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Coefficient and Path Analyses of the Impact of Root Galls Caused by *Meloidogyne javanica* on Some Growth and Yield Parameters of Tomato (*Solanum lycopersicum*)

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Authors' contributions

This work was carried out in collaboration between all authors. Author SIO carried the experiment, literature search and the analysis. Author KIU helped in the identification of the nematode species in collaboration with author SIO and also helped in proof reading the manuscript. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Pot experiments were used to examine the impact of root galls caused by *Meloidogyne javanica* on some growth and yield parameters of tomato (*Solanum lycopersicum*) in Federal College of Agriculture Ishiagu, Ebonyi State, SE Nigeria in 2009 and 2010. The experiment was arranged in completely randomized design with four replications. Correlation and path coefficient analyses were used to determine the extent of the biological associations between number of galled roots with gall index, plant height, number of leaves, number of fruits and fresh fruit weight of three varieties (Roma, Roma VF and UC82B) of tomato. The results indicated strong positive correlations with gall indices and strong negative correlations with plant height, number of leaves, number of fruits and fresh fruit weight. The number of galled roots showed high positive direct effects on the gall indices and low positive effects on the fresh fruit weight. There were negative direct effects on the plant height and the number of leaves. The analyses showed that the negative effects on the growth parameters account for the reduction in the yield of the plants.

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1. INTRODUCTION

Tomato (*Solanum lycopersicum*) is a solanacious plant. The fruit is very rich in essential vitamins and mineral salts [1]. It generates income to its growers. It is tropical warm season crop, said to have originated in Tropical Central and South America as posited by Centre for Overseas Pest Research (COPR), [2], and it is grown all over Nigeria. The bulk of production is from the dry season cropping particularly under irrigation in the Northern states and near riverbanks in the southern states of Nigeria. According to COPR [2], the total land area covered annually is over one million hectares with most of the production from the Northern Guinea Sudan Savannah.

Uguru [3] stated that tomato is a short –lived herbaceous annual with weak trailing much branched stem with hairs at juvenile stage of development. Fruits of *Local* varieties in Nigeria are thin-walled, heavily seeded and sour in taste. Tomato grows well in many types of soils ranging from sandy to the heavy clayey soils [3]. Jaraba et al. [4] reported that sand to sandy-loam soils are conducive to *Meloidogyne* species.

The production of tomato is limited by the attack of pest and diseases. This results in acute shortage of the fresh fruits in certain periods of the year. Yield losses are partly attributed to the susceptibility of tomato cultivars to serious pests and diseases [5]. More than a hundred different pest species have been recorded worldwide on tomato crops [1,5]. They include nematodes, mites, thrips, aphids, moths, whiteflies, beetles and flies [2].

Nematodes constitute the major pests of tomato globally especially in the tropical and subtropical regions. The production of tomato is impaired by among other factors its infections by nematodes [6]. Adesiyan et al. [7] reported reductions in yield ranging from 28 to 68%. Over sixty species of plant parasitic nematode attack tomato but the most destructive nematodes responsible for enormous yield losses of tomato are the root-knot nematodes belonging to the genus, *Meloidogyne* [8,9,5]. This objective of this research was therefore to evaluate the biological impact of root galls on the growth and yield parameters of susceptible tomato varieties using coefficient and path analyses. Path coefficient analysis is a standardized partial regression coefficient and as such measures the direct and indirect influence of one variable upon one another and permits the separation of the correlation coefficient into components of direct and indirect effects [10].

2. MATERIALS AND METHODS

This research was conducted at the Research and Teaching Farm of Federal College of Agriculture Ishiagu, Ebonyi State, Nigeria, located in the derived savannah zone on latitude 05º, 56' N, longitude 07º, 31' E and altitude 150m above sea level.

The seedlings of Roma, Roma VF, and UC82B varieties of tomato (*Solanum lycopersicum)* which are susceptible to root knot nematodes were used in the study. The seeds were purchased from Seeds Company Nigeria Limited Kano. The experiment was conducted in 2009 and repeated in 2010, between April and July.

2.1 Identification of Root-Knot Nematode Species Used

The infected roots of *Spinacia oleracea* were cut into small pieces, put into glass ware, mixed with acid fuchsin and heated over flame for about 5 minutes. The roots were stained with lactophenol and transferred to slide. The anal end of the female root-knot nematode was cut off and transferred to another slide where it was cut into a square. The section was cleared of contents with a brush and mounted under the microscope. The perineal patterns were exposed and the type observed conformed with those of *Meloidogyne javanica*. [11,8]. The identification was done in the Plant Pathology Laboratory of the Department of Crop Science, University of Nigeria, Nsukka.

2.2 Nematode Eggs Extraction and Estimation

The extraction method outlined by Jepson [11], was used. The infected roots were washed under running tap water and cut into pieces of about 2 cm long. The roots were put into a stoppered flask. An aqueous solution of sodium hypochlorite (commercial bleach) was mixed at the ratio of 1:4 of bleach and water. 200 ml bleach solution was poured into the flask with roots, stoppered and shaken vigorously for 4 minutes.

The weak bleach solution broke down the gelatinous matrix surrounding the eggs thus releasing them from the roots. The mixture was poured through a 200-mesh sieve, set inside a 500-mesh sieve, shaking the sieves as the liquid passed through. The 200-mesh sieve was removed and the eggs caught in the 500-mesh sieve were washed thoroughly with a wash bottle, into a flask.

The liquid in the flask containing the eggs was made to 500 ml by pouring water into it. The mixture was thoroughly mixed and with the aid of a graduated syringe, 1 ml of the inoculum was introduced into a counting dish, and placed under a light microscope. Following the grid on the counting dish, the total number of eggs in 1 ml was counted. This was repeated 3 times and the average of 3 counts obtained. This was estimated at 500 eggs/ml.

2.3 Nursery and Potting

The tomato seedlings were raised in wooden trays (80 cm x 50 cm x 20 cm) using 3 parts top soil, two parts well cured poultry droppings and one part river sand, which were sterilized for 30 minutes at 90ºC in an electric soil sterilizer.

Black polythene bags of 29 by 30 cm were used for these experiments in 2009 and 2010. Five kg sterilized soil were filled into poly bags. Four weeks old seedlings were transplanted into the pots. The varieties were inoculated with 5000 eggs of *M. javanica* around their roots one week after transplanting. The experiments were arranged in a Completely Randomized Design (CRD) with four replications with five bags per replicate.

Data collection were based on the following: Number of galled roots per plant at harvest; Gall index; Plant height (cm) at 50% anthesis; Number of leaves at 50% anthesis; Number of fruits per plant at harvest and Fresh fruits weight (g) per plant at harvest. The gall indices were evaluated using the rating scheme of Taylor and Sasser [12] as follows: 0 = no galls, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11 – 30 galls, 4 = 31 – 100 galls and 5 = > 100 galls.

2.4 Data Analysis

Correlation and Path coefficient analyses showing the direct and indirect effects of number of galled roots on other plant attributes were computed using SPSS version 17.0.

3. RESULTS

3.1 Correlation Analysis

The summary of the correlation analysis for 2009 and 2010 are recorded in Table 1. The number of galled roots had positive and highly significant correlations with the root gall index (r = 0.904 and r = 0.909) in 2009 and 2010 respectively. The number of galled roots had negative and highly significant correlations with plant height (-0.761 and -0.571), number of leaves (-0.563 and -0.479), number of fruits (-0.574 and -0.539) and fruit weights (-0.523 and -0.539) in 2009 and 2010 respectively. Plant height correlated positively with number of leaves (0.581 and 0.494), number of fruits (0.538 and 0.448) and fruit weights (0.459 and 0.226) in both years respectively. The number of leaves correlated positively and significantly with number of fruits (0.584 and 0.591) and fruit weight (0.416 and 0.372) in both cropping seasons. The number of fruits positively and significantly correlated with the fruit weight (0.685 and 0.635) in 2009 and 2010 respectively.

Table 1. Linear correlation matrix between number of galled roots and growth and yield parameters of the three cultivars in 2009 and 2010

2009	NGR	GIND	PLTHT	NOLVS	NOFRT	WTFRT
NGR	1	0.904**	-0.761**	-0.563**	-0.574**	-0.523**
GIND		1	-0.706**	-0.411**	-0.484**	-0.502**
PLTHT			1	0.581**	0.538**	0.459**
NOLVS				1	0.584**	0.416**
NOFRT					1	0.685**
WTFRT						1
2010						
NGR	1					
GIND	0.909**	1				
PLTHT	-0.571**	-0.406**	1			
NOLVS	-0.479**	-0.318*	0.494**	1		
NOFRT	-0.539**	-0.498**	0.448**	0.591**	1	
WTFRT	-0.539**	-0.589**	0.226 ns	0.372*	0.635**	1

**= significant at 5%; **= significant at 1%; ns= not significant*
NGR= Number of galled roots; GIND= Gall index; PLTHT= Plant height; NOLVS= Number of leaves; NOFRT= Number of fruits; WTFRT= Weight of fruits.

3.2 Path Analysis

The number of galled roots showed various direct and indirect associations with the growth and yield parameters (Fig. 1). The path coefficient analysis (Table 2) showed that the number of galled roots had low positive direct effect (P= 0.013 and P= 0.021) on the fruit weight in 2009 and 2010 respectively. There were negative indirect effects on the weight of fruits through root gall index (− 0.362 and − 0.478), number of fruits (− 0.051) and positively

(0.015) in 2010, negatively on number of leaves (− 0.064 and − 0.057) and plant height (− 0.059 and − 0.041) in 2009 and 2010 respectively.

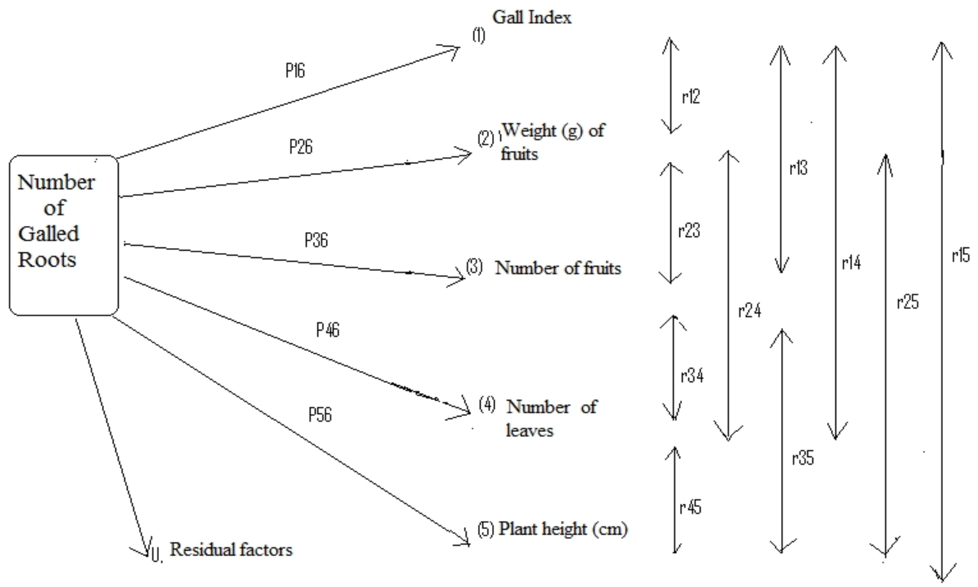

Fig. 1. Path diagram showing direct and indirect effects of number of galled roots on Gall index, Weight of fruits(g), Number of fruits, Number of leaves and Plant height (cm) in 2009 and 2010

P = Direct effects; r = indirect effects.

Table 2. Direct (diagonal) and indirect effects of number of galled roots on the growth and yield parameters of the three cultivars in 2009 and 2010

Plant attributes	GIND	WTFRT	NOFRT	NOLVS	PLTHT	Correlation coefficients
2009						
GIND	[0.721]	− 0.007	0.036	0.063	0.090	0.904
WTFRT	− 0.362	[0.013]	− 0.051	− 0.064	− 0.059	− 0.523
NOFRT	− 0.349	0.009	[− 0.075]	− 0.090	− 0.069	− 0.574
NOLVS	− 0.296	0.005	− 0.044	[− 0.154]	− 0.074	− 0.563
PLTHT	− 0.509	0.006	− 0.040	− 0.089	[− 0.128]	− 0.761
Residual						0.358
2010						
GIND	[0.811]	− 0.012	− 0.012	0.049	0.074	0.909
WTFRT	− 0.478	[0.021]	0.015	− 0.057	− 0.041	− 0.539
NOFRT	− 0.404	0.013	[0.023]	− 0.090	− 0.082	− 0.539
NOLVS	− 0.258	0.008	0.014	[− 0.153]	− 0.090	− 0.479
PLTHT	− 0.329	0.005	0.010	− 0.076	[−0.182]	− 0.571
Residual						0.332

GIND= Gall index; WTFRT= Weight of fruits; NOFRT= Number of fruits; NOLVS= Number of leaves; PLTHT= Plant height.

The number of galled roots had low negative direct effect (P= − 0.075) on the number of fruits in 2009 but had low positive direct effect (P= 0.023) on the number of fruits in 2010. There were negative indirect effects through gall index (− 0.349 and − 0.404), low positive indirect effects through fruit weight (0.009 and 0.013), low negative indirect effect through plant height (− 0.069 and − 0.082) in 2009 and 2010 respectively.

Number of galled roots had negative direct effects (− 0.154 and − 0.153) on the number of leaves produced in 2009 and 2010 respectively. There were negative indirect effects through gall index (− 0.296 and − 0.258), low positive indirect effects through fruit weight (0.005 and 0.008) in both years. In 2009, there was low negative indirect effect through number of fruits (− 0.044), but had low positive indirect effect (0.014) in 2010. Low negative indirect effects through plant height (− 0.074 and − 0.090) were observed in 2009 and 2010 respectively.

Number of galled roots had low direct effects (P= − 0.128 and P= − 0.18) on the plant height in both cropping seasons. There were high negative indirect effects (− 0.509 and − 0.329) through gall index, low positive indirect effect (0.006 and 0.005) through weight of fruits in both years. In 2009, there was low indirect effect (− 0.040) and low positive indirect effect (0.010) through number of fruits in 2010. Low negative indirect effect (− 0.089 and − 0.076) through number of leaves were obtained in 2009 and 2010 respectively.

4. DISCUSSION

Positive correlations between the number of galled roots and root gall index indicate that an increase in the number of galled roots leads to increase in the root gall index. Root gall index denotes the amount of root knots observed in a root. Root galling is as a result of nematode injury on plant roots which leads to adverse performance of the growth and yield parameters of the affected plants.

The number of galled roots and root gall index led to negative associations with plant height, number of leaves, number of fruits and weight of fruits though of low magnitude. This means that an increase in the number of galled roots and root gall index would lead to decrease in plant height, number of leaves, number of fruits and weight of fruits. Root galling as a result of root knot nematode attack leads to yield losses. This is in line with findings of other workers [5,6,7]. The attack by root knot nematodes resulting in the formation of galls in the roots lead to morphological and physiological disorders in the growth and yield parameters of the affected plants. This was expressed by the correlations of the number of galled roots and gall indices with growth and yield parameters.

Kang [13] stated that associations detected from correlation coefficients may not necessarily be attributed to a single variable but rather to a number of interdependent variables. Decisions based solely on correlation coefficients may not necessarily be reliable, as only limited information is revealed about what may essentially be a complex series of interrelationships between variables.

Path analysis is an important analytical tool, which has been, or can be, used to quantify a perceived biological relationship through partitioning of correlation coefficients into direct and indirect effects [14]. The path analyses indicated high positive relationships between the number of galled roots with gall indices. This corroborated the results of the correlation analyses, showing that high gall index contributed to poor performance of the growth and yield parameters of the plants. This marks the high susceptibility of the tomato plants to *M. javanica*.

The low positive impact of the galled roots on the weight of fruits may have been contributed by other environmental factors such as the soil nutrients. This is because there was strong negative correlations between the galled roots and the weight of fruit culminating in low positive direct effect on the weight of fruit produced. This indicates that the number of galled roots affected weight of fruits minimally through negative indirect effects by number of fruits, number of leaves and plant height. The negative effects on the plant height and number of leaves affected the solar radiation received and photosynthetic potentials of the plants due to lower plant height and the number of leaves produced by the plants. This further means that the negative effects of *Meloidogyne javanica* on number of fruits, leaves and plant height resulted in reduction of fruit weight.

The residual effects that determined the extent of nematode damage to the studied attributes of the plants accounted for the variability of the plants resistance to attack by the nematode were 35.80% and 33.20% in 2009 and 2010 respectively. This indicated that 64.20% and 66.80% of the growth and yield attributes of the plants were adversely affected by the nematode in 2009 and 2010 respectively. *Meloidogyne javanica* effects on the vegetative parameters especially the number of leaves produced by the plants as well as the other physiological functions of the plants lead to low yield thereby causing enormous economic losses to the farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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