Journal of Nematology 25(1):55–58. 1993.

Reproduction of *Heterodera zeae* and Its Suppression of Corn Plant Growth as Affected by Temperature[1]

SARWAR HASHMI, LORIN R. KRUSBERG, AND SANDRA SARDANELLI[2]

Abstract: Reproduction of the corn cyst nematode (*Heterodera zeae*) and its effect on growth of corn (*Zea mays*) was studied in plant growth chambers at 24, 27, 30, 33, and 36 C. Reproduction of *H. zeae* increased directly with increase in temperature from 24 to 36 C. Fifteen-cm-d pots of corn seedlings inoculated with a mixture of 5,000 eggs + J2 and maintained for 8 weeks in growth chambers contained an average of 7,042 cysts + females at 36 C, but only 350 cysts + females at 24 C. Fresh weights of plants without nematodes were highest at 27 C and lowest at 36 C. Nematodes suppressed plant fresh weight by an average of 30% at 27 C and by 27% at 33 C but did not suppress plant weight at 36 C. *Heterodera zeae* has the highest reported temperature optimum for reproduction of any cyst nematode.

Key words: Corn cyst nematode, growth suppression, *Heterodera zeae*, nematode, reproduction, temperature, *Zea mays*.

The corn cyst nematode, *Heterodera zeae* Koshy et al., 1971, was discovered in the Western Hemisphere in Kent County, Maryland, in 1981 (7). This nematode was first described in India (4) and has been reported as an economic pest of *Zea mays* L. in India (3) and in Egypt (1). The economic pest status of a Maryland population of this nematode is being evaluated, and various aspects of its biology are under study.

Plot tests in Maryland during 1981–84 in grower fields naturally infested with soil population densities of corn cyst nematode of 50–300 cysts/250 cm^3 soil failed to demonstrate a yield increase from corn plants treated with fumigant and nonfumigant nematicides (Krusberg, unpublished). However, reports from India and Egypt stated that *H. zeae* stunted plants and suppressed yields of corn (1,3). Recently, the optimum temperature for development of a Maryland population of *H. zeae* was reported to be 33 C (2). It is suspected that low field soil temperatures and heavy applications of fertilizer in Maryland alleviate the damage to corn caused by the corn cyst nematode because nematode activity seems to be favored by high soil temperature and poor plant nutrition. The high soil temperatures in India and Egypt may be a primary reason why *H. zeae* is economically important to corn in those countries.

Our objective was to investigate the influence of soil temperature on the reproduction and suppression of corn plant growth by a Maryland population of *H. zeae* on *Z. mays* in a controlled environment.

MATERIALS AND METHODS

Cultures of *H. zeae* were maintained on corn (*Zea mays* Pioneer brand 3184) in the greenhouse in 20-liter pots of autoclaved river sand placed on plant propagation mats that maintained a sand temperature of 30 C. Cysts placed on a 150-µm-pore sieve were broken open by gentle rubbing with a rubber stopper to release the eggs; second-stage juveniles (J2) were used as inoculum. The mixed eggs and J2 were collected on a 25-µm-pore sieve and were then suspended in tap water. Twenty ml of aqueous suspension containing 5,000 ± 250 mixed eggs and juveniles were pipeted onto the surface of 800 cm^3 of autoclaved river sand contained in each of 50 15-cm-d plastic pots. Five seeds of Pioneer 3184 corn were placed onto the sand in each pot and covered with another 200 cm^3 of autoclaved river sand. Fifty pots similarly prepared, without *H. zeae,* served as controls. All pots were subsequently placed in growth chambers for 7 days at 27 C for

Received for publication 19 February 1992.
[1] Scientific article number A 6300, contribution number 8471 of the Maryland Agricultural Experiment Station.
[2] Graduate Research Assistant, Professor, and Laboratory Scientist, Department of Botany, University of Maryland, College Park, MD 20742-5815.

seed germination, after which the plants were thinned to two per pot. Pots in groups of 10 inoculated and 10 uninoculated were placed in a growth chamber at 24, 27, 30, 33, or 36 C, all in a completely randomized design. Plants in all growth chambers were maintained under a 12-hour photoperiod with a light intensity of 100 μwatt/m^2/sec as measured using a Quantum Sensor, Model L1-185 A (LI-COR-Inc, Lincoln, NE). Each treatment was replicated 10 times. Plants were fertilized weekly and watered as required.

After 8 weeks, including the 7 days at 27 C, plants were harvested and fresh plant weights, numbers of cysts in the sand, numbers of females, and numbers of free juveniles in the sand of each pot were determined. In addition, 50 cysts were collected at random from each pot, the cysts were broken open, and numbers of eggs and juveniles from the cysts were counted. The experiment was conducted twice; experiment 1 ran from June to August 1988 and experiment 2 from September to November 1988. Temperatures were randomly assigned to growth chambers separately for each experiment. The data of both experiment 1 and 2 were combined and analyzed by ANOVA for a factorial (temperature × nematode number × experiment) design; treatment means were compared by LSD at $P = 0.05$. Regression analysis of the data did not provide any additional information.

RESULTS

Reproduction of *H. zeae* increased with increase in temperature from 24 to 36 C (Fig. 1). The greatest numbers of full cysts, females, and free soil J2 were recovered at 36 C and the fewest at 24 C. The numbers of cysts, females, and J2 produced dropped off very steeply, by 49, 39, and 41%, respectively, as temperature decreased from 36 to 33 C; and then the numbers continued to decrease somewhat more gradually at 30 C and 27 C. At 24 C, populations of cysts, females, and J2 were only 7, 4, and 1% of those at 36 C, and only 46, 13, and 2% of those at 27 C, respectively. In both experiments, females were 4–6 times more numerous than cysts at all temperatures except at 24 C, at which the numbers of females were only 1.5–2 times

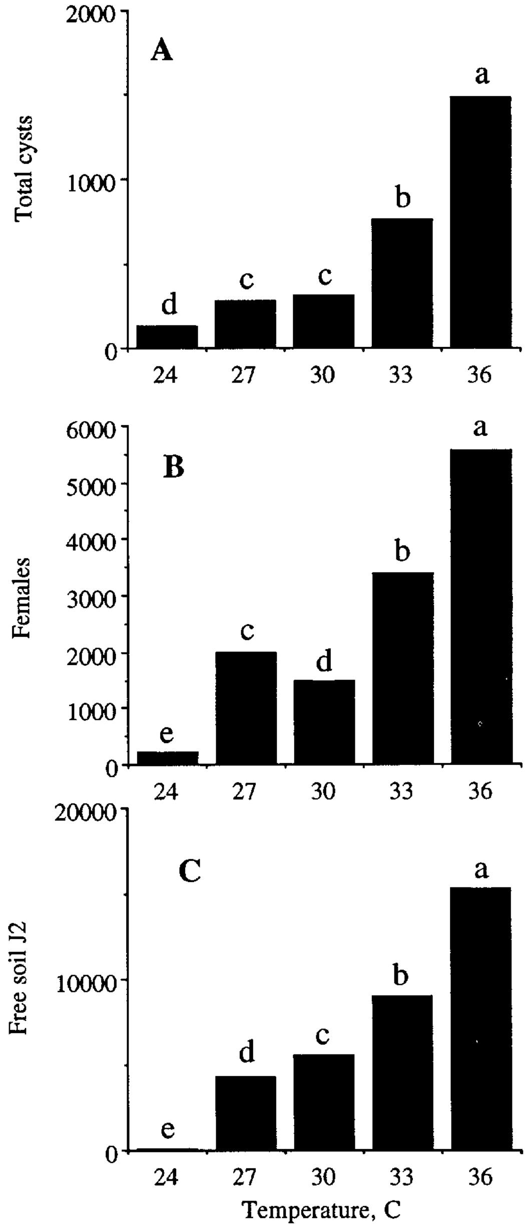

FIG. 1. Effect of temperature on numbers of life stages per 1,000 cm^3 soil in pots of *Heterodera zeae* after multiplication on Pioneer 3184 corn for 8 weeks in growth chambers. A) Total cysts, B) Females, C) Free soil juveniles. Bars with the same lowercase letter(s) within nematode class are not significantly different ($P = 0.05$).

greater than the number of cysts. Although the numbers of cysts and females produced were different over the temperature range of 24 to 36 C, the numbers of eggs averaged 150 ± 10 per cyst, regardless of temperature.

Based on fresh weights, corn plants in the absence of corn cyst nematode grew best at 27 C in both experiments (Fig. 2). In both experiments, corn plant weights were consistently lower by 17–30% in the presence than in the absence of this nematode at the four temperatures 24, 27, 30, and 33 C. At 36 C, growth of both inoculated and uninoculated plants was suppressed by the high temperature, and the presence of corn cyst nematode caused no additional growth suppression.

Discussion

Maximum reproduction of *H. zeae* in two experiments occurred at the highest temperature used, 36 C, and minimum reproduction occurred at the lowest temperature used, 24 C. The low reproduction of *H. zeae* at 24 C indicates that during winter in Maryland population increase in host plants is unlikely. However, corn cyst nematode persists in fallow field soil for several years (5). Temperature has been reported to influence the susceptibility of relatively poor host plants to infection by *H. zeae*. Ringer et al. (6) reported that several cultivars of oat and wheat, which failed to support detectable reproduction of *H. zeae* when grown at fluctuating greenhouse conditions where average temperatures were 11–22 C, supported low levels of nematode reproduction when grown in growth chambers at 33 C. Our study showed that temperature affected not only nematode reproduction but also suppression of plant growth by the corn cyst nematode.

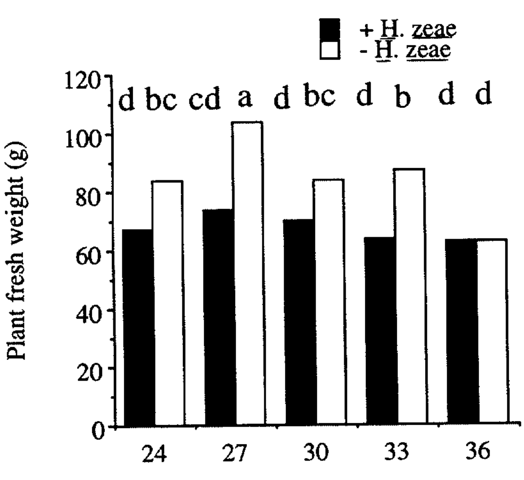

FIG. 2. Effect of temperature and presence or absence of *Heterodera zeae* life stages on fresh weight of Pioneer 3184 corn plants after 8 weeks in growth chambers. Bars with the same lowercase(s) are not significantly different ($P = 0.05$).

Our study showed that 36 C supported maximum reproduction of *H. zeae*. At 36 C there was no significant difference in total fresh weight between *H. zeae*-inoculated and uninoculated corn plants. Total fresh weights of uninoculated plants grown at 36 C were significantly lower than when grown at 27–33 C. Suppression of corn plant growth by *H. zeae* in plant growth chambers at 27–33 C is in accord with the damage to corn in the field in India and Egypt, where soil temperatures reach more than 35 C in the daytime for several weeks during the corn growing season.

Wallace (8) suggested that, in general, nematodes have optimum temperature requirements for reproduction in the range of 20–30 C and minimum requirements of 10–15 C. The results of our study demonstrated that *H. zeae* has an optimum temperature of 36 C for reproduction, which is the highest reported for any cyst nematode. The maximum and minimum temperatures used in the present study were selected after it was determined that at continuous temperatures above 38 C, corn plants grew very poorly and that below 24 C, development of *H. zeae* was very slow. However, temperatures would fluctuate in a field, and a diurnal maximum of 38 C might be reached without the plants being exposed to a 38 C average for any extended time. Our study further suggests that in warmer regions of the United States, *H. zeae* might develop high soil population densities and might be an economically important pest of corn. Although the geographic range of *H. zeae* is not known, the high temperature optimum for reproduction and its sensitivity to cool temperatures suggest a tropical or subtropical origin.

Literature Cited

1. Aboul-Eid, H. Z., and A. I. Ghorab. 1981. The occurrence of *Heterodera zeae* in maize fields in Egypt. Egyptian Journal of Phytopathology 13:51–61.

2. Hutzell, P. A., and L. R. Krusberg. 1990. Temperature and the life cycle of *Heterodera zeae*. Journal of Nematology 22:414–417.

3. Koshy, P. K., and G. Swarup. 1971. Distribution of *Heterodera avenae, H. cajani,* and *Anguina tritici* in India. Indian Journal of Nematology 1:106–111.

4. Koshy, P. K., G. Swarup, and C. L. Sethi. 1971. *Heterodera zeae* n. sp. (Nematoda: Heteroderidae), a cyst-forming nematode on *Zea mays*. Nematologica 16:511–516.

5. Krusberg, L. R., and S. Sardanelli. 1989. Survival of *Heterodera zeae* in soil in the field and in the laboratory. Journal of Nematology 21:347–355.

6. Ringer, C. E., S. Sardanelli, and L. R. Krusberg. 1987. Investigations of the host range of the corn cyst nematode, *Heterodera zeae,* from Maryland. Journal of Nematology 1:97–106.

7. Sardanelli, S., L. R. Krusberg, and A. M. Golden. 1981. Corn cyst nematode, *Heterodera zeae,* in the United States. Plant Disease 65:622.

8. Wallace, H. R. 1961. The bionomics of the free living stages of 200 parasitic and phytoparasitic nematodes. A critical survey. Helminthological Abstracts 30:1–22.