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Effect of *Meloidogyne incognita* and *M. javanica* on Leaf Water Potential and Water Use of Tobacco[1]

G. S. Rahi, J. R. Rich, and C. Hodge[2]

Abstract: Greenhouse lysimeter and field microplot tests were conducted to evaluate the effects of *Meloidogyne incognita* and *M. javanica* on plant water relations and growth performance of NC 2326 flue-cured tobacco. In the greenhouse, afternoon leaf water potential values at 8–11 weeks after transplanting were lower by as much as 0.22 MPa in plants infected with either nematode than in the control plants. From 11 to 22 weeks, leaf water potential values were similar in all treatments. Over the course of the 22-week experiment, all infected plants showed similar evapotranspiration patterns, and plants in these treatments used 87–88% of the water utilized by noninfected plants. Biomass production from nematode-infected plants, however, was only about 50% of the biomass of control plants. The field microplot study showed water use patterns similar to those in the lysimeter study.

Key words: evapotranspiration, leaf water potential, *Meloidogyne incognita, Meloidogyne javanica, Nicotiana tabacum.*

The effects of nematodes on the ability of plants to absorb water have been widely investigated (4,9,11,15,18). Cotton plants infected with *Meloidogyne incognita* use water equal to or greater than noninfected plants when the soil is maintained at or near field capacity (13). When water fluctuates between 50 and 100% of field capacity, nematode-infected plants use about one-half the amount of water used by control plants. Water use and water use efficiency of nematode damaged sorghum, corn, and potato plants are less than those of healthy plants (2,11).

Studies have indicated that transpiration of plants is affected by nematode parasitism. Transpiration rates of *M. incognita*-infected tomato and tobacco plants are higher on a per unit leaf tissue basis than those of noninfected plants (14,19). Potato plants heavily infected with *Globodera rostochiensis* have greater stomatal resistance and lower plant water potential values than do lightly infected plants (3). Tomato plants infected with *M. javanica* experience increased suction pressure in roots, but no difference in transpiration rates of the infected and control plants has been observed (12). Diffusive resistance, however, appears to increase in infected plants as infection progresses and is higher than in healthy plants. On the other hand, it was found that a resistant and a susceptible potato variety behave identically in wet soil infested with nematodes, but leaf water potentials of the susceptible variety are significantly lower in a relatively dry soil (9). Inoculum density of *Pratylenchus penetrans* did not always affect transpiration rates of different potato cultivars (10); however, root hydraulic conductivity of susceptible varieties was adversely affected by nematode infection.

Most of the previous studies dealt with short-term effects of nematodes on plant water relations. There is a lack of information on soil and plant water relations, water use, and water use efficiency (ratio of water use to dry matter produced) on a long-term or cumulative basis. Therefore, the present studies were designed to evaluate the effect of nematode infection, specifically *M. incognita* and *M. javanica,* on plant growth, soil and plant water relations, weekly and cumulative water use (evapotranspiration), and water use efficiency in tobacco.

Materials and Methods

Lysimeter studies: Lysimeters (55 cm d and 45 cm deep) were constructed from 0.7-cm-thick plastic barrels. A 5-cm-thick layer of 0.5–1.0-cm-d pieces of inert rock was

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[1] Florida Agricultural Experiment Station, Journal Series No. 8366.

[2] Assistant Research Scientist, Professor, and Biologist II, University of Florida, IFAS Agricultural Research and Education Center, Route 2, Box 2181, Live Oak, FL 32060.

placed at the bottom, and lysimeters were fitted with drainage outlets. The lysimeters were filled with methyl bromide treated Lakeland fine sand (*Typic Quartzipsamments, thermic,* coated, 93% sand, 4% clay, 3% silt), packed to an approximate bulk density of 1.40 g/cm^3. Soil was infested with 30 eggs and juveniles of *M. incognita* (Kofoid and White) Chitwood or *M. javanica* (Treub) Chitwood per 100 cm^3 soil. Nematode inoculum was collected from roots of *Lycopersicon esculentum* Mill. cv. Rutgers tomato by using the sodium hypochlorite method (6). After infesting the soil, two 7-week-old NC 2326 tobacco seedlings were transplanted into each lysimeter. The three treatments (control, *M. incognita,* and *M. javanica*) were placed in a randomized complete block design containing eight replications. Standard practices for growing healthy tobacco plants were followed.

After transplanting, soil in each lysimeter was brought to field capacity. Initially, an equal amount of water was added weekly to each lysimeter for 8 weeks for establishment of seedlings. During the 8–18-week period, calculated amounts of water were added twice a week to each lysimeter to maintain moisture at or near field capacity. Calculations were based on average weekly evapotranspiration (ET) rates averaged over replications in a given treatment. During the final 4 weeks before harvest, the actual amount of water depleted in each lysimeter in the preceding week was replenished instead of adding water based on average ET rates. This was done because control lysimeters started showing significant differences in their individual water requirements.

Because of slow growth resulting from cool winter temperatures, 8 weeks were allowed for plant establishment before any data were collected. Data then collected on a weekly basis included plant height, soil water content, and leaf water potential. The height of each plant, from base to terminal bud, was measured until 5 weeks before harvest. Soil water content was determined gravimetrically in each lysimeter, and these data were utilized to interpret leaf water potential measurements. Soil was replaced in the lysimeters after each water content measurement. Differences in soil water status and the amount of water added to each lysimeter were used to compute weekly evapotranspiration rates. Leaf water potential was evaluated using a pressure bomb technique (16). Leaf water potential measurements were made on the sixth fully expanded leaf from the top of the plant between 2 and 3 p.m. at weekly intervals when soil samples were taken for water content measurements. The sixth leaf was used in these measurements because preliminary measurements with a number of leaf positions indicated that this leaf gave the most consistent water potential values.

Twenty-two weeks after transplanting, fresh and dry biomass weights, root gall index ratings, and second-stage juvenile numbers in the soil were determined. Plants were excised at the soil line and fresh weight was determined. Plants were then dried in an oven at 70 C for 48 hours and weighed. The total biomass (fresh or dry) computations included leaves that had become detached through senescence or were removed for water potential measurements. Root galling was rated on a scale of 0–4 with 0 = no gall development and 4 = > 76% root galling. A modified centrifugation sugar-flotation technique was used to extract juveniles from 250 cm^3 soil (7).

Microplot studies: Fiberglass microplots (76 cm d and 60 cm deep) were established in Lakeland fine sand (8). Soil in the microplots was treated with 988 kg methyl bromide and 189 liters 1,3-dichloropropene per hectare to eliminate weed and nematode contamination. On 17 April 1985 individual microplots were infested with *M. incognita* or *M. javanica* at the rate of 56 eggs and juveniles per 100 cm^3 soil to a depth of 23 cm. Two NC 2326 tobacco seedlings were transplanted into each microplot on 23 April 1985. Three treatments including a noninfested control were arranged in a randomized complete block design and replicated 12 times. Plants were grown for 2 weeks before water potential

TABLE 1. Influence of *Meloidogyne incognita* and *M. javanica* on plant growth, root galling, and second-stage juveniles in tobacco grown in lysimeters.†

Measurement	*M. incognita*	*M. javanica*	Control
Plant height (cm)	72.0 b	66.0 b	87.0 a
Plant fresh weight (g)	85.0 b	107.2 b	210.4 a
Plant dry weight (g)	12.8 b	16.1 b	31.6 a
Root gall rating‡	4.0 b	3.9 b	0.0 a
Juveniles/250 cm^3 soil	1,027.0 b	855.0 b	20.0 a

Means in horizontal array followed by the same letters are not significantly different according to Duncan's new multiple-range test ($P \leq 0.05$).

† Data taken 22 weeks after transplanting.

‡ Root gall rating: 0 = no galling, 1 = 1–25, 2 = 26–50, 3 = 51–75, and 4 = 76–100% of roots galled.

and water content measurements were initiated.

Data collection was similar to that made in the lysimeter studies. Six of the microplots in each treatment were used for leaf water potential measurements and the remainder for evaluation of evapotranspiration patterns. Leaf water potential measurements were made periodically during the growth span of the crop. Evapotranspiration patterns of the tobacco plants were evaluated during rain-free periods of the growing season. For evapotranspiration calculations, soil was considered to be at or near field capacity 36–48 hours after rain or irrigation of 4 cm or greater. Soil samples for water content determination were taken at that time and again after 24–48 hours. The differences in water content in the two determinations represented evapotranspiration patterns during different growth stages of the plant. Plants were harvested three times over the season, and fresh weights were determined. Root gall index ratings were made at the last harvest, 15 weeks after transplanting.

RESULTS AND DISCUSSION

Tobacco growth was suppressed by both *M. incognita* and *M. javanica* when compared with controls in the lysimeter studies (Table 1). Mean weekly heights of control plants were significantly greater than heights of infected plants only at 17 weeks after transplanting. Fresh and dry biomass of infected plants was nearly half of that produced by the control plants. Roots of infected plants were heavily and equally galled by both nematode species.

Leaf water potential values varied from −1.4 to −0.7 Mega Pascal (MPa) between 9 and 19 weeks after transplanting in all treatments. As plants aged, water potential values generally decreased in all treatments. Beginning 9 weeks after transplanting, the first three weekly plant water potential measurements in the *M. incognita*-infected plants were −0.78, −1.14, −0.89, compared with −0.72, −0.92, −0.75 MPa in the controls. Leaf water potential values observed in the *M. javanica*-infected plants were very similar to those of *M. incognita*-infected plants. These values indicated that leaf water potential of infected plants was reduced as much as 0.22 MPa, compared with the control plants. Later leaf water potential measurements did not differ significantly for any treatment. The lower leaf water potential values of infected plants during the early growth stages may have resulted from accelerated growth of the plants due to nematode infection, similar to the response reported earlier in tobacco (15).

Leaf water potential values in relation to soil water content for control plants exhibited a significant positive and linear relationship (Fig. 1). The relationship between leaf water potential and soil water content for nematode-infected plants was not significant, however; consequently data for only *M. incognita* are shown. These trends indicated that control plants were more sensitive than the nematode-infected plants to the changes in soil water content, probably because of healthier roots.

Weekly evapotranspiration (ET) rates in the control and *M. incognita*-infected plants were similar during weeks 9–11 after transplanting (Fig. 2). Water use values of the nematode-infected plants became lower after 11 weeks, and the difference between ET values of the control and diseased plants increased with plant age. All infected plants used comparatively less water, sometimes as little as 40% of the

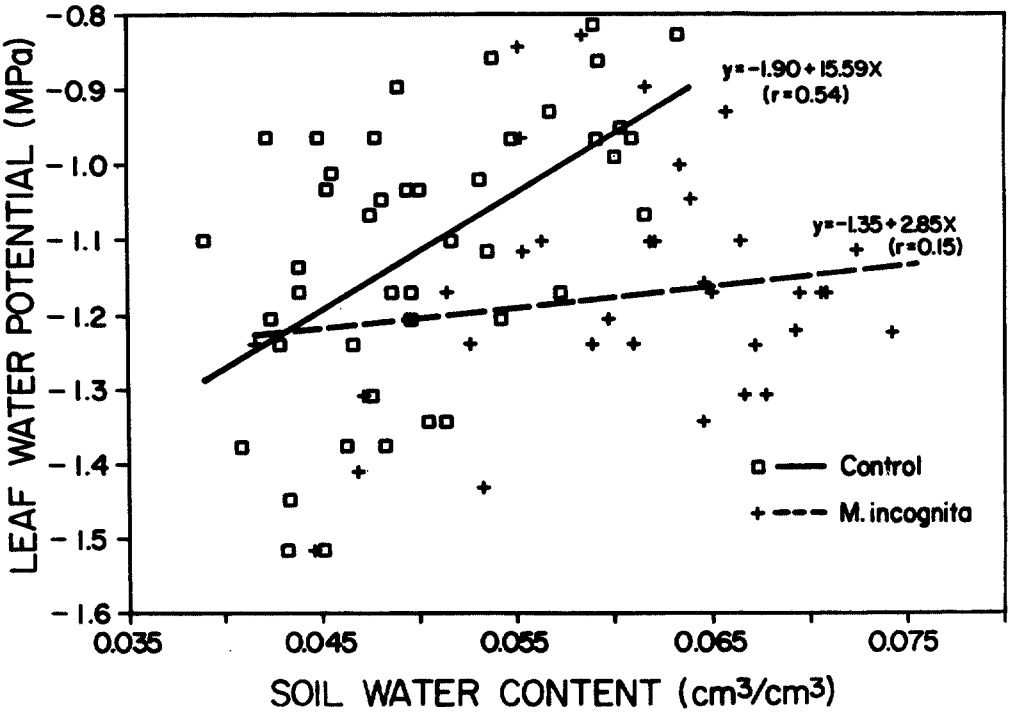

FIG. 1. Influence of *Meloidogyne incognita* on the relationship between tobacco leaf water potential and soil water content in a greenhouse lysimeter test.

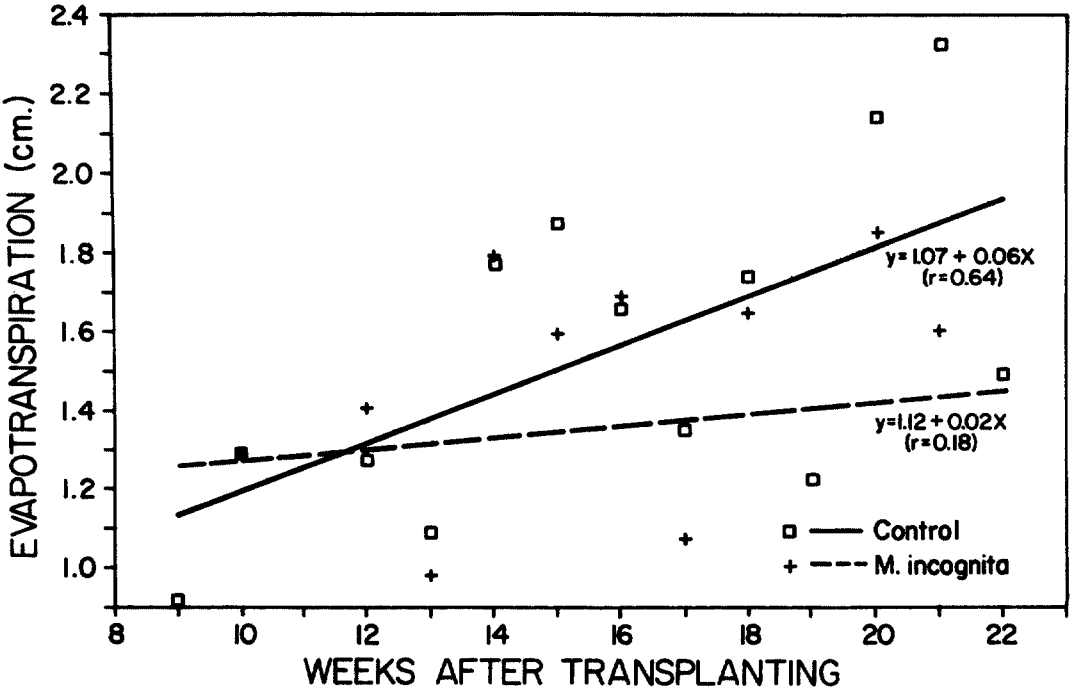

FIG. 2. Influence of *Meloidogyne incognita* on evapotranspiration of tobacco grown in greenhouse lysimeters.

TABLE 2. Water use of tobacco as influenced by *Meloidogyne incognita* and *M. javanica* in lysimeters.

Measurement	*M. incognita*	*M. javanica*	Control
Evapotranspiration (cm)†	19.01 a	18.84 a	21.54 a
Total water use (cm)	25.62 a	25.45 a	28.15 a
Water use efficiency (kg water/g dry wt)	5.12 a	4.04 a	2.82 b

Means in horizontal array followed by the same letters are not significantly different according to Duncan's new multiple-range test ($P \leq 0.05$).

† Water for initial establishment to 8 weeks was 6.61 cm in each lysimeter, and cumulative measurements were made weekly during weeks 9–22 after transplanting.

water utilized by control plants. Linear regression analysis indicated that weekly ET rates of the control plants significantly increased with time, whereas no significant relationship was observed for nematode-infected plants. The weekly ET rates for *M. javanica*-infected plants were similar to those for the *M. incognita*-infected plants. An earlier study indicated that infected cotton plants used water equal to or greater than the control plants if soil water was maintained at or near field capacity (13); however, the control plants used twice as much water as infected plants when soil water fluctuated between 50 and 100% of field capacity. Our studies revealed that healthy and infected plants in the initial stages have comparable water use rates, but with age the diseased plants extracted less water even when the soil contained water at or near field capacity.

Cumulative water use (ET) during weeks 9–22 by infected plants was about 88% (*M. incognita*) and 87% (*M. javanica*) of the total water use of the control plants (Table 2). There was no significant difference among treatments in cumulative water use. Water use efficiency computed from total water use and dry matter production, however, showed that nematode-infected plants used significantly higher amounts of water per unit dry mass. They used about twice the amount of water used by control plants to produce the same amount of dry mass. These data suggested either increased surface evaporation, increased transpiration rates, or both in nematode-infested lysimeters. These data conform to observations of others who found higher transpiration rates in nematode-infected plants (2,15,19).

In the microplot studies, measurements made on days during rain-free periods also showed that leaf water potential values for nematode-infected plants were lower in the initial stages, sometimes by as much as 0.20 MPa, relative to control plants. The leaf water potentials ranged from −1.5 to −1.0 for *M. incognita*-infected plants and from −1.3 to −0.8 MPa for control plants. During the later stages of plant growth, control plants exhibited lower leaf water potential than the *M. incognita*-infected plants. This probably was caused by the greater transpiration rates of healthy plants under fluctuating natural rainfall conditions.

Water use patterns in the microplots similarly indicated that in the initial growth stages (up to about 11 weeks), water use was not different for nematode-infected and healthy plants (Table 3). Later (12–15 weeks), however, the control plants were extracting more water than the plants in-

TABLE 3. Water use and growth of tobacco 9, 11, 12, and 14 weeks after transplanting as affected by *Meloidogyne incognita* and *M. javanica* in microplots.

Treatment	Evapotranspiration				Fresh biomass (g/microplot)	Root gall rating†
	9	11	12	14		
M. incognita	2.11	2.80	2.27	2.99	863	3.8
M. javanica	2.19	2.73	1.99	2.59	940	3.5
Control	2.15	2.68	2.47	3.31	1,365	0.7

† Root gall rating in Table 1.

fected with *M. incognita* or *M. javanica*. Similar trends for evapotranspiration were observed in both the lysimeter and field microplot studies. Microplot experiments were conducted to investigate water uptake trends only, therefore no statistical analysis was executed on the data.

Compared with plants in control microplots, nematode-infected plants produced significantly smaller amounts of fresh biomass and their roots were severely galled (Table 3). Water use efficiency values for microplots were not compared because of uncontrolled environmental conditions. The water use patterns and amount of fresh biomass produced in different treatments, however, indicated that nematode-infected plants were using the same amount of water as the control plants, or just slightly less, for production of proportionately smaller amounts of biomass. These microplot studies confirm observations, made from lysimeter studies, that nematode-infected tobacco plants have lower water use efficiency than noninfected plants.

The reduced biomass production in nematode-infected plants may be attributed, in part, to reduction in leaf water potential as observed in these studies (up to 0.22 MPa). A decrease in tissue water potential of as little as 0.1 MPa may halve the rate of cell division (5). The decrease in plant water potential also affects other physiological functions, such as photosynthesis, stomatal closure, and carbon fixation efficiency, thus resulting in reduced plant growth (17,20).

Results of these studies indicate that water potential values of control plants could serve as an index of soil moisture, but no such relation exists for the nematode-infected plants. The differences in growth of nematode-infected and control plants were not reflected in their water use, especially cumulative water use. Previous results indicate that the total or cumulative water use (transpiration + soil evaporation) is not significantly affected by nematodes if soil moisture is maintained at or near field capacity (13). The computed water use efficiency values, however, showed that the diseased plants were only half as efficient water users as the control plants. Fluctuations in weekly evapotranspiration rates for control plants were more distinct and were characteristic of normal plant requirements. Weekly ET values, however, were less distinct for nematode-affected plants and were more typical of climatic water demand. This behavior of nematode-infected plants could be attributed to adversely affected transpirational requirements. Water absorbed by the diseased plants may not be utilized efficiently because they lack effective mechanisms to regulate internal water balance. Research has indicated that plant pathogens may immobilize stomata or lower stomatal resistance resulting in lower water use efficiency of the plant (1).

In our investigations of total plant water use, the loss of water due to soil surface evaporation was not separated. Further research is needed to evaluate the effect of nematode infection on the transpiration of tobacco plants.

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