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Research Article

Host-parasite Interactions between *Solanum aethiopicum, Meloidogyne incognita,* and *Fusarium oxysporum* f.sp. melongenae as Portrayed by Disease Traits and Crop Yield

Elias Mjaika NDIFON*[1,2]

[1]Alex Ekwueme Federal University Ndufu-Alike, Faculty of Agriculture, Department of Crop Science, PMB 1010 Abakaliki, Nigeria
[2]Federal University of Agriculture Makurdi, College of Agronomy, Department of Crop and Environmental Protection, PMB 2743 Markurdi, Nigeria

[1]https://orcid.org/0000-0001-6027-4714

*Corresponding author e-mail: emndi4nn@yahoo.com

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Abstract: *Solanum aethiopicum L.* cultivation is highly constrained by wilt disease induced by *Fusarium oxysporum* f.sp melongenae and *Meloidogyne incognita*. The effects of initial population densities of these pathogens on the crop were investigated to enhance knowledge of the host-parasite interactions. The 4 x 4 factorial set of treatments were laid out in the field using the randomized complete block design with three replications. Data were collected on plant vigour, vascular discoloration, fruit weight, shoot weight, root-gall index, final nematode population, disease incidence, and disease severity. The different initial population densities of *Fusarium* and/or *Meloidogyne* spp. had detrimental effects on the crop compared to the Control. The main effects of the pathogens on the crop/wilt showed the existence of cross-over interactions for all the disease parameters. The effects of the pathogens on yield (fruit weight and shoot weight) were partially directly proportional to population densities even though the effects were significantly different ($P \leq 0.05$) compared to the Control. All the disease parameters were positively correlated. Each of the pathogens was capable of causing severe damage to the crop in either single or concomitant infection.

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Footnote: Concomitant and single infection with *Fusarium oxysporum* and *Meloidogyne incognita* on wilt of African garden egg (*Solanum aethiopicum* L) and its management in Makurdi, Nigeria.

1. Introduction

In nature/agroecosystems, a crop is hardly ever exposed to the influence of a single pathogen. In some cases, the occurrence of disease is tied to the concomitant occurrence of two or more pathogens (vital tripartite inter-kingdom interactions). For instance, *Meloidogyne* Göldi (N.b: The order and family of this genus are presented in the discussion section due to the multiplicity of names in the literature related to the order and family), and *Fusarium* (Hypocreales; Nectriaceae) species occurred concurrently on coffee in Costa Rica leading to corchosis disease. The presence of *Meloidogyne arabicida* López & Salazar, or *Meloidogyne exigua* Goeldi alone caused a reduction in coffee shoot height and galling but no corchosis developed (Bertrand et al., 2000; Ndifon, 2019).

Nematodes often help to breach the endodermal barrier enabling the other pathogen(s) to drastically damage the host as was reported for potato cyst nematode and *V. dahliae* in different potato varieties. Back et al. (2002) in a review of disease complexes in plants emphasized the yield loss that results from the occurrence of these disease complexes, knowledge of which is inadequate for most host-parasite interactions. This inadequacy of knowledge on disease complex is still here with us.

Many mechanisms of disease complexes exist. One of which is the mechanism based on the utilization of wounds induced by nematodes for the entrance of soil-borne pathogens. This has as its basis the removal of physical impenetrable barriers that the fungi or bacteria pathogens could not by themselves breach. The type of wound depends on the feeding pattern of the nematode and its life cycle. The timing of inoculation of the second pathogen after the nematode is critical especially when the wounds are just micro-punctures or the pathogen depends more on the splitting of galls, or the presence of channels for the growth of hyphae, or cell proliferation (Back et al., 2002).

Finally, the pathogen may induce changes to the host plant, which may encourage the proliferation of the roots. An increase in number of galls and population of nematode juveniles recovered at the termination of experiments was reported by Back et al. (2002). The pathogen may increase the rate or the quantity of root exudates and the release of carbon dioxide that attracts the nematodes to the roots. The following factors affect disease complexes: i.e. the nematode species present, the initial population of the pathogens, the fungi genotypes, the environmental factors, and the abiotic factors (i.e.; soil pH, the soil structure, the soil moisture content, and the prevalent weather conditions).

African garden eggplant/African garden egg (*Solanum aethiopicum* L. (Solanales; Solanaceae)) is a very important constituent of the human diet and medicine. Cultivation of African garden eggplant is plagued by pests and diseases among which are *Fusarium* and *Meloidogyne* species. Sulaiman et al. (2019) showed that all the inoculum levels (500-8000) of *Meloidogyne incognita* reduced growth parameters leading to a corresponding decrease in the yield of eggplant (*Solanum* spp.). They indicated that the lowest nematode population used (500 eggs/juveniles of *M. incognita*) was capable of reducing the yield of the variety of eggplant used.

Research on diseases of this garden eggplant has not been carried out to the level of those of tomato and potato even though it is a good source of income and employment wherever it is cultivated. This study of the effect of the *Fusarium* /*Meloidogyne* wilt complex on African garden egg was necessitated by the paucity of information on this devastating disease. This study concentrated on the effects of the pathogen species and variation in their initial population densities on the wilt disease of African garden eggplant.

2. Material and Methods

2.1. The study site

The experiment was carried out at the Teaching and Research Farm of the College of Agronomy, Federal University of Agriculture, Makurdi (07°45″N by 08°37″E). Ibrahim and Idoga (2015) reported that the farm which is within the flood plain of River Benue is underlain by consolidated Makurdi sandstone, Turanian Eze-Aku shales, and Alluvium. They pointed out that superficial deposits such as weathered rocks, laterites, and alluvium extensively cover the study area. Furthermore, they observed that the soils were low in fertility and had a predominant sandy loam texture with a low total porosity, are moderate to slightly acidic (pH range of 5.56-6.17), are low in available P, total N, exchangeable K, Ca, while Mg and Na are moderate.

2.2. Experimental procedures

2.2.1. Sourcing, culturing, raising, and identification of the pathogens

F. oxysporum Schelecht ex Fries (Syn. & Hans) f.sp. melongenae Mauto and Ishigami (no races of this forma specialis have been reported so far (Edel-Hermann and Lecomte, 2019)) were isolated from *S. aethiopicum* plants (obtained from farmers' farms in Makurdi and the Research Farm), showing wilt symptoms. The fungus was isolated using Acetate Differential Agar (i.e. a Difco dehydrated medium) which was enriched with dextrose.

The African garden egg stems were thoroughly washed with tap water to reduce bacterial contamination. Pieces of the stem and roots (2 cm long) were surface sterilized using 1% sodium

hypochlorite for 20 minutes (Bertrand et al., 2000). Each medium was autoclaved at 15 psi for 15 minutes at 121 ^{o}C after which they were allowed to cool to about 50 ^{o}C and 50 mg L^{-1} of streptomycin sulphate in sterile distilled water was added to each of the media to minimize bacterial contamination. The fungal colonies were subcultured till pure cultures were obtained and identified using literature and microscopy. The fungal spores were counted using haemocytometry (Ndifon, 2019).

The *Meloidogyne incognita* (Kofold & White) Chitwood (race 1 is very common in the area), but the race was not determined as explained later. The nematode was obtained initially from *S. aethiopicum* roots (obtained from farmers' farms in Makurdi and the Research Farm). At the laboratory, the female nematode for each specific eggmass was identified by cutting the perennial pattern. Thereafter the egg masses were used to inoculate the sterilized soil in pots on which three-week-old *S. aethiopicum* seedlings were transplanted in the screenhouse. The *S. aethiopicum* plants were replaced when they stopped growing.

Estimating of the population of the nematodes in the soil before the experiments: The initial nematode population was estimated by collecting soil and plants from the inoculum that was being raised under an African garden egg (containing previously identified nematode specimens). These were taken to the laboratory for extraction using the modified Baermann tray method. All the galled roots were cut into tiny pieces (approximately 1 cm long). Any remaining egg masses in the soil that were dislodged from the female nematode were used as well to produce J2 larvae by allowing eggs to hatch for 6 days in Baerman trays.

This modified Baermann tray method for extraction of nematodes consisted of a coarse mesh sieve which was used to support the root/soil/eggmass sample when setting up the apparatus. On top of the sieve, a double layer 2-ply fine texture paper tissue was placed. The sieve was made to rest on top of a collecting tray and 200 cm^3 of finely crumbled soil (less than 8 mm particle size) or plant tissue was spread in the sieve setup. Tap water was gently added to the inside of the collecting tray until the soil layer was completely saturated.

The extracted nematodes were decanted after every 12 hours and the water in the collecting tray was topped up often to avoid desiccation until the 6th day after commencement of extraction. The nematodes being collected were stored at room temperature in shallow trays filled with water and stirred daily. The sieve was gently removed and the nematode suspension in the tray was poured into a tall 500 ml beaker. This was allowed to stand for four hours.

Then excess supernatant was gently decanted. The process ensured that the eggs were hatched and thus included in the count of the real population of nematodes applied during the study. The nematodes finally utilized for inoculation were referred to simply as nematodes. The final population (Pf) values consisted of the hatched J2 plus already present J2 plus any adult males present in the soil i.e. Pf = (J2 from egg masses + J2 juveniles already in plant/soil + adults in the soil if any) nematodes (Ndifon, 2019). The nematode larvae were counted by taking an aliquot and counting the larvae content of a counting dish under a stereomicroscope. Three counts were averaged to get the number of nematodes per litre of water.

2.2.2. Inoculation of the soil

Based on the field layout, the soil was inoculated at transplanting time using this *Meloidogyne* (Pf) extracted. After placing the seedling in the hole and the hole filled up with the soil scooped out of the hole, the required quantity of supernatant was poured using a pipette pump under the base of the plants in the plot at transplanting. Inoculation of the soil with *Fusarium* was carried out at transplanting time. The *Fusarium* inoculants were applied using sterile distilled water. The inoculum was obtained from 6 day-old-young culture by scooping the fungus mycelium off and smearing it to dislodge the spores then filtered through Whatmann No. 1 filter paper. Two shallow holes were made at the base of the transplanted seedling and the fungus inoculum was poured into the holes. The holes were then covered with the soil.

2.2.3. Experimental design

The research commenced with the sowing of the seeds on the 21st of June in both years. Transplanting of the seedlings was carried out on July 21st (28 days after sowing). The land was cleared, pegged and micro-plot beds were made manually. The seedlings were transplanted at a spacing of 25 cm intra-row in the centre of the micro-plot. The experiment was carried out using the microplot

technique (Ndifon, 2019). Each field microplot was 1.35 x 1.0 m^2. The inter-block furrow was 1.2 m wide and the spacing between treatments in a block was 0.45 m wide. The 4 x 4 factorial set of treatments used was arranged in a randomized complete block design and each treatment was replicated three times. The treatments consisted of four levels/population densities/population concentrations of *Fusarium* sp. (0, 1 x 10^4, 1 x 10^5, and 1 x 10^6 spores) and four levels/population densities/population concentrations of *Meloidogyne* sp. (0, 300, 600, and 900 nematodes) as shown in Table 1.

Table 1: The treatment set utilized for the experiment

Treatment	Description of the treatments
T1	Control (Meloidogyne 0* x Fusarium 0* spore)
T2	Meloidogyne 300 x Fusarium 0 spore
T3	Meloidogyne 600 x Fusarium 0 spore
T4	Meloidogyne 900 x Fusarium 0 spore
T5	Meloidogyne 0 x Fusarium 1x10^4 spores
T6	Meloidogyne 300 x Fusarium 1x10^4 spores
T7	Meloidogyne 600 x Fusarium 1x10^4 spores
T8	Meloidogyne 900 x Fusarium 1x10^4 spores
T9	Meloidogyne 0 x Fusarium 1x10^5 spores
T10	Meloidogyne 300 x Fusarium 1x10^5 spores
T11	Meloidogyne 600 x Fusarium 1x10^5 spores
T12	Meloidogyne 900 x Fusarium 1x10^5 spores
T13	Meloidogyne 0 x Fusarium 1x10^6 spores
T14	Meloidogyne 300 x Fusarium 1x10^6 spores
T15	Meloidogyne 600 x Fusarium 1x10^6 spores
T16	Meloidogyne 900 x Fusarium 1x10^6 spores

*The Figure behind *Meloidogyne* or *Fusarium* spp. refer to the population level/densities/population concentrations. In the text, references to *Fusarium* population densities are shortened by using only the exponent of the density without the 1x.

2.3. Data collection

Transplanting of the seedlings was carried out after four weeks (28 days) from germination. Five African garden egg seedlings were planted in each microplot along a row when the experiment was set up. The plants were cultivated for 75 days after inoculation/transplanting (DAT/DAS/DAI) before the termination of the experiment. The data that were collected included yield data (fruit weight and shoot weight) and disease data (root-gall index, number of nematodes per 500 cm^3 of soil, wilt discoloration index, disease incidence, and disease severity). Other plant growth data were presented elsewhere.

2.3.1.Disease incidence

This was calculated using Equation 1.

$$D.I = \{(\sum I_p)/\sum A_p\} \times 100\% \quad (1)$$

Where

D.I = Disease incidence
Ip = Number of infected plants (wilted, stunted, drooped leaves, epinastic leaves, chlorotic leaves, dead plants)
Ap = Number of assessed plants

Source: Ndifon (2019) as modified

2.3.2. Disease severity

Disease severity was obtained using Equation 2.

$$D.S = \{(\sum I_s)/3 \times \sum P_a\} \times 100\% \quad (2)$$

Where

D.S = Disease severity

3 = Highest severity score (Three (3) was the highest score on the individual disease severity scale below)
P_a = number of plants assessed
I_s = Individual disease severity scores (obtained using the modified individual disease severity scale below).
Source: Ndifon (2019) as modified

2.3.3. Modified individual disease severity scores

I_s as in equation 2
0 = No wilting at all, healthy plants
1 = Less than 1/3 of leaves wilted/dropped off
2 = More than 1/3 of leaves wilted/dropped off
3 = More than 2/3 of leaves wilted/dropped off or dead plants

2.3.4. Plant Vigour scale

Overall landscape performance scale
10 = Perfect foliage absolutely covered with blossoms/fruits, outstanding growth habit, flawless plants (very rare to attend).
9 = Very healthy foliage, an abundance of blossoms/fruits, and really nice growth habit.
8 = Healthy foliage with a significant number of blossoms/fruits, nice growth habit.
7 = Healthy foliage, only a few blossoms/fruits, nice growth habit.
6 = Healthy foliage, no blossoms/fruits, nice growth habit.
5 = 10% leaf drop, no blossoms/fruits
4 = 25% leaf drop, no blossoms/fruits
3 = 50% leaf drop, no blossoms/fruits
2 = 75% leaf drop, no blossoms/fruits
1 = 90% leaf drop, no blossoms/fruits
0 = Dead plants

Plus or minus a point

Use these adjustments with this National Earth-Kind Rose rating scale

- Good blossoms with fragrance = add 1 point
- If leaves intact but insect infected = minus 1 point
- If old sepals did not drop off = minus 0.5 point
- If poor growth habit overall = minus 1 point
- If significant chlorosis = minus 1 point
- If the disease in a replication = use zero in averaging e.g. (0+1+3)/3 = 4/3.

Scale as modified by Ndifon (2019) from National Earth-Kind Rose ratings (usually for use at blossom and fruiting stages of plant life)

2.3.5. Root knotting/root-gall index

Before putting the uprooted plants in polythene bags to take to the laboratory, nematode gall rating was carried out based on the following scale.

0 = Completely healthy root system, no infection.
1 = Very few small galls that can only be seen under close examination.
2 = Small galls as in "1" but more numerous and easy to detect.
3 = Numerous small galls, some galls coalesced, majority of roots still functioning.
4 = Numerous galls, a few big galls, root severely affected.
5 = 25% of root system severely galled.
6 = 50% of the root system severely galled.
7 = 75% of root system severely galled
8 = No healthy roots, plant still green.
9 = Completely galled, root system is rotting, dying.

10 = Plant and roots dead.
Sources: Ndifon (2019) as modified.

2.3.6. Fusarium vascular wilt discoloration rating

When plants were uprooted at the farms, the basal parts of the shoots were split longitudinally and discoloration of the vascular tissues was scored.

1 = No browning.
2 = Browning only around the base.
3 = Faint or patchy browning but limited below the first stem node.
4 = Strong browning but limited below the first stem node.
5 = Browning visible and extending above the first stem node.
6 = Browning extending above the first stem node and in up to half of the total number of nodes.
7 = Strong vascular browning in all but the uppermost internodes.
8 = Strong browning throughout the stem vascular tissue.
9 = Strong browning throughout the stem vascular tissue, branches wilted.
10 = Strong browning throughout the stem vascular tissue, dead plant.
Source: Ndifon (2019) as modified

2.3.7. Number of Meloidogyne sp. per 500 cm^3 of soil

Composite soil samples from the bases of the plants per plot were taken from the field to the laboratory and the nematodes were extracted at 75 days after inoculation (DAI) using the modified Baermann tray method.

2.3.8. Shoot and fruit weights

Shoot and fruit weights (g) per plant were taken at 75 DAI from three plants using an electronic balance and the mean weight was calculated.

2.4. Data analysis

Data were collected from the middle three plants per plot. The data collected were subjected to analysis of variance (ANOVA) using Genstat® statistical software (2nd edition, Discovery). Significant differences between means were separated using the new Duncan's multiple range test (DMRT) ($P \leq 0.05$).

3. Results

3.1. Determination of main effects of the population densities of these two pathogens using tests of between subjects effects in the 2014 cropping season

Tests of between subjects effects were used to determine the main effects of *Meloidogyne* sp. on vascular discoloration ($F(0.05) = 0.392$, $p = 0.759$) which was not significant though inoculation of soil with *Fusarium* sp. ($F(0.05) = 7.056$, $p = 0.00$) showed significant main effects of vascular discoloration. Analysis of incidence of wilt disease ($F(0.05) = 8.531$, $p = 0.00$), the severity of wilt disease ($F(0.05) = 3.969$, $p = 0.017$), root gall index ($F(0.05) = 36.081$, $p = 0.00$), and nematode count ($F(0.05) = 904.26$, $p = 0.000$) using tests of between subjects effects revealed the existence of significant main effects due to inoculation of soil with *Meloidogyne* sp. Analysis of the incidence of wilt disease ($F(0.05) = 5.990$, $p = 0.001$) and severity of wilt ($F(0.05) = 3.289$, $p = 0.023$) revealed that inoculation of soil with *Fusarium* sp. resulted in significant main effects.

Analysis of vigour ratings ($F(0.05) = 0.718$, $p = 0.549$) and fruit weights ($F(0.05) = 0.827$, $p = 0.489$) using tests of between-subjects effects revealed the existence of significant main effects due to inoculation of soil with *Meloidogyne* sp. Analysis of plant vigour ($F(0.05) = 1.168$, $p = 0.344$) and fruit weight ($F(0.05) = 0.680$, $p = 0.611$) revealed that inoculation of soil with *Fusarium* sp. resulted in significant main effects. Analysis of shoot weight revealed that inoculation of soil with *Meloidogyne* sp. ($F(0.05) = 0.177$, $p = 0.911$) and *Fusarium* sp. ($F(0.05) = 0.376$, $p = 0.824$) did not show significant main effects.

3.2. Determination of the main effects of these two pathogen species using tests of between subjects effects in the 2015 cropping season

Determination of the main effects using tests of between-subjects effects in 2015-cropping season revealed that incidence of wilt disease (F (0.05) = 2.313, p = 0.097), severity of wilt disease (F (0.05) = 4.369, p = 0.011), root gall index (F (0.05) = 10.109, p = 0.00), and nematode count (F (0.05) = 6.828, p = 0.001) showed the presence of significant main effects due to inoculation of the soil with *Meloidogyne* sp., while analysis of incidence of wilt disease (F (0.05) = 13.168, p = 0.000), severity of wilt disease (F (0.05) = 6.828, p = 0.001) using tests of between subjects effects revealed existence of significant main effects due to inoculation of the soil with *Fusarium* sp. Analysis of vascular discoloration scores showed that *Meloidogyne* sp. population densities had significant main effects (F (0.05) =2.665, p = 0.064), while *Fusarium* sp. population densities had significant main effects (F (0.05) = 37.896, p = 0.00).

Analysis of plant vigour ratings (F (0.05) = 3.274, p = 0.034), and fruit weight (F (0.05) = 0.936, p = 0.435) using tests of between subjects' effects revealed the existence of significant main effects due to inoculation of soil with *Meloidogyne* sp. While analysis of plant vigour (F (0.05) = 1.628, p = 0.202) revealed that *Fusarium* population densities had significant main effects but the fruit weight did not show significant main effects (F (0.05) = 0.137, p = 0.937) due to inoculation of the soil with *Fusarium* sp. Analysis of shoot weight revealed that *Meloidogyne* sp. population densities (F (0.05) = 0.097, p = 0.961) did not have significant main effects, but *Fusarium* sp. population densities (F (0.05) = 2.230, p = 0.104) had significant main effects.

3.3. Interaction of these two pathogen species at different population densities

3.3.1. Interaction of these two pathogen species at different population densities in 2014 cropping season

Interactions of different population densities of *Meloidogyne* sp. and *Fusarium* sp. on African garden egg in the 2014-cropping season are presented in Figure 1. There was a significant interaction between population densities of *Meloidogyne* sp. and those of *Fusarium* sp. as shown in the Figure for the incidence of wilting (F (0.05) = 1.178, p = 0.343), severity of wilt (F (0.05) = 2.966, p = 0.012), vascular discoloration (F (0.05) = 1.711, p = 0.129), root gall index (F (0.05) = 1.828, p = 0.104), and nematode count (F (0.05) = 2.166, p = 0.053). The type of interaction for all these parameters was cross-over interaction. For all the parameters assessed the interactions were such that when the pathogens were combined at lower population densities, lower parameter marginal mean scores were recorded while higher population densities led to higher parameter marginal mean scores compared to the lower population densities/combinations.

3.3.2. Interaction of these two pathogens at different population densities in 2015-cropping season

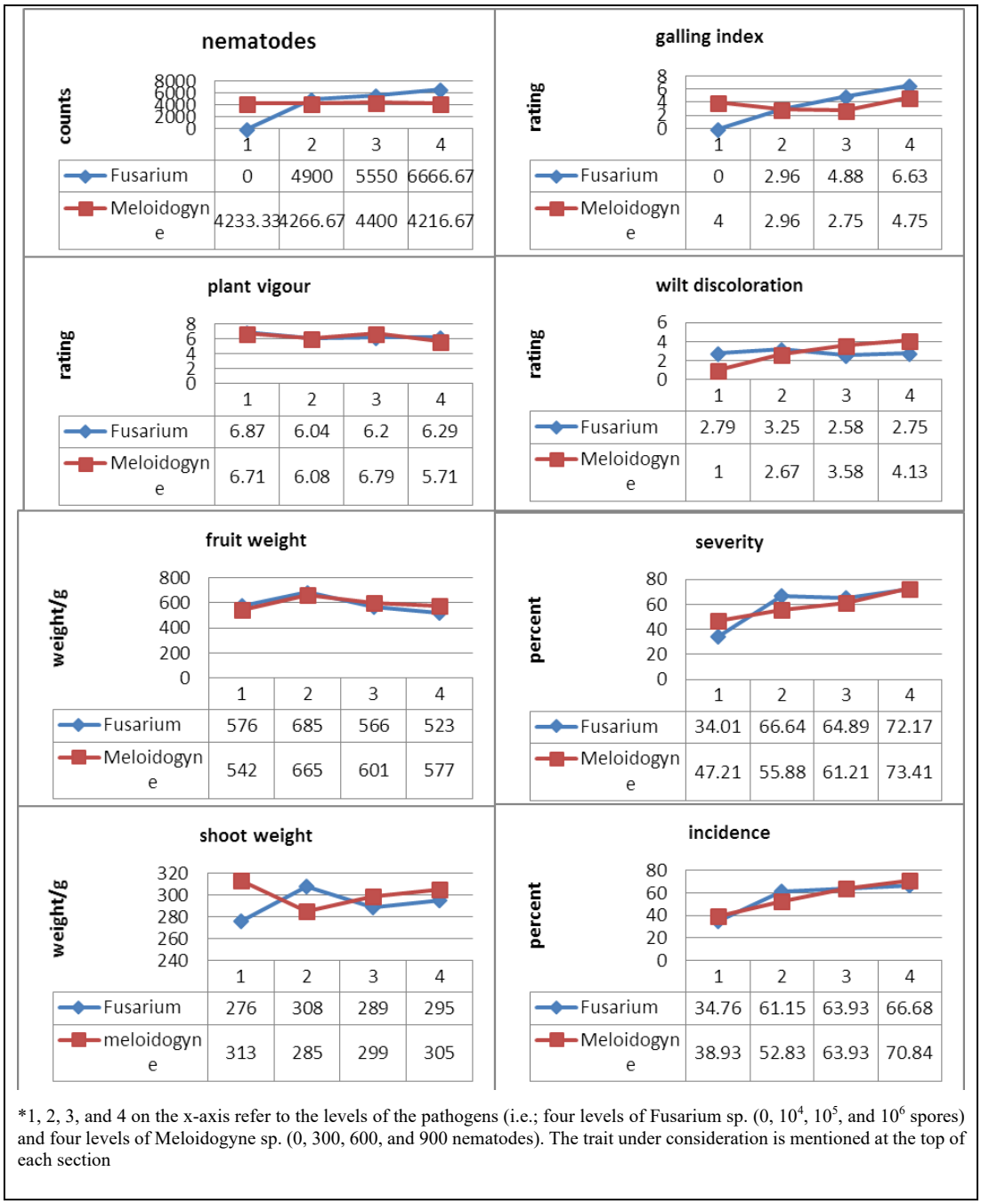
Interactions of different population densities of *Meloidogyne* and *Fusarium* spp. on African garden eggplant in the 2015-cropping season are presented in Figure 2. There was a significant interaction between population densities of *Meloidogyne* sp. and those of *Fusarium* sp. for incidence of wilting (F (0.05) =1.612, p = 0.158), vascular discoloration (F (0.05) = 0.772, p = 0.642), root gall index (F (0.05) = 1.652, p = 0.142), nematode count (F (0.05) = 2.853, p = 0.014), while for severity of wilt, the interaction was significant (F (0.05) = 1.342, p = 0.255).

There was a significant interaction between the population densities of *Meloidogyne* and those of *Fusarium* sp. for plant vigour (F (0.05) = 2.135, p = 0.056), fruit weight (F (0.05) = 0.705, p = 0.700), and shoot weight (F (0.05) = 1.091, p = 0.397). For growth parameters (plant vigour and shoot weight) the interactions were such that when the pathogens were combined at lower population densities, higher parameter marginal mean scores were recorded, while higher population densities led to lower growth parameter marginal mean scores.

The type of interaction for all these parameters was cross-over interaction. For disease parameters (incidence of wilting, vascular discoloration, root gall index, and nematode count) the interactions were such that when the pathogens were combined at lower population densities, lower parameter marginal mean scores were recorded, while higher population densities led to higher parameter marginal mean scores compared to the lower population densities.

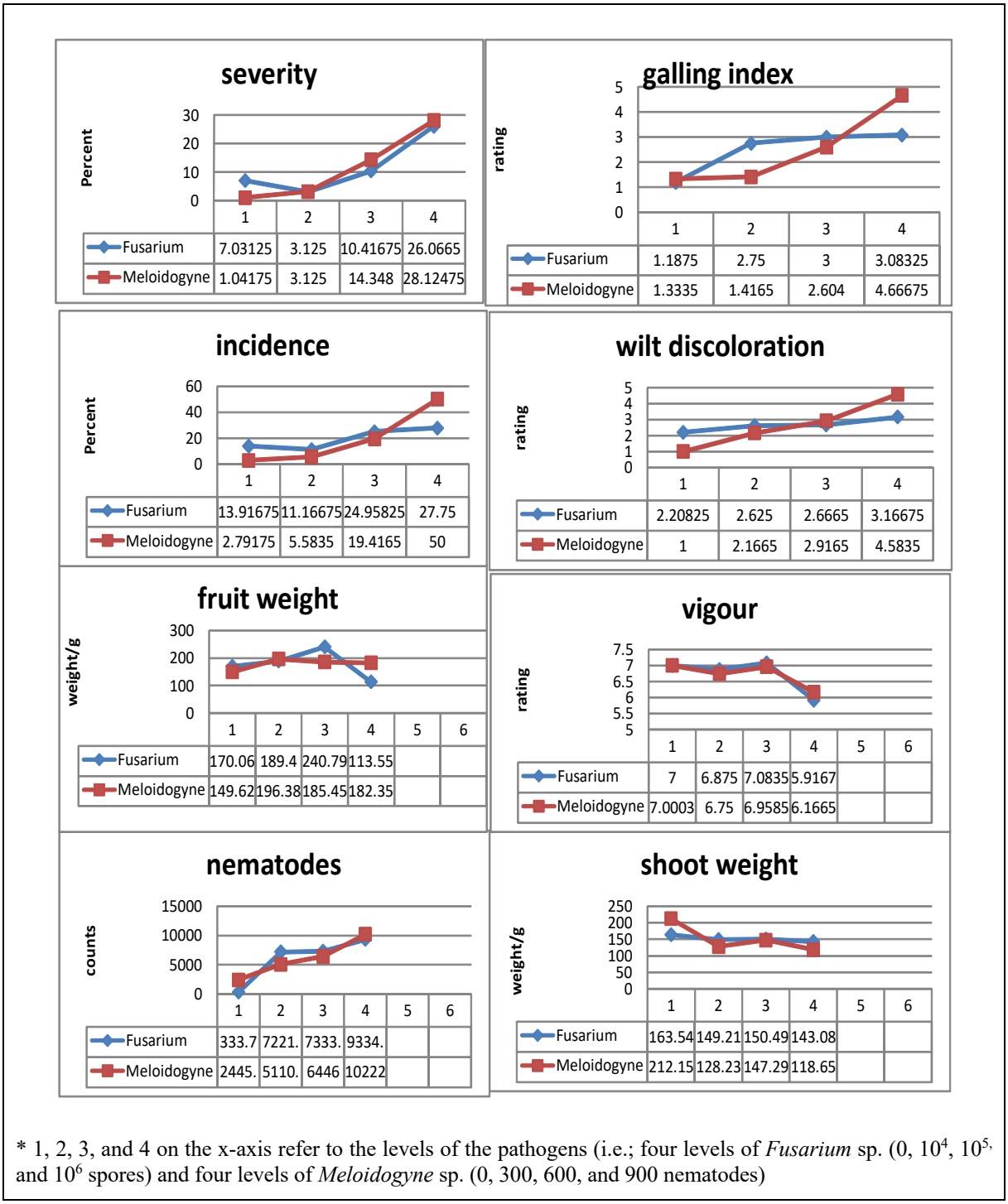
3.3.3. Correlation of disease parameters due to inoculation of soil with different population densities of these two pathogens during the two cropping seasons

The correlation of disease parameters due to inoculation of soil with different *Meloidogyne* sp. and *Fusarium* sp. concentrations in both cropping seasons are presented in Table 2 All the disease parameters (incidence of wilt, severity of wilt, vascular discoloration, root gall index, and nematode count) were positively correlated except root gall index in 2014 and 2015 (which was negatively correlated with vascular discoloration). All the parameters (vascular discoloration, root gall index, severity, and incidence of wilt disease) were positively correlated with 0.76, 0.03, 0.33, and 0.59 respectively in the first year and 0.02, 0.76, 0.33, and 0.57 respectively in the second year with nematode counts.



*1, 2, 3, and 4 on the x-axis refer to the levels of the pathogens (i.e.; four levels of Fusarium sp. (0, 10^4, 10^5, and 10^6 spores) and four levels of Meloidogyne sp. (0, 300, 600, and 900 nematodes). The trait under consideration is mentioned at the top of each section

Figure 1. Interaction of different population densities of *Meloidogyne* and *Fusarium* spp. on African garden egg at 75 DAS in 2014-cropping season.



* 1, 2, 3, and 4 on the x-axis refer to the levels of the pathogens (i.e.; four levels of *Fusarium* sp. (0, 10^4, 10^5, and 10^6 spores) and four levels of *Meloidogyne* sp. (0, 300, 600, and 900 nematodes)

Figure 2. Interaction of the different population densities of *Meloidogyne* sp. and *Fusarium* sp. on African garden egg at 75 DAS in the 2015-cropping season.

Table 2. Correlation of disease parameters due to inoculation of soil with different *Meloidogyne* and *Fusarium* spp. population densities in both cropping seasons

2014 cropping season at 75 DAS	Wilt incidence	Wilt severity	Root gall index	Wilt discoloration	Nematode count
Wilt incidence	1				
Wilt severity	0.32	1			
Root gall index	0.23	0.14	1		
Wilt discoloration	0.42	0.24	-0.01	1	
Nematode count	0.59	0.33	0.03	0.76	1
2015 cropping season at 75 DAS					
Wilt incidence	1				
Wilt severity	0.31*	1			
Root gall index	0.42**	0.24	1		
Wilt discoloration	0.25	0.13	-0.01	1	
Nematode count	0.57**	0.33*	0.76**	0.02	1

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

3.3.4. Interaction of the densities of these two pathogen species at 75 DAS in 2014

Interactions of varying population densities of *Fusarium* and *Meloidogyne* spp. inoculants on wilt disease, growth, and yield of African garden egg in the field during the 2014-cropping season are presented in Table 3. It was observed that infected treatments performed significantly worse than the uninfected control no matter the population density of *Meloidogyne* or *Fusarium* species based on the root gall index, incidence, and severity of wilt.

Vascular discoloration increased with population densities of *Meloidogyne* and *Fusarium* spp. thereby resulting in a higher level of discoloration which was directly proportional to the population density of the *Fusarium* sp. utilized. Vigour and fruit weight did not show clear trends in this study even though significant differences were observed between treatments. This observation was typical of wilt disease induced by *Fusarium* sp. which may result in sudden death of asymptomatic plants. Nematode count was higher in plots infected with *Meloidogyne* (900 nematodes) by *Fusarium* 10^4 spores, *Meloidogyne* 900 x *Fusarium* 10^5 spores, and *Meloidogyne* 900 *x Fusarium* 10^6 spores followed by treatments with *Meloidogyne* 600 nematodes at all levels of *Fusarium* sp. At *Fusarium* 0, 10^4, 10^5, and 10^6 spores, the severity of wilting was significantly higher in all infected plots compared to the control.

Incidence of African garden egg wilt was lowest in the control and was highest in *Meloidogyne* 900 nematodes x *Fusarium* 10^4 spores, *Meloidogyne* 300 x *Fusarium* 10^6 spores, *Meloidogyne* 600 x *Fusarium* 10^6 spores, and *Meloidogyne* 900 x *Fusarium* 10^6 spores. The severity of the wilt disease was significantly lowest in the control and nematode count was significantly higher in *Meloidogyne* 900 nematodes by *Fusarium* 0 spores.

The highest severity was recorded in *Meloidogyne* 900 nematodes x *Fusarium* 10^4 spores and *Meloidogyne* 300 x *Fusarium* 10^6 spores, although these were not significantly different from other infected treatments. Galling was significantly higher ($P \leq 0.05$) in plots infected with *Meloidogyne* 900 x *Fusarium* 10^6 spores compared with the other treatments except for *Meloidogyne* 600 x *Fusarium* 10^6 spores. The nematode count followed the same trend as the root gall index. The vascular discoloration was significantly ($P \leq 0.05$) lower in treatments without *Fusarium* sp. compared with the other treatments (except plots treated with *Meloidogyne* 900 x *Fusarium* 10^4 spores and in *Meloidogyne* 900 x *Fusarium* 10^6 spores).

Fruit weight was significantly ($P \leq 0.05$) lower in treatments infected with *Meloidogyne* 300 nematodes x *Fusarium* 10^4 spores compared with other treatments (except in *Meloidogyne* 900 x *Fusarium* 0 spore and *Meloidogyne* 300 x *Fusarium* 0 spore). Higher fruit weights were recorded in the control and treatments infected with *Meloidogyne* 600 x *Fusarium* 10^5 spores. The lowest plant vigour was recorded from *Meloidogyne* 300 nematodes x *Fusarium* 10^4 spores.

Table 3. Interaction of the varying population densities of *Fusarium* and *Meloidogyne* species inoculants on wilt disease and yield of African garden egg in the field during the 2014-cropping season

Treatment at 75 DAS	Disease severity (%)	Root galling index	Wilt discoloration	Nemato de count /500 cm^3	Plant vigour	Fruit weight (g)	Shoot weight (g)	Disease incidence (%)
Meloidogyne 0 nematode x *Fusarium 0* Spore (control)	0.0a	0.0a	1.0a	0.0a	8.2b	708ab	800	0.0d
Meloidogyne 300 x *Fusarium* 0 spore	65.9b	4.7bc	1.0a	4933bc	5.5ab	450a	338	44.5abc
Meloidogyne 600 x *Fusarium* 0 spore	70.1b	5.6bc	1.0a	5733def	6.8ab	692ab	327	44.5bc
Meloidogyne 900 x *Fusarium* 0 spore	62.5b	5.8bc	1.0a	6267fg	6.3ab	317a	296	66.7a
Meloidogyne 0 x *Fusarium* 10^4 spores	56.8b	0.0a	3.3bc	0.0a	6.8ab	583a	247	33.4c
Meloidogyne 300 x *Fusarium* 10^4 spores	78.4b	3.2b	4.3bc	4667b	6.0ab	1100b	354	55.6abc
Meloidogyne 600 *x Fusarium* 10^4 spores	74.3b	3.0b	2.0bc	5867ef	4.8a	343a	206	66.7ab
Meloidogyne 900 *x Fusarium* 10^4 spores	83.3b	5.7bc	1.0a	6533gh	6.7ab	683ab	333	55.6abc
Meloidogyne 0 x *Fusarium* 10^5 spores	65.9b	0.0a	4.7bc	5200bcd	7.2a	565a	275	66.7ab
Meloidogyne 300 *x Fusarium* 10^5 spores	79.2b	0.0a	2.3ab	0.0a	6.0ab	600ab	346	55.6abc
Meloidogyne 600 *x Fusarium* 10^5 spores	50.0b	4.7bc	4.0abc	5333cde	7.3ab	712ab	289	66.7ab
Meloidogyne 900 *x Fusarium* 10^5 spores	59.5b	6.3cd	3.3abc	7067h	6.7ab	527a	288	66.7ab
Meloidogyne 0 x *Fusarium* 10^6 spores	62.5b	0.0a	4.7bc	0.0a	6.2ab	592a	260	44.5bc
Meloidogyne 300 x *Fusarium* 10^6 spores	74.3b	4.0bc	3.0abc	4800bc	5.5ab	625ab	264	77.8a
Meloidogyne 600 x *Fusarium* 10^6 spores	65.2b	6.3cd	3.3abc	5267cd	5.8ab	517a	346	77.8a
Meloidogyne 900 x *Fusarium* 10^6 spores	83.3b	8.7d	5.7c	6800gh	5.5ab	567a	263	77.8a
SED	15.3	1.3	1.2	259	1.2	220	81	13.02

Means in the same column followed by the same letter(s) are statistically similar using DMRT (P≤0.05).

3.3.5. Interactions between population densities of these two pathogen species at 75 DAS in 2015

Interaction of varying population densities of *Fusarium* and *Meloidogyne* spp. inoculum on wilt disease, growth, and yield of African garden egg in Makurdi in the field during the 2015-cropping season are presented in Table 4. Incidence and severity of wilt disease increased with an increase in both *Meloidogyne* and *Fusarium* spp. population densities. Root gall index and nematode count increased with an increase in both *Meloidogyne* and *Fusarium* spp. population densities. Vascular wilt discoloration ratings were higher in the presence of *Fusarium* sp. and it increased with the population densities of both *Meloidogyne* and *Fusarium* spp.

When the plants were not infected with *Fusarium* (0 spores), root gall index, and nematode counts were significantly higher in infected treatments but when the plants were infected with *Fusarium* 10^4 spores, root gall index was significantly higher in *Meloidogyne* 600 nematodes by *Fusarium* 10^4 spores compared with the other treatments. Nematode count was significantly higher in *Meloidogyne* 300 by *Fusarium* 10^4 spores and *Meloidogyne* 900 nematodes by *Fusarium* 10^4 spores.

When the plants were infected with *Fusarium* 10^5 spores, the root gall index was significantly higher in all *Meloidogyne* infected treatments. When the plants were infected with *Fusarium* 10^5 spores, nematode count was significantly higher in *Meloidogyne* 600 by *Fusarium* 10^5 spores compared with other treatments. When the plants were infected with *Fusarium* 10^6 spores, root gall index, and nematode counts were significantly higher in *Meloidogyne* 300 x *Fusarium* 10^6 spores and *Meloidogyne* 900 nematodes x *Fusarium* 10^6 spores compared with the other treatments.

Root gall index was significantly higher in plots infected with *Meloidogyne* 900 nematodes by *Fusarium*10^6 spores, and *Meloidogyne* 300 by *Fusarium* 10^6 spores. Root gall index was lower in plots infected with *Meloidogyne* 900 by *Fusarium* 10^4 spores, *Meloidogyne* 300 by *Fusarium* 10^4 spores,

Meloidogyne 900 x *Fusarium* 0 spores, and *Meloidogyne* 600 x *Fusarium* 0 spores. Nematode count was higher in plots infected with *Meloidogyne* 900 by *Fusarium* 10^6 spores, and *Meloidogyne* 300 by *Fusarium* 10^6 spores. Nematode count was lower in plots infected with *Meloidogyne* 300 x *Fusarium* 0 spores.

Generally, the incidence of wilt was lowest in the control and in the treatments infected with *Meloidogyne* 600 nematodes x *Fusarium* 0 spore, *Meloidogyne* 900 x *Fusarium* 0 spore, and *Meloidogyne* 300 x *Fusarium* 10^4 spores. *Meloidogyne* 600 x *Fusarium* 10^4 spores, *Meloidogyne* 0 x *Fusarium* 10^4 and *Meloidogyne* 300 x *Fusarium* 10^5 spores. The highest incidence was recorded in *Meloidogyne* 600 x *Fusarium* 10^6 spores and this was not different from those of *Meloidogyne* 900 x *Fusarium* 10^6 spores, *Meloidogyne* 300 x *Fusarium* 10^6 spores, *Meloidogyne* 0 x *Fusarium* 10^6 spores and *Meloidogyne* 900 x *Fusarium* 10^5 spores.

The severity of wilt was significantly ($P \leq 0.05$) higher in treatments infected with *Meloidogyne* 900 x *Fusarium* 10^6 spores compared with the other treatment (except *Meloidogyne* 900 x *Fusarium* 10^5 spores). No wilt was observed in the control and plots treated with *Meloidogyne* 300 x *Fusarium* 0 spore, *Meloidogyne* 600 x *Fusarium* 0 spore, *Meloidogyne* 900 x *Fusarium* 0 spore, *Meloidogyne* 300 *Fusarium* 10^4 spores, and *Meloidogyne* 600 x *Fusarium* 10^4 spores. The vascular discoloration was lowest in the control and treatments without *Fusarium* (0 spore).

Furthermore, nematode count was significantly ($P \leq 0.05$) higher in treatments infected with *Meloidogyne* 900 x *Fusarium* 10^6 spores compared with the other treatments, except *Meloidogyne* 300 x *Fusarium* 10^6 spores and *Meloidogyne* 600 x *Fusarium* 10^5 spores. Root gall index was significantly lowest in *Meloidogyne* 0 x *Fusarium* 10^4 spores, *Meloidogyne* 0 x *Fusarium* 10^5 spores, *Meloidogyne* 300 x *Fusarium* 10^5 spores, and *Meloidogyne* 0 x *Fusarium* 10^6 spores, but it was significantly higher in all other treatments.

The vascular discoloration was significantly ($P \leq 0.05$) higher in *Meloidogyne* 900 nematodes x *Fusarium* 10^6 spores compared with the other treatments. Fruit weight was highest in treatments infected with *Meloidogyne* 900 x *Fusarium* 10^4 spores, but this was not different from those of control, *Meloidogyne* 900 x *Fusarium* 10^6 spores and *Meloidogyne* 600 x *Fusarium* 10^6 spores, *Meloidogyne* 600 x *Fusarium* 10^5 spores *Meloidogyne* 300 x *Fusarium* 10^5 spores and *Meloidogyne* 300 x *Fusarium* 0 spore. The lowest fruit weight was recorded in plots infected with *Meloidogyne* 900 nematodes x *Fusarium* 0 spore and *Meloidogyne* 900 x *Fusarium* 10^6 spores.

Table 4. Interaction of the varying population densities of *Fusarium* and *Meloidogyne* inoculum on wilt disease and yield of African garden egg in the field during the 2015-cropping season

Treatment at 75 DAS	Disease severity (%)	Root gall index	Wilt discoloration	Nematode counts /500 cm^3	Plant vigour	Fruit weight (g)	Shoot weight (g)	Disease incidence (%)
Meloidogyne 0 x *Fusarium 0* spore (control)	0.0a	0.0a	1.0a	0.0a	7.6b	177	218ab	0.0a
Meloidogyne 300 x *Fusarium* 0 spore	4.2a	2.0bcd	1.0a	888a	7.7b	254	210ab	11.7ab
Meloidogyne 600 x *Fusarium* 0 spore	0.0a	1.7bc	1.0a	3557ab	6.0ab	45	159ab	0.0a
Meloidogyne 900 x *Fusarium* 0 spore	0.0a	1.7bc	1.0a	5334ab	6.7b	120	259b	0.0a
Meloidogyne 0 x *Fusarium* 10^4 spores	4.2a	0.0a	1.3ab	0.0a	7.0b	157	133ab	11.2ab
Meloidogyne 300 x *Fusarium* 10^4 spores	0.0a	1.3ab	2.3abc	8886bcd	6.0ab	4	42a	0.0a
Meloidogyne 600 *x Fusarium* 10^4 spores	8.3ab	3.0cde	2.3abc	2666ab	8.0b	385	206ab	0.0a
Meloidogyne 900 *x Fusarium* 10^4 spores	0.0a	1.3ab	2.7bcd	8890bcd	6.0ab	147	130ab	11.2ab
Meloidogyne 0 x *Fusarium* 10^5 spores	0.0a	3.0cde	3.0cd	4448ab	7.0b	237	174ab	0.0a
Meloidogyne 300 *x Fusarium* 10^5 spores	4.2a	0.0a	2.0abc	0.0a	6.7b	114	224ab	0.0a
Meloidogyne 600 *x Fusarium* 10^5 spores	16.7ab	3.3def	3.3cde	13331cd	7.7b	247	116ab	33.3abc
Meloidogyne 900 *x Fusarium* 10^5 spores	37.bc	3.3def	3.3cde	71114abc	6.7b	118	84ab	44.3bc
Meloidogyne 0 x *Fusarium* 10^6 spores	20.ab	4.0ef	4.0de	0.0a	6.3b	192	92ab	44.5bc
Meloidogyne 300 x *Fusarium* 10^6 spores	8.3ab	4.7fg	4.7ef	1510d	7.3b	183	165ab	22.3abc
Meloidogyne 600 x *Fusarium* 10^6 spores	25.0ab	4.0ef	4.0de	9778bcd	6.7b	284	118ab	22.3abc
Meloidogyne 900 x *Fusarium* 10^6 spores	58.3c	6.0g	5.7f	15999d	4.3a	68	97ab	55.5c
SED	13.2	0.7	0.7	2860	0.9	112	62	15.7

Means in the same column followed by the same letter(s) are statistically similar using DMRT ($P \leq 0.05$).

4. Discussion

Zhang et al. (2020) stated that vital tripartite inter-kingdom interactions between plants, bacteria, nematodes, and fungi are very common in nature which corroborated the findings of this study. Indeed, chemical signals (such as volatile organic compounds) released by organisms such as bacteria, nematodes, fungi, or plants have been detected to initiate interactions between fungi and nematodes. Plant root metabolites affect communication between plants and nematodes. This was the basic premise of this study and it was proven to be true. The pathogens co-existed in the plant and successfully completed their life cycles.

The results showed the presence of significant main effects of inoculation of the soil with either *Fusarium* or *Meloidogyne* spp. (single pathogen infection/alone) in both the 2014- and the 2015-cropping seasons. This implies that each pathogen (*Fusarium* or *Meloidogyne* spp.) could cause significant wilt disease in African garden egg everything being equal, as has been variously reported in the literature (Safikhani et al., 2013; Ndifon et al*.,* 2015; Feyisa et al., 2016; USDA, 2016; Göze Özdemir et al., 2022).

The effects of the pathogens on the crop/wilt disease showed the existence of cross over interaction for all the parameters (disease incidence, severity of wilt, wilt vascular discoloration, root gall index, and final nematode population). The effects of different concentrations of *Meloidogyne* species were corroborated by the findings of Abbasi and Hisamuddin (2014) who reported that by inoculating *Vigna radiata* (L.) R. Wilczek (Fabales; Fabaceae) with different population densities of *M. incognita* in a green-house, the leguminous plant showed a progressive decrease in growth and biochemical parameters**.**

It was also shown in this study that *Meloidogyne* sp. was not just an incitant or wound inducing agent for enhancing infection by *Fusarium* sp. (Agbenin, 2005). It was observed that African garden eggplant experienced less combined infection of these pathogens during the survey by Ndifon et al. (2015). The presence of other nematodes was however encountered during the survey along with *Fusarium* species. The association of other pathogens with nematodes or fungi may cause severe damage to vegetable crops in Benue State as was confirmed in another survey by Eche et al. (2018).

The findings of Sulaiman et al. (2019) showed that all the *M. incognita* inoculum concentrations (500-8000 juveniles) reduced the level of eggplant growth for all growth parameters with a corresponding decrease in the yield of eggplant (*Solanum* spp.) They revealed that the lowest nematode population used (500 eggs/juveniles of *M. İncognita* per plot) was capable of significantly reducing yield of the eggplant variety used. These findings corroborated the findings of this current study. Moreover one can observe that the levels of nematode population used in this current study were above and below 500 nematodes per plot. Thus this current study added much to our knowledge of the effect of inoculum potential especially in situations of disease complex.

The interaction of the two pathogens showed that they had a synergistic effect on the damage caused to the crop. This implies that different levels/population densities of *Meloidogyne* sp. had significant effects on different levels of *Fusarium* sp. which resulted in significant damage to African garden egg in the field. This was affirmed by the correlation results herein. The correlation of disease parameters (disease incidence, disease severity, vascular discoloration, root-gall index, and nematode counts) revealed a positive correlation among the disease parameters. Concomitant infection by *Fusarium* sp. and *Meloidogyne* sp. on tomato, African garden egg, pepper, and *Solanum melongena* L. (Solanales; Solanaceae) has been reported (Mehrotra and Aggarwal, 2010) which corroborates this current finding on concomitant infection by *Fusarium* sp. and *Meloidogyne* sp.

It was reported that tomato plants wilted faster and even died when inoculated simultaneously with root-knot nematode species and *Fusarium oxysporum* (Agbenin, 2004). Zhang et al. (2020) purported that in farms, the fungal species composition can vary, depending on whether the fields are infested by root-knot nematodes or not. İn fact, *F. oxysporum* (11% frequency) followed by *F. solani* (6% frequency) were found to be the most frequent fungal species associated with the presence of *Meloidogyne* spp., and fungal diversity played an important role in the interactions between host plants and soil microorganisms. This finding affirmed the results of this current study that revealed the capacity of these pathogens to co-exist successfully.

Another instance of an increase in disease severity due to the contemporaneous occurrence of pathogens has been reported involving potato cyst nematode and *Verticillium dahliae* Kleb.

(Hypocreales; Incertae-sedis) on potato (Ndifon, 2019). Both of these pathogens caused only mild disease when each occurred alone. Their combined effects were mostly synergistic although additive damage did occur, which corroborated the current findings on cross-interactions.

İt was reported that *Heterodera schachtii* Schmidt (Tylinchida; Heteroderidae), and *Rhizoctonia solani* Kühn Cantharellales; Ceratobasidiaceae) synergistically parasitized sugar beet (Ndifon, 2019). *M. incognita*, and *Thielaviopsis basicola* (Berk. & Broome) Ferraris (*Microascales; Ceratocystidaceae*) in cotton also show synergistic interaction, which converts the pathogens into more important pathogens than when each occurs alone on cotton (Back et al*.,* 2002; Ndifon, 2019).

Asari et al*.* (2022) established that plant parasitic nematodes are capable of inducing disease in plants whether singly or in combination with other pathogens. However, they noted that the combined effects of such relationships result in a greater level of damage produced compared to a single infection of any of the pathogens. The results of this present study agreed with this statement. Zhang et al. (2020) reported that fungi-nematode interactions in the soil can involve endophytic fungi triggering host plant defense against plant pathogenic nematodes or the plants may help the nematodes to escape fungal attacks through the production of metabolite complexes. These situations may have occurred in this current study based on the significant differences obtained between treatments.

Herczeg et al*.* (2021) insisted that these fungi and nematodes provide essential ecosystem services and play crucial roles in maintaining the stability of food-webs and facilitating nutrient cycling in the ecosystem. Besides that, tomato plants that were resistant to *F. oxysporum* lost some of their resistance in the presence of *Meloidogyne* species (Ndifon, 2019). However, Agbenin (2002) reported that simultaneous inoculation of resistant tomato varieties with *Fusarium* and *Meloidogyne* species did not result in the breakdown of the resistance to the *Fusarium* wilt pathogen. But pre-inoculation of the soil with *Meloidogyne* before *Fusarium* resulted in breaching of the resistance of the wilt resistant tomatoes (varieties Walter F and Petomech). İn this current study, it was observed that the inoculation of the pathogens simultaneously did not have an apparanent negative effect.

In this current experiment, the inoculation of the pathogens was carried out simultaneously at transplanting time, but the effect of time of inoculation was not studied herein. It was observed that fruit weight was highest in the middle of the nematode initial population density range. Zhang et al*.* (2020) reiterated the existence of a nematode–fungi disease complex in plants, whereby damage by *F. oxysporum* f. sp. *vasinfectum* was more severe in the presence of *Meloidogyne* spp. *Meloidogyne* species and cyst nematodes have been shown to interact with *Fusarium* wilt thereby negatively impacting a number of crops.

Entomopathogenic nematodes and pathogenic fungi are capable of generating additive effects which increase insect pest mortality. Besides in the rhizosphere, nematode attacks can lower the resistance of plants to pathogens and increase their susceptibility to infection by soil-borne fungal pathogens. In these situations, the physiological status of all three interacting partners plays a very important role in the outcome of such tripartite interactions.

Odeyemi et al*.* (2010) expounded that reproduction and root galling of *M. incognita* were significantly lower in cowpea varieties treated with *Glomus mosseae.* In fact, *G. mosseae* alleviated the damage induced by the root-knot nematode on all the cowpea varieties. Freire (1982) reported that *M. incognita* did not predispose black pepper (*Piper nigrum*) to infection by *Nectria haematococca*. However, *Radopholus similis* predisposed black pepper seedlings to attack by a less virulent isolate of *F. solani*. Thus interkingdom interactions do not always result in negative effects.

Zhang et al*.* (2020) reported that the time of inoculation of the pathogens seems to have varied effects on the disease complex. This affirmed the decision to inoculate the two pathogens utilized in this research simultaneously. However, Herczeg et al*.* (2021) revealed that the order of succession of different parasites and the time lag between exposure appear in many cases to fundamentally shape competition and disease pathogenesis/progression. They argued that intermediate mortality is obtained when exposure to the two agents is sequential, regardless of which pathogen was added first. This confirmed the fact that the pathogens studied herein both successfully caused significant disease severity. They said that the outcome of co-infection with the two chytrids studied appeared to depend on the relative timing of the exposures and the dose of the zoospores. These interactions they reported may result in both synergistic or antagonistic effects.

Herczeg et al*.* (2021), Göze Özdemir et al. (2022), and Rijal (2022) pointed out that direct or indirect relationships may result in either antagonism, parasitism, mutualism, or commensalism.

Different soil temperatures, moisture contents, textures, plant ages, and NPK nutrients did not alter the relationships between fungi and nematodes (Freire, 1982). Curtis (2008) stated that plant root exudates contain a range of compounds that mediate below ground interactions with pathogenic and beneficial soil organisms. The effect of population density (inoculum potential) was studied in this present research and it was shown to be effective in contributing positively to the amount of damage on the crop. Much work still needs to be carried out on other factors that enhance disease establishment and damage.

It has been stated that the interaction between nematodes and host plants is influenced by primary factors like crop species and the initial population density of nematodes at sowing time (Agbenin, 2002). Moreover, Herczeg et al. (2021) confirmed that simultaneous exposure to viral and fungal parasites tends to cause higher mortality than a sequential encounter with the same agents or single infections. However, the species composition of parasites and interestingly the degree of relatedness between them may significantly influence interactions and ultimately disease outcomes (Göze Özdemir et al., 2022). This also corroborated the findings of this current study.

Moreover, some microbes in the environments (internal and external) can exert antagonistic effects on both nematode and fungal pathogens, while others can form mutualistic interactions with plant pathogens (Toju and Tanaka, 2019; Göze Özdemir et al., 2022). For instance, continuous sole cropping of soybeans was observed to be effective in altering the composition of both bacterial and fungal communities in the rhizosphere and negatively impacted the rhizosphere microbiome in its ability to suppress the soybean cyst nematodes (*Heterodera* sp.) (Hamid et al., 2017). This shows how diverse the relationships between organisms may be. The host-multipathogens relationships reported herein are thus only the peak of the iceberg. We can sum up these views by stating that based on the perspective of the hosts, the presence of co-infecting parasites can cause disease synergisms via enhanced virulence (Rigaud et al*.,* 2010), even if the interactions among parasites are antagonistic (Malapi-Nelson et al., 2009).

Before rounding up this discourse, Unl.edu (Accessed 13/5/2023) expounded that nematodes have been classified into four different phyla with different Phyla names. There are two contending names for the phylum of nematodes (i.e. Nematoda and Nemata). In 1919, Cobb placed nematodes in their own phylum (i.e. the phylum Nemata). However, when nematodes were moved to the phylum Aschelminthes, they were classified as class Nematoda. In 1932, the class Nematoda was elevated to the rank of a phylum (leaving the name Nematoda the same). While both names have been used (and are still used today), many authors believe that Nemata is a more precise name. In addition, the name Nemata was used first and therefore should be given priority.

Al-Banna and Gardner (2022) recently did some work on this revived name - Nemata. At the family and order levels. GBIF (2023) has a classification that is of interest: Phylum Nematoda, Order Rhabditida, Family Meloidogynidae, with a Genus *Meloidogyne*. Yet Gebissa (2021) and Myers et al. (2023) presented another classification as follows: Phylum Nematoda, Order Tylenchida, and Family Heteroderidae, with the same Genus *Meloidogyne*. This work is not a taxonomy study but this could arouse our interest in the classification of this important genus. Finally, the issue of race and formae speciales is one that was left out of this work due to limited resources and after consulting the work of Edel-Hermann and Lecomte (2019). Once the effects of epigenomics and environment are fully determined and the naming of races sorted out then it can be easy to determine which race one is dealing with. Our laboratory normally identifies organisms to species epithet only, while forma specialis are determined based on host type and elimination of other host types that are not affected by the species.

5. Conclusion

A trial on the effects of the initial population densities of *Fusarium* and *Meloidogyne* species revealed that the different combinations of the pathogens had detrimental effects on the African garden eggplant compared to the uninfected Control. The growth, yield, and disease parameters assessed in tandem all showed these effects. The pathogens seemed to complement each other and co-existed in the rhizosphere amicably. The pathogens multiplied in the host effectively to the tone of several times above the initial populations used to inoculate the soil in the field. Thus the reproductive indices were very high. Gall rating was average to moderately high. The disease severity ranged from average to very high depending on the treatment and this was reflected in the reduction of the vigour of the treatments. Therefore it is recommended that the cultivation of African garden egg be carried out on land free from

Fusarium and *Meloidogyne* species to avoid economic damage to the crop. Future research on these eggplant pathogens should concentrate on concurrent integrated management of *Fusarium* and *Meloidogyne* species so as to reduce yield loss. The effect of climatic and environmental factors on the host multipathogens relationships needs to be studied as well.

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