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The Combined Effects of Soil Sterilisation and Organic Mulching on *Fusarium* Crown Rot Incidence and Growth Performance in *Amaranthus viridis* L

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Abstract
Amaranthus viridis L. is a nutrient-rich leafy vegetable with considerable potential to alleviate food insecurity in tropical regions. Despite its nutritional value and high yield potential, its production remains suboptimal, even under favourable growing conditions, largely due to Fusarium crown rot caused by *Fusarium oxysporum*. This study examined the synergistic effects of soil sterilisation and organic mulching on the suppression of *Fusarium* crown rot and the enhancement of growth in *A. viridis*. The experiment was conducted in a screenhouse facility at the Department of Biological Sciences, Tai Solarin University of Education, Ijagun, Ogun State, Nigeria. Seeds were sourced from Oke-Aje Market, Ijebu-Ode. A completely randomised design with six replicates was employed. A 2 × 2 factorial arrangement was used to evaluate soil sterilisation (autoclaved versus unsterilised) and organic mulching (5 cm layer of dried *Tectona grandis* leaves versus no mulch). The results revealed significant differences ($p < 0.05$) in plant height and leaf number across treatments. The sterilised and mulched treatment recorded a 42% increase in plant height and a 38% increase in leaf number compared with the control. Disease incidence was lowest in the sterilised and mulched soil (12.0 ± 2.1%) and highest in the unsterilised, unmulched control (54.3 ± 5.6%). Organic mulching effectively moderated soil temperature (±1.5°C diurnal variation), thereby creating conditions less favourable for the development of *F. oxysporum*. These findings demonstrate that soil sterilisation significantly improves the growth performance of *A. viridis* while reducing pathogen incidence. When combined with organic mulching, which regulates the soil microclimate, this approach offers effective protection against Fusarium crown rot. The combined application of soil sterilisation and organic mulching is therefore recommended as a sustainable strategy for enhancing *A. viridis* production.

Keywords: Organic mulching, Disease incidence, Fusarium crown rot, *Amaranthus viridis*, Soil sterilisation

1. Introduction

Amaranthus viridis L. (family Amaranthaceae), commonly known as slender amaranth or green amaranth, is a fast-growing leafy vegetable that is increasingly recognised for its nutritional and agronomic importance. As a highly nutritious pseudocereal, *A. viridis* contains remarkable levels of protein (18–30%), iron (9–15 mg/100 g), and vitamin C (80–120 mg/100 g), making it an important crop for enhancing food security, particularly in resource-constrained settings (Gautam & Khedkar, 2024; Abbas *et al*., 2023). Its ability to adapt to a wide range of climatic conditions, coupled with its short growth cycle of approximately 4–6 weeks and high biomass yield (Mukuwapasi *et al*., 2024), further highlights its potential to improve nutrition and livelihoods across Sub-Saharan Africa and other tropical regions.

Despite these advantages, the production of *A. viridis* in many areas remains considerably below its agronomic potential, with yield losses estimated at between 40% and 60% under field conditions (Cunha-Chiamolera *et al*., 2024). One of the major constraints to productivity is Fusarium crown rot, a soil-borne disease caused by *Fusarium oxysporum* Schlecht. This pathogen attacks the root and crown tissues, impairs nutrient uptake, disrupts vascular function, and ultimately results in wilting, stunted growth, and plant death (Cerkauskas, 2017). The persistence of the pathogen is further enhanced by the production of resilient chlamydospores, which can survive in the soil for prolonged periods, thereby making disease management particularly difficult.

Conventional approaches to disease management frequently depend on the use of synthetic fungicides to suppress *Fusarium* populations. However, these chemicals present significant environmental risks, including contamination of soil and water resources, toxicity to non-target organisms, and the possible emergence of fungicide-resistant pathogen strains. In addition, health concerns are especially pronounced in smallholder farming systems, where access to protective equipment and adequate regulatory oversight may be limited (FAO, 2022). Consequently, there is an increasing need for sustainable and environmentally friendly alternatives that can effectively reduce disease incidence while simultaneously improving soil health and crop productivity.

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Integrated soil management practices involving soil sterilisation and organic mulching have been widely reported to reduce soil-borne pathogens and improve crop performance. Soil sterilisation methods such as solarisation and steaming can effectively suppress pathogenic microorganisms and weed propagules (Sahoo et al., 2025), while organic mulches improve soil moisture retention, regulate temperature, suppress weeds, and enhance beneficial microbial activity (Bonanomi et al., 2018). Studies have also shown that combining sterilisation and organic amendments can enhance disease suppression compared with either practice alone (Klein *et al*., 2011; van der Sloot *et al*., 2024). However, most of these studies have focused on major vegetable crops, with limited information available for indigenous leafy vegetables such as *Amaranthus viridis*. Consequently, the combined effects of soil sterilisation and organic mulching on pathogen suppression, growth, and yield of *A. viridis* remain poorly understood, highlighting an important knowledge gap that this study seeks to address.

This study was therefore designed to address this knowledge gap by: (1) quantifying the combined effects of soil sterilisation and organic mulching on key growth parameters of *A. viridis*; (2) assessing their influence on the incidence and severity of Fusarium crown rot; and (3) developing context-appropriate and sustainable cultivation protocols that can be adopted by smallholder farmers to improve yield and reduce disease burden.

2. Materials and Methods

2.1 Study Site and Experimental Design

A controlled screenhouse experiment was conducted at the Department of Biological Sciences, Tai Solarin University of Education, Ijagun, Ogun State, Nigeria (latitude 6°53′N, longitude 3°42′E), between March and June 2023. The study area is characterised by a tropical climate, with a mean daily temperature of 28.5 ± 2.3°C and relative humidity ranging from 75% to 85% during the experimental period. The screenhouse environment provided protection from direct rainfall and uncontrolled pest infestation, thereby enabling effective regulation of environmental conditions and experimental treatments (Resh, 2013).

2.2 Soil Collection and Preparation

Loamy soil was collected from a fallow section of the university agricultural farm at a depth of 0–20 cm. The soil was air-dried, sieved through a 5 mm mesh to remove debris and stones, and thoroughly homogenised following standard soil preparation procedures for greenhouse experiments (Black, 1965). The soil was stored from an uncultivated area with no recent cropping activities, thereby minimising recent pathogen input. Soil pH was measured in a 1:2.5 (w/v) soil-to-water suspension using a calibrated digital pH meter (Hanna Instruments HI98107), following standard procedures for soil reaction determination (Thomas, 1996). Organic matter content was determined using the loss-on-ignition method, where oven-dried soil (105°C for 24 h) was combusted at 360°C for 2 h, and organic matter percentage calculated as weight loss relative to initial dry weight (Nelson & Sommers, 1996).

For the sterilised treatment, soil samples were autoclaved at 121°C and 15 psi for 60 minutes per cycle, with the procedure repeated twice at a 24-hour interval to ensure elimination of heat-resistant propagules such as chlamydospores and bacterial endospores (Baker & Cook, 1974; Atlas, 2010). Although autoclaving effectively eliminates soil microorganisms, it may also alter soil physicochemical properties by increasing nutrient availability through the breakdown of organic matter and release of mineral nutrients, which can influence plant growth responses. After sterilisation, soils were cooled to room temperature under sterile conditions prior to use to prevent contamination.

2.3 Treatments and Experimental Layout

The study employed a 2 × 2 factorial experimental design to evaluate the effects of soil sterilisation and organic mulching on the growth performance of *Amaranthus viridis* and the incidence of Fusarium crown rot. The two factors investigated were soil sterilisation (autoclaved and unsterilised soil) and mulching (application of a 5 cm layer of dried *Tectona grandis* leaf litter and no mulch), resulting in four treatment combinations: (i) autoclaved soil with mulch, (ii) autoclaved soil without mulch, (iii) unsterilised soil with mulch, and (iv) unsterilised soil without mulch. Each treatment was replicated six times, giving a total of 24 experimental units arranged in a completely randomised design. Each experimental unit consisted of a 20-litre plastic pot containing 15 kg of prepared soil, with five *A. viridis* seedlings transplanted per pot. *Tectona grandis* leaves were selected due to their local availability and suitability as organic mulch material for moisture conservation and soil surface protection. For pathogen inoculation, *Fusarium oxysporum* f. sp. *spinaciae* was isolated from infected plant tissues and cultured on potato dextrose agar (PDA) for 7 days at 25 ± 2°C. A spore suspension was prepared by flooding sporulating cultures with sterile distilled water and adjusting the concentration to 1×10^6 conidia mL^{-1} using a haemocytometer. Each pot was inoculated with the suspension via soil drench at the root zone one week prior to transplanting to ensure uniform pathogen establishment. All pots were maintained under uniform watering and weed management conditions throughout the experimental period.

2.4 Seed Source and Establishment

Seeds of *Amaranthus viridis* were procured from Oke-Aje Market, Ijebu-Ode, Ogun State, Nigeria. Prior to sowing, seeds were surface-sterilised in 1% sodium hypochlorite solution for two minutes, rinsed thoroughly with distilled water, and pre-germinated in sterile Petri dishes lined with moist filter paper, following standard seed sterilisation and germination procedures used in plant physiology and microbiological studies (Baskin & Baskin, 2014). After

48 hours, uniformly germinated seeds were transplanted into the experimental pots at a density of five seedlings per pot. Plants were watered daily with tap water to maintain field capacity, and no supplementary fertilizer was applied, in line with controlled pot experiment protocols designed to minimise external nutrient variability (Poorter *et al*., 2012).

2.5 Data Collection

2.5.1 Growth Parameters

Plant height was measured weekly from the soil surface to the apical meristem using a graduated ruler, while leaf number was recorded as the count of fully expanded leaves exceeding 2 cm in length. Measurements were taken on all plants within each pot, and mean values per pot were used for analysis. These procedures followed standard agronomic growth assessment methods commonly used in horticultural and vegetable crop studies, where plant height and leaf number serve as primary indicators of vegetative performance and productivity (Gomez & Gomez, 1984; Hunt, 2012).

2.5.2 Disease Assessment

Disease incidence was determined as the percentage of infected plants per pot relative to the total number of plants. Disease severity was assessed using a standardised 0–4 rating scale, where 0 indicated no visible symptoms, 1 represented slight yellowing of lower leaves affecting less than 10% of foliage, 2 denoted moderate chlorosis and wilting affecting 10–30% of foliage, 3 indicated severe wilting and stunting affecting 31–50% of foliage, and 4 corresponded to plant death or more than 50% foliage affected with pronounced crown rot symptoms. This approach follows standard disease assessment methods widely used in plant pathology for quantifying disease incidence and severity in crop systems (Agrios, 2005; Madden *et al*., 2007).

2.5.3 Soil Parameters

Soil temperature was monitored at a depth of 10 cm using digital soil thermometers installed in representative pots from each treatment. Measurements were taken at two-hour intervals between 07:00 and 19:00 to capture diurnal variation in soil microclimate conditions (Hille, 2003). At the end of the experiment, soil samples (10 g) were collected from each pot at a depth of 0–15 cm for determination of *Fusarium oxysporum* population density. Serial dilution plating was performed using Komada's selective medium (Komada, 1975), and aliquots were incubated at 25°C for seven days. Developed colonies were counted and expressed as colony-forming units per gram of dry soil (CFU g^{-1}). Identification of *Fusarium* isolates was based on colony morphology (colour, growth pattern, pigmentation) and microscopic examination of conidia and conidiophores using standard mycological keys (Leslie & Summerell, 2006). Where necessary, morphological identification was cross-checked against reference descriptions to improve diagnostic accuracy.

2.6 Statistical Analysis

All data were analysed using two-way analysis of variance (ANOVA) in SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). The main effects of soil sterilisation, mulching, and their interaction were tested at a significance level of $p < 0.05$. Where significant differences were observed, treatment means were separated using Tukey's honestly significant difference (HSD) test. Prior to analysis, data were assessed for normality using the Shapiro–Wilk test and for homogeneity of variance using Levene's test. Results are presented as mean ± standard deviation unless otherwise stated.

3. Results

3.1 Growth Performance

The growth performance of *Amaranthus viridis* was significantly influenced by soil sterilisation, organic mulching, and their interaction (Table 1). Two-way ANOVA revealed significant main effects of soil sterilisation ($F = 42.3$, $p < 0.001$) and mulching ($F = 28.7$, $p < 0.001$) on final plant height, as well as a significant interaction effect ($F = 8.9$, $p = 0.008$).

Plants grown under combined sterilisation and mulching treatment exhibited the highest mean plant height (68.3 ± 3.1 cm) and leaf number (24.5 ± 1.8), while the lowest values were recorded in the control treatment (48.2 ± 2.8 cm and 17.7 ± 1.2 leaves, respectively). Sterilisation alone produced intermediate growth responses, followed by mulching alone.

Overall, the combined treatment resulted in a 42% increase in plant height and a 38% increase in leaf number relative to the control. All measured growth parameters differed significantly among treatments ($p < 0.05$), indicating a strong positive effect of the integrated management approach on vegetative development.

3.2 Disease Suppression

The incidence and severity of Fusarium crown rot differed significantly across the treatment groups (Table 2). The lowest disease incidence was recorded in the combined sterilisation and mulching treatment (12.0 ± 2.1%), followed by the sterilised-only (23.5 ± 3.0%) and mulch-only (37.2 ± 4.1%) treatments, while the highest incidence occurred in the control (54.3 ± 5.6%). A comparable pattern was observed for disease severity scores, with the combined treatment recording the lowest mean severity (0.8 ± 0.2) and the control the highest (3.2 ± 0.7).

Statistical analysis using two-way ANOVA revealed significant main effects of sterilisation ($F = 156.4$, $p < 0.001$) and mulching ($F = 42.8$, $p < 0.001$) on disease incidence, along with a significant interaction effect ($F = 11.3$, $p = 0.003$). These findings indicate that both treatments independently contributed to disease suppression, while their combined application provided the most effective control of *Fusarium oxysporum*, reducing disease incidence by approximately 78%

Table 1 Effect of soil sterilisation and organic mulching on growth performance of *Amaranthus viridis* after six weeks

Treatment	Final Plant Height (cm)	Leaf Number (per plant)	Increase in Height (%)	Increase in Leaves (%)
Sterilised + Mulch	68.3 ± 3.1^{a}	24.5 ± 1.8^{a}	42	38
Sterilised only	59.4 ± 2.9^{b}	21.3 ± 1.5^{b}	23	20
Mulch only	53.7 ± 3.0^{c}	19.6 ± 1.4^{c}	11	11
Control (Unsterilised + No Mulch)	48.2 ± 2.8^{d}	17.7 ± 1.2^{d}	0	0

Note: Values are presented as mean ± standard deviation (n = 6). Different superscript letters within each column indicate significant differences at $p < 0.05$ (Tukey's HSD). Percentage increases are relative to the control treatment.

Table 2 Effect of soil sterilisation and organic mulching on Fusarium crown rot incidence and severity in *Amaranthus viridis*

Treatment	Incidence (%)	Severity (0–4 scale)
Sterilised + Mulch	12.0 ± 2.1^{a}	0.8 ± 0.2^{a}
Sterilised only	23.5 ± 3.0^{b}	1.4 ± 0.3^{b}
Mulch only	37.2 ± 4.1^{c}	2.1 ± 0.5^{c}
Control (unsterilised + no mulch)	54.3 ± 5.6^{d}	3.2 ± 0.7^{d}

Note: Values are presented as mean ± standard deviation (n = 6). Means within the same column followed by different superscript letters are significantly different at $p < 0.05$ according to Tukey's honestly significant difference (HSD) test.

relative to the control.

3.3 Pathogenicity and Symptom Characterisation

The progression of *Fusarium* crown rot in *Amaranthus viridis* followed a distinct and predictable symptomatic pattern, which was documented and categorised into five levels of severity (Figure 1). Initially, inoculated plants appeared asymptomatic, maintaining healthy, turgid green foliage (Score 0). The first physiological indication of infection typically manifested as localised chlorosis, primarily affecting the margins and interveinal regions of the lower, older leaves (Score 1). As the fungal colonization progressed, symptoms became increasingly systemic. Moderate infection was characterized by widespread chlorosis and the onset of drooping leaves, indicating a loss of vascular integrity and turgor pressure (Score 2). In the advanced stages of disease, plants exhibited severe wilting and a marked reduction in growth compared to the control group, with extensive stunting of the main stem and apical meristem (Score 3). The final stage of the disease cycle resulted in complete plant mortality, characterized by total desiccation of the foliage and necrotic collapse of the crown tissues (Score 4). These morphological observations confirm the high virulence of the *Fusarium* isolate and provide a standardised baseline for quantifying disease resistance in future trials.

3.4 Soil Conditions

Physicochemical analysis of the composite soil sample prior to treatment application indicated a pH of 6.2 and organic matter content of 2.1%, representing the baseline soil condition of the experiment (Table 3). Organic mulching significantly moderated soil microclimatic conditions throughout the experimental period, resulting in a reduced mean diurnal soil temperature fluctuation of 2.3 ± 0.4°C compared with 4.8 ± 0.6°C in unmulched soils, representing an approximate 52% reduction. In addition, peak afternoon soil temperatures in mulched treatments were consistently 2–3°C lower than in unmulched soils, indicating a buffering effect of the mulch on soil heat dynamics and overall temperature stability within the root zone.

The population density of *Fusarium oxysporum* in the rhizosphere was also significantly influenced by treatment (Table 3). The combined sterilisation and mulching treatment resulted in a 92% reduction in colony-forming units (CFU/g) relative to the control (1.2×10^3 CFU/g versus 1.5×10^4 CFU/g). Soil sterilisation alone achieved a 78% reduction (3.3×10^3 CFU/g), while mulching alone resulted in a 45% reduction (8.3×10^3 CFU/g). All reductions were statistically significant ($p < 0.01$), underscoring the strong suppressive effect of the integrated treatment approach on pathogen load.

Discussion

The present study demonstrates that the combined application of soil sterilisation and organic mulching significantly enhances the growth performance of *Amaranthus viridis* while effectively suppressing Fusarium crown rot caused by *Fusarium oxysporum*. The observed improvements in plant height and leaf production under the integrated treatment reflect the complementary roles of pathogen reduction and

Figure 1. Representative symptoms of Fusarium crown rot in *Amaranthus viridis* showing (A) healthy plant, (B) early chlorosis, (C) severe wilting and stunting, and (D) plant death under untreated control conditions.

Table 3. Effect of soil sterilisation and organic mulching on soil temperature dynamics and *Fusarium oxysporum* population in *Amaranthus viridis* rhizosphere

Treatment	**Diurnal Temperature Fluctuation (°C)**	**Peak Temperature Reduction (°C)**	***F. oxysporum* (CFU/g soil)**	**Reduction (%)**
Sterilised + Mulch	2.3 ± 0.4^{a}	$2–3^{a}$	1.2×10^{3a}	92
Sterilised only	4.8 ± 0.6^{b}	0^{b}	3.3×10^{3b}	78
Mulch only	2.3 ± 0.4^{a}	$2–3^{a}$	8.3×10^{3c}	45
Control (unsterilised + no mulch)	4.8 ± 0.6^{b}	0^{b}	1.5×10^{4d}	0

Note: Values are presented as mean ± standard deviation (n = 6). Means within the same column followed by different superscript letters are significantly different at $p < 0.05$. Peak temperature reduction represents the decrease in maximum afternoon soil temperature relative to the control. CFU = colony-forming units. Percentage reduction in *Fusarium oxysporum* population was calculated relative to the control treatment using the formula: Reduction (%) = [(Control − Treatment) / Control] × 100.

improved soil microenvironment in promoting plant growth.

The superior growth observed in sterilised soils is consistent with earlier reports indicating that soil sterilisation reduces the burden of soil-borne pathogens, thereby minimising root damage and improving nutrient uptake efficiency (Bonanomi et al., 2018). By eliminating or drastically reducing pathogenic propagules, sterilisation creates a more favourable rhizosphere environment, allowing plants to allocate more resources to growth rather than defence. This is particularly important for fast-growing leafy vegetables such as *A. viridis*, where early establishment and uninterrupted vegetative growth are critical for yield optimisation.

Organic mulching further enhanced plant performance, both independently and in combination with sterilisation. Mulched treatments exhibited reduced temperature fluctuations and improved moisture conservation, conditions that are widely recognised to support root development and microbial balance (Kader et al., 2017). The stabilisation of soil temperature observed in this study aligns with findings by Teasdale and Mohler (2000), who reported that organic mulches buffer diurnal temperature variations and improve soil physical conditions. These moderated conditions likely contributed to the enhanced physiological performance of *A. viridis*, as reflected in increased leaf production and biomass accumulation.

The marked reduction in disease incidence and severity under sterilised and mulched conditions highlights the effectiveness of integrated soil management in controlling *Fusarium oxysporum*. Soil sterilisation alone significantly reduced disease incidence, which corroborates earlier studies demonstrating the efficacy of thermal treatments in suppressing *Fusarium* populations (Stapleton, 2000). However, the persistence of some level of infection in sterilised soils suggests possible recontamination or survival of resistant propagules, such as chlamydospores.

Mulching contributed to disease suppression through indirect effects on the soil environment. Organic

mulches have been reported to enhance the activity of beneficial soil microorganisms that may compete with or antagonise soil-borne pathogens (Bonanomi et al., 2010), although microbial activity was not directly assessed in this study. In the present experiment, mulched treatments were characterised by reduced soil temperature fluctuations and lower peak temperatures, which may have created less favourable conditions for *Fusarium oxysporum*, a pathogen known to proliferate under warm and fluctuating soil environments (Agrios, 2005). The combined sterilisation and mulching treatment produced the greatest reduction in pathogen load (92%), indicating a strong integrated effect likely driven by initial pathogen reduction through sterilisation and improved post-treatment soil environmental stability under mulching.

The substantial decrease in *Fusarium oxysporum* colony-forming units observed in this study further indicates the effectiveness of the integrated soil management approach. Similar reductions in pathogen density following organic amendments and mulching have been reported in other cropping systems, where improved soil organic matter and associated biological activity contribute to disease suppression (Larkin & Griffin, 2007). However, because this study was conducted over a relatively short duration under controlled pot conditions, it does not provide sufficient evidence to confirm the development of long-term disease-suppressive soil properties. Nevertheless, the observed reductions suggest that combined soil sterilisation and mulching can create short-term conditions that are unfavourable for *F. oxysporum* survival and proliferation.

From an agronomic perspective, the 42% increase in plant height and 38% increase in leaf number observed under the combined treatment are highly significant, particularly for smallholder farming systems where productivity gains directly translate into improved food security and income. The results suggest that integrating soil sterilisation with organic mulching can serve as a viable alternative to chemical fungicides, thereby reducing environmental and health risks associated with synthetic inputs. This is in line with global recommendations advocating sustainable and climate-smart agricultural practices (FAO, 2022).

Of note, this study provides a practical framework for understanding the combined effects of soil sterilisation and organic mulching on the growth and health of *Amaranthus viridis* under controlled conditions. The integrated application of these treatments significantly improved plant growth while reducing disease burden, indicating potential benefits of combining soil hygiene practices with surface organic amendments. Although soil sterilisation under controlled conditions is not directly scalable to field environments, similar disease reduction effects in field agriculture are often achieved through soil solarisation, which also reduces soil-borne pathogen populations via heat-mediated mechanisms. When combined with organic mulching using locally available residues such as *Tectona grandis* leaves, the findings suggest a potentially low-cost strategy for improving soil microclimate conditions and suppressing soil-borne pathogens in smallholder systems, although field validation would be required before recommendation.

However, certain limitations must be acknowledged. The experiment was conducted under screenhouse conditions, which do not fully replicate field variability such as fluctuating rainfall patterns, complex soil microbial communities, and diverse environmental stressors. In addition, autoclave sterilisation, while effective experimentally, is not directly transferable to farmer-managed field systems, and therefore the practical recommendation should be interpreted in the context of field-level analogues such as solarisation. Furthermore, the study did not assess long-term soil microbial recovery or multi-season effects of the treatments, which are important for understanding sustainability and soil ecosystem resilience. Future research should therefore focus on field validation, long-term assessments, and economic feasibility analyses to strengthen adoption potential.

In conclusion, this study suggests that the integrated application of soil sterilisation and organic mulching can enhance the growth performance and health status of *Amaranthus viridis* under controlled screenhouse conditions. The combined treatment was associated with reduced *Fusarium* infection and improved plant growth parameters, indicating a beneficial interaction between soil pathogen reduction and microclimatic moderation. However, given the short experimental duration and controlled conditions, these findings should be interpreted as preliminary evidence rather than definitive field-scale outcomes. Further studies under field conditions are recommended, particularly exploring soil solarisation as a more practical alternative to autoclave sterilisation, alongside locally available organic mulching materials, to validate the applicability of this integrated approach in tropical agroecosystems.

References

Abbas, A., Ahmad, N., Saeed, W., Qamar, M., Usama, M., Khan, M. Z., & Esatbeyoglu, T. (2023). Amaranth (Amaranthus spp.): Food Properties and Potential Health Benefits. In *Neglected Plant Foods of South Asia: Exploring and valorizing nature to feed hunger* (pp. 283-299). Cham: Springer International Publishing.

Agrios, G. N. (2005). *Plant pathology* (5th ed.). Elsevier Academic Press.

Atlas, R. M. (2010). *Handbook of microbiological media* (4th ed.). CRC Press.

Baker, K. F., & Cook, R. J. (1974). *Biological control of plant pathogens*. W. H. Freeman.

Baskin, C. C., & Baskin, J. M. (2014). *Seeds: Ecology, biogeography, and evolution of dormancy and germination* (2nd ed.). Academic Press.

Black, C. A. (1965). Operator variation. In C. A. Black (Ed.), *Methods of soil analysis: Part 1. Physical and mineralogical properties, including statistics of measurement and sampling* (pp. 50–53). American Society of Agronomy.

Bonanomi, G., Antignani, V., Capodilupo, M., & Scala, F. (2010). Identifying the characteristics of organic soil amendments that suppress soilborne plant diseases. *Soil Biology and Biochemistry*, *42*(2), 136–144.

Bonanomi, G., Lorito, M., Vinale, F., & Woo, S. L. (2018). Organic amendments, beneficial microbes, and soil microbiota: toward a unified framework for disease suppression. *Annual Review of Phytopathology*, *56*(1), 1-20.

Cerkauskas, R. F. (2017). Etiology and management of Fusarium crown and root rot (Fusarium oxysporum) on greenhouse pepper in Ontario, Canada. *Canadian journal of plant pathology*, *39*(2), 121-132.

Cunha-Chiamolera, T. P. L. D., Chileh-Chelh, T., Urrestarazu, M., Ezzaitouni, M., López-Ruiz, R., Gallón-Bedoya, M., & Guil-Guerrero, J. L. (2024). Crop productivity, phytochemicals, and bioactivities of wild and grown in controlled environment slender amaranth (Amaranthus viridis L.). *Agronomy*, *14*(9), 2038.

Food and Agriculture Organization of the United Nations. (2022). *The state of food and agriculture 2022: Leveraging automation in agriculture for transforming agrifood systems*. https://doi.org/10.4060/cb9479en

Gautam, K., & Khedkar, R. (2024). Amaranthus: Biology, Functional Potential and Sustainable Utilization: Pseudo Millets. In *Millets: The Multi-Cereal Paradigm for Food Sustainability* (pp. 177-231). Cham: Springer Nature Switzerland.

Hillel, D. (2003). *Introduction to environmental soil physics*. Elsevier Academic Press.

Hunt, R. (2012). *Basic growth analysis: plant growth analysis for beginners*. Springer Science & Business Media.

Kader, M. A., Senge, M., Mojid, M. A., & Ito, K. (2017). Recent advances in mulching materials and methods for modifying the soil environment. *Soil and Tillage Research*, *168*, 155–166.

Komada, H. (1975). Development of a selective medium for quantitative isolation of *Fusarium oxysporum* from natural soil. *Review of Plant Protection Research*, *8*, 114–125.

Klein, E., Katan, J., & Gamliel, A. (2011). Soil suppressiveness to Fusarium disease following organic amendments and solarization. *Plant disease*, *95*(9), 1116-1123.

Larkin, R. P., & Griffin, T. S. (2007). Control of soilborne potato diseases using Brassica green manures. *Crop Protection*, *26*(7), 1067–1077.

Leslie, J. F., & Summerell, B. A. (2006). *The Fusarium laboratory manual*. Blackwell Publishing.

Madden, L. V., Hughes, G., & van den Bosch, F. (2007). *The study of plant disease epidemics*. APS Press.

Mukuwapasi, B., Mavengahama, S., & Gerrano, A. S. (2024). Grain amaranth: A versatile untapped climate-smart crop for enhancing food and nutritional security. *Discover Agriculture 2*(1), 44.

Nelson, D. W., & Sommers, L. E. (1996). Total carbon, organic carbon, and organic matter. *Methods of soil analysis: Part 3 Chemical Methods*, *5*, 961-1010.

Poorter, H., Bühler, J., van Dusschoten, D., Climent, J., & Postma, J. A. (2012). Pot size matters: A meta-analysis of the effects of rooting volume on plant growth. *Functional Plant Biology*, *39*(11), 839–850.

Resh, H. M. (2013). *Hydroponic food production* (7th ed.). CRC Press.

Sahoo, D., Mahapatra, P., & Panigrahi, I. (2025). Environment-friendly methods for soil disinfestation. In *Organic production of vegetable crops* (pp. 97-122). Apple Academic Press.

Stapleton, J. J. (2000). Soil solarization in various agricultural production systems. *Crop Protection*, *19*(8–10), 837–841.

Teasdale, J. R., & Mohler, C. L. (2000). The quantitative relationship between weed emergence and the physical properties of mulches. *Weed Science*, *48*(3), 385–392.

Thomas, G. W. (1996). Soil pH and soil acidity. *Methods of soil analysis: part 3 chemical methods*, *5*, 475-490.

van der Sloot, M., Maerowitz-Mcmahan, S., Postma, J., Limpens, J., & De Deyn, G. B. (2024). Soil-borne disease suppressiveness after short and long term application of fermented, composted or fresh organic amendment treatments in arable soils. *Applied Soil Ecology*, *195*, 105268.