip	47	12	7	3.3	10.1	8.7	
			16	[1] 6	10.7	13.9	14.0	
			20	[1] 6	10.7	13.3	14.0	
			24	7	11.0	13.5	15.0	
			27	7	12.8	14.0	16.4	
			30	7	12.8	13.7	16.0	
			34½	7	9.6	11.3	14.0	
			38½	7	6.0	8.6	10.7	
2	do	32	9½	7	1.3	7.3	4.4	
			15	7	7.1	13.0	10.8	
			20	7	11.1	15.1	12.8	
			24½	7	14.0	16.1	13.3	
			28½	7	13.9	17.3	12.7	
			32½	7	12.8	17.1	11.8	
			37	7	2.3	7.9	4.6	
			[2] 41½	7	1.8	1.9	1.4	
3	do	49	10½	1	9.5	8.5	11.0	
			16	1	17.0	12.5	17.0	
			20	1	18.5	13.5	18.0	
			24½	1	18.5	14.5	17.0	
			28	1	21.5	14.0	20.0	
			31½	1	21.5	13.0	18.0	
			35	1	13.5	10.5	13.0	
			38½	1	4.0	4.5	5.0	
4	No 301	31	6	7	1.5	2.8	2.4	2.4
			11½	7	1.3	3.3	3.0	2.9
			16½	7	2.7	6.1	7.7	16.1
			21½	7	4.3	8.1	9.7	27.6
			26	7	6.1	9.5	11.1	42.1
			30	7	5.6	8.7	10.7	33.3
			34½	7	5.1	7.9	9.9	25.7
			39	7	3.4	4.9	7.1	9.3
5	do	21	11	8	1.8	3.9	4.4	3.9
			16	7	3.3	6.4	6.6	10.0
			20	7	3.6	6.8	7.0	11.7
			24½	7	4.8	8.0	7.6	17.0
			28½	7	5.1	8.3	7.6	15.3
			32	7	5.2	7.7	7.9	16.0
			36½	7	3.4	4.9	6.4	7.3
			[3] 40½	8				

[1] 1 plant accidentally killed. [2] Plants nearly dead. [3] All plants dead or dying.

EFFECT OF CONSTANT SOIL TEMPERATURE ON THE DEVELOPMENT OF BLACK SHANK

Four trials were conducted to determine the cardinal soil temperatures for the development of black shank caused by *Phytophthora parasitica* var. *nicotianae* Tucker (*11*). These temperatures may be defined as follows: Minimum, the lowest temperature at which symptoms of the disease appear; optimum, the temperature at which symptoms of the disease appear in the largest percentage of the plants within the shortest time after inoculation; maximum, the highest temperature at which symptoms of the disease appear.

Seven transplanted seedlings of the Round Tip variety, which is very susceptible to black shank, were inoculated and incubated at each temperature for each trial. The fungus used originated from a single-spore culture of *Phytopthora* isolated from tobacco at this station, and was grown on potato-dextrose agar or on steamed wheat. The fungus and the medium were mixed with the soil shortly before transplanting in two trials, and placed in contact with the stems below the surface of the soil in two others. The amount of inoculum was the same in all cans of each experiment, and was evidently sufficient in every trial to insure prompt infection at favorable tem-

peratures. One noninoculated check plant per compartment was left in each trial.

The plants used in the first three trials were placed in the cans in blocks of soil in which they had been transplanted a few days previously, so that the growth of the plants was not seriously interrupted. The plants used in the last trial were pulled and transplanted according to the usual field practice.

The time which elapsed between inoculation and the appearance of the symptoms of the disease was carefully observed. Diseased plants were recognized by permanent wilting, generally followed by the blackening of the stem above the soil and cork. Stunting of the inoculated plants, as compared with the check plant at the same temperature, was often noticeable before the wilting; the checks remained healthy in every instance.

The results of four trials with Round Tip plants are given in table 2. That temperature has an important effect on the pathogenic activity of the fungus is shown by the number of plants infected and the time required for the appearance of symptoms of the disease. The minimum temperature varied considerably with the age of the plants, from 16° C. or lower for newly transplanted seedlings to about 24° for plants inoculated 41 or 47 days after transplanting. The optimum was approximately 28°. The maximum was near 34°, but was not clearly defined, for a few plants died apparently from the combined effects of black shank and unfavorably high temperature.

TABLE 2.—*Effect of various constant soil temperatures on the development of black shank in tobacco plants of the Round Tip variety*

Trial No.	Soil temperature	Period of incubation before inoculation	Plants showing symptoms of black shank after indicated number of days						
			4	6	10	14	15	20	40
	°C.	*Days*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1	12	47		0				0	
	16			0				0	
	20			0				0	
	24			0				2	
	27			2				6	
	30			4				6	
	34½			4				5	
	38½			0				1	
2	9½	41		0			0		
	15			0			0		
	20			0			0		
	24½			0			1		
	28½			6			6		
	32½			4			6		
	37			0			0		
	41½			(1)			(1)		
3	10½	0			0				0
	16				0				0
	20				0				2
	24½				0				6
	28				5				6
	31½				2				6
	35				0				0
	38½				0				0
4	16	0	0	0	0	3	3		
	19		0	0	3	4	5		
	22½		0	0	2	5	6		
	25½		1	3	6	6	6		
	28		1	4	6	6	6		
	31½		0	0	3	3	4		
	34		1	1	1	1	1		
	37		0	0	1	2	2		

[1] Plants nearly dead at time of inoculation.

The effect of soil temperature on the development of the disease is probably due to the effect of temperature on the rate of growth of the fungus either saprophytically in the soil or parasitically in the tissues of the host. In fact, the cardinal temperatures for the development of the disease correspond somewhat closely to those reported by Tisdale and Kelley (*10*) and Tucker (*11*) for the growth on culture media of the pathogen isolated by Tisdale at this station.

The number of plants available for observation in the experiments reported was limited by the capacity of the apparatus, but the general agreement of the results of the various trials indicates that the conclusions are fairly reliable. The plants inoculated several weeks after transplanting (table 2, trials 1 and 2) were grown at the same temperature at which they were held after inoculation. It is possible that the temperature at which the plants were grown had some influence on their susceptibility. This subject warrants further investigation.

RELATION OF SOIL TEMPERATURE TO THE DEVELOPMENT OF BLACK SHANK IN THE FIELD

The results of the experiments reported above, as well as those of Tisdale and Kelley (*10*), show that the temperature of the soil may affect the activity of the black shank organism in the field. Some further field observations may be of interest here.

In September 1932, Round Tip plants were transplanted in the trial plot at this station, where high percentage of the Round Tip plants in the check rows had died during the usual growing season which ended in July. These plants were still free from black shank when they were pulled for examination in November. This indicates that the pathogen had become inactive in the soil during the midsummer months. No soil-temperature records for these months are available. The following season, Round Tip plants transplanted in the same field in March remained healthy for several weeks. The first wilted plants were observed about the first of May, when the soil temperature at a depth of 2 to 4 inches ranged from about 20° C. at night to 24° during the day. This agrees closely with the minimum temperature (24°) reported above for the development of black shank in Round Tip plants inoculated several weeks after transplanting.

The problem of the survival, multiplication, and distribution of the black shank fungus under field conditions deserves further investigation.

SUMMARY AND CONCLUSIONS

Experiments were conducted to determine the cardinal soil temperatures for the growth of transplanted cigar-wrapper tobacco seedlings. The minimum and maximum were found to be approximately 9° and 40° C., respectively, and the optimal range from about 24½° to 32°.

Experiments were conducted to determine the effect of constant soil temperatures on the development of black shank (*Phytophthora parasitica* var. *nicotianae* Tucker) in Round Tip tobacco plants, which are very susceptible to the disease. The minimum temperature for infection was found to vary considerably with the age of the plants, ranging from 16° C. or lower for newly transplanted seedlings to about 24° for plants inoculated several weeks after transplanting. The optimum is about 28° and the maximum about 34°.

Observations on black shank in the field indicate that soil temperature is an important factor in the development of the disease.

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