RESEARCH NOTES

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Penetration, Development, Reproduction, and Sex Ratio of *Meloidogyne javanica* in Three Carrot Cultivars[1]

S. P. Huang[2]

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Meloidogyne javanica (Treub.) Chitwood, 1949 is one of the most important root-knot nematode species affecting carrot (*Daucus carota* L.) in Brazil. The nematode galls tap roots causing significant economic loss. The most effective and inexpensive method of managing the nematode is to plant resistant cultivars. Our recent study (2) showed Nantes, the most widely planted carrot cultivar in Brazil, to be susceptible to *M. javanica,* whereas Kuronan and Brasilia cultivars were tolerant and resistant, respectively. My objective was to investigate the reactions of these carrot cultivars to *M. javanica* and to monitor the life stages of this nematode within them.

Soil in 200-ml plastic seedling cups was inoculated with 2,000 eggs of *M. javanica* per cup (2). Noninoculated cups served as controls. Carrot cultivars Nantes Superior, Kuronan, or Brasilia were seeded on the soil and after emergence thinned to two plants per cup. Cups were randomly arranged on a greenhouse bench.

Forty-eight seedlings were collected from each cultivar at 4, 9, 12, 24, 31, 34, and 40 days after emergence and divided into three lots of 16 each. Roots and shoots were weighed and numbers of root galls counted. Percentage of infected plants in each lot of 16 was calculated. The roots were stained by cotton blue-lactophenol solution (3) and then destained in clear lactophenol for at least 30 days before observation. Roots were macerated manually to release the nematodes. The resulting suspension was rinsed with water and passed through a 250-μm-pore sieve to remove root debris. Nematodes were collected on a 37-μm-pore sieve. The development stages and sex of *M. javanica* were determined (5).

In addition, 40, 44, and 54 days after seed germination five plants were collected from each cultivar and grouped into one replicate. Fresh roots were stained directly (1) and egg masses counted. Eleven replicates were evaluated in Nantes Superior, nine in Kuronan, and seven in Brasilia. Egg masses were dipped in 0.5% sodium hypochlorite for 30–45 minutes to release eggs for counting.

Nematodes had penetrated roots of all Nantes Superior and Kuronan plants 9 and 33 days after germination, respectively (Fig. 1A). At 40 days, 25% of Brasilia plants still did not exhibit root galls. Maximum penetration occurred 9–12 days after germination in all three cultivars (Fig. 1B). At 9, 12, and 24 days, Nantes Superior roots had more ($P = 0.01$) juveniles than did the other two cultivars.

Numbers of root-galls were different ($P = 0.05$) after 24 days in the three cultivars (Fig. 1C). Numbers of females in Brasilia after 24 days were fewer ($P = 0.05$) than in the other two cultivars (Fig. 1D). Numbers of root-galls and females in Brasilia decreased ($P = 0.05$) between 31 and 40 days after germination, indicating a hindrance to nematode development in roots.

As early as 4 days after germination, 6% of juveniles had begun to enlarge in Nantes Superior, but less than 1% had developed in Kuronan roots, and none were found in

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[2] CNPq-PESAGRO-RIO/EEI, Estrada Rio-São Paulo, Km 47, Seropédica, Itaguaí, Rio de Janeiro, CEP 23.851, Brazil.

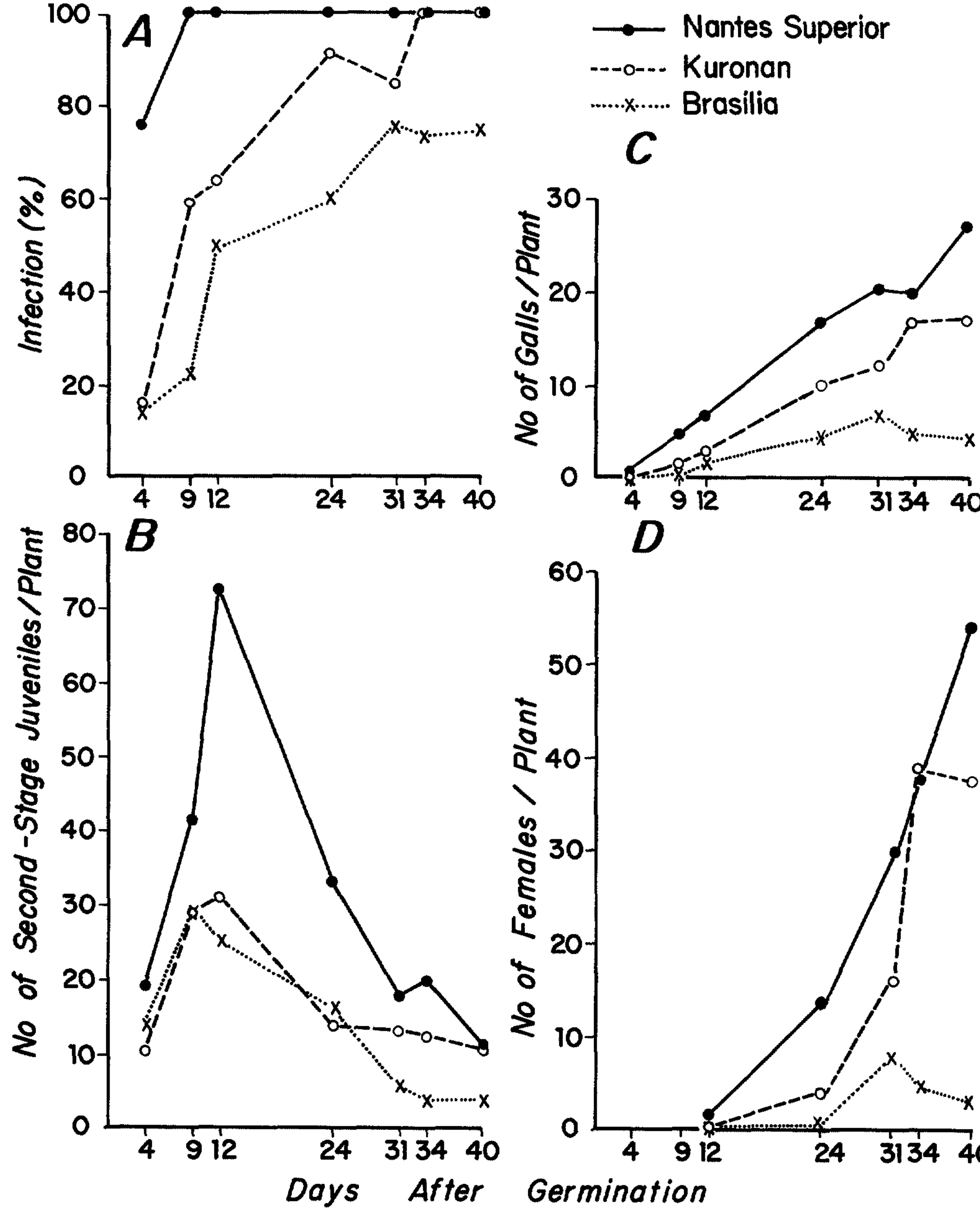

FIG. 1. Infection (A), penetration (B), gall formation (C), and female maturation (D) of *Meloidogyne javanica* in three carrot cultivars. Females include molted fourth-stage female juveniles and adult females; second-stage juveniles include preparasitic and parasitic second-stage juveniles.

Brasilia (Fig. 2). After 9 days, juvenile development in Kuronan and Nantes Superior were similar, whereas development was significantly less ($P = 0.05$) in Brasilia. At 24 days, only 3% of the nematodes had attained the fourth stage in Brasilia, as compared with 22% in Nantes Superior and 16% in Kuronan. A higher percentage ($P = 0.05$) of preparasitic second-stage juveniles was found in Brasilia than in the other two cultivars at all times.

The male : female ratio (%) at 31 days after germination was not different in the three cultivars (4.7 in Nantes Superior, 8.2 in Kuronan, and 3.3 in Brasilia). The ratio was not different between Kuronan (11.1) and Nantes Superior (12.9) at 34 days, but it was higher ($P = 0.05$) in Kuronan (27.1)

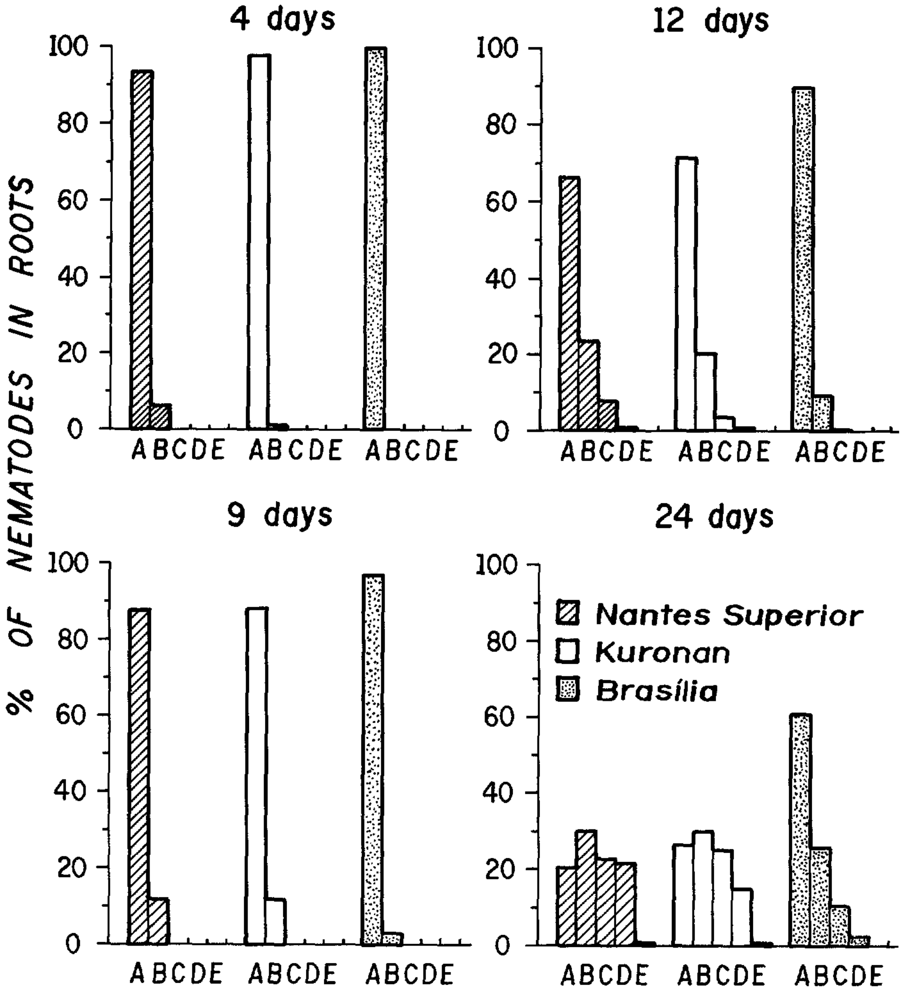

FIG. 2. Distribution of development stage of *Meloidogyne javanica* on three carrot cultivars. A = preparasitic second-stage juveniles (filiform shaped), B = parasitic second-stage juveniles (spindle shaped), C = third- to fourth-stage juveniles (sausage shaped), D = molted fourth-stage juveniles (molted sausage shaped), E = adults (females + males) (sac and filiform shaped, respectively).

TABLE 1. Reproduction of *Meloidogyne javanica* in three carrot cultivars at 40, 44, and 54 days after germination.

	Days					
	40		44		54	
Cultivar	Egg masses/ root system	Eggs/ egg mass	Egg masses/ root system	Eggs/ egg mass	Egg masses/ root system	Eggs/ egg mass
Nantes Superior	5.8 a	25 a	12.3 a	ND*	26.9 a	492 a
Kuronan	4.1 a	26 a	8.7 ab	ND	18.0 b	480 a
Brasilia	1.8 b	6 b	3.9 b	ND	2.3 c	247 b

Means in the columns followed by the different letter indicate significant difference in Duncan's multiple-range tests ($P = 0.05$).

* No data obtained.

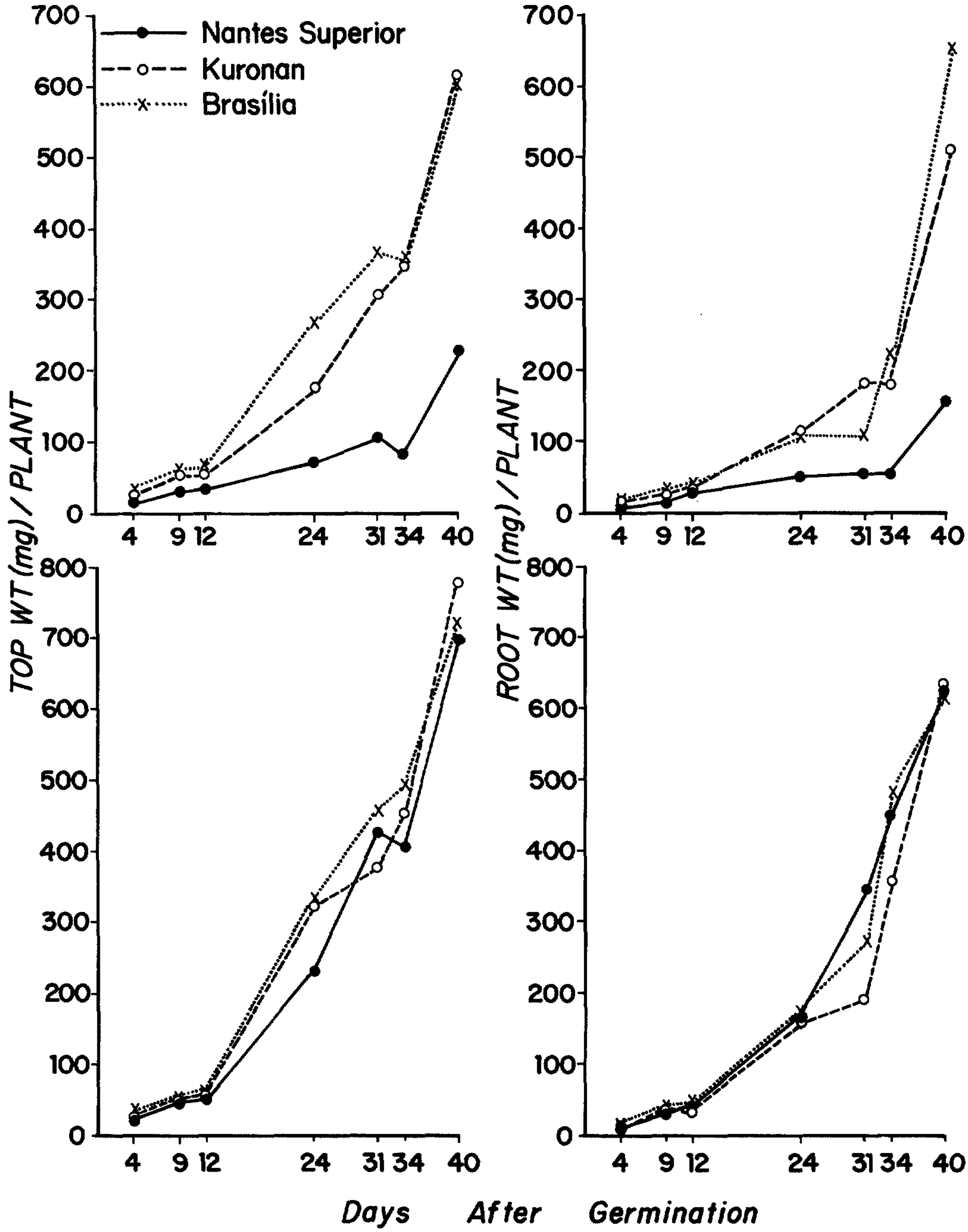

FIG. 3. Growth rates of three carrot cultivars inoculated (top) and noninoculated (bottom) with *Meloidogyne javanica*.

than in Nantes Superior (14.0) at 40 days. In Brasilia, females were few and males undetectable at 34 and 40 days.

At 40, 44, and 54 days, more ($P = 0.05$) egg masses were produced in Nantes Superior than in Brasilia (Table 1). Egg mass production in Kuronan was intermediate between the other two cultivars. Number of eggs per egg mass was lowest in Brasilia and similar in Nantes Superior and Kuronan.

Top and root growth in nematode-inoculated treatments were different ($P = 0.01$) between Nantes Superior and Brasilia or Kuronan, but not different ($P = 0.01$) between Brasilia and Kuronan (Fig. 3). Plant growth in the controls were not different ($P = 0.05$) in the three cultivars.

Seinhorst and Kozlowska (4) reported that during the development of carrot plants the population density of *Rotylenchus uniformis* was diluted because of fast growth of the root system. Vrain (6), with the parameter of root weight, found that the tolerance level of carrots to *M. hapla* Chitwood increased from 29 to 59 days. In my study with *M. javanica,* at 31, 34, and 40 days after germination, only 75, 30, and 5 fourth-stage female juveniles and adult females were found per gram of roots in Brasilia; 214, 285, and 116 in Kuronan; and 600, 706, and 385 in Nantes Superior, respectively. These data show distinct differences in nematode population densities in the roots of the three cultivars ($P = 0.05$).

Resistance in Brasilia to *M. javanica* is associated with retarded nematode penetration, development, and egg production and fast plant growth resulting in a low nematode population density. Consequently, few nematodes completed their life cycle in Brasilia. Slow juvenile penetration into the roots of Kuronan also occurred. Because of the similar developmental rates of the nematode in the roots of Kuronan and Nantes Superior (Fig. 2), the differences in numbers of females, galls, and egg masses between the cultivars might result from the differences in the numbers of juveniles penetrating roots. However, the high growth rate of Kuronan plants may account for their low numbers of root-knot nematodes.

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