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ROLE OF CERTAIN INORGANIC FERTILIZERS ON CONTROLLING *Meloidogyne incognita* INFECTING TOMATO PLANTS UNDER GREENHOUSE CONDITIONS

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ABSTRACT

The role of spray application of three inorganic fertilizers $MnSO_4$, $ZnSO_4$ and $CaCl_2$ at three concentration each viz: 50, 100 and 150 mg/l of the first two elements and 100, 200 and 300 mg/l for the latter fertilizer three times at one week interval in comparison with oxamyl at the recommended dose (0.39/plant) on development and reproduction of *M. incognita* infecting tomato plants cv. Castle Rock and plant growth was studied under greenhouse conditions (29±7ºC). Obviously all tested nutrient minerals with their concs. significantly improved plant growth parameters and reduced nematode criteria, respectively as well to great extent. Among the tested inorganic fertilizers, $CaCl_2$ at 200 mg/l/plant overwhelmed other treatments, followed by that of $MnSO_4$ at 150 mg/l in the increments values of plant growth parameters such as shoot dry weights (30 and 21.1%). whereas, $ZnSO_4$ at 100 mg/l application had the lowest value (9.6%) in this respect, respectively. Similar trend was noticed regarding reduction of nematode criteria such as population density (90.8, 90.7 and 90.2%) respectively. Likewise, nematode multiplication was also affected by the tested nutrient elements performing the above trend, where $CaCl_2$ at 200 mg/l and $ZnSO_4$ at 50 mg/l/plant represented of minimum and maximum values that averaged 0.13 and 0.16 vs 1.39 for nematode alone respectively. N, P, K concs., chlorophyll and total phenol contents in leaves of tomato either infected with *M. incognita* or not as influenced by foliar spraying of the tested inorganic fertilizers were reported and discussed.

Keywords: Inorganic fertilizers, *M. incognita*, Tomato, N, P, K, total chlorophyll, total phenol contents.

INTRODUCTION

Literature revealed the eminent role of inorganic fertilizers in ameliorating plant condition, quality and quantity of crops. However, the negative effects of such inorganic chemicals on nematode reproduction and development is scanty and controversial. In 1955, Oteifa recorded that ammonia diminished reproduction of *M. incognita* for the first time and since then several reports have been registered on such trend (Melakeberhan *et al.,* 1988, Gupta; 1988, 1990; Alam, 1991, Ahmed *et al.,* 1991 and Kheir *et al.,* 2009). Moreover, the efficacy of N, P, K and urea on different nematode species, especially root-knot nematodes and crop growth have been extensively noticed (El-Nagar 1990; Khan& Khan, 1995; Mitchell& Gazaway, 1996, Gelster& Romaneko, 1997; Akhtar *et al.,* 1998; Gupta *et al.,* 1999; Trifonova, 2001; Agu (2002), Bamel *et al.,* 2003, Sinha &Neog, 2003, El-Sherif *et al.*, 2008, Kheir *et al.,* 2009 and El-Sherif *et al.,* 2010). However, trace elements and heavy metals with only few reports in the literature were recorded by several workers (Osman *et al.,* 1993; Smith *et al.,* 2000; Siddiqui *et al.,* 2002 and Goldi-Arora *et al.,* 2003).

Therefore, the present investigation is dealing with the impact of certain inorganic fertilizers on controlling *Meloidogyne incognita* infecting tomato plant under greenhouse conditions.

MATERIALS AND METHODS

Source of Nematodes and Preparation of *Meloidogyne incognita* Eggs as Nematode inoculum:

The root-knot nematode, *M. incognita* culture was initiated by single eggmass of previously identified females (Talyor *et al.,* 1955) and isolated from galled roots of highly infected tomatoes collected from Mansoura country, Dakahlia governorate, Egypt and propagated on coleus plants, (*Coleus blumei*) plants in the greenhouse of Nematology Research Unit, Agricultural Zoology Department , Faculty of Agriculture , Mansoura University , where this work was done. Nematode inoculum of *M. incognita* eggs was then prepared according to the method recorded by Hussey and Barker, (1973).

Pesticide:

Oxamyl: (Vydate 10% G.) Methyle – N– N– dimethyl – (N (methyl) carbomycocyl) - 1- Thioxamidate.

Impact of spraying three nutrient minerals in comparison with oxamyl against *Meloidogyne incognita* infecting tomato plants under greenhouse conditions (29±7°C):

In order to study the effect of spraying three nutrient minerals i.e. Calcium chloride ($CaCl_2$), Manganese sulphate ($MnSO_4$) and Zinc sulphate ($ZnSO_4$) at three concentrations each in comparison with oxamyl at the recommended dose on controlling *M. incognita* infecting tomato plants under greenhouse condition 29±7ºC, one hundred and five (105) tomato seedlings cv. Castle Rock at 30 days-old with thirty tomato seedlings per each nutrient mineral at five seedlings, per concentration plus five for oxamyl treatment, five seedlings for nematode alone and another five seedlings free of nematode and any chemical to serve as check were used in this study. All tomato seedlings were transplanted into plastic bags (with four pores, two at each side/bag), filled with one kg steam-sterilized sandy loam soil (1:1) (v:v) and irrigated with tap water. One week later, fifty five tomato seedlings were separately inoculated with 1500 eggs of *M. incognita* each. Seven days later spraying process of tested minerals i.e. $CaCl_2$ at the rate of 100, 200 and 300 ppm; $MnSO_4$ at 50, 100 and 150 ppm and $ZnSO_4$ at 50, 100 and 150 ppm was separately done at the level of ten tomato seedlings for each concentration/ mineral of plastic bags with or without nematodes. Soil surface of each treated pot was covered with aluminum foil during spraying to avoid spilling of the sprayed material. This process was then repeated twice at one week interval. Treatments were replicated five times.

Treatments were as follows:

1- N + $CaCl_2$ (100 mg/l),
2- $CaCl_2$ (100 mg/l) only,
3- N + $CaCl_2$ (200 mg/l),
4- $CaCl_2$ (200 mg/l) only,
5- N+ $CaCl_2$ (300 mg/l),
6- $CaCl_2$ (300 mg/l) only,
7- N+ $MnSO_4$ (50 mg/l),
8- $MnSO_4$ (50 mg/l) only,
9- N+ $MnSO_4$ (100 mg/l),
10- $MnSO_4$ (100 mg/l) only,
11- N+ $MnSO_4$ (150 mg/l),
12- $MnSO_4$ (150 mg/l) only,
13- N+ $ZnSO_4$ (50 mg/l),
14- $ZnSO_4$ (50 mg/l) only,
15- N+ $ZnSO_4$ (100 mg/l),
16- $ZnSO_4$ (100 mg/l) only,
17- N+ $ZnSO_4$ (150 mg/l),
18- $ZnSO_4$ (150 mg/l) only,
19- N+ Oxamyl (0.39),
20- N alone and
21- Plant free of N and any chemical as well.

Plastic bags with tomato seedlings were arranged in a randomized complete block design on a greenhouse bench maintained at 29±7ºC. Plants received water and were protected by conventional pesticides against mites and insects as needed. Plants were harvested after 45 days from nematode inoculation. Data dealing with plant length, fresh weights of shoot and root, shoot dry weight and number of leaves, branches and flower/plant were determined and recorded. Infected tomato roots of each concentration per mineral/replicate, oxamyl and nematode alone were separately washed in tap water, fixed in 4% formalin for 48 hr and then stained in hot lacto phenol in acid fuchsin (Franklin, 1949) and examined with stereoscopic microscope for counting the number of galls, eggmasses, developmental stages and females of *M. incognita* and recorded. *M. incognita* (J_2) was extracted from soil through sieving and modified Baermann technique (Goodey, 1957) counted and recorded.

Chemical analysis:

Samples of dried leaves ground, wet digested and their nitrogen (N), Phosphorus (P), Potassium (K) contents were determined according to kjeldahl methods A.O.A.C., (1980) described by Pregl (1945), John (1970) and Jakson (1967).

Chlorophyll content:

Represent sample from the upper fourth leaf were obtained at 75 days after sowing and both chlorophyll a and b were determined mg/g F.W following equations that were used for the calculation pigments content according to Goodwine (1965).

$$\text{Chlorophyll (a)} = \frac{12.7\ D\ 663 - 2.69\ D\ 645 \text{x}\ V \text{ x } 10}{d \text{ x } 1000 \text{ x } 0.5}$$

$$\text{Chlorophyll (b)} = \frac{22.9\ D\ 645 - 4.68\ D\ 663 \text{ x } V \text{ x } 10}{d \text{ x } 1000 \text{ x } 0.5}$$

V = Aceton volume
D = Optical density reading at the wave length
d = / cm

Determination of total phenols:

In this experiment, total phenols were determined after harvesting in fresh roots and stems bases using the Folin-Ciocalteau reagent (Kaur and

Kapoor 2002). Total content of phenolic compounds in plant ethanolic extracts was calculated as catechol equivalents by the following equation:

$$T = \frac{c \times V}{m} \times 100$$

where:

T- Total content of phenolic compounds, in mg of catechol/100 g of fresh weight material.

c- The concentration of catechol established from the calibration curve, in mg/ml.

V- The volume of extract in ml.

m- The weight of pure plant ethanolic extract in g.

Statistical analysis:

Statistically, the obtained data were subjected to analysis of variance (ANOVA) (Gomez and Gomez, 1984) followed by Duncan's multiple range tests to compare means (Duncan, 1955).

RESULTS AND DISCUSSION

Data presented in Tables 1, 2, and 3 illustrate the effects of three nutrient minerals i.e. $CaCl_2$, $ZnSO_4$ and $MnSO_4$, at three concentrations each applied as foliar spray three times at one week intervals in comparison with oxamyl on development and reproduction of *M. incognita* infecting tomato plants cv. Castle Rock and plant growth response as well under greenhouse conditions (29±7ºC). Obviously all tested nutrient minerals with their concentrations showed remarkable improvement in plant growth parameters on the basis of length, fresh and dry weights of shoot and roots; number of leaves, branches and flowers/plant for both the infected and the uninfected plants, comparing to nematode alone and plant free of nematode and untreated with chemicals, respectively. It is evident that observations were reported on the increments in tested plant growth parameters receiving foliar spray with the tested components in the infected plants in most parameters over that of the uninfected ones for the same treatments, whereas plant length with $ZnSO_4$ concentrations showed opposite results (Tables 2), comparing to nematode alone, respectively. Among tested concentrations of such nutrient minerals, i.e. 50 mg/l, 100 mg/l and 150 mg/l concentrations of Manganese sulphate, and Zinc sulphate; and Calcium chloride at the rates of 100 mg/l, 200 mg/l and 300 mg/l accomplished the best results in ameliorating plant growth characters where $CaCl_2$ at 200 mg/l overwhelmed other tested concentrations of such nutrient elements (Table 1) including oxamyl treatment in values of plant growth criteria i.e. shoot length (23.1%), root length (28%), shoot fresh weight (25.9%), root fresh weight (37.1%) shoot dry weight (30%), number of leaves/plant (30.2%) and number of branches/plant (500%) and number of flower/plant (50.0%), followed by that of $MnSO_4$ at 150 mg/l with values of 14.6, 19.1, 17.2, 27.6, 21.1, 21.2, 45.5

and 300% for the same plant characters respectively, (Table 3) whereas $ZnSO_4$ at 100 mg/l had the least values that averaged 3.8, 8.0, 6.2, 15.7, 9.6, 9.8, 27.3 and 300% for the same plant growth parameters, respectively, comparing to nematode alone (Tables 2). Meanwhile, Oxamyl as a systemic nematicide ranked second to $CaCl_2$ at 200 mg/l in improving plant growth characters with values of 20.7, 25.4, 23.4, 34.4, 27.5, 27.6, 50.0 and 300% for plant length (shoot+ root), shoot fresh weight, root fresh weight, shoot dry weight, number of leaves, branches and flower/plant, respectively, comparing to nematode alone (Tables 1, 2 and 3).

Data as depicted in Table (4) verify that all tested nutrient minerals i.e. $MnSO_4$, $ZnSO_4$ and $CaCl_2$ at three concentrations each as foliar spraying three times at one week intervals to tomato seedlings infected with *M. incognita* were significantly effective in reducing number of formed root galls as well as juveniles recorded from the soil, the embedded stages as measured by the developmental stages, eggmasses, size of nematode final population and the subsequent calculated rates of build-up when compared with those of the inoculated untreated check. It is worthy to note that calcium chloride ($CaCl_2$) at 200 mg/l as foliar spraying treatment was the ultimate efficacious application performing crucial diminishing in number of galls, eggmasses, developmental stages, and females by 84.7, 60.8, 95.7 and 60.6%, respectively, followed by that of $MnSO_4$ at 150 mg/l with values of 83.6, 58.7, 93.6 and 57.7%, respectively whereas, $ZnSO_4$ at 100 mg/l application had the lowest values in this respect that were amounted to 82.6, 56.3, 92.5 and 55.2%, respectively comparing to nematode alone (Table 4). Moreover, foliar spray applications of $CaCl_2$ at its tested concentrations surpassed other tested concentrations of the other two elements in suppressing nematode population density with values of 90.2, 90.8 and 90.4% for 100, 200 and 300 mg/l/plant, followed by that of $MnSO_4$ at 50, 100 and 150 mg/l/plant with values of 89.4, 90.0 and 90.7%, then that of $ZnSO_4$ at the same concentrations with values that averaged 88.8, 90.2 and 89.3%, respectively, comparing to nematode alone. It is worthy to notice that $CaCl_2$ at 200 mg/l/plant applied three times as foliar spray application ranked first in suppressing nematode population with value of 90.8, followed by that of $MnSO_4$ at 150 mg/l/plant and that of $ZnSO_4$ at 100 mg/l/plant for the same application with value of 90.7% each, comparing to nematode respectively. Oxamyl as a systemic nematicide ranked first over all treatments tested in suppressing nematode population with value of 91.25%, followed by that $CaCl_2$ at 200 mg/l/plant (90.8%), comparing to nematode alone respectively.

Accordingly, the nematode multiplication was also affected by the tested elements performing the above mentioned trend. Such rate of build-up folded 1.389 times in check application, while its multiplication rates was restricted between 0.128 to 0.15, 0.14 to 0.16 and 0.13 to 0.14 for $MnSO_4$, $ZnSO_4$ and $CaCl_2$ concentrations, where $CaCl_2$ at 200 mg/l and $ZnSO_4$ at 50 mg/l represented of minimum and maximum values for such concentrations studied, respectively. Oxamyl as a nematicide gave the lowest value of nematode multiplication that averaged 0.115 comparing to nematode alone.

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However, it is interesting to note that all indices of root galls and eggmasses number showed equal values for foliar spray applications even with oxamyl treatment that averaged 4 vs 5 for nematode alone respectively.

MG/LData presented in Table (5) show the influence of spraying manganese nutrient at 50, 100 and 150 mg/l concentrations twice at one week interval in comparison with oxamyl at full dose on nitrogen (N), phosphorus (P) and potassium (K) concentrations; total chlorophyll content and total phenol content in tomato cv. Castle Rock infected with *M. incognita* under greenhouse conditions. It is evident that N and P concentrations and total phenol content were significantly diminished except K concentration, while that of total chlorophyll content sharply increased by nematode infection alone. Similar trend was obtained with case of uninfected plants where a positive value for K conc. and total chlorophyll content was evident; whilst a negative value for total phenol was also recorded. However, all tested manganese concentrations showed significant increase in N, P concentration and total phenol content values except that of K concentration and total chlorophyll content in the infected plants where negative reduction values were existed comparing to nematode alone. Meanwhile, as manganese concentrations increased from 50 up to 150 mg/l, N and P percentage increase values increased that averaged 8.63 up to 15.91%, respectively, whereas values of K recorded negative values that amounted to -10.48% and -5.94% for 50 and 150 mg/l concentrations, comparing to nematode alone, respectively. Moreover, similar trend of percentage increase values of total phenol content was recorded to be 12.83, 15.94 and 21.11% for 50, 100 and 150 mg/l concentrations, comparing to nematode alone.

It is worthy to notice that manganese element at 150 mg/l concentrations achieved the highest percentage increase values of N, and P that averaged 15.91 and 12.7% respectively while K value for this element concentration was the lowest one that averaged -5.94% accompanied with the highest value of total phenol content (21.11%), comparing to nematode alone. Oxamyl as a systemic nematicide accomplished the highest values of percentage increase exceeding all tested manganese concentrations with values of 22.27, 24.5 and 30.84% for N, P and total phenol content, respectively comparing to nematode alone.

Data in Table (6) verify the impact spraying zinc nutrient at 50, 100 and 150 mg/l concentrations twice at one week interval in comparison with oxamyl on nitrogen (N), phosphorus (P) and potassium (K) concs., total chlorophyll and total phenol contents in tomato cv. Castle-Rock infected with *M. incognita* under greenhouse conditions. It is obviously that N and P conc. and total phenol content were significantly reduced except K conc., while that of total chlorophyll content clearly increased by nematode infection alone. Similar trend was evident within the uninfected plants where a positive value of percentage increase for K conc. and negative values of reduction percentage for total chlorophyll content and total phenol content was also recorded, comparing to the plant free of nematode and any chemical added.

Meanwhile, among the zinc conc. 100 mg/l conc. accomplished the highest percentage increase values for N (5.9%), P (6.48%) and ranked first in value of percentage increase for total phenol that averaged 30.02% followed by that 150 mg/l of zinc conc., whereas 50 mg/l zinc conc. gave the modest value (26.70%) in this respect, whereas the least value of this element recorded by zinc at 50 mg/l (23.39%), comparing to nematode alone. Similar results were recorded for oxamyl as in the case of manganese element.

Data in Table (7) illustrate the efficacy of spraying calcium nutrient at 100, 200 and 300 mg/l concs. twice at one week intervals comparing to oxamyl on nitrogen (N), phosphorus (P) and potassium (K) concs., total chlorophyll and total phenol contents in tomato cv. Castle-Rock infected with *M. incognita* under greenhouse conditions. It is evident that N, P and total phenol content were significantly diminished except that K conc. in certain cases, while that of total chlorophyll content obviously increased by nematode infection alone. Among the calcium nutrient concs. tested 200 mg/l conc. gave the highest percentage increase for N, P, K and total phenol content values as well that averaged 27.72, 20.27, 2.05 and 33.12 % f.wt. for the infected plants; and 20.95, 16.6, 20.62 and -27.0% for the uninfected ones, comparing to nematode alone. On the other hand, calcium nutrient at 100 Mg/l conc. achieved the least values of percentage for N (21.36%), P (17.59%), K (-2.79 mg/100g f.wt) and total phenol (3.72%) in the infected plants while those of uninfected ones showed similar trend with values of 13.92, 8.93, 15.7 and -19.8% for the same criteria, respectively comparing to nematode alone. Oxamyl as a nematicide recorded considerable increase values of N (22.77%), P (24.19%), K (2.3%), and total phenol (30.84%), respectively comparing to nematode alone (Tables 5, 6 and 7).

Apparently, foliar spray applications of the tested three inorganic fertilizers with three concs. each on tomato plants under the stress of *M. incognita* infection in comparison with oxamyl proved its role in improving plant conditions quality and quantity of such crop and in diminishing nematode development and reproduction in the present study. Moreover, these mineral nutrients play a vital role in bio- and physiological activities in such plants. On the other hand, these nutrients may either increase or decrease resistance or tolerance in plants to attacking nematodes. In this present study, nematode population and rate of build-up were in all cases diminished by more than 90.9%. The highest nematode reductions were accomplished by the concentration levels of 200, 150 and 100 mg/l/plant for $CaCl_2$, $MnSO_4$ and $ZnSO_4$, with values of 90.8% and 0.13; 90.7% and 0.13; and 90.2% and 0.14, respectively. The present findings are in agreement with those reported by kheir *et al.,* (2009) in respect to $MnSO_4$, $MgSO_4$ and NH_4Cl at the highest concentration levels that were the most efficient in reducing the nematode biomass criteria, whereas $ZnSO_4$ achieved the least significant reduction.

The obtained results are supported by the findings reported by Agu (2002), Coyne *et al.,* (2004) and Quraishi (1985). Reduction in nematode reproduction as a result of applying inorganic fertilizers may be attributed to their suppressive effect on giant cell development.

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The excessive uptake of some elements and accumulation of fertilizers in plants may enhance natural defense against nematodes or accumulation of such compounds in the cell sap may reach to toxic levels to nematode (Kesba, 2003). However, the present findings indicate that the tested three nutrients as foliar spraying on tomato infected with *M. incognita* especially at the levels of Ca200 or Mn150 or Zn100 mg/l achieved the highest percentage increase of N, P, K and total phenol contents in leaves, a situation which may be play a biotic vital resistance inducers against such pathogenic nematodes. Moreover, these present results are in accordance with these reported by Barker (1999) who stated that plants grown in various nutritional regimes indicated different actions to nematode infection due to ammonium accumulation and ethylene evolution. Moreover, in certain cases an increase in nematode population in Zn treated plots may be occurred that is due to negative effects of the heavy metals on some of their antagonists (Georgieval *et al.,* 2002). In conclusion, proper and good nutritional status of plants could enhance and magnify their defense systems agonist such nematode pathogens.

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دور بعض الأسمدة الغير عضوية في مكافحة نيماتودا تعقد الجذور *Meloidogyne incognita* التي تصيب الطماطم تحت ظروف الصوبة السلكية

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تم دراسة ثلاثة أسمدة غير عضوية هى كبريتات المنجنيز وكبريتات الزنك وكلوريد الكالسيوم عند ثلاثة تركيزات وهى 50، 100، 150 ملليجرام /لتر للسماد الأول والثانى و100، 200، 300 ملليجرام/ لتر للسماد الأخير رشاً ثلاث مرات بين كل رشة والاخرى 5 أيام على التوالى مقارنة بمبيد الأوكساميل عند الجرعة الموصى بها (0.3 جرام / نبات) على نباتات الطماطم صنف كاستل روك المصاب بنيماتودا تعقد الجذور "ميليدوجيني انكوجنيتا" تحت ظروف الصوبة السلكية (29 ±7°م)

وأسفرت النتائج على ما يلى :-

1- أدت جميع المواد المختبرة بتركيزاتها الى تحسن معنوى فى مقاييس النمو النباتيه المختبرة مع خفض واضح فى مقاييس النيماتودا المختبرة بدرجة كبيرة لحد ما.
2- كانت المعامله بسماد كلوريد الكالسيوم عند تركيز 200ملليجرام/ لتر الأفضل يليها المعاملة بكبريتات المنجنيز عند تركيز 150 ملليجرام/ لتر فى معدلات الزيادة للمقاييس النباتيه المختبرة مثل الوزن الجاف وللمجموع الخضري بنسب 30 و 21.1 % على التوالى وكانت المعاملة بكبريتات الزنك عند تركيز 100 ملليجرام/ لتر الأقل فى قيمة الوزن الجاف للمجموع الخضرى بمعدل 9.6 % على التوالى.
3- لوحظ اتجاه مشابه فى معدلات خفض مقاييس النيماتودا المختبرة مثل تعداد النيماتودا الكلى بمعدلات 90.8 % ، 90.7 و 90.2 على التوالى لنفس المعاملات السابقة الذكر.
4- تأثر تكاثر النيماتودا بالمعاملات المختبرة للأسمدة الغير عضوية وتركيزاتها التى أعطت نتائج مشابهة لما سبق فى المقاييس النباتية حيث كان المعاملة بكلوريد الكالسيوم عند تركيز 200 ملليجرام/ لتر وكبريتات الزنك عند تركيز 50 ملليجرام/ لتر انهما يمثلان الحد الادنى والحد الأقصى لقيم التكاثر بمعدل 0.13 و 0.15 مقابل 1.39 للنيماتودا منفردة على التوالى.
5- إن تركيزات النيتروجين والفوسفور والبوتاسيوم والمحتوي الكلي للكلوروفيل والفينول في أوراق الطماطم المصابة بالنيماتودا أو الغير المصابة طبقاً لتأثرها بالرش الورقي للأسمدة الغير العضوية المختبرة وتم تسجيلها ومناقشتها.

قام بتحكيم البحث

أ.د / فاطمة عبد المحسن مصطفي	**كلية الزراعة – جامعة المنصورة**
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Table (1): Plant growth response of tomato plant cv. Castle Rock infected with *Meloidogyne incognita* as affected by spraying calcium nutrient at three concentrations in comparison with oxamyl under greenhouse conditions (29±7º C).

Treatments	**Conc. mg/l**	****Plant growth parameters**															
		Plant length (cm)				**Plant fresh wt (g)**				**Shoot D. wt (g)**	**% Inc.**	**No. of leaves**	**% Inc.**	**No. of branches**	**% Inc.**	**No. of flowers**	**% Inc.**
		Shoot	**%Inc.**	**Root**	**%Inc.**	**Shoot**	**%Inc.**	**Root**	**%Inc.**								
INFECTED																	
Ca	**100 mg/l**	32.38 e	19.9	11.22 c	24.7	17.16 f	22.6	9.35 cd	33.6	9.49 f	26.5	25.37 e	26.9	3.3 d	50.0	2 bc	300
	200 mg/l	33.25 d	23.1	11.52 c	28.0	17.62 d	25.9	9.60 c	37.1	9.75 d	30.0	26.03 d	30.2	3.3 d	50.0	3 ab	500
	300 mg/l	31.31 f	15.9	10.84 d	20.4	16.59 g	18.5	9.03 d	29.0	9.18 g	22.4	24.51 f	22.6	3.2 e	45.4	3 ab	500
Oxamyl		32.61 e	20.7	11.29 c	25.4	17.28 ef	23.4	9.41 c	34.4	9.56 e	27.5	25.52 e	27.6	3.3 d	59.1	2 c	300
***N alone**		27.0 g	-----	9.00 e	-----	14.0 h	-----	7.0 e	-----	7.5 h	-----	20.0 g	-----	2.2 f	-----	0.5 d	-----
UNINFECTED																	
Ca	**100 mg/l**	36.63 c	10.5	12.69 b	10.4	19.41 c	10.5	10.57 b	10.4	10.74 c	10.4	28.67 c	10.4	3.7 b	8.8	2 bc	100
	200 mg/l	39.23 a	18.3	13.59 a	18.3	20.79 a	18.3	11.35 a	18.6	11.50 a	18.2	30.71 a	18.3	3.9 a	14.7	3 a	200
	300 mg/l	38.36 b	15.7	13.29 a	15.7	20.33 b	15.7	11.07 a	15.7	11.25 b	15.1	30.03 b	15.7	3.8 ab	11.8	3 a	200
Plant free		33.16 d	-----	11.49 c	-----	17.57de	-----	9.57 c	-----	9.73 d	----	25.96 d	-----	3.4 c	-----	2 bc	-----
L.S.D 5%		**0.331**	**-----**	**0.330**	**-----**	**0.330**	**-----**	**0.332**	**-----**	**0.067**	**------**	**0.331**	**-----**	**0.127**	**-----**	**0.934**	**-----**

N= 1500 eggs of *M. incognita **** Each value is the mean of five replicates.**

Means in each column followed by the same letter (s) did not differ at P< 0.05 according to Duncan multible- range test

Table (2): Plant growth response of tomato plant cv. Castle Rock infected with *Meloidogyne incognita* as affected by spraying zinc nutrient at three concentrations in comparison with oxamyl under greenhouse conditions (29±7ºC).

Treatments	Conc. mg/l	**Plant growth parameters															
		Plant length (cm)				Plant fresh Wt (g)				Shoot D. wt (g)	% Inc.	No. of leaves	% Inc.	No. of branches	% Inc.	No. of flowers	% Inc.
		Shoot	%Inc.	Root	%Inc.	Shoot	%Inc.	Root	%Inc.								
INFECTED																	
Zn	**50 mg/l**	27.54 g	2.0	9.54 e	6.00	14.59de	4.2	7.95 e	13.6	8.07 g	7.6	21.56 g	7.8	2.7 b	22.7	1 bc	100
	100 mg/l	28.05 f	3.8	9.72 e	8.00	14.87 d	6.2	8.10 e	15.7	8.22 f	9.6	21.96 f	9.8	2.8 b	27.3	2 a	300
	150 mg/l	27.58 g	2.0	9.55 e	6.11	14.62de	4.4	7.96 e	13.7	8.08 g	7.7	21.59 g	7.9	2.8 b	27.3	2 a	300
Oxamyl		32.61 e	20.7	11.29 d	25.4	17.28 c	23.4	9.41 d	34.4	9.56 e	27.5	25.52 e	27.6	3.3 a	50.0	2 a	300
***N alone**		27.0 g	-----	9.0 f	-----	14.0 e	----	7.0 f	-----	7.5 h	-----	20.0 h	-----	2.2 c	-----	0.5 c	-----
UNINFECTED																	
Zn	**50 mg/l**	33.91 c	2.3	11.74 bc	2.17	17.96 b	2.2	9.78 bc	2.2	9.94 c	2.2	26.54 c	2.2	3.4 a	0.0	2 a	100
	100 mg/l	35.37 b	6.7	12.25 a	6.61	18.75 a	6.7	10.21 a	6.7	10.37 a	6.5	27.69 a	6.7	3.5 a	2.9	2 a	100
	150 mg/l	37.72 a	13.8	12.03 ab	4.69	18.48 a	5.2	10.02 ab	4.7	10.18 b	4.6	27.18 b	4.6	3.5 a	2.9	2 ab	100
Plant free		33.16 d	-----	11.49 cd	-----	17.57 c	-----	9.57 cd	-----	9.73 d	-----	25.96 d	-----	3.4 a	-----	2 ab	-----
L.S.D 5%		**0.331**	**-----**	**0.330**	**-----**	**0.331**	**-----**	**0.332**	**-----**	**0.034**	**-----**	**0.330**	**-----**	**0.136**	**-----**	**0.934**	**-----**

N= 1500 eggs of *M. incognita **** Each value is the mean of five replicates.**

Means in each column followed by the same letter (s) did not differ at P< 0.05 according to Duncan multible- range test

Table (3): Plant growth response of tomato plant cv. Castle Rock infected with *Meloidogyne incognita* as affected by spraying manganese nutrient at three concentrations in comparison with oxamyl under greenhouse conditions (29±7º C).

Treatments	Conc. mg/l	**Plant growth parameters															
		Plant length (cm)				Plant fresh Wt (g)				Shoot D. wt (g)	% Inc.	No. of leaves	% Inc.	No. of branches	% Inc.	No. of flowers	% Inc.
		Shoot	%Inc.	Root	%Inc.	Shoot	%Inc.	Root	%Inc.								
INFECTED																	
Mn	50 mg/l	29.57 h	9.5	10.24 e	13.8	15.67 f	11.9	8.53 d	21.9	8.67 h	15.6	23.15 h	15.8	3.0 c	36.4	1 bc	100
	100 mg/l	30.35 g	12.4	10.51 de	16.8	16.08 e	14.9	8.76 cd	25.1	8.90 g	18.7	23.76 g	18.8	3.0 c	36.4	2 a	300
	150 mg/l	30.95 f	14.6	10.72 d	19.1	16.41 d	17.2	8.93 c	27.6	9.08 f	21.1	24.24 f	21.2	3.2 b	45.5	2 a	300
Oxamyl		32.61 e	20.7	11.29 c	25.4	17.28 c	23.4	9.41 b	34.4	9.56 e	27.5	25.52 e	27.6	3.3 ab	50.0	2 ab	300
*N alone		27.0 i	-----	9.0 f	-----	14.0 g	-----	7.0 e	-----	7.5 i	-----	20.0 i	-----	2.2 d	-----	0.5 c	-----
UNINFECTED																	
Mn	50 mg/l	36.19 c	9.1	12.54 b	9.1	19.18 b	9.2	10.52 a	9.9	10.62 c	9.1	28.34 c	9.2	3.6 ab	5.9	2 a	100
	100 mg/l	36.89 b	11.2	12.78 ab	11.2	19.55 a	11.3	10.65 a	11.3	10.82 b	11.2	28.88 b	11.2	3.7 ab	8.8	2 ab	100
	150 mg/l	37.45 a	12.9	12.97 a	12.9	19.85 a	12.9	10.81 a	12.9	10.98 a	12.8	29.32 a	12.9	3.8 a	11.8	2 ab	100
Plant free		33.16 d	-----	11.49 c	-----	17.57 c	-----	9.57 b	-----	9.73 d	-----	25.96 d	-----	3.4 ab	-----	2 a	-----
L.S.D 5%		**0.330**	**-----**	**0.330**	**-----**	**0.331**	**-----**	**0.330**	**-----**	**0.048**	**-----**	**0.330**	**-----**	**0.479**	**-----**	**0.934**	**-----**

N= 1500 eggs of *M. incognita **** Each value is the mean of five replicates.**

Means in each column followed by the same letter (s) did not differ at P< 0.05 according to Duncan multible- range test

Table (4): Nematode parameters of *M. incognita* infecting tomato plants cv. Castle Rock as influenced by spraying three nutrient minerals at three concentrations each in comparison with oxamyl under greenhouse conditions (29±7° C).

Treatments	Conc. mg/l	*Nematode parameters									
		J_2 in soil	In root						Final population (Pf)	RF	% Red.
			No. of galls	RGI**	No. of D. Stages	No. of Female	No. of Egg-masses	EI**			
$MnSO_4$	**50**	98.67 d	43.61 e	4	30 c	92.95 c	85.8 e	4	221.62 d	0.15	89.4
	100	96.74 e	42.76 f	4	20 d	91.13 f	84.12 f	4	207.87 e	0.14	90.0
	150	74.25 k	41.66 g	4	30 c	88.79 g	81.96 g	4	193.04 h	0.13	90.7
$ZnSO_4$	**50**	105.98 b	45.63 c	4	30 c	97.24 c	89.76 c	4	233.22 b	0.15	88.8
	100	74.77 j	44.11 d	4	35 b	93.99 d	86.76 d	4	203.76 f	0.14	90.2
	150	103.22 c	46.85 b	4	20 d	99.84 b	92.16 b	4	223.06 c	0.15	89.3
$CaCl_2$	**100**	89.42 f	39.52 h	4	30 c	84.24 h	76.32 j	4	203.66 f	0.14	90.2
	200	87.76 h	38.79 j	4	20 d	82.68 i	77.76 h	4	190.44 i	0.13	90.8
	300	87.91 g	38.85 i	4	30 c	82.81 i	76.44 i	4	200.72 g	0.13	90.4
Oxamyl		75.91 i	35.93 k	4	2 e	75.89 j	70.36 k	4	171.80 j	0.12	91.75
N alone		1408.4 a	254.02 a	5	465.6 a	210.0 a	198.56 a	5	2084 a	1.39	-----
LSD 0.05		**0.052**	**0.009**	**-----**	**1.103**	**0.294**	**0.031**	**-----**	**0.296**	**-----**	**-----**

N= 1500 eggs of *M. incognita*.

***Each value is the mean of five replicates.**

*** Rate of build-up (R) =** $\frac{\text{final population}}{\text{Initial population}}$ **= RF**

**** Root gall index (RGI) or egg-masses index (EI) was determined according to the scale given by Taylor& Sasser (1978) as follows : 0= no galls or eggmasses, 1= 1-2 galls or eggmasses , 2= 3-10 galls or eggmasses, 3= 11-30 galls or eggmasses, 4= 31-100 galls or eggmasses and 5= more than 100 galls or eggmasses.**

Table (5): **N, P, and K concentration of leaves; chlorophyll content and total phenol of tomato infected or uninfected with *Meloidogyne incognita* by spraying Manganese nutrient at three concentrations each in comparison with oxamyl under greenhouse conditions (29± 7°C).**

Treatments	Conc. mg/l	**Chemical components											
		Leaves						Leaves				T. phenol mg/100 f.wt.	% Inc. & Dec.
		N%	% Inc.	P%	% Inc.	K%	% Inc. & Dec.	Chlorophyll content mg/g F.Wt.					
								Chlo. a	Chlo. b	a + b	% Inc. & Dec.		
INFECTED													
Mn	**50 mg/l**	2.39 e	8.63	0.407 f	10.0	2.56 e	-10.48	0.394 g	0.289 i	0.683 i	-24.6	0.545 c	12.83
	100 mg/l	2.48 d	12.72	0.409 f	10.5	2.61 e	-8.74	0.403 fg	0.298 h	0.701 h	-22.6	0.560 d	15.94
	150 mg/l	2.55 d	15.91	0.417 e	12.7	2.69 d	-5.94	0.408 f	0.307 g	0.715 g	-21.0	0.585 f	21.11
Oxamyl +N		2.69 c	22.27	0.461 d	24.5	2.30 f	-19.58	0.441 e	0.312 f	0.738 f	-18.5	0.632 a	30.84
***N alone**		2.20 f	-----	0.370 g	-----	2.86 c	-----	0.509 a	0.397 a	0.906 a	-----	0.483 i	-----
UNINFECTED													
Mn	**50 mg/l**	2.95 b	8.45	0.495 b	5.31	2.13 g	-25.52	0.480 c	0.356 d	0.836 d	9.13	0.551 e	-10.26
	100 mg/l	3.02 ab	11.02	0.502 ab	6.80	3.20 b	11.88	0.489 b	0.363 c	0.852 c	11.22	0.528 g	-14.00
	150 mg/l	3.10 a	13.97	0.509 a	8.29	3.27 a	14.33	0.493 b	0.372 b	0.865 b	12.92	0.511 h	-16.77
Plant free		2.72 c	-----	0.470 c	-----	2.86 c	-----	0.450 d	0.316 e	0.766 e	-----	0.614 b	-----
L.S.D 0.05%		**0.082**	**-----**	**0.008**	**-----**	**0.059**	**-----**	**0.008**	**0.001**	**0.001**	**-----**	**0.005**	**-----**

N= 1500 eggs of *M. incognita **** Each value is the mean of five replicates.**

Means in each column followed by the same letter (s) did not differ at P< 0.05 according to Duncan multiple- range test

Table (6): N, P, and K concentration of leaves; chlorophyll content and total phenol of tomato infected or uninfected with *Meloidogyne incognita* by spraying Zinc nutrient at three concentrations each in comparison with oxamyl under greenhouse conditions (29± 7°C).

Treatments	Conc. mg/l	**Chemical components											
		Leaves						Leaves				T. phenol mg/100 f.wt.	% Inc. & Dec.
		N%	% Inc.	P%	% Inc.	K%	% Inc. & Dec.	Chlorophyll content mg/g F.Wt.					
								Chlo. a	Chlo. b	a + b	% Dec.		
INFECTED													
Zn	50 mg/l	2.25 ef	2.27	0.380 fg	2.70	2.33 de	-18.5	0.375 fg	0.261 c	0.636 e	-29.8	0.596 b	23.39
	100 mg/l	2.33 e	5.91	0.394 e	6.48	2.47 c	-13.6	0.379 f	0.269 a	0.648 d	-28.4	0.628 e	30.02
	150 mg/l	2.23 f	1.36	0.385 ef	3.89	2.40 cd	-16.1	0.371 g	0.266 bc	0.637 e	-29.6	0.612 c	26.70
Oxamyl +N		2.69 d	22.2	0.461 d	24.59	2.30 e	-19.5	0.441 e	0.312 abc	0.738 c	-18.5	0.632 b	30.84
*N alone		2.20 f	-----	0.370 g	----	2.86 b	-----	0.509 a	0.397 ab	0.906 a	----	0.483 a	-----
UNINFECTED													
Zn	50 mg/l	2.80 bc	2.94	0.474 bc	0.84	2.94 b	2.79	0.458 c	0.325 abc	0.636 e	-16.9	0.602 d	-19.54
	100 mg/l	2.91 a	6.98	0.489 a	3.88	3.08 a	7.69	0.471 b	0.346 abc	0.648 d	-15.4	0.566 g	-8.48
	150 mg/l	2.83 ab	4.04	0.481 ab	2.28	3.03 a	5.94	0.467 b	0.335 abc	0.637 e	-16.8	0.583 f	-5.04
Plant free		2.72 cd	-----	0.470 cd	-----	2.86 b	-----	0.450 d	0.316 abc	0.766 b	-----	0.614 c	-----
L.S.D 0.05%		**0.082**	**-----**	**0.010**	**-----**	**0.082**	**-----**	**0.005**	**0.132**	**0.006**	**-----**	**0.006**	**-----**

N= 1500 eggs of *M. incognita **** Each value is the mean of five replicates.**

Means in each column followed by the same letter (s) did not differ at P< 0.05 according to Duncan multiple- range test

Table (7): N, P, and K concentration of leaves; chlorophyll content and total phenol of tomato infected or not infected with *Meloidogyne incognita* by spraying Calcium nutrient at three concentrations each in comparison with oxamyl under greenhouse conditions (29± 7°C).

Treatments		**Chemical components											
		Leaves						**Leaves**				**T. phenol mg/100 f.wt.**	**% Inc. & Dec.**
		N%	**% Inc.**	**P%**	**% Inc.**	**K%**	**% Inc. & Dec.**	**Chlorophyll content mg/g F.Wt.**					
	Conc. mg/l							**Chlo. a**	**Chlo. b**	**a + b**	**% Inc. & Dec.**		
INFECTED													
Ca	**100 mg/l**	2.67 f	21.36	0.449 e	17.83	2.78 f	-2.79	0.427 g	0.321 cd	0.748 f	-17.4	0.501 e	3.72
	200 mg/l	2.81 d	27.72	0.445 d	20.27	2.92 d	2.05	0.433 f	0.335 bcd	0.768 d	-15.2	0.643 a	33.12
	300 mg/l	2.74 e	24.54	0.436 de	17.59	2.84 e	-0.70	0.425 g	0.298 d	0.723 h	-20.2	0.513 d	6.21
Oxamyl +N		2.69 ef	22.27	0.461 c	24.59	2.30 g	-19.58	0.441 e	0.312 d	0.738 g	-18.5	0.632 b	30.84
***N alone**		2.20 g	-----	0.370 f	-----	2.86 e	-----	0.509 a	0.397 a	0.906 a	----	0.483 g	-----
UNINFECTED													
Ca	**100 mg/l**	3.16 c	13.92	0.512 b	8.93	3.31 c	15.7	0.469 c	0.377 abc	0.846 c	10.44	0.492 f	-19.8
	200 mg/l	3.29 a	20.95	0.520 ab	16.6	3.45 a	20.62	0.437 ef	0.301 d	0.738 g	-3.65	0.448 i	-27.0
	300 mg/l	3.22 b	18.38	0.526 a	11.91	3.39 b	18.5	0.502 b	0.384 ab	0.886 b	15.66	0.467 h	-31.4
Plant free		2.72 ef	-----	0.470 c	-----	2.86 e	-----	0.450 d	0.316 d	0.766 e	-----	0.614 c	-----
L.S.D 0.05%		**0.059**	**-----**	**0.010**	**-----**	**0.059**	**----**	**0.005**	**0.057**	**0.001**	**-----**	**0.002**	**-----**

N= 1500 eggs of *M. incognita **** Each value is the mean of five replicates.**

Means in each column followed by the same letter (s) did not differ at P< 0.05 according to Duncan multiple- rage test