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RESEARCH ARTICLE

# Moringa and Neem Leaf Extracts Enhance Resistance to *Sclerotinia Sclerotiorum* and Improve Yield in Tomato Genotypes

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A B S T R A C T

Tomato production is constrained by diseases such as white mold, stem rot, and foliage wilt caused by *Sclerotinia sclerotiorum*. This study evaluated the incidence of *S. sclerotiorum*, the effectiveness of botanical extracts—*Moringa oleifera* (Moringa) and *Azadirachta indica* (Neem)—in disease management, and the performance of different tomato genotypes under pathogen pressure. Disease incidence was significantly reduced by Moringa extract, achieving a 2.6% incidence compared to 13% with Neem and 37% in untreated plants. Among the genotypes tested, a local variety showed superior fruit production and vigor despite disease challenge. These findings demonstrate the potential of botanical extracts, particularly Moringa, as sustainable alternatives for managing *S. sclerotiorum* and highlight the value of tolerant tomato genotypes for improving yield. The study provides insights for integrated disease management strategies that can enhance tomato productivity under pathogen pressure.

**Keywords**: Tomato, *Sclerotinia sclerotiorum*, botanical extracts, Moringa, Neem, disease management

## INTRODUCTION

Tomato (*Solanum lycopersicum*), a key horticultural crop worldwide, is highly valued for its economic and nutritional importance (Safdar *et al.,* 2023; Matloob *et al.,* 2025). Despite advances in cultivation and breeding, tomato production is significantly constrained by fungal pathogens, with *Sclerotinia sclerotiorum*, the causal agent of white mold, being particularly destructive. This pathogen infects multiple plant parts at various growth stages, causing stem rot, leaf blight, and fruit decay, and is favored by high humidity and moderate temperatures (Bolton *et al.,* 2006; Butt *et al.,* 2021; Li *et al.,* 2022). White mold leads to substantial yield losses globally and poses challenges for sustainable tomato production.

Conventional control strategies, including cultural practices and chemical fungicides, often provide limited protection. Overreliance on fungicides has led to the emergence of resistant *S. sclerotiorum* populations, reducing their long-term efficacy (Ashraf *et al.,* 2019; Wang *et al.,* 2023). Biological control using microorganisms such as *Trichoderma* spp. offers promise, but cost, accessibility, and environmental adaptability can limit their practical application (Nasir *et al.,* 2023). In this context, crude botanical extracts have gained attention as eco-friendly and cost-effective alternatives. Extracts from *Moringa oleifera* and *Azadirachta indica* exhibit antifungal activity against several plant pathogens, including *S. sclerotiorum*, and offer potential for integration into sustainable disease management strategies (Amenu *et al.,* 2024; Ali *et al.,* 2025).

Given the need for environmentally safe and effective disease management approaches, this study aimed to: (i) evaluate the incidence and severity of *S. sclerotiorum* on tomato, (ii) assess the efficacy of *Moringa oleifera* and *Azadirachta indica* extracts in suppressing disease, and (iii) identify tomato genotypes with tolerance to white mold. By addressing these objectives, the study provides insights into sustainable strategies for improving tomato productivity under fungal disease pressure.

## MATERIALS AND METHODS

**Acquisition of materials:** The experiment was conducted at the screen house of Bowen University, Iwo, Osun State, Nigeria. The tomato genotypes ($H_1$ to $H_4$, $W_5$ to $W_8$) were gotten from the National Horticultural Institute of Nigeria while the $I_9$ (Beske) was obtained within the locality of Iwo, Osun State, Nigeria. $H_1$ to $H_4$ (NHTO-0752, NHTO-0400, NHTO-0239, NHTO-0410) are hybrid genotypes while $W_5$ to $W_8$ (LA-4345, LA-1714, LA-3315, AVTO-2133) are wild genotypes. Neem leaves and Moringa leaves were sourced within Bowen University, Iwo, Osun state. Isolates of *Sclerotinia sclerotiorum* was gotten from Pathology Laboratory of the International Institute of Tropical Agriculture (IITA), Ibadan. Seeds of the nine (9) genotypes of tomato were sown in nursery trays filled with sterilized soil in the screen house for twenty-one (21) days. After which the seedlings were transplanted into well labelled sterile 20 cm diameter x 25–30 cm height polythene bags.

Isolates of *Sclerotinia sclerotiorum* were sub-cultured in the laboratory at Bowen University. Potato Dextrose Agar (PDA) served as the culture medium. Once prepared, the medium was autoclaved at 121°C and 15 psi for 20 minutes, then poured into sterilized petri dishes for sub-culturing the pathogen (Usman *et al.,* 2025; Ahmad *et al.,* 2024; Tahir *et al.,* 2023).

**Preparation of Inoculum:** Two weeks old *Sclerotinia sclerotiorum* cultures were flooded with 10 ml of sterile distilled water containing 1% (v/v) concentration of the surfactant tween 20. Spores and conidia on agar surfaces were dislodged using a sterile inoculating wire loop and sieved through a double layer of sterile muslin cloth to remove mycelial mats and collect spore suspensions. Stock concentrations of fungal spore suspensions were diluted serially to a concentration of $10^{-7}$ at $1\times10^{6}$ ascospores/ml (using an hemocytometer) for onward inoculation onto healthy tomato seedlings. After 2 weeks of transplanting, the inoculum was applied to the stem base of the plant right next to the soil. 100 µl of inoculum was applied per plant.

**Preparation of Botanical extracts:** Healthy leaves of moringa and neem plants were collected for the preparation of botanical extracts. Aqueous extracts of each plant were prepared separately by mechanically blending 720 g of the leaves with 7200 ml of sterile distilled water using a laboratory blender, resulting in a 10% (w/v) extract. The mixture was then filtered through four layers of cheesecloth to remove plant debris, and the clear extracts were collected in a container.

**Treatment Application:** The experiment was arranged in a randomized complete block design with four replicates. The treatments included:

a) Control (no inoculation, no extract application)
b) *Sclerotinia sclerotiorum* inoculum + neem extract
c) *Sclerotinia sclerotiorum* inoculum + moringa extract
d) Inoculation only (no extract application)

Two weeks after transplanting, 100 µl of inoculum were applied to the stem base of each plant, directly adjacent to the soil. Botanical extract was applied to the plants at an application rate of 50 ml per plant per treatment using hand sprayers every three (3) days for 30 days. The soil was also sprayed.

## DATA COLLECTION

Data were collected weekly for four weeks on the number of leaves, number of wilted leaves, number of flowers, and number of fruits. To determine disease incidence, the number of leaves and wilted leaves were recorded. The disease incidence of white mold caused by *S. sclerotiorum* was calculated as follows:

$$\text{DI (\%)} = \left(\frac{\text{NI}}{\text{TN}}\right) X\ 100$$

Where:

DI = Disease Incidence (%)
NI = Number of Infected plant part
TN = Total Number of plant part

## STATISTICAL ANALYSIS

Data was analyzed using the Statistical Package for Social Science (SPSS) software. Mean disease incidence values were compared using the Duncan Multiple Range Test (DMRT) at a significance level of $p \leq 0.05$.

## RESULTS

**Pathogenesis of *Sclerotinia Sclerotiorum:*** Disease symptoms appeared on the infected (inoculated only, no treatment) tomato plants one week after inoculation, with the leaves beginning to wilt. Table 1 showed a steady increase in leaf wilting from week 7 to week 10 across all genotypes. Figure 1 illustrated the initial variation in disease incidence among the genotypes, with genotype H3 exhibiting the highest incidence at 52%, while genotypes

W6 and W8 had the lowest incidences of 2% and 3%, respectively. By week 8, genotype H3 recorded the highest disease incidence of 57%, whereas genotypes W6 and W8 continued to show the lowest incidences at 7% and 8%, respectively. In week 9, genotype H3 still had the highest disease incidence at 53%, while genotype W5 recorded the lowest at 18%. By week 10, disease incidence in genotype W6 rose sharply to 51%, marking the highest number of wilted leaves after a prolonged infestation period, whereas genotype W8 maintained the lowest incidence at 29%, closely followed by genotype H4 at 28%.

Table 1. Genotype-treatment Relationship weeks 7-10

| Genotype | Week 7 | | Week 8 | | Week 9 | | Week 10 | |
|---|---|---|---|---|---|---|---|---|
| | Number of Leaves | Number of wilted leaves | Number of Leaves | Number of wilted leaves | Number of leaves | Number of wilted leaves | Number of leaves | Number of wilted leaves |
| H1 NHTO-0752 | 11.19$^{b}$ | 2.13$^{abc}$ | 12.19$^{ab}$ | 2.38$^{abc}$ | 12.00$^{b}$ | 2.63$^{ab}$ | 11.94$^{b}$ | 1.75$^{ab}$ |
| H2 NHTO-0400 | 11.13$^{b}$ | 2.44$^{abc}$ | 11.63$^{ab}$ | 2.31$^{abc}$ | 11.19$^{b}$ | 1.75$^{ab}$ | 11.69$^{b}$ | 1.31$^{b}$ |
| H3 NHTO-0239 | 7.56$^{c}$ | 2.06$^{abc}$ | 8.31$^{c}$ | 2.44$^{abc}$ | 8.00$^{c}$ | 2.25$^{ab}$ | 7.56$^{c}$ | 1.06$^{b}$ |
| H4 NHTO-0410 | 10.94$^{b}$ | 3.00$^{ab}$ | 11.13$^{b}$ | 3.25$^{ab}$ | 10.31$^{bc}$ | 2.19$^{ab}$ | 11.06$^{b}$ | 1.31$^{b}$ |
| W5 LA-4345 | 9.00$^{bc}$ | 1.13$^{abc}$ | 9.75$^{bc}$ | 1.44$^{abc}$ | 10.25$^{bc}$ | 2.06$^{ab}$ | 9.94$^{bc}$ | 1.81$^{ab}$ |
| W6 LA-1714 | 9.63$^{bc}$ | 0.19$^{c}$ | 10.75$^{bc}$ | 0.56$^{c}$ | 10.25$^{bc}$ | 1.38$^{b}$ | 10.19$^{bc}$ | 1.56$^{b}$ |
| W7 LA-3315 | 10.00$^{b}$ | 1.00$^{bc}$ | 10.50$^{bc}$ | 1.19$^{bc}$ | 10.25$^{bc}$ | 1.44$^{b}$ | 10.69$^{b}$ | 1.31$^{b}$ |
| W8 AVTO-2133 | 9.69$^{bc}$ | 0.56$^{c}$ | 10.50$^{bc}$ | 0.94$^{c}$ | 9.69$^{bc}$ | 1.06$^{b}$ | 11.00$^{b}$ | 0.88$^{b}$ |
| I9 *beske* | 14.69$^{a}$ | 3.38$^{a}$ | 13.88$^{a}$ | 3.69$^{a}$ | 15.81$^{a}$ | 3.13$^{a}$ | 15.94$^{a}$ | 2.69$^{a}$ |
| Treatment x Treatment | | | | | | | | |
| Control | 8.67$^{b}$ | 0.00b | 9.39$^{b}$ | 0.00$^{b}$ | 9.17$^{b}$ | 0.00$^{c}$ | 9.69$^{c}$ | 0.00$^{c}$ |
| Moringa | 10.83$^{a}$ | 1.72$^{a}$ | 11.53$^{a}$ | 2.03$^{a}$ | 10.67$^{ab}$ | 1.47$^{bc}$ | 11.89$^{ab}$ | 0.31$^{c}$ |
| Neem | 11.14$^{a}$ | 1.97$^{a}$ | 11.89$^{a}$ | 2.36$^{a}$ | 12.22$^{a}$ | 2.31$^{ab}$ | 12.53$^{a}$ | 1.64$^{b}$ |
| Isolate Only | 11.06$^{a}$ | 2.25$^{a}$ | 11.03$^{a}$ | 2.58$_{a}$ | 11.39$^{a}$ | 3.17$^{a}$ | 10.33$^{bc}$ | 3.83$^{a}$ |
| Variety x Treatment | | | | | | | | |

Mean values with similar letter(s) in the same column are not significantly ($p < 0.05$) by Duncan's Multiple Range Test (DMRT)

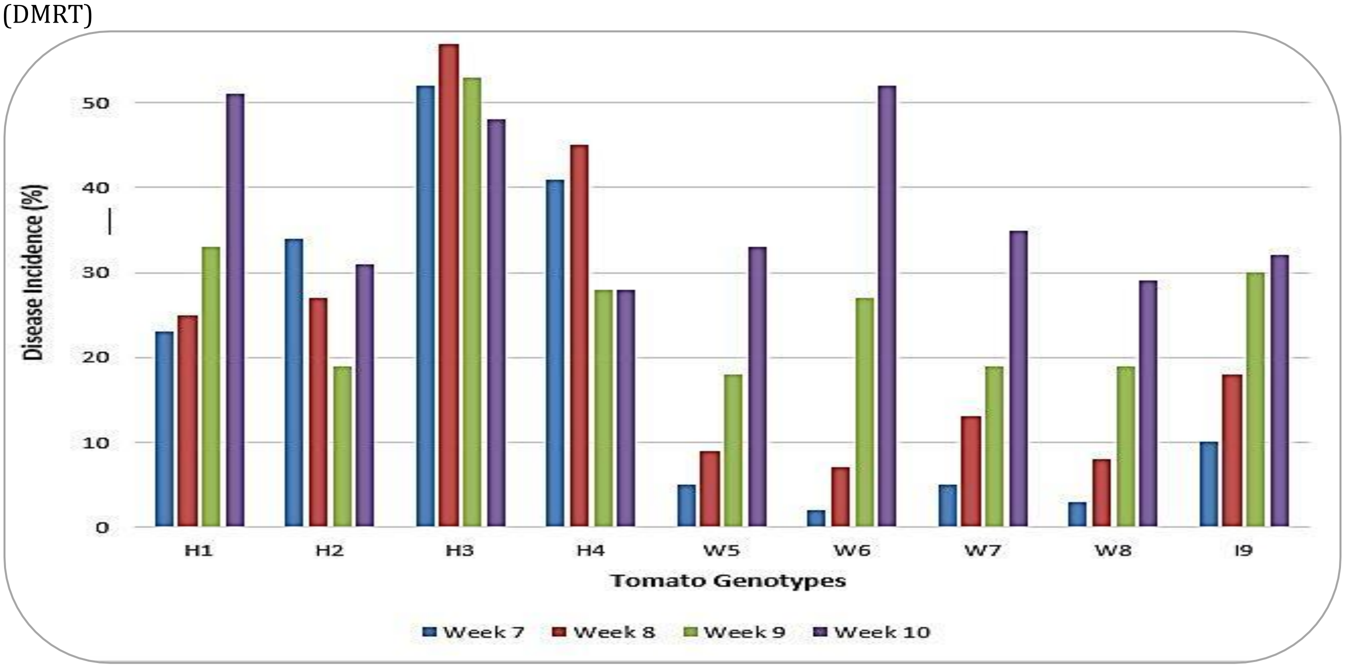


Figure 1. Disease incidence on untreated infected plants

**Effects of Botanical extract on pathogen:** Neem extract was not as effective as moringa extract in the control of the spread of the disease-causing pathogen as shown in Figure 2 and Table 1. Moringa treated tomato had lower disease incidence compared to neem leaf. In general, Moringa extract was able to stop the spread of the pathogen in most of the plants as shown in Figure 3 and by week 10 it reduced disease incidence to 2.6%, as shown in Table 1.

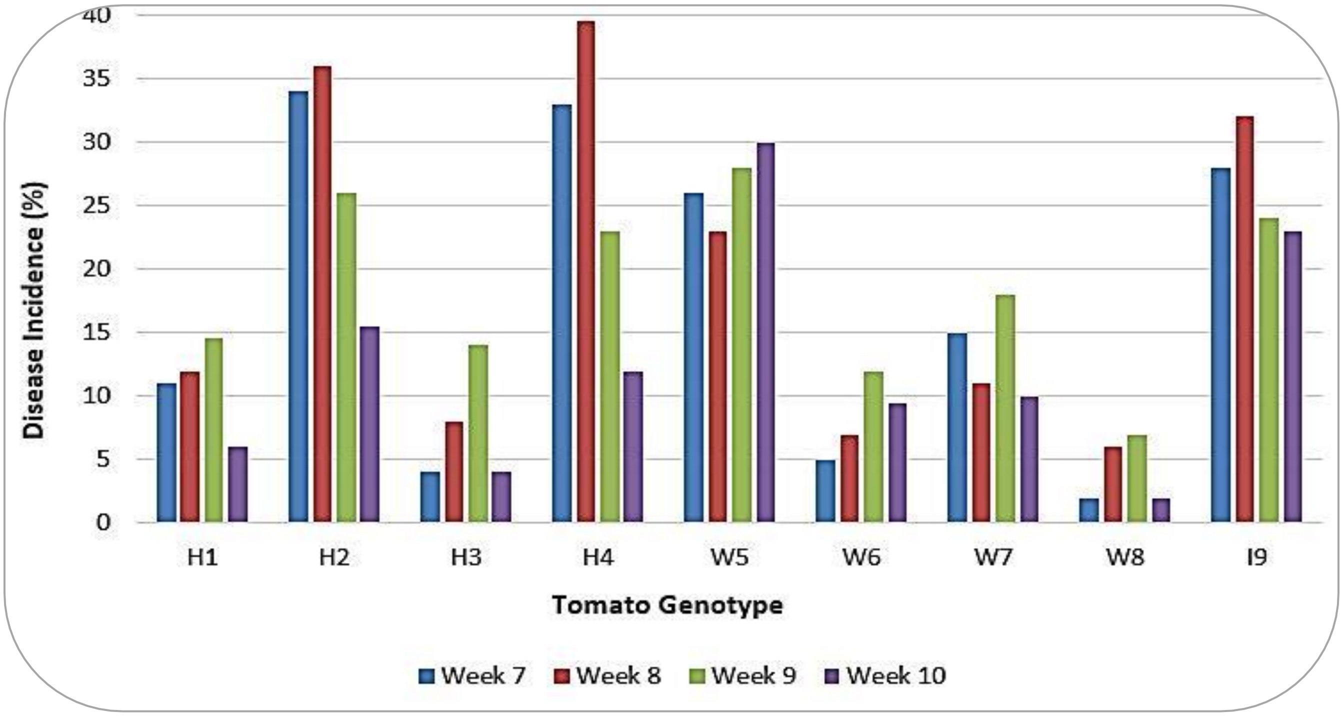


Figure 2. Effect of neem extract on infected plants

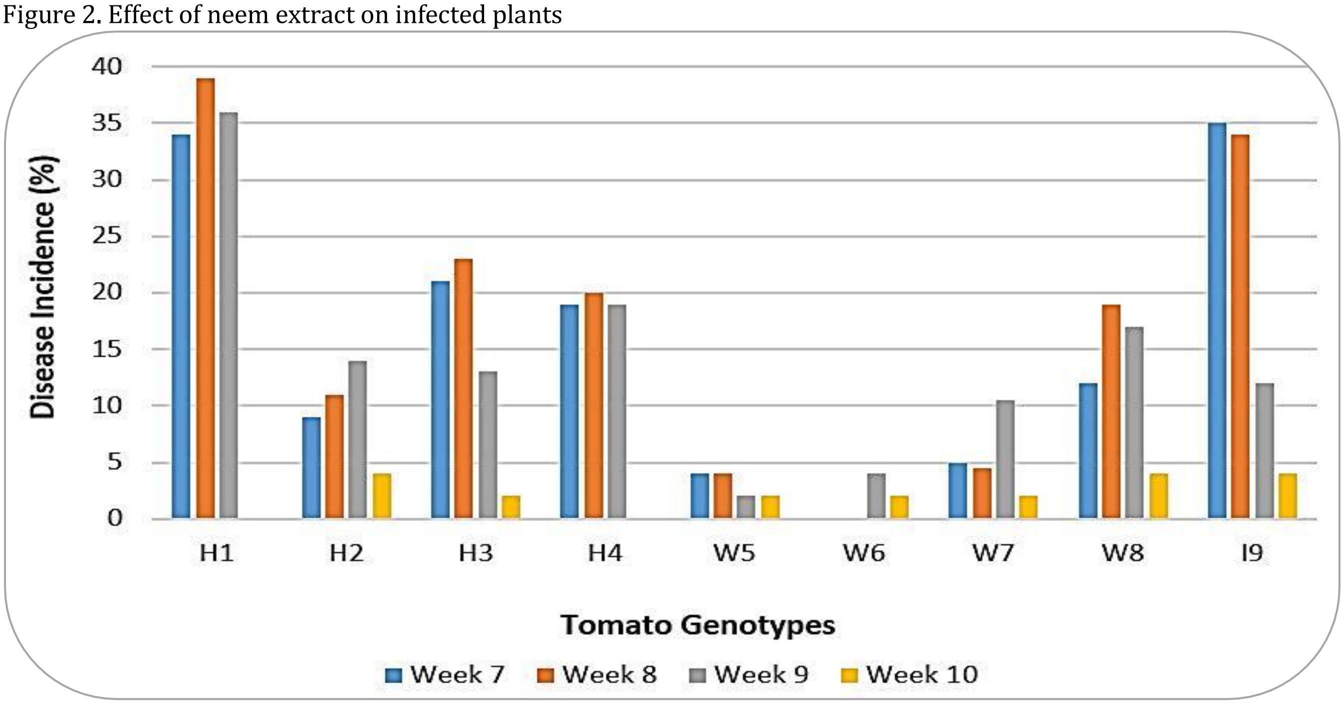


Figure 3. Effect of moringa extract on infected plants

**Effect of Botanical extracts on yield:** During the experiment, the tomato genotypes produced flowers at different rates although some flowers were lost to disease infections. Infected plants treated with Moringa extract had more flowers compared to untreated infected plants as shown in figures 4, 5 and 6. At week 8, most genotypes treated with moringa produced more flowers compared to other treatments, with genotype 6 being the highest. However, flowers would eventually become fruits. During the experiment, as shown in figures 7, 8, and 9, more fruits were produced by most of the plants treated with Moringa extracts and by the end of week 10 the effect of Moringa was pronounced on $W_9$ and $W_6$.

Table 2. General effect of treatment on plants

| Treatment | Wilted | Disease Incidence (%) |
|---|---|---|
| Moringa | 0.31[c] | 2.6 |
| Neem Leaf | 1.64[b] | 13 |
| Isolate | 3.83[a] | 37 |
| Control | 0[d] | 0 |

Mean values with similar letter(s) in the same column are not significantly ($p < 0.05$) different by Duncan's Multiple Range Test (DMRT)

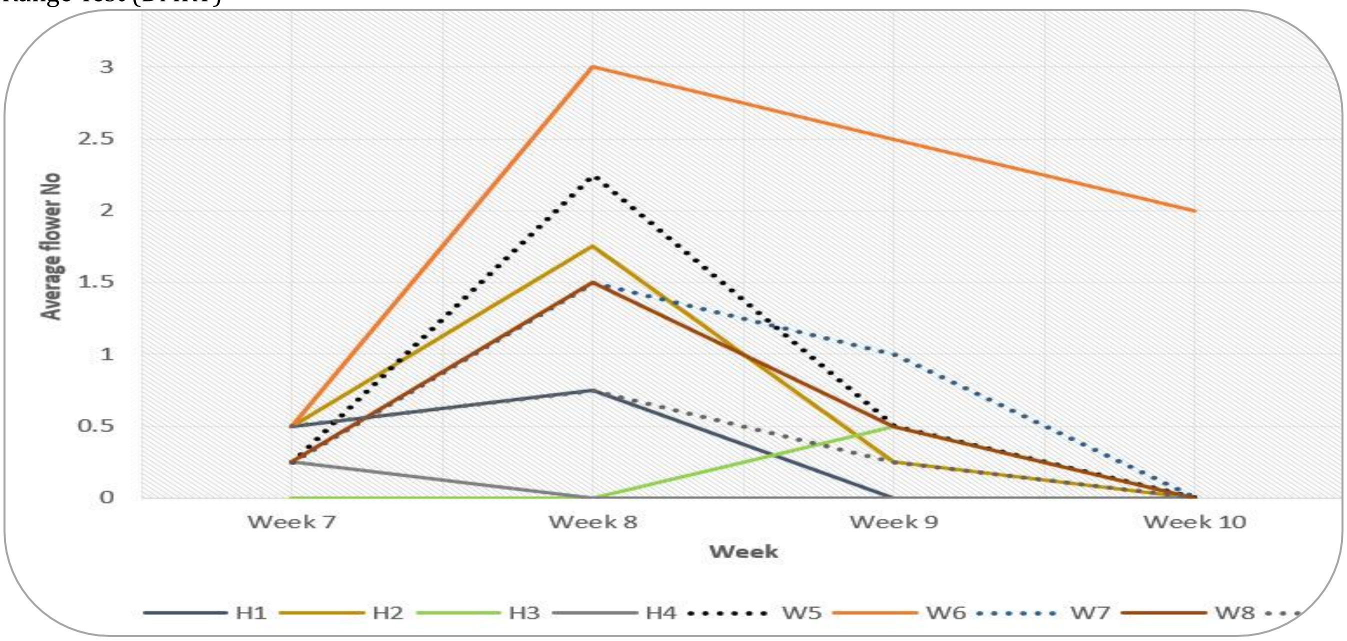


Figure 4. Production of flowers by infected tomato plants

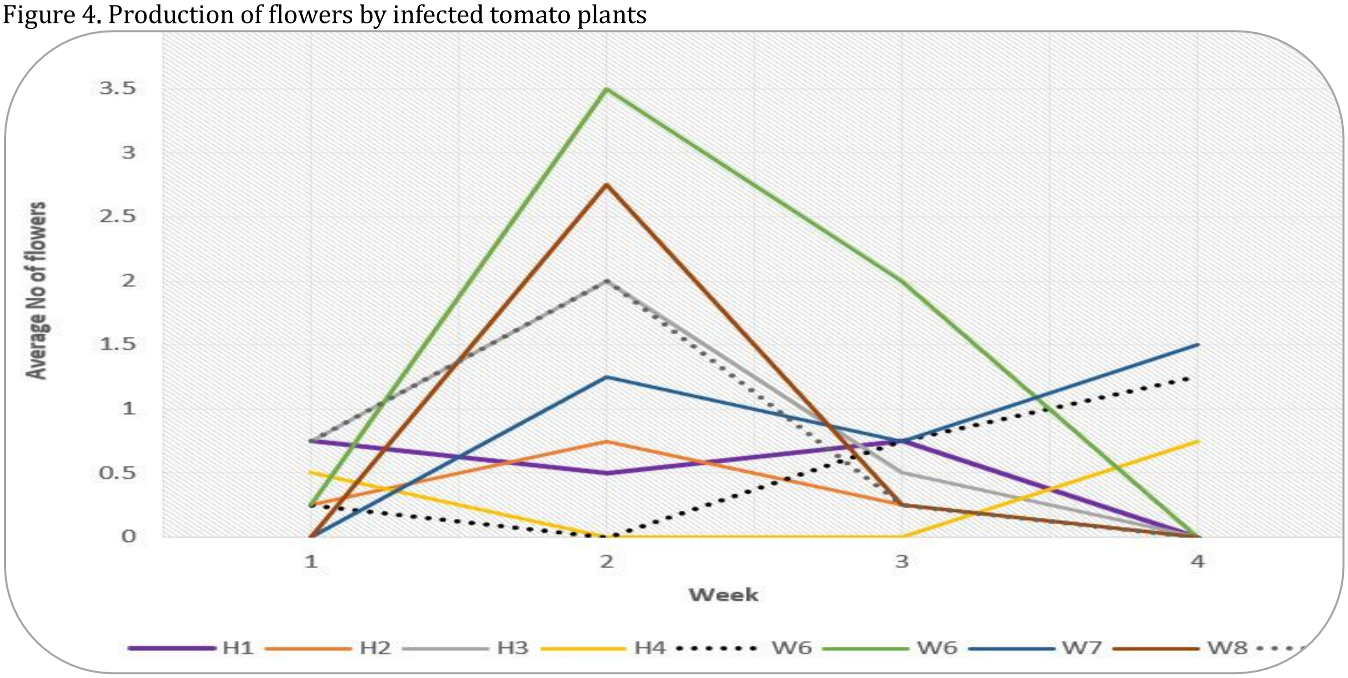


Figure 5. Production of flowers by Neem treated tomato plants

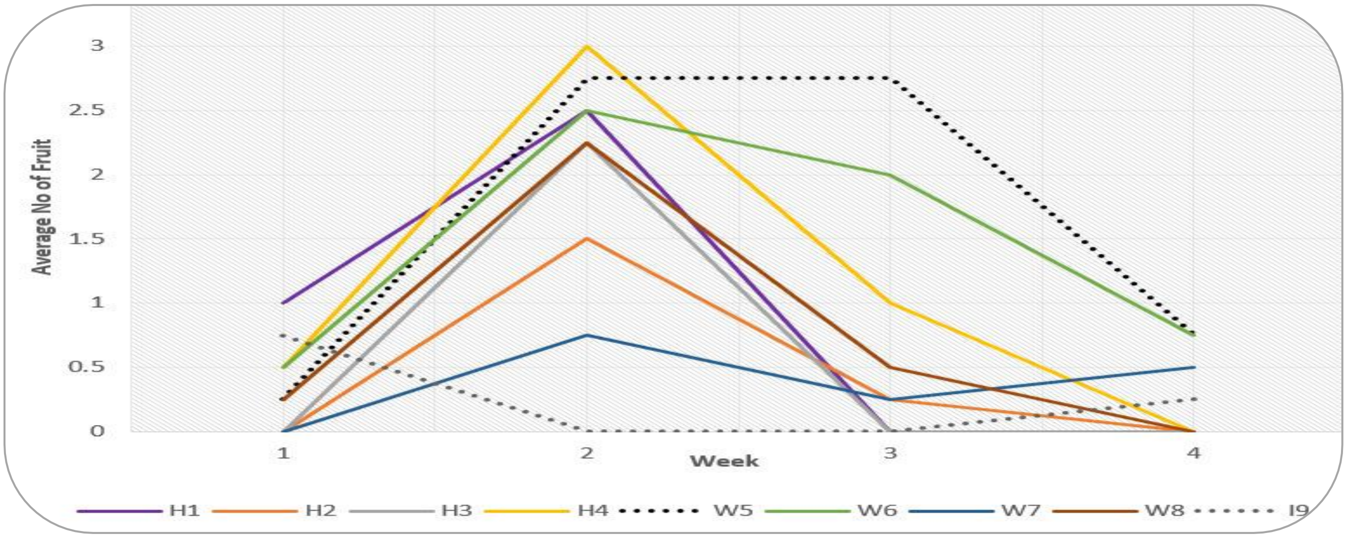

Figure 6. Production of flowers by Moringa treated tomato plants

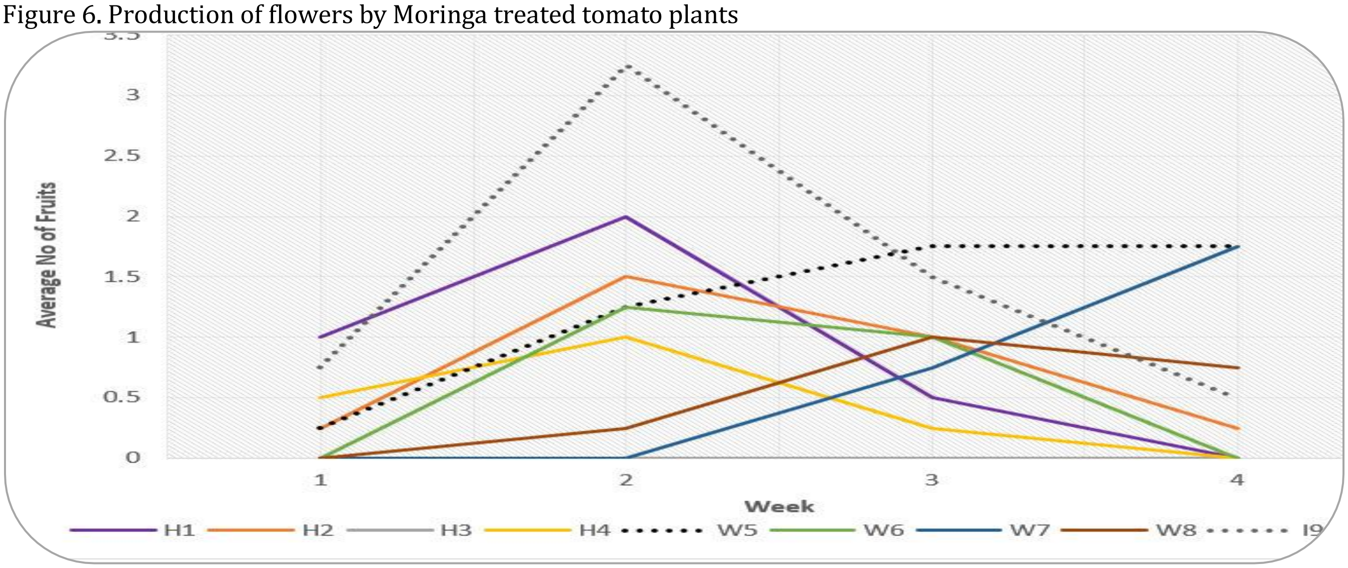

Figure 7. Fruit production of control plants

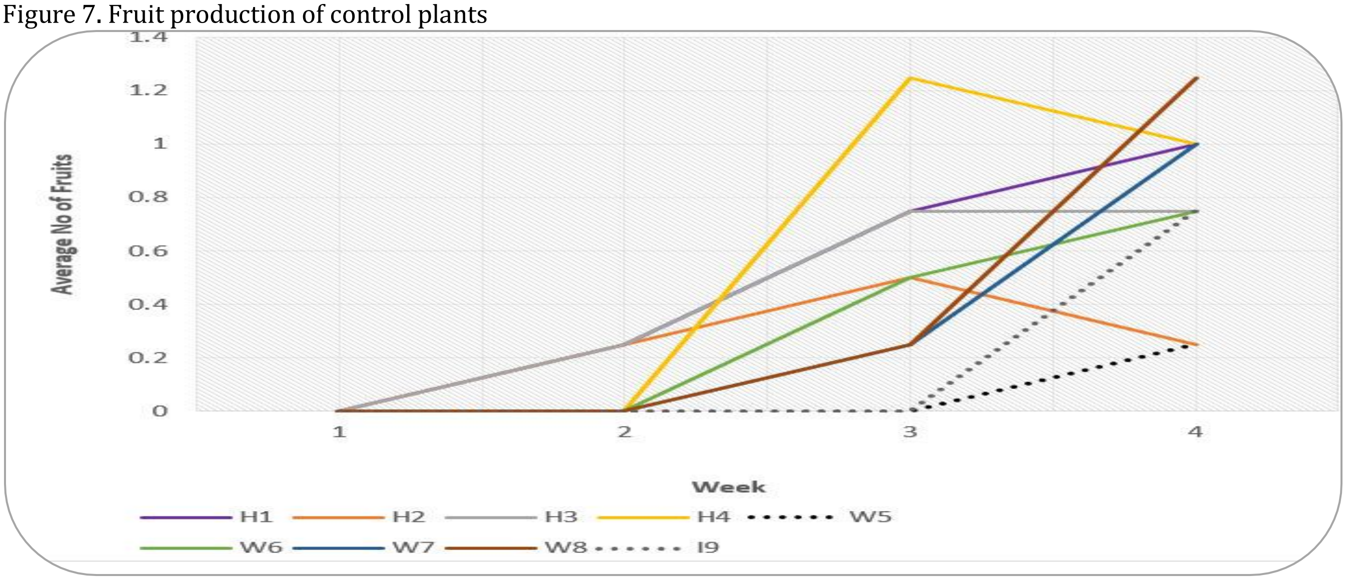

Figure 8. Fruit production of infected plants

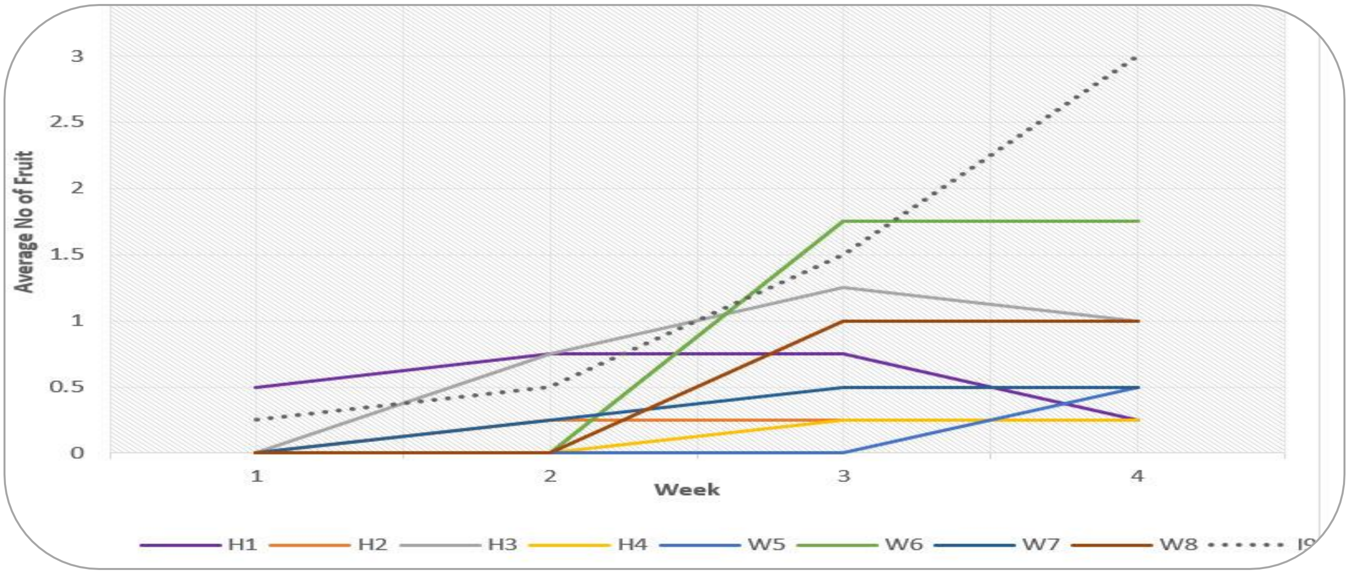

Figure 9. Production of fruits by plants treated with neem extract

**DISCUSSION**

This study demonstrates that tomato genotypes vary in their response to *Sclerotinia sclerotiorum*, reflecting underlying genetic differences in resistance and susceptibility. Early low disease incidence in wild genotypes suggests the presence of innate defense mechanisms, possibly related to structural barriers or induced biochemical responses that initially suppress pathogen colonization. Over time, the systemic nature of *S. sclerotiorum* allowed the pathogen to overcome these defenses, consistent with its two-phase infection strategy, which involves initial suppression of host defenses followed by apoplastic colonization and tissue degradation (O'Sullivan *et al.,* 2021). These findings provide insight into the temporal dynamics of disease progression and highlight the importance of evaluating resistance over the entire growth cycle.

Botanical extracts, particularly *Moringa oleifera*, were highly effective in reducing disease incidence and limiting pathogen spread. The efficacy of Moringa may be attributed to its bioactive compounds, including phenolics, ascorbic acid, and fatty acids, which can disrupt fungal growth and inhibit sclerotia germination (Ahmadu *et al.,* 2020; El-Mohamedy and Mohamed, 2018). In this study, Moringa-treated plants not only exhibited lower disease incidence but also maintained higher flowering and fruiting rates, indicating that disease suppression translated directly into improved yield. Neem extracts were moderately effective, reducing disease incidence in most genotypes but failing to fully suppress infection in susceptible varieties. This suggests that while both extracts have antifungal properties, Moringa may provide a broader spectrum of activity or higher potency against *S. sclerotiorum*.

The positive impact of Moringa on plant growth and yield aligns with its known biostimulant properties. Compounds in Moringa extracts can enhance chlorophyll content, nutrient uptake, and stress tolerance, contributing to increased leaf production, fruit size, and overall plant vigor (Zannah *et al.,* 2020; Tahsina *et al.,* 2021; Masroor *et al.,* 2024). These physiological effects may synergize with its antifungal activity, providing dual benefits of disease control and growth promotion.

Despite these promising findings, the study has limitations. Disease assessments were conducted under controlled greenhouse conditions, which may not fully capture field-level variability, environmental stresses, or pathogen diversity. Additionally, the study focused on foliar and stems inoculation, and did not evaluate post-harvest or soil-mediated effects of the extracts. Future research should explore field trials across diverse environments, investigate the molecular mechanisms underlying genotype resistance, and assess the long-term efficacy and optimal application strategies of botanical extracts, alone or in combination, for integrated disease management.

**CONCLUSION**

The study demonstrates that botanical extracts from *Moringa oleifera* and *Azadirachta indica* effectively suppress *Sclerotinia sclerotiorum* in tomato plants, reducing disease incidence and improving plant vigor and yield. Among the extracts, Moringa showed the highest efficacy in limiting pathogen spread and enhancing productivity. These results highlight the potential of integrating botanical extracts into sustainable tomato disease management programs. Future studies should explore the combined application of Moringa and Neem extracts, optimize dosages and application timing, and validate effectiveness under diverse field conditions.

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**CONFLICT OF INTEREST**

The authors declare no conflict of interest.

**AUTHORS' DECLARATION**

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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**Contribution of Authors:**

| | | |
|---|---|---|
| Tolulope D. Onasanya | : | Conceived and designed the experiment, carried out the screenhouse experiment, prepared inoculum and botanical extracts, conducted data collection, performed statistical analysis, interpreted results, and contributed to writing and revising the manuscript. |
| Vincent I. Esan | : | Supervision |
| Aruna O. Adekiya | : | Supervision |