

Influence of Soil Temperature on *Meloidogyne incognita* Resistant and Susceptible Cotton, *Gossypium hirsutum*

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Abstract: The degree of resistance by a cotton plant to *Meloidogyne incognita* is affected by soil temperature, particularly in moderately resistant cultivars. The total number of nematodes in the resistant and moderately resistant roots at 35 C was equal to, or greater than, the number in susceptible roots at 20, 25, or 30 C. A shift in numbers to developing and egg-bearing forms of nematodes in the susceptible cultivar as temperature increased indicates development was affected by temperature rather than by genetic resistance mechanisms. However, the nematode resistant cultivar did not support maturation of nematodes until a soil temperature of 35 C was attained. This indicated that resistance mechanisms are partially repressed at 35 C and differences in nematode development cannot be explained in terms of accumulated heat units. The moderately resistant cultivar was significantly more sensitive to the effects of high temperature than was the resistant cultivar. *Key words:* rootknot nematode, host-plant resistance, soil temperature.

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Temperature can be an important factor influencing the expression of resistance by

plants to parasitic nematodes. Grundbacher and Stanford (6), for example, found that resistance in alfalfa, *Medicago sativa*, to the stem nematode, *Ditylenchus dipsaci*, is lower at 21 and 16 C than at 11 C. Griffin et al. (4,5) observed that alfalfa plants susceptible to *Meloidogyne hapla* attract more larvae than resistant plants, but the magnitude of

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this difference decreases as temperature increases. Additionally, root galling is usually not observed in resistant alfalfa cultivars grown at 28 C; however, if these inoculated cultivars are grown at 32 C, about 50% produced galls. Similarly, the number of *M. incognita* and *M. hapla* females reaching maturity in resistant and susceptible common bean increases when the soil temperature is increased from 25 to 30 C (8). Temperature also affects the ability of resistant soybean and tomato varieties to support growth and reproduction of *M. incognita* (2,3,7). Penetration and development of *M. incognita* in resistant tomato roots is greater at 30 and 34.5 C than at 20 and 25 C (7). In other studies on tomato, Dropkin (3) and Paulson and Webster (13) reported decreased hypersensitive necrotic response to nematode invasion at temperatures near or above 30 C. Dropkin (3) also observed that the moderately resistant cotton cultivar, 'Auburn 56,' (12), at high temperatures has a low incidence of necrosis accompanied by accelerated larval development.

The purpose of this experiment was to compare the effects of soil temperature on root penetration and nematode development by *M. incognita* on cotton cultivars possessing a wide range of rootknot nematode resistance.

MATERIALS AND METHODS

Three cotton cultivars with different levels of resistance to the rootknot nematode were used: resistant 'Auburn 623,' moderately resistant 'Clevewilt 6-3-5,' and susceptible 'Deltapine 16' (14,16). Seeds were germinated at 30 C in 15-cm-d pots filled with a steam-sterilized sandy clay loam. Twenty pots with five seed per pot were included for each cultivar. After emergence, the potted seedlings were transferred to a growth chamber for inoculation under uniform conditions: 25 ± 1 C and 24,800 lux with a 14-h photoperiod. Twenty-four hours after transfer to 25 C, suspensions of 2,000 larvae/seedling were introduced with a syringe 4-cm into the soil next to each seedling.

Inoculum obtained from a single egg mass isolation (1) was propagated in the greenhouse on tomato (*Lycopersicon*

esculentum Mill.); second-stage larvae were obtained by Lownsberry and Viglierchio's (9) method. After 48 h at 25 C, five pots of each cotton cultivar were transferred to growth chambers at either 20, 25, 30, or 35 C with light intensity and photoperiod regimes as above. Plants were removed from the soil 23 days after inoculation, washed in tap water, blotted dry, and individually weighed. Roots were then fixed in FAA (formalin-acetic acid-alcohol 5:2:93), stained in boiling acid fuchsin-lactophenol (10), and cleared in chloral hydrate for microscopic examination. The numbers of nematodes in root tissue were recorded based on developmental stage as follows: i) immature larvae with no indication of body swelling; ii) developing nematodes with swollen bodies but no egg masses; and iii) adults with egg masses. No effort was made to distinguish between males and developing females. Gelatinous matrices were counted as egg masses only if they contained one or more eggs. All counts were transformed by $\log_{10} (\text{Count} + 1)$ to normalize data for analysis. The protected least significant difference (LSD) was determined or a Duncan's multiple-range test was conducted for each set of data. Heat units accumulated were calculated according to Tyler (15).

RESULTS

At each temperature regime, significantly ($P = 0.05$) more *M. incognita* of all stages were counted in susceptible than in moderately resistant or resistant roots (Table 1). However, in each cultivar more nematodes were counted at 35 C than at 20, 25 or 30 C. The number of nematodes in the resistant and moderately resistant roots at 35 C was equal to, or greater than, the number in susceptible roots at 20, 25, or 30 C. Except at 35 C, there was no difference in the total number of *M. incognita* in resistant and moderately resistant roots. At 35 C, the resistant cultivar had fewer nematodes than did the moderately resistant cultivar.

Significantly ($P = 0.05$) fewer immature *M. incognita* were counted in susceptible than in resistant or moderately resistant roots at 30 C; at 35 C, the number of immature forms in susceptible and moderately resistant roots was the same but significantly

Table I. Means ($\text{Log}_{10}[\text{Count} + 1]$) of the total number of *Meloidogyne incognita* per gram of cotton root.

Cultivar*	Host response†	Temperature			
		20 C	25 C	30 C	35 C
A-623	R	1.2304 a‡	1.6739 b	1.5635 ab	2.1206 d
CW 6-3-5	MR	1.2095 a	1.7589 b	1.7497 b	2.2788 e
DP 16	S	1.9823 c	2.0755 cd	2.0043 c	3.4116 f

*A-623 = Auburn - 623; CW 6-3-5 Clewilt 6-3-5; DP 16 = Deltapine 16.

†R = resistant; MR = moderately resistant; S = susceptible host.

‡Values followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple-range test.

less than in resistant roots (Fig. 1-C). Conversely (except at 35 C, where no difference existed), compared to moderately resistant and resistant roots, susceptible roots contained significantly more developing forms (Fig. 1-B) and egg bearing adults (Fig. 1-A) at all temperatures. Significantly more developing forms were counted in moderately resistant than resistant roots at 30 and 35, but not at 20 or 25 C (Fig. 1-B).

No egg-bearing stages of *M. incognita* were counted in any cultivar at 20 C (Fig. 1-A); at 25 C, egg-bearing stages of the nematode were found only in the susceptible cultivar. Thus, at least 8,280 heat units are required for nematode egg production in

the susceptible cultivar. At 30 C and 35 C, the susceptible cultivar had a larger number of egg-bearing forms compared to the resistant and moderately resistant cultivars.

DISCUSSION

Dropkin (3) classes the cotton cultivar 'Auburn 56' as moderately resistant and notes a low incidence of necrosis at either 28 or 32 C and an increase in larval growth at the higher temperature. He states that the increase in larval growth may simply reflect the accumulation of more heat units at the higher temperature. However, the low incidence of necrosis in itself is indicative of increased susceptibility. In this experiment, the shift in numbers to developing and adult (egg bearing) forms of nematodes in the susceptible cultivar as temperature increased does indicate that development in susceptible cotton cultivars is primarily affected by temperature (heat units acquired), rather than by genetic resistance mechanisms of the host. However, the nematode resistant cultivar did not support maturation of nematodes to a significant degree until a soil temperature of 35 C was attained. This indicates that resistance mechanisms are partially repressed at 35 C and differences in nematode development cannot be explained only in terms of accumulated heat units. The moderately resistant cultivar was significantly more sensitive to the effects of high temperature than was the resistant cultivar. The sensitivity of the moderately resistant 'CW 6-3-5' to high temperature agrees with the observation of Dropkin for moderately resistant 'Auburn 56' (3). The number of heat units

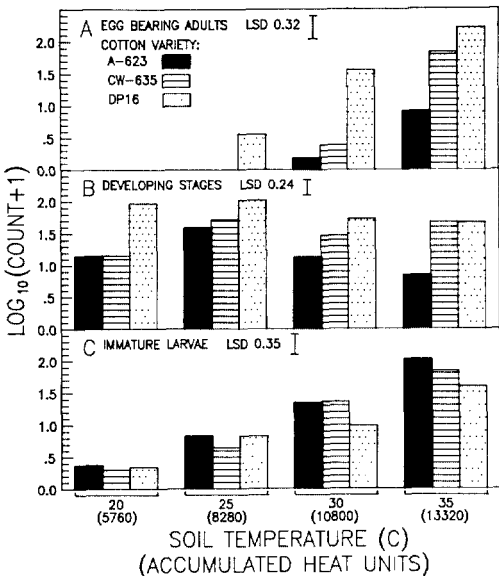


Fig. 1. Mean number of adult (A), developing (B), and immature (C) *M. incognita* in a gram of root as affected by soil temperature and cotton cultivar.

(hu) required for maturation of *M. incognita* in the susceptible cultivar (8,280 hu) compares favorably to Tyler's (15) for root-knot in tomato (6,500-8,000 hu). However, these numbers of heat units were considerably lower than the 12,000 hu required for *M. incognita* in soybean (2).

This study shows that the degree of resistance "expressed" by a cotton plant to *M. incognita* is affected by soil temperature, particularly in moderately resistant cultivars. Comparative biochemical assays (11, 16,17) designed to determine chemical factors involved in nematode resistance would be critically affected by root temperature. Altering soil temperatures could provide a useful experimental tool to better determine or eliminate chemical factors involved in nematode resistance mechanisms in cotton.

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