ORIGINAL RESEARCH REPORT NIGER. J. PLT. PROT. 40(2):112-121(2026)

# EFFECTS OF MAJOR SESAME PATHOGENIC FUNGI ON CHLOROPHYLL CONTENT AND FOLIAR DISEASE OCCURRENCE ON TWO SESAME (*Sesamum indicum* L.) VARIETIES

**[1]ANJORIN TOBA SAMUEL, [1]AKINBOLA HANNAH, [2]WADZANI PALNAM DAUDA**

[1]Department of Crop and Environmental Protection, Faculty of Agriculture, University of Abuja

[2]Crop Science Unit, Department of Agronomy, Federal University Gashua, Gashua, P.M.B. 1005, Yobe State, Nigeria

Corresponding author's email: toba.anjorin @uniabuja.edu.ng; GSM: 08062242866

## SUMMARY

**This study evaluated the growth performance and responses of two sesame varieties, Ex Sudan and Gwagwalada Local, to three fungal pathogens under screenhouse conditions. The experiment was conducted in a screenhouse at the University of Abuja Teaching and Research Farm, Nigeria, using a 2 × 3 factorial arrangement in a Completely Randomized Design (CRD) with four replications. We inoculated two sesame varieties with *Alternaria sesami, Cercospora sesami, and Helminthosporium sesami,* along with control, which was the uninoculated plot. Growth, disease incidence, severity, and using Soil Plant Analysis Development (SPAD), chlorophyll were assessed periodically and analysed using ANOVA and correlation analysis. Following inoculation, disease incidence and severity increased from 7 to 21 days after inoculation (DAI). At 21 days, *Helminthosporium* produced the highest disease incidence (96.38%) and severity (85.38%), followed by *Cercospora* (77.00%; 62.38%) and *Alternaria* (60.75%; 45.63%), while controls remained minimally affected. All pathogens reduced chlorophyll content, with *Helminthosporium* causing the greatest decline (24.3%) in Gwagwalada Local Variety. There was no significant difference ($p \geq 0.05$) in the disease infection responses between the two sesame varieties. Variety and variety × pathogen effects were non-significant, indicating comparable disease responses. Chlorophyll content at 21 days was strongly negatively correlated with disease incidence ($r = -0.824$) and severity ($r = -0.803$; $p < 0.05$). The findings demonstrate differential pathogenicity among the fungi and establish SPAD chlorophyll measurements as a useful non-destructive indicator of disease-associated physiological stress. Future investigations should include field validation of the current findings.**

**Key words:** Chlorophyll content; Disease severity; Fungal pathogens; Sesame; SPAD.

## INTRODUCTION

Sesame (*Sesamum indicum* L.), commonly known as benniseed, is an important oilseed crop cultivated widely in tropical and subtropical regions. It contributes to food and nutritional security, rural livelihoods, and the edible-oil and industrial sectors because of its high-quality oil and diverse applications in food, cosmetics and pharmaceuticals. Global sesame production has remained above 6 million tonnes annually in recent years, reflecting its continuing importance in international oilseed production and trade (1). Despite its economic and export importance,

productivity remains below attainable levels because of interacting agronomic, environmental and biotic constraints (2).

Foliar fungal diseases are important constraints to sesame production because they reduce functional leaf area, interfere with photosynthesis and may accelerate premature senescence. Important foliar pathogens include *Cercospora* spp., *Alternaria* spp. and *Helminthosporium spp*., which cause leaf spots, blights, chlorosis, necrosis and defoliation (3). Their development is favoured by warm temperatures, high humidity and prolonged leaf wetness, while disease severity varies with pathogen pressure, environmental conditions and host genotype (4,5). The effects of foliar fungal infection extend beyond visible symptoms to physiological processes that influence plant growth and productivity (6). Cercospora leaf spot and Alternaria leaf blight are reported to cause 20–55% yield losses in tropical sesame production systems, alongside reductions in seed quality (7).

Chlorophyll is essential for photosynthetic light capture and carbon assimilation, processes that contribute to biomass production and ultimately crop yield (8). Pathogen infection may disrupt chloroplast structure and function, impair photosynthesis, and promote chlorophyll degradation through tissue damage, oxidative stress, and pathogen-induced physiological disturbances (6). Recent transcriptomic studies of sesame responses to fungal infection have demonstrated alterations in pathways associated with carbon metabolism, plant–pathogen interactions and defence responses, providing evidence of substantial physiological disruption during disease development (8). Chlorophyll content can therefore serve as a useful physiological indicator of pathogen-induced stress, as pathogen infection can alter photosynthetic performance and chlorophyll-related responses before or alongside visible disease symptoms (9,10). Rapid, non-destructive Soil Plant Analysis Development (SPAD) measurements offer a practical way to monitor relative chlorophyll status and detect disease-associated physiological changes (10).

Sesame growth involves stem elongation, branching and leaf production, which depend on sustained photosynthetic activity and healthy foliage. Reduction in chlorophyll and functional leaf area caused by foliar pathogens may restrict plant height, leaf production and biomass accumulation. However, these effects vary among genotypes because sesame varieties differ in morphological, physiological, biochemical and molecular defence mechanisms. Recent studies have demonstrated substantial variation in disease reaction among sesame genotypes and identified molecular mechanisms associated with resistance to important fungal pathogens (11).

Despite these advances, limited information exists on the relationship between specific foliar fungal pathogens, disease severity, and chlorophyll content of locally relevant Nigerian sesame varieties. In particular, responses of Ex Sudan and Gwagwalada Local to *Cercospora sesami*, *Alternaria sesami* and *Helminthosporium sesami* under controlled conditions remain insufficiently documented. Differences in chlorophyll retention and growth under equivalent pathogen pressure may help identify varieties with greater resistance or tolerance and provide useful criteria for disease screening, breeding and integrated disease management. Therefore, this study evaluated the effects of *Cercospora sesami*, *Alternaria sesami* and *Helminthosporium sesami* on growth characteristics,

chlorophyll content, disease incidence and severity of Ex Sudan and Gwagwalada Local sesame varieties under controlled conditions.

## MATERIALS AND METHODS

### Study Location and Experimental Conditions

The experiment was conducted between February and June, 2026 in a screenhouse at the Teaching and Research Farm, University of Abuja, Federal Capital Territory, Nigeria (9°02′N, 7°26′E; 360 m above sea level). Temperature and relative humidity (RH): Day and night temperatures ranged from 27.2–32.4°C and 21.8–25.1°C, respectively, and RH from 68- 87%.

### Soil Preparation and Experimental Design

Sandy-loam soil (78% sand, 14% silt and 8% clay) was collected from 0–20 cm depth at the University farm. The soil had pH 6.4, organic carbon 1.18%, total nitrogen 0.087%, available phosphorus 11.8 mg $kg^{-1}$, exchangeable potassium 0.21 cmol $kg^{-1}$ and CEC 8.2 cmol $kg^{-1}$. It was steam-sterilized at 100°C for 2 h twice, separated by 48 h interval and mixed with sand and rice husk at 3:2:1 (v/v/v). The medium was placed in 7-L plastic pots.

A **2 × 3 factorial experiment** was arranged in a Completely Randomized Design with four replications, giving 32 experimental units. The factors comprised two sesame varieties (Ex Sudan and Gwagwalada Local) and four inoculation treatments: uninoculated control, *Alternaria sesami*, *Cercospora sesami* and *Helminthosporium sesami*. Each experimental unit consisted of one pot containing three plants. The treatments were randomized among experimental pots. Irrigation was maintained at approximately 65% field capacity, and no fungicide was applied.

### Plant Materials and Fungal Isolates

Seeds of Ex Sudan were obtained from the National Cereals Research Institute, Badeggi, Nigeria. Seeds of Gwagwalada Local were obtained from a farmer's store in Gwagwalada Abuja, Nigeria. Visually healthy seeds were surface disinfected in 1% sodium hypochlorite for 1 min, and rinsed with sterile distilled water.. Seedlings were subsequently thinned to one plant per pot.

The molecularly identified fungal isolates (*A. sesami*, *C. sesami* and *H. sesame)* from the repository of the Department of Crop Protection, Ahmadu Bello University, Zaria were collected and sub-cultured, by plating them on Potato Dextrose Agar (PDA)

### Inoculum Preparation and Inoculation

Seven-day-old cultures were flooded with 10 mL of sterile distilled water containing 0.01% Tween 20, and the conidia were gently dislodged from the culture surface using a sterile glass rod (or sterile inoculating loop). The resulting conidial suspension was filtered through sterile cheesecloth to remove mycelial fragments. Conidial concentrations were determined with a haemocytometer and adjusted to **$1 \times 10^6$ conidia $mL^{-1}$.** Inoculation was conducted at 49 days after planting (DAP), corresponding approximately to early flowering.

Plants were lightly misted with sterile water 2 h before inoculation. Each fungal suspension was uniformly sprayed onto the foliage using a hand atomizer until leaf surfaces were thoroughly wetted. Control plants received sterile water containing 0.01% Tween 20. Following inoculation, plants were maintained under high humidity for 48 h by covering each inoculated plant with a transparent polyethylene humidity bag supported by stakes to facilitate infection and subsequently returned to normal screenhouse conditions.

### Assessment of Disease Incidence and Chlorophyll

Plant height and number of fully expanded leaves were recorded weekly after inoculation. Plant height was measured from the soil surface to the apical growing point, while leaf number was determined for each plant and averaged per pot. Disease

incidence and severity were assessed at 7, 14 and 21 days after inoculation (DAI). Disease incidence was calculated as:
Disease incidence (%)=Total plants assessed/ Number of infected plants×100
Disease severity was estimated as the percentage of leaf area showing disease symptoms.
SEV% = [Σ(rating × number of plants at that rating)] / (total plants × 9) × 100 (12)
This was scored using a modified 0–9 rating scale (13):

| Rating | Description |
|---|---|
| 0 | No symptoms visible |
| 1 | 1–10% leaf area affected |
| 3 | 11–25% leaf area affected |
| 5 | 26–50% leaf area affected |
| 7 | 51–75% leaf area affected |
| 9 | >75% leaf area affected or plant wilted/dead |

Severity percentage per pot was calculated as:

Relative chlorophyll content was measured using a **SPAD-502Plus meter** before inoculation and at 7, 14 and 21 DAI (**14**). Three readings from 3 pots per plot were taken from the third fully expanded leaf below the apex and averaged. Measurements were conducted between 8.00 am and 10.00 am to minimize diurnal variation. SPAD values were interpreted as relative chlorophyll content rather than absolute chlorophyll concentration.

**Statistical Analysis**

Data collected were analysed using IBM SPSS Statistics version 29. Mean values of the three readings per plot were used. Treatment means were separated using Tukey's HSD test at $\mathbf{p \leq 0.05}$, with effect sizes and 95% confidence intervals reported. Pearson correlation analysis assessed relationships among disease severity, SPAD values, and growth characteristics.

## . RESULTS

The two-way ANOVA showed a significant effect of fungal treatment on mean SPAD values ($F_{3,24} = 4.064$, $p = 0.018$, partial $\eta^2 = 0.337$), indicating that treatment accounted for approximately 33.7% of the variance in mean SPAD values after accounting for error. The effects of variety ($F_{1,24} = 0.786$, $p = 0.384$, partial $\eta^2 = 0.032$) and the Variety × Treatment interaction ($F_{3,24} = 0.385$, $p = 0.765$, partial $\eta^2 = 0.046$) were not significant.

**Table 1: ANOVA of Mean Chlorophyll Content in the foliage of two fungal-inoculated sesame varieties**

| Source | SS | Df | MS | F | p-value | Partial $\eta^2$ |
|---|---|---|---|---|---|---|
| Variety | 21.000 | 1 | 21.000 | 0.786 | 0.384 | 0.032 |
| Treatment | 325.777 | 3 | 108.592 | 4.064 | 0.018 | 0.337 |
| Variety × Treatment | 30.829 | 3 | 10.276 | 0.385 | 0.765 | 0.046 |
| Error | 641.321 | 24 | 26.722 | – | – | – |

*SS = Sum of Squares. MS = Mean Square. Error df = 24.*

**Effect of Fungal Pathogens on Chlorophyll Content**

The foliage of the plants under the control plots maintained stable chlorophyll levels (38.55 - 40.38 SPAD throughout the experiment (Table 2). All three fungal inoculations were associated with a progressive decline in SPAD values. At 7 DAI, all treatment groups had comparable SPAD values (37.95 - 40.80); by 14 DAI, a difference was evident; and by 21 DAI, all fungal treatments had produced significantly lower SPAD readings relative to the control ($p \leq 0.05$). At 21 DAI, the lowest chlorophyll values were recorded in *Helminthosporium*-inoculated plants (28.98–31.70 SPAD),

At 7 DAI, the mean chlorophyll values for the two sesame varieties were statistically similar across all treatment groups, indicating that inoculation had not yet induced measurable physiological change at this early time-point (Table 3). At 14 DAI, all fungal treatments had significantly lower chlorophyll than controls, though fungal treatments remained similar to each other. By 21 DAI, *Helminthosporium*-inoculated plants had lost the most chlorophyll (−9.75 SPAD; −24.3%), followed by *Cercospora* (−8.07 SPAD; −20.1%) and *Alternaria* (−6.10 SPAD; −16.0%). Control plants showed a marginal increase (+1.67 SPAD; +4.3%), consistent with continued vegetative growth in the absence of disease pressure.

**Table 2: Chlorophyll content (SPAD Index) of two sesame varieties' leaves inoculated with pathogenic fungi**

| Variety | Treatments | SPAD Index | | |
|---|---|---|---|---|
| | | 7 DAI | 14 DAI | 21 DAI |
| Ex Sudan | *Alternaria sesami* | 38.28 ± 3.9b | 34.83 ± 3.3a | 32.15 ± 3.3b |
| | *Cercospora sesami* | 39.83 ± 3.6b | 34.33 ± 2.9a | 30.93 ± 3.0b |
| | *Helminthosporium sesami* | 39.38 ± 2.9b | 32.93 ± 2.9b | 28.98 ± 3.2c |
| | Control | 38.73 ± 1.2b | 39.50 ± 1.1a | 40.38 ± 1.2a |
| Gwagwalada Local | *Alternaria* | 37.95 ± 2.3b | 34.93 ± 2.0a | 31.88 ± 1.9b |
| | *Cercospora* | 40.38 ± 2.9b | 36.75 ± 3.2a | 33.13 ± 3.0b |
| | *Helminthosporium* | 40.80 ± 3.4b | 35.88 ± 2.8a | 31.70 ± 2.9b |
| | Control | 38.55 ± 4.0b | 39.25 ± 3.9a | 40.25 ± 3.8a |

*Values are means ± SD (n = 4 per treatment -variety cell). Different superscript letters within a column indicate significant differences at p < 0.05 (Tukey HSD)*

**Effects of Fungal inoculation on Disease Incidence on the foliage of two sesame varieties**

Disease incidence increased in the foliage from 7 to 21 DAI across all inoculated treatments (Table 4). At 21 DAI, *Helminthosporium*-inoculated plants recorded the highest incidence (96.38%), followed by *Cercospora* (77.00%) and *Alternaria* (60.75%); all were significantly greater than the control (3.25%). Low incidence was observed in the uninoculated control plants.

**Table 4: Effects of Pathogenic fungi on Disease Incidence on of sesame varieties**

| Treatment | 7 DAI (%) | 14 DAI (%) | 21 DAI (%) |
|---|---|---|---|
| Control | 0.88 ± 0.84d | 1.88 ± 0.84d | 3.25 ± 1.17d |
| *Alternaria sesami* | 28.63 ± 2.83c | 44.50 ± 3.89c | 60.75 ± 4.10c |
| *Cercospora sesami* | 40.63 ± 3.38b | 59.00 ± 3.78b | 77.00 ± 4.38b |
| *Helminthosporium sesami* | 58.75 ± 4.20a | 79.75 ± 4.03a | 96.38 ± 3.07a |

*Values are means ± SD (n = 8, pooled across varieties). Different superscript letters within a column indicate significant differences at p < 0.05 (Tukey HSD).*

**Effects of selected pathogenic fungi on Mean Disease Severity on the Foliage of Sesame**

Mean disease severity in the leaves of the two sesame varieties increased across all inoculated treatments from 7 to 21 DAI (Figure 1). By 21 DAI, *Helminthosporium* spp produced the highest severity (85.38%), followed by *Cercospora* spp (62.38%) and *Alternaria* spp (45.63%). Control plants maintained minimal severity throughout (0.50–1.63%). *Helminthosporium* produced the greatest severity in the Gwagwalada Local variety at all time points.

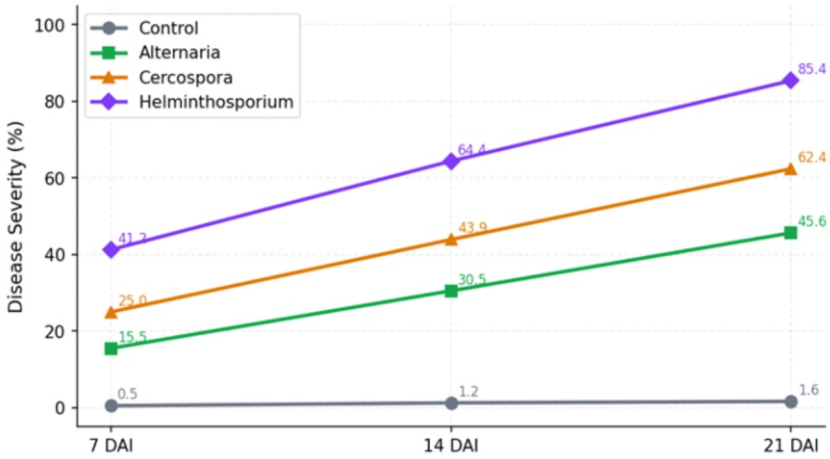



*Figure 1: Mean Disease severity (%) at 7, 14, and 21 days after inoculation (DAI) for four treatment groups.*

**Relationships Among Variables (Correlation Analysis)**

Pearson correlation analysis revealed strong negative associations between chlorophyll at 21 DAI and both disease incidence ($r = -0.824$, $p < 0.05$) and disease severity ($r = -0.803$, $p < 0.05$; Table 5) These findings are consistent with Devadas et al. (2021), who reported $r = -0.85$ to $-0.92$ between SPAD values and rust severity in wheat, and Singh et al. (2024), who documented $r = -0.78$ to $-0.88$ between chlorophyll and *Cercospora* severity in sesame. There was no significant association detected between SPAD and disease incidence at 7 DAI. The strong positive correlation indicates that incidence and severity increased concurrently under the experimental conditions.

SPAD readings at 21 DAI were strongly associated with disease incidence and severity under the experimental conditions,

supporting the utility of SPAD measurements as a rapid, non-destructive tool for assessing disease-induced physiological damage. The temporal pattern of no correlation at 7 DAI, moderate at 14 DAI, and very strong at 21 DAI likely reflects the time required for pathogens to establish infection, develop lesions, and induce measurable chlorophyll degradation. SPAD readings provide indirect estimates of relative chlorophyll; biochemical validation is recommended in future studies. The very strong correlations observed may partly reflect the controlled environment; similar relationships in field settings would be expected to be weaker due to greater environmental variability.

**Table 5: Selected Pearson correlation coefficients from the Analysis**

| Variable Pair | r | p-value | Strength | Biological Interpretation |
|---|---|---|---|---|
| SPAD21DAI vs. INC21DAI | -0.824 | <0.05 | Very strong (-) | Higher incidence linked to lower chlorophyll at 21 DAI |
| SPAD21DAI vs. SEV21DAI | -0.803 | <0.05 | Very strong (-) | Higher severity linked to lower chlorophyll at 21 DAI |
| SPAD14DAI vs. INC14DAI | -0.582 | <0.05 | Moderate (-) | Mid-course relationship at 14 DAI |
| SPAD14DAI vs. SEV14DAI | -0.565 | <0.05 | Moderate (-) | Developing infection apparent at 14 DAI |
| SPAD7DAI vs. INC7DAI | +0.148 | 0.418 | Negligible | No chlorophyll-disease relationship at 7 DAI stage |
| INC21DAIvs. SEV21DAI | +0.994 | <0.05 | Very strong (+) | Incidence and severity co-progressed throughout |
| SPAD14DAI vs.SPAD21DAI | +0.940 | <0.05 | Very strong (+) | Strong positive association between SPAD values at 14 and 21 DAI |

*All correlations involving* SPAD21DAI*, INC, and SEV variables are significant at p < 0.05.* SPAD7DAI *vs. INC7DAI are not significant (p = 0.418).*

## DISCUSSION

The results showed a progressive decline in chlorophyll content, measured as SPAD values, following inoculation with the three fungal pathogens. The decline was more evident at 14 and 21 days after inoculation (DAI), particularly in plants inoculated with *Helminthosporium spp*, *Cercospora* spp and *Alternaria* spp In contrast, control plants maintained relatively stable or slightly increased SPAD values throughout the assessment period. This indicates that fungal infection was associated with a reduction in leaf chlorophyll during disease development.

The observed reduction is consistent with previous findings that *Alternaria sesami* infection can cause structural changes in chloroplasts and reductions in chlorophyll and other physiological constituents of sesame leaves (15). However, the present results should be interpreted as an association between disease development and reduced chlorophyll status rather than evidence of a specific biochemical mechanism, since chloroplast structure or photosynthetic activity was not directly measured.

The ANOVA showed a significant effect of fungal treatment on chlorophyll content, whereas variety and the variety × treatment interaction were not significant. Thus,

under the conditions of this screenhouse experiment, fungal infection had a stronger detectable effect on SPAD values than varietal differences. Disease incidence and severity increased progressively from 7 to 21 DAI in the inoculated treatments, whereas control plants showed only very low levels of disease. At 21 DAI, *Helminthosporium* spp. produced the highest mean disease incidence and severity, followed by *Cercospora* spp and *Alternaria spp*. These differences indicate that the three pathogens differed in their ability to establish and develop disease under the experimental conditions.

The occurrence and importance of *Cercospora* leaf spot and *Alternaria* leaf blight in sesame have also been documented under field conditions in Nigeria. Enikuomehin *et al.* (17) reported substantial incidence and severity of these foliar diseases in sesame and demonstrated that crop arrangement and environmental conditions could influence disease development. Therefore, the present findings are consistent with earlier Nigerian reports, although the relative disease response observed here should be regarded specifically as a response under the controlled screenhouse conditions of this experiment.

The correlation analysis showed strong negative relationships between chlorophyll content and both disease incidence and severity at 21 DAI. Thus, higher disease development was associated with lower SPAD values. The relationship was weaker and nonsignificant at the earliest assessment, suggesting that the physiological effect of infection became more evident as disease progressed. This pattern agrees with Lubaina &Murugan. (15), who reported physiological and ultrastructural changes, including reduced chlorophyll, following *A. sesami* infection in sesame. The strong association observed in the present study suggests that SPAD measurements may provide a useful supplementary indicator of disease-related physiological stress. Nevertheless, SPAD is not disease-specific, and the correlations do not establish a causal relationship between chlorophyll loss and disease severity.

The lack of significant variety and variety × treatment effects suggests that the two sesame varieties did not differ significantly in their overall SPAD response to fungal inoculation under the conditions of this study. This finding should not, however, be interpreted as proof that the varieties possess identical levels of genetic resistance. Previous Nigerian work has demonstrated variation among sesame cultivars in response to *Alternaria* leaf blight (17). Differences in cultivar response may therefore become more apparent under different pathogen populations, environmental conditions or longer periods of disease development.

The progressive increase in disease incidence and severity observed in the inoculated plants highlights the importance of early disease management. Previous Nigerian studies have shown that cultural practices such as crop arrangement and population density can influence the development of sesame foliar diseases (16). In addition, Jimoh et al. (18) reported that plant extracts of *Tithonia diversifolia* and *Ocimum gratissimum* reduced the incidence and severity of *Cercospora* leaf spot and *Alternaria* leaf blight in sesame.

## CONCLUSION

The present findings therefore support the need for an integrated approach involving the use of less susceptible cultivars, appropriate crop management and effective

disease-control measures. Further field studies are required to determine whether the responses observed under screenhouse conditions are consistent across different production environments and seasons.

## LITERATURE CITED

1. **Food and Agriculture Organization of the United Nations (FAO) (2018).** *FAOSTAT statistical database: Crops and livestock products—Sesame production.* Rome, Italy: FAO.
2. **Gani, M., & Tunwari, B. A. (2023).** Sesame (*Sesamum indicum* L.) baseline survey in Taraba State, Nigeria. *Greener Journal of Agricultural Sciences, 13*(2), 113–118. https://doi.org/10.15580/gjas.2023.2.080323074
3. **Anjorin, T. S., Salako, E. A., & Nwogbo, O. (2016).** Effects of botanical extracts on fungal load of sesame (*Sesamum indicum* L.) seeds. *International Journal of Science and Research, 5*(2).
4. **Adhikary, N. K., Roy, K., Biswas, K. K. (2020).** Influence of weather parameters on foliar diseases of sesame (*Sesamum indicum* L.) in coastal ecosystem of West Bengal, India. *International Journal of Environment and Climate Change, 10*(9), 83–88. https://doi.org/10.9734/ijecc/2020/v10i930231
5. **Anjorin, T. S.**, & Inje, T. V. (2014). Effect of total aflatoxin on the growth characteristics and chlorophyll level of sesame (*Sesamum indicum* L.). *New York Science Journal, 7*(4), 8–13.
6. **Cheaib, A., & Killiny, N. (2025).** Photosynthesis responses to the infection with plant pathogens. *Molecular Plant-Microbe Interactions, 38*(1), 9–29. https://doi.org/10.1094/MPMI-05-24-0052-CR
7. **Jimoh, M., Enikuomehin, O. A., Afolabi, C. G., & Olowe, V. I. O. (2021**). Improving the efficacy of *Tithonia diversifolia* extract in management of foliar diseases of sesame intercropped with maize under tropical conditions. *Agricultura Tropica et Subtropica, 54*, 165–173.
8. **Croft, H., Chen, J. M., Luo, X., Bartlett, P., Chen, B., & Staebler, R. M. (2017).** Leaf chlorophyll content as a proxy for leaf photosynthetic capacity. *Global Change Biology, 23*(9), 3513–3524.
9. **Barón, M., Pineda, M., & Pérez-Bueno, M. L. (2016).** Picturing pathogen infection in plants. *Zeitschrift für Naturforschung C, 71*(9–10), 355–368. https://doi.org/10.1515/znc-2016-0134
10. **Oh, D., Ryu, J.-H., Oh, S., Jeong, H., Park, J., Jeong, R.-D., Kim, W., & Cho, J. (2018).** Optical sensing for evaluating the severity of disease caused by *Cladosporium* sp. in barley under warmer conditions. *The Plant Pathology Journal, 34*(3), 236–240. https://doi.org/10.5423/PPJ.NT.11.2017.0247
11. **Bevanur, A., Jayalakshmi, S. K., Bharath, M., Manthesha, H. D., Savitha, A. S., Chavan, S. S., & Suvarna. (2024).** Screening of sesame germplasm against major foliar diseases. *International Journal of Advanced Biochemistry*

*Research, 8*(4), 710–714. https://doi.org/10.33545/26174693.2024.v8.i4i.1032

12. **Bock, C. H., Chiang, K. S., & Del Ponte, E. M. (2022).** Plant disease severity estimated visually: A century of research, best practices, and opportunities for improving methods and practices to maximize accuracy. *Tropical Plant Pathology, 47*, 25–42.
13. **Madhusaisri, S., Reddy, B. R. K., Bharathi, D., & Pradeep, M. (2025).** Field screening of sesame (*Sesamum indicum* L.) genotypes for resistance to *Alternaria* leaf spot. *Andhra Pradesh Journal of Agricultural Sciences, 11*(4), 318–324.
14. **Parry, C., Blonquist, J. M., Jr., Bugbee, B. (2014).** In situ measurement of leaf chlorophyll with a SPAD-502 meter. *Photosynthesis Research, 121*(2–3), 251–261. https://doi.org/10.1007/s11120-014-9986-8
15. **Lubaina, A. S., & Murugan, K. (2013).** Ultrastructural changes and oxidative stress markers in wild and cultivar *Sesamum orientale* L. following *Alternaria sesami* (Kawamura) Mohanty and Behera inoculation. *Indian Journal of Experimental Biology, 51*(8), 670–680.
16. **Enikuomehin, O. A., Jimoh, M., Olowe, V. I. O., Ayo-John, E. I., & Akintokun, P. O. (2011).** Effect of sesame (*Sesamum indicum* L.) population density in a sesame/maize (*Zea mays* L.) intercrop on the incidence and severity of foliar diseases of sesame. *Archives of Phytopathology and Plant Protection, 44*(2), 168–178. https://doi.org/10.1080/03235400902952244
17. **Enikuomehin, O. A., Aduwo, A. M., Olowe, V. I. O., Popoola, A. R., & Oduwaye, A. (2010).** Incidence and severity of foliar diseases of sesame (*Sesamum indicum* L.) intercropped with maize (*Zea mays* L.). *Archives of Phytopathology and Plant Protection, 43*(10), 972–986. https://doi.org/10.1080/03235400802214810
18. **Jimoh, M., Enikuomehin, O. A., Afolabi, C. G., Olowe, V. I. O., & Egbontan, A. (2016).** Achieving improved control of foliar diseases of sesame (*Sesamum indicum* L.) intercropped with maize (*Zea mays* L.) through foliar spray of plant extracts. *Archives of Phytopathology and Plant Protection, 49*(19–20), 1–15. https://doi.org/10.1080/03235408.2016.1245061