



# EFFECT OF *Choanephora cucurbitarum* (Berkeley & Ravenel) Thaxter ON PEROXIDASE ACTIVITY IN *Abelmoschus esculentus*, *Zea mays*, *Arachis hypogaea*, *Cucumis melo* IN CALABAR CROSS RIVER STATE NIGERIA

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## ABSTRACT

Vegetables are an essential source of dietary fiber, vitamins, minerals, and antioxidants, as well as a key income source for farmers in Nigeria. However, wet rot disease caused by *Choanephora cucurbitarum* (Berkeley & Ravenel) Thaxter poses a major threat to their production. This study investigated the effect of *C. cucurbitarum* infection on peroxidase activity in okra (*Abelmoschus esculentus*), maize (*Zea mays*), groundnut (*Arachis hypogaea*), and melon (*Cucumis melo*) in Calabar, Nigeria. The causal pathogen was isolated from infected plant tissues and characterized based on its cultural and morphological features. Healthy plants were inoculated with *C. cucurbitarum* using a millet substrate, while uninoculated plants served as controls. The effects of infection on growth parameters such as plant height, number of leaves, leaf area, fresh weight, and dry weight were assessed, alongside the determination of peroxidase activity in both infected and control plants. Results revealed that *C. cucurbitarum* infection significantly reduced growth parameters and peroxidase activity in all test crops compared with controls ( $P \leq 0.05$ ), with reductions varying among species. Maize and groundnut exhibited the highest peroxidase activity, while melon and okra showed the lowest, indicating possible differences in host defense responses. The findings confirm the pathogenic potential of *C. cucurbitarum* on multiple crop species and highlight the role of peroxidase as a biochemical marker of plant defense against wet rot disease. This study provides insight on the physiological impact of *C. cucurbitarum* infection and emphasized the need for integrated management strategies to mitigate on vegetable and field crop production in tropical regions.

**KEYWORDS:** *Abelmoschus esculentus*, *Arachis hypogaea*, *Choanephora cucurbitarum*, *Cucumis melo*, peroxidase activity, *Zea mays*.

## INTRODUCTION

Pathogens are a major cause of crop loss around the world, especially in tropical and subtropical regions where warm temperatures and high humidity encourage their spread. One such economically important pathogen is the fungus *Choanephora cucurbitarum*, (Berkeley & Ravenel) Thaxter, a member of the order Mucorales.

This fungus is well known for causing blossom and wet rot in a range of crops, often attacking flowers and young fruits. This attack often leads to softening and decay of plant tissues, significantly reducing crop yields (Singh, 2002). *C. cucurbitarum* has been found to infect several key food and cash crops, including okra (*Abelmoschus esculentus*), corn (*Zea mays*), groundnut (*Arachis hypogaea*), and melon (*Cucumis melo*).

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Its activity tends to intensify under warm, humid conditions, making tropical regions particularly vulnerable to outbreaks (Saha & Haque, 2015).

In their interaction with pathogens, plants undergo a dynamic physiological shift that includes the synthesis of pathogenesis-related proteins and enzymes such as peroxidases. These enzymes serve not only as markers of plant defense responses but also as active agents in the resistance process. Studies (Agrios, 2005; Jones & Dangl, 2006) have shown that elevated peroxidase activity is commonly associated with plant resistance to fungal pathogens, making it a useful biochemical indicator of disease resistance.

Agriculture plays a key role in the local economy. Hence, the presence of fungal pathogens such as *C. cucurbitarum* poses a serious challenge to food security and the livelihoods of farmers (Etebu & Ekpo, 2007). This underscores the necessity of this study to investigate the effect of *C. cucurbitarum* on peroxidase activity in okra (*A. esculentus*), corn (*Z. mays*), groundnut (*A. hypogaea*), melon (*C. melo*) in Calabar.

Plants defend themselves against pathogens in several ways, and one of the first responses involves the activation of biochemical defenses. Among these, the production of enzymes like peroxidases is particularly important. Peroxidases help protect plants by neutralizing reactive oxygen species (ROS), strengthening cell walls, and initiating defense signaling pathways. Since peroxidase activity often increases when a plant is under attack, it serves as a useful marker for accessing how resistant or susceptible a plant might be to disease (Passardi, Cosio, Penel & Dunand, 2005).

Given the favorable climate for the production of these vegetables in Calabar and the vulnerability of commonly grown crops to *C. cucurbitarum*, it is important to examine how this fungus affects the plants' natural defense systems. Studying the interaction between *C. cucurbitarum* and peroxidase activity in okra, corn, groundnut, and melon can offer valuable insights into how these plants respond to infection. This knowledge can support the development of more effective disease management strategies, including breeding resistant crop varieties and creating targeted control measures.

## MATERIALS AND METHODS

Research design

The study adopted a **factorial experimental design (2 × 4) arranged in a Completely Randomized Design (CRD)** with three replications to evaluate the effect of *C. cucurbitarum* infection on peroxidase activity in okra, corn, groundnut, and melon.

### Experimental Site

This research was carried out in the laboratory of the Department of Plant and Ecological Studies, University of Calabar, Calabar. All laboratory procedures were performed in the postgraduate

research laboratory of the department under aseptic conditions.

### Source of pathogen

The pathogen used in the study (*C. cucurbitarum*) was isolated from naturally infected okra flowers exhibiting blossom blight and soft rot. Samples were collected from the University farm site in Cross River State and transported to the laboratory within 24 hours in sterile polythene bags for processing.

### Isolation, purification, spore count and identification of *C. cucurbitarum*

#### Preparation of culture medium

Potato Dextrose Agar (PDA) was used as culture medium. The Media was prepared by dissolving 39 g of commercial potatoes dextrose agar in one litre of distilled water and autoclaved at 121 °C for 15 minutes. The media was allowed to cool to about 40 °C before dispensing into sterile glass petri-dishes.

#### Culturing and purification of pathogen

The pathogen was cultured following the method of Umana and Ikotun (2000). Section (3 mm<sup>2</sup>) of the infected okra flowers showing symptoms of blossom blight and soft rot was aseptically taken, surface sterilised using 70 % ethanol, and rinsed severally with distilled water. The sterile section was inoculated into the prepared PDA in petri dishes and incubated at 27±1 °C the culture was examined daily for growth and sub-cultured on the third day to obtain pure cultures. The isolate was stored as stock culture in McKaney bottle as agar slant and stored in a refrigerator at 4 °C for further use.

#### Spore count of *C. cucurbitarum*

Spore suspension was prepared in sterile distilled water (1 x 10<sup>6</sup> spores/ml). A Hemocytometer was used to determine spore concentration following Pitt and Poole (1981).

#### Identification of isolate

The fungus isolate was microscopically identified using the identification guides of the International Mycological institute, and according to method of Hashem and Farag (2005) and Barnet and Hunter (2006).

#### Pathogenicity test

The method of Bassey, Akwaji & Godwin (2018) was adopted for the pathogenicity test. *C. cucurbitarum* was confirmed following Koch's postulates. Healthy leaves of *A. esculentus*, *Z. mays*, *A. hypogaea*, *C. melo* were surface sterilised with 70% ethyl alcohol. Wounds were created using sterile inoculating needle to facilitate the entry of the fungus. A spray inoculation with spore's suspension from a four-day old pure culture of the isolate was aseptically transferred into the wounds on leaves of the test plant and covered with transparent polyethylene bag to prevent moisture loss and entry of other pathogens. Daily observation was made for rot symptom development and spread on the leaves. Re-isolation of the pathogen from the artificially inoculated leaf yielded the pathogen identified in the original cultures

**Cultural characterisation of the pathogen**

The cultural characteristic of *C. cucurbitarum* was carried out by growing it on potatoes dextrose agar (PDA) and observation made on the nature of growth and sporulation of the pathogen.

**Morphological characterisation of the pathogen**

The morphological characters of the pathogen *C. cucurbitarum* was studied by preparing slides from pure culture of the pathogen. The slides were stained with Lactophenol in cotton blue and observed for the mycellial characters, sporulation and characteristics of the sporangiospores using Olympic microscope and observed under 40x and 100x magnification in oil emersion.

**Source of test plants**

The test plants *A. esculentus*, *Z. mays*, *A. hypogaea*, and *C. melo* were obtained from Agricultural Development Project, Murtala Mohammed highway, Calabar, Cross River State.

**Preparation of growth medium**

The top soil, 0-15cm depth was obtained from the botanical garden of University of Calabar, and sieved through a 0.5 x 0.5cm wire mesh to remove large objects and root particles, and was used as the growth medium (Biodgett and Swart, 2002). Sieved soil was sterilized at 160°C in a hot air oven (Mode: DHG 9053A).

**Seedling inoculation technique**

Healthy seedling of test plants growing at same time with the inoculated seeds in another area of the experimental site were also inoculated after four weeks of planting. The seedling leaves were surface sterilized and inoculated with the inoculum by introducing 0.05ml spore suspension of the inoculum on the leaves. The experiment was laid out in a complete randomized design. Growth parameters such as number of leaves, plant height and dry weight were used for assessment.

**Growth Parameter Measurement**

Growth data were collected weekly for four weeks after inoculation to assess the impact of *C. cucurbitarum* infection on the four plant species. The following growth parameters were measured:

- i. Plant height (cm): The height of each plant was measured from the soil level to the apical bud using a meter rule or measuring tape.
- ii. Number of Leaves per Plant: The total number of leaves on each plant was counted manually.
- iii. Leaf area (cm<sup>2</sup>): Leaf area was estimated using the formula:

$$LA = L \times W \times 0.75$$

where L = leaf length and W = leaf width, following the method described by Akindele (2007).

- iv. Fresh weight (g): At harvest, plants were carefully uprooted and separated into leaves, stems, and roots.

The fresh biomass of each part was weighed immediately to determine the total fresh weight.

v. Dry weight (g): After fresh weight measurement, plant parts (leaf, stem, and root) were oven-dried to constant weight. The dry biomass was then recorded to assess the impact of infection on plant dry matter accumulation.

**DETERMINATION OF PEROXIDASE ACTIVITY**

The activity of peroxidase was assayed by adopting the methods of enzyme extraction and assay described by Ngele, Agba, Bassey & Egeh (2024).

**Enzyme extraction**

Enzymes were extracted in a mixed phosphate buffer (50 mM monobasic and dibasic potassium phosphate salts), pH 7.5, containing 1% of the phenolic absorbent- polyvinyl pyrrolidone (PVPP), 0.2g of leaves was pulverized in 5ml of extraction buffer and centrifuged at 6000 rpm (rotation per minute) for 10 min. The supernatant was stored in an ice chamber and used as crude enzyme extract.

**Enzyme assay**

The enzyme assay was carried out in a mixed phosphate buffer (50mM monobasic and dibasic potassium phosphate salts). Assay for peroxidases was done spectrophotometrically by following the dehydrogenation product of guaiacol at 436nm. In a quartz cuvette with an internal diameter of 1 cm was added 2 mls of assay buffer, 0.6 mls of enzyme extract, and 0.1 ml of 10 mM guaiacol. These were mixed together and the reaction started by adding 0.1 ml of 10 mM H<sub>2</sub>O<sub>2</sub>; the final assay volume was 2.8 mls. Absorbance reading was read at 436 nm after 30 seconds. The readings were used in calculating volume activity (μmol product/L/min) using an extinction coefficient of 6.39 mMcm<sup>-1</sup> for guaiacol dehydrogenation product.

**Statistical analysis of data**

Leaf area (cm<sup>2</sup>) was calculated as the product of the total length and breadth at the broadest point of the longest leaf on the plant i.e. leaf area = lamina length x maximum width x k (where k is the coefficient to be derived = 0.62) (Musa, Yusuf, Ojogbane & Nwodo, 2010). Mean and standard deviation was performed with the Statistical Package for the Social Sciences (SPSS) 23.0 Version.

Mean separation was based on Duncan's Multiple Range Test and data expressed as means of three replicates ± standard error (SE). Means followed by different letters in each column are significantly different (P ≤ 0.05).

**RESULTS****Cultural characterization of Pathogen**

The growth of *C. cucurbitarum* studied using Potato Dextrose Agar (PDA) medium showed that the isolate from the infected okra leaves (*A. esculentus*) sporulated between 22 hours with multiple mycelia on the surface of the PDA.

**Morphological characterization of pathogen**

The morphological characteristics of the isolate (*C. cucurbitarum*) on prepared slides viewed under the Olympus microscope (Model: 08100000) revealed that the isolate from okra (*A. esculentus*) had mycelium that was hyaline, unbranched and without septation (Plate 1). The sporangiosphere bearing sporangium was non-septate and apically brown at maturity indistinctly straight with dropping multisporous sporangia that were subglobose in shape. The sporangiosphere from which the sporangium arose was long slender with vesicle which bore as spore (conidia).



**Fig. 1:** Photomicrograph of *C. cucurbitarum* isolate from *A. esculentus*

**Symptomatology**

The symptom of soft rot of *C. cucurbitarum* emerged with water soaked and dark grey brown lesion on okra, and progressed by showing rapid rot under high temperature and humid conditions. The leaves appeared wet and slimy to the touch. The disease effect was localized and not system.

**Effect of *C. cucurbitarum* on leaf area, plant height and number of leaves on okra**

The effect of *C. cucurbitarum* infection on okra growth parameters recorded in Table 1 revealed that leaf area increased progressively in both control and infected plants throughout the eight-week period, with control plants recording higher mean values at all stages (e.g.,  $859.00 \pm 202.00$  cm<sup>2</sup> vs.  $802.67 \pm 244.45$  cm<sup>2</sup> at week 2;  $2006.33 \pm 278.25$  cm<sup>2</sup> vs.  $1585.67 \pm 421.42$  cm<sup>2</sup> at week 8), though differences were not statistically significant ( $P > 0.05$ ). Plant height followed a similar trend initially, but significant differences emerged at week 4 ( $P = 0.002$ ) and week 8 ( $P = 0.010$ ), where control plants ( $30.00 \pm 2.89$  cm;  $91.67 \pm 10.14$  cm) were consistently taller than infected plants ( $22.67 \pm 2.91$  cm;  $75.00 \pm 8.66$  cm). The number of leaves increased with plant age in both treatments, yet infected plants consistently had fewer leaves, with significant reductions observed at week 4 ( $P = 0.010$ ) and week 6 ( $P = 0.003$ ). Although controls still had

more leaves by week 8, the difference at that stage was not statistically significant.

**Effects *C. cucurbitarum* on plant biomass**

Infection by *C. cucurbitarum* caused significant reductions in both fresh and dry biomass components of okra plants as recorded in Table 2. Leaf fresh weight declined from  $17.33 \pm 1.76$  g in control plants to  $11.50 \pm 1.04$  g in infected plants ( $P = 0.015$ ), stem fresh weight from  $12.00 \pm 1.15$  g to  $8.50 \pm 0.87$  g ( $P = 0.007$ ), and root fresh weight from  $8.00 \pm 0.87$  g to  $5.33 \pm 0.72$  g ( $P = 0.026$ ). Similar trends were observed for dry weights, with leaves decreasing from  $4.03 \pm 0.46$  g to  $2.80 \pm 0.29$  g ( $P = 0.020$ ), stems from  $2.63 \pm 0.26$  g to  $1.97 \pm 0.20$  g ( $P = 0.010$ ), and roots from  $1.60 \pm 0.23$  g to  $1.13 \pm 0.15$  g ( $P = 0.034$ ). These findings indicate that *C. cucurbitarum* infection markedly impairs biomass accumulation in okra by reducing leaf, stem, and root weights in both fresh and dry forms.

Table 1:

Growth parameter	Week 2		Week 4		Week 6		Week 8	
	Control	Infected	Control	Infected	Control	Infected	Control	Infected
Leaf Area	859.00±202.00	802.67±244.45	1713.33±98.21	1336.67±431.13	1539.33±159.62	1978.00±302.02	2006.33±278.25	1585.67±421.42
Plant Height	10.00 <sup>a</sup> ±1.15	5.00 <sup>a</sup> ±1.15	30.00 <sup>a</sup> ±2.89	22.67 <sup>a</sup> ±2.91	60.00 <sup>a</sup> ±5.77	50.00 <sup>a</sup> ±5.77	91.67 <sup>a</sup> ±10.14	75.00 <sup>a</sup> ±8.66
No. of Leaves	5.00 <sup>a</sup> ±0.58	4.00 <sup>a</sup> ±0.58	12.00 <sup>a</sup> ±1.15	8.67 <sup>a</sup> ±0.88	23.33 <sup>a</sup> ±1.76	17.67 <sup>a</sup> ±1.45	35.37 <sup>a</sup> ±3.48	27.67 <sup>a</sup> ±1.45
LXBK	637.50±151.50	600.33±181.73	1286.50±74.18	560.05±323.35	207.35±119.72	391.60±226.09	1504.75±208.69	1189.25±316.07

\* = Statistically significant

<sup>a</sup> = The correlation and t cannot be computed because the standard error of the difference is 0. Implies that all observed differences between paired samples are identical (there is no variability in the differences).

Table 2

Plant weight (g)	Leaf weight		Stem weight		Root weight	
	Control	Infected	Control	Infected	Control	Infected
Fresh Weight	17.33 <sup>a</sup> ±1.76	11.50 <sup>a</sup> ±1.04	12.00 <sup>a</sup> ±1.15	8.50 <sup>a</sup> ±0.87	8.00 <sup>a</sup> ±1.15	5.33 <sup>a</sup> ±0.72
Dry Weight	4.03 <sup>a</sup> ±0.46	2.80 <sup>a</sup> ±0.29	2.63 <sup>a</sup> ±0.26	1.97 <sup>a</sup> ±0.20	1.60 <sup>a</sup> ±0.23	1.13 <sup>a</sup> ±0.15

\* = Statistically significant

<sup>a</sup> = The correlation and t cannot be computed because the standard error of the difference is 0. Implies that all observed differences between paired samples are identical (there is no variability in the differences).

Effect of *C. cucurbitarum* on the peroxidase activity of okra plant

The results in Figure 2 show that infection by *C. cucurbitarum* led to a noticeable increase in peroxidase activity in okra plants compared to the control. Infected okra plants recorded a peroxidase activity of 711.8µmol product/L/min, which was higher

than 548.7 µmol product/L/min observed in the control plants.

This increase suggests that *C. cucurbitarum* infection triggered a defensive biochemical response in okra, leading to elevated peroxidase production. The heightened enzyme activity in infected plants indicates that okra recognizes the fungal attack and responds by enhancing its defense mechanisms.

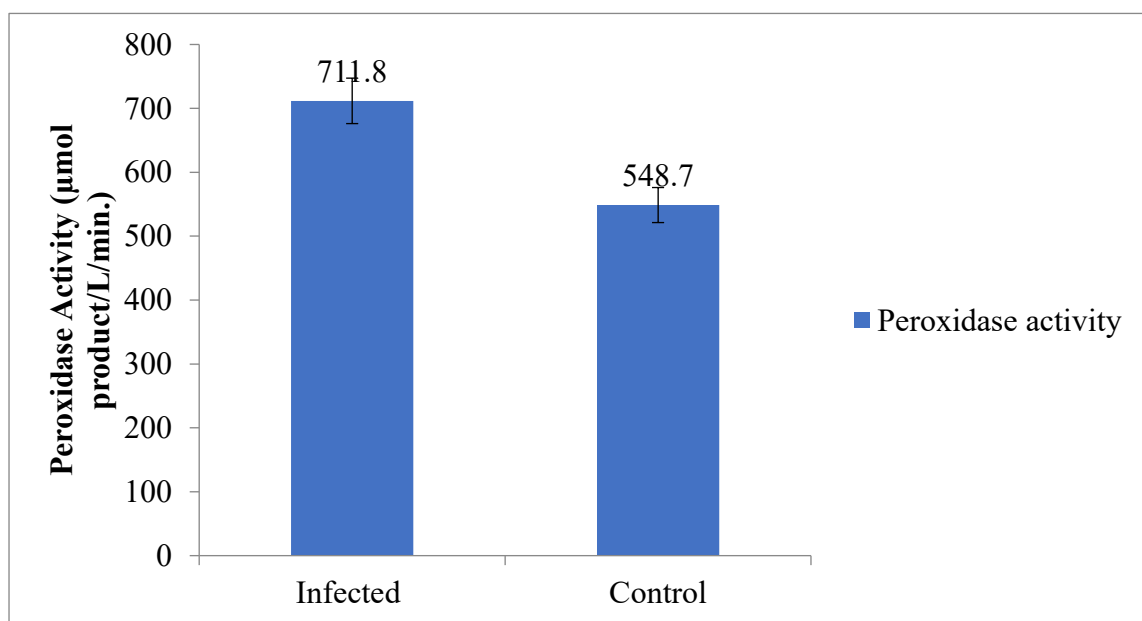


Fig. 2: Peroxidase activity in okra

Effect of *C. cucurbitarum* on leaf area, plant height and number of leaves on groundnut

Table 3 shows the effects of *C. cucurbitarum* infection on plant height, leaf area, and number of leaves of *A. hypogaea*. The results indicate that plant height was significantly reduced ( $p \leq 0.05$ ) in infected plants compared to controls from week 4 onward. At week 8, infected plants recorded an average height of  $28.17 \pm 0.44$  cm, significantly lower than the control plants, with average height of  $35.27 \pm 0.43$  cm. Leaf area was not significantly different between infected and control plants during the early weeks but showed a marked reduction at week 6 and week 8 in infected plants. At week 8, the mean leaf area of infected plants was  $567.00 \pm 38.55$  cm<sup>2</sup> compared to  $659.00 \pm 38.97$  cm<sup>2</sup> in controls. The number of leaves followed a similar

trend, with infected plants consistently producing fewer leaves from week 4 onward. At week 8, infected plants had an average of  $18.00 \pm 1.15$  leaves, significantly fewer than the control plants, which averaged  $24.00 \pm 2.30$  leaves.

**Effect on plant biomass**

Biomass analysis revealed that *C. cucurbitarum* infection reduced both fresh and dry weights of leaves, stems, and roots (Table 4). Although, fresh weights showed no statistically significant differences in some cases, dry weights were significantly ( $p \leq 0.05$ ) lower in infected plants. For example, dry leaf weight decreased from 2.40 g in controls to 1.67 g in infected plants, and root dry weight declined from  $0.80 \pm 0.12$ g to 0.57 g. These reductions reflect pathogen-induced impairment of photosynthetic efficiency and nutrient allocation, leading to decreased biomass production.

Table 3

Growth parameter	Week 2		Week 4		Week 6		Week 8	
	Control	Infected	Control	Infected	Control	Infected	Control	Infected
Leaf Area	197.00±31.00	206.00±22.00	284.00±28.00	292.00±20.00	502.67±9.67	387.33±37.67	659.00±38.97	567.00±38.55
Plant Height	8.03 <sup>a</sup> ±0.09	6.53 <sup>a</sup> ±0.09	12.10 <sup>a</sup> ±0.21	9.43 <sup>a</sup> ±0.30	16.10 <sup>a</sup> ±0.21	13.57 <sup>a</sup> ±0.23	35.27 <sup>a</sup> ±0.43	28.17 <sup>a</sup> ±0.44
No. of Leaves	5.40 <sup>a</sup> ±0.36	3.00 <sup>a</sup> ±0.58	10.00±1.15	7.00±0.58	16.00 <sup>a</sup> ±1.15	12.00 <sup>a</sup> ±1.15	24.00 <sup>a</sup> ±2.30	18.00 <sup>a</sup> ±1.15
LXBKX	142.14±15.18	267.95±26.34	201.48 <sup>a</sup> ±13.80	201.48 <sup>a</sup> ±13.80	267.26 <sup>a</sup> ±25.99	391.23 <sup>a</sup> ±26.60	391.23 <sup>a</sup> ±26.60	391.23 <sup>a</sup> ±26.60

\* = Statistically significant

<sup>a</sup> = The correlation and t cannot be computed because the standard error of the difference is 0. Implies that all observed differences between paired samples are identical (there is no variability in the differences).

Table 4

Plant weight (g)	Leaf weight		Stem weight		Root weight	
	Control	Infected	Control	Infected	Control	Infected
Fresh Weight	8.27±2.79	5.83±1.96	4.87±1.66	3.43±1.19	2.67±0.88	1.80±0.59
Dry Weight	2.40 <sup>a</sup> ±0.23	1.67 <sup>a</sup> ±0.18	1.20±0.12	0.97±0.09	0.80 <sup>a</sup> ±0.12	0.57 <sup>a</sup> ±0.09

\* = Statistically significant

<sup>a</sup> = The correlation and t cannot be computed because the standard error of the difference is 0. Implies that all observed differences between paired samples are identical (there is no variability in the differences).

**Effect of *C. cucurbitarum* on the peroxidase activity of groundnut**

The results presented in Fig 3 show that infection by *C. cucurbitarum* significantly reduced peroxidase activity in groundnut plants. Infected samples recorded a peroxidase activity of 784.83  $\mu\text{mol product/L/min}$ , compared to 1075.98  $\mu\text{mol product/L/min}$  in the control plants.

Peroxidase plays a vital role in plant resistance, and its lower activity in infected groundnut plants suggests

that *C. cucurbitarum* could be actively suppressing this enzyme to enhance its pathogenicity. Similar findings have been reported in other host-pathogen interactions where fungal infections were associated with a decline in peroxidase activity, leading to increased vulnerability of the host. In groundnut, this decrease could contribute to weakened structural integrity and greater susceptibility to disease progression under infection conditions.

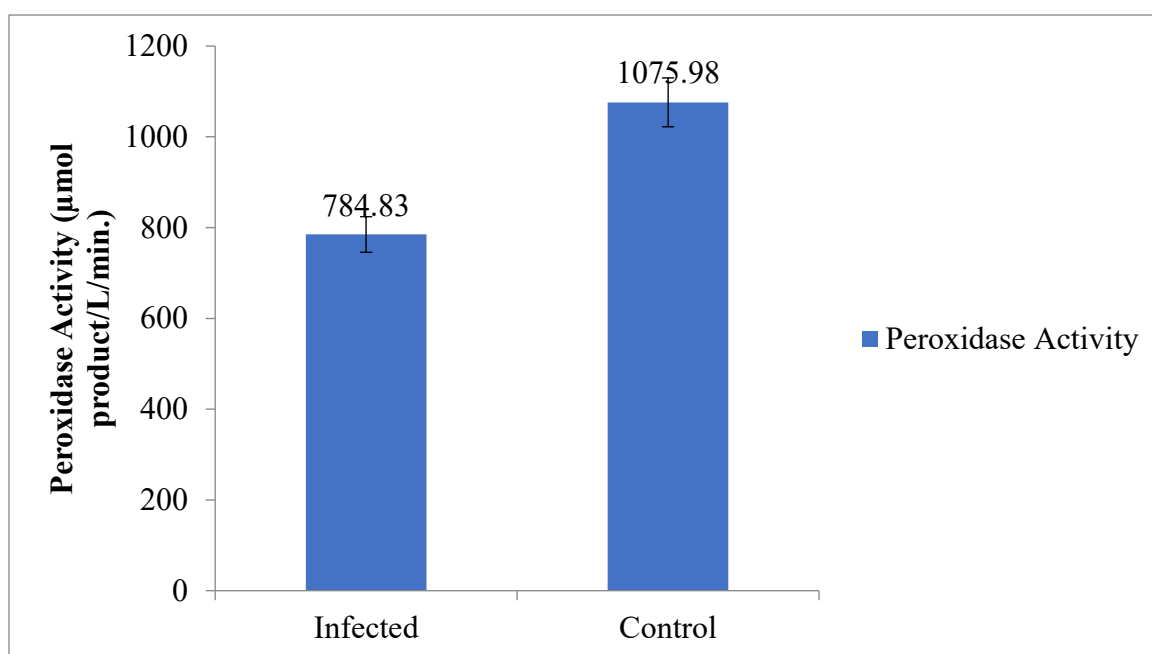


Fig. 3: Peroxidase activity in groundnut

Effect of *C. cucurbitarum* on leaf area, plant height and number of leaves on melon

In Table 5, the effect of *C. cucurbitarum* infection on melon growth parameters showed variable trends across the eight-week period. Leaf area increased in both treatments, with infected plants recording higher values than controls at several stages, including week 2 ( $954.00 \pm 97.87 \text{ cm}^2$  vs.  $847.33 \pm 90.36 \text{ cm}^2$ ) and week 4 ( $1550.00 \pm 61.13 \text{ cm}^2$  vs.  $977.00 \pm 41.07 \text{ cm}^2$ ), the latter being significantly higher ( $p < 0.05$ ). A similar advantage for infected plants persisted at week 6 ( $1794.00 \pm 62.79 \text{ cm}^2$  vs.  $1317.00 \pm 290.53 \text{ cm}^2$ ) and week 8 ( $1949.00 \pm 80.01 \text{ cm}^2$  vs.  $1924.33 \pm 312.08 \text{ cm}^2$ ), although these differences were not statistically significant. Plant height increased progressively in both treatments, with control plants generally taller; however, no significant differences were observed at any stage, e.g., week 8 values of  $58.33 \pm 4.41 \text{ cm}$  (control) and  $55.00 \pm 2.89 \text{ cm}$  (infected). The number of leaves rose steadily in both treatments, but infected plants consistently had fewer leaves, with significant reductions at week 2 ( $p < 0.05$ ) and week 6 ( $p < 0.05$ ), such as  $24.00 \pm 2.31$  leaves in controls compared to  $18.33 \pm 2.03$  leaves in infected plants at week 6. For leaf area per biomass (LXBK), control plants had higher values

at weeks 2, 6, and 8, but infected plants had significantly lower values at week 4 ( $732.75 \pm 30.80$  vs.  $1162.50 \pm 45.85$ ;  $p < 0.05$ ). Overall, *C. cucurbitarum* infection in melon resulted in increased leaf area at certain stages but generally reduced leaf number and leaf area per biomass, while plant height remained largely unaffected.

Effect on plant biomass

Results in Table 6 show *C. cucurbitarum* infection significantly reduced both fresh and dry biomass components of melon plants. Leaf fresh weight declined from  $12.33 \pm 1.45 \text{ g}$  in control plants to  $8.17 \pm 1.01 \text{ g}$  in infected plants ( $p < 0.05$ ), stem fresh weight from  $14.33 \pm 2.33 \text{ g}$  to  $9.50 \pm 1.60 \text{ g}$  ( $p < 0.05$ ), and root fresh weight from  $7.00 \pm 1.15 \text{ g}$  to  $4.83 \pm 1.01 \text{ g}$  ( $p < 0.05$ ). A similar pattern was observed for dry weights, with leaves decreasing from  $3.03 \pm 0.32 \text{ g}$  to  $2.07 \pm 0.23 \text{ g}$  ( $p < 0.05$ ) and stems from  $2.83 \pm 0.44 \text{ g}$  to  $1.97 \pm 0.32 \text{ g}$  ( $p < 0.05$ ), while root dry weight fell slightly from  $1.37 \pm 0.15 \text{ g}$  to  $0.97 \pm 0.15 \text{ g}$ , though this difference was not statistically significant ( $P > 0.05$ ). These findings indicate that *C. cucurbitarum* infection substantially impairs biomass accumulation in melon, particularly in the leaf and stem components.

TABLE 5

Growth parameter	Week 2		Week 4		Week 6		Week 8	
	Control	Infected	Control	Infected	Control	Infected	Control	Infected
Leaf Area	847.33±90.36	954.00±97.87	977.00*±41.07	1550.00*±61.13	1317.00±290.53	1794.00±62.79	1924.33±312.08	1949.00±80.01
Plant Height	12.00 <sup>a</sup> ±1.15	8.00 <sup>a</sup> ±1.15	21.00±2.08	20.00±2.89	38.33±4.41	35.00±2.89	58.33±4.41	55.00±2.89
No. of Leaves	4.00 <sup>a</sup> ±0.58	3.00 <sup>a</sup> ±0.58	10.00 <sup>a</sup> ±1.15	8.00 <sup>a</sup> ±1.15	24.00*±2.31	18.33*±2.03	48.33±6.01	35.00±2.89
LXBXK	715.50±73.40	635.50±67.77	1162.50*±45.85	732.75*±30.80	1345.50±47.09	987.75±217.90	1461.75±60.01	1443.25±234.06

\* = Statistically significant

<sup>a</sup> = The correlation and t cannot be computed because the standard error of the difference is 0. Implies that all observed differences between paired samples are identical (there is no variability in the differences).

TABLE 6

Plant weight (g)	Leaf weight		Stem weight		Root weight	
	Control	Infected	Control	Infected	Control	Infected
Fresh Weight	12.33*±1.45	8.17*±1.01	14.33*±2.33	9.50*±1.60	7.00*±1.15	4.83*±1.01
Dry Weight	3.03*±0.32	2.07*±0.23	2.83*±0.44	1.97*±0.32	1.37 <sup>a</sup> ±0.15	0.97 <sup>a</sup> ±0.15

\* = Statistically significant

<sup>a</sup> = The correlation and t cannot be computed because the standard error of the difference is 0. Implies that all observed differences between paired samples are identical (there is no variability in the differences).

Effect of *C. cucurbitarum* on the peroxidase activity of melon

The results in Fig 4 indicate that *C. cucurbitarum* infection led to a reduction in peroxidase activity in melon plants. Infected samples recorded a peroxidase activity of 824.76  $\mu\text{mol product/L/min}$ , compared to 985.91  $\mu\text{mol product/L/min}$  in the control plants. This decrease suggests that the pathogen negatively influences the plant's enzymatic defense system. Peroxidase enzymes are vital for reinforcing cell walls

through lignification, detoxifying reactive oxygen species (ROS), and triggering other defense responses against pathogens. The lower activity in infected melon plants implies that *C. cucurbitarum* may suppress or weaken these defenses, potentially facilitating further colonization and damage. For melon, this reduction in peroxidase activity could contribute to increased susceptibility and faster disease progression under pathogen pressure.

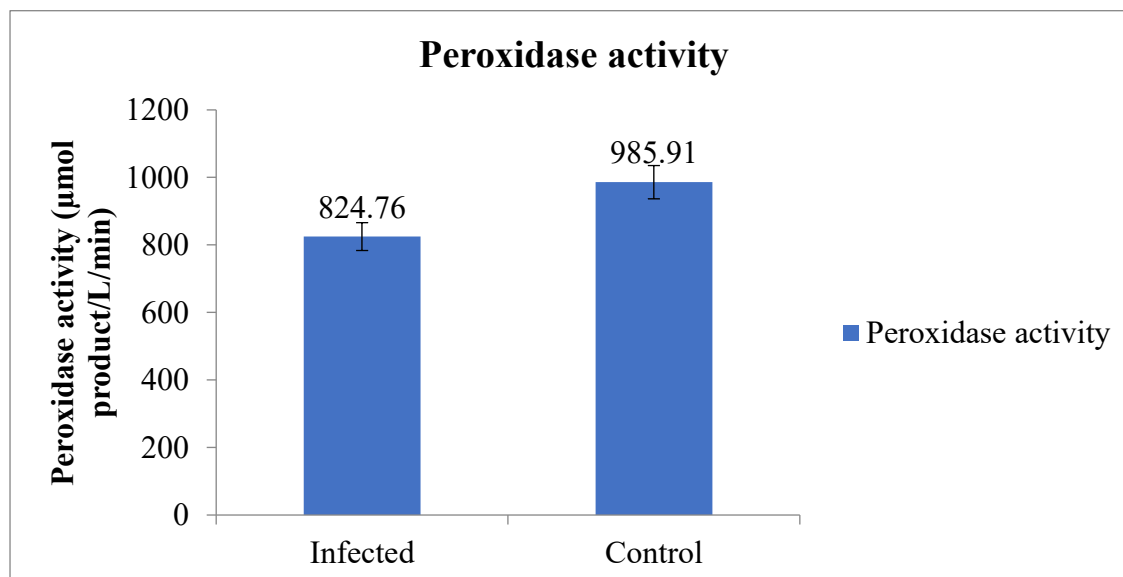


Fig. 4: Peroxidase activity in melon

Effect of *C. cucurbitarum* on leaf area, plant height and number of leaves on corn

Table 7 shows the effect of *C. cucurbitarum* infection on maize growth parameters. The leaf area increased steadily in both treatments, with control plants generally recording higher values except at week 8, when infected plants had significantly greater leaf area ( $1900.00 \pm 57.74 \text{ cm}^2$  vs.  $336.67 \pm 272.84 \text{ cm}^2$ ;  $p < 0.05$ ). Early growth measurements revealed lower values in infected plants, such as at week 2 ( $35.00 \pm 2.89 \text{ cm}^2$  vs.  $60.00 \pm 2.89 \text{ cm}^2$ ) and week 4 ( $230.00 \pm 11.55 \text{ cm}^2$  vs.  $280.00 \pm 11.55 \text{ cm}^2$ ), though these differences were not statistically significant. Plant height was more consistently affected, with significant reductions observed at week 2 ( $14.00 \pm 0.58 \text{ cm}$  vs.  $19.00 \pm 0.58 \text{ cm}$ ;  $p < 0.05$ ), week 4 ( $42.33 \pm 1.45 \text{ cm}$

vs.  $57.67 \pm 1.45 \text{ cm}$ ;  $p < 0.05$ ), and week 8 ( $151.67 \pm 4.41 \text{ cm}$  vs.  $210.00 \pm 5.77 \text{ cm}$ ;  $p < 0.05$ ), while week 6 differences were not significant.

The number of leaves also declined under infection, with significant differences at week 4 ( $5.67 \pm 0.33$  vs.  $7.33 \pm 0.33$ ;  $p < 0.05$ ) and week 8 ( $13.33 \pm 0.33$  vs.  $17.00 \pm 0.58$ ;  $p < 0.05$ ), but not at weeks 2 and 6. Leaf area per biomass (LXBK) varied across stages, with no significant differences observed, although infected plants occasionally recorded slightly higher values, such as at week 2 ( $44.25 \pm 4.88$  vs.  $40.88 \pm 2.28$ ). Overall, *C. cucurbitarum* infection in maize resulted in reduced plant height and leaf number at several growth stages, while effects on leaf area and LXBK were variable and sometimes reversed in later stages

Table 7

Growth parameter	Week 2		Week 4		Week 6		Week 8	
	Control	Infected	Control	Infected	Control	Infected	Control	Infected
Leaf Area	$60.00^a \pm 2.89$	$35.00^a \pm 2.89$	$280.00^a \pm 11.55$	$230.00^a \pm 11.55$	$1150.00 \pm 28.87$	$633.33 \pm 142.40$	$336.67 \pm 272.84$	$1900.00^* \pm 57.74$
Plant Height	$19.00^* \pm 0.58$	$14.00^* \pm 0.58$	$57.67^* \pm 1.45$	$42.33^* \pm 1.45$	$125.00^a \pm 2.89$	$95.00^a \pm 2.89$	$210.00^* \pm 5.77$	$151.67^* \pm 4.41$
No. of Leaves	$4.00 \pm 0.00$	$2.67 \pm 0.33$	$7.33^* \pm 0.33$	$5.67^* \pm 0.33$	$11.33^a \pm 0.33$	$9.33^a \pm 0.33$	$17.00^* \pm 0.58$	$13.33^* \pm 0.33$
LXBK	$40.88 \pm 2.28$	$44.25 \pm 4.88$	$65.37 \pm 24.52$	$68.25 \pm 19.24$	$98.63 \pm 29.45$	$100.50 \pm 18.51$	$148.85 \pm 36.95$	$136.70 \pm 21.70$

\* = Statistically significant

<sup>a</sup> = The correlation and t cannot be computed because the standard error of the difference is 0. Implies that all observed differences between paired samples are identical (there is no variability in the differences).

Effect on plant biomass

*C. cucurbitarum* infection reduced both fresh and dry biomass components of maize, although the magnitude and statistical significance varied among plant parts. Results in Table 8 show fresh leaf weight decreased from  $32.00 \pm 1.15 \text{ g}$  in control plants to  $20.00 \pm 1.15 \text{ g}$  in infected plants, and stem fresh weight declined from  $36.00 \pm 1.15 \text{ g}$  to  $24.00 \pm 1.15 \text{ g}$ ; however, these differences were not statistically significant ( $P > 0.05$ ). Root fresh weight showed a significant reduction ( $p < 0.05$ ), falling from  $22.00 \pm 1.15 \text{ g}$  in controls to  $16.00 \pm 0.58 \text{ g}$  in infected plants.

A similar pattern was observed for dry weights, with leaves decreasing from  $6.40 \pm 0.23 \text{ g}$  to  $4.00 \pm 0.23 \text{ g}$  and stems from  $7.20 \pm 0.23 \text{ g}$  to  $4.80 \pm 0.23 \text{ g}$ , neither of which was statistically significant. In contrast, root dry weight was significantly lower in infected plants ( $3.20 \pm 0.12 \text{ g}$ ) compared to controls ( $4.40 \pm 0.23 \text{ g}$ ) ( $p < 0.05$ ). These results indicate that maize root biomass, both fresh and dry, is particularly sensitive to *C. cucurbitarum* infection, while reductions in leaf and stem weights, though notable, were not statistically significant.

Table 8

Plant weight (g)	Leaf weight		Stem weight		Root weight	
	Control	Infected	Control	Infected	Control	Infected
Fresh Weight	$32.00^a \pm 1.15$	$20.00^a \pm 1.15$	$36.00^a \pm 1.15$	$24.00^a \pm 1.15$	$22.00^* \pm 1.15$	$16.00^* \pm 0.58$
Dry Weight	$6.40^a \pm 0.23$	$4.00^a \pm 0.23$	$7.20^a \pm 0.23$	$4.80^a \pm 0.23$	$4.40^* \pm 0.23$	$3.20^* \pm 0.12$

\* = Statistically significant

<sup>a</sup> = The correlation and t cannot be computed because the standard error of the difference is 0. Implies that all observed differences between paired samples are identical (there is no variability in the differences).

**Effect of *C. cucurbitarum* on the peroxidase activity of corn**

The results in Figure 5 show that infection by *C. cucurbitarum* caused a marked reduction in peroxidase activity in maize plants. Infected maize recorded a peroxidase activity of 793.11  $\mu\text{mol product/L/min}$ , which was considerably lower than the 1136.84  $\mu\text{mol product/L/min}$  observed in the control plants.

This decline in enzyme activity suggests that *C. cucurbitarum* may interfere with or suppress the maize plant's natural defense mechanisms, possibly through the production of fungal toxins or enzyme inhibitors.

Peroxidases are essential in plant defense, playing key roles in cell wall strengthening, detoxification of reactive oxygen species (ROS), and activation of other defense pathways. The reduced activity in infected plants may therefore make them more vulnerable to disease progression and tissue damage. These findings are consistent with previous research showing that some aggressive pathogens can suppress host defense enzymes as part of their infection strategy. In the case of maize, the data indicates that *C. cucurbitarum* not only infects but also likely impairs the plant's biochemical capacity to resist infection.

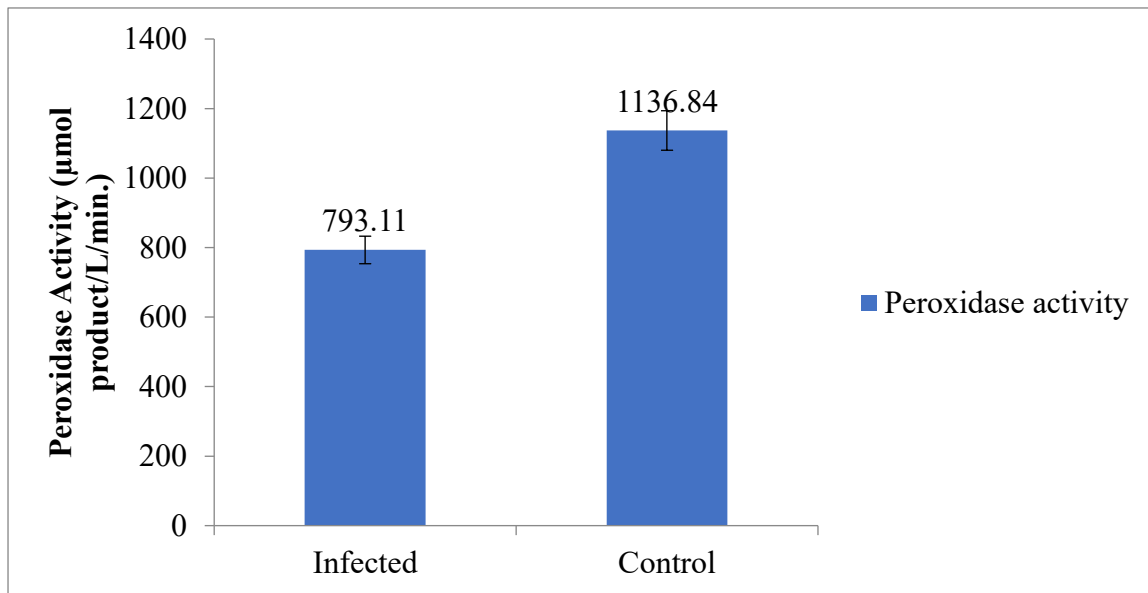


Fig. 5: Peroxidase activity in maize

**DISCUSSION**

This study investigated the effect of *C. cucurbitarum* infection on peroxidase activity in okra (*A. esculentus*), corn (*Z. mays*), groundnut (*A. hypogaea*), and melon (*C. melo*) in Calabar, Cross River State, Nigeria. The pathogen, known for causing wet rot and blossom blight in a wide range of crops, was isolated from symptomatic plants and identified based on morphological characteristics consistent with previous reports (Bassey *et al.*, 2018; Markson *et al.*, 2014.).

The results showed that *C. cucurbitarum* infection significantly increased peroxidase activity in all tested crops compared with uninoculated controls. Peroxidase is a key defense enzyme that strengthens cell walls, participates in lignin biosynthesis, and detoxifies hydrogen peroxide during pathogen attack. Elevated peroxidase activity suggests that the pathogen triggered an oxidative stress response, in agreement with Siddiqui *et al.* (2012) who found that *C. cucurbitarum* infection in okra induced peroxidase and other defense-related enzymes.

Peroxidase activity varied among crops, with okra and melon showing higher levels than corn and groundnut.

These differences may be related to variations in host susceptibility, biochemical composition, or pathogen colonization rate. Similar patterns of host-dependent susceptibility have been reported by Bassey *et al.* (2018) in southern Nigeria and by Liu *et al.* (2019) in China, where okra exhibited pronounced symptoms and biochemical responses under favorable environmental conditions.

The warm, humid climate of Calabar supports the rapid spread and sporulation of *C. cucurbitarum*. Field symptoms included water-soaked lesions on flowers, stems, and leaves, which progressed to wet rot with abundant sporulation. These observations match earlier descriptions from West Africa (Markson *et al.*, 2014) and other regions such as China (Liu *et al.*, 2019) and Thailand (Pornsuriya *et al.*, 2017). Reports from Korea also indicate that the pathogen is capable of infecting unrelated hosts such as *Dahlia pinnata*, further emphasizing its adaptability and broad host range (Park *et al.*, 2016).

Despite the marked increase in peroxidase activity following infection, disease symptoms still developed in all crops.

This suggests that while peroxidase is an important part of the plant's defense, it may be insufficient to halt disease progression in the absence of other complementary defense mechanisms. Siddiqui *et al.* (2012) demonstrated that integrating biological control methods, such as compost tea treatments, could enhance host defenses and reduce disease severity. Given the economic importance of okra, corn, groundnut, and melon in southern Nigeria, and the environmental conditions favorable to *C. cucurbitarum*, integrated disease management approaches are necessary. Such approaches may include using resistant cultivars, applying biocontrol agents such as *Bacillus subtilis*, reducing crop canopy humidity, and employing plant-derived fungicides. These strategies have been shown to suppress *C. cucurbitarum* and enhance plant biochemical resistance (Emoghene & Okigbo, 2017; Li *et al.*, 2023).

The findings of this study confirm *C. cucurbitarum* as a significant pathogen in Calabar and demonstrate that peroxidase activity is a valuable biochemical marker of host defense activation. However, its effectiveness in limiting disease depends on the timing, intensity, and combination with other defense pathways, stress the need for integrated and environmentally sustainable control measures.

### CONCLUSION

The findings from this study confirm that *C. cucurbitarum* is capable of infecting multiple vegetable crops in Calabar, Southern Nigeria, including okra (*A. esculentus*), maize (*Z. mays*), groundnut (*A. hypogaea*), and melon (*C. melo*). The pathogen exhibited varying effects on the peroxidase activity of these crops, with some hosts showing elevated enzyme activity in response to infection, while others experienced a marked reduction. These differences suggest that *C. cucurbitarum* employs diverse infection strategies depending on the host species, which may contribute to its ability to infect a broad range of plants. The results highlight the potential of biochemical markers such as peroxidase activity in understanding host-pathogen interactions and assessing plant defense responses. This knowledge is vital for developing targeted and sustainable disease management strategies to reduce the impact of wet rot disease on vegetable production in tropical regions.

### RECOMMENDATIONS

From the findings of this study, it is recommended that:  
Further research should be carried out to determine the full host range of *C. cucurbitarum* in Calabar and other vegetable-growing regions of Nigeria.

Since peroxidase activity was shown to vary significantly among infected hosts, more studies should be undertaken to explore the relationship between enzymatic defense responses and resistance levels in different crops.

Farmers should be educated on early detection and management practices for *C. cucurbitarum*, including the potential integration of plant-derived bio-control agents as environmentally friendly alternatives to synthetic fungicides.

Breeding programs should consider incorporating biochemical defense traits, such as elevated peroxidase activity, into new crop varieties to enhance resistance against wet rot disease.

### REFERENCES

- Agrios, G. N., 2005. Plant pathology (5th ed.). Elsevier Academic Press.
- Barnett, H. L., and Hunter, B. B., 2006. Illustrated genera of imperfect fungi (4th ed.). The American Phytopathological Society.
- Bassey, R. A., Akwaji, P., and Godwin, M. U., 2018. Effect of *Choanephora cucurbitarum* on the morphology of some plants in the Malvaceae family in Calabar, Cross River State, Nigeria. *IOSR Journal of Pharmacy and Biological Sciences*, 13(1), 53–59.
- Biodgett, J. T., and Swart, W. J., 2002. Infection, colonization, and disease of *Amaranthus hybridus* leaves by the *Alternaria tenuissima* group. *Phytopathology*, 86, 1199–1205.
- Emoghene, A. O., and Okigbo, R. N., 2017. Phylloplane microbiota of *Amaranthus hybridus* and their effect on shoot disease caused by *Choanephora cucurbitarum*. *Tropical Agriculture*, 94(2), 123–131.
- Etebu, E., and Ekpo, E. J. A., 2007. An overview of crop diseases and pest problems in the Niger Delta region. *Niger Delta Biologia*, 2(1), 52–60.
- Hashem, M., and Farrag, E. S. H., 2005. Biological control of *Cercospora beticola* leaf spot of sugar beet and its associated invaders. *Egyptian Journal of Biotechnology*, 20, 312–327.
- Jones, J. D. G., and Dangl, J. L., 2006. The plant immune system. *Nature*, 444(7117), 323–329.

- Li, Y., Zhang, L., Wang, X., and Huang, H., 2023. Pathogenic diversity of *Choanephora cucurbitarum* infecting cucurbits in Eastern China. *Plant Pathology Journal*, 39(4), 555–565.
- Liu, S., Chen, X., and Zhang, H., 2019. First report of leaf blight caused by *Choanephora cucurbitarum* on okra in China. *Canadian Journal of Plant Pathology*, 41(2), 278–283.
- Markson, A. A., Udo, S. E., and Etukudo, M. M., 2014. Pathogenicity and host range of *Choanephora cucurbitarum* in vegetables cultivated in Nigeria. *Researchers Journal of Science and Technology*, 2(1), 45–53.
- Musa, A. D., Yusuf, G. O., Ojogbane, E. B., and Nwodo, O. F. C., 2010. Screening of eight plants used in folkloric medicine for the treatment of typhoid fever. *Journal of Chemical and Pharmaceutical Research*, 2(4), 7–15.
- Ngele, B. A., Agba, M. O., Basse, R. A., and Egeh, A. E., 2024. Effect of irrigation with household detergent on germination, activities of oxidative stress enzymes, and chlorophyll content of pod maize. *Pakistan Journal of Agricultural Research*, 37(3), 290–299.
- Park, M. J., Lee, J. Y., and Kim, H. T., 2016. First report of flower blight caused by *Choanephora cucurbitarum* on *Dahlia pinnata* in Korea. *Plant Disease*, 100(5), 1025.
- Passardi, F., Cosio, C., Penel, C., and Dunand, C., 2005. Peroxidases have more functions than a Swiss army knife. *Plant Cell Reports*, 24(5), 255–265.
- Pitt, J. I., and Poole, P. C., 1981. Calcium-induced conidiation in *Penicillium notatum* in submerged culture. *Transactions of the British Mycological Society*, 76, 0007–1536.
- Pornsuriya, C., Soyong, K., and Hyde, K. D., 2017. *Choanephora* rot of *Brassica chinensis* caused by *Choanephora cucurbitarum* in Thailand. *Journal of Plant Protection Research*, 57(1), 96–101.
- Saha, O., and Haque, M. E., 2015. Prevalence and control of *Choanephora* rot of vegetables in tropical areas. *Journal of Agricultural Technology*, 11(2), 381–390.
- Siddiqui, Y., Meon, S., Ismail, R., and Rahmani, M., 2012. Bio-potential of compost tea from agro-waste to suppress *Choanephora cucurbitarum*, the causal pathogen of wet rot of okra. *Biological Control*, 64(2), 103–109.
- Singh, R. S., 2002. *Plant diseases* (8th ed.). Oxford and IBH Publishing Co. Pvt. Ltd.
- Umana, E. J., and Ikotun, T., 2000. Effect of pH on enzyme productivity by three pathotypes of *Choanephora cucurbitarum*. *Global Journal of Pure and Applied Sciences*, 6, 413–418.