# Effects of Salinity and *Meloidogyne incognita* Infection on the Distribution of Sodium ($Na^+$), Potassium ($K^+$) and Chloride ($Cl^-$) in Tomatoes*

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## ABSTRACT

Four tomato cultivars (*Lycopersicon esoulentum* c.v. Beefmaster, c.v. Hunts 2580, c.v. Atkinson, and c.v. Ronita) were grown in a sandy soil treated with 1:1 ratio of NaCl and $CaCl_2$ to produce $EC_e$ of 0, 1.5, 2.5, 3.5 and 5.0 mmhos/cm. Half the plants of each cultivar at each salinity level were inoculated with root-knot nematode (Meloidogyne incognita). Samples of roots and leaves were taken from 12 replicates of each treatment after 60 days. The roots and leaves were analysed for $Na^+$, $Cl^-$, and $K^+$. The concentration in leaves and roots of these elements increased with an increase in salinity. The addition of nematodes increased the concentration of chloride in both roots and leaves of Atkinson and Hunts and in roots of Beefmaster. Nematode infection of salt-stressed c.v. Ronita caused slight increase in $Cl^-$ concentration of leaves or roots. Salt-stressed plant roots contained higher $Na^+$ than leaves, but were much lower in $K^+$ in all varieties. However, the interaction of salinity and root-knot nematode resulted in less $Na^+$ in leaves and roots of all varieties tested. Nematode recovery from roots was low for the first 96 hours, possibly due to some inhibitory effects of these ions on egg hatching.

## INTRODUCTION

Yield and quality of vegetable crops can be altered by variations in ionic root environment and the biotic agents in, or on, the roots. The composition of the ionic root environment is influenced by the soil exchange complexes, organic matter, fertilizer application, and soil-water (4). There are many reports on the deterimental effects of excess salt on plant growth, including inhibition of growth and impairment of cytokinin formation (16). Several hypotheses have been proposed to explain the effects of salts on protein synthesis, enzymatic activity, and the activity of mitochondria and chloroplasts (11). Plants subjected to sodium chloride (NaCl) solution undergo changes in fine structure of cells and an exchange of K from the Chloroplasts for Na from the soil solution (6, 11). Sodium and Cl accumulation may be directly toxic and cause characteristic symptoms on leaves of susceptible species (2). Salinity also can induce Ca-deficiencies with symptoms of blossom-end rot of tomato and bell pepper, and black heart of celery (4). Nutritional imbalances of major elements are known to

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be associated with salinity, although addition of mixed salts tend to correct the imbalances. Carrots increased their uptake of Ca, and Na and decreased K when salinized with NaCl and $CaCl_2$ solutions (2).

Van Gundy and Martin (22) noted that addition of nematode (*Tylenchulus semipenetrans*) to citrus seedlings maintained in soils at levels of $CaCO_3$, Na, or K unfavourable to growth of uninfected plants, resulted in reduced leaf Cu, and Zn. They have found that leaves of these plants, when infected with citrus nematode, contain higher Na than uninfected plants. It was concluded that nematodes caused increased uptake of Na by the plants, led to reach a toxic level in the plant tissues. Excesses of K affected nematode-infected plants in much the same way. Levels of Na were lower in roots of tomatoes infected with root-knot nematodes than leaves of uninfected plants (10). Leaves of rose plants parasitized by *Pratylenchus vulnus* were deficient in Fe, Cu and K while Zn, Ca, Mg, and N concentrations were higher than in leaves of uninfected plants (18). There were no differences in P, Na, Mn, and Mg. The K content in leaves of walnut seedlings was lower in plants exposed to large numbers of root-lesion nematodes than in plants uninfected with *Pratylenchus* spp. whereas Na was higher in diseased leaves, stems and roots (21).

The length of time for egg production of root-knot nematode was inversely related to increasing K nutrition of the host (13). The K, Ca, Mg, N, and P contents were lower for infected bean plants than healthy plants (12, 13, 14). They also found that ammonia ions decreased nematode injury as well as the number of females and egg masses produced on infected roots. Most of the previous work has dealt with effects of various nutritive levels on nematode growth and development, and nutrient status of plants, but there is very little information on the effects of salinity on nematode-induced nutritional status of plants.

The purposes of the work reported herein were to provide information on: (i) accumulation of Na, Cl, and K in roots and leaves of the four tomato cultivars as affected by salinity; (ii) the role of root-knot nematode (*Meloidogyne incognita*) infection on this accumulation; and (iii) levels of each element which can be tolerated by these cultivars.

## MATERIALS AND METHODS

Four tomato (*Lycopersicon esoulentem*) cultivars: Beefmaster (Burpee Seed Co.), Atkinson and Ronita (Petoseed Co.), and Hunts 2580 (Wesson Foods Co.), were grown in sandy soil treated with a 1:1 ratio of NaCl and $CaCl_2$ to produce a conductivity of 0, 1.5, 2.5, 3.5, 3.5 and 5.0 mmhos/cm. Half of the plants of each cultivar at each salinity level were inoculated with 400 freshly-hatched *M. incognita* juveniles three days after salinization and ten days after transplanting.

The twelve replications of each treatment were randomized in rows on a greenhouse bench. The experiments were terminated 60 days after transplanting. One gram of root sample was taken from each replicate. The two fully-expanded uppermost leaves were removed from every plant for chemical analyses. The leaf and root samples were bulked from each treatment and dried at 55°C for 48 hours in paper bags. The dried samples were ground and weighed. A sub-sample of 0.25 g roots and leaves was analyzed for chloride ($Cl^-$) using automatic titrator method (1). A 2.5 g portion of the remainder of each sample was ashed in crucibles at 500°C for 8 hours (7). The samples were allowed to cool overnight, dissolved in 5 ml of 3N HCl, filtered, and made to 50 ml volume with diionized water. $Na^+$ and $K^+$ concentrations were determined by flame photometry.

## RESULTS AND DISCUSION

Important differences between nematode-infected and uninfected plants were found in leaf and root analysis. As salinity of the soil increased, the uptake of chloride increased, especially at $EC_e$ above 2.5 mmhos/cm. Salt-stressed tomato plants (Hunts 2580) infected with *M. incognita* contained higher chloride in leaves and roots, while Beefmaster showed higher concentrations in roots than in leaves (Fig. 1). Addition of nematode to salt-stressed plants increased the accumulation of $Cl^-$ in roots about 2.5 and 2.0 fold for Beefmaster and Hunts 2580, respectively. However, addition of root-knot nematode to stressed tomato Ronita and Atkinson resulted in about two-fold increases of $Cl^-$ in leaves of Ronita, but very little increase in the total $Cl^-$ in roots or leaves of Atkinson when compared to untreated plants. (Fig. 2).

The levels of $Na^+$ in plant roots subjected to salinity stress were about four times higher in absence of nematodes than that in salt-stressed plants infected with nematodes, especially Hunts 2580 and Beefmaster (Fig. 3). Although the four tomato cultivars tested showed an increase in the leaf salt uptake, the highest $Na^+$ concentrations were accumulated in the roots of salt stressed plants without the nematodes (Fig. 3). Ronita and Atkinson showed the least Na concentration in roots in the presence of salts and absence of nematodes (Fig. 4). These variations in the results obtained may be explained due to nature of resistance of these varieties to nematodes and tolerance to salts (4).

As the concentration of the electrolytes (Ca, Na, Cl) in the soil solution increased, potassium (K) concentration in leaves of all varieties increased. In contrast, $K^+$ in roots remained low as salinity increased. Addition of root-knot nematodes to salt-stressed K concentration in leaves of Hunts 2580, Beefmaster, and Atkinson, but not for Ronita (Fig. 5/6). The highest K was found in leaves of Beefmaster infected with root-knot. Tomato Hunts 2580 showed the same general trends (Fig. 5). Roots of Beefmaster, and Hunts 2580 contained less K than that of leaves as salinity increased. The concentration of K in Atkinson increased as salinity increased in the presence of nematodes, but decreased as salinity rose. K concentration in roots remained low as

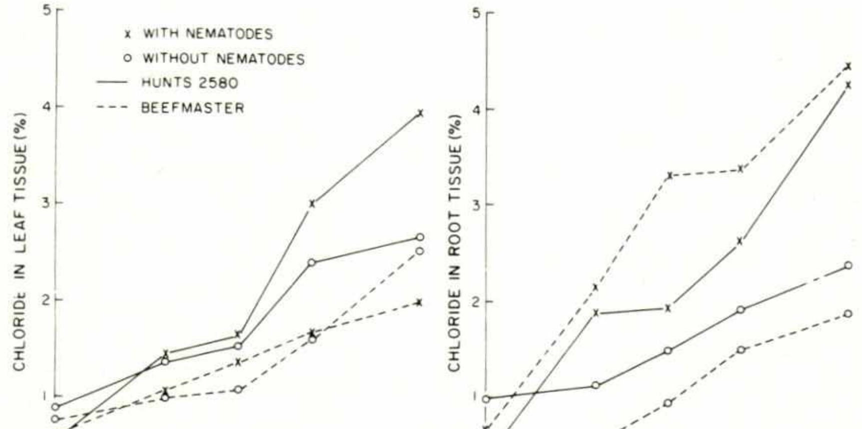


Fig. 1. Effect of root-knot nematode, salinity, and their interaction on distribution of $Cl^-$ in two tomato cultivars (Beefmaster and Hunts 2580).

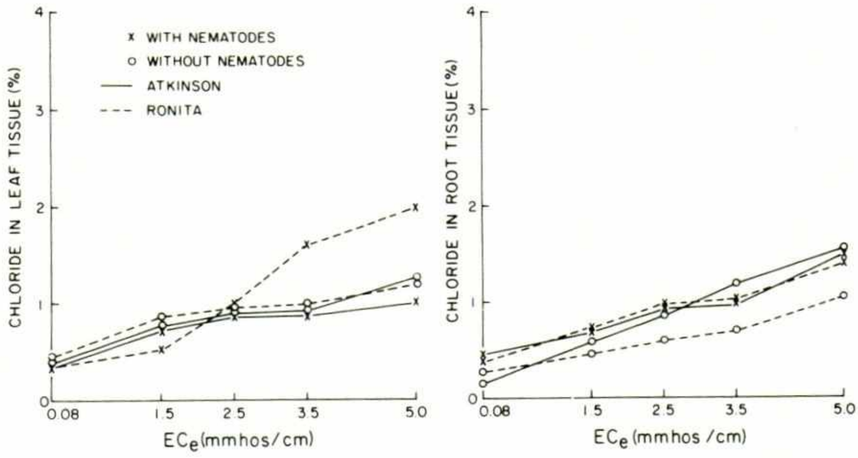


Fig. 2. Effect of root-knot nematode, salinity, and their interaction on distribution of $Cl^-$ in two tomato cultivars (Atkinson and Ronita).

salinity increased (Fig. 6). Tomato, Ronita, uptake remained almost constant as the concentration of salts in the soil increased in roots as well as in leaves.

The threshold salinity for tomato reported by Bernstein (2) and Maas *et al.* (9) in 2.5 mmhos/cm where plant growth optimum. Beyond this level yield decreases as salinity increases. In the present work, tomato cultivars were found to vary in their uptake and accumulation of $Cl^-$, $Na^+$ in leaves and roots. Beefmaster, Hunts 2580, and Atkinson showed greater tendencies to absorb more $Cl^-$, but less $Na^+$ when inoculated with nematodes. This was not true for Ronita. A possible explanation is

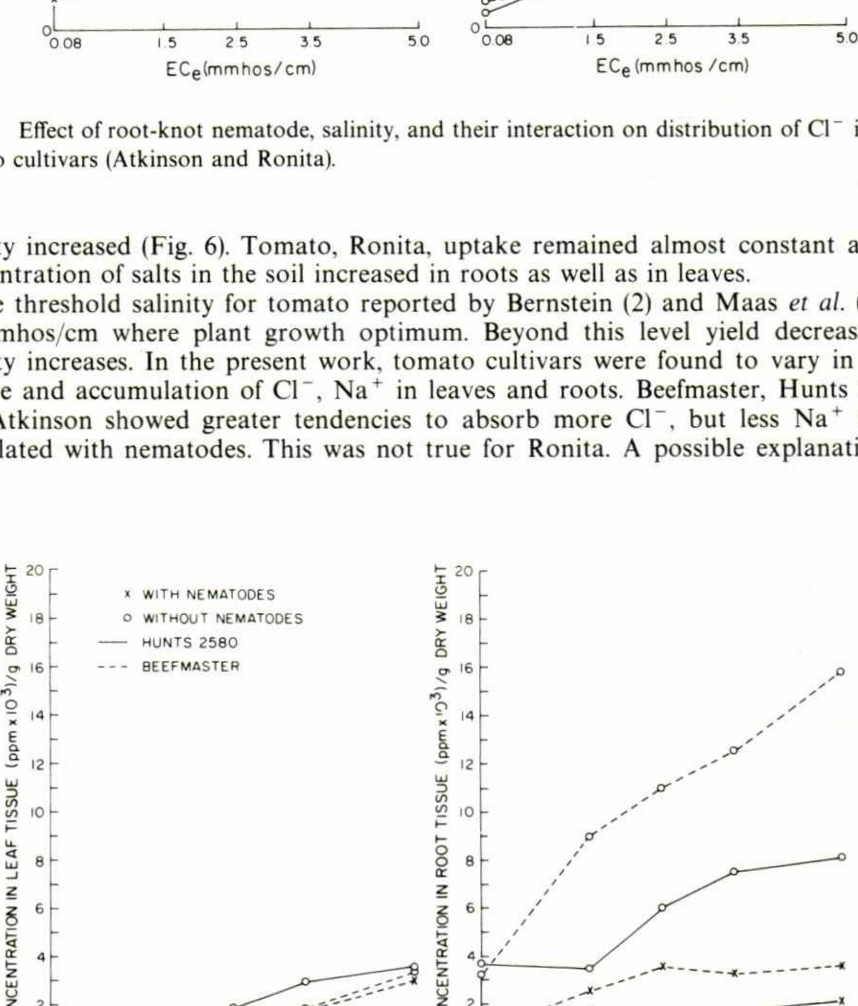


Fig. 3. Effect of root-knot nematode, salinity, and their interaction on distribution of $Na^+$ in two tomato cultivars (Beefmaster and Hunts 2580).

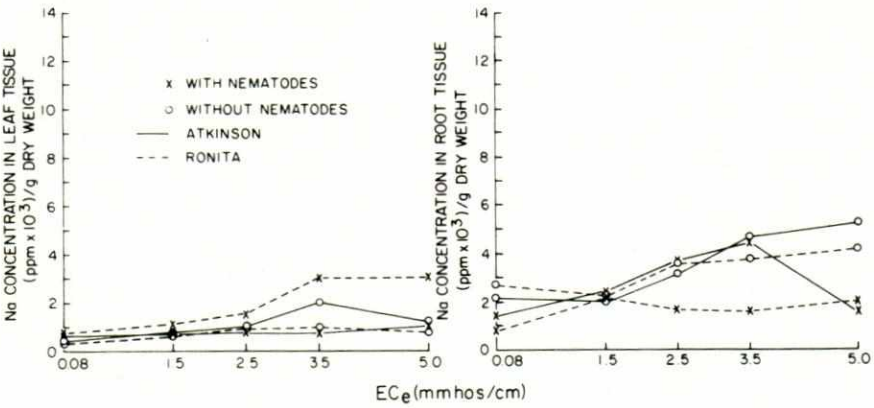


Fig. 4. Effect of root-knot nematode, salinity, and their interaction on distribution of $Na^+$ in two tomato cultivars (Atkinson and Ronita).

that uptake of $Cl^-$ and $Na^+$ is passive, while $K^+$ is active (6). Root penetration and damage caused by juveniles and females (at maturity), might allow an increase in flow of ($Cl^-$). Ronita roots possibly have the ability to exclude Na as long as a sufficient supply of $K^+$ is available. This hypothesis has been suggested by Besford (3). He also suggested that K is necessary to aid the plants in their exclusion mechanism. This theory cannot be used to explain the increase in K concentration in Beefmaster and Hunts 2580 unless the nematode is included.

As salinity increased, chloride concentration in roots was higher, especially in the presence of nematodes. Our results are in agreement with Maung (10), but in contrast

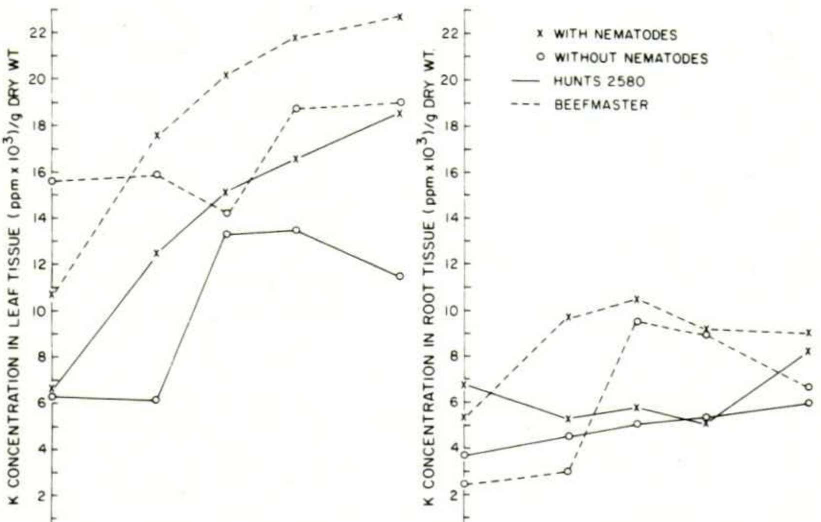


Fig. 5. Effect of root-knot nematode, salinity, and their interaction on distribution of $K^+$ in two tomato cultivars (Beefmaster and Hunts 2580).

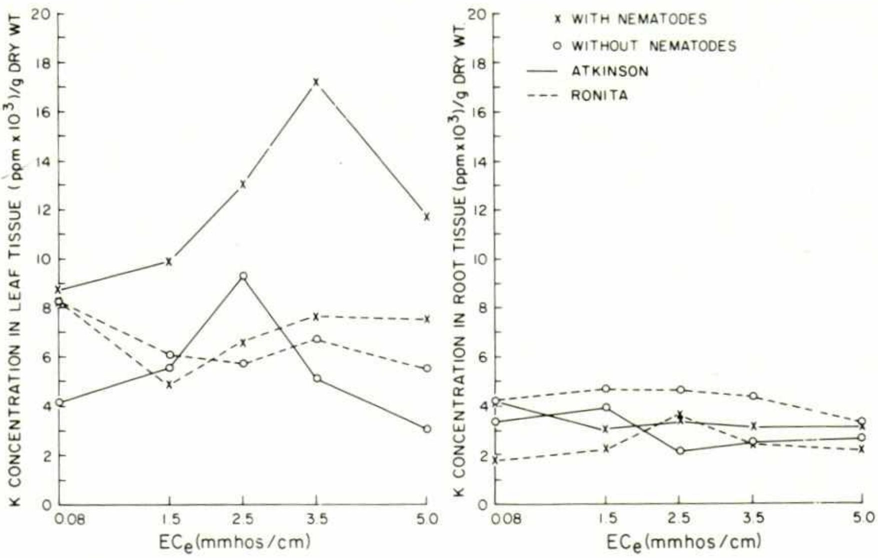


Fig. 6. Effect of root-knot nematode, salinity, and their interaction on distribution of $K^+$ in two tomato cultivars (Atkinson and Ronita).

to Van Gundy and Martin (22) in which addition of nematodes decreased Na concentration in leaves and increased it in roots. $K^+$ increased in leaves, but decreased relatively in roots. These results agree with Oteifa (12), (13). However, West (23), (24) found the K concentration was not affected by increases in salinity in apple trees.

The tomato cultivars can be ranked according to their ability to tolerate nematode-salt interaction as follows: (i) Beefmaster and Hunts 2580 can tolerate high concentration of $Cl^-$ and $Na^+$ without showing injury symptoms, although Beefmaster aborted most of its flowers at higher salinity in the presence of nematodes, (ii) Atkinson absorbed moderate amounts of Cl and Na but was very sensitive to nematodes and accumulated large amounts of $K^+$ in both leaves and roots compared to other varieties.

In conclusion, this plant root-parasite (root-knot nematode) is very important in aggravating salt-stressed plants by increasing their uptake of non-essential elements. This might lead to nutritional imbalances that result in deficiencies or excesses of desirable and undesirable elements. This is true in cases where higher salt concentrations increased the incidence of blossom-end rot of tomato fruits. Toxic levels of each element was not established using these concentrations. It is appropriate to recommend higher concentration of salts to evaluate these criteria. Consideration of nematode populations can be a necessary component of decision about soil-nutritional problems.

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# تأثير الملوحة ونيماتودا تعقد الجذورعلى توزيع الصوديوم والبوتاسيوم والكلوريد فى بعض اصناف الطماطم

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المستخلص

اختيرت اربعة اصناف من الطماطم هى : بيف ماستر ،هنت ٢٥٨٠ ، اتكنسن ورونيتا لاختبار مدى قدرتها على النمو فى تربة مضاف اليها املاح ومعاملة بنيماتودا تعقد الجذور(*Meloidogyne incognita*) زرعت أصناف الطماطم المختلفه فى اصص بها تربة رملية عوملت بكلوريد الصوديوم وكلورات الكالسيوم بنسبة ١ : ١ لكى يصل تركيز الاملاح الذائبة بها مقدرة بالمليموس/ سم³ (عند درجة حرارة ٢٥ مئوية ) الى ٥ر١ ، ٥ر٢ ، ٥ر٣ ، ٠ر٥ ، ثم اضيف الى التربة تركيز معين من نيماتودا تعقد الجذور ، وبعد مرور ستين يوما من هذه المعاملة اخذت عينات من الاوراق والجذور لتقدير كميات الصوديوم ، البوتاسيوم والكلوريد بها .

وقد وجد ان كمية هذه العناصر تزداد بزيادة الملوحة فى التربة وان المعاملة بالنيماتودا تؤ دى الى زيادة ملحوظة فى تركيز عنصر الكلور بكل من الاوراق والجذور فى صنفى اتكنسن ، وهنت . اما بالنسبة للصنف بيف ماستر فان الزيادة كانت فى الجذور فقط . بينما لم تؤد اضافة النيماتودا الا الى زيادة طفيفة فى تركيز الكلور بصنف رونيتا . كما وجد ان تركيز الصوديوم يزداد فى الجذور ويقل فى الاوراق بزيادة الاملاح بالمقارنة بالبوتاسيوم ولكن وجود النيماتودا والاملاح معا يقلل من كمية الصوديوم فى الجذور والاوراق فى كل الاصناف .

وقد تبين ان عدد النيماتودا المستخلصه من الجذور كان قليلا ولربما كان ذلك نتيجة تأثير الاملاح على عملية فقس البيض .

واثبتت هذه الدراسة ان صنف هنت ٢٥٨٠ ويليه بيف ماستر مقاومان للاملاح ، ثم يأتى فى المرتبة الثانية اتكنسن ورونيتا . وكذلك ان وجود الاملاح فى التربه يقلل من قدرة النبات على المقاومة للنيماتودا ، حيث ان بيف ماستر واتكنسن اصبحا غير مقاومين للنيماتودا فى وجود الاملاح الذائبه .