EFFECT OF SOIL TEMPERATURE ON *LONGIDORUS AFRICANUS* DAMAGE TO CARROT AND LETTUCE SEEDLINGS

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ABSTRACT

Huang, X., and A. T. Ploeg. 2001. Effect of soil temperature on *Longidorus africanus* damage to carrot and lettuce seedlings. Nematropica 31:87-93.

The effect of soil temperature on *Longidorus africanus* damage to lettuce and carrot seedlings was studied in greenhouse experiments. Cones containing 70 ml sterilized sand were seeded with carrot or lettuce, inoculated with a range of *L. africanus* densities and placed in waterbaths maintaining soil temperatures of 17, 20, 25, or 30°C. At harvest, 30 days and six weeks after inoculation for lettuce and carrot respectively, lettuce dry weights and carrot fresh weights were determined. Data analysis showed that minimum yields were significantly lower at 25°C than at 17°C but that effects of soil temperature on tolerance limits were very minor. Results from this study suggest that seeding of carrot or lettuce at soil temperatures ≤17°C would significantly reduce damage by *L. africanus*.

Key words: carrot, damage function, lettuce, *Longidorus africanus*, minimum yield, temperature, tolerance.

RESUMEN

Huang, X., and A. T. Ploeg. 2001. Efecto de la temperatura del suelo sobre el daño causado po *Longidorus africanus* en plantas de zanahoria y lechuga. Nematrópica 31:87-93.

El efecto de la temperatura del suelo sobre el daño causado por *Longidorus africanus* en plantas de lechuga y zanahoria se estudió en condiciones de invernadero. Semillas de zanahoria o lechuga previamente incubadas con diferentes densidades de *L. africanus* se sembraron en conos que contenían 70 ml de arena esterelizada. Posteriormente, los conos se colocaron en baño maría para matener las temperaturas del suelo a 17, 20, 25, ó 30°C. La cosecha se realizó a los 30 días y seis semanas después de la inoculación de la lechuga y zanahoria respectivamente. En ese momento se midió el peso seco de la lechuga y peso fresco de la zanahoria. El análisis de los datos demostró que los mínimos rendimientos fueron significativamente más bajo a 25°C que a 17°C, pero el efecto de la temperatura del suelo en los limites de tolerancia fueron menores. Estos resultados sugieren que el cultivo de la lechuga y zanahoria en suelos cuya temperatura es inferior a los 17°C reduciría significativamente el daño causado por *L. africanus*.

Palabras claves: función de daño, lechuga, *Longidorus africanus*, redimiento mínimo, temperatura, tolerancia, zanahoria.

INTRODUCTION

The distribution of the ectoparasitic nematode *Longidorus africanus* Merny appears to be restricted to areas with hot desert-type climates e.g., Egypt, Israel, Portugal, Sudan, South Africa, and Southern California (Aboul-Eid, 1970; Bravo and Roca, 1995; Cohn, 1969; Jacobs and Heyns, 1987; Radewald *et al.*, 1969a; Zeidan and Coomans, 1992). This nematode has a wide host range (Cohn and Mordechai, 1969; Kolodge *et al.*, 1986, 1987), but in the Imperial Valley of Southern California, USA, carrot and lettuce are particularly susceptible to damage (Lamberti, 1986; Radewald *et al.*, 1969a). Aboveground symptoms of *L. africanus* infestations in these crops are generally nonspecific and may include stunting, chlorosis and wilting (Kolodge *et al.*, 1986; Radewald *et al.*, 1969a). In lettuce, *L. africanus* causes root-tip galling and severe retardation of root growth (Huang and Ploeg, 2001; Radewald *et al.*, 1969a). Typical symptoms in carrot include stubbing and forking of the taproot (Huang and Ploeg, 2001; Kolodge *et al.*, 1986), that may result in severe economic losses.

Relationships between initial nematode population densities (Pi) and plant growth can be modeled according to Seinhorst's damage function:

$$y/y_{max} = 1 \text{ for Pi} \leq T\text{, and}$$
$$y/y_{max} = m + (1\text{-}m) \times 0.95^{(Pi/T)-1} \text{ for Pi} > T \quad \text{(I)}$$

with y_{max} representing plant growth in the absence of nematodes, Pi the initial nematode density, *m* the minimum yield obtained even at very high initial population densities, and *T* the tolerance limit i.e., the lowest population density affecting plant growth (Seinhorst, 1998). Estimated values of *m* and *T* for *L. africanus* on carrot and lettuce were very low compared to several other nematode-crop associations, indicating the high susceptibility of these crops to damage by this nematode species (Huang and Ploeg, 2001).

Field studies in the Imperial Valley, CA, showed a strong correlation between the vertical distribution of *L.africanus* and soil temperature, with high populations occurring in the upper soil layers during the hot summer months (Ploeg, 1998). The relatively high optimum soil temperature of *ca.* 30°C for *L. africanus* multiplication (Lamberti, 1969; Ploeg, 1999) confirmed the preference of this nematode for warm conditions.

Longidorus africanus can be effectively controlled with nematicides (Radewald *et al.*, 1969b), but because of increasing costs and restrictions on their use, alternative methods need to be developed. Adjustment of sowing or planting dates to periods when nematode population levels are generally low or nematodes are inactive, has been shown to be promising for reducing crop damage by other nematodes (Belair, 1987; Jeffers and Roberts, 1993; Pacumbaba and Tadesse, 1991; Roberts, 1987). In the Imperial Valley, CA, where carrot and lettuce are sown nearly year round, average soil temperatures at 15 cm depth range from ca. 30°C in summer, to ca. 13°C in winter (Fig. 1). The objective of this study was to determine the effect of soil temperature on the relationship between initial population densities of *L. africanus* and damage to lettuce and carrot seedlings, and from the results obtained, to evaluate the possibility to avoid crop damage by adjusting sowing dates.

MATERIAL AND METHODS

Longidorus africanus, originally obtained from carrot field soil in the Imperial Valley, were cultured on tomato (*Lycopersicon esculentum* Mill. cv. Pixie) in 1-L pots in a greenhouse at a constant soil temperature of 26°C in steam-sterilized coarse sand. Subculturing took place every 2 to 3

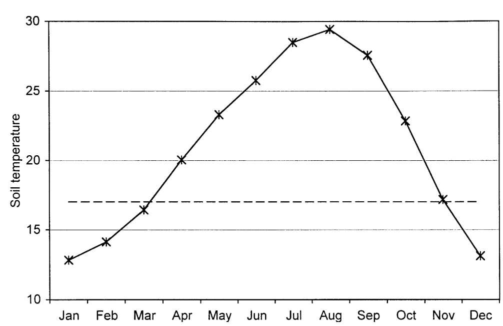

Fig. 1. Monthly average soil temperature (°C) at 15 cm depth for El Centro, Imperial County, CA over the 1989-2000 period. Calculated from data at http://www.ipm.ucdavis.edu/. Dashed line at 17°C.

months. Nematodes used as inoculum were extracted from the cultures with a modified sieving and decanting technique (Brown and Boag, 1988). Final separation was by migration of the nematodes through a 100 µm pore nylon sieve for 12 hours into a plastic saucer filled with enough water to touch the bottom of the sieve. Inocula containing 5, 10, and 20 *L. africanus* per 2 ml were handpicked from the suspension using a fine needle, higher inoculum densities were prepared by concentration or dilution of the original nematode suspension.

Three seeds of lettuce (*Lactuca sativa*, L. cv. Burpee's Iceberg, Burpee Seeds, Warminster, PA) were sown in each of 192 plastic cones (80 ml volume; Stuewe & Sons, Corvallis, OR), closed at the bottom and filled with 70 ml steam-sterilized sandy soil. The cones were placed in 48, 1-L plastic cups (4 cones per cup), and the space between the cones and the inside of the cup was filled with sand. The cups were then placed in waterbaths running at 17, 20, 25 or 30°C (±1°C), with the water level *ca.* 1 cm below the upper rim of the cup, but level with the upper rims of the cones in the cups. Thus, each waterbath contained 12 cups holding a total of 48 cones. One of eight *L. africanus* inoculum levels (0, 5, 10, 20, 50, 100, 200, or 400 nematodes) was assigned at random to each of these 48 cones (six cones per inoculum level) for each waterbath. Immediately after seeding, a shallow hole was made in the sand in each cone and 2 ml of a suspension containing the previously assigned number of *L. africanus* were poured into the hole in each cone. Soon after emergence of the seedlings, they were thinned to 1 seedling per cone. The plants were watered as necessary and fertilized with full strength liquid fertilizer weekly. Thirty days after inoculation, the lettuce plants were carefully removed from their cones, and the root systems were washed free of soil. Tops were separated from the roots and placed in an oven at 65°C. Four days later, dry weights of tops and roots were determined. An experiment using carrot cv. Triumph (Petoseed, Saticoy, CA, USA) was set-up in a similar manner, but with inoculum densities of 0, 5, 10, 20, 50, 100 and 200 *L. africanus* added per cone (70 ml soil) resulting in a total of 168 cones (7 inoculum densities × 4 temperatures × 6 replicates). Carrots were harvested six weeks after inoculation and tap root fresh weight and length was determined. Relationships between plant growth and *L. africanus* inoculum densities were fitted to the Seinhorst model (I), and LSD's between estimated parameters were calculated using SAS statistical software (SAS Institute, Cary, NC, U.S.A.).

RESULTS

Longidorus africanus caused obvious symptoms on lettuce and carrot consisting of stunted top and root growth, root tip galling (lettuce and carrot) and tap root forking (carrot). Growth of the "no nematode control" carrot and lettuce plants was affected by temperature, with the carrots grown at 30°C, and the lettuce grown at 17°C resulting in the smallest plants (Table 1). When fitting the data to the Seinhorst model (I), more than 95% of the observed variance was accounted for, indicating a good fit (Figs. 2, 3, and 4). Tolerance limits for lettuce top growth (dry weight) were not significantly different ($P > 0.05$) between the four soil temperatures and averaged at *ca.* 11 *L. africanus* per L soil (Table 2). The estimated tolerance limit for lettuce root growth (dry weight) was significantly lower ($P \leq 0.05$) at soil temperatures of 25 and 30°C, than at 20°C (Table 2). At 25°C, the estimated minimum yield (dry weight) for lettuce

Table 1. Effect of soil temperature on growth of carrot and lettuce seedlings not inoculated with nematodes.

	Soil temperature			
Weight (g)	17	20	25	30
carrot fresh root	6.87 a[z]	7.50 a	7.49 a	3.34 b
lettuce dry top	0.57 c	0.74 ab	0.83 a	0.66 bc
lettuce dry root	0.29 b	0.39 ab	0.50 a	0.35 b

[z]Different letters within a row represent significant differences at the 95% confidence level.

top and root growth was significantly lower ($P \leq 0.05$) than at the 17°C soil temperature (Table 2). Similar results were obtained with carrots. The tolerance limit for tap root growth (fresh weight) was not affected by soil temperature ($P > 0.05$) and averaged *ca.* 19 *L. africanus* per L soil (Table 3). Estimates for tap root minimum yields (fresh weight) were lower ($P \leq 0.05$) at 25 and 30°C soil temperatures than at the 17°C soil temperature. There was a highly significant correlation between the length and the fresh weight of the carrot tap roots (corr. coeff. = 0.65, $P \leq 0.0001$).

DISCUSSION

Our results confirm the damaging potential of *L. africanus* to lettuce and carrot, with tolerance limits as low as 11 and 19 nematodes per L soil respectively, and maximum reductions of 64% in lettuce top dry weight and 43% in carrot tap root fresh weight. As the weight of the carrot tap roots was significantly correlated with their length, the nematodes also strongly affected tap root length. There were no significant effects of soil temperature on the tolerance limit for top growth of lettuce or

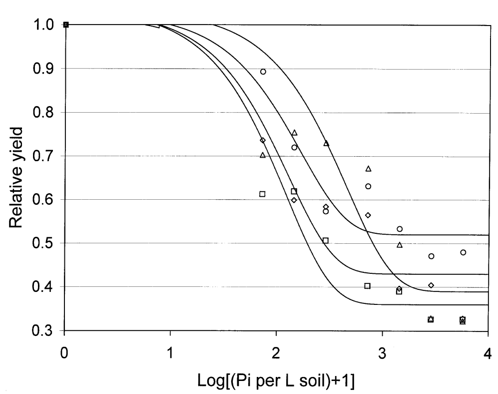

Fig. 2. Effect of soil temperature (○: 17°C, △: 20°C, □: 25°C, ◇: 30°C) on the relative yield (dry weight) of lettuce tops, 30 days after inoculation with a range of *Longidorus africanus* densities (Pi). Data points are averages of six replicates. Solid lines represent values fitted according to the Seinhorst model (I).

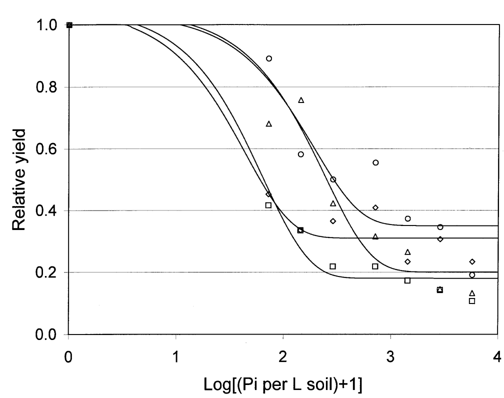

Fig. 3. Effect of soil temperature (○: 17°C, △: 20°C, □: 25°C, ◇: 30°C) on the relative yield (dry weight) of lettuce roots, 30 days after inoculation with a range of *Longidorus africanus* densities (Pi). Data points are averages of six replicates. Solid lines represent values fitted according to the Seinhorst model (I).

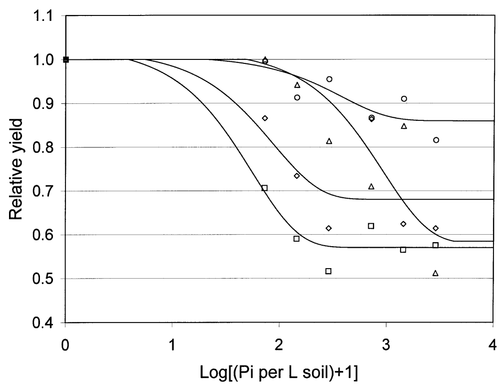

Fig. 4. Effect of soil temperature (○: 17°C, △: 20°C, □: 25°C, ◇: 30°C) on the relative yield (fresh weight) of carrot tap roots, six weeks after inoculation with a range of *Longidorus africanus* densities (Pi). Data points are averages of six replicates. Solid lines represent values fitted according to the Seinhorst model (I).

tap root growth of carrot. However, soil temperature did significantly affect minimum yields, with maximum damage occurring at 25°C. At this temperature, the maximum damage was always significantly higher than at 17°C. The optimum temperature for *L. africanus* multiplication and egg development was reported to be ca. 30°C (Lamberti, 1969; Ploeg, 1999). Nematode populations did not increase when cultured at temperatures below c. 23°C, although *L. africanus* eggs continued to develop at a slow rate at 17°C (Lamberti, 1969; Ploeg, 1999). Thus, the optimum temperature for nematode development and multiplication appears slightly higher than the temperature at which maximum damage occurs. Kolodge *et al.* (1987) suggested that the life cycle of *L. africanus* could be completed within 7-9 weeks under good hosts and at optimum soil temperatures. In our experiment, lettuce plants, good hosts for *L. africanus* (Kolodge *et al.*, 1986, 1987), were harvested after 30 days, and carrots, a mediocre host (Kolodge *et al.*, 1986) after 6 weeks. Therefore, it is very unlikely that the effect of soil temperature on minimum yields resulted from differences in nematode multiplication rates. It is more likely that the observed effects of temperature on minimum yields resulted from differences in nematode activity. Although no data are available to support this hypothesis, a maximum activity of the nematodes (e.g., movement, feeding) at c. 25°C would explain the data: soon after inoculation nematodes reach the roots and start feeding, causing initial damage at all temperatures. How-

Table 2. Effect of soil temperature on estimated tolerance limits (*T*; nematodes per L soil) and minimum yields (*m*) of lettuce seedlings 30 days after inoculation with *Longidorus africanus*.

	Soil temperature			
Dry weight	17	20	25	30
Top				
m	0.52 a[z]	0.39 ab	0.36 b	0.43 ab
T	8.65 a	23.29 a	6.26 a	6.59 a
Root				
m	0.35 a	0.20 ab	0.18 b	0.31 a
T	9.77 ab	12.39 b	3.33 a	2.27 a

[z]Different letters within a row represent significant differences at the 95% confidence level.

Table 3. Effect of soil temperature on estimated tolerance limits (*T*; nematodes per L soil) and minimum yields (*m*) for carrot tap root growth (fresh weight) six weeks after inoculation with *Longidorus africanus*.

	Soil temperature			
	17	20	25	30
m	0.86 a[z]	0.58 ab	0.57 b	0.68 b
T	19.58 a	47.66 a	2.89 a	4.52 a

[z]Different letters within a row represent significant differences at the 95% confidence level.

ever, only at temperatures close to 25°C, would feeding be frequent and nematodes continue to move to new root tips throughout the period, ultimately resulting in strong growth reductions. Roberts *et al.* (1981) reported that the temperature range in which *Meloidogyne incognita* was active, was different from the temperature range in which the nematodes developed. A similar phenomenon could explain the apparent discrepancy between temperature optima for *L. africanus* multiplication and damage potential. Our results suggest that severe damage to lettuce or carrot by *L. africanus* can be avoided by sowing these crops during periods when soil temperatures are close to or lower than ca. 17°C. In the Imperial Valley of Southern California, where *L. africanus* occurs, this would correspond to the period from November through March. However, for the lettuce variety used in this study, the reduction in nematode damage at 17°C was nearly nullified by the inhibition of seedling growth due to temperature. Field experiments on the effect of adjusting sowing dates of carrot and lettuce on damage caused by *L. africanus* remain to be done, but this practice may provide growers with an additional tool for an integrated nematode management strategy.

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