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Ethylene Production by *Meloidogyne* spp.-Infected Plants[1]

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Abstract: Gall size and rates of ethylene production by various hosts infected with *Meloidogyne javanica* and by excised tomato root cultures infected with *M. javanica* or *M. hapla* were measured. Infection with *M. javanica* increased the rate of ethylene production in dicotyledonous plants (cabbage, pea, carrot, cucumber, carnation, and tomato), but not in infected monocotyledonous plants (corn, wheat, and onion). Nematode infection induced large galls on roots of dicotyledonous, but not monocotyledonous, plants. Excised tomato roots in culture infected with *M. javanica* produced ethylene at high rates and formed large galls, whereas roots infected with *M. hapla* produced ethylene at low rates and induced smaller galls.

Key words: Meloidogyne javanica, M. hapla, monocotyledon, dicotyledon, gall size.

The relationship between *Meloidogyne* spp.-induced galls and plant growth regulators has been studied for many years (2,8). However, the role of ethylene in gall formation has received little attention (1,9–12). Increased rate of ethylene production in tomatoes was closely associated with formation of root galls induced by *Meloidogyne javanica* (5). The rate of gall growth was accelerated by stimulators of ethylene production and suppressed when the production or action of the hormone was inhibited (6). These findings suggested that ethylene plays a major role in the pathogenic symptoms displayed by *M. javanica*-infected plants.

The present study examined the rates of ethylene production by various hosts infected with *M. javanica* and by the same host infected with *M. javanica* or *M. hapla,* emphasizing the relationship between ethylene production and gall size.

MATERIALS AND METHODS

Ethylene evolution and gall size were determined in seedlings of the monocotyledonous plants corn (*Zea mays* cv. Tal), wheat (*Triticum aestivum* cv. Barkai), and onion (*Allium cepa* cv. Uri) and dicotyledonous plants cabbage (*Brassica oleracea* cv. Tasty), pea (*Pisum sativum* cv. Target), carrot (*Daucus carota* cv. Danvers 126), cucumber (*Cucumis sativum* cv. Dixie), carnation (*Dianthus caryophyllus* cv. Goldstar), and tomato (*Lycopersicon esculentum* cv. Hosen Eilon). All the plants examined were susceptible to *M. javanica.* Seedlings were grown in a greenhouse in 500-ml plastic pots containing sterile quartz sand and were fertilized weekly with mineral nutrient solution. Ten days after planting, seedlings were inoculated with 2,000–2,200 eggs of *M. javanica* obtained from monoxenic cultures (7).

The rate of ethylene production by noninfected and infected seedlings was determined 16 days after inoculation, because in a previous study the highest rates of ethylene production by infected tomato plants occurred at this time (5). Potted plants were enclosed in glass jars, and accumulated ethylene was determined in 1 cc of air withdrawn from each jar with a gas syringe and injected into a gas chromatograph equipped with a flame ionization detector. The gas components were separated on a 91-cm-long glass column packed with 80–100-mesh activated alumina. At the end of the experiments the roots were examined visually for galls.

Ethylene production and gall growth of excised tomato roots in culture infected with *M. javanica* or *M. hapla* were also determined.

Tomato seeds were surface-sterilized with 1% sodium hypochlorite for 10 minutes, rinsed three times with sterile distilled water, and placed on 1% water agar in petri dishes. After germination 1-cm-long primary root tips were excised and transferred into petri dishes or 25-ml erlenmeyer flasks containing a chemically defined medium (13). Lateral roots that emerged were inoculated with egg masses of *M. javanica* or *M. hapla,* obtained from

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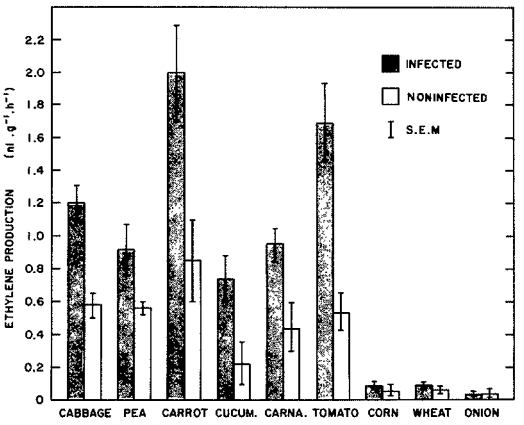

FIG. 1. Ethylene production determined 14 days after inoculation in various plants, noninfected and infected by *Meloidogyne javanica*.

monoxenic cultures, by placing the eggs 1–2 cm from root tips.

Ethylene production was measured in roots grown in 25-ml erlenmeyer flasks covered with cotton plugs. Ethylene in each flask was measured 18 days after nematode inoculation. Twenty-four hours before ethylene determinations, the cotton plugs were replaced by rubber caps to prevent loss of ethylene. Gas samples (1 cc) were tested for ethylene content, as described earlier. Ethylene production is expressed as nanoliters per gram fresh weight of whole plant tissue per hour. After ethylene measurements, the roots in the flasks were weighed and then 25 galls from each flask were weighed individually.

Each trial consisted of six replicate flasks and each test was conducted three times; the data are presented with the standard error of the mean.

RESULTS

Rates of ethylene production by different whole plants noninfected or infected with *M. javanica* varied (Fig. 1). Rates of ethylene production by noninfected monocotyledonous plants did not exceed 0.08 $nl \cdot g^{-1} \cdot h^{-1}$. In contrast, infected dicotyledonous plants produced far more ethylene, ranging from 0.2 to 0.9 $nl \cdot g^{-1} \cdot h^{-1}$. Infection with nematodes had no significant effect on the rate of ethylene production in monocotyledonous plants, whereas ethylene production was increased substantially by nematode infection in dicotyledonous plants (Fig. 1).

TABLE 1. Ethylene production and gall weight in excised tomato roots in culture, noninfected or infected with *Meloidogyne javanica* or *M. hapla*. Measurements taken 18 days after inoculation.

Treatment	Ethylene production ($nl \cdot g^{-1} \cdot h^{-1}$)	Average gall fresh weight (mg)
M. javanica	31 ± 8.0	3.2 ± 0.7
M. hapla	12 ± 3.0	1.8 ± 0.3
Noninfected control	3 ± 0.9	

Ethylene production varied considerably among the dicotyledonous plants examined (Fig. 1). Noninfected cucumber plants produced the least ethylene (0.2 $nl \cdot g^{-1} \cdot h^{-1}$) and *M. javanica* infection caused a 3.5-fold increase to 0.7 $nl \cdot g^{-1} \cdot h^{-1}$. Noninfected carrots produced ethylene at the rate of 0.85 $nl \cdot g^{-1} \cdot h^{-1}$ and *M. javanica* infection increased production to 2.0 $nl \cdot g^{-1} \cdot h^{-1}$. *M. javanica*-infected carrots and tomatoes produced the highest ethylene production. *M. javanica* infection induced large root galls in roots of dicotyledonous plants, but only small galls in roots of monocotyledonous plants.

Differences in ethylene production were noted not only in various hosts infected by the same root-knot nematode species, but also when excised tomato roots in cultures were infected by two different *Meloidogyne* species (Table 1). *M. javanica*-infected tomato roots produced three times as much ethylene per gram fresh weight of roots as roots infected by *M. hapla*. Root galls induced by *M. javanica* were also nearly twice as heavy as those induced by *M. hapla* (Table 1).

DISCUSSION

Differences in the rates of ethylene produced by monocotyledonous and dicotyledonous plants have been reported (3). Our results showed that, in general, dicotyledons infected by *M. javanica* produced ethylene at high rates, but such infection does not stimulate ethylene production in monocotyledons. It has been reported (4) that monocotyledonous plants, such as grasses, infected with root-knot nematodes either fail to form galls or produce smaller galls than those produced by dicotyledons.

This work provides further evidence of this phenomenon. Hence, ethylene production by plants infected with *M. javanica* correlated directly with the size of the galls induced. *M. javanica* induces large galls on tomato roots which produce more ethylene on a fresh gall weight basis than do the small galls induced by *M. hapla.* This provides further evidence of the relation between ethylene production and gall size. The differences in gall size are due to differences in growth intensity of the cortical hypertrophy rather than differences in the giant cells (5). Thus, one might suggest that there is a relation between ethylene production and the size of the cortical hypertrophy in galls induced by root-knot nematode species.

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