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Relation of Temperature to the
Growth and Infecting Power
of *Fusarium Lini*

L. Part I

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RELATION OF TEMPERATURE TO THE GROWTH AND INFECTING POWER OF *FUSARIUM LINI*

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WITH PLATE XI AND ONE FIGURE IN THE TEXT

Studies on the nature and inheritance of resistance in flax to the wilt disease, caused by *Fusarium Lini* Bolley, were begun with the departments of plant pathology and experimental breeding of the University of Wisconsin in the winter of 1914-15. While growing plants in the greenhouse for these breeding experiments in the winter of 1915-16 the writer noted that marked differences existed in the rate of wilting of susceptible flax plants which were growing at different distances from the heating system. These observations, combined with temperature records, suggested the possibility that soil temperature might be one of the chief factors influencing the rate of infection of these plants. In order to determine this point experiments were arranged so that both the relation of temperature to the growth of the fungus in pure culture, and the relation of soil temperature to the infection of susceptible flax plants might be studied.¹

RELATION OF TEMPERATURE TO THE GROWTH OF THE FUNGUS IN CULTURE

After ascertaining by careful measurement that actual correlation existed between soil temperatures and the rate of wilting of the flax plants, a study was undertaken of the relation of the fungus to various temperatures while growing in pure culture on artificial media. An investigation of this kind was considered of fundamental importance in order to work out and understand thoroughly the relation of soil temperature to infection. By using an incomplete series of temperatures ranging from 0 to 37°C. it was found that the organism failed to grow below 10°C. and at or above 37°C. This preliminary experiment showed approximately the temperature limits of the fungus and gave some indications as to what temperatures were best suited for its growth. Another experiment was arranged, using a more complete series of temperatures, in which plates

¹The writer wishes to express his hearty appreciation to Professor H. L. Bolley of the North Dakota Agricultural Experiment Station for supplying flax seed and flax sick soil for the work. He is also indebted to Professor L. R. Jones of the University of Wisconsin for invaluable suggestions and kindly criticisms of the work as it progressed.

poured with a 1.8 per cent potato agar and inoculated in the center with bits of mycelium were incubated in duplicates at different temperatures for six days. After incubation the colony diameters were measured (table 1) and the plates arranged in a temperature series and photographed (plate XI). The plate numbers in table 1 correspond to the numbers in the photograph.

TABLE I

The effect of temperature on the growth of Fusarium Lini. Cultures six days old

PLATE NO.	TEMPERATURE	DIAMETER OF COLONY
	°C.	mm.
1	8.5-10	0
2	11	7
3	12-13	20
4	14	25
5	15	29
6	16	34
7	17	38
8	19	43
9	22	68
10	24-25	70
11	25-26	72
12	26-28	78
13	29-30	75
14	34	17
15	37	0

It appears from table 1 that the minimum temperature for growth of the fungus lies between 10° and 11°C., the optimum at about 26° to 28°C., and the maximum between 34° and 37°C. Another set of experiments showed that the fungus is able to grow slightly at a temperature ranging from 35° to 36°C. Judging from the vigor of the fungus at the various temperatures, it would be expected that flax plants would wilt more readily with soil temperatures between 20° and 30°C. This was actually found to be the case with susceptible plants growing in the greenhouse.

RELATION OF SOIL TEMPERATURE TO INFECTION²

While growing flax plants in the greenhouse for breeding experiments in the winter of 1915-16, as previously stated, a series of flats was placed near a system of heating pipes, while others were placed at a greater distance from the pipes where the temperature was lower. A more rapid

² Tisdale, W. H. Relation of soil temperature to the infection of flax by *Fusarium Lini* Boll. (Abst.) *Phytopath* 6: 412. 1916.

wilting of susceptible plants was noticed in flats near the heating system. Soil temperatures were taken and it was found that the temperature in flats near the heating pipes ran at 18° to 20°C., while the temperature in flats farther from these pipes, where there was much less infection, ran at 14° to 17°C. This seemed to indicate that the critical temperature for the infection of flax by *Fusarium Lini* is somewhat below 17°C., which was of the more interest, in view of the fact that Gilman found that the lowest temperature for the infection of cabbage by *Fusarium conglomerans* Wr. is about 17°C.

Following these observations an attempt was made by controlling the soil temperature to determine more accurately the lowest temperature for infection of flax by *Fusarium Lini*. The first attempt was made by placing pots of infected soil containing germinating flax seeds in the cold-storage cellar near a small window where they could get light. Other pots planted at the same time were kept in the greenhouse as controls. The temperature in the cellar often ran below 10°C. during the nights. This temperature was too low for the plants to remain in a vigorous condition. The plants in the control pots began wilting in ten days and nineteen of the twenty-two plants were wilted at the end of twenty-two days, whereas none of the plants at the lower temperature in the cellar had wilted. The experiment was then terminated by a sudden drop in temperature which froze the plants in the cellar.

A second attempt was made at controlling the soil temperature by arranging a cool, circulating water jacket (fig. 1). A six-inch earthenware jar was filled about three-fourths full of infected soil and susceptible flax seeds planted. This jar was then supported in a larger jar, through which cold water flowed continuously, as shown in the figure. Seeds were planted in a similar jar and placed nearby at greenhouse temperature as a control. At the time these experiments were begun the temperature of the water was about 9°C. By careful regulation of the flow by means of the faucet valve it was possible to hold a fairly constant temperature between this point and the greenhouse temperature. A temperature ranging between 12° and 15°C. was maintained for eight days and the plants remained free from infection. The temperature was then raised to 16° to 17°C. for two days and lowered again to 12° to 15°C. Four of the twenty-three plants in the jar showed signs of the wilt within two days even at these low temperatures. Infection evidently occurred during the brief period at the higher temperature. The small earthenware jar was found to be unsatisfactory due to the fact that the material allowed too much condensation or seepage which kept the soil almost saturated. The experiment was then repeated with a glass battery jar substituted for the earthenware jar. The glass jar proved more satisfactory. In the second

experiment it was found that at temperatures below 15°C. no wilting of flax plants occurred, while plants in the control pot at temperatures ranging from 19° to 21°C. wilted rapidly. During the earlier part of this trial when the temperature was held at 13° to 14°C. the flax plants grew fairly well and no indications whatever of wilt were evident (fig. 1, A). After one month, when the temperature had risen to 15°C. only one plant of the twenty-one in the cold jar showed any sign of infection, while all of the thirty-three plants in the control jar were killed by wilt. The temperature in the cold jar could not be lowered as the water was warming up with the coming spring.

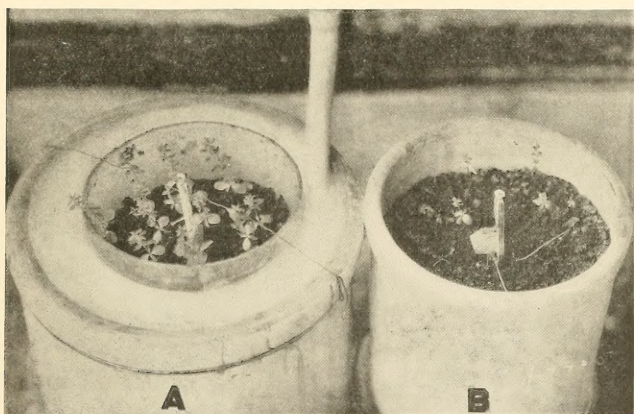


FIG. 1. RELATION OF TEMPERATURE TO THE INFECTION OF FLAX BY *F. LINI*

A, Susceptible flax plants growing at 13° to 15°C. in infected soil in a glass jar surrounded by running water. The smaller jar is supported by a glass tumbler inverted on the bottom of the larger jar. B, Susceptible plants growing in infected soil at greenhouse temperatures (19°-21°C.). Plants in this jar are practically all dead with wilt.

It seems from these experiments that the critical temperature for infection of flax by *Fusarium Lini* is between 14° and 16°C. This conclusion accords well with the previous evidence secured by culturing the fungus on agar at graduated temperatures. As stated in table 1 the minimum temperature was found to be 10° to 11°C. and reference to plate I will show that but little growth occurred below 15°C. We should expect the critical temperature for infection to be somewhat higher than the minimum tem-

perature at which the parasite will grow, especially since the host plant thrives well at the lower temperatures. In this case it seems clear that the host plant which is susceptible at the higher temperatures is able to resist or overcome whatever weak attempts at invasion the fungus can make at the lower temperatures.

The evidence here presented supplementing that secured by Gilman³ should at least warrant further careful attention to the relation of temperatures to infection with the soil parasites, and especially the species of *Fusarium*.

CONCLUSIONS

1. *Fusarium Lini* grows on culture media at temperatures between 10° and 37°C., with its optimum temperature at 26° to 28°C.
2. Flax thrives well with soil temperatures as low as 13°C.
3. The critical temperature for the infection of flax by *Fusarium Lini* is about 15°C.
4. There is a close correlation between the temperatures at which *Fusarium Lini* grows best in pure culture and those at which flax wilt is most destructive.

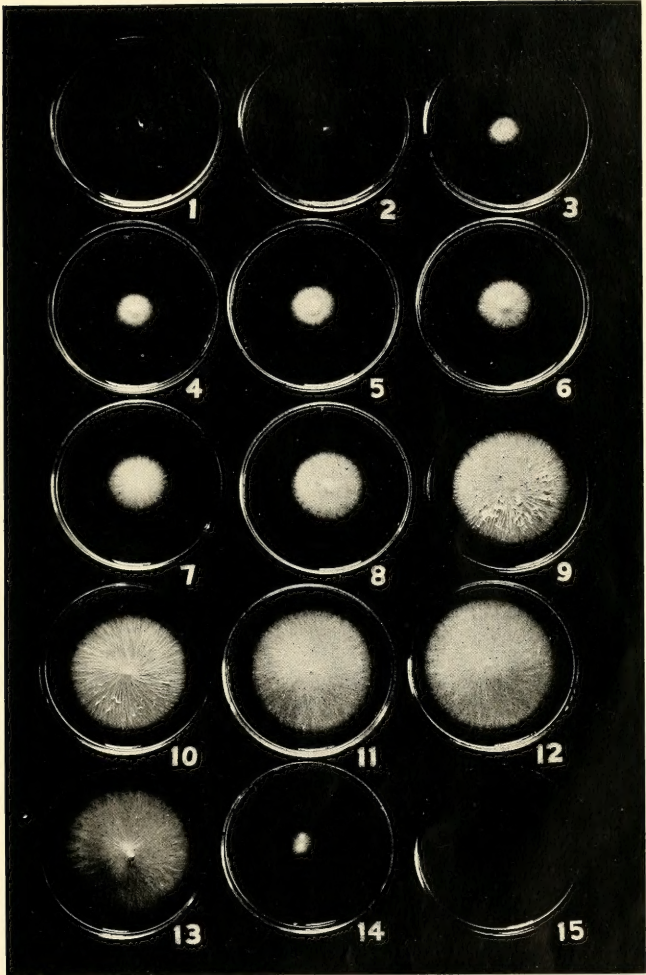
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³ Gilman, J. C. The relation of temperature to the infection of cabbage by *Fusarium conglutinans* Wollenw. *Phytopath.* 4: 404. 1914.

— Cabbage yellows and the relation of temperature to its occurrence. *Ann. Missouri Bot. Gard.* 3: 25-84. 1916.

PLATE XI. RELATION OF TEMPERATURE TO THE GROWTH OF FUSARIUM LINI

These culture plates (1.8 per cent potato agar) were inoculated with much care as to uniformity and then incubated for six days at different temperatures, as follows: (1) 8.5-10°, (2) 11°, (3) 12-13°, (4) 14°, (5) 15°, (6) 16°, (7) 17°, (8) 19°, (9) 22° (10) 24-25°, (11) 25-26°, (12) 26-28°, (13) 29-30°, (14) 34°, (15) 37°.



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