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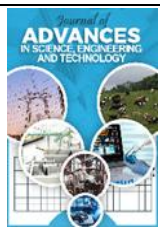
Journal of Advances in Science, Engineering and Technology



Phytochemicals in *Mondia whitei* Confer Fungistatic Activity Against *Alternaria solani* and *Phytophthora infestans* and Improves Tomato (*Solanum lycopersicum*) Performance

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ABSTRACT

Tomato is a significant vegetable, but is adversely attacked by several fungal diseases that lower yield. Bio-extracts from plants, as fungicides are safe to human and the environment. This study assessed the impact of *Mondia whitei* extracts on tomato plant growth and antifungal activity in vitro and in vivo and screened for fungistatic phytochemicals in the plant's extract. The extracts were obtained from *M. whitei* roots using methanol, dichloromethane, and ethyl acetate solvents and tested against *Alternaria solani* and *Phytophthora infestans* at concentrations of 10% and 20% in vitro and 2.5%, 10%, and 20% in vivo. Ridomil was used as positive control and blank as negative control. In vitro and in vivo experiments were replicated three and four times, respectively, in a completely randomized design. The extracts completely inhibited in vitro growth of the pathogens. In vivo *M. whitei*-treated plants showed a significant reduction ($p \leq 0.05$) in *A. solani* and *P. infestans* disease incidences which were recorded at 18.57% and 35% respectively for 20% bio-extract. Tomato plants treated with negative control recorded 57.86% and 80% for *A. solani* and *P. infestans*, respectively. Disease severity index in *A. solani* inoculated plants was 4.43 for 20% bio-extract compared to negative control that recorded an index of 8.29. For *P. infestans*, 20% bio-extract recoded disease severity index of 7.14 compared to 10.42 in the negative control plants. Plant height increased with increase in extract concentration. Negative control, 2.5%, 10% and 20% bio-extract concentrations recorded heights of 93.49 cm, 119.04 cm, 128.72 cm and 133.96 cm respectively for *A. solani* inoculated plants and 99.30 cm, 99.97 cm, 111.42 cm and 117.71 cm respectively for *P. infestans* inoculated plants. Phytochemicals such as flavonoids, tannins, and steroids among others were detected. This study presents *M. whitei* as a potentially safe and affordable alternative to synthetic fungicides against fungal diseases in tomato crops.

ARTICLE INFO

Keywords:
Mondia whitei,
Alternaria solani,
Phytophthora infestans,
Phytochemicals,
Bio-extracts.

Article History:
Received 9 October 2024
Received in revised form 3 February 2025
Accepted 5 February 2025
Available online 8 April 2025

1. Introduction

Tomato, *Solanum lycopersicum*, is a major horticultural crop, and is the most consumed vegetable in the world due to its economic and nutritional value (Sandoval-Ceballos et al., 2021; Quinet et al., 2019). It is the most produced vegetable fruit globally, accounting for 14% of Kenya's overall vegetable production and 7% of the country's total horticulture products (FAOSTAT, 2022). In Kenya, smallholder farmers are the majority of tomato producers (Ochilo et al., 2019). The fruit's consumption in Kenya was estimated to be at 583,000 metric tons in the year 2021 and is estimated to increase to 632,000 metric tons by the year 2026 (ReportLinker, 2022). The average area harvested in Kenya is 28,330 ha, yielding 23.2 tons per ha annually (FAOSTAT, 2022).

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Editor: Gershom Mutua, Masinde Muliro University of Science and Technology, Kenya.
Citation: Maurice C., Evelyne M., Mary K., & Peter K. (2025). Phytochemicals in *Mondia whitei* Confer Fungistatic Activity Against *Alternaria solani* and *Phytophthora infestans* and Improves Tomato (*Solanum lycopersicum*) Performance. Journal of Advances in Science, Engineering and Technology 1 (2025), 25 – 33.

However, the potential yield is above 30.7 metric tons per ha (Ochilo et al., 2019). The yield gap is attributed to a number of yield-reducing factors, including both biotic and abiotic factors, which can lead to losses of up to 100% (Mwangi et al., 2015).

Tomato diseases, including fungal diseases, pose a significant risk to tomato yield (Godfray et al., 2016). Early and late blight diseases, caused by *Alternaria solani* and *Phytophthora infestans*, respectively, can severely limit yield when conditions are favorable (Panthee et al., 2024). For both blights, losses in marketable crops can range from 79.81%-100% in an unmanaged tomato field, while the loss in managed fields can be between 12%-65% (Amin et al., 2013). Synthetic fungicides are the most popular method of disease control, but they are costly, persist in the environment and hazardous to users. Some pathogens have also become resistant to synthetic pesticides, forcing farmers to use pesticides more frequently (Peng et al., 2021), and this has resulted in fresh vegetable interceptions to profitable foreign markets due to chemical residues (Lengai et al., 2017).

To control these diseases, safer, more economical, and ecologically friendly fungicidal options are required. Plant extracts have been shown to possess fungicidal capabilities (Gizaw et al., 2022; Choga et al., 2021). Particularly, *M. whitei* could be a valuable source of antimicrobial metabolites (Deeh et al., 2024; Gbadamosi & Erinoso, 2015). The plant has been proven to inhibit growth of *Candida albicans* and *Aspergillus niger* (Mayunzu et al., 2012). Therefore, this experiment aimed to examine the potential antifungal activity of *M. whitei* root extracts against *A. solani* and *P. infestans*, which are harmful plant pathogens in the *Solanaceae* plant family, and thereafter screen for the presence or absence of secondary metabolites.

2. Materials and Methods

2.1. Collection and Authentication of Plant Materials

Medicinal plant species *M. whitei* was collected in October 2022. It was specifically collected from Kakamega forest in Lurambi Sub-County, Kakamega County at an elevation of 1400-1700 m above sea level. The forest is located in the western part of Kenya (0°07' 0°27' N, 34°46' 34°57' E) and covers an area of 238 km^2. Over the year the temperature typically varies from 14°C to 29°C with 78% average relative humidity. The area also receives an average annual rainfall ranging from 1280.1 mm to 2214.1 mm. The identification of the plant used was confirmed by a botanist, in the Department of Agriculture and Land use Management at Masinde Muliro University of Science and Technology (MMUST).

2.2. Preparation and Extraction of Plants Materials

Mondia whitei roots were washed with running tap water and air dried in the shade for eight weeks at the MMUST Biotechnology laboratory. Preparation of the aqueous crude extracts of *M. whitei* was done using the method described by Kritzinger (2006) with minor modifications. The dried roots were ground into a fine powder using an electric blender (Mixer Blender RN-999 350W). Three hundred grams (300 g) of the powdered plant roots were each soaked in 900 ml of absolute dichloromethane (DCM), ethyl acetate (EtOA), and methanol (MeOH) solvents for 72 hours with occasional shaking of the mixture after every 12 hours. The solution was then filtered using a vacuum filter. Thereafter, the filtrate obtained was concentrated in a vacuum at each solvent's respective boiling points (DCM-39.6 °C, EtOA-77.1 °C, and MeOH- 64.7 °C) using rotary evaporator bio-based equipment (EYELA Digital Water Bath SB-1000-Oasis Scientific, Inc.). Stock solutions containing 100% *M. whitei* were prepared, followed by a working solution using the formula: $C1V1 = C2V2$ for each solvent extract. Where C1V1 means concentration and volume of working solution, respectively, while C2V2 means concentration and volume of stock solution, respectively. The working solutions were then stored in the refrigerator at 4°C until use.

2.3. Inhibition of Mycelium Growth In vitro

Pour plate method was used in the screening of *M. whitei* extracts for their antifungal properties. For each pathogen, mycelia growths were evaluated in 60 mm petri dishes filled with PDA medium amended with either 10% or 20% aqueous extracts from each solvent extract of *M. whitei*, 0.25% of fungicide-ridomil (positive control), and a non-treated control. The experiment was laid in a completely randomized design, and replicated three times. The center of each petri dish was inoculated with a 5 mm diameter disc of fungal mycelium, taken from pure culture. All the inoculated dishes were incubated at 28°C for 7 days. Mycelial growth was observed as an indicator of the antifungal activity of each solvent extract. Observations on the growth of the fungus were recorded at three and seven days after inoculation.

2.4. Phytochemical Screening of *M. whitei* Extracts

The existence or lack of phytochemicals in each plant extract was examined using common laboratory qualitative procedures in accordance with the protocol established by Harborne (1998).

2.5. Effects of *M. whitei* Extracts on Pathogens and Tomato Growth in vivo

The in vivo experiment employed a CRD with five treatments: three levels of bio-extracts (2.5%, 10%, and 20%), a positive control (0.25% ridomil) and a negative control, which were replicated four times, giving a total of forty plots. Plants were established in pots, with five plants per plot. There were two hundred plants, one hundred for each pathogen experiment. Sanitized pots were filled with sterilized loam soil and supplemented with well-decomposed farmyard manure. Three-week-old healthy "*Moneymaker*" variety tomato seedlings were carefully selected and then transplanted in the pots. Seven days after recovering from transplanting stress, tomato plants in the first and second 100 bags were foliar inoculated with *A. solani* and *P. infestans*,

respectively. The conidia were isolated using pour plate technique. Using haemocytometer (Superior Marienfeld, Germany) under the binocular light microscope (Labomed cxl mono) (400x) the conidia were adjusted to the concentration of 1×108 and 1×109 conidia mL^{-1}. The plants were monitored for infection and disease progression. After four days when the symptoms of both blights were observed, the bio-extract treatments were sprayed on the tomato plant foliage and thereafter weekly. Three spray dosages of the fungicide ridomil were sprayed at 14-day intervals. Collection of data from every plant commenced on the first day of application of treatments and thereafter weekly. Plants were tagged for consistency in data collection. Data was collected on the following parameters:

Disease Incidence: The incidence of blight was determined by counting infected plants per treatment and expressing as the percentage of total plants in the same treatment using the formula: $DI\% = \left(\frac{NI}{TNP}\right) \times 100$. Where DI is disease incidence, NI is number of infected plants, and TNP is total number of plants (Amin et al., 2013).

Disease severity: The study used the modified Horsfall-Barrat rating scale to assess disease severity in 12 compound leaves in each plant (1 = 0%, 12 = 100% disease severity) (Choga, 2021).

Plant height (cm): The height of the plants was measured from the ground to the tip using a tape measure.

Leaflet size and compound leaves number: The length of a compound leaf was measured from the apex to the stalk, and the number of compound leaves counted per plant and recorded.

Flower trusses: The number of flower trusses in each plant was counted and recorded.

Yield: Fruits were harvested based on the skin color maturity index, when three-quarters of the skin turned to pink color. All the fruits were harvested including damaged ones, and this was done weekly from week 4-8 of the experiment.

Marketable Yield: Tomato fruits were collected from each treatment, and respondents, already familiar with their quality and marketability, were asked to rate their satisfaction using a five-level satisfaction Likert scale (Tansakul & Yenradee, 2020).

Total Dry Biomass: At the end of the season, the plants were carefully uprooted, washed with tap water, wrapped using foil paper, and dried in an oven at 70°C for 24 hours and then weighed using a weighing scale.

2.6. Data analysis

Data for the different parameters were analyzed using JMP SAS software version 17.2. Data collected was subjected to Analysis of Variance (ANOVA) and mean separated using the Tukey's test at P≤ 0.05 to determine which specific means within the different variables among treatments were different from each other.

3. Results

3.1. In vitro efficacy trial of *M. whitei* extracts on fungi

The results showed that there was no growth (0.0 mm) on the petri dishes treated with both concentrations of *M. whitei* extracts of all the solvents (MeOH, DCM, and EtOA) for both *A. solani* and *P. infestans* experiments (Table 1). Petri dishes treated with positive control (0.25% ridomil) also exhibited no growth of the two pathogens in both experiments. A significantly high (p≤0.05) mean radial growth of 29.5 mm, 29.4 mm, and 31.1 mm were recorded in non-treated media for MeOH, DCM, and EtOA extract solvents, respectively, for *A. solani* (Table 1). While a significantly high (p≤0.05) mean radial growth of 60.0 mm, 60.0 mm, and 60.0 mm was recorded in non-treated media (control) for MeOH, DCM, and EtOA extract solvents, respectively, for *P. infestans* (Table 1).

Table 1: *Antifungal activity of Mondia whitei* root extracts against *Alternaria solani* and *Phytophthora infestans*

		Mean Radial growth (mm)	
Plant Extract	**Concentration**	***A. solani***	***P. Infestans***
MeOH	10%	0.0 b	0.0 b
MeOH	20%	0.0 b	0.0 b
Ridomil	0.25%	0.0 b	0.0 b
Control	non-treated media	29.5 a	60.0 a
DCM	10%	0.0 b	0.0 b
DCM	20%	0.0 b	0.0 b
Ridomil	0.25%	0.0 b	0.0 b
Control	non-treated media	29.4 a	60.0 a
EtOA	10%	0.0 b	0.0 b
EtOA	20%	0.0 b	0.0 b
Ridomil	0.25%	0.0 b	0.0 b
Control	non-treated media	31.1 a	60.0 a

Numbers with the same letter within a column are not significantly different according to Tukey HSD test at p≤0.05. Key: MeOH: Methanol, DCM: Dichloromethane, EtOA: Ethyl-acetate

3.2. Phytochemical screening

Mondia whitei extracts were found to have various tested secondary metabolites, except for triterpenoids and anthraquinones. MeOH extract was found to have steroids, cardiac glycosides, carbohydrates, alkaloids, saponins, terpenoids, and volatile oils, while DCM extract had tannins, steroids, glycosides, flavonoids, cardiac glycosides, alkaloids, and volatile oils. EtOA extract had tannins, steroids, glycosides, flavonoids, cardiac glycosides, alkaloids, and volatile oils. However, a number of secondary metabolites were not detected in MeOH extract, including tannins, glycosides, and flavonoids, while DCM extract did not have carbohydrates, saponins, or terpenoids. EtOA extracts did not have carbohydrates, saponins, or terpenoids.

3.3. In vivo efficacy trial of *M. whitei* extracts against antifungal activities and growth of tomato

3.3.1. Disease Incidences

The study found that *A. solani* inoculated plants had significantly lower (p≤0.05) disease incidences of 18.57% and 20.0% in plants treated with 20% extract concentration and 0.25% ridomil, respectively. The two

treatments were, however, statistically at par (p≤0.05) with each other. Nevertheless, there was a significant difference (p≤0.05) in *P. infestans* disease incidences between plants treated with 20% extract concentration (35% disease incidences) and those treated with 0.25% ridomil (30% disease incidences). In addition, disease incidences were significantly higher (p≤0.05) in both pathogen experiments on tomato plants treated with negative control (57.86% and 80% for *A. solani* and *P. infestans*, respectively) compared to the rest of the treatments.

Generally, with increasing extract concentration, disease incidences significantly reduced (p≤0.05) from 30% to 18.57% and 52.14% to 35% in *A. solani* and *P. infestans* inoculated plants, respectively. Additionally, the experiment showed that negatively controlled plants experienced exponentially increasing disease incidences (Fig. 1).

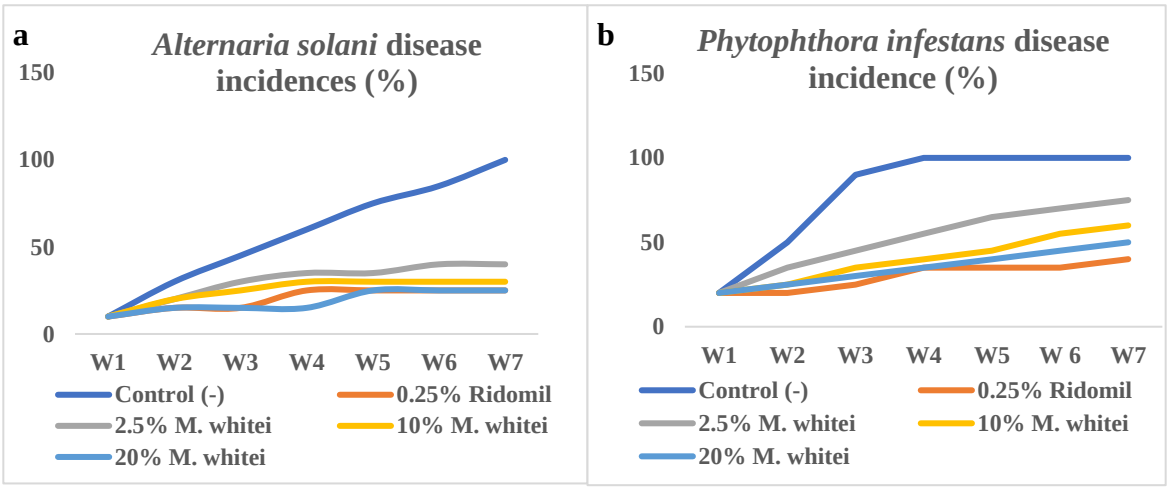

Fig. 1: Effect of *Mondia whitei* extracts on incidences of early blight and late blight of tomato (a) *Alternaria solani* (b) *Phytophthora infestans* inoculations

Disease Severity: The study found that *A. solani* inoculated plants had a significantly lower (p≤0.05) disease severity index of 4.71, 4.43, and 4.57 in plants treated with 10%, 20% extract concentrations, and 0.25% ridomil, respectively, but a significantly higher (p≤0.05) severity index of 8.29 in tomato plants treated with negative control, compared to the rest of the treatments in the experiment, which recorded severity indexes of 4.57, 6.0, 4.71, and 4.43, respectively, for 0.25% ridomil, and *M. whitei* extracts 2.5%, 10%, and 20%.

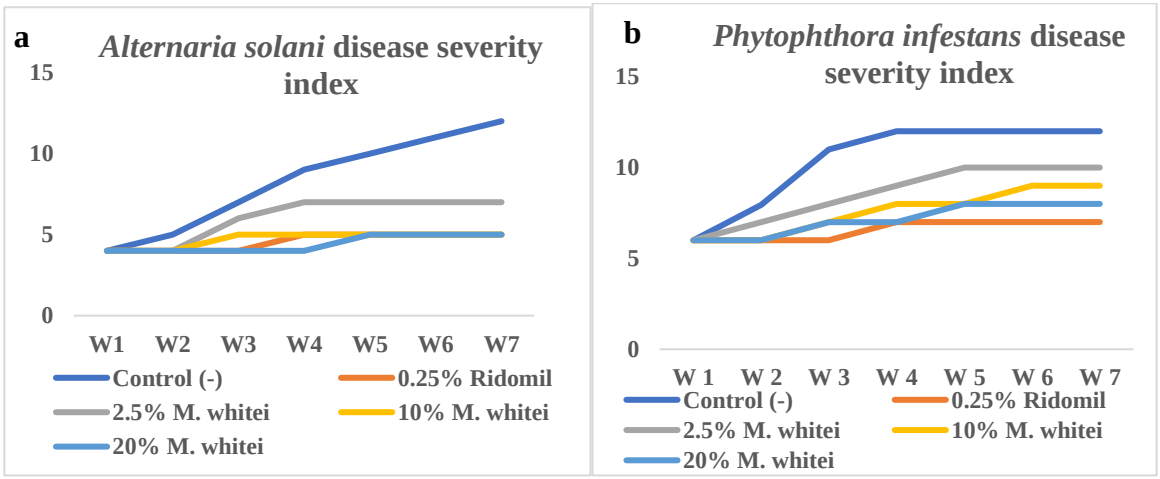

Fig. 2: Effect of *Mondia whitei* extracts on disease severity on tomato plants (a) Early blight (b) Late blight

Similarly, in the *P. infestans* experiment, disease severity was significantly higher (p≤0.05) in the negative control treatment, which recorded a severity index of 10.42, compared to the rest of the treatments, which recorded severity indexes of 6.57, 8.57, 7.57, and 7.14 for 0.25% ridomil, 2.5%, 10%, and 20% extract concentrations, respectively. However, plants treated with 0.25% ridomil recorded a significantly low (p≤0.05) disease severity compared to other treatments in the plants inoculated with *P. infestans*.

Overall, plants treated with negative control showed an exponential increase in disease severity from 4.00 in week one to 12.00 in week seven in *A. solani* inoculated plants, while plants inoculated with *P. infestans* showed

an exponential increase from 6.00 in week one and 12.00 by the fourth week (Fig. 2).

Plant height: Significantly high (p≤0.05) plant heights were obtained from plants that were treated with 20% extract concentration (133.96cm and 117.71cm for *A. solani* and *P. infestans*, respectively) and 0.25% ridomil (134.07cm and 121.41cm for *A. solani* and *P. infestans*, respectively) compared to all other treatments in both pathogen experiments. Moreover, the two treatments exhibited no significant difference (p≤0.05) with each other in both experiments (Table 2).

From week 1 to week 7, plant height grew in every treatment, with the exception of the negative control plants, which showed low growth of 84.55 cm in week one and 97.10 cm in week seven for *A. solani* and 95.60 cm in week one and 100.50 cm in week seven for *P. infestans* inoculated plants.

Table 2: Average tomato plant height after *Alternaria solani* and *Phytophthora infestans* inoculation

Treatment	*A. Solani* inoculated plant height (cm)	*P. infestans* inoculated plant height (cm)
Control (-)	93.49 d	99.30 c
0.25% Ridomil	134.07 a	121.41 a
2.5% *M. Whitei*	119.04 c	99.97 c
10% *M. Whitei*	128.72 b	111.42 b
20% *M. Whitei*	133.96 a	117.71 a

Numbers with the same letter are not statistically different at p≤0.05

Plant Leaflet Size: Significantly large (p≤0.05) leaflet size was recorded where plants were treated with 20% extract concentrations (9.81 cm and 8.44 cm for *A. solani* and *P. infestans* inoculated plants, respectively) and 0.25 ridomil (9.66 cm and 9.10 cm for *A. solani* and *P. infestans* inoculated plants, respectively). Though the two treatments did not have a significant difference (p≤0.05) in *A. solani* inoculated plants, but there was a significant difference between the two treatments in the *P. infestans* inoculated plants (Table 3).

Table 3: Average tomato plant leaflet size following *Alternaria solani* and *Phytophthora infestans* inoculation

Treatment	*A. Solani* inoculated tomato leaflet size (cm)	*P. infestans* inoculated tomato leaflet size (cm)
Control (-)	7.83 c	7.13 c
0.25% Ridomil	9.66 a	9.10 a
2.5% *M. Whitei*	8.77 b	7.36 c
10% *M. Whitei*	9.37 ab	8.10 b
20% *M. Whitei*	9.81 a	8.44 b

Numbers with the same letter are not statistically different at p≤0.05

Plant Compound leaf number: Significantly high (p≤0.05) compound leaf numbers were recorded from plants that were treated with 20% extract concentration, which recorded 17.30 and 15.43 compound leaves for *A. solani* and *P. infestans* inoculated plants, respectively. Similarly, 0.25% ridomil-treated plants recorded 16.92 and 15.76 compound leaf numbers for *A. solani* and *P. infestans*, respectively, which are significantly high (p≤0.05) compound leaf numbers in the experiments. The treatments did not significantly differ (p≤0.05) on *A. solani* and *P. infestans* inoculated plants. The plants that were treated with negative control recorded 10.17 and 8.26 compound leaves, which was a significantly low (p≤0.05) number of compound leaves compared to all other treatments in the *A. solani* and *P. infestans* inoculated plants, respectively.

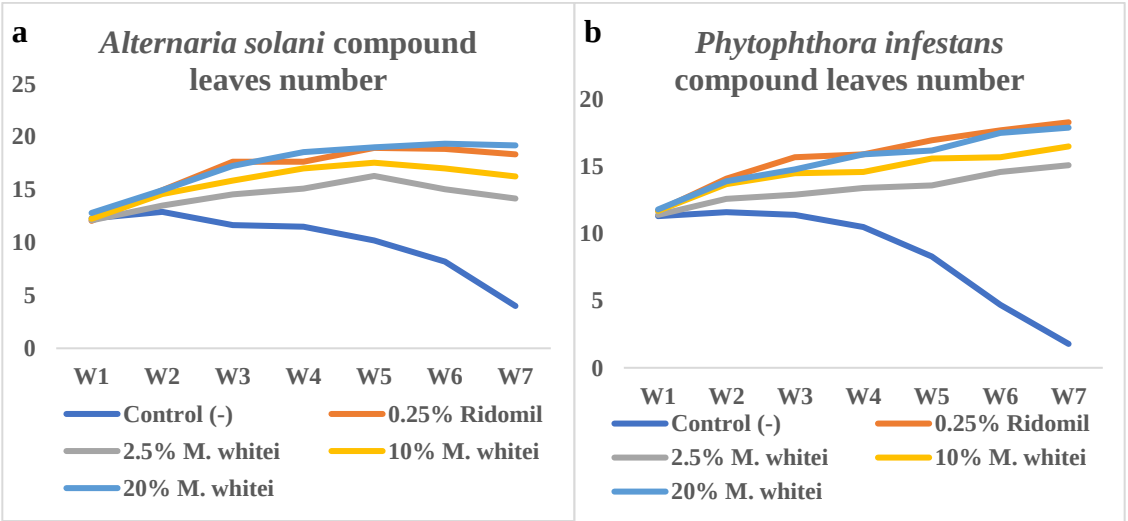

Fig. 3: Effect of *Mondia whitei* extracts on compound leaves number in tomato (a) *Alternaria solani* (b) *Phytophthora infestans* inoculation

Mondia Whitei extracts showed concentration-dependent increase in compound leaf number for both pathogens, while plants treated with negative control showed exponential reduction in compound leaf number from 12.30 to 4.00 and 11.30 to 1.78 in weeks one to

seven for *A. solani* and *P. infestans* inoculated plants (Fig. 3).

Number of flower trusses: *Alternaria solani* inoculated plants that were treated with 20% extract concentration recorded an average of 4.45 flower trusses, which was significantly greater (p≤0.05) than all other treatments in the experiment. However, this record was not significantly different (p≤0.05) from the number of flower trusses recorded from plants that were treated with 0.25% ridomil, which recorded 4.31 flower trusses. The plants that were treated with negative control recorded an average of 2.24 flower trusses, which is a significantly lower (P≤0.05) number of flower trusses compared to all other treatments in the *A. solani* inoculated plants. Similarly, plants that were treated with negative control in the *P. infestans* inoculated plants recorded an average of 1.96 flower trusses, which is a significantly lower (p≤0.05) number of flower trusses than all other treatments in the *P. infestans* inoculated plants. *Phytophthora infestans* inoculated plants that were treated with 0.25% ridomil and 20% extract concentration recorded 3.61 and 3.48 number of flower trusses, which were both statistically at par with each other (p≤0.05) and both significantly higher (p≤0.05) than the other treatments in the experiment. Generally, for all the treatments, flower trusses number increased as weeks progressed from week one to week seven, except for negative control plants that had a decline in the flower trusses numbers in both *A. solani* and *P. infestans* inoculated plants (Fig. 4).

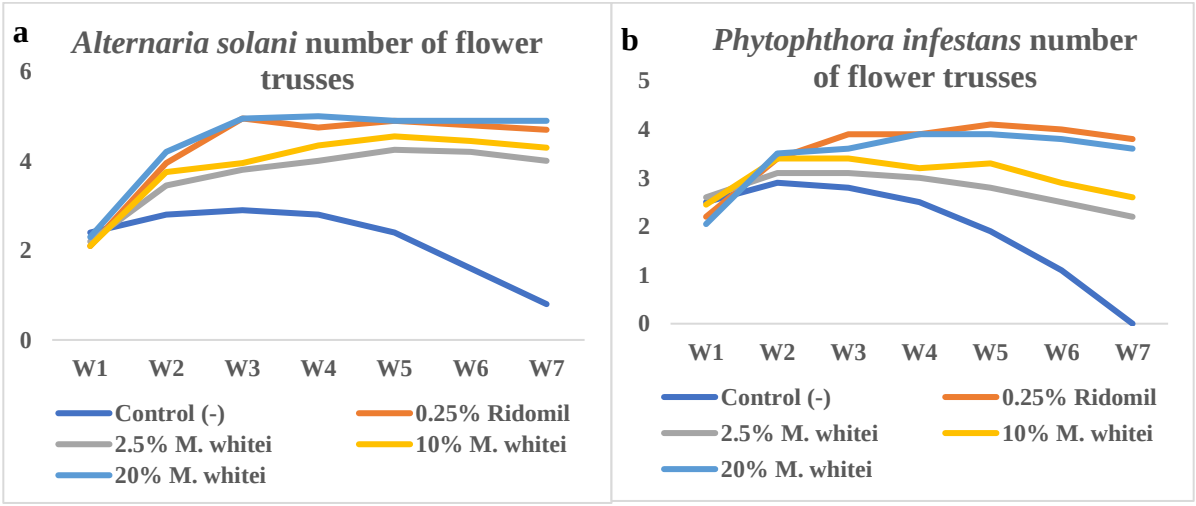

Fig. 4: Effect of *Mondia whitei* extracts on number of flower trusses of tomato (a) *Alternaria solani* (b) *Phytophthora infestans* inoculation

Number of fruits: *Alternaria solani* inoculated plants that recorded an average number of 4.32 and 4.14 fruits were recorded in plants that were treated with 20% extract concentration and 0.25% ridomil, respectively. These two treatments had no significant difference (P≤0.05) and recorded a significantly higher number (P≤0.05) of fruits compared to the rest of the treatments in the experiment. The negative control treatment recorded an average of 0.95 fruits, which was significantly smaller (P≤0.05) compared to other treatments in the *A. solani* inoculated plants (Table 4). *Phytophthora infestans*-inoculated plants recorded an average of 3.13 and 2.99 fruits where plants were treated with 0.25% ridomil and 20% extract concentration, respectively. These two treatments did not have any significant difference (P≤0.05) and recorded a significantly high (P≤0.05) number of fruits compared to the other treatments in the experiment. Additionally, the negative control recorded an average of 0.79 fruits, which is significantly smaller (P≤0.05) than the other treatments in the experiment (Table 4).

Table 4: Average tomato fruits numbers, after *Alternaria solani* and *Phytophthora infestans* inoculation

Treatment	*A. Solani* inoculated tomato fruit number	*P. infestans* inoculated tomato fruit number
Control (-)	0.95 d	0.79 d
0.25% Ridomil	4.14 a	3.13 a
2.5% *M. Whitei*	2.91 c	1.52 c
10% *M. Whitei*	3.49 b	2.48 b
20% *M. Whitei*	4.32 a	2.99 ab

Levels that are not connected by the same letter are statistically different at P≤0.05

Fruit weight: *Alternaria solani* inoculated plants treated with 20% extract concentration and 0.25% ridomil recorded an average weight of 120.15 g and 108.78 g, respectively. The two treatments recorded significantly high (P≤0.05) average fruit weight compared to all other treatments. Though the two treatments were not significantly different (P≤0.05) from each other. Additionally, fruits from the negative control recorded an average weight of 31.50 g, which was significantly lower (P≤0.05) than all other treatments in *A. solani* inoculated plants (Table 5). Whereas, in *P. infestans* inoculated plants, an average weight of 107.78 g and 102.41 g was recorded where plants were treated with 0.25% ridomil and 20% extract concentration, respectively. The two treatments recorded significantly high (P≤0.05) average fruit weight compared to all other

treatments but were statistically at par (P≤0.05) with each other. Similarly, plants treated with the negative control recorded an average weight of 25.04 g, which was significantly lower (P≤0.05) compared to all the other treatments in the *P. infestans* experiment (Table 5).

Table 5: Average tomato fruit weight after *Alternaria solani* and *Phytophthora infestans* inoculation

Treatment	*A. Solani* inoculated tomato fruit weight (g)	*P. infestans* inoculated tomato fruit weight (g)
Control (-)	31.50 c	25.04 d
0.25% Ridomil	108.78 a	107.78 a
2.5% *M. Whitei*	76.48 b	69.60 c
10% *M. Whitei*	86.55 b	90.84 b
20% *M. Whitei*	120.15 a	102.41 a

Levels that are not connected by the same letter are statistically different at P≤0.05

Fruit marketability: *Alternaria solani* inoculated plants that were treated with 20%, 10%, and 2.5% extract concentrations recorded 95.4% marketable and 4.6% non-marketable fruits, 92.6% marketable and 7.4% non-marketable fruits, and 85.6% marketable and 14.4% non-marketable fruits, respectively. On the other hand, those treated with 0.25% ridomil and negative control recorded 94.7% marketable and 5.3% non-marketable fruits and 27.4% marketable and 72.6% non-marketable fruits, respectively (Figure 5A). Whereas, *P. infestans* inoculated plants that were treated with 20%, 10%, and 2.5% extract concentrations recorded 90.3% marketable and 9.7% non-marketable fruits, 87.1% marketable and 12.9% non-marketable fruits, 73.0% marketable and 27.0% non-marketable fruits, respectively, whereas those that were treated with 0.25% ridomil and negative control recorded 92.3% marketable and 7.7% non-marketable fruits and 8.9% marketable and 91.1% non-marketable fruits, respectively (Fig. 5).

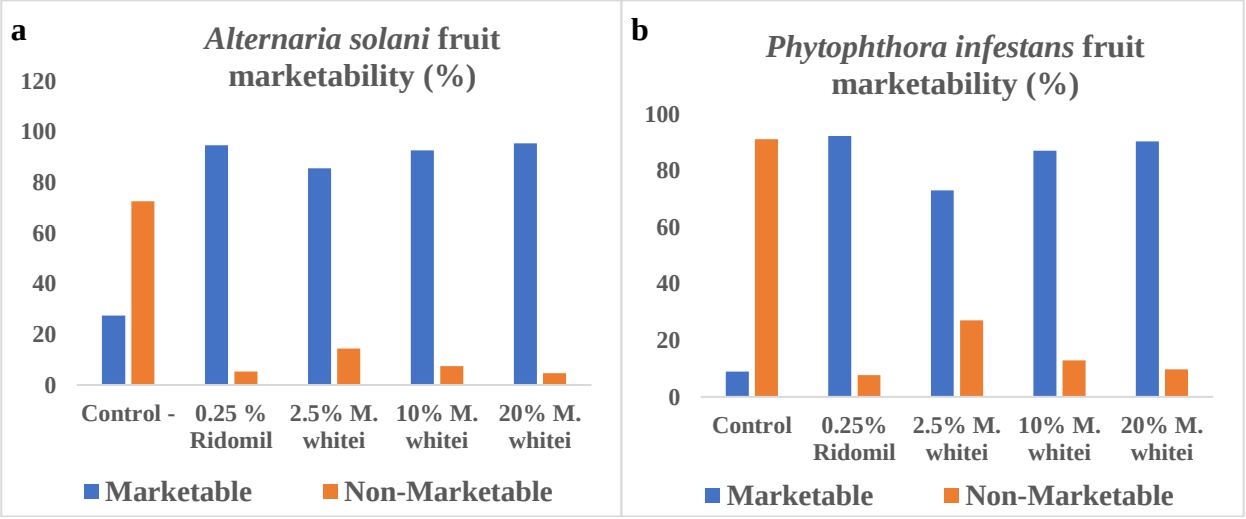

Fig. 5: Effect of *Mondia whitei* extracts on marketability of tomato fruits (a) *Alternaria solani* (b) *Phytophthora infestans* inoculation

Total dry biomass: The 20% extract concentration and 0.25% ridomil treatments recorded a significantly high (P≤0.05) total dry biomass of 32.98g and 32.78g, respectively, compared to all other treatments in the *A. solani* experiment, but the two treatments were not significantly different (P≤0.05) from each other. Additionally, negative control recorded a significantly low total dry biomass of 6.36g. *Phytophthora infestans*-inoculated plants recorded an average dry biomass of 30.01g and 29.44g where plants were treated with 0.25% ridomil and 20% extract concentration, respectively. The two treatments recorded significantly high (P≤0.05) average total dry biomass compared to all other treatments in the experiment, but were not significantly different (P≤0.05) from each other. Whereas, negative control recorded a significantly low total dry biomass of 5.57g. (Table 6).

4. Discussion

The study revealed that extracts from *M. whitei* have antifungal properties against *P. infestans* and *A. solani*, with 100% inhibition at concentrations of 10% and 20%. The presence of active secondary metabolites, such as tannins, alkaloids, flavonoids, saponins, steroids, phenols, and glycosides, may contribute to the inhibitory capacity of *M. whitei* extracts. These secondary metabolites detected in *M. whitei* have been reported to have antimicrobial activities (Roy et al., 2022; Othman et al., 2019), and this could confer the inhibitory effect in *M. whitei*. In a study by Zhu et al. (2019), tannins acted against *Penicillium digitatum* fungi by inhibiting its mycelial growth and spore germination. Alkaloid compounds are able to prevent infections enzyme activity in plants according to a study by Patra (2012), while according to Al Aboody & Mickymaray (2020) flavonoids damages plasma membranes and lowers cell wall production of pathogens. Saponins, a special kind of glycoside, also have a strong antifungal ability and soapy qualities according to Morcia et al. (2022). Steroids have also been found to have antifungal properties against pathogens like *Candida tropicalis* (Tarbet et al., 1953).

Mondia whitei extracts effectively inhibited the growth of *P. infestans* and *A. solani* in tomato plants at extract concentrations of 2.5%, 10%, and 20%. These extracts also showed an extract-dependent increase in the plant's growth parameters and yield. A similar investigation by Mkindi et al. (2020) found that using pesticidal plants in common bean, *Phaseolus vulgaris*, increased plant development and seed yield. The study found that extracts from *Tephrosia vogelii* and *Tithonia diversifolia* significantly increased pod number, chlorophyll content, and overall seed yield. These findings suggest that plant extracts can aid in managing crop diseases and improving plant nutrition. The increased growth rate and yield in plants could be attributed to metabolic processes induced through the application of plant extracts. Additionally, *M. whitei* extracts can increase the marketability of harvested tomato fruits by controlling the two pathogens' effects. A greenhouse study by Hassan et al. (2021) found that treatments with *T. viride*, *E. camaldulensis*, and *P. fluorescens* + *T. viride* improved zucchini plant yields (marketable and non-marketable). These results may be due to active secondary metabolites in the plant extract containing antioxidant compounds that enhance the fruit preservation properties of edible coatings, which enhance fruit preservation properties in edible coatings (Bajaj et al., 2023).

5. Conclusion

This study's findings implies that *M. whitei* can be a safe alternative fungicide against early blight and late blight of tomato, and can be used in organic tomato production to produce aesthetically appealing tomato and improved yield. The study suggests isolation of specific antifungal compounds from *M. whitei* through graph chromatography and the development of a bio fungicide.

Acknowledgements

The writers express gratitude to MMUST for providing necessary facilities and genuine assistance from Mr. Protus Mbezi, Mr. Kepher Ogencha, and Dr. Seline Ooko for completing the project.

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