

INFLUENCE OF PLANT RESISTANCE AND NEMATOCIDES ON GROWTH AND YIELD OF
TOMATO (LYCOPERSICON ESCULENTUM) AND ON POPULATION DYNAMICS OF
ROOT-KNOT NEMATODES (MELOIDOGYNE INCOGNITA AND MELOIDOGYNE
HAPLA) WITH AN ASSOCIATED STUDY OF ROOT-KNOT NEMATODE
RESISTANCE IN LETTUCE (LACTUCA SPECIES)

A Thesis

Presented to the Faculty of the Graduate School
of Cornell University
in Partial Fulfillment for the Degree of
Doctor of Philosophy

by

Conrad Komla Bonsi

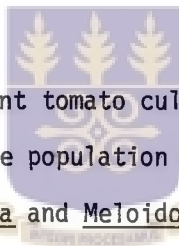
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Conrad Komla Bonsi, Ph.D.
Cornell University, 1982



The influence of resistant tomato cultivars, chemical applications and both in combination on the population dynamics of root-knot nematode species (Meloidogyne incognita and Meloidogyne hapla) and on growth and yield of subsequent susceptible tomato crops was studied.

Both growth chamber and field experiments were conducted. High initial inoculum densities (P_i) of root knot nematode species reduced growth but had slight or no effect on growth of resistant cultivars.

Nematode reproduction was positively correlated with the initial inoculum density. M. incognita was more virulent than M. hapla on the susceptible (Rutgers) tomato. VFN-8 was found to be partially resistant to M. hapla.

Continuous cropping of a susceptible cultivar in infested soil greatly increased the nematode population and decreased the growth of susceptible plants. Resistant cultivars or applications of Vorlex alone permitted one (at highest P_i 's) and two to three (at lowest P_i 's)

susceptible crops to be grown before the nematode population reached a plant damaging level. Applications of Vorlex after a crop of resistant cultivar resulted in sufficient reductions of the nematode populations that at least three successive crops of the susceptible cultivar could be grown before the population reached a plant damaging level. A lower dosage of chemical was needed when used in combination with a resistant cultivar to control root knot nematodes.

In field experiments, Vorlex significantly increased marketable yields of tomatoes. Further increases in marketable yields of Rutgers tomato were obtained when Vorlex was applied to infested soil that had been previously planted to a resistant cultivar. In another study, only the resistant tomato seedlings when transplanted after 2 wk from highly infested to noninfested soil, grew as well as those transplanted from noninfested to noninfested soil.

In the third study, none of either the Lactuca species or the lettuce breeding lines tested were resistant to M. incognita and M. javanica. L. saligna and L. dregeana were resistant to a greenhouse population of M. hapla but were susceptible to a field population of M. hapla.

BIOGRAPHICAL SKETCH

Conrad Komla Bonsi was born on December 11, 1950 in Ghana, W. Africa. He attended Evangelical Presbyterian Secondary and Kpandu Secondary Schools for his secondary education. He holds a Bachelor of Science (HONS) degree in Crop Protection from the University of Ghana. He received his Master of Science degree in Plant and Soil Science from Tuskegee Institute, Alabama in May 1978.

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To my mother, Akosua, who didn't believe,

To my very special friends
Eunice, Akweley, Dilys, and Janice

and

To the taxpayers in Ghana



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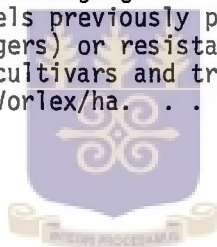
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GENERAL INTRODUCTION

Root-knot nematodes (Meloidogyne spp.) account for significant yield losses of vegetable crops grown throughout the world. The most common species encountered worldwide are M. incognita, M. javanica, M. arenaria and M. hapla (5); which are pathogenic on tomatoes. M. incognita, M. javanica and M. arenaria occur mostly in the tropical and subtropical regions where average annual temperature is between 18 to 30°C, while M. hapla is limited to the cooler regions of the world. Wong and Mai (7, 8, 9), however, found that higher temperatures (21-26°C) are favorable for invasion of M. hapla. Once invasion has occurred, the nematodes develop readily if temperatures are high; in the regime of 27°C night and 30°C day, eggs can be produced in 20 days. It is, therefore, possible that M. hapla once introduced in the tropics can survive and cause severe crop damage. On the other hand, M. incognita is unable to withstand cold temperatures and therefore does not survive long when introduced in the fields in temperate regions.

Because of the wide host range of root knot nematode species that attack vegetable crops, the use of plant resistance and chemicals are likely to remain more important control measures than crop rotation. Increases of plant growth and yield of vegetable crops often result from applications of broad spectrum fumigants or nematicides such as Vorlex. These growth and yield responses are not only due to the control of plant parasitic nematodes but also to the control of other non target organisms. Thus, frequent or high dosage applications of fumigants and nematicides are often used in an effort to produce crops that are of high economic value. This, however, can cause serious health and economic problems.

Current research emphasis is therefore being directed towards other forms of control in order to reduce the dependence on chemicals.

One of the control measures being turned to more frequently is the use of plant resistance. Plant resistance is an effective, economical and environmentally safe method of control. It has been used quite effectively in reducing both the populations of root knot nematodes and losses caused by their attack (1). The dependence solely on resistant cultivars may pose a serious control problem due to the variability that can exist in populations of root knot nematodes and the frequent occurrence of mixed species in field populations (2, 6). Some resistant cultivars are horticulturally unsuitable or culturally unacceptable in certain localities. The use of such resistant cultivars more than once in a cropping system may therefore be economically unacceptable. It has been suggested (2, 3, 5) that in situations of heavy infestations, Meloidogyne populations should be reduced by either chemical or cultural means before growing a non host or a resistant variety. The use of available information can help in developing integrated control systems. In these systems non hosts, resistant cultivars, cultural practices and periodic nematicide applications can be combined to keep the nematode population below the damaging levels. This practice will also help to avoid development of resistance breaking biotypes. The importance of developing a management system that will combine effective control measures and permit the continued use of desirable but susceptible cultivars but without developing a damaging nematode population cannot be overemphasized.

The main objective of this research was to investigate the influence

of resistant hosts, chemical treatments, and combinations of the two on population dynamics of two root knot nematode species and on the growth and yield of subsequent susceptible tomato crops. Research was also conducted to study the effect on resistant and susceptible tomato transplants of various periods of exposure to root knot nematodes. Also several Lactuca species and breeding lines of Lactuca sativa were evaluated for resistance to root knot nematode species.



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Chapter 1

INFLUENCE OF PLANT RESISTANCE AND CHEMICAL TREATMENTS ON GROWTH AND
YIELD OF TOMATO AND POPULATION DYNAMICS OF ROOT KNOT NEMATODES
(MELOIDOGYNE INCOGNITA AND M. HAPLA)

Abstract

Both growth chamber and field experiments were conducted to study the influence of resistant tomato cultivars and applications of Vorlex (DD MENCS) on the population dynamics of root knot nematode species and growth and yield of subsequent crops of a susceptible tomato cultivar. Four initial M. incognita inoculum densities (10^3 , 5×10^3 , 10^4 and 10^5 eggs/500 cm³ of soil) and two initial M. hapla inoculum densities (10^3 and 5×10^3 eggs/500 cm³ of soil) were used. Two resistant tomato cultivars (Nematex and VFN-8) and a susceptible cultivar (Rutgers) were used in studies with M. incognita. A resistant tomato species (Lycopersicon peruvianum), partially resistant (VFN-8) and susceptible (Rutgers) tomato cultivars were used in studies with M. hapla. Field experiments were conducted with M. hapla using the same initial inoculum densities of the nematode and the same tomato cultivars as in the growth chamber experiments. Vorlex was used at 22.5, 45 and 90 L/ha in growth chamber studies and at 45 L/ha in field studies. In the growth chamber studies both resistant and susceptible tomato plants were inoculated with the different initial inoculum density (P_1) levels of the Meloidogyne sp. Six weeks after inoculation, plant tops were removed and the nematode population was determined. Vorlex was applied to seven replications of each treatment. An equal number of replicates

were left untreated. Four weeks after fumigation, pots were replanted with seedlings of the susceptible cultivar and grown for 6 wks. The population of the nematode was determined and pots were immediately replanted with seedlings of the susceptible cultivar. Three more successive plantings of Rutgers were made before the experiment was terminated. Continuous cropping of a susceptible cultivar in infested soil greatly increased the nematode population and decreased the growth of plants. Resistant plants and applications of Vorlex to infested soil had similar effects in reducing nematode populations. Resistant cultivars alone or Vorlex alone resulted in nematode reduction that permitted one (at highest P_{1s}) and two to three (at lowest P_{1s}) plantings of susceptible crops to be grown before the nematode population returned to a damaging level. Applications of Vorlex after growing a resistant tomato cultivar resulted in sufficient reductions of the nematode populations so that at least three successive plantings of the susceptible cultivar could be grown before the population reached a damaging level. In field experiments, applications of Vorlex significantly increased marketable yields of the susceptible tomatoes. A further increase in yield of Rutgers was obtained when Vorlex was applied to infested soil that had been previously planted to resistant tomatoes before growing the susceptible cultivar. Fewer nematodes were recovered from the infested soil at the end of the second season although heavy galling was observed on infected roots.

Introduction

It has been shown by several workers (3, 4, 22, 23, 26, 33, 40) that the fundamental quantitative relationships between plant parasitic

nematodes and growth and yield of annual crops are primarily the function of preplant densities.

Seinhorst (32, 33) observed that the relationship between the density of populations of root infecting nematodes and the yield of infected plants can be expressed by an equation which showed two phenomena; (a) a certain density up to which yield is not affected and (b) a certain minimum yield which remained unaffected even at the highest densities.

The initial density required to cause significant plant damage and yield losses varies with different nematode species (33); the plant species, variety (21, 22, 23), age at planting (21, 45) and the environmental conditions (41, 45). Wallace (40) observed that Meloidogyne javanica at low numbers stimulated growth of some plant species. In some species, top growth was reduced while in another species, there was no effect on top growth. Swarup and Sharma (35) observed that 100 M. javanica larvae per 400 gm of soil and 1,000 M. incognita larvae per 400 gm of soil caused significant reduction in growth of tomatoes. In an experiment conducted by Potter and Olthof (26), in which M. hapla was used as inoculum, marketable yields of beet, lettuce and spinach tended to be inversely correlated with preplant nematode densities. Yield losses of marketable produce at highest initial inoculum density were 22% for beet, 81% for lettuce and 13% for spinach. In a similar experiment, Olthof and Potter (22) showed that yields of cabbage and cauliflower were reduced by 9% and 24%, respectively at the highest inoculum density. The numbers and fresh weights of potato and onions decreased with increase in initial inoculum density but commercial

losses were 46% and 64%, respectively. Olthof and Potter (23), in another experiment with 'Veebrite' tomatoes, showed that low nematode populations stimulated and highest nematode populations suppressed vegetative plant growth and yield of marketable produce.

Control of root knot nematodes through development of resistant cultivars has gained importance since the recent increased concern for environmental, health and ecological hazards due to pesticide chemicals. Successful use of root knot resistance requires the manipulation of genetic systems to transfer resistant genes to a susceptible plant that has acceptable horticultural characteristics.

Hypersensitivity is the most usual type of resistance response. This reaction occurs within a few hours after penetration (17, 24, 29, 43). The browning reaction of the root, which indicates hypersensitivity, is due to an accumulation of phenolic compounds in the tissues around the infection sites (5, 25, 34). Resistance to root knot nematodes can be modified by the plant's genotype (27, 28) and environmental factors (11). Holtzman (10) showed that resistance of tomato to M. incognita was less at 30 and 34.5°C than at 20 and 25°C although invasion was not as great as in a susceptible cultivar at these temperatures. Dropkin (5) showed that the resistant tomato cv. Nematex grown at 28°C and below was highly resistant to M. incognita acrita. However, resistance diminished with each degree above 29°C and the seedlings were fully susceptible at 33°C. Similar temperature effects were observed with beans (7) and sweet potato (13). Some resistant plants, on the other hand, showed increased resistance as temperature increased. Dropkin (5) observed that the resistance of African horned cucumber, Cucumis metulifera, to M. incognita

increased as the temperatures rose from 28 to 32°C. He also observed that resistant reactions differed between cultivars within the same species.

There are a number of reports on the inheritance of resistance to root knot nematode with most reporting one (1, 9, 27, 38, 42), a few more than one (2, 9) dominant or incompletely (9) dominant gene(s) for resistance. Sidhu and Webster (23) in their study of four genes for resistance in tomato against M. incognita found that two of the genes were different rather than either allelic or identical. Two other resistant genes were found to be allelic or identical. They, however, found no relationship between the third gene (possessed by tomato cv. Cold Set-1) and the other genes. In another experiment, the same workers (27) showed that the F_2 and backcross ratios from crosses between Nematex, Rutgers and Bonny Best suggest monogenic control of resistance in each case. They observed that the resistance expressed by Nematex was dominant over the partial resistance of Rutgers and the complete susceptibility of Bonny Best. It was not evident as to whether the resistant genes in cv. Nematex and Rutgers were identical or closely linked. They, however, noted that since resistance in Nematex and Rutgers was derived from different genetic material, it was quite possible that the resistant genes might be allelic or identical but manifest different levels of resistance when influenced by a different genetic background.

Differences in the host-parasite (resistant) reactions are due not only to the genetic background of the host but also to the variability of different populations of the species of Meloidogyne (19). It is therefore possible that when different populations of a species of

Meloidogyne are tested against several cultivars of the same host, there can be complex host-parasite relationships since variability of both host and parasite are involved.

Cultivation of resistant cultivars generally results in reduction of populations of root knot nematodes (6, 18, 19, 20, 36). However, repeated cultivation of such cultivars may result in a buildup of the nematode population (16, 19, 36). Resistant breaking biotypes or populations of Meloidogyne spp. have been reported by several workers (29, 30, 36, 39). However, resistant varieties of several other crop plants other than the crop on which the biotype developed were found to be resistant to the new population (30, 39).

Sauer and Giles (31) observed that resistant tomatoes did not reduce the nematode population sufficiently to make possible the successful cultivation of a subsequent susceptible crop. Johnson and Campbell (14) in studies of the effects of cropping systems and nematicides found that clean fallow reduced nematode populations more effectively than rotation crops of millet, milo, soybean, crotalaria or pigeon pea. Furthermore, after 2 years of growing the susceptible crop, nematode populations increased to damaging levels and could not be controlled by fallowing even when used in combination with fensulfolthion.

Soil fumigation is the most common chemical treatment used to achieve economical control of nematodes in agricultural land. The most commonly used soil fumigants contain 1,3, dichloropropene as the active ingredient. Application rates ranging between 100-500 L/ha have been used to increase yields of tomatoes (15). Vorlex, one of the commonly used nematicides contains 80% dichloropropene and 20% methylisothiocynata

Vorlex is more effective than 1,3-D alone. It persists longer in soil and the two compounds act synergistically in the water phase. It is also considered to be a broad spectrum fumigant because of its fungicidal and herbicidal properties. The use of soil fumigants is limited because of the need for special equipment, trained personnel, special environmental conditions or because of long persistence and phytotoxicity (15). Various environmental factors as well as method of application affect the efficiency of soil fumigation (37, 46).

Guskova (8) showed that application of thiazone at a low dosage rate followed by growing the resistant potato variety 'Sagitta' resulted in a decrease in the number of viable eggs and larvae of potato cyst nematode. The same level of decrease was obtained when the soil was treated with 1,000 kg/ha of thiazone alone. Johnson and Campbell (14) were able to reduce the population of root knot nematodes to a level that allowed growing of a susceptible tomato variety for about 3 seasons before damaging population levels were reached by using combinations of non hosts and fensulfolthion. Minton et al. (18) showed that there was a limited benefit to the subsequent crop from the residual effect of DBCP and resistant soybean cultivars when plant resistance and the chemical were used for 2 previous years.

Most nematode control studies that involve an integrated approach usually deal with one initial population level of the nematodes and one chemical dosage level. In this study, different initial root knot nematode densities and chemical dosage levels as well as plant resistance were used to study their residual effects on population dynamics of root knot nematodes and the growth and yield of subsequent susceptible tomato

crops.

Materials and Methods

A. Growth Chamber Experiments

Meloidogyne incognita and Meloidogyne hapla were obtained from populations maintained on Rutgers tomato (Lycopersicon esculentum) in the greenhouse. Eggs were used as inoculum and were extracted from heavily infested tomato roots with 0.8% NaOCl solution using a method described by Hussey and Barker (12). Two initial inoculum densities ($P_1 = 1,000$ and 5,000 eggs per 500 cm³ soil) were used. One application rate (90 L/ha) of Vorlex (80% dichloropropenes + 20% methyl isothiocyanate) was used in the first experiment. In subsequent experiments, 22.5 and 45 L/ha, were used. In experiments involving M. incognita, two resistant tomato cultivars, Nematex and VFN-8 and a susceptible cultivar, Rutgers, were used. In studies with M. hapla the resistant tomato, Lycopersicon peruvianum, and susceptible Rutgers and VFN-8 tomato cultivars were used.

In order to avoid contamination, the experiments in which different nematode species were used were conducted in separate growth chambers. Four week old tomato plants of each cultivar were inoculated with eggs of the Meloidogyne spp. at the different P_1 levels by spreading the inoculum on the surface of moist soil in which plants were growing and then covering the inoculum with a 4-6 cm layer of moist soil. Plants were grown in 12.5 cm pots in a growth chamber with 14 hrs light (22,596 lux) and $25 \pm 2^\circ\text{C}$. They were watered daily and fertilized with 20-20-20 water soluble fertilizer every 10 days. The experiment was terminated

6 weeks after inoculation. Roots were washed gently and rated for gall index using a rating system of 0 = no galling, 1 = 1-10% galling, 2 = 11-25% galling, 3 = 26-50% galling, 4 = 51-75% galling and 5 = above 75% galling. Roots and soil samples were taken from each replicate and the number of eggs and larvae per gm root and the number of larvae per 100 cm³ soil were determined. Eggs and larvae were extracted from the roots using 0.8% NaOCl solution, and larvae in the soil were extracted by the pie pan method (a modification of Baermann funnel method). Fresh weight of roots as well as fresh weight and dry weight of shoots were recorded. Number of eggs and larvae per 500 cm³ of soil was determined.

After root and soil samples had been taken, the remaining roots were cut into small pieces, returned to the original pots and mixed thoroughly in the soil. Appropriate dosages of Vorlex were then applied to 7 of the replicates. A similar number remained untreated. A small amount of water was poured on the soil in all pots. Pots were then stored in the laboratory (20 ± 2°C) undisturbed for 3 weeks. Prior to transplanting, the soil in each pot was cultivated and left to aerate for 7 days.

Four week old Rutgers seedlings were then transplanted into all the pots and grown in the growth chamber for 6 weeks. Nematode reproduction (i.e., gall index as well as egg and larval counts in roots and soil) and plant growth (fresh and dry wt.) were determined. This procedure was followed 3 more times with successive plantings of Rutgers tomatoes without any further applications of the chemical.

A completely randomized design was used and each experiment was conducted twice, with all final treatments replicated 7 times unless

otherwise stated.

B. Field Experiments

Microplots were established in the field in 1979 using a similar experimental design and the same treatments as in the growth chamber experiments. A section of fiberglass screen 120 x 50 cm was wrapped around a 30 cm (d) and 45 cm (ht) plastic cylinder with open ends. The remaining screening was folded to form a bottom of the microplot. The overlapping longitudinal ends were held together by strips of masking tape. The cylinder with the screen around it was then inserted in a hole dug in the soil. Soil was filled in around the outsides of the cylinder. The cylinder was filled with sandy loam soil collected from an orchard in New York State. The cylinder was then lifted gently so that the screening remained in place, forming walls of the microplot. Five rows of 18 microplots per row were established, 1 m apart.

The area between the microplots was tilled and the whole area was then fumigated with methylbromide and left undisturbed for 12 days. The soil in the microplots was cultivated and allowed to aerate for 1 week before the inoculum was added.

The inoculum was obtained from a culture of root knot nematode (M. hapla) maintained on Rutgers tomato in the greenhouse. Heavily infected roots were cut into small pieces and by using a coning technique mixed thoroughly in the soil. The number of eggs and larvae per 100 cm³ soil samples were determined. Depending on the treatment, appropriate volumes of the infested soil were added to the microplots.

Susceptible red kidney beans were planted in late summer to increase the root knot nematode populations. The following spring, soil samples were taken from all the infested plots and the population of nematodes

were determined. Populations were adjusted by adding appropriate volume of infested soil or by diluting the soil in the microplot with autoclaved soil. Initial population densities of 1,000 and 5,000 eggs and larvae/500 cm³ of soil were used.

Six week old tomato plants of Rutgers, VFN-8 and L. peruvianum (PI 2704325) were transplanted on May 28. The experiment consisted of 9 treatments with 10 replications per treatment in a completely randomized design.

Recommended cultural practices for fresh market tomato production were followed. Five harvests were made and soil samples were taken at each harvest. The tops of the plants were removed at the end of the season.

In mid April, of the following year, soil in each microplot was mixed with a trowel and soil samples were taken. Vorlex at the rate of 45 L/ha was then applied to 5 replications of each treatment. The experiment now consisted of 18 treatments with 5 replications per treatment because half of all the original treatments were treated with Vorlex

After 4 weeks, the soil in the microplots was mixed thoroughly and allowed to remain undisturbed for 2 weeks. Six week old Rutgers tomato plants were then transplanted in all the microplots on the 3rd of June. Recommended cultural practices for fresh market tomato production were followed. Six harvests were made and soil samples were taken at mid season (August 15) and at the end of the season (October 4).

Results

A. Effects of P_i level, resistant tomatoes and Vorlex applications on population dynamics of root-knot nematode species.

i) Effect of P_i level and resistant tomatoes on reproduction of the root-knot nematode species.

Tomatoes resistant to the root knot nematode species supported very little or no reproduction of the nematodes whereas Rutgers (susceptible) tomato supported high reproduction of the nematodes (Tables 1.1; 1.2 and 1.3). Higher P_i levels resulted in higher P_f . Although VFN-8 and Rutgers are susceptible to M. hapla, reproduction of M. hapla on VFN-8 was much less than on Rutgers (Table 1.3). Higher final populations of nematodes were observed when Rutgers was inoculated with M. incognita than when Rutgers was inoculated with the same P_i levels of M. hapla (Table 1.1 and 1.3).

ii) Influence of P_i level and resistant tomato on population dynamics of root-knot nematode species on subsequent susceptible host plantings.

A subsequent crop of Rutgers grown in infested soil previously planted to a susceptible tomato resulted in very large increases in the root knot nematode populations (Tables 1.4; 1.5; 1.6 and 1.7). Continuous cropping of Rutgers in infested soils previously planted to susceptible tomato maintained the population of the nematodes above damaging levels regardless of the P_i level (Figs. 1.1A; 1.2A; 1.3A, 1.4A; 1.5 A, D and 1.6 A, D), assuming a previously determined damaging level of 1,000 eggs and larvae/500 cm³ of soil.

Population dynamics of the root knot nematode species on subsequent Rutgers tomato grown in infested soils previously planted to resistant tomatoes depended more on the P_i level of the nematodes than on the source of resistance. At low P_i levels (1,000 and 5,000 eggs/500 cm³ of soil) resistant cultivars alone did not reduce the populations of the nematodes

sufficiently enough to allow more than three successive crops to be grown before damaging population levels again occurred (Figs. 1.1D, G; 1.2 D, G; 1.5 G and 1.6 G). At P_f levels of 10,000 and 100,000 eggs of M. incognita/500 cm³ of soil, only one additional susceptible crop could be grown before damaging population levels again occurred (Figs. 1.3D and 1.4D, G).

iii) Effects of Vorlex applications on population dynamics of root knot nematode species on subsequent plantings of Rutgers.

Applications of Vorlex to infested soil significantly reduced the populations of root knot nematode species regardless of the previous tomato cultivar (Tables 1.4; 1.5; 1.6 and 1.7). Less control of the nematode was achieved when 22.5 L Vorlex/ha was applied than when 45 or 90 L Vorlex/ha were applied to the infested soil. The dosage level of Vorlex as well as the P_f level of the nematode affected the population dynamics of the root knot nematode species on subsequent Rutgers crops. At low P_f levels of both nematode species (1,000 and 5,000 eggs/500 cm³ of soil) applications of 45 L Vorlex/ha to infested soil previously planted to susceptible tomatoes permitted Rutgers to be grown 3 times before damaging population levels reoccurred (Figs. 1.1 C; 1.2 C; 1.5 C, F, and 1.6 C, F). However, at higher P_f levels (10,000 and 100,000 M. incognita/500 cm³ of soil), the same dosage level of Vorlex reduced the nematode population enough to allow only one subsequent crop of Rutgers to be grown before damaging nematode populations reoccurred (Figs. 1.3 C and 1.4 C). Applications of 22.5 L Vorlex/ha to infested soil previously planted to susceptible tomato permitted either two or one successive Rutgers crops to be grown at either low or high P_f levels, respectively,

before damaging population levels reoccurred (Figs. 1.1 B; 1.2 B; 1.3 B; 1.4 B; 1.5 B, E; and 1.6 B, E).

iv) Influence of combinations of Vorlex applications and resistant tomatoes on population dynamics of root knot nematode species on subsequent Rutgers crops.

A much lower residual population of root knot nematodes resulted when resistant tomatoes were used in combinations with Vorlex. At low P_i levels, applications of Vorlex at the rate of either 22.5 or 45 L/ha in combination with resistant plants resulted in sufficient reduction of the nematode which permitted more than three successive crops of Rutgers to be grown before any substantial reproduction was detected (Figs. 1.1 E, F, H, I; 1.2 E, F, H, I; 1.5 H, I; and 1.6 H, I). At higher P_i levels, populations of M. incognita on successive Rutgers crops grown in infested soil were lower following Nematex and Vorlex than following VFN-8 and Vorlex. The combined effects of Nematex and Vorlex allowed more than 4 successive crops of Rutgers to be grown without nematode populations reaching a damaging level (Figs. 1.3 H, I and 1.4 H, I). VFN-8 combined with Vorlex permitted 3 successive Rutgers crops to be grown before damaging population levels were reached (Figs. 1.3 E, F and 1.4 E, F).

B. Effects of P_i level, resistant tomatoes and Vorlex applications on growth of subsequent Rutgers crops.

i) Effect of P_i level on growth of tomato.

Top dry weight and root fresh weight of resistant tomato were not affected significantly when plants were inoculated with different P_i levels of M. incognita (Tables 1.1 and 1.2) or M. hapla (Table 1.3). On the other hand, top dry weight of susceptible tomato (Rutgers) decreased and fresh weight of roots increased significantly with increase in P_i

level. Although VFN-8 is susceptible to M. hapla, no significant decrease from the uninoculated control in top dry weight was observed with an increase in the P_i (Table 1.3). A much higher percentage decrease in dry weight of shoots was observed when Rutgers was inoculated with M. incognita (12-33% reduction) than when Rutgers plants were inoculated with M. hapla (7-19% reduction) at the same P_i levels.

ii) Influence of P_i level and resistant tomato on growth of subsequent Rutgers crops.

Generally, top dry weight and root fresh weight of Rutgers tomatoes grown in infested soils previously planted to resistant tomatoes were not significantly different from the uninfested controls (Tables 1.3; 1.4 and 1.5). Both the top dry weight and root fresh weight were significantly lower than the uninfested controls when Rutgers tomatoes were grown in infested soils previously planted to susceptible cultivars. Successive plantings of Rutgers in soils infested with M. incognita showed fluctuations in growth of the plants depending on the previous P_f (Table 1.8 and Figs. 1.7 and 1.8). These fluctuations in data on growth are primarily due to the fact that at very high nematode population densities, some plants died 3-4 weeks after transplanting. This consequently reduced the residual nematode population for the next planting resulting in much less damage. In some cases, fresh root weight of plants from successive plantings in highly infested soil were significantly lower than roots from uninfested controls (Figs. 1.7 and 1.8). This was due to limited root growth or severe root pruning resulting from the severe attack of the nematodes at high population densities.

iii) Influence of the combinations of Vorlex and resistant tomatoes on growth of subsequent Rutgers crops.

Applications of Vorlex to noninfested soil or soils previously planted to resistant tomato had no significant effects on the growth of subsequent Rutgers crops (Tables 1.4; 1.5; 1.6 and 1.7). The effects of the different dosage levels of Vorlex on the growth of subsequent Rutgers crops were not significantly different (Table 1.8 and Figs. 1.7 and 1.8). At any P_i , resistant tomatoes used in combinations with Vorlex significantly increased the growth of subsequent Rutgers crops when compared to using plant resistance alone or Vorlex alone (Table 1.8). Vorlex applied to infested soil previously planted to a susceptible cultivar significantly increased the growth of subsequent Rutgers crops (Tables 1.4; 1.5; 1.6 and 1.7).

C. Influence of P_i level, resistant tomato and Vorlex applications on yield of tomatoes in field studies.

The 1980 results indicated a 41% and 42% reduction in total marketable yields of Rutgers tomato grown in soil infested with 1,000 and 5,000 eggs and larvae of M. hapla/500 cm³ of soil, respectively (Table 1.10). Although there were reductions in the total marketable yields of VFN-8 tomatoes (10% and 7% at P_i s of 1,000 and 5,000 eggs and larvae/500 cm³ of soil, respectively) these yield reductions were not significantly different from those of the uninfested plots. No yield data were taken for L. peruvianum because this plant normally does not produce edible marketable fruits.

Very little reproduction of the nematode was observed on L. peruvianum throughout the season (Table 1.11). The build up of the

nematode population on VFN-8 was much slower than on Rutgers throughout the season. The higher the P_j , the higher the final population at the end of the season for all cultivars and species of tomato tested.

The yield data for Rutgers planted in all the plots in the 1981 growing season indicated significant effects from the control of root knot nematode due to plant resistance (Table 1.12). Total marketable yields of Rutgers grown in infested plots previously planted to L. peruvianum were higher than yields of Rutgers grown in infested plots previously planted to Rutgers. Yields of tomatoes grown in infested plots previously planted to VFN-8 were 10-16% higher than yields obtained when plants were grown in infested plots previously planted to L. peruvianum; however, these were not statistically significantly different. The effects of resistant tomato (L. peruvianum) alone in controlling the nematode resulted in about 16-53% increase in total marketable yield of the subsequent susceptible crop. Yields of Rutgers grown in infested plots previously planted to VFN-8 were 26 and 79% higher than those obtained from infested plots of the same inoculum levels previously planted to Rutgers.

Application of 45 L Vorlex/ha to uninfested plots previously planted to Rutgers, VFN-8 or L. peruvianum resulted in significant increases in yields of Rutgers tomatoes. Vorlex applied to plots previously infested with 1,000 or 5,000 eggs and larvae/500 cm³ of soil and planted to Rutgers resulted in 45% and 50% increases in marketable yields, respectively.

The combined effects of L. peruvianum and Vorlex in reducing nematode populations resulted in increased yields of Rutgers in the following

season by 23 and 84% at P_is of 1,000 and 5,000 eggs and larvae/500 cm³ of soil, respectively. At the same P_is, VFN-8 and Vorlex combined increased yields by 50 and 72%, respectively.

Very small numbers of nematode larvae were recovered from the infested soil at the beginning of 1981 season (Table 1.13) compared to the number recovered at the end of the 1980 season (Table 1.11). There was an increase in the population of the nematode in the middle of the season but very little or no additional increase in the nematode count was made at the end of the season (Table 1.13). Although the nematode counts were generally low at the end of the season, fewer or no, larvae were recovered from plots to which Vorlex had been applied. When roots were examined at the end of the season, very heavy galling was observed on roots of plants that were grown in infested plots previously planted to Rutgers. Lower gall index ratings were obtained where VFN-8 or L. peruvianum were the previous cultivars and also where Vorlex was applied (Table 1.13).

Discussion and Conclusions

Varietal differences in the reaction of plant species to root knot nematode are well documented in the literature. Results of this study support observations of several workers (3, 22, 23, 26, 33, 36, 45) concerning the reduction in growth and yield of a susceptible cultivar when inoculated with high inoculum densities of root knot nematodes. On the other hand the influence on the growth of the resistant plants was affected very slightly. Although gall indices were very high in some plants infected by M. incognita (Figs. 1.7 and 1.8), root weights were lower than the uninfected plants. This was due to limited root

growth or severe pruning of the roots that resulted from a severe attack of the nematodes at high nematode populations. This supports some of the observations made by Olthof and Porter (22, 23) of root knot nematode attack on some vegetable crops.

Reproduction of M. hapla on VFN-8 was much lower than on Rutgers although the two cultivars are known to be susceptible to M. hapla. This was probably an indication of the manifestation of different levels of resistance due to different genetic background (28) since VFN-8 and Rutgers may have originated from different genetic material. The higher percentage reduction in dry weight of tops of Rutgers tomato inoculated with the same P_1 of M. incognita as M. hapla indicates a more virulent action of M. incognita. This was also evident in the reproduction of the two species on Rutgers at the temperature at which the experiments were conducted. Similar observations were made in field experiments conducted by Barker et al. (3) on the pathogenicity of the two species of tomatoes.

Significant root knot nematode population reductions were obtained by the use of resistant cultivars or application of the nematicide. At lower P_1 levels, much higher population reductions were obtained whereas at higher P_1 levels the effects of either the resistant tomatoes alone or chemical applications alone in reducing the nematode population did not last long after a crop of a susceptible cultivar. Although the application of 90 L Vorlex/ha resulted in the reduction of the nematode population below a detectable level, the nematodes were not completely eliminated. Some reproduction was observed on the subsequent susceptible crops. Such observations have been made for

several other nematicides (15, 19, 20). Reproduction of the root knot nematode species on resistant plants was relatively low. Therefore applications of Vorlex after a resistant crop further reduced the nematode population thereby permitting several successive susceptible crops to be grown without the nematodes reaching a damaging level. Significant yield increases were observed in Rutgers tomatoes grown in noninfested soil previously planted to Rutgers, VFN-8 or L. peruvianum followed by applications of Vorlex in the field experiments. However, in the growth chamber experiments, the growth of subsequent Rutgers plants grown in noninfested soil previously planted to these cultivars and treated with Vorlex were not significantly affected. This was probably due to the fact that autoclaved soil was used in the growth chamber experiment and very little recontamination of the soil with other soilborne organisms occurred. On the other hand, in the field, although the entire experimental area was fumigated at the beginning of the study (1979) the soil was probably recolonized rapidly with other soilborne organisms that could cause a reduction in growth of the plants. Thus treatments with a broad spectrum chemical such as Vorlex could result in growth responses in the absence of the nematodes.

One of the important ways of maintaining the usefulness of a resistant cultivar for controlling root knot nematodes is to avoid growing the resistant host in heavily infested soil. This helps to reduce the possibility of selecting and developing biological races from the existent root knot populations. According to Netscher and Taylor (9), if such biological races can be assumed to be independent of the number of the root knot nematodes present, then in soils con-

taining few root knot nematodes these races will be rare or absent. Results of this study thus support the observation that the higher the P_i , the greater the residual population from the previous crop of the resistant cultivar. There is, therefore, a need for an alternate control measure before or after growing the resistant cultivar that would allow a subsequent susceptible cultivar to be grown without any substantial increase in the nematode populations.

In field studies, Minton et al. (18) observed only limited effects in reducing populations of M. incognita the first year after resistant soybean cultivars and DBCP had been used in the two previous years. Results of this study both in the growth chamber and in the field showed substantial effects of resistant tomato cultivars and Vorlex in reducing populations of root knot nematode species. Differences in the observations of the field experiments in this study and those of Minton et al. may be due to the different root knot nematode species used, different P_i s, the different host plants, nematicides, experimental design, cultural practices as well as the different temperatures and locations of the experiments. Because of the use of tractor drawn agricultural equipment in their study, the risks of recontamination might have been higher than in this study. Recontamination in this study was kept to the minimum by sanitation and contamination prevention. M. hapla is known to survive cold weather conditions. However, lower nematode counts were recorded at the beginning of the season in 1981 when compared to the number recovered at the end of the previous season. This may have been due to the severe cold of the 1980-81 winter. The low survival of the nematode may also be due to interaction with other soil micro-

organisms. Based on the 1981 midseason nematode counts, one would expect a higher increase in population at the end of the season than was observed. This lower nematode count may be due to adverse effects of other soil microorganisms on root knot nematodes. Or a chance contamination of the mid-season soil samples during processing. The field experiment supported the observations made in the growth chamber experiments on the differences in the pathogenicity of M. hapla to Rutgers and VFN-8. There was a lower rate of population buildup on VFN-8 than on Rutgers.

Application of Vorlex increased the yield of tomatoes. However, a much greater yield was achieved when a resistant cultivar was used in combination with chemical application before growing the susceptible cultivar. Based on the end of season nematode counts, and gall index ratings it appears that the combined effects of plant resistance and Vorlex in reducing nematode populations would be much more beneficial than either chemical treatment alone or plant resistance alone.

Based on the results of this study, it can be concluded that (a) both the frequency and the amount of Vorlex needed to control root knot nematodes were reduced when the chemical was used in combination with a resistant cultivar in the cropping sequence, (b) the effects of plant resistance and chemical treatments were similar in the reduction of root knot nematode populations, (c) VFN-8 is partially resistant to M. hapla population that was used in the study, and (d) M. incognita was more virulent on Rutgers than M. hapla at 25 + 2°C.

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Table 1.1. Effects of P_i levels of M. incognita on the growth of 3 tomato cultivars and reproduction of the nematode.

P_i (eggs/500 cm ³ soil)	Tomato cultivar	Plant growth		Nematode Reproduction		
		Shoot dry wt (g)	Root fresh wt (g)	Gall index	Egg and larvae /gm roots	Larvae/ 100 cc soil
0	Rutgers	10.7 b	13.9 a	0.0 a	0.0 a	0.0 a
	VFN-8	10.4 b	15.1 ab	0.0 a	0.0 a	0.0 a
	Nematex	9.5 b	13.0 a	0.0 a	0.0 a	0.0 a
1,000	Rutgers	8.4 ab	13.9 a	4.5 b	4528.0 b	152.0 b
	VFN-8	9.9 a	16.4 ab	0.1 a	1.6 a	0.0 a
	Nematex	9.2 b	12.9 a	0.0 a	0.3 a	0.1 a
5,000	Rutgers	7.2 a	19.4 b	5.0 b	7735.0 c	409.0 c
	VFN-8	9.4 b	12.8 a	0.0 a	2.0 a	1.5 a
	Nematex	10.4 b	12.9 a	0.0 a	6.0 a	1.2 a

Means followed with the same letter in a column are not significantly different at 5% level according to Duncan's multiple range test.

Table 1.2 Effects of P_i levels of *M. incognita* on growth of three tomato cultivars and reproduction of the nematode.

P_i (eggs/500 cm ³ soil)	Tomato cultivar	Plant growth		Nematode Reproduction		
		Shoot dry wt (g)	Root fresh wt (g)	Gall Index	Eggs and larvae /gm roots	Larvae/ 100 cc soil
0	Rutgers	12.9 c	14.2 a	0 a	0 a	0 a
	VFN-8	14.1 c	15.9 ab	0 a	0 a	0 a
	Nematex	10.6 bc	13.2 a	0 a	0 a	0 a
10,000	Rutgers	6.4 a	20.6 eb	5 b	20148 b	15 a
	VFN-8	15.1 c	16.3 ab	0 a	0 a	0.2 a
	Nematex	9.7 b	20.4 cb	0 a	0 a	0 a
100,000	Rutgers	5.1 a	27.3 c	5 b	158800 c	1911 b
	VFN-8	13.3 c	20.8 cb	0 a	1.2 a	0.4 a
	Nematex	9.4 b	16.3 ab	0 a	0 a	0 a

Means followed with the same letter in a column not significantly different at 5% level according to Duncan's multiple range test.

Table 1.3. Effects of different P_i levels of *M. hapla* on the shoot and root weights of two cultivars and a wild species of tomatoes and on the reproduction of the nematode.

P_i (eggs/500 cm ³ soil)	Tomato cultivar	Plant growth		Nematode Reproduction		
		Shoot dry	Root fresh	Gall Index	Eggs and larvae /gm roots	Larvae/ 100 cc soil
0	Rutgers	14.1 a	14.4 a	0 a	0 a	0 a
	VFN-8	19.0 b	19.3 ab	0 a	0 a	0 a
	<u>L. peruvianum</u>	13.5 a	22.5 c	0 a	0 a	0 a
1,000	Rutgers	13.1 a	21.8 cb	4.7 b	3164 c	239 b
	VFN-8	18.8 b	24.8 c	1.3 a	160 b	11.8 a
	<u>L. peruvianum</u>	14.0 a	19.4 ab	0 a	0 a	1.4 a
5,000	Rutgers	11.4 a	25.5 c	5.0 b	4928 d	649 c
	VFN-8	16.8 ab	23.1 c	1.7 a	394 b	27.4 a
	<u>L. peruvianum</u>	14.0 a	23.8 c	0 a	2.8 a	1.0 a

Means followed with the same letter in a column are not significantly different at the 5% level according to Duncan's multiple range test.

Table 1.4. Effect of root knot nematode P_i levels and tomato cultivars followed by Vorlex applications on the growth of subsequent Rutgers (susceptible) tomato and reproduction of *M. incognita*.

P_i (eggs/500 cm ³ soil)	Previous cultivar	Vorlex 90 L/ha	Plant growth		Nematode Reproduction		
			Shoot dry wt (g)	Root fresh wt (g)	Gall index	Eggs & larvae /gm roots	Larvae/ 100 cc soil
0	Rutgers	-*	22.4 b	14.5 bc	0 a	0 a	0 a
		+	9.6 b	13.9 bc	0 a	0 a	0 a
	VFN-8	-	9.4 b	9.8 b	0 a	0 a	0 a
		+	7.9 ab	13.1 b	0 a	0 a	0 a
	Nematex	-	10.9 b	11.8 b	0 a	0 a	0 a
		+	7.4 ab	10.3 b	0 a	0 a	0 a
1,000	Rutgers	-	5.3 a	7.4 a	5.0 b	36601 b	311 b
		+	10.5 b	14.6 bc	0.5 a	11 a	0 a
	VFN-8	-	9.2 b	9.6 b	0.6 a	16 a	0 a
		+	9.2 b	11.2 b	0 a	0 a	0 a
	Nematex	-	10.0 b	12.9 b	0.5 a	13 a	1.8 a
		+	8.2 b	11.2 b	0 a	0 a	0 a
5,000	Rutgers	-	4.1 a	4.5 a	5 b	32842 b	690 b
		+	9.9 b	15.1 bc	0 a	12 a	1.7 a
	VFN-8	-	11.6 b	10.1 b	1.2 a	49 a	2 a
		+	10.7 b	10.6 b	0 a	0 a	0 a
	Nematex	-	10.5 b	11.6 b	0.9 a	30 a	0 a
		+	8.8 b	15.1 bc	0 a	0 a	0 a

*- = no Vorlex applied; + = Vorlex applied.

Means followed with the same letter in a column are not significantly different at the 5% level according to Duncan's multiple range test.

Table 1.5. Effects of root-knot nematode P_j levels, tomato cultivars and Vorlex applications (0, 22.5 and 45 L/ha) on the growth of subsequent Rutgers (susceptible) tomato and reproduction of residual populations of *M. incognita*.

P_j (eggs/500 cm ³ soil)	Previous cultivar	Vorlex L/ha	Plant growth		Nematode Reproduction					
			Shoot dry wt (g)	Root fresh wt (g)	Gall index	Eggs & larvae /gm roots		Larvae/ 100 cc soil		
0	Rutgers	0	13.3 c	15.0 c	0	a	0	a	0	a
		22.5	13.5 c	14.8 c	0	a	0	a	0	a
		45.0	13.0 c	15.5 c	0	a	0	a	0	a
	VFN-8	0	14.1 c	14.3 c	0	a	0	a	0	a
		22.5	13.5 c	18.9 cd	0	a	0	a	0	a
		45.0	14.8 c	16.4 c	0	a	0	a	0	a
	Nematex	0	10.1 b	15.3 c	0	a	0	a	0	a
		22.5	13.0 c	16.0 c	0	a	0	a	0	a
		45.0	14.1 c	16.1 c	0	a	0	a	0	a
1,000	Rutgers	0	2.4 a	4.5 a	5	c	40811	b	117	bc
		22.5	10.1 b	13.3 bc	0	a	150	a	8	a
		45.0	13.0 c	19.9 cd	0	a	40	a	0	a
	VFN-8	0	15.5 c	20.6 d	2.6	b	12	a	86	b
		22.5	13.3 c	13.9 bc	0	a	4	a	0	a
		45	10.8 bc	13.5 bc	0	a	0	a	0	a
	Nematex	0	14.0 c	20.1 d	1.4	a	14	a	0	a
		22.5	13.4 c	15.5 c	0	a	0	a	0	a
		45.0	13.7 c	16.0 c	0	a	0	a	0	a

-- continued --

Table 1.5. (Continued)

5,000	Rutgers	0	2.1 a	9.0 b	5 c	60832 c	74 b
		22.5	12.1 c	19.1 cd	0 a	234 a	0 a
		45.0	12.2 c	17.5 cd	0 a	67 a	0 a
	VFN-8	0	11.5 bc	21.0 d	5 c	51 a	179 c
		22.5	11.2 bc	16.3 c	0 a	0 a	0 a
		45.0	12.0 c	14.3 c	0 a	0.5 a	0 a
	Nematex	0	12.1 c	21.7 d	2.6 b	60 a	6.2 a
		22.5	12.4 c	15.7 c	0 a	1.0 a	0.2 a
		45.0	13.0 c	17.5 cd	0 a	0 a	0 a

Means followed with the same letter in a column are not significantly different at the 5% level according to Duncan's multiple range test.

Table 1.6. Effects of P_i levels, tomato cultivars and Vorlex applications on the growth of subsequent Rutgers (susceptible) tomato, and reproduction of the residual populations of *M. hapla*.

P _i (eggs/500 cm ³ soil)	Previous cultivar	Vorlex 90 L/ha	Plant growth		Nematode Reproduction		
			Shoot dry wt (g)	Root fresh wt (g)	Gall index	Eggs & Larvae /gm roots	Larvae/ 100 cc soil
0	Rutgers	-*	16.5 ab	16.7 a	0 a	0 a	0 a
		+	15.8 ab	14.4 a	0 a	0 a	0 a
	VFN-8	-	18.4 b	17.5 a	0 a	0 a	0 a
		+	19.5 b	19.5 ab	0 a	0 a	0 a
	<u>L. peruvianum</u>	-	19.4 b	18.8 ab	0 a	0 a	0 a
		+	17.7 b	17.8 ab	0 a	0 a	0 a
1,000	Rutgers	-	14.8 a	35.7 c	5.0 c	88800 d	1414 c
		+	18.4 b	17.7 ab	0 a	4 a	0 a
	VFN-8	-	20.8 b	23.0 b	0.6 a	53.8 b	3.0 a
		+	17.4 b	21.2 b	0 a	0 a	0 a
	<u>L. peruvianum</u>	-	19.0 b	21.4 b	0.4 a	0.4 a	4.0 a
		+	17.4 b	18.7 ab	0 a	0 a	0 a
5,000	Rutgers	-	14.2 a	27.4 bc	50 c	78333 d	31.4 b
		+	19.2 b	21.0 b	0 a	10.5 a	0 a
	VFN-8	-	18.1 b	20.5 b	2.4 ab	3108 c	53 a
		+	17.8 b	22.7 b	0 a	0 a	0 a
	<u>L. peruvianum</u>	-	18.2 b	20.1 b	1.5 a	165 ab	1.0 a
		+	17.7 b	19.9 b	0 a	0 a	0 a

*- = no Vorlex applied; + = Vorlex applied.

Means followed with the same letter in a column are not significantly different at the 5% level according to Duncan's multiple range test.

Table 1.7. Effects of P_i levels, tomato cultivars and Vorlex applications (0, 22.5 and 45 L/ha) on growth of subsequent Rutgers (susceptible) tomato and reproduction of the residual populations of *M. hapla*.

P_i (eggs/500 cm ³ soil)	Previous cultivar	Vorlex L/ha	Plant growth		Nematode Reproduction					
			Shoot dry wt (g)	Root fresh wt (g)	Gall Index	Eggs & larvae /gm roots		Larvae/ 100 cc soil		
0	Rutgers	0	15.6 b	16.5 b	0	a	0	a	0	a
		22.5	18.0 c	16.3 b	0	a	0	a	0	a
		45.0	15.0 b	17.0 b	0	a	0	a	0	a
	VFN-8	0	16.4 b	15.8 b	0	a	0	a	0	a
		22.5	15.8 b	20.4 c	0	a	0	a	0	a
		45.0	15.0 b	17.4 b	0	a	0	a	0	a
	<u>L. peruvianum</u>	0	12.4 b	16.8 b	0	a	0	a	0	a
		22.5	15.0 b	17.8 b	0	a	0	a	0	a
		45.0	16.4 b	17.6 b	0	a	0	a	0	a
1,000	Rutgers	0	4.4 a	6.0 a	5	b	51642	c	248	d
		22.5	12.0 b	14.8 b	1	a	64	a	0	a
		45.0	15.2 bc	20.4 c	0	a	35	a	0	a
	VFN-8	0	17.6 b	22.4 c	4	b	624	a	86	ab
		22.5	15.6 b	15.6 b	0	a	10	a	0	a
		45.0	12.8 b	15.0 b	0	a	0	a	0	a
	<u>L. peruvianum</u>	0	16.0 b	21.6 c	1	a	61	a	2	a
		22.5	15.4 b	17.0 b	0	a	0	a	0	a
		45.0	15.8 b	17.4 b	0	a	0	a	0	a

-- Continued --

Table 1.7. Continued

5,000	Rutgers	0	1.6 a	21.3 c	5 b	99834 d	178 c
		22.5	14.4 b	20.6 c	1.3 a	78 a	0 a
		45.0	14.8 b	19.0 bc	0.3 a	30 a	0 a
	VFN-8	0	13.2 b	22.7 c	5 b	2040 b	179 bc
		22.5	13.2 b	17.8 b	1.1 a	14 a	0 a
		45.0	14.2 b	15.8 b	0 a	0 a	0 a
	<u>L. peruvianum</u>	0	14.6 b	23.2 c	1 a	40 a	5 a
		22.5	14.8 b	17.4 b	0 a	2 a	0 a
		45.0	15.0 b	19.0 bc	0 a	2 a	0 a

Means followed with the same letter in a column are not significantly different at the 5% level according to Duncan's multiple range test.

Table 1.8. Effect of P_i levels of *M. incognita*, previous tomato cultivar, and chemical treatments on dry shoot weight of subsequent crops of Rutgers tomato.

P_i (eggs/500 cm ³ soil)	Previous cultivar	Vorlex L/ha	Top dry wt. of subsequent crops of Rutgers			
			1	2	3	4
0	Rutgers	0	10.9	9.6	10.3	8.7
		22.5	13.4	6.6	12.6	8.4
		45.0	10.8	8.7	13.2	8.5
	VFN-8	0	10.4	8.6	12.0	9.8
		22.5	9.6	5.7	12.6	10.6
		45.0	11.2	11.1	14.0	10.4
	Nematex	0	10.7	7.6	13.4	9.0
		22.5	10.7	7.5	12.2	8.6
		45.0	9.4	9.2	14.0	9.4
10,000	Rutgers	0	2.4	9.4	5.8	4.2
		22.5	11.6	9.3	9.4	6.6
		45.0	11.6	9.4	12.2	4.2
	VFN-8	0	9.4	2.1	7.8	8.8
		22.5	9.4	9.2	13.4	8.0
		45.0	9.7	7.0	12.4	8.4
	Nematex	0	10.9	6.7	11.0	7.5
		22.5	10.9	9.9	13.0	7.8
		45.0	10.9	9.3	12.2	8.3

-- Continued --

Table 1.8. Continued

100,000	Rutgers	0	3.1
		22.5	12.4
		45.0	10.8
	VFN-8	0	10.9
		22.5	10.9
		45.0	11.4
	Nematex	0	11.0
		22.5	13.4
		45.0	10.4
LSD at 5%		2.8	

5.3	11.4	6.0
7.3	11.0	8.0
7.7	13.6	7.4
2.1	10.4	6.2
6.8	11.6	7.8
8.8	8.8	7.8
6.1	10.0	11.5
8.6	10.2	10.0
7.7	10.8	9.2
2.5	4.5	3.2

Table 1.9. Effects of P_1 levels of *M. incognita*, previous tomato cultivar and chemical treatments on fresh root weight of subsequent crops of Rutgers tomato.

P_1 (eggs/500 cm ³ soil)	Previous cultivar	Vorlex L/ha	Root fresh wt. of subsequent crops of Rutgers			
			1	2	3	4
0	Rutgers	0	15.7	8.7	18.7	13.0
		22.5	21.2	9.6	17.6	12.5
		45.0	19.5	9.5	17.6	13.1
	VFN-8	0	14.4	10.8	18.6	15.6
		22.5	18.8	5.7	18.7	16.2
		45.0	18.3	9.7	18.7	14.9
	Nematex	0	11.8	8.3	19.2	14.4
		22.5	15.7	9.2	18.1	13.3
		45.0	15.8	10.2	21.1	13.8
10,000	Rutgers	0	14.6	16.5	23.8	20.1
		22.5	17.6	9.6	24.8	26.1
		45.0	18.3	9.5	24.2	20.2
	VFN-8	0	21.5	6.5	27.2	22.7
		22.5	16.9	11.3	18.3	16.8
		45.0	16.1	10.5	13.2	13.7
	Nematex	0	15.4	9.0	17.3	16.8
		22.5	19.0	11.4	18.1	17.7
		45.0	16.6	8.9	17.5	15.4

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Table 1.9. Continued

100,000	Rutgers	0	19.5
		22.5	18.4
		45.0	19.1
	VFN-8	0	19.5
		22.5	17.5
		45.0	19.6
	Nematex	0	17.9
		22.5	19.6
		45.0	15.1
LSD at 5%		6.2	

10.5	28.0	22.9
10.1	26.2	17.6
10.5	23.8	18.1
5.4	26.8	17.9
8.3	17.8	17.2
10.2	23.4	15.7
9.9	27.8	18.5
10.2	23.4	15.7
9.9	16.5	13.6
3.8	5.2	4.3

Table 1.10. Influence of P_i levels of M. hapla on yield of two cultivars of tomato (1980).

P_i (eggs and larvae /500 cm ³ soil)	Tomato cultivar	Yield (g/plant)					Total marketable yield (kg/ha)
		Harvest No.					
		1	2	3	4	5	
0	Rutgers	13	365	1166	2050	648	42420 a
1,000		5	263	782	1117	299	25640 b
5,000		0	196	671	1413	274	24980 b
0	VFN-8	75	382	1190	1825	959	44310 a
1,000		98	213	936	1698	1025	39680 a
5,000		77	352	775	1647	1262	40790 a

Means followed with the same letter are not significantly different at 5% level according to Duncan's multiple range test.

Table 1.11. Influence of P_i levels and source of resistance on population development of M. hapla.

P_i (eggs and larvae / 500 cm ³ soil)	Previous tomato cultivar	Nematode counts (larvae/100 cc of soil)		
		1	3	5
1,000	Rutgers	180	315	920
	VFN-8	0	0	13
	<u>L. peruvianum</u>	0	0	0.2
5,000	Rutgers	320	946	1294
	VFN-8	4	35	65
	<u>L. peruvianum</u>	0	0.2	5

Table 1.12. Total marketable yield of tomato (cv. Rutgers) as influenced by initial inoculum density (P_i) of M. hapla, plant resistance and chemical treatments (1981).

P_i (eggs & larvae /500 cm ³ soil)	Previous tomato cultivar (1980)	Yield kg/ha	
		No Vorlex	Chemical treatments Vorlex at 45 L/ha
0	Rutgers	45,230 b	53,790 a
1,000		36,070 cd	51,382 a
5,000		27,330 d	42,270 cd
0	VFN-8	47,373 b	55,004 a
1,000	(Better Boy)	45,548 b	54,292 a
5,000		491030 ab	47,142 b
0	<u>L. peruvianum</u>	46,514 b	53,970 a
1,000		41,768 bc	44,080 b
5,000		41,844 bc	50,244 a

Means followed by the same letter are not significantly different at 5% level according to Duncan's multiple range tests.

Table 1.13. Influence of plant resistance and chemical applications on population development of *M. hapla* and galling of Rutgers tomato (1981).

P _i (Eggs/500 cm ³ soil)	Previous tomato cultivar	Vorlex 45 L/ha	Larvae/100 cc of soil			Gall Index End of season
			Beginning of season	Mid season	End of season	
1,000	Rutgers	-	15	240	260	4.7
		+		17.6	0	2
	VFN-8	-	0.5	50	4	1.0
		+		2.8	0	0
	<u>L. peruvianum</u>	-	0.3	2.0	3.6	0.8
		+		0	0	0
5,000	Rutgers	-	26	620	768	5.0
		+		23	10	2
	VFN-8	-	3	100	2.8	2.4
		+		2	0	0
	<u>L. peruvianum</u>	-	1	4	3.8	1.0
		+		0	0	0

Figure 1.1-1.4.

Population dynamics of M. incognita on successive Rutgers tomato plantings grown in infested soil of different P_i levels previously planted to either susceptible (Rutgers) or resistant (VFN-8 and Nematex) tomato cultivars and treated with either 0, 22.5 or 45 L Vorlex/ha.

Figure 1.1 = P_i level of 5,000 eggs/500 cm³ of soil

Figure 1.2 = " " 1,000 " "

Figure 1.3 = " " 10,000 " "

Figure 1.4 = " " 100,000 " "

In all the figures,

A, B and C represent applications of Vorlex at either 0, 22.5 or 45 L/ha, respectively, following a crop of Rutgers;

D, E and F represent applications of Vorlex at either 0, 22.5 or 45 L/ha, respectively, following a crop of VFN-8;

and G, H and I represent applications of Vorlex at either 0, 22.5 or 45 L/ha, respectively, following a crop of Nematex.

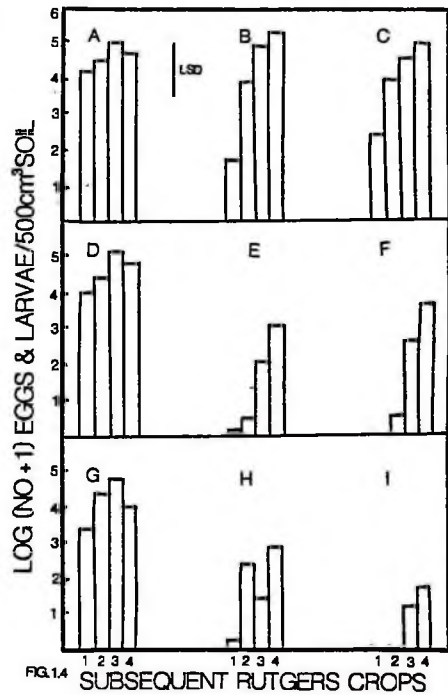
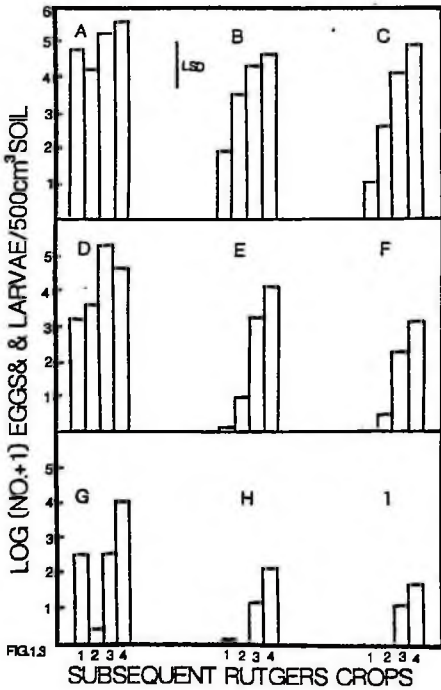
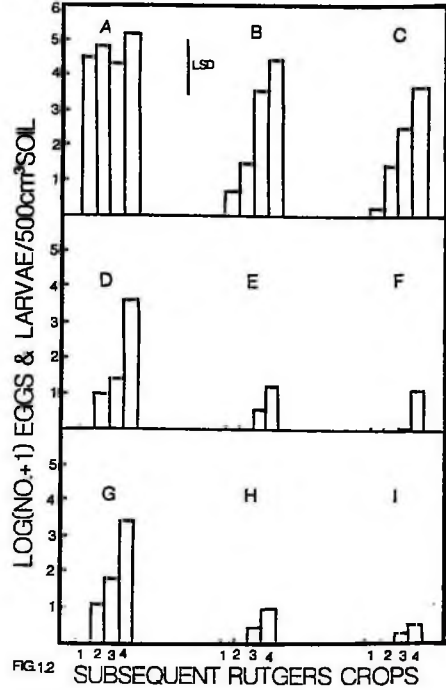
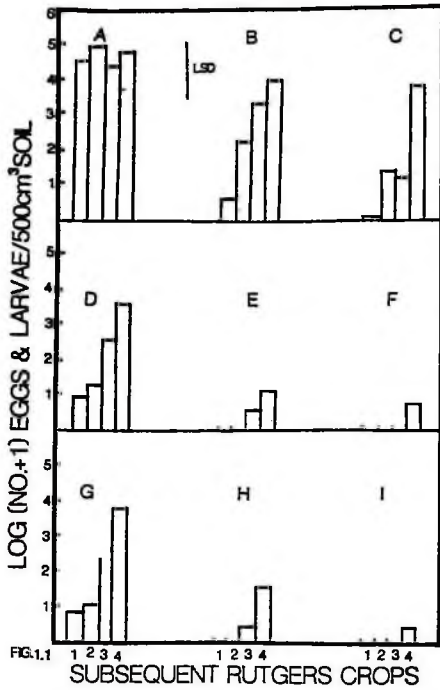


Figure 1.5-1.6.

Population dynamics of M. hapla on successive Rutgers tomato plantings grown in infested soil of different P_i levels previously planted to either susceptible (Rutgers), partially resistant (VFN-8) or resistant (L. peruvianum) tomatoes and treated with either 0, 22.5 or 45 L Vorlex/ha.

Figure 1.5 = P_i level of 1,000 eggs/500 cm³ of soil

Figure 1.6 = " " 5,000 " "

In all the figures,

A, B and C represent applications of Vorlex at either 0, 22.5 or 45 L/ha, respectively, following a crop of Rutgers;

D, E and F represent applications of Vorlex at either 0, 22.5 or 45 L/ha, respectively, following a crop of VFN-8;

and G, H and I represent applications of Vorlex at either 0, 22.5 or 45 L/ha, respectively, following a crop of L. peruvianum.

Figure 1.7-1.8

Fresh root weight and gall index of subsequent Rutgers tomato plantings, grown in infested soil of different P_i levels previously planted to either Rutgers VFN-8 or Nematex and treated with either 0, 22.5 or 45 L Vorlex/ha.

Figure 1.7 = P_i level of 10,000 eggs/500 cm³ of soil

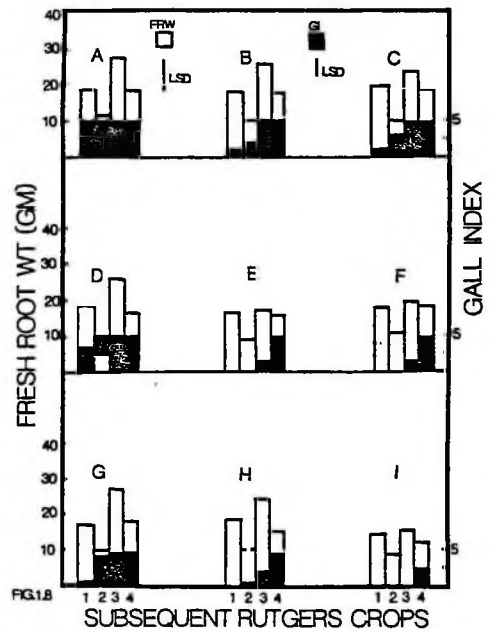
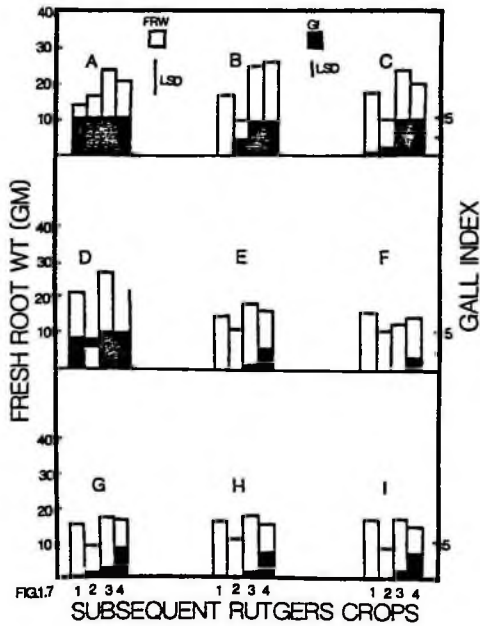
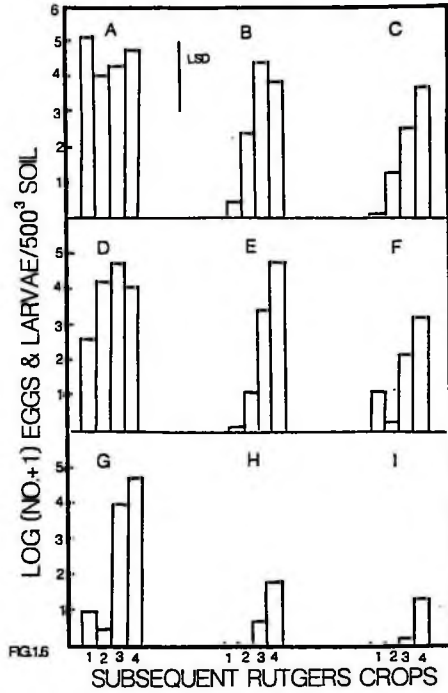
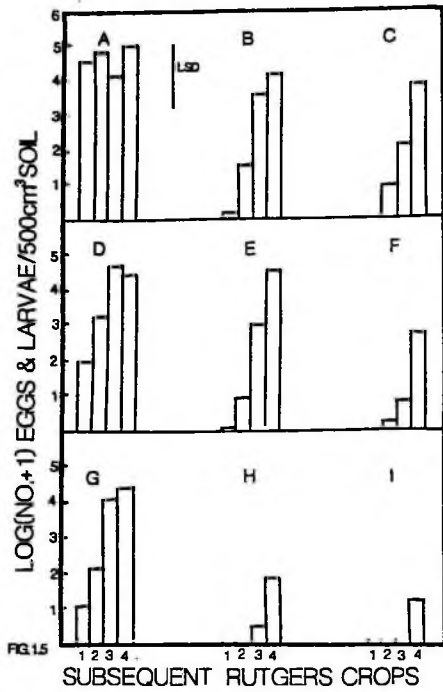
Figure 1.8 = " " 100,000 " "

In all the figures,

A, B and C represent applications of Vorlex at either 0, 22.5 or 45 L/ha, respectively, following a crop of Rutgers;

D, E and F represent applications of Vorlex at either 0, 22.5 or 45 L/ha, respectively, following a crop of VFN-8;

and G, H and I represent applications of Vorlex at either 0, 22.5 or 45 L/ha, respectively, following a crop of Nematex.



Chapter 2

EFFECT OF VARIOUS PERIODS OF EXPOSURE TO ROOT-KNOT NEMATODES ON GROWTH OF RESISTANT AND SUSCEPTIBLE TOMATO TRANSPLANTS

Abstract

Experiments were conducted to determine the effects of length of time of exposure in root-knot nematode infested soil on growth of susceptible and resistant tomato seedlings. Susceptible (Rutgers) and resistant (Nematex) tomatoes were grown in soil infested with different initial inoculum densities (0, 100, 1,000, 5,000, 10,000, and 50,000 eggs and larvae/kg of soil) of Meloidogyne incognita for either 2, 4, or 6 wk. Seedlings of Nematex were stunted when they were grown in soils infested with 10,000 or 50,000 eggs and larvae/kg of soil. They grew as well as the uninfested control, however, if in 2 wk they were repotted in non-infested soil. Rutgers seedlings were severely stunted when they were grown for 2, 4, or 6 wk in infested soil that contained more than 1,000 eggs and larvae per kg of soil. Although transplants recovered from the nematode attack when they were reported in noninfested soil, they did not grow as well as the controls. Before the end of 6 wks, all the Rutgers seedlings grown in the highest inoculum level soil had died.

Introduction

The use of nematode free planting stocks is often recommended, not only to avoid the consequences of nematode infection of the crop but also to avoid the possibility of infesting uncontaminated land. Growth reductions (7, 10, 11) as well as yield losses (1, 7, 9) often result

when healthy seedlings are transplanted to root knot nematode infested soil. The amount of damage caused by root knot nematodes can be influenced by the initial inoculum density (1, 7, 9, 10, 11), time of inoculation (3, 10) and other environmental and edaphic factors (2, 5, 13). The possibility of regeneration or recovery of damaged roots is greater when seedlings infected by root knot nematodes are transferred or transplanted to uninfested soil. Lamberti (6) demonstrated the importance of transplanting nematode-free seedlings into fumigated soil, and he also showed that even infested seedlings may yield well in uninfested soil.

The purpose of this study was to investigate the effects of the length of exposure period of tomato seedlings to M. incognita on growth of these tomato transplants, both before and after transplanting.

Materials and Methods

Eight centimeter (dm) pots were filled with autoclaved soil to which 0, 100, 1,000, 5,000, 10,000 or 50,000 eggs and larvae of M. incognita per kg of soil was added. Tomato seeds (3 per pot) were planted in all the pots, which were placed randomly on the greenhouse (temperature 22-26°C) bench and watered daily. Seedlings were thinned to one per pot after emergence.

Two weeks after the seeds were sown, the first batch of seedlings (7 replications per treatment) were carefully removed from the soil, washed in water and transplanted to 12.5 cm (dm) pots filled with autoclaved soil. Plant height and root gall index were determined at the time of transplanting. The same procedure was followed 4 and 6 wks

after the seeds were sown. Both the infected and uninfected plants were grown for six more weeks after repotting. Plants were watered daily and fertilized with soluble 20-20-20 NPK every 10 days. Plant growth and root gall index were determined at the end of each experiment. Cultivars susceptible (Rutgers) and resistant (Nematex) to M. incognita were used. Soil infested with 1,000, 10,000 or 50,000 eggs and larvae/kg of soil were used in the experiments with Nematex. A completely randomized design was used. A quantitative scoring index based on percent root system galled was used: 0 = no galling, 1 = 1-10% galling, 2 = 11-25% galling, 3 = 26-50% galling, 4 = 51-75% galling and 5 = above 75% galling.

Results

There was a reduction in height of Rutgers seedlings exposed to infested soil for 2 wks at the two highest inoculum densities (Table 1). Seedlings repotted in uninfested soil after 2 wks exposure to infested soil recovered very quickly from the nematode attack, but the recovery was slower for those that were exposed to the two highest inoculum density levels (Table 2.3A). Plant height as well as top growth weight were lowest at the 50,000 inoculum density. Some galls were observed on repotted plants exposed to inoculum densities of 5,000 or more eggs and larvae per kg of soil. Rutgers seedlings exposed to M. incognita for 4 wks showed severe stunting and galling at inoculum densities above 5,000 eggs and larvae (Table 2.1). When plants were repotted after 4 wks exposure to infested soil (Table 2.3B), the recovery in growth from the nematode attack was slower at higher inoculum densities. While the shoots at all inoculum densities were shorter than the

uninoculated control, significant differences from the control were observed only at the highest densities. Galls were observed on roots of repotted plants exposed to infested soil for 4 or more weeks. Plants exposed to infested soil for 6 wks showed significant differences from the uninfested control in growth (Table 2.1). There was stimulation of growth at the inoculum level of 100 eggs and larvae/kg of soil. All seedlings exposed to 50,000 eggs and larvae/kg of soil died before the end of 6 wks. Seedlings exposed to 5,000 and 10,000 eggs and larvae/kg of soil were very stunted. Although the seedlings recovered from the nematode attack when repotted after the 6 wks exposure (Table 2.3C) to 1,000, 5,000 and 10,000 inoculum densities, they were not as tall as the control. Dry weights of tops and roots were lowest at the highest inoculum density. All plants grown in infested soil before transplanting were heavily galled. Seedlings that were grown in highly (10,000 and 50,000 eggs and larvae/kg of soil) infested soil for 4 to 6 wks before repotting to uninfested soil flowered a week later than those that were grown in and repotted to uninfested soil. The effects of exposure of seedlings of the resistant cultivar (Nematex) to infested soil were not as drastic as those observed when the susceptible cultivar was exposed to the same level of inoculum. Seedlings grown for 2 or 4 wks in infested soil showed significant differences in height only at the 50,000 inoculum level (Table 2.2). Growing seedlings in infested soil for 6 wks resulted in significant reduction in growth at the 10,000 and 50,000 inoculum densities. Some galls were observed on the seedlings at the highest inoculum level only if they had been grown in the infested soil for more than 4 wks at the highest inoculum level. Repotted seed-

lings after 2 wks growth in infested soil (Table 2.4A) did not show any significant differences from the controls in growth of the plants. Compared to controls, seedlings grown for 4 or 6 wks in infested soil resulted in a decrease in height of the repotted plants, but significant differences were only observed at the highest inoculum level (Tables 2.4B, C).

Discussion and Conclusions

Survival of transplanted seedlings and subsequent yields of transplanted crops are often a reflection of the quality of the seedlings. Thus, more emphasis should be directed toward the preparation of the nursery material. Although the results of these experiments indicate a regeneration and rapid regrowth of seedlings after exposure to different levels of inoculum density, they also emphasize the importance of the effects of infested soil on the initial and subsequent growth and maturity of tomato transplants. Growing seedlings of a susceptible cultivar for as little as 2 wks in a highly infested soil could cause considerable damage even when transplanted to uninfested soil. Severe damage can result when the seedlings are exposed for a longer period of time. Since tomato seedlings are normally transplanted 4-8 wks after seeding, growing tomato plants in seed beds with soil infested with more than 100 eggs and larvae/kg of soil would result in considerable loss in yield, even when they are transplanted to uninfested soil. Heavy galling observed on roots of transplants of Rutgers seedlings exposed to infested soil at higher inoculum densities for 4 or more wks was probably due to the fact that some of the females had matured and laid eggs before the plants were repotted. The eggs subsequently hatched and the second

stage larvae reinfected the newly developing roots. Galls on repotted plants that were grown in the infested soil for 2 wks were limited to roots that had galls on them before they were repotted to uninfested soil.

Root necrosis has often been associated with resistance to root knot nematodes (8, 14). It is, therefore, possible that in cases where there is a heavy infestation of root knot nematodes, severe root necrosis could slow the growth of the resistant plant. Results of this experiment showed that exposure of seedlings of resistant plants even for 2 wks to very high densities could cause a reduction in growth even when repotted to uninfested soil. The longer the time of exposure, the more the damage, which will subsequently delay maturity and probably reduce yield of the crop. This would be especially true when growing seasons are short. Vito and Lamberti (12) showed reduction in yield of two tomato cultivars resistant to *M. incognita*, although no gall formation was observed on the roots of the resistant cultivars.

Some of the differences observed in growth of the seedlings grown in infested soil could also be due to the delay in seed emergence in the heavily infested soil. Emergence delay of two to three days was observed in some cases. When the seedlings were repotted to uninfested soil, the ratios of the initial height, before repotting, to the final height at the end of the experiment were much higher for plants that were grown in higher inoculum level soil than for those that were grown in uninfested or low inoculum level soil. This was probably due to the delay in maturity of the repotted plants that were grown in highly infested soil. Repotted plants grown in uninfested soil flowered a week earlier than

those grown in infested soil. Thus, much of the vegetative growth, especially growth in height, probably had slowed down in order for the photosynthate to be diverted to the reproductive growth at the time that the experiments were terminated.

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Table 2.1. Height and gall index of Rutgers tomato seedlings grown in root knot nematode infested soil for 2, 4 or 6 weeks before repotting to uninfested soil.

Inoculum density (eggs and larvae /kg soil)	Plant height (cm)			Gall index		
	Exposure time (wks)			Exposure time (wks)		
	2	4	6	2	4	6
0	4.5	14.5	23.0	0	0	0
100	4.7	14.0	28.3	0	2.6	3.5
1,000	3.0	12.5	20.5	1	4.8	4.5
5,000	3.5	4.7	8.0	2	5.0	5.0
10,000	2.8	3.0	4.8	5	5.0	5.0
50,000	2.5	3.1	-			
LSD at 5%	1.8	2.6	8.2	1.8	0.7	0.8

Table 2.2. Height and gall index of Nematex tomato seedlings grown in different levels of root knot nematode infested soil for 2, 4 or 6 weeks before transplanting to uninfested soil.

Inoculum density (eggs and larvae /kg soil)	Plant height (cm)			Gall Index		
	Exposure time (wks)			Exposure time (wks)		
	2	4	6	2	4	6
0	4.5	10.2	21.0	0	0	0
1,000	4.3	10.4	18.6	0	0	0
10,000	4.1	8.0	11.2	0	0	1.0
50,000	2.9	7.4	10.6	0	0	2.0
LSD at 5%	0.8	1.5	3.2	NS	NS	0.5

Table 2.3. Effects of period of exposure of Rutgers tomato seedlings to different inoculum densities of root knot nematode infested soil on growth and root gall index of plants reotted to uninfested soil.

Inoculum density (eggs and larvae /kg soil)	Plant growth			Gall Index
	Shoot height (cm)	Shoot dry wt. (gm)	Root dry wt. (gm)	
A. Exposure for 2 wks				
0	38.0	6.2	0.8	0
100	40.3	9.9	0.5	0
1,000	37.8	4.8	0.7	0
5,000	34.2	3.7	0.6	1.0
10,000	32.0	3.7	0.8	1.0
50,000	29.0	3.4	0.6	1.3
LSD at 5%	6.4	2.0	NS	0.4
B. Exposure for 4 wks				
0	51.8	11.8	1.7	0
100	48.3	10.5	1.8	1.8
1,000	46.3	9.8	1.8	2.3
5,000	36.8	8.7	1.5	3.5
10,000	35.8	4.6	0.8	4.3
50,000	24.0	4.9	0.9	5.0
LSD at 5%	8.8	3.9	0.5	0.8
C. Exposure for 6 wks				
0	55.8	13.5	1.8	0
100	60.0	16.4	2.1	2.8
1,000	45.8	8.9	1.6	4.5
5,000	39.0	6.7	2.0	5
10,000	31.0	3.9	0.7	5
50,000	-	-	-	-
LSD at 5%	4.1	3.9	0.6	1.7

Table 2.4. Effects of period of exposure of Nematex tomato seedlings to different inoculum densities of root knot nematode infested soil on the growth and root gall index of plants repotted to uninfested soil.

Inoculum density (eggs and larvae /kg soil)	Plant growth			Gall Index
	Shoot height (cm)	Shoot dry wt. (gm)	Root dry wt. (gm)	
A. Exposure for 2 wks				
0	36.8	8.7	1.1	0
1,000	36.4	7.5	1.1	0
10,000	34.6	6.7	0.7	0
50,000	32.6	7.6	1.0	0
LSD at 5%	3.6	NS	0.2	NS
B. Exposure for 4 wks				
0	40.6	6.4	1.8	0
1,000	38.4	6.2	1.4	0
10,000	35.0	6.8	1.4	0
50,000	34.0	6.2	1.3	0
LSD at 5%	3.2	NS	0.5	NS
C. Exposure for 6 wks				
0	70.8	17.4	2.2	0
1,000	66.0	14.6	1.8	0
10,000	67.6	17.6	2.1	0
50,000	65.2	15.2	2.0	0
LSD at 5%	5.1	2.9	NS	NS

Chapter 3

EVALUATION OF LACTUCA SPECIES AND BREEDING LINES OF LACTUCA SATIVA
FOR RESISTANCE TO ROOT KNOT NEMATODE SPECIES
(MELOIDOGYNE INCOGNITA, M. JAVANICA, M. HAPLA)

Abstract

Several plant introductions of Lactuca species and breeding lines of lettuce were screened for resistance to M. incognita, M. javanica and M. hapla. The Lactuca sp. and breeding lines tested were not resistant to either M. javanica or M. incognita. Although two of the plant introductions (L. saligna and L. dregeana) were highly resistant to a greenhouse population of M. hapla, they were susceptible upon further testing with a field population of M. hapla.

Introduction

Meloidogyne hapla is an important pathogen of lettuce grown in the muck soil regions of NY State and Canada. Light green chlorotic leaves and a delay of maturity are some of the symptoms associated with root knot nematode infected plants. Plants severely infected when young often die from the attack (7). Yield losses as high as 87% have been reported in Canada (4, 5). Most crops suitable to be grown in rotation with lettuce are susceptible to this nematode, making it economically unsuitable to reduce the nematode populations by rotation. This makes lettuce growers dependent on preplant chemical soil treatments for nematode control. Because of the problems of dispersion and adsorption by organic matter, two or three times the normal amount of nematicides that are recommended for mineral soils are generally

applied to organic soils for economic control (7). Control of the nematode by fumigation is therefore very difficult and expensive. An effective and more desirable method of control would be the use of resistant cultivars.

The objective of this study was to evaluate resistance to root knot nematode species in some breeding lines and plant introductions of Lactuca species obtained from the Geneva Agricultural Experiment Station vegetable breeding program.

Materials and Methods

Three root knot nematode species, M. incognita, M. javanica, and M. hapla, were used. The inoculum (eggs) for each species was obtained from populations maintained on Rutgers tomato in the greenhouse. The eggs were extracted from heavily infested tomato roots with 0.8% NaOCl solution, using the method described by Hussey and Barker (2). Approximately 2,000 eggs/500 cm³ of soil were mixed with autoclaved greenhouse soil. The seeds of several lettuce breeding lines and plant introductions were planted 5 per 12.5 cm -d- pots about 1/3" deep in the infested soil. Each treatment was replicated four times in pots that were kept on a bench in the greenhouse (temperature 21-26°C). Pots were watered as necessary and the seedlings were fertilized with soluble 20-20-20 NPK every ten days after seed emergence. Four weeks after seed emergence, the plants were carefully removed from the soil, washed and were rated for gall index. An index based on the percent root system galled was used: 0 = no galling; 1 = 1-10% galling; 2 = 11-25% galling; 3 = 26-50% galling; 4 = 51-75% galling and 5 = above 75% galling. Breeding lines and plant introductions that had low gall ratings to M.

hapla obtained from a lettuce field in the summer of 1981.

Rutgers tomato was planted in the infested soil collected from a lettuce field near Oswego, New York. Six weeks after planting, roots were dug and washed gently in water. Twenty mature females were dissected from the roots and put in a petri dish containing 45% lactic acid (6). Perineal sections were made and observed under 100X oil immersion objective. It was found that 90% of the perineal patterns matched those described for M. hapla (1). The population was then increased on Rutgers tomato and inoculum for the study was obtained as described earlier.

Results and Discussion

Tables 3.1 and 3.2 present results of screening lettuce plant introductions and breeding lines for resistance to M. incognita and M. javanica. None of the Lactuca species or breeding lines were resistant to any of the two root knot nematode species, as determined by the gall index rating. Reactions of the breeding lines and plant introductions to the original greenhouse population of M. hapla are also presented in Tables 3.1 and 3.2. In the preliminary screening, L. dregeana (PI 273574), L. augustana (PI 190906), L. virosa (PI 273579) and L. saligna (PI 261653) appeared to have some resistance to M. hapla (Table 3.1). Breeding lines 80-40, 80-63, 80-438 were intermediate in resistance to the greenhouse population of M. hapla (Table 3.2). Breeding lines 76-503-6, 80-70, 80-39, 80-366, 80-42 and L. sativa were susceptible. Except for one plant, all plants of L. saligna were resistant. In another experiment, 3 week old seedlings of these plant introductions and L. sativa (cv. Ithaca) were inoculated with 5,000 or 10,000 eggs

of M. hapla. The experiment was terminated 6 weeks after inoculation. The wild species of lettuce supported a slower rate of reproduction of the nematode (Table 3.2) when compared to the cultivated species, L. sativa, L. saligna and L. dregeana were highly resistant to the high inoculum rate of 10,000 eggs/plant. Based on these results, several plant introductions of L. saligna, L. dregeana, L. augustana, L. virosa and L. sativa breeding lines were screened against the field populations of M. hapla. Results (Tables 3.2 and 3.4) showed that none of the wild species or breeding lines were resistant to this field population. Similar results were obtained when the experiment was repeated. Variability in pathogenicity of populations of root knot nematodes has been demonstrated on several crops (3). Results of these experiments indicate variability in pathogenicity of the two populations of M. hapla on lettuce species. The original greenhouse population had been maintained on Rutgers tomato for several years. It is, therefore, probable that there had been a change in the population with a loss of virulence for lettuce. The field population was collected from a field that had been cropped to lettuce for several years. The difference in pathogenicity between the two populations may also have been due to the fact that the original greenhouse population had been collected from a different host. Since no further tests were made with any other plant species or crops, it is difficult to conclude that these are two different races. These results, therefore, demonstrate the need to test these plant introductions against populations of M. hapla collected from other locations.

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Table 3.1. Evaluation of Lactuca sp. for resistance to greenhouse populations of M. hapla, M. javanica and M. incognita.

<u>Lactuca</u> sp.	PI	Mean Gall Index		
		<u>M. hapla</u>	<u>M. javanica</u>	<u>M. incognita</u>
<u>L. sativa</u> (cv. <u>Ithaca</u>)		5.0 d	5 a	4.5 a
<u>L. augustana</u>	190906	2.8 c	4.5 a	4.3 a
<u>L. saligna</u>	273582	1.0 ab	5.0 a	5.0 a
<u>L. saligna</u>	261653	0.5 a	4.8 a	4.0 a
<u>L. saligna</u>	253229	0.3 a	4.5 a	4.7 a
<u>L. dregeana</u>	273574	1.2 ab	5.0 a	4.0 a
<u>L. virosa</u>	270901	2.1 b	5.0 a	3.5 a
<u>L. virosa</u>	273579	1.0 ab	5.0 a	4.5 a
<u>L. virosa</u>	271439	1.9 b	4.6 a	5.0 a
<u>L. virosa</u>	271939	3.4 c	5.0 a	5.0 a
<u>L. virosa</u>	274375	1.0 ab	5.0 a	5.0 a
<u>L. serriola</u>	251246	5.0 d	5.0 a	5.0 a
<u>L. serriola</u>	204753	4.0 cd	-	5.0 a
<u>L. serriola</u>	251245	5.0 d	-	5.0 a
<u>L. liv da</u>	273505	3.4 c	5.0 a	-
<u>L. squarrosa</u>	236396	3.8 c	-	-

Means followed by the same letter in a column are not significantly different at 5% level according to Duncan's Multiple Range Test.

Table 3.2. Evaluation of lettuce breeding lines for resistance to greenhouse populations of M. hapla, M. javanica and M. incognita and a field population of M. hapla.

Breeding Line	(Pedigree)	Mean Gall Index Greenhouse Population			Field Population
		<u>M. hapla</u>	<u>M. javanica</u>	<u>M. incognita</u>	<u>M. hapla</u>
80-70	(<u>L. sativa</u> Vanguard 75 X <u>L. saligna</u> PI 261653) F ₄	3.5 cd	3.7 ab	5.0 a	5.0 a
80-39	" "	3.3 cd	3.6 ab	4.6 a	5.0 a
80-43	" "	5.0 d	-	4.8 a	4.8 a
80-40	" "	2.7 bc	2.7 a	5.0 a	5.0 a
80-42	" "	4.0 d	2.9 a	5.0 a	4.6
80-63	" "	2.8 bc	-	-	4.8 a
80-438	" ' F ₅	3.0 c	4.5 cb	5.0 a	4.8 a
80-366	[(<u>Vanguard 75</u> <u>L. saligna</u> F ₁ X Vanguard 75)] B& F ₄	4.5 d	5.0 c	5.0 a	5.0 a
76-503-6	(Vanguard 75 X Ithaca) F ₂	4.3 d	3.8 ab	5.0 a	5.0 a
<u>L. saligna</u>	(PI 26153)	1.5 a	5.0 c	4.3 a	5.0 a
<u>L. sativa</u>	(cv. Ithaca)	4.7 d	4.9 c	5.0 a	5.0 a

Means followed by the same letter in a column are not significantly different at 5% level according to Duncan's multiple range test.

Table 3.3. Reactions of selected Lactuca sp. to two initial inoculum densities (P_i) of a greenhouse population of M. hapla.

<u>Lactuca</u> sp.	Gall Index		Eggs & larvae/g root	
	$P_i=5,000$	$P_i=10,000$	$P_i=5,000$	$P_i=10,000$
<u>L. sativa</u> (cv. Ithaca)	5.0 c	5.0 b	15,000 c	24,000 c
<u>L. virosa</u> (PI 274375)	2.1 b	3.2 b	45 a	1,700 b
<u>L. virosa</u> (PI 273579)	2.4 b	4.5 b	300 b	1,500 b
<u>L. saligna</u> (PI 261653)	0.0 a	1.3 a	15 a	52 a
<u>L. augustana</u> (PI 190906)	3.8 c	4.8 b	402 b	800 ab
<u>L. dregeana</u> (PI 274375)	1.2 b	1.8 a	20 a	100 a

Means followed by the same letter in a column are not significantly different at 5% level according to Duncan's Multiple Range Test.

Table 3.4. Reactions of selected Lactuca sp. to a field population of M. hapla.

<u>Lactuca</u> sp.	Mean Gall Index
<u>L. saligna</u> (PI 273582)	4.3 a
<u>L. saligna</u> (PI 3739)	4.5 a
<u>L. saligna</u> (PI 261653)	4.3 a
<u>L. saligna</u> (PI 253227)	4.7 a
<u>L. augustana</u> (PI 190906)	4.8 a
<u>L. virosa</u> (PI 273579)	5.0 a
<u>L. dregeana</u> (PI 273574)	4.8 a
<u>L. sativa</u> (cv. Ithaca)	5.0 a

Means followed by the same letter in a column are not significantly different at 5% level according to Duncan's Multiple Range Test.