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FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

DEPARTMENT OF CROP SCIENCE

EFFICACY OF SEED TREATMENT WITH BIOPESTICIDES ON DAMPING-OFF DISEASE IN NURSERY GROWN TOMATOES *(SOLANUM LYCOPERSICUM)*.

A dissertation submitted in partial fulfilment of the requirements of the

Bachelor of Agricultural Science Honours Degree in Crop Science

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By

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Submission date: June 2026

APPROVAL FORM

The undersigned certified that they have supervised and recommend to Bindura University of Science Education for acceptance of dissertation entitled **Efficacy of biopesticides on damping-off disease in nursery grown tomatoes *(Solanum lycopersicum)*** submitted by MARAMBE RUVIMBO I in partial fulfilment of the bachelor of Agricultural Science Honours Degree in Crop Science.

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I have supervised the research project for the above-mentioned student and I am convinced that the research can be submitted.

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DECLARATION

I, MARAMBE RUVIMBO I, registration number B220487B, do hereby declare that this dissertation is my own original work and has not been copied from any source without due acknowledgement of the source.

DEDICATION

I dedicate this dissertation to my family and friends in appreciation of their steadfast love, support and encouragement throughout the whole project.

ACKNOWLEDGEMENTS

My utmost gratitude is directed to the Almighty God for his guidance, grace and strengthening me throughout my academic journey. This project would not have been a success without God's support. I would like to express my indebted gratitude and special appreciation to my supervisor Dr N Mgocheki for their invaluable advice, supervision and encouragement throughout the course of the study. Sincere appreciation to my family for the provision of all necessary requirements needed for the dissertation to be a success. Lastly, special thanks to my friends for their unconditional love and support during the entire duration of my studies.

ABSTRACT

The study was conducted to evaluate the efficacy of seed treatment with biopesticides ginger, garlic and *Trichoderma harzianum* in controlling damping-off disease in nursery grown tomatoes. The experiment was conducted at Masembura, Sanyika village in Bindura, Zimbabwe using a Randomised Complete Block Design (RCBD) with six treatments replicated four times. The treatment consisted of untreated control, *Trichoderma harzianum* 10^5 cfu/ml, ginger extract 25% (w/v), garlic extract 25% (w/v), combination of garlic, ginger and *Trichoderma harzianum* and Apron star 42WS as a positive control. Data collected included germination percentage, disease incidence and seedling vigour. Analysis of variance revealed highly significant differences among treatments for all measured parameters ($P < 0.001$). Apron star 42WS recorded the highest germination percentage (98%) followed by *T. harzianum* (96.60%) while the untreated control recorded the lowest germination percentage (88.75%). Disease incidence decreased progressively across all treatments from 2 to 6 weeks after planting, with the untreated control consistently recording the highest disease incidence (12.75). Apron star 42WS and the combination of ginger, garlic and *T. harzianum* recorded the lowest disease incidence throughout the assessment periods (1.50 and 1.50 respectively). *T. harzianum* consistently produced the highest seedling vigour at 2, 4 and 6 weeks after planting, while garlic extract performed better than ginger extract in reducing disease incidence and improving seedling vigour. The study concluded that biological and botanical seed treatments effectively reduced damping-off disease and improved seedling performance in tomatoes. *T. harzianum* and the combination treatment of ginger, garlic and *T. harzianum* showed strong potential as environmentally friendly alternatives to synthetic fungicides for sustainable tomato production.

Keywords: Tomato (*solanum lycopersicum*), damping-off disease, *Trichoderma harzianum*, garlic extract, ginger extract, seed treatment and biopesticides.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
CV	Coefficient of variation
LSD	Least significant difference
RCBD	Randomised complete block design
SED	Standard error of difference
WAP	Weeks after planting
w/v	Weight/volume
cm	Centimetre
cfu	Colony forming units
g	Grams
kg	Kilograms
m	Meters
ml	millilitre
%	Percentage
P	Probability value
Spp	Species
w/v	weight per volume

CHAPTER 1

1.1 Introduction

Tomato (*Solanum lycopersicum*) originated in Central America, with early domestication occurring in Mexico. It was introduced to Europe by the Spanish shortly after 1535 and later spread to Asia by the Portuguese before 1604 (Peralta and Spooner, 2007). The Portuguese also introduced tomatoes to parts of Southern Africa at an early stage with explorers documenting their presence around 1850. The Afrikaans name “tamatie” is believed to derive from the Malay word “tamatte”. From its humble beginnings, tomato has become one of the most widely cultivated and consumed vegetable crops globally (Starke Ayres).

Tomatoes belong to the Solanaceae family, which includes peppers, eggplant and Irish potatoes. They are a very important source of nutrients and phytochemicals such as lycopene, potassium, iron, folate, and vitamin C (Bhowmik *et al*., 2012). In addition, tomatoes contain other antioxidants such as beta-carotene and phenolic compound (Borguini *et al*., 2009). Tomatoes can be consumed fresh or processed, with approximately 80% of commercially produced tomatoes used in processed products such as juice, soup and ketchup (Hamid and Sadaf, 2017).

Tomato production exceeds 180 million annually globally and serves as an important source of income for millions of farmers (Kumar *et al*., 2020). Cultivation has expanded progressively due to increasing demand from fresh markets and agro-processing industries (Singh, 2007). In Zimbabwe, tomatoes are a vital cash crop and a key source of income and nutrition of both commercial and smallholder farmers, making them central to the horticultural sector and local economic development (Saunyama and Knapp 2003).

However, tomato productions are constrained by several diseases, notably damping-off, which can cause up to 50% seedling loss in tomato nurseries (Mazarura *et al*., 2020). *Rhizoctonia solani*, a soil-borne fungus, is one of the major pathogens responsible for damping-off (Ohkura *et al*., 2009 and Agrios, 2005). Damping-off is highly destructive, affecting seeds and young seedlings under moist tomato nursery conditions (Adhikari *et al*., 2024)

The continuous use of chemical fungicides has led to environmental pollution, pathogen resistance and health concerns. Therefore, there is a need for sustainable alternatives such as biopesticides. Plant extracts and biological agents are environmentally friendly and have shown effectiveness in inhibiting fungal growth (Bovers and Loek, 2002).

Biological seed treatment using beneficial microorganisms such as *Trichoderma harzianum* is an eco-friendly approach. This fungus enhances plant growth, improves nutrient uptake, restores soil fertility and suppresses pathogens through mechanisms such as competition, enzyme production and induction of plant defence responses (Cardarelli *et al*., 2022; Harman, 2006).

Plant extracts such as ginger (*Zingiber officinale*) and garlic (*Allium sativum)* also possess antifungal properties. Ginger contains compounds that disrupt microbial activity (Vita *et al*., 2019), while garlic contains allicin and diallyl sulphides with strong antifungal effects (Ankr & Mirelman (1999).

Although individual effects of these biopesticides have been studied, there is limited research evaluating their comparative effectiveness under Zimbabwean nursery conditions. This study therefore aims to assess their efficacy in controlling damping-off disease and improve seedling performance.

1.2 Problem statement

Damping-off disease continues to cause significant losses in tomato nurseries, resulting in poor crop establishment and reduced yields. While chemical fungicides are commonly used, their excessive application poses environmental, health and economic challenges.

Biopesticides offer a safer alternative however, their effectiveness under local nursery conditions is not well established. Most studies have been conducted under laboratory or greenhouse conditions with limited field-based evidence. Therefore, evaluating their performance under nursery conditions is essential.

1.3 Justification

Damping-off significantly affects tomato production in Zimbabwe. Chemical control methods are associated with resistance, environmental pollution and health risks. Biopesticides offer sustainable alternatives but remain underutilised due to limited local validation.

This study will provide scientific evidence supporting eco-friendly disease management strategies, contributing to improved productivity, food security and farmer livelihoods particularly smallholder farmers.

1.4 Aim and Research objectives

1.4.1 Aim

- To assess the impact of biopesticides seed treatment in reducing damping-off disease in nursery-grown tomatoes.

1.4.2 Objectives

- To compare the germination rates of treated and untreated seeds on the 14th day after emergence.
- To assess disease incidence at 2 weeks, 4 weeks and 6 weeks after emergence.
- To determine the most effective biopesticide for improving seedling vigour.

1.4.3 Research questions

- How effective is garlic extracts in reducing damping-off disease in tomato seedlings?
- Does *T. harzianum* significantly improve seedling survival compared to untreated controls?
- What is the effectiveness of ginger in promoting seedling growth when damping-off pathogens are present?

1.5 Hypothesis

(H_0): No significant difference in germination rates, disease incidence and seedling vigour among treatments *T. harzianum*, garlic, ginger, combination of garlic, ginger and *T. Harzianum* and Apron star 42WS as positive control.

(H_1): There is a significant difference in germination rates, disease incidence and seedling vigour among treatments.

CHAPTER 2

Literature Review

2.1 Origin and economic importance of Tomato (*Solanum lycopersicum*)

Tomato (*Solanum lycopersicum*) originated in Central America, with early domestication occurring in Mexico. It was introduced to Europe by the Spanish shortly after 153 and later spread to Asia by the Portuguese before 1604 (Peralta and Spooner, 2007). The Portuguese also introduced tomatoes to parts of Southern Africa at an early stage with explorers documenting their presence around 1850. The Afrikaans name “tamatie” is believed to derive from the Malay word “tamatte”. From its humble beginnings, tomato has become one of the mostly widely cultivated and consumed vegetable crops globally (Starke Ayres).

Tomatoes are part of the Solanaceae family which includes peppers, eggplant and Irish potatoes. Tomatoes (*S. lycopersicum*) are a very important source of phytochemicals and nutrients such as lycopene, potassium, iron, folate, and vitamin C (Bhowmik *et al*., 2012). Apart from lycopene and vitamin C tomatoes provide other antioxidants such as beta carotene and phenolic compounds (Borguini *et al*., 2009). Tomatoes can make an important effect to a healthy diet and can be consumed raw or cooked still maintaining their nutritive value (Bhowmik *et al*., 2012).

In Zimbabwe, tomato production contributes significantly to household income, employment creation and food security particularly amongst smallholder farmers (Zvomunya, 2022). Production can be rain-fed or irrigated making them available in the market all year round (Nyarko *et al*., 2025). However, tomato production faces several challenges such as pests, diseases, poor soil fertility and damping-off disease being a destructive disease affecting nursery establishment (Solankey *et al*., 2021).

2.2 Damping-Off Disease

Damping-off is a destructive disease that affects seedlings in nurseries, leading to pre- and post-emergence mortality. The primary pathogens responsible for damping-off are *Pythium spp*. and *Rhizotonia solani*, which thrive in warm and moist conditions typical of Zimbabwe (Madyirwa *et al*., 2016).

The pathogens responsible for damping-off diseases can also infect mature plants, causing various symptoms such as root rot, crown rot, stem lesions, and stem girdling. *R. solani* and

Pythium species are the two most common fungi associated with damping-off (Adhikari *et al*., 2024). *R. solani* is a soil fungus that survives between crops on plant debris and as microsclerotia, typically attacking seedlings near the soil surface and causing stem lesions and damping-off symptoms (Agrios, 2005). According to Bhardwaj, (2019) *R. solani* survives in the soil as mycelia and sclerotia and infects seedling through direct penetration of epidermal tissues and secrete enzymes that destroy the stem near the soil surface. This results in water-soaked lesions, stem girdling and eventually lodging of seedlings (Adhikari *et al*., 2024). *Pythium* species, produce oospores which remain dormant until favourable conditions occur (Elshahawy *et al*., 2019). Usually it causes root rot, surviving as oospores in the soil and attacking root hairs and tips, leading to progressive root deterioration (Shankar, 2016). The disease is particularly problematic for smallholder farmers who lack access to effective control measures, resulting in significant economic losses.

2.3 Biopesticides and Their Mechanisms

Biopesticides are derived from natural sources such as plants, microbes, and minerals, and they offer a sustainable alternative to chemical pesticides (Oguh *et al*., 2019). Garlic extract has been widely studied for its antimicrobial properties, primarily due to the presence of allicin**,** which inhibits fungal growth by disrupting cell membranes (Ankri and Mirelman, 1999). Ginger extracts have the ability to suppress damping-off disease by leveraging potent phytochemicals like gingersols and zingerone which affects bacterial and fungal pathogens (Yadav *et al*., 2023). Similarly, *Trichoderma harzianum* is a well-known biocontrol agent that suppresses fungal pathogens through mechanisms such as mycoparasitism, competition for nutrients, and induction of systemic resistance in plants (Harman e*t al*., 2004).

Biological seed treatment is an environmentally sustainable way that involves coating seeds with beneficial microorganisms, such as *T. harzianum* (Sharma *et al*., 2015). The use of these microbes has developed into an effective technology for managing a wide range of planting pathogens, while also offering additional advantages by enhancing key plant growth parameters (Khan *et al*., 2005).

Furthermore, bio agents inhibit seed and soil-borne pathogens through multiple antagonistic mechanisms, including rhizosphere colonisation, competition for nutrients and space, mycoparasitism and production of diverse bioactive compounds such as siderophores, antibiotics, volatile substances and growth promoting metabolites (Zaghloul *et al.*, 2008).

They also enhance plant defence by inducing systemic resistance (Mancini and Romanazzi, 2013).

2.4 *Trichoderma harzianum* as a biopesticide

Trichoderma harzianum is one of the widely studied and commercially used biological control agents due to its strong antagonistic activity against soil-borne plant pathogens responsible for damping-off disease (Elshahawy *et al*., 2019). It is commonly found in the soil where it colonises the rhizosphere and protects plants through several colonies including competition, mycoparasitism, antibiosis induced systemic resistance and plant growth promotion (Dutta *et al*., 2023). Due to these multiple mechanisms *T. harzianum* is considered an important component of sustainable disease management strategies (Harman *et al*., 2021).

One major mechanism is mycoparasitism which involves the direct attack of pathogens by *T. harzianum* (Elshahawy *et al*., 2019). During this process it recognises pathogens fungi, grows towards them coils around their hyphae and secretes cell wall that degrading enzymes such as chitinases, glucanases, and proteases (Viterbo *et al*., 2010). These enzymes break structural components of the pathogen cell wall causing destruction. Direct parasitic interaction significantly reduces pathogen survival in the soil. Benitez *et al*. (2020) demonstrates that that enzymes production is a key factor contributing to the effectiveness of *Trichoderma* as a biological control agent.

Furthermore, *T. harzianum* contributes to plant growth promotion making it beneficial not only for disease control but also for improving crop performance (Sharma *et al*., 2012). It improves nutrient solubility especially phosphorous and micronutrients making them more available for plant uptake. It also produces plant regulators stimulating hormones like auxins, cytokinin, gibberellins, ACC deaminase, enhanced nutrient uptake, phosphorous solubilisation, nitrogen fixation regulators that enhance root development and seedling vigour (Hakim *et al*., 2021). Improved root systems increase water absorption and nutrient uptake resulting in healthy seedlings with improved tolerance to stress. Harman *et al* (2021) reported that *Trichoderma-treated* seeds often show improved germination and enhanced overall plant growth.

2.5 Garlic as a biopesticide

Garlic (*Allium sativum*) has a strong antimicrobial, antifungal and antioxidant properties when used as seed treatment against soil-borne pathogens responsible for causing damping-

off disease as it contains sulphur-containing compounds such as allicin, diallyl disulphide which are released when garlic tissues are crushed or processed (Lydia, 2015). Another mechanism which makes garlic function as a biopesticide is the disruption of microbial cell membranes by allicin which penetrates fungal and bacterial cell walls because of its high membrane permeability. This reaction stops all activities of the pathogen resulting in its death or growth inhibition (Hayat *et al*., 2022)

In addition to microbial activity the garlic extracts also benefit to physiological and biochemical defence responses in tomato seedlings. Priming seeds with aqueous garlic extracts has been recorded that it enhances antioxidant enzyme activities which detoxify reactive oxygen species generated during pathogen attack or environmental stress thereby improving seedling vigour and stress tolerance (Tiwari and Agarwal, 2021).

2.6 Ginger as a biopesticide

Ginger (*Zingiber officinale*) is an effective botanical biopesticide because it contains bioactive compounds such as gingerols, zingerone and essential oils that possess antifungal, antibacterial, antioxidants and insecticidal properties and when used as a seed treatment ginger extracts create a protective layer around the seed surface reducing infection by soil-borne pathogens during germination (Upadhyaa *et al.,* 2020). These extracts also enhance plant defence mechanism by stimulating antioxidant enzymes such as catalase, peroxide and superoxide dismutase, which reduce oxidative stress and improve seedling vigour. In addition, ginger compounds may induce systemic resistance in tomato plants, helping seedlings better tolerate pathogen attack (Hyder *et al*., 2024)

2.7 Effect of plant extracts on seed treatment

Plant extract seed treatment have been reported for its antifungal and antibacterial effects by a large number of researchers (Hubert *et al*., 2015). Plant extract seed treatment is an ecologically sound, environmentally friendly, cost-effective method used to eliminate or reduce incidence of seed-borne pathogens and potentially suitable for use as an alternative to currently used fungicides, because these constitute a rich source of bioactive chemicals such as alkaloids, flavonoids, quinons, tannins, sterols and saponins (Mehedi *et al*., 2016).

2.8 Effect on disease incidence

Treating seeds with bio-agents provides an environmentally friendly method for pathogens control because of its ability to manage disease less dependent on the use of currently used

chemicals (Vanitha *et al.,* 2009). A demonstration was conducted by Dania and Omidiora (2019), to determine effect of tomato seed treatment with combination of biological control agents and garlic clove extract in minimising disease incidence of damping- off. The results revealed that combined application of BCAs *T. harzianum* and *A. sativum* extract showed the effectiveness in reducing mycelial growth of pathogen and significantly reduced disease incidence in tomato caused by *Pythium spp*. Seed treatment with *Z. offcinale* and *Curcuma longa* (turmeric) rhizome extract was found to be very successful in suppressing growth of *Pythium* optimum in chilli (Zagade *et al*., 2012). Tomato seed treatment with *A. sativum* extract proved most effective in reducing disease incidence by early blight as compared to other treatments and seed treatment with *Ocimum basilicum* (Basil) extract was found efficient in inducing resistance in tomato plants against *Fusarium wilt* (Nashwa and Abo-Elyousr., 2012; Akladious *et al*., 2014).

2.9 Effect on germination, seedling vigour and plant growth

Seed treatment with *A. sativum* extract was found efficient in reducing mycelial growth of *Pythium aphanidermatum* and significantly increased germination percentage, growth and vigour index of tomato seedlings (Kurucheve and Padmavathi, 1997). Plant extracts seed treatment have been proved effective in improving seed quality parameters in various crops. According to Rawal and Adhikari (2016), tomato seeds treated with *Z. officinale* and *A. sativium* extracts significantly improved germination percentage and seedling development greatly as compared to untreated seeds that is the control. Treating seeds with *T. harzianum* reduced mycelial growth of *Drechslera oryzae* and improved various seed quality parameters in rice (Kumawat *et al.,* 2010). A study conducted by Xue *et al.* (2017) demonstrated that treating seeds with *Trichoderma* spp. reduced mycelial growth of *fusarium graminearum*. *T. harzianum* enhanced emergence and yield of pea in *Fusarium* affected soils (Gupta *et al.,* 2021). According to Arzoo *et al*., (2013) he noted that wheat seeds treated with different plant extracts such as *Z. officinale, A. sativum* and ginger extracts proved that germination increased and also seedling vigour index. Application of *T. harzianum* and garlic extracts was recorded highly effective in providing maximum shoot length (25.50cm), root length (21.94cm) along with minimum root rot incidence (11.48%) (Kumawat *et al*., 2025).

2.10 Research gap

Despite growing interest in biological control of damping-off disease, several knowledge gaps still exist regarding the practical use of biological and botanical treatments in tomato

seedling production. Recent studies have shown that botanical extracts such as garlic (*A. sativum*) and ginger (*Z. officinale*) possess antifungal properties capable of suppressing plant pathogens. For instance, recent experiment demonstrated by Lurwanu and Khadeejah (2025) that plant extracts garlic and ginger at 25-100% concentration can significantly inhibit fungal growth and reduce pathogen development indicating potential alternative of chemical fungicides.

However, most studies have focused on laboratory evaluation of antifungal activity such as rather than evaluating the performance of this treatment under nursery conditions where environment factors such as moisture, temperature and management practices influence disease development. Recent research by Mendoza-Buenrostro *et al*. (2025) emphasizes the need for more applied studies evaluating plant-based diseases management strategies under practical production systems.

Furthermore, most studies evaluate the disease suppression alone without considering the combined effects of botanical treatments on both disease control and plant growth parameters such as germination, seedling vigour and survival rate. Sustainable disease management approaches require treatments that not only suppress pathogens but enhance plant establishment and productivity.

In addition, there is limited research under smallholder farmer conditions particularly developing countries including Zimbabwe where farmers require affordable safe disease management options. Since biological control effectiveness may vary depending on local environmental conditions studies are needed to validate the effectiveness of these treatments under practical nursery conditions.

Therefore, this study aims to address these gaps by evaluating the effectiveness of *T. harzianum*, garlic extracts and ginger extracts as seed treatment in controlling tomato damping-off disease and improving seedling growth under nursery conditions.

CHAPTER 3

Methodology and experimental design

3.1 Site

The experiment was done at Masembura, Sanyika village located in Bindura district in Mashonaland Central province Zimbabwe 17° 24` 50` S, 31° 15`33` E. The area falls under natural region IIb. The altitude varies from 940 m to 1440 m above sea level. Temperature ranges from 25 to 35 degrees Celsius and receiving annual rainfall from 700 mm to 1000 mm.

3.2 Experimental Design.

A Randomised Complete Block Design (RCBD) with one factor (treatment) was used.

Treatments: 6

Replication: 4

Total pots: 24

Seeds per pot: 30

3.3 Treatments

Table 3.1: Treatment used in the study.

Treatment	**Description**
T_1	Control
T_2	*Trichoderma harzianum* 10^5 cfu/ml
T_3	Garlic extracts 25% (w/v)
T_4	Ginger extracts 25% (w/v)
T_5	Combination of garlic 25% (w/v), ginger 25% (w/v) and T. *harzianum* 10^5 cfu/ml.

T_6	Positive control Apron star 42WS

3.4 Layout

Table 3.2: Treatment layout.

Block 1		Block 2		Block 3		Block 4	
T4	**T6**	**T2**	**T3**	**T6**	**T1**	**T2**	**T6**
T3	**T1**	**T4**	**T1**	**T4**	**T5**	**T1**	**T5**
T2	**T5**	**T5**	**T6**	**T2**	**T3**	**T3**	**T4**

3.5 Materials

The following materials were used during the field experiment:

- Tengeru certified tomato seeds (*solanum lycopersicum)* obtained from a reputable seed supplier.
- Garlic cloves
- Ginger
- *Trichoderma harzianum*
- Apron star 42WS
- Growth medium composed of mountain loam soil.

3.6 Preparation of treatments

Garlic and ginger extracts were prepared at 25% (w/v) 25 g plant extract into 100 ml of distilled water. Seeds soaked for 1 hour and air-dried before planting.

Trichoderma harzianum 10^5 cfu/ml was added in distilled water and soaked for 1 hour and air-dried before planting. This is done to introduce beneficial disease fighting microbes directly to the seed coat to prevent infection.

Application of Apron star 42WS was done by pouring water in a plastic bottle and add apron star 42ws and mix together shaking for a minute as per recommendation by the manufacturer then let the seeds dry before planting.

3.7 Nursery establishment and agronomic practises

The nursery was established under smallholder farmer conditions using pots as planting units. The use of pots allowed better control of soil conditions and accurate disease assessment while simulating nursery management practices commonly used by smallholder farmers.

The selected site was cleared of any vegetation, rocks or debris using a hoe. Using a rake, the ground was levelled so that the pots can sit properly. The pots were then arranged according to plot number and field in with humus soil collected from nearby mountain.

Plastic pots measuring 28 cm diameter and 25 cm depth were used filled with a prepared growth media dense mountain loam soil collected from a nearby mountain to improve soil structure, fertility, moisture holding capacity, good aeration and root development. Basal fertiliser was applied 20 g per pot.

The pot had holes at the bottom for drainage to prevent waterlogging and development of damping-off pathogens. The pots were arranged according to the experimental design with adequate spacing between pots to avoid treatment interference and allow easy management.

Each pot was labelled according to the treatment and replicated to ensure proper identification during data collection. The soil was then watered to field capacity to ensure adequate moisture for seed germination.

Tomato seeds were then planted according to treatment specifications. The pots were placed in an open environment where they received adequate sunlight similar to typical smallholder nursery conditions.

Tengeru Certified seeds were used in the experiment to ensure high quality viability and uniform germination. Seeds were planted at a uniform depth of approximately 3 cm to ensure proper emergence and a spacing of 5 cm between rows and 3 cm in rows was maintained to reduce overcrowding and allow proper seedling development. Proper spacing was important to reduce humidity around seedlings which may favour damping-off disease development.

Irrigation was done using a watering can to maintain adequate soil moisture necessary for germination while avoiding waterlogging. Watering was done lightly and regularly depending on moisture conditions to prevent pathogen development. Care was taken to make sure all treatments received equal amounts of water.

Application of Ammonium nitrate was applied as a top dressing at 2 g per pot 3 weeks after emergence.

Weeding was done manually to remove unwanted plants that could compete with tomato seedlings for nutrients water and light. Removal of weeds also helped reduce possible alternative hosts for pathogens. Thinning was done where necessary to maintain uniform plant density.

3.8 Data collection

3.8.1 Germination percentage

Germination was recorded on day 14th day.

$$germination\ \% = \frac{\text{number of germinated seeds}}{\text{total number of seeds}} \times 100$$

3.8.2 Disease incidence

$$disease\ incidence\ \% = \frac{\text{number of diseased seedlings}}{\text{total number of seeds}} \times 100$$

Disease incidence was assessed at 2, 4, and 6 weeks after planting by counting seedlings showing damping-off symptoms.

3.8.3 Seedling vigour

$$vigour\ index = germination\ \% \times (shoot\ length + root\ length)$$

Seedling vigour was assessed at 2, 4, and 6 weeks after planting.

3.9 Data analysis

The data was analysed using Analysis of variance (ANOVA), GenStat Statistical Analysis package seventeenth edition software. An analysis of variance was performed, and a least significant difference at $p \leq 0.05$ level was used to separate means.

CHAPTER 4

Results

4.1 Effect of synthetic, botanical and microbial seed treatment on germination percentage at day 14 (2 weeks) after planting

There was a highly significant effect on tomato seed germination percentage by the seed treatments at day 14 after planting shown by ($P<0.001$). The highest germination percentage recorded in seeds treated with Apron star 42WS 98% followed by *Trichoderma harzianum* 96.60%. Those treated with garlic recorded 94.25% and combination of *T. harzianum,* garlic and ginger had 91.50% whilst the lowest were control having 88.75% (Table 4.1).

Table 4.1: Comparative efficacy of synthetic, botanical, and microbial seed treatments showing (Apron Star, ginger, garlic and *T. harzianum)* on germination percentage.

Treatment	**Germination percentage**
Apron star	98.00^{a}
Combination (garlic, ginger and *T. harzianum*)	93.50^{abc}
Control	88.75^{c}
Garlic	94.25^{abc}
Ginger	91.50^{bc}
T. harzianum	96.60^{ab}
Grand mean	93.67
P-value	<0.001
S.E.D	1.380
L.S.D	2.942
CV%	2.1

Means followed by different superscript letters are significantly different.

4.2: Effect of synthetic, botanical and microbial seed treatment on disease incidence at 2 weeks, 4 weeks and 6 weeks after planting

There was a highly significant effect on disease incidence at all assessment times (P <0.001). The grand mean on disease incidence decreased progressively from 13.50% at 2 weeks to 10.21% at 4 weeks up to 5.67% at 6 weeks after planting. The control consistently recorded the highest disease incidence across all the assessment times. Apron star 42WS and combination of *T. harzianum* garlic and ginger showed the lowest values 4.50%, 3.50%, 1.50% at 2, 4 and 6 weeks after planting respectively. *T. harzianum* performed very well with disease incidence of 8.00% at 2 weeks, 5.00% at 4 weeks and 2.50% at 6 weeks. Garlic and Ginger were intermediate with garlic (15.00%, 12.00% 7.00%) showing slightly better suppression than ginger (18.25%, 14.50%, and 8.75%) (Table 4.2).

Table 4.2: Effect synthetic, botanical and microbial seed treatment on disease incidence at 2, 4 and 6 weeks after planting.

Treatment	**Disease incidence at 2 weeks**	**Disease incidence at 4 weeks**	**Disease incidence at 6 weeks**
Apron star	4.50[a]	3.50[a]	1.50[a]
Combination (garlic, ginger and *T. harzianum*)	4.50[a]	3.50[a]	1.50[a]
Control	30.75[e]	22.75[f]	12.75[e]
Garlic	15.00[c]	12.00[d]	7.00[c]
Ginger	18.25[d]	14.50[e]	8.75[d]
T. harzianum	8.00[b]	5.00[c]	2.50[b]
Grand mean	13.50	10.21	5.67
P-value	<0.001	<0.001	<0.001
S.E.D	0.511	0.536	0.465
L.S.D	1.089	1.143	0.992
CV%	5.4	7.4	11.6

Means followed by the different superscript letters are significantly different.

4.3 Effect of synthetic, botanical, and microbial on seedling vigour at 2 weeks, 4 weeks and 6 weeks after planting

There was a highly significant effect (P<0.001) on seedling vigour at 2, 4 and 6 weeks after planting. Seedling vigour increased progressively over time across all treatments. At 2 weeks *T. harzianum* produced the highest vigour (1220.0) secondly Apron star 42WS (1178.5) and the combination of garlic, ginger and *T. harzianum* (1130.3) whilst the control recorded the lowest value (917.8). At 4 weeks *T. harzianum* remained superior (2948) but combination of garlic, ginger and *T. harzianum* (2848) performed nearly as well as Apron star 42WS (2698). Garlic (2253) and ginger (2351) improved vigour compared to control (1491). At 6 weeks *T. harzianum* had the highest vigour compared to Apron star 42WS and combination of garlic, ginger and *T. harzianum* (3812) showing comparable performance. Ginger and garlic performed better than control (Table 4.3).

Table 4.3: Comparative efficacy of synthetic, botanical and microbial seed treatment (Apron Star, garlic, ginger and *T. harzianum*) on seedling vigour at 2, 4 and 6 weeks.

Treatment	**Seedling vigour at 2 weeks**	**Seedling vigour at 4 weeks**	**Seedling vigour at 6 weeks**
Apron star	1178.5[a]	2698[ab]	3899[ab]
Combination (garlic, ginger and *T. harzianum*)	1130.3[ab]	2848[a]	3812[a]
Control	917.8[c]	1491[c]	2346[c]
Garlic	968.4[bc]	2253[b]	3351[b]
Ginger	950.8[c]	2351[b]	3245[b]
T. harzianum	1220.0[a]	2948[a]	4040[a]
Grand mean	1060.9	2431	3899
P-value	<0.001	<0.001	<0.001
S.E.D	29.82	60.3	112.5
L.S.D	63.56	128.6	239.7
C.V%	4.0	3.5	4.6

Means followed by different superscript letters are significantly different.

CHAPTER 5

Discussion

5.1 Effect of synthetic, botanical and microbial seed treatment on germination percentage at day 14 (2 weeks) after planting

The demonstrated results from this study show that seed treatment with biopesticides significantly improved tomato seed germination compared to untreated control $P < 0.001$. The highest germination was recorded in seeds treated with Apron star 42WS followed by *T. harzianum* while the control recorded the lowest.

Trichoderma harzianum's performance in enhancing germination is consistent with findings by Harman *et al* 2021, who recorded that *T. harzianum* treated seeds often show improved germination and enhanced overall plant growth. The ability of *T. harzianum* to produce plant growth regulators such as auxins, cytokinins and gibberellins which stimulate root development and seedling vigour by engineering the rhizosphere to improve nutrient utilization and biomass development (Hakim *et al*., 2021). Furthermore, the fungus enhances nutrient solubility, particularly phosphorus making essential nutrients more available for germinating seeds (Gonilha, 2025). The results agree with research done by Gupta *et al.* (2021) who reported enhanced seed emergence and plant establishment following seed treatment with *T. harzianum* species. Similarly, Cardarelli *et al*. (2022) observed that microbial seed treatments exert bio stimulant effects that improve germination and seedling growth.

The effectiveness of ginger and garlic extracts in improving germination percentage correspond with observations by Rawal and Adhikari (2016), suggesting that tomato seeds treated with *Zingiber officinale* and *Allium sativum* extracts significantly improved germination percentage compared to untreated seeds. Similarly, Arzoo *et al*. (2013) observed

that wheat seeds treated with ginger and garlic extracts showed increased germination percentage and seedling vigour. The bio-active compounds in these plant extracts including allicin in ginger and gingerols in ginger may create a protective micro-environment around the seed reducing pathogen pressure and allowing better germination Ankri and Mirelman, (1999); Vita *et al*., (2019).

The lower germination percentage observed in the untreated control may be attributed to the unrestricted activity of damping-off pathogens, which affect seed viability and reduce seedling emergence. The results therefore demonstrate that seed treatment not only protects seeds against pathogens rather they also enhance physiological processes involved in germination

5.2 Effect of synthetic, botanical and microbial seed treatment on disease incidence at 2 weeks, 4 weeks and 6 weeks after planting

The study proved a highly significant effect $P<0.001$ of seed treatment on damping-off disease incidence at all assessment times (2, 4 and 6 WAP). The untreated control persistently recorded the highest disease incidence at 2, 4 and 6 weeks respectively confirming the destructive nature of damping-off disease under nursery conditions. According to Adhikari *et al*. (2024) high disease level may be associated with the activity of soil-borne pathogens such as *Pythium spp*. *Rhizoctonia solani* which thrive under moist conditions. Apron star 42WS and the combination of *T. harzianum*, ginger and garlic treatment showed the lowest disease incidence values across all assessment times indicating that they were effective in suppressing disease incidence over time.

There was progressive decrease in disease incidence with time across all treatments grand mean from 2 weeks to 6 weeks. Young seedlings are susceptible to damping-off pathogens and as stems lignify and roots develop plants become more resistant to infection (Agrios, 2005). *T. harzianum's* strong performance against damping-off disease through mycoparasitism, competition for nutrients and space production of antifungal metabolites and induction of systemic resistance in plants (Harman *et al*., 2004). Benitez *et al*. (2020) reported that enzyme production by *Trichoderma* species contribute significantly to suppression of fungal pathogens.

Garlic extract showed moderate disease suppression while ginger extracts showed slightly lower effectiveness. Antimicrobial properties of garlic are due to allicin and diallyl suphides,

which disrupt fungal cell membranes and inhibit pathogen growth (Ankri and Mirelman, 1999; Muhammad *et al*., 2020). The better performance of garlic over ginger in this study is consistent with findings by Dania and Omidiora, (2019) who reported that combined application of *T. harzianum* and garlic extracts significantly reduced disease incidence in tomato caused by *Pythium spp*. The comparable performance of the combination treatment to Apron star 42WS suggests that the integration of biological and botanical agents can achieve disease control effects similar to the chemical fungicides, supporting the potential for biopesticides.

The comparative performance of the combination of garlic, ginger and *Trichoderma harzianum* and Apron Star 42WS suggests that integrated application of botanical and biological agents can provide disease control comparable to synthetic fungicides. This highlights the potential of combining environmentally friendly approaches for sustainable disease management.

5.3 Effect of synthetic, botanical, and microbial on seedling vigour at 2 weeks, 4 weeks and 6 weeks after planting

Seedling vigour showed high significant treatment effects $P<0.001$ at all assessment periods. Seedling vigour increased progressively with time for all treatments with *T. harzianum* consistently producing the highest vigour across all assessment times reflecting normal growth and development.

The high performance observed in *T. harzianum* treated seedlings can be explained by the versatile growth promoting effects of this biopesticide. According to Harman *et al*. (2021), *T. harzianum* enhance root development, improve water and nutrient uptake and produce plant growth regulators that altogether contribute to high seedling vigour. Furthermore, the induction of systemic resistance by *T. harzianum* primes the plant's defence mechanisms allowing good resource allocation to growth other than sorely to disease response (Mancini and Romanazzi, 2013).

Garlic and ginger extracts performance in improving seedling vigour at 6 weeks compared to the control supports findings by Kurucheve and Padmavathi (1997), who reported that garlic extract significantly increased germination percentage, growth and vigour of tomato seedlings. Besides antimicrobial effects, garlic extracts have been shown to enhance antioxidant enzyme activities in tomato seedlings which detoxify reactive oxygen species

generated pathogen attack thereby improving stress tolerance and vigour (SIkandar Hayat, 2020).

CHAPTER 6

Conclusions and Recommendations

Conclusion

This study evaluated the efficacy of seed treatment with biopesticides *Trichoderma harzianum*, garlic and ginger and their combination against damping-off disease in nursery grown tomatoes under smallholder farmer conditions in Zimbabwe. Based on the findings all biopesticides significantly improved germination percentage compared to untreated control, with *T. harzianum* performing comparably with a synthetic fungicide Apron Star 42WS demonstrating its potential as effective and eco-friendly seed treatment for enhancing germination. Biopesticides significantly reduced damping-off disease at all assessment times *T. harzianum* proved high effectiveness while garlic extracts performed better than ginger extracts. The combination of these biopesticides performed similar to Apron star 42WS indicating potential for integrated biological control and suggesting that it can be used as an alternative in order to avoid over reliance on synthetic fungicides. On seedling vigour, *T. harzianum* consistently improved the growth rate across all assessment times followed by Apron star 42WS and the combination treatment. Garlic and ginger extracts also significantly improved seedling vigour compared to the control demonstrating their dual role in disease

suppression and growth promotion. *T. harzianum* and garlic at 25% (w/v) offer environmentally friendly and cost-effective alternatives to synthetic fungicides for managing damping-off diseases in tomato nurseries.

Recommendations

- The adoption of *T. harzianum* as a seed treatment for tomato is strongly encouraged as it demonstrated excellent performance in increasing germination percentage, low disease suppression and seedling vigour improvement.
- For farmers with limited access to commercial biocontrol products, garlic extract prepared at 25% (w/v) concentration provides an effective low cost and locally available alternative for reducing damping-off incidence and improving seedling health.
- Combined use of garlic, ginger and *T. harzianum* should be considered since it produced suppression of disease compared to Apron Star 42WS.
- Farmers should reduce excessive dependency on chemical fungicides to minimize environmental pollution, pathogen resistance and health risks associated with synthetic chemicals.
- Further studies should also investigate the long-term effects of biopesticides treatments on tomato yield, fruit quality and soil microbial health.
- Agriculture colleges and extension training programs should incorporate biopesticides production and application techniques into their curricula to build local capacity for sustainable disease management.
- Biopesticides can also be incorporated into integrated pest and disease management programmes to avoid resistance
- Future research should be evaluated for different combination and concentrations of *Trichoderma harzianum*, ginger and garlic to increase their effectiveness against damping-off disease.

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APPENDICES

Analysis of varience

Variate: Germination Percentage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	12.333	4.111	1.08	
Block. Units stratum					
Treatment	5	213.833	42.767	11.22	<.001
Residual	15	57.167	3.811		
Total	23	283.333			

Analysis of variance

Variate: Disease_incidence_at_2_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	1.6667	0.5556	1.06	
Block. Units stratum					
Treatment	5	2058.5000	411.7000	788.36	<.001
Residual	15	7.8333	0.5222		
Total	23	2068.0000			

Analysis of variance

Variate: Disease_Incidence_at_4_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	3.1250	1.0417	1.81	
Block. Units stratum					
Treatment	5	1184.2083	236.8417	411.90	<.001
Residual	15	8.6250	0.5750		
Total	23	1195.9583			

Analysis of variance

Variate: Disease_incidence_at_6_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	4.0000	1.3333	3.08	
Block. Units stratum					
Treatment	5	424.8333	84.9667	196.08	<.001
Residual	15	6.5000	0.4333		
Total	23	435.3333			

Analysis of variance

Variate: Seedling_vigour_at_2_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	2033.	678.	0.38	
Block. Units stratum					
Treatment	5	340506.	68101.	38.29	<.001
Residual	15	26680.	1779.		
Total	23	369219.			

Analysis of variance

Variate: Seedling_vigour_at_4_weeks

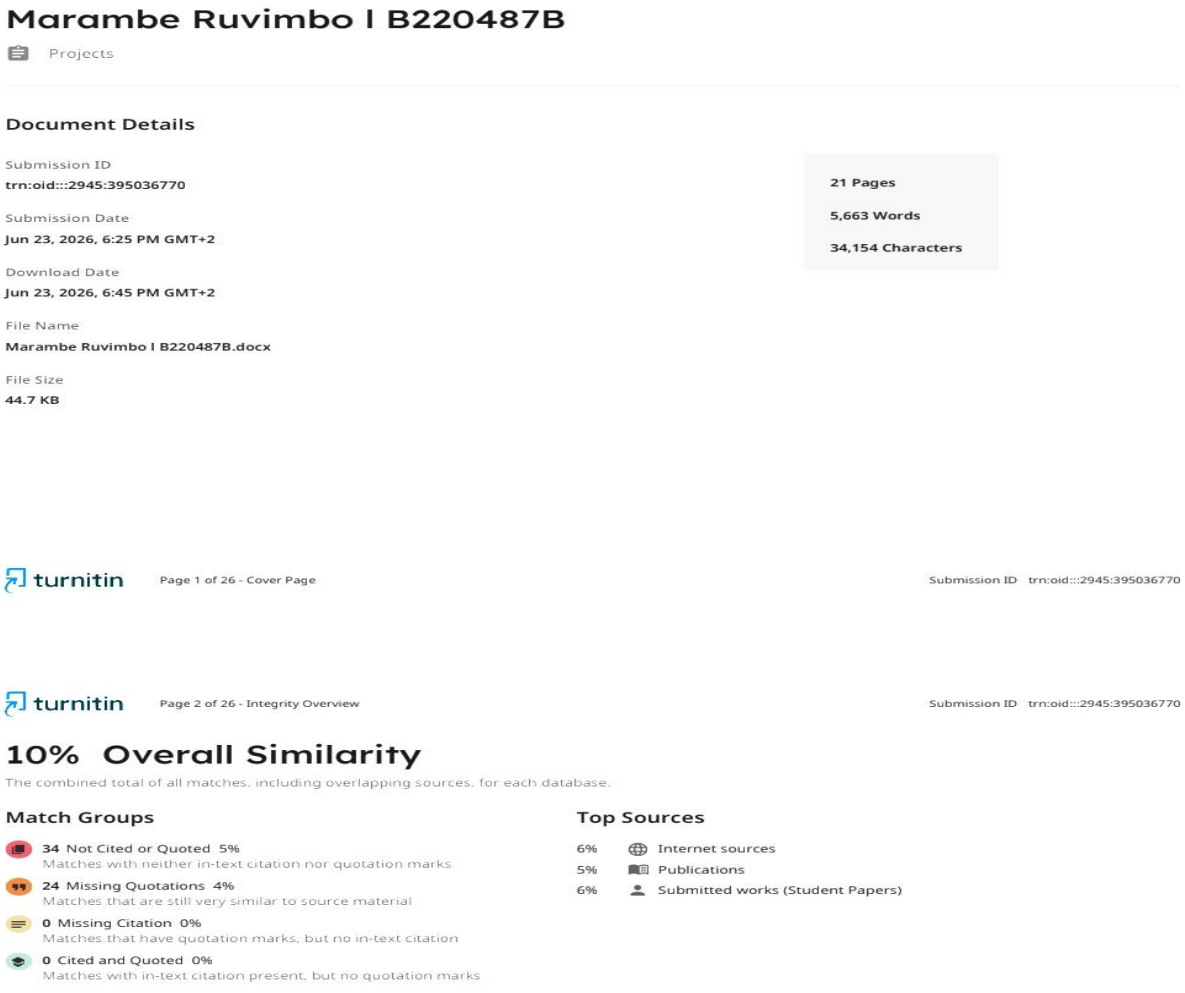
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	11862.	3954.	0.54	
Block. Units stratum					
Treatment	5	5738535.	1147707.	157.76	<.001
Residual	15	109128.	7275.		
Total	23	5859524.			

Analysis of variance

Variate: Seedling_vigour_at_6_weeks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	21867.	7289.	0.29	

Block. Units stratum					
Treatment	5	7808514.	1561703.	61.74	<.001
Residual	15	379435.	25296.		
Total	23	8209817.			



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34 Not Cited or Quoted 5%
Matches with neither in-text citation nor quotation marks

24 Missing Quotations 4%
Matches that are still very similar to source material

0 Missing Citation 0%
Matches that have quotation marks, but no in-text citation

0 Cited and Quoted 0%
Matches with in-text citation present, but no quotation marks

Top Sources

6% Internet sources
5% Publications
6% Submitted works (Student Papers)