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Interactive Effects of *Meloidogyne incognita*, Salinity and Seasonal Length on Productivity and Growth of Pepper in Limpopo Province, South Africa

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ABSTRACT

Capsicum annuum cv. 'Serrano' is tolerant to both salinity and the root-knot nematode (*Meloidogyne incognita*). Most salt-tolerant cultivars are not resistant to nematodes, vice versa. A study was conducted to determine how *M. incognita* race 2 and salinity would affect growth of cv. 'Serrano' at different time intervals. Treatments were arranged in a split-plot design with the main factor being nematode, sub-plot being salinity and sub-sub-plot harvest time. At harvest, second-order interactions for all variables were not significant ($P \leq 0.05$), while nematode × time interaction contributed 9%, 23%, 22%, 13%, 14% and 16% to the total treatment variation (TTV) in fresh fruit mass, dry shoot mass, dry root mass, stem diameter, plant height and chlorophyll content, respectively. Salt × time interaction contributed to TTV in dry root mass, stem diameter and plant height by 4%, 8% and 5%, respectively. Results suggested that the interactions were additive, multiplicative and/or synergistic on various variables. In conclusion, both nematode and salinity must be managed overtime for successful growth and productivity of cv. 'Serrano'. © 2012 Friends Science Publishers

Key Words: Cultivar 'Serrano'; Salinity; *Meloidogyne incognita*; Nematode; Pepper; Salt-tolerance

INTRODUCTION

The Serrano pepper (*Capsicum annuum*) is a type of chili pepper that originated in the mountainous regions of the Mexican states of Puebla and Hidalgo, with the name referring to the mountains (*sierras*) in the regions (DeWitt & Boslund, 2009). Chilies have high vitamin C and capsaicin, which have been linked to providing benefits against certain cancers (DeWitt & Boslund, 2009), which increased economic importance of this crop. Cultivar 'Serrano' was bred for nematode-resistance in Central and South America (DeWitt & Boslund, 2009), where *Meloidogyne incognita* races 3 and 4 are dominant (Pofu *et al*., 2011). In a recent trial, Aluvilu (2009) demonstrated that cv. 'Serrano' was tolerant instead of being resistant to *M. incognita* race 2, which is dominant in Limpopo Province (Kleynhans *et al*., 1996). Biological or physiological races in plant-parasitic nematology are nematode species, which are morphologically similar, with varying degrees of virulence that can be separated through the North Carolina Differential Host Test and/or molecular markers (Taylor & Sasser, 1978). *M. incognita* races 5 and 6 had recently been added to the tally (Robertson & Diez-Rojo, 2008; Devran & Sogut, 2011). The southern root-knot nematode is one of the major limiting factors in commercial crop production in tropical areas (Taylor & Sasser, 1978), with instances of complete crop failure when the pest is not managed (Lamberti, 1979).

Nematode-resistant cultivars are the best alternatives to synthetic nematicides, which are being withdrawn from agrochemical markets (Pofu *et al.,* 2011). The challenge is that nematode resistance can be overcome by abiotic and biotic factors. Dropkin (1963) demonstrated that the Mi gene-resistance in tomato was temperature-sensitive and overcome by the pathogen at soil temperatures above 28°C. Also, high nematode population densities could lead to the development of virulent nematode races (Cain *et al*., 1984). Recently, Pofu (2011) demonstrated that the greenhouse whitefly (*Trialeurodes vaporariorum*) was shown to overcome resistance to *M. javanica* in wild cucumber (*Cucumis africanus*). Similarly, Mashela *et al.* (1992b) demonstrated that salinity decreased resistance to the citrus nematode (*Tylenchulus semipenetrans*), while *T. semipenetrans* infection also eliminated salt tolerance in citrus seedling rootstocks (Mashela & Nthangeni, 2002).

Limpopo Province is the sixth vegetable-producing province in South Africa, with irrigation water being among the limiting factors. Most regions in the province receive approximately 250-450 mm/annum rainfall, which occurs over short summer (November-January) periods.

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Consequently, irrigation is almost always indispensable for a successful crop. Most sources of irrigation water are boreholes with inherent poor quality water, while water from rivers is also becoming increasingly marginal due to industrial contamination and increased urbanisation. Incidentally, in peri-urban agriculture, where peppers are almost always rotated with other crops, chlorine-treated municipality water increases accumulation of this salinity ion in soil.

Salinity has a detrimental effect on nematode population densities in annual and perennial crops (Machmer, 1958; Mashela *et al*., 1992a & b; Mashela & Nthangeni, 2002). Continuous salinity suppresses egress, infectivity and mobility of *M. incognita*, *M. javanica*, *M. arenaria* and *T. semipenetrans* (Lal & Yadav, 1975; Bird, 1977; Maqbool *et al.*, 1987; Khan & Khan, 1990; Mashela *et al*., 1992a). Generaly, seven days after exposing second stage juveniles (J2s) and eggs of *M. incognita, M. javanica* and/or *T. semipenetrans* to salinity egress was reduced, while mortalities increased (Khan & Khan, 1990; Maqbool *et al.*, 1987). Also, when subjected to continuous salinity, population levels of *Aphelenchus avenae*, *Belanolaimus longicaudatus*, *Hoplolaimus galeatus*, *Pratylenchus thornei*, *Helicotylenchus* species and *Rotylenchulus reniformis* showed considerable reduction (Lal & Yadav, 1976; Hixson *et al*., 2005). In contrast, cyclic salinity increased nematode population densities under both natural and greenhouse conditions (Machmer, 1958; Mashela *et al*., 1992b).

Biotic and abiotic factors exert various pressures on development of biological races (Cain *et al*., 1984). Existence of biological races dictates that exotic cultivars with claims of nematode resistance in other countries be locally screened to ensure that they are resistant to existing biological races. Recently, it was shown that cv. 'Serrano' was salt-tolerant (Aluvilu, 2009), with claims of nematode resistance in Central and South America. However, in various trials it was shown that this cultivar was, instead of being resistant, tolerant to *M. incognita* race 2 in Limpopo Province, which implied that it was allowed to feed and to reproduce on this cultivar without reducing plant growth. The observations were unique because most salt-tolerant cultivars are not resistant to plant-parasitic nematodes, *vice versa* (Mashela & Nthangeni, 2002). The objective of this study, therefore, was to investigate the interactive effects of *M. incognita*, salinity and three harvest times on productivity and growth of cv. 'Serrano'.

MATERIALS AND METHODS

The study was conducted under microplot conditions at the Plant Protection Skills Centre of the University of Limpopo (23°53"10'S, 29°44"15'E) in spring (July-September) and autumn (January-March). Plots comprised 30-cm-diameter plastic pots, inserted into 25-cm-deep holes at 1.0 m x 1.0 m inter-row and intra-row spacing (8 333 plants/ha), with border rows. Pots were filled with 10 L steam-pasteurised (300°C, 2 h) Hutton soil collected from topsoil (65% sand, 30% clay, 5% silt; 1.6% organic C, EC_e 0.148 dS/m & pH 6.5) of dug holes. Three-week-old pepper seedlings were purchased from a commercial nursery (Martindale Seedlings CC, Tzaneen, RSA).

Isolates of *M. incognita* race 2 were cultured on tomato (*Solanum lycopersicum*) cv. 'Floradade' in the greenhouse. Nematode eggs and J2s when required were extracted from tomato roots in 1% NaOCl and incubated for 72 h in a growth chamber (28°C, 40% RH) using the modified Baermann trays to obtain J2s for inoculation (Hussey & Barker, 1973). Approximately 0.96 mols NaCl per m^3 tapwater plus 0.32 mols $CaCl_2$ per m^3 were prepared for use as salt solutions.

The 2 × 2 × 3 factor experiment was arranged in a split-split plot design, with 10 replications. The main plot factor was nematode (No, N_1), the sub plot factor salinity (S_o, S_1) and the sub-sub plot factor harvest time interval (T_{90}, T_{120}, T_{150}). Inoculation was done on the transplanting day to simulate natural conditions by applying approximately 8 000 J2s of *M. incognita* race 2 per plot into 5-cm-deep holes around the crown of a seedling using a 20-mL-plastic syringe. Salt and nematode treatments were initiated at transplanting. Salinity was induced through application of 2 L salt solution and 2 L tapwater in appropriate plants when randomly deployed three moisture meter (Hadeco, New Delhi, India) readings averaged 2 units. Aphids were controlled using Metasystox-R (56) when necessary, with weeds being hand-hoed among plots. Seven days after transplanting, each plant was fertilised using 2.5 g of 2:3:2 N: P: K (22% active), which provided 155 mg N, 105 mg P and 130 mg K and 3 g 2:1:2 (43) which provided a total of 0.70 mg N, 0.64 mg K and 0.64 mg P per mL water. Also, the latter provided 1.8 mg Mg, 1.5 mg Fe, 0.15 mg Cu, 0.70 mg Zn, 2 mg B, 6 mg Mn and 0.14 mg Mo/mL tapwater. Fertilisation with the first mixture was repeated at the beginning of the first fruit harvest.

Fruits were collected weekly and a day before termination for each period. At 90, 120 and 150 days after treatment, plant height was recorded, along with chlorophyll content of selected mature leaves, which was assessed using a chlorophyll content meter (CCM-200). Stems were cut at the crown and diameters measured at 5-cm distal to the severed end using a digital vernier caliper. Pots were emptied to remove roots, which were immersed in water to free soil particles, excess water was removed from roots by pressing between two pieces of tissue-paper and weighed. Roots were assessed for galls using the North Carolina Differential Scale of 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls and 5 ≥ 100 galls per root system (Taylor & Sasser, 1978) and necrosis. Nematodes were extracted from 10 g roots per plant by maceration and blending for 30 s in 1% NaOCl (Hussey & Barker, 1973). Samples were sieved through nested sieves of 150-µm and 25-µm openings, with eggs and J2s collected from the 25-µm-openings sieve.

Soil per pot was mixed and a litre-soil sample collected for nematode assessment using the sugar-floatation extraction method from a 250-mL subsample soil (Jenkins, 1964). Soil nematode numbers were converted to 10 000 mL soil per pot and combined with nematodes/total root/plant to estimate final nematode population density (Pf). Shoots were oven-dried at 70°C for 72 h for determination of dry shoot mass, with roots from border plants used to determine a proportion for converting fresh roots with nematodes to dry root mass. Soil pH and soil electrical conductivity (EC) were measured using the pH meter and the EC meter, respectively, using IFAS method (Rhue & Kidder, 1983). Data were subjected to analysis of variance (ANOVA) procedure using SAS software (SAS Institute, Inc., Cary, NC). Nematode numbers were transformed by Ln (x + 1) before analysis in order to homogenise the variances (Gomez & Gomez, 1984), but untransformed data were reported.

RESULTS

The interaction between seasons for variables was not significantly ($P \leq 0.05$) different and data were pooled (n = 240). Second order interaction, nematode × salt × time, for all variables was not significant at 5% level of probability (Table I), while the first order interaction, nematode × time, was significant for all variables, with total treatment variation (TTV) ranging from 9% to 23%. The first order interaction, salt × time, was significant ($P \leq 0.10$) for dry root mass, stem diameter and plant height, with TTV ranging from 4% to 8%. Individual factors, particularly nematode and time, were each significant for all variables except for nematode against chlorophyll content. Instead, salinity affected fresh fruit mass and stem diameter only. The first order interaction, salt × time, was significant at 5% level for soil pH (data not shown). The first order interaction, nematode × salinity, was also significant at the 5% level of probability for soil EC. Since the first order interactions were significant, data were further analysed for magnitude and direction of effect using two-way tables. Also, salinity had no effect on nematode numbers, with nematode and time each having an effect on the variable.

Relative to untreated control at 90 days, fruit yield of cv. 'Serrano' without nematodes decreased with time, yield decreasing by 58% at 150 days (Table II). However, relative to untreated control, fruit yield increased by 10% under nematode infection at 90 days, followed by reduction of 71% and 169% at 120 and 150 days, respectively. In contrast, dry shoot mass increased in plots without nematodes by 15% and 68% at 120 and 150 days, respectively, and under nematode infection at 90 days (6%) and 120 days (17%), but decreased at 150 days.

Relative to untreated control, stem diameter decreased with time, with higher reductions occurring in plots with nematodes (Table III). Relative to untreated control, in plots without nematodes the variable was reduced by 4% and 19% at 120 and 150 days, respectively, while under nematode infection the variable was reduced by 2%, 18% and 25% at the three respective times. In contrast, dry root mass increased from 33% and 68% in plots without nematodes, while under nematode the variable also increased by 10%, 49% and 132% during the respective timelines.

Relative to untreated control, chlorophyll content had slightly increased (4%) at 120 days in plots without nematodes, but decreased (14%) at 150 days (Table IV). In plots with nematodes, the variable increased (8%) at 90 days and then decreased by 4% and 7% at 120 and 150 days, respectively. Under non-salinity dry root mass increased by 33% and 67% at 120 and 150 days, respectively, while under salinity the variable decreased (7%) at 90 days and then increased by 22% and 25% at 120 and 150 days, respectively. Under non-salinity, soil pH increased and decreased with time progression by 10% and 5% at 120 and 150 days, respectively, while under salinity the decline was from 1% to 10% over time (data not shown). In contrast, salt application increased soil EC in plots with and without nematodes by 296% and 238%, respectively (data not shown).

Table I: Split-split analysis of variance of fresh fruit mass, dry shoot mass, dry root mass, plant height, stem diameter and chlorophyll content from pepper cv. 'Serrano' at two levels of *M. incognita* race 2, two salinity levels and three time intervals (n = 240)

Source	DF	Fresh fruit mass		Dry shoot mass		Dry root mass		Stem diameter		Plant height		Chlorophyll cont.	
		SS	%	SS	%	SS	%	SS	%	SS	%	SS	%
Rep (R)	19	7.57	5^{**}	186.97	4^{**}	498.55	21^{***}	205.74	6^{*}	258.94	3^{*}	67.71	5^{ns}
Nematode (N)	1	12.80	8^{**}	1134.03	27^{***}	149.79	6^{***}	634.28	20^{**}	2625.04	31^{***}	101.60	7^{ns}
Error a	19	3.67	2	75.73	2	62.62	3	115.01	4	178.37	2	127.10	9
Salinity (S)	1	25.59	16^{**}	6.91	0^{ns}	217.02	9^{**}	438.87	13^{***}	388.74	4^{ns}	10.22	1^{ns}
S × N	1	4.56	3^{ns}	55.37	1^{ns}	70.64	3^{ns}	50.23	2^{ns}	233.69	3^{ns}	108.46	7^{ns}
Error b	79	4.57	3	112.20	3	75.63	3	44.55	1	229.28	2	36.29	2
Time (T)	2	71.83	46^{***}	1511.16	35^{***}	574.68	24^{***}	850.98	27^{***}	2860.90	33^{**}	705.00	47^{***}
N × T	2	13.49	9^{*}	963.81	23^{***}	513.68	22^{***}	409.95	13^{***}	1185.34	14^{**}	232.06	16^{***}
S × T	2	5.09	3^{ns}	77.48	2^{ns}	92.43	4^{*}	260.89	8^{*}	419.30	5^{**}	52.25	3^{ns}
N × S × T	2	3.20	2^{ns}	83.77	2^{ns}	60.16	3^{ns}	89.57	3^{ns}	75.84	1^{ns}	13.18	1^{ns}
Error c	152	2.90	2	48.55	1	36.25	2	98.22	3	140.41	2	39.78	3
TOTAL	228	155.27	100	4255.98	100	2351.45	100	3198.29	100	8595.85	100	1493.63	100

^{ns} = Means that the factor(s) was not significant at $P \leq 0.05$; while *, **, and *** mean that the factor(s) was significant at $P \leq 0.10$, $P \leq 0.05$ and $P \leq 0.01$, respectively

Table II: Two-way table of first order interaction, *M. incognita* race 2 × time (90, 120 and 150 days), for fresh fruit yield and dry shoot mass of *Capsicum annum* cultivar 'Serrano' (n = 240)

Time (days)	Fresh fruit yield (g)				Dry shoot mass (g)			
	Nematode				Nematode			
	N_o	Impact (%)	N_1	Impact (%)	N_o	Impact (%)	N_1	Impact (%)
90	201.3	–	221.5	10	19. 9	–	21.1	6
120	200.8	−0.3	144.3	−71	22.8	15	23.4	17
150	84.6	−58	74.8	−169	33.5	68	18.7	-6
	Standard error = 9.88				Standard error = 1.11			

Table III: Two-way table of first order interaction, *M. incognita* race 2 × time (90, 120 and 150 days), for stem diameter and dry root mass of *Capsicum annum* cv. 'Serrano' (n = 240)

Time (days)	Stem diameter (mm)				Dry root mass (g)			
	Nematode				Nematode			
	N_o	Impact (%)	N_1	Impact (%)	N_o	Impact (%)	N_1	Impact (%)
90	13.35	–	13.06	−2	3.00	–	3.31	10
120	10.85	−4	10.96	−18	3.98	33	4.48	49
150	12.88	−19	9.98	−25	5.02	68	6.95	132
	Standard error = 0.22				Standard error = 1.63			

Table IV: Two-way table of first order interaction, *M. incognita* race 2 × time (90, 120 and 150 days), for chlorophyll content, and first order interaction, salt × time, for dry root mass of *Capsicum annum* cv. 'Serrano' (n = 240)

Time (days)	Chlorophyll content				Dry root mass (g)			
	Nematode				Salt			
	N_o	Impact (%)	N_1	Impact (%)	S_0	Impact (%)	S_1	Impact (%)
90	65.28	–	70.68	8	3.00	–	2.80	−7
120	67.74	4	62.38	−4	3.98	33	3.67	22
150	55.61	−14	60.60	−7	5.02	67	3.76	25
	Standard error = 1.12				Standard error = 1.63			

Impact (%) = [(Treatment/Control) – 1] × 100

DISCUSSION

Salinity had no effect on numbers of *M. incognita* race 2 on cv. 'Serrano', with the cultivar supporting nematode feeding and reproduction, as previously observed (Aluvilu, 2009). Consequently, nematode results did not confirm those of continuous salinity in other studies where nematode numbers were consistently reduced (Mashela *et al*., 1992a; Hixson *et al*., 2005), while cyclic salinity increased the variable (Machmer, 1958; Mashela *et al.*, 1992a). Generally, during salinity, nematode numbers do not change since they have a survival strategy against osmotic potential, referred to as osmobiosis under the auspices of cryptobiosis (Mashela, 2007). When salinity stress is diminished through leaching, eggs and juveniles exit osmobiosis to assume egress and feeding, respectively.

In cv. 'Serrano' all second order interactions were not significant ($P \leq 0.05$) for any variable, suggesting that the factors had either additive or multiplicative effect (Salisbury & Ross, 1992). In additive responses, the factors act on different sites or organelles to elicit a greater response, while in multiplicative responses, the factors act on different steps of a process in a causal sequence, so that the effect of one is always a fraction of the other (Salisbury & Ross, 1992). In contrast, when interactions are significant ($P \leq 0.05$), the factors are said to have synergistic effects (Salisbury & Ross, 1992), which implies that the factors act on the same site, resulting in a much greater response than when the reaction towards their action is the sum of individual reactions (Salisbury & Ross, 1992). In cv. 'Serrano', the main factors (nematode, time or salt) acted on pairs in the same site or organelle to elicit a greater or lesser response as shown on two-way tables.

At 150 days, fresh fruit yield in untreated controls declined by more than half, suggesting an innate response since there was no evidence of root bound. Pepper, a perennial crop, is grown as an annual crop due to its intrinsic sensitivity to time after initial flower initiation (McMahon *et al*., 2002). The 10% increase in fruit yield in plants infected with nematodes at 90 days is one of the interesting features, which may be better understood through using the concept of damage threshold levels (Seinhorst, 1965). By definition, the damage threshold level is that level of nematode numbers where yield reduction starts. Before the damage threshold, infection by various nematode species invariably increases plant yield (Coursen & Jenkins, 1958; Seinhorst, 1965; Wallace, 1973; Mashela, 2002). The mechanism involved in this curious process is not clear. The observed increase in fruit yield in response to low nematode numbers is the first such observation in pepper cultivars. Generally, biological systems respond to external factors through the density-dependent growth pattern, which is characterised by three phases: stimulation, saturation and inhibition phases (Salisbury & Ross, 1992; Liu *et al.*, 2005). Generally, stimulation occurs at low dosages or concentrations, while inhibition occurs as dosages increased. Using the curve-fitting allelochemical response data (CARD) model, Mafeo *et al.* (2010) demonstrated that various crops responded to crude extracts of '*nemarioc*' bio-nematicide in a density-dependent growth pattern as dosages of the material were increased.

Reduction in fresh fruit yield at 120 and 150 days under nematode infection suggested that nematode numbers were then beyond the damage threshold levels (Seinhorst, 1965) and therefore, inflicting damage to pepper, with sensitivity being the highest on fresh fruit. Since infection by *M. incognita* race 2 at 150 days had reduced fresh fruit yield by as much as 169%, this race may be a limiting factor when the cultivar is grown for an extended period without keeping nematode numbers under check. This is particularly important in tropical areas where nematode population

numbers rise faster than outside the tropics (Khan & Ahmad, 2000; Khan *et al*., 2000).

In control plots, dry shoot mass in cv. 'Serrano' increased continuously with patterns being different to those of fresh fruit yield. Increase in dry shoot mass in all harvest dates under *M. incognita* race 2 except at day 150 can also be explained using the damage threshold levels. Generally, sensitivities of organs to external factors that induce density-dependent growth patterns differ (Mafeo *et al*., 2010). Root mass increased throughout the study regardless of the treatment. Since cv. 'Serrano' is tolerant to *M. incognita* race 2, it implied that infection occurred, with the observed root galls resulting into increased root mass, as observed elsewhere (Dropkin, 1980; Hartmann & Sasser, 1985). Generally, as a perennial plant like pepper approaches winter, it channels more carbohydrates towards the root systems, resulting in increased root mass. Thus, the increase in root mass should not be viewed in isolation, since infection by nematode and the seasonal effect each may increase root mass, as shown by the time intervals in this study.

Decrease in stem diameter of cv. 'Serrano' with time progression in treatments with and without nematodes, is in agreement with observations of increased root mass. The variable was associated with root systems becoming active sinks for sucrose (Salisbury & Ross, 1992). Arrival of sucrose in organs in high plants lowers osmotic potential (Campbell, 1990; Mashela & Nthangeni, 2002), resulting in more water moving into such organs, with increased osmotic pressure (Campbell, 1990). Reduction in stem diameter is a physical means of restricting the flow of sucrose into the root system as a means of managing osmotic pressure in root cells. Factors which increase flow of sucrose into roots, like *Meloidogyne* species (Mashela, 2002), arbo-vascular mycorrhiza (Graham & Syvertsen, 1989), salinity stress (Mashela & Nthangeni, 2002), drought stress (Mafeo, 2005) and root pruning (Mashela & Nthangeni, 2002), all result into reduced stem diameters. In their classical osmotic regulation study, Mashela & Nthangeni (2002) demonstrated that decreased stem diameter was a physical response to chemical activities in root cells required to curb osmotic pressure. In their model, Mashela and Nthangeni (2002) demonstrated that accumulation of sucrose in organs was inversely proportional to accumulation of osmoticum ions (K, Na, Cl). This explanation agrees with the observed increased dry root mass with time in plants without nematodes.

At 90 days, dry root mass under salinity was reduced by 7%, followed by increases throughout the study, which agreed with the explanation of increased flow of growth substances towards the root systems, particularly with old age. However, after enduring salinity stress for some time, root growth increased at a decreasing rate when compared with under non-saline conditions. In most halophytes like pepper, plants adapt to salinity through channelling more sucrose to roots, in exchange of mobilising osmoticum ions to other organs (Mashela & Nthangeni, 2002). Increased sucrose level is further converted into glucose for use in various energy-driven activities, with excess being stored as starch (Mashela & Nthangeni, 2002).

Chlorophyll content invariably decreases with maturity of leaves (Salisbury & Ross, 1992). When salinity is introduced in halophytes, the plant enters a shocked state, resulting in the reduction of various physiological activities to mitigate for the shock (Salisbury & Ross, 1992). However, with adaptation, the processes recover, followed by a reduced but permanent decline in physiological activities (Salisbury & Ross, 1992). By definition, halophytes are plants, which tolerate or even require low NaCl concentrations in soil water for proper growth and development (Greenway & Munns, 1980). Observations in photosynthesis of cv. 'Serrano' due to salinity stress support the previously documented work in photosynthesis of citrus seedlings (Mashela & Mphosi, 1999). Decrease in soil pH and increase in soil EC under salinity observed in this study are commonly documented under salinity (Bohn *et al*., 1985). Infection of roots by *Meloidogyne* species results in the release of various amino acids from root galls (Wallace, 1973), which invariably reduce soil pH. The observed negligible effect of *M. incognita* race 2 infections on cv. 'Serrano' in soil pH suggested that the infections were not aggressive enough to allow for the release of sufficient amino acids into soil solutions.

CONCLUSION

The concept of interaction, namely multiplicative and synergistic effects, is important in describing the forces at play in this study. Individual main factors were highly significant for the growth variables determined. Consequently, both multiplicative and synergistic effects should be considered when viewing the effects of nematode, salinity and time interval on growth of pepper cv. 'Serrano'. Ideally, both nematode and salinity must be managed for successful growth and production of cv. 'Serrano'.

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