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Research Paper

Evaluation of oil palm *Elaeis guineensis* Jacq. progenies for *Fusarium* wilt tolerance using African countries *Fusarium oxysporium* f. sp. *elaeidis*

Chidi N. I.[1,2] • Adekunle A. A.[2] • Eziashi E. I.[1]* • Samuel T. O.[2]

[1]Nigerian Institute for Oil Palm Research (NIFOR), Plant Pathology Division, P.M.B. 1030, Benin City, Edo State, Nigeria.
[2]Department of Botany, University of Lagos, Yaba, Lagos State, Nigeria.

*Corresponding author. E-mail: eziashius@yahoo.com.

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Abstract. Evaluation of oil palm progenies for *Fusarium* wilt tolerance using West African *Fusarium oxysporium* f, sp. *elaedis* had been studied. The objective of the study was to determine the pathogenicity of *F. oxysporium* species on oil palm progenies. The results revealed that some *F. oxysporium* f. sp. *elaeidis* species were virulent to some oil palm progenies and not to few progeny seedlings. The highest mean of initial height was recorded by progeny 7 with 24.97 in *F. oxysporium* 1, while the least mean was 17.29 in *F. oxysporium* 13. The highest mean final height was recorded by progeny 5 with 78.67 in *F. oxysporium* 4, while the least mean final height was 36.78 also in *F. oxysporium* 4 by progeny 1. The highest mean initial height of control treatment was 20.35, while the least mean was 19.04. The highest mean final height of control treatment was 70.47 while the least mean was 63.56. The F – statistics of the initial and final heights indicated that all the progenies were significantly different from the control treatment. The initial height of different progenies showed that the seedlings had similar height measurements pre inoculation. However, the final height of different progenies showed that they all responded to fertilizer application, although there were variations in final height measurements at post inoculation when compared with the control treatment. After forty days of post inoculation, there were no visible external and internal symptoms on the seedlings. From fifty to Sixty days post inoculation; external symptoms of vascular disease began to appear. Post inoculation also shows high level aggressiveness of isolate 4 as well as the ability to colonize the roots and shoot of the seedlings. The seedlings infected with *F. oxysporium* f. sp. *elaeidis* showed yellowish colour, stunted growth, loss of vigour, chlorosis and necrosis. Bole discoloration was seen in the internal tissue, as a clear symptom and indication of Fusarium wilt disease. The control treatment seedlings distinguished itself with normal height and creamy bole colour when compared with the infected seedlings. The ability of *Fusarium* species to cause infection indicates virulence, while different progenies showed different degrees of susceptibility and tolerance. *F. oxysporium* 4 exhibited high virulence when compared with other *Fusarium* species.

Keywords: *Fusarium*, pathogenicity, progenies, oil palm, symptom.

INTRODUCTION

Oil palm (*Elaeis guineensis*) is native to West Africa, including Nigeria. It produces the world's largest and most consumed vegetable oil. The oil palm contributes 72% of the nation's vegetable oil production estimated at one million metric tons, and is therefore significant in growing the vegetable oil industry in Nigeria. Presently, Nigeria produces 1.3 million metric tons of vegetable oil as against the national demand of 1.6 million metric tons. The deficit of 0.3 million metric tons is met through import. The oil palm is the most productive oil crop in the world with yields per hectare about nine times that of soybean and six times that of sunflower oil (Basiron, 2007; de Vries *et al*., 2010).

World demand for fats and oils is continuously increasing, thereby enhancing the need to extend the areas planted with oil crops which is the highest oil yielding crop in the world (Rival and Levang, 2014).

Fusarium wilt or vascular wilt is presently the most serious disease of the oil palm in West and Central Africa. The disease which attacks oil palm seedlings in the nursery as well as young and adult palms in plantations and in the groves is caused by the soil-borne fungus, *Fusarium oxysporum* f. sp. *elaeidis* (Fraselle, 1951; Aderungboye, 1976).

The external symptoms of the disease in the adult palms include stunted growth, yellowing of the leaves, desiccation and fracture of the fronds, followed by death of the palms within 6 months (acute type) or a few years (chronic type).The internal symptoms include blackening and necrosis of the cortex and plugging of the vascular system. In the nursery seedlings, the symptoms commence with stunted growth, followed by yellowing of leaves, desiccation and death.

In Nigeria, the disease has been reported to have destroyed up to 47% of the field palms in Imo state (Oritsejafor, 1989) and yield reductions of up to 50% as a result of the disease. It had also been reported (Renard *et al*., 1993).

In Ghana, the incidence of the disease at the plantations of the oil palm research institute, Kusi and the Benso Oil palm plantation is less than 1%. Whereas at the Plantation of the Ghana Oil palm development company (GOPDC) the incidence of the disease is about 12% (Dakwa and Afrim, 1995).

In Cameroon, *Fusarium* wilt is responsible for 42% of vacancies in oil palm plantations (Tengoua and Bakoumé, 2008). However, the disease was known to have been aggregated in the South West region of Cameroon (Tengoua, 1994), but now has been identified in both the Northern and central regions of Cameroon (Tenguoa, 2003).

Recent effort by Nigeria Ministry of Agriculture in turning the industry under agriculture transformation agenda (ATA) is geared towards increasing productivity of both organized and unorganized farmers. Susceptible oil palm planting materials to *Fusarium* wilt disease will put the ATA program in a serious jeopardy, hence the importance of this study. The objective of the study was to determine the pathogenicity of *F. oxysporium* species on oil palm progenies.

MATERIALS AND METHODS

Disease survey and samples collection

The survey was carried out in three West African countries, namely Nigeria, Ghana and Cameroon to determine where the disease is really prevalent and severe. Geographical Positioning Systems (GPS) co-ordinates were used to collect samples from these three West African countries. In Nigeria, two field numbers: 25 and 54 characterized by a climate tropical rain forest contain susceptible and tolerant oil palm progenies of 40 hectares each in the Nigerian Institute for Oil Palm Research (NIFOR), Benin City.

In Ghana, samples were collected from Oil Palm Research Institute (OPRI), Kusi, Benso Oil Palm Plantation (BOPP) and Ghana Oil Palm Development Company (GOPDC); and also in Cameroon a grove with an area of 16.86 hectares belonging to the Institute of Agricultural Research for Development (IRAD) Ekona (South West Region) and Cameroon Development Company (CDC) both of South-West region were also explored.

Vegetative material

The vegetative materials studied were oil palms showing chronic symptoms of vascular wilt disease at the Nigerian Institute for Oil Palm Research (NIFOR); Ghana Oil Palm Development Company (GOPDC) in Ghana; Benso Oil Palm Plantation (BOPP) in Ghana; Oil Palm Research Institute (OPRI) Kusi, also in Ghana, and the Institute for Agricultural Research and Development (IRAD) and Cameroon Development Company (CDC) also in Cameroon.

Isolation of *Fusarium oxysporum* f. sp. *elaeidis*

Four *F. oxysporum* f. sp. *elaeidis* species and other pathogens were isolated from the vascular bundles, petioles and soil samples of adult oil palms showing chronic vascular wilt symptoms from different locations in Nigeria, Ghana and Cameroon using geographic position system (GPS). Vascular bundles and petioles of chronic vascular infected oil palms were cut into smaller bits using a sterile knife to expose the infected internal portions. They were aseptically extracted using a flamed sterile scalpel, and plated on already prepared mycelium medium (MM) that have been cooled with added streptomycin antibiotic; incubated at a room temperature of 26 to 29°C. Root samples were also plated out, cut portions of the roots were surface sterilized with 1% sodium hypochlorite mixture. Plated vascular bundles were not surface sterilized because they were cut deep into the tissues that are assumed to be free from secondary pathogens. Also 1 g of the soil samples were weighed and transferred to McCartney bottles containing 9 ml sterile water. The bottles were shook using an orbit shaker for 15 min. 1 ml of the solution was obtained and transferred to a waiting 9.0ml of sterilized distilled water.

They were serially diluted from 10^{-1} to 10^{-5}**.** Using a sterile syringe, 1ml each of the serially diluted samples were released into sterile Petri dish, then 9 ml of 45°C cooled mycelium medium was poured into the dishes and swirled. The plates were incubated at ambient temperature for 48 h. The emerging four *Fusarium* colonies were sub cultured aseptically into solidified PDA plates until pure cultures were obtained.

Preparation of conidial suspensions

Preparations of conidia suspensions were done by cutting 3 mm potions of the already grown *F. oxysporum* f. sp. *elaeidis* species in Petri dishes. The portions were inoculated into 250 ml conical flasks containing sterilized 50 ml of Armstrong medium. At each preparation, four flasks were inoculated for each isolate of *F. oxysporum* f. sp, *elaeidis* and incubated for 10 days at room temperature (26 to 28°C). At the end of the incubation period, contents in the flasks were poured out into a warren blender and macerated. The macerated mixture of each isolate was then filtered through muslin cloth. The supernatants were decanted and the suspensions were made up with sterile water to the required spore concentrations.

Determination of spore count

A drop of the inoculum of was pipetted on a haemocytometer and covered with a cover slip. Using a phase contrast illumination microscope, the spores were counted with a 10x ocular and 4 mm objective and this was done for at least 20 squares. The average number per square was determined. Three counts of diluted spore suspension were made, and their average was taken. The number per millilitre of the original spore suspension (undiluted) was calculated as follows:

(Average No. per square) × y × 4,000,000
(Odigie, 1994).

Collection of oil palm germinating seeds

The germinating seeds used in this investigation were raised from germinated susceptible and tolerant progenies produced at the Nigerian Institute for Oil palm Research (NIFOR), near Benin City. The seeds were sprouted by dry heat treatment method.

Experimental design

A total of 1,232 oil palm seedlings were used. Seven progenies were used. Each progeny had 14 seedlings per plot. There are 10 plots and 1 control plot per block (14×11×8). The control treatment had the combination of 2 seedlings from each progeny of 7, making up 14 progenies per plot in a block. The seedlings were randomized and the experiment was repeated twice.

Pathogenicity of *F. oxysporum* f. sp. *elaeidis* species on oil palm progenies

The conidia suspension of *F. oxysporum* f. sp. *elaeidis* species from different West African countries were inoculated on two months old oil palm seedlings for pathogenicity (Figure 3). The pathogenicity tests were carried out by inoculating the roots of both susceptible and tolerant oil palm progenies grown in black polythene bags with conidia suspension. The roots were exposed by removing layers of soil covering the root system. Conidia suspensions of 10^6 spores/ml were then dispensed into the root system and the soils were used to cover up the exposed roots. In the control experiments, sterile distilled water was used instead of spore suspension. After one month of inoculation, fertilizer of NPG 15: 15: 20 was applied to the inoculated seedlings. After eight months of post inoculation, seedlings were analyzed for external symptoms. Final height measurement of seedlings were taken and harvested for observation of leaf change in colour and deformation, internal bole, root color and infection.

Statistical analysis

Univariate Analysis of variance with LSD was used to analyze the data for morphological parameters using SPSS version 17 for Windows. The significantly different means were separated by the least significant difference calculated at the 95% Confidence Interval for Difference. Bar charts were used to compare the effect of the different *F. oxysporum* f. sp. *elaeidis* species on growth rate of the different oil palm progenies.

RESULTS

Survey was carried out in Nigeria, Ghana and Cameroon, a total of about 20 oil palm trees infected with *Fusarium* wilt disease showing different chronic symptoms were felled (Figure 1A to D) with chronic symptoms of *Fusarium* wilt disease having wilting leaves, cracking of the trunk and terminal point trunk at the apex. Vegetative samples were also collected (Figure 2E, F and G)

Geographical Position System (GPS) coordinates of the samples were collected and recorded in Tables 1 to 4 for both the susceptible and tolerant oil palm progenies in fields 25, 54. Ekona, Powo and Cameroon development Company where oil palm were collected, were infected with *Fusarium* wilt disease were collected.

Four species of *F. oxysporum* f. sp. *elaeidis* (Herbarium

Figure 1. A: Shows an oil palm with chronic symptoms of vascular wilt disease having wilting. B: shows an oil palm with chronic symptoms of vascular wilt disease exhibiting cracking of the trunk. C. Shows an oil palm with chronic symptoms of vascular wilt disease having hallow in vascular bundles. D: Shows an oil palm with chronic symptoms of vascular wilt disease having terminal point trunk at the apex. E: Shows infected vegetative parts of oil palm by *Fusarium oxysporum* f. sp. *elaeidis.* F: Shows infected petiole of oil palm with chronic vascular wilt symptom. G: Shows the cut transverse section of vascular bundle of an infected oil palm with vascular wilt disease.

IMI No.KP942906.1, species (1) from Cameroon); *F. oxysporum* f. sp. *elaeidis* (Herbarium IMI No.AY928419.1, species (4) from Cameroon); *F. oxysporum* f. sp. *elaeidis* (Herbarium IMI No.KR094464.1, species (CRT) from Ghana) and *F. oxysporum* f. sp. *elaeidis* (Herbarium IMI No.JF807394.1, species (13) from Nigeria) were isolated and selected for use throughout these studies. Different strains of *F. oxysporum* f. sp. *elaeidis* were also isolated from different parts of the oil palm (base, mid and apex).

The results of the pathogenicity tests of *F. oxysporum* f. sp. *elaeidis* species for initial and final heights of the seedlings are shown in Tables 5 and 6. Some *F. oxysporum* f. sp. *elaeidis* species were virulent to some oil palm progenies and not to few progeny seedlings. The highest mean of initial height was recorded by progeny 7 with 24.97 in *F. oxysporium* 1, while the least mean was 17.29 in *F. oxysporium* 13 (Table 5). The highest mean final height was recorded by progeny 5 with 78.67 in *F. oxysporium* 4 while the least mean final height was 36.78 also in *F. oxysporium* 4 by progeny 1 (Table 6 and Figure 3). The highest mean initial height of control treatment was 20.35 while the least mean was 19.04. The highest mean final height of control treatment was 70.47 while the least mean was 63.56. The F – statistics of the initial and final heights indicated that all the progenies were significantly different from the control treatment.

The initial height of different progenies showed that the seedlings had similar height measurement pre inoculation. However, the final height of different progenies showed that they all responded to fertilizer application; although there were variations in final height measurements at post inoculation of different species of *F. oxysporum* f. sp. *elaeidis* when compared with the control treatment.

After forty days of post inoculation of *F. oxysporium* f. sp. *elaedis*, there were no visible external and internal symptoms on the seedlings. From fifty to Sixty days post inoculation; external symptoms of vascular disease began to appear (Figure 2B, D, F). Post inoculation also shows high level aggressiveness of isolate 4 as well as the ability to colonize the roots and shoot of the seedlings. The infected seedlings showed yellowish colour, stunted growth and loss of vigour with chlorosis and necrosis (Figure 2B). Bole discoloration was seen in the internal tissue, as a clear symptom and indication of Fusarium wilt disease and symptom (Figure 2D, F). The control treatment seedlings distinguished itself with normal height and creamy bole colour (2A, C, E) when compared with the infected seedlings showing stunted growth and brownish discolouration (Figure 2G). The ability of *Fusarium* species to cause infection indicates virulence, while different progenies showed different degrees of susceptibility and tolerance.

DISCUSSION

Initial heights of different oil palm progenies were significantly different from each other in different blocks of the experiment. This could be attributed to difference in vegetative cells and gens. Similar studies by Godswill *et al*. (2015) stated that the morphological parameters of oil palm seedlings in the nursery showed significant differences in morphological parameters.

Figure 2. (A, C, E): Control treatment of healthy oil palm seedlings with normal height and creamy bole colour sixty days post inoculation with sterile distilled water. B, D, E. Arrow heads show infected oil palm seedlings, external and internal symptoms of vascular wilt began to appear with stunted growth and brownish bole discolouration sixty days post inoculation. G. The control treatment seedlings distinguished itself with normal height and creamy bole colour when compared with the infected seedlings showing stunted growth and brownish bole discolouration.

The variance in height of the progenies showed the effect of *F. oxysporum* f. sp. *elaeidis* on the progenies. This was supported by the work of Hefny *et al*. (2012) which stated that *Fusarium* infection generally cause a decrease in plant height. Also the report of Tagoe (1995) supported this further by stating that in other progenies, seedlings inoculated with P.38 were therefore reduced in height by the twelfth week and those inoculated with P.50 for all the progenies except G51 grew steadily to the twelfth week almost competing with the control plant.

F. oxysporum f. sp. *elaeidis* from Cameroon and Ghana were pathogenic. They caused susceptibility and wilting of oil palm seedlings. This was supported by the report of Hefny *et al*. (2012), which stipulates that the *F. oxysporum* f. sp. *elaeidis* from Ghana were isolated from chronic, acute and symptomless palms.

The *Fusarium* species showed different levels of aggressiveness and pathogenicity. The highest mean final height was recorded by progeny 5 with 78.67 in *F. oxysporium* 4 while the least mean final height was 36.78 also in *F. oxysporium* 4 by progeny 1. This was supported with the works of Göksel and Bayraktar, 2015 which stated that isolates showed significant variability in their aggressiveness, ranging from 54.2 to 100%. To

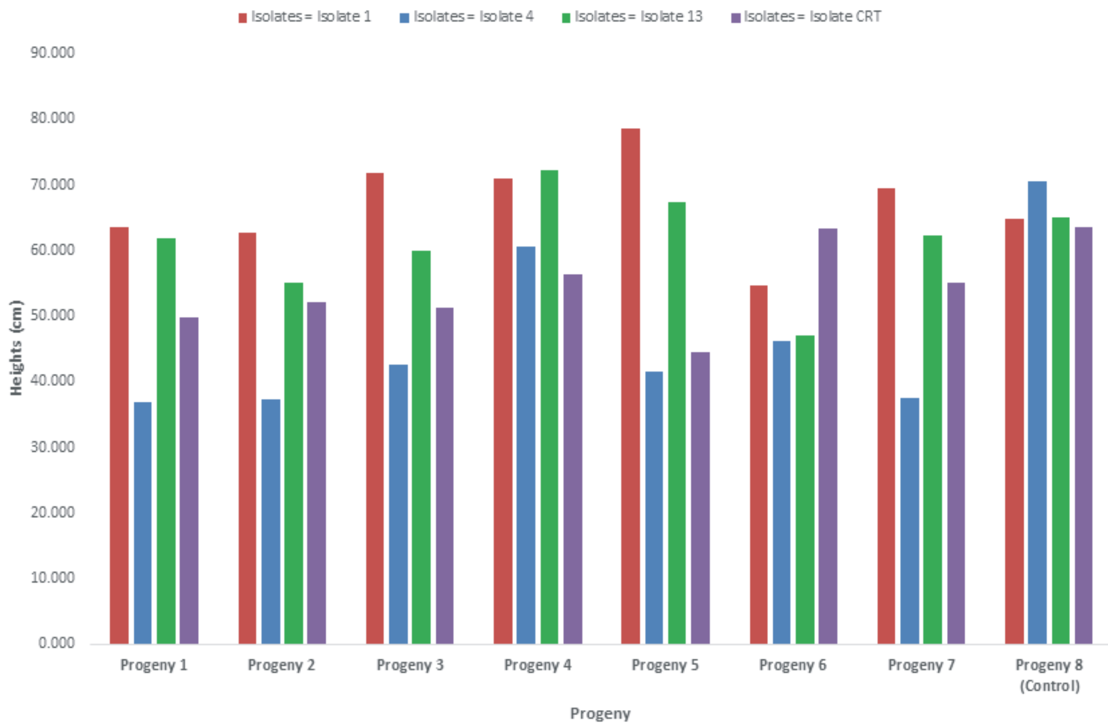

Figure 3. Final heights (cm) of progenies in all species of *Fusarium oxysporum* f. sp. *elaeidis. Plate 8A: Shows the devastating effects of Fusarium oxysporum f. sp. elaeidis (4) on both the seedling height and the florals (right) as compared to the control (left) with no symptoms; Plate 8B-C: Shows arrows pointing bole discolorations in the oil palm seedling (down) as compared to the control which showed no symptoms (up)*

Table 1. Geographical positioning system (GPS) of coordinates of susceptible oil palm progenies from NIFOR field 25.

Progeny number	Palm number	Coordinates		Elevation (m)	Location/ field number
		N	E		
1	120	6.54° N	5.60° E	132	25
8	2211	6.54° N	5.611° E	138	25
8	2228	6.544312° N	5.611471° E	144	25
15	2478	6.544366° N	5.611497° E	135	25
18	2601	6.544520° N	5.611765° E	135	25
10	2990	6.543653° N	5.612354° E	132	25
4	3023	6.541001° N	5.612368° E	130	25
4	3263	6.543432° N	5.612853° E	134	25
3	3456	6.541616° N	5.612618° E	137	25
11	4189	6.542498° N	5.613671° E	146	25

support this study further, the report of Mehta *et al*. (2012) which revealed that Pathogenicity tests using *Fusarium* wilt isolates from different countries revealed aggressiveness variation among the pathogen isolates.

The case of some species of *F. oxysporum* f. sp. *elaeidis* being virulent to one oil palm progeny and not to another progeny seedling brings some concern that an isolate that proves virulent in one country may not be virulent in another country. This was supported with the work of Teguoa and Bakome (20008) which stated that a study undertaken in Cameroon revealed variability in the virulence of *F. oxysporum* f. sp. *elaeidis* strains from different sources.

SisǏić *et al*. (2018) stated that aggressiveness among isolates of both species is highly variable however the interaction between the seedlings of same progenies with the isolate were not significantly different.

In this study different strains of *F. oxysporum* f. sp. *elaeidis* were isolated from different parts of the oil palm (base, mid and apex). This was supported by the work of Teguoa and Bakome (2008) which stated that strains found to be pathogenic to oil palm and the non-pathogenic

Table 2. Geographical positioning system (GPS) of coordinates of tolerant oil palm progenies from NIFOR field 54.

Progeny number	Palm number	Coordinates		Elevation (m)	Location/field number
		N	E		
1	120	6.5546° N	5.6222° E	163	54
2	368	6.5544° N	5.6219° E	170	54
3	735	6.5540° N	5.6215° E	169	54
4	856	6.5537° N	5.6213° E	169	54
5	1126	6.5540° N	5.6210° E	167	54
6	1345	6.5532° N	5.6208° E	167	54
8	1621	6.5541° N	5.6204° E	162	54
9	1713	6.5529° N	5.6203° E	168	54
10	1723	6.5537° N	5.6203° E	150	54

Table 3. Geographical positioning systems of coordinates of oil palm field of Cameroon Development Company (CDC), Powo and Matango locations in Cameroon.

No.	Block/ year of plantation/ location	Variety	Geographical co-ordinates (Degrees)		Elevation (m)
			Latitude	Longitude	
1	30/ 1970/Powo11		9.348170°N	4.249434°E	292
2	30/ 1970/Powo11		9.348290°N	4.249422°E	298
3	29/ 1970/Powo11		9.347705°N	4.248452°E	310
4	29/ 1970/Powo11		9.348082°N	4.248257°E	308
5	29 /1969/Matango11	Tenera	9.325495°N	4.236812°E	404
6	14/ 1969/Matango11		9.325574°N	4.236949°E	399
7	14/ 1969/Matango11		9.325911°N	4.236981°E	406
8	14/ 1969/Matango11		9.326519°N	4.236634°E	406
9	131 / 1969/Matango11		9.326619°N	4.236649°E	395

Table 4. Continuation of geographical positioning systems of coordinates of oil palm field of Cameroon Development Company (CDC), Powo and Matango locations.

No.	Block/ year of plantation/location	Variety	Geographical co-ordinates (degrees)		Elevation (m)
			Latitude	Longitude	
1	32/ 1970/Powo11		9.351790°N	4.249453°E	307
2	7/ 2013/Powo11		9.351234°N	4.248816°E	285
3	32/ 1970/powo11		9.349533°N	4.249844°E	295
4	32/ 1970/powo11		9.349418°N	4.249747°E	291
5	32 /1970/Powo11		9.349440°N	4.249769°E	280
6	32/ 1970/Powo11		9.349229°N	4.249876°E	259
7	32/ 1970/Powo11		9.34865°N	4.249362°E	286

were collected at the top of the trunk of vascular wilt of infected palms

The intensity and sustenance of the disease by some of the *F. oxysporum* f. sp. *elaeidis* species post inoculation depends on the level of aggressiveness of the isolates as well as the ability to colonize the host plants defense system. This task was supported with the work of Hefny *et al*. (2012).

The ability of *Fusarium* species to cause infection indicates virulence, while the different progenies showed different degrees of susceptibility. This is in line with the study Rusli *et al*. (2015) which stated that two palm lines (PK 5463 and PK 5493) showed apparent differential responses to the two *F. oxysporum* f. sp. *elaeidis* isolates.

The *F. oxysporum* f. sp. *elaeidis* species from Nigeria showed little effect on progenies from Nigeria when compared with isolates from Ghana and Cameroon; however, species from Cameroon did not equally cause effect on all the progenies of oil palm seedlings. This report is in line with the report of Rusli *et al*. (2015) which stated that Malaysian *F. oxysporum* f. sp. *elaeidis*

Table 5. Mean ± SE of Initial height for each progeny for all species of *Fusarium oxysporum* f. sp. *elaeidis*

Initial height (cm)	***Fusarium oxysporum* f. sp. *elaeidis* (1)2**	***Fusarium oxysporum* f. sp. *elaeidis* (4)2**	***Fusarium oxysporum* f. sp. *elaeidis*(13)1**	***Fusarium oxysporum* f. sp. *elaeidis* (CRT)1**
Progeny	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Progeny 1	22.21 + 2.43^{bc}	21.93 + 2.95^{bc}	21.93 + 2.95b^{c}	18.17 + 2.74^{a}
Progeny 2	21.12 + 2.06^{ab}	20.74 + 2.67^{b}	17.29 + 2.04^{a}	18.94 + 2.73^{ab}
Progeny 3	23.1 + 2.00^{c}	22.85 + 3.75^{cd}	18.35 + 3.09^{a}	19.77 + 3.11^{b}
Progeny 4	22.19 + 2.67^{bc}	23.87 + 2.79^{d}	21.72 + 3.10^{b}	21.93 + 2.8^{c}
Progeny 5	22.3 + 2.86^{bc}	23.07 + 2.79^{cd}	20.47 + 3.02^{b}	19.51 + 3.25^{ab}
Progeny 6	22.52 + 2.32^{bc}	19.07 + 2.73^{a}	24.60 + 3.06^{c}	22.69 + 2.21^{c}
Progeny 7	24.97 + 2.06^{d}	20.86 + 2.66^{b}	23.51 + 2.66^{c}	24.32 + 1.77^{d}
Progeny 8 (Control)	20.35 + 4.71^{a}	21.96 + 2.99bc	20.12 + 30^{b}	19.04 + 3.09^{ab}
F-Statistics	F7,221 = 6.774; p < 0.001	F7,221 = 7.696; p < 0.001	F7,221 = 19.812; p < 0.001	F7,221 = 19.370; p < 0.001

NB: Progenies with the same superscript are not significant different with each other at 5% level.

Table 6. Mean ± SE of Final height for each progeny for all species of *Fusarium oxysporum* f. sp. *elaeidis.*

Final height (cm)	***Fusarium oxysporum* f. sp. *elaeidis*1^{4}**	***Fusarium oxysporum* f. sp. *elaeidis*4^{1}**	***Fusarium oxysporum* f. sp. *elaeidis*13^{3}**	***Fusarium oxysporum* f. sp. *elaeidis* CRT^{2}**
Progeny	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Progeny 1	63.60 + 15.20^{bc}	36.78 + 12.70^{a}	61.87 + 7.64^{cd}	49.75 + 21.74^{ab}
Progeny 2	62.65 + 13.93^{b}	37.40 + 17.37^{ab}	55.04 + 8.70^{b}	52.19 + 14.00^{ab}
Progeny 3	71.91 + 10.09^{e}	42.50 + 14.24^{ab}	59.96 + 19.44^{bc}	51.31 + 14.31^{ab}
Progeny 4	70.89 + 10.98^{de}	60.67 + 20.65^{c}	72.30 + 10.60^{e}	56.31 + 22.13^{bc}
Progeny 5	78.67 + 10.91^{f}	41.56 + 16.23^{ab}	67.39 + 9.70^{de}	44.51 + 18.95^{a}
Progeny 6	54.63 + 4.75^{a}	46.11 + 14.03^{b}	47.11 + 7.92^{a}	63.39 + 13.58^{c}
Progeny 7	69.44 + 8.68^{cde}	37.61 + 8.84^{ab}	62.33 + 11.85^{cd}	55.17 + 15.05^{bc}
Progeny 8 (Control)	64.82 + 13.02^{bcd}	70.47 + 15.20^{d}	65.11 + 11.81^{cd}	63.56 + 12.26^{c}
F-Statistics	$F_{7,221}$ = 10.809; p < 0.001	$F_{7,221}$ = 22.873; p < 0.001	$F_{7,221}$ = 12.767; p < 0.001	$F_{7,221}$ = 4.796; p < 0.001

NB: Progenies with the same superscript are not significant different with each other at 5% level.

species were non-pathogenic to palms grown from Malaysian seed or to the wilt-susceptible palms from African seed.

External and internal symptoms observed on the progenies revealed different response to the effect of the different *Fusarium* species. The oil palm progenies exhibited difference in response to the different *F. oxysporum* f. sp. *elaeidis* isolate in terms of internal and external wilting features. Rusli *et al*. (2015) went further to report that a particular progeny inoculated with *F. oxysporum* f. sp. *elaeidis* showed severe symptoms from week 5 after inoculation, whereas another progeny PK5463 started to show mild symptoms until week 10, which did not further develop substantially.

CONCLUSION

This study has shown the pathogenicity of *F. oxysporium* f. sp. *elaeidis* species, whose effects were shown on different progenies of oil palm seedlings. The study also shows that *F. oxysporum* f. sp. *elaeidis* has the ability to enhance disease susceptibility. The Pathogenic and non-pathogenic species of *F. oxysporum* coexist in the same plant and in the same tissue. The studies on the pathogenic variability revealed that the typical symptoms of the disease for most of the *F. oxysporum* species appeared early while some appeared late. The *Fusarium* species showed variations in the virulence level on different seedlings of the oil palm. The information regarding variation among the isolates of *Fusarium* species would form the basis for resistant breeding programs.

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