Influence of Potassium and Nitrogen Fertilization on Parasitism by the Root-knot Nematode *Meloidogyne javanica*[1]

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Abstract: The influence of various concentrations of K^+, nitrogen sources, and inoculation with root-knot nematode *Meloidogyne javanica* were evaluated in tomato plants. Increased potassium concentration increased top and root fresh weights of intact plants and fresh weights of excised roots. Nitrate-fertilized plants weighed more than plants receiving ammonium independent of the K level in the medium. Nematode counts on roots were not affected by nutritional differences in intact or excised roots. In intact roots a high percentage of males was recorded at low K^+ levels, whereas in excised roots the proportion of males in the population rose as the K^+ levels increased. Inoculated intact roots accumulated K^+ when the level of potassium supply was low; infected excised roots contained less K^+ than did nematode-free roots. *Key words:* ammonium, nitrate, nutrition, physiology, potassium.

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There is ample information in the literature concerning the different reactions of plants to ammonium (NH_4^+) and nitrate (NO_3^-) nutrition (8,9). Nitrate nutrition increases the pH value in plant cells; in root exudates it enhances the production of organic anions and inorganic cation accumulation and reduces the inorganic anion content. Ammonium nutrition has the opposite effects (8). Potassium is a vital cation in plant tissue. It is a cofactor of various enzyme systems, it enhances the translocation of assimilates, and it tends to harden plant structures (9,15). These functions indicate that potassium can affect both the development of plant parasites and the damage to the host plant caused by them (15).

Most reports on the interaction between plant nutrition and plant parasitic nematodes refer to the root-knot nematode, *Meloidogyne,* in relation to the nutrient elements N, P, and K (1,3,4,12,14,16). Another aspect of this interaction involves the effect of plant nutrients on nematode population levels (2,11). It appears that nutrients affect nematode development indirectly by improving root growth (2).

This work was carried out to study the effect of various ratios of NH_4^+/NO_3^- and K^+ nutrition on parasitism by the root-knot nematode *M. javanica.*

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MATERIALS AND METHODS

Tomato seedlings (*Lycopersicon esculentum* Mill) cv. Hosen-Eilon, germinated from seeds surface-sterilized with 0.5% sodium hypochlorite, were grown in twice-autoclaved silica-sand in 750-cm^3 plastic pots in a temperature-controlled greenhouse (27–29 C). The plants were irrigated with Hoagland solution (5) in which the nitrogen component was varied in combination with different levels of potassium: three NH_4^+/NO_3^- ratios (100/0, 50/50, 0/100) at constant concentration of 8 meq N/liter and four potassium levels at concentrations of 1.5, 3.0, 6.0, and 12.0 meq K^+/liter. Fourteen days after transplanting, half of the seedlings were inoculated with approximately 2,000 *Meloidogyne javanica* second-stage juveniles by introducing equal numbers of juveniles and eggs suspended in deionized water into the soil in the vicinity of the tomato roots. Thirty days after inoculation, the following were recorded: top and root fresh weights, root-knot index (galling on a 0–5 scale), and sex ratio of the nematode populations, determined from acid fucin nematode dissected from fixed root (7). Samples of 100 mg dry weight of plant tops and roots were individually wet ashed. Potassium content was determined with an EEC flame photometer. Phosphorous and total nitrogen content determined by a technican autoanalyzer. The experiments were conducted in a 2 × 3 × 4 factorial experimental design in three replicates. In a parallel experiment, surface-sterilized tomato seeds were germinated at 20 C on 2% water-agar in petri dishes. Roots were aseptically cut at the hypocotyl and transferred onto a petri plate in which the water-agar surface was covered with a cellophane to avoid a direct contact of the roots with the agar. The water-agar contained a modified Skoog, Tsui, and White nutrient medium (7) in which the potassium component was given in five different ratios: 1.5, 3.0, 6.0, 12.0, and 24.0 meq/liter. The plates were sealed and incubated at 23 C. Seven days later, five to six *M. javanica* egg masses (2,000–2,500 juveniles), sterilized with 0.5% hypochlorite, were transferred aseptically to the excised roots in half of the petri plates. The plates were resealed and incubated at 23 C for 60 days. The roots were then harvested and root fresh weights, composition of the nematode populations, and potassium concentration of the excised roots were determined. The experiment was repeated four times, each with five or six replicates.

Data were analyzed by an analyses of variance, for unbalanced data, and Duncan's multiple-range test using the harmonic means of the number of replications.

RESULTS

Increasing the potassium level in the medium had a direct but progressively diminishing effect on top and root fresh weight of intact plants (Table 1). The plant weight differences between 1.5 and 3.0 meq/liter K^+ levels was 38.5%, but between 3.0 and 6.0 meq/liter the increase was only 6.9%. Excised root fresh weights were similarly affected by potassium: excised roots grown on 24.0 meq K^+/liter

Table 1. Effect of the concentration of K^+ in the nutrient medium on top and root weights of tomato plants inoculated with *Meloidogyne javanica.*

K^+ concentration (meq/liter)	Average weight (g/plant) Top	Root	Total weight
12.0 (77)*	40.66 a†	8.47 a	49.14 a
6.0 (76)	38.84 b	8.11 a	46.95 a
3.0 (77)	36.81 b	7.10 b	43.92 b
1.5 (54)	27.11 c	4.59 c	31.71 c

*No. in bracket = No. of replications.

†Data followed by the same letter in columns are not different (P = 0.05) according to Duncan's multiple-range test.

weighed two times more than roots grown on 1.5 meq K^+/liter (Table 2). Nematode-infected roots from intact plants or excised root cultures were heavier than the nematode-free roots. This phenomenon was particularly marked in the excised roots where the ratio between the inoculate and nematode-free roots dropped as the concentration of K^+ in the medium increased up to 12.0 meq/liter (Fig. 1).

Nitrate fertilized plants weighed 27.6%

Table 2. Total weight of excised tomato roots grown in various concentrations of potassium and inoculated with *Meloidogyne javanica.*

K^+ in nutrient medium* (meq/liter)	Average weight (mg)
24.0 (21)*	711.90 a†
12.0 (27)	799.63 a
6.0 (37)	540.81 b
3.0 (43)	450.70 c
1.5 (31)	313.31 c

*No. in bracket = No. of replications.

†Data followed by the same letter in columns are not different (P = 0.05) according to Duncan's multiple-range test.

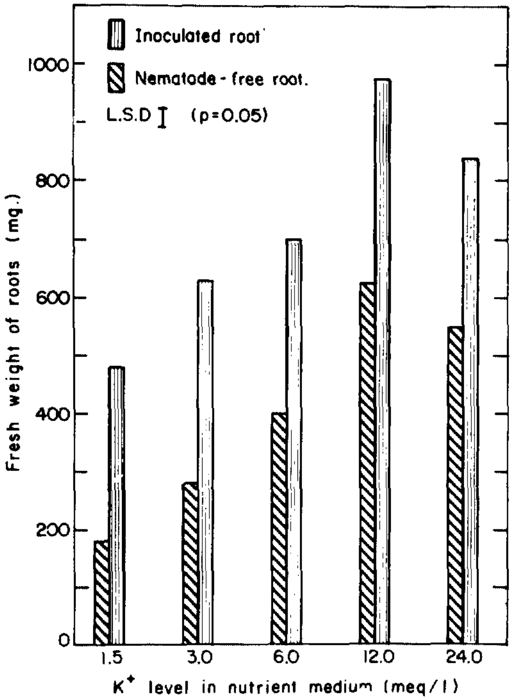

Fig. 1. Fresh weights of excised tomato roots fertilized with different K^+ levels and inoculated with the root-knot nematode *Meloidogyne javanica.*

more than plants receiving ammonium as the only source of nitrogen (Table 3); this response was independent of the K^+ level in the medium.

Numbers of nematode females excised roots were not affected by nutritional differences (Table 4). In intact roots a high percentage of males occurred at low K^+ levels (1.5 and 3.0 meq/liter), whereas in excised roots (Table 4) the proportion of males in the population rose as the K^+ levels increased. The extent of nematode infection in intact roots was not affected by nutritional differences; the galling rating was between 4.0 and 4.5.

In intact plants, N. P. K concentrations were influenced by the NH_4^+/NO_3^- ratio and/or the potassium level in the nutrient medium (Tables 5, 6). Nitrogen percentage was low in the top when the nitrogen was applied in the form of nitrate and increased as the ammonium level in the nutrient medium increased (Table 5). Potassium levels did not influence the difference in nitrogen content between the inoculated and nematode free plants (Fig. 2). However, NH_4^+/NO_3^- fertilization caused differences in nitrogen percentage between inoculated and nematode-free roots: the ratio between the inoculated and nematode-free roots in ammonium fed plants was 1.9 times more than this ratio in nitrate-fed plants (Fig. 3).

Differences in phosphorous between inoculated and nematode-free plants were

Table 4. Population development of *Meloidogyne javanica*, on excised tomato roots fertilized with different K^+ levels.

K^+ in nutrient medium (meq/liter)*	Average ratio male/female	Average counts of females per root
24.0 (21)†	0.338:1 a‡	0.227 a
12.0 (27)	0.256:1 a	6.311 a
6.0 (37)	0.192.1 a	0.341 a
3.0 (43)	0.122:1 b	0.218 a
1.5 (31)	0.107:1 b	0.203 a

*Skoog, Tsui, and White nutrient medium (7).
†No. in bracket = No. of replications.
‡Data followed by the same letter in columns are not different (P = 0.05) according to Duncan's multiple-range test.

Table 3. Influence of NH_4^+/NO_3^- nutrition on top and root weights of tomato plants inoculated with *Meloidogyne javanica*.

% NH_4^+ in nutrient medium	% NO_3^- in nutrient medium	Top	Root	Total weight
100	0	30.25 a*	6.57 a	36.83 a
50	50	39.58 b	7.88 b	47.47 b
0	100	39.66 b	7.33 b	46.99 b

*Data followed by the same letter in columns are not different (P = 0.05) according to Duncan's multiple-range test.

Table 5. Influence of NH_4^+/NO_3^- nutrition on the N,P,K contents of tomato plants fertilized with different K^+ levels and inoculated with *Meloidogyne javanica*.*

		Element, % of dry wt.					
		Nitrogen		Phosphorus		Potassium	
% NH_4^+ in nutrient medium	% NO_3^- in nutrient medium	Top	Root	Top	Root	Top	Root
100	0	2.76 a†	2.15 a	0.48 a	0.45 a	4.67 a	3.34 a
50	50	2.30 b	2.10 a	0.39 b	0.42 a	4.34 b	3.11 b
0	100	2.14 c	2.04 a	0.36 c	0.49 a	4.41 b	2.57 c

*No. of replications = 74.
†Data followed by the same letter in columns are not different (P = 0.05) according to Duncan's multiple-range test.

Table 6. Influence of potassium nutrition on N,P,K contents of tomato plants fertilized with different K^+ levels and NH_4^+/NO_3^-, and inoculated with *Meloidogyne javanica.*

K^+ application level in the nutrient medium (meq/liter)	Element, % of dry wt.					
	Nitrogen		Phosphorus		Potassium	
	Top	Root	Top	Root	Top	Root
12.0 (60)*	1.99 a†	2.06 a	0.36 a	0.40 a	5.75 a	5.08 a
6.0 (60)	2.76 b	2.04 a	0.41 b	0.51 a	0.61 a	3.27 b
3.0 (60)	2.33 c	2.24 b	0.41 b	0.47 a	3.51 b	1.85 c
1.5 (42)	2.59 b	2.02 a	0.48 c	0.43 a	2.40 c	1.31 d

*No. in bracket = No. of replications.

†Data followed by the same letter in columns are not different (P = 0.05) according to Duncan's multiple-range test.

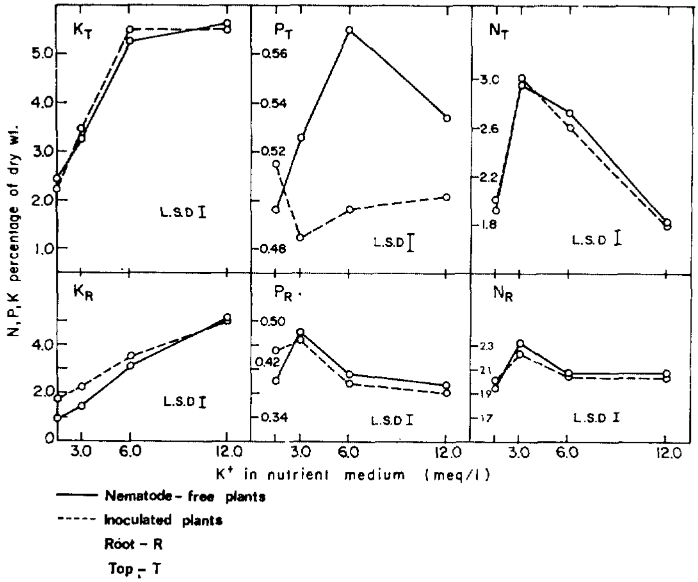

Fig. 2. Top and root N,P,K contents of tomato plants fertilized with different K^+ levels and inoculated with the root-knot nematode *Meloidogyne javanica.* (Averages of all NH_4^+/NO_3^- application level values.)

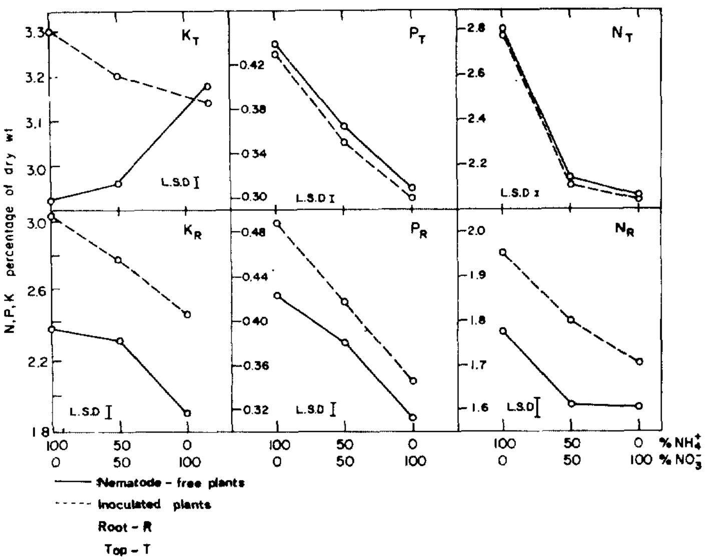

Fig. 3. Influence of NH_4^+/NO_3^- fertilization on top and root N,P,K content of tomato plants inoculated with the root-knot nematode *Meloidogyne javanica.* (Averages of all K^+ application level values.)

evident in relation to different potassium levels in the nutrient medium (Fig. 2). A low P percentage was detected in the top of the inoculated plants, while inoculated roots had higher P rates only in plants fertilized with 1.5 meq K^+/liter.

Ammonium fertilized inoculated plants contained more potassium than did nematode-free plants; in nitrate fertilized plants this difference in potassium content was less marked (Fig. 3).

No differences in the foliar parts were found in K^+ percentage between inoculated and nematode-free plants, but the K content rose linearly with the K level in the nutrient medium up to the 6.0 meq K^+/liter application rate (Fig. 2). As the K^+ level in the nutrient medium dropped, the K content in inoculated roots rose, as compared with the nematode-free roots. An application of 6.0 meq K^+/liter led to a difference of 12.5%, while at the 3.0 and 1.5 meq K^+/liter levels, this difference reached 50.2% and 112.5%, respectively (Fig. 4).

Except for the lowest K^+ level (1.5 meq/liter), the K content in excised roots was not affected by the K^+ nutrient medium level (Fig. 4). Inoculated roots contained less K^+ than did nematode-free roots. This difference was influenced by the K^+ level in the medium: at 1.5 meq K^+/liter there was a 37.0% difference between the inoculated and the nematode-free roots, rising to 62.5% at the 3.0, 6.0, and 12.0 meq/liter application rates and reaching 74.5% when 24.0 meq K^+/liter was applied.

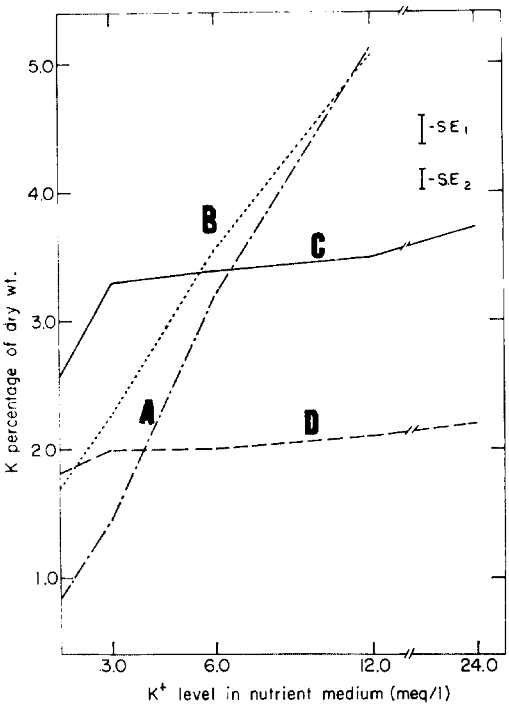

Fig. 4. Influence of different K^+ application levels on K content of intact and excised roots of tomato plants inoculated with the root-knot nematode *Meloidogyne javanica*. A) Intact nematode-free root. B) Intact inoculated root. C) Excised nematode-free root. D) Excised inoculated root. SE_1 = standard error for the intact-root experiments, SE_2 = standard error for the excised-root experiments.

DISCUSSION

The effect of potassium on phytonematode parasitism has been well documented (15). The concensus that emerges from these studies appears to be that in spite of the fact that potassium stimulates rather than depresses nematode development, the growth of infected plants is generally enhanced. This conclusion was confirmed by the present work: while the extent of infection degree did not increase significantly with increased nutrient potassium, it seems from Table 1 that tolerance to nematode parasitism by the infected plant did.

McClure and Viglierchio (11) observed that root-knot nematodes penetrated and developed better on excised roots as the macronutrient concentrations increased in the medium. However, they did not find any influence of the nutrient factor on the male/female ratio. In the present work this ratio rose at the highest K^+ application level (24.0 meq/liter), whereas in intact plants the highest ratio of males to females was observed at the lowest application (1.5 meq K^+/liter). The extreme application levels (1.5 and 24.0 meq K^+/liter) might cause stress conditions in the intact and excised roots; thus, the relatively high proportion of males that were encountered at these levels is in accordance with the concept that the number of males tends to increase under stress conditions (2,6).

Root-knot nematode infected roots are known to accumulate potassium (1). Generally, we found that as potassium was added to the medium, shoot and root potassium levels increased. This accumulation may be explained by the greater metabolic demand placed on the infected roots by the developing nematode population (17). To meet this demand, organic anions, among other things, are supplied from the shoots. During translocation organic anions are accompanied to the roots by K^+ cations (9); this could explain the potassium demand in the infected roots. Additionally, K^+ is the most efficient cation for the activation of various enzyme systems functioning in the syncitia (17). Oteifa (13) observed that nematode-free plants were influenced by potassium fertilization, but, contary to our findings, he reported that potassium content decreased while nitrogen and phosphorus levels rose. However, it should be emphasized that, in addition to different experimental conditions, Oteifa also worked with a different nematode species (*M. incognita*).

Whereas in intact infected roots the potassium content increased as the concentration of available potassium decreased, in excised infected roots the potassium content was not influenced by the concentration of available potassium in the nutrient medium; in fact, it was even lower than the concentration found in nematode-free roots. This descrepancy may be explained by the important role the foliar part of the intact plant plays in potassium absorption and transportation within the root (10).

It is concluded, therefore, that K^+ accumulation in *M. javanica*-infected roots appears to be due to a flow of potassium from the leaves to the roots and/or increased absorption of K^+ by roots, rather than to interference in K^+ transport upward from the roots.

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