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(RESEARCH ARTICLE)

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Antifungal potential of local plant extracts in the biological control of soil-borne diseases of tomato and eggplant in Daloa, Centre-West, Côte d'Ivoire

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Abstract

Tomato and eggplant play a significant role in peri-urban agriculture. However, their production in the city of Daloa is limited by biotic diseases. This study aimed to evaluate the antifungal activity of six plant extracts against soil-borne fungal pathogens affecting tomato and eggplant. A microbiological study of the soil was conducted using a composite sample from the experimental plot. Two tomato cultivars (Petomech and F1 Cobra 26) and one eggplant cultivar (N'drowa) were used in the varietal sensitivity test. The first application of the plant extracts was carried out immediately after transplanting. Mancozeb was used as a reference control. Health monitoring of the tomato and eggplant plants involved assessing the incidence, severity and mortality rate. Samples taken from diseased plants were subjected to microbiological analysis. The collected data were analysed using Statistica 7.1 software. The results revealed the presence of four fungal genera on the plot: *Botrytis* sp, *Trichoderma* sp, *Sclerotium* sp and *Aspergillus* sp. The fungal genera isolated from the diseased plants were *Phytophthora* sp, *Alternaria* sp and *Trichoderma* sp. The biological control test showed that eggplant plants treated with *Securidaca* sp exhibited the greatest tolerance to disease, with a severity index of 2.1%. The F1 Cobra 26 variety, with a severity index of 5%, was less susceptible than the Petomech variety, with a severity index of 11.5%. Aqueous extracts of *Securidaca* sp and *Solanum* sp reduced mortality rates more effectively than synthetic fungicide. These aqueous extracts can therefore be recommended as an alternative for controlling soil-borne fungal diseases in tomato and eggplant.

Keywords: Biofungicide; Essential oil; Aqueous Extract; Soil and Ivory Coast

1. Introduction

Agriculture is one of the main sectors that contribute to the socio-economic development of populations. It employs over 40% of the global workforce, including over 52% in Africa and Asia [1]. Market gardening plays a significant role in human nutrition within this sector. In West Africa, it is one of the main components of urban and peri-urban agriculture, playing a key role in the economic development of cities [2]. Market gardening is a key component of many nutrition and poverty reduction programmes. In Côte d'Ivoire, market gardening is important for feeding the population and reducing poverty. Tomato (*Lycopersicon esculentum* Mill.) and eggplant (*Solanum aethiopicum* G.) are among the most widely produced crops in the country. They are almost indispensable ingredients in many Ivorian dishes and an important source of income for producers. However, despite the introduction of new production systems and the proliferation of plant protection products, national production of these vegetables remains insufficient to meet growing domestic demand. This could be due to the low productivity of these crops in certain parts of the country. These areas are characterised by diseases and pests that cause considerable damage to tomato and eggplant plants and fruits. This is the case in Daloa, where production is affected by soil-borne pathogens that cause various symptoms from the nursery stage through to harvest. Despite the development of pathogen-resistant cultivars, controlling soil-borne fungi in

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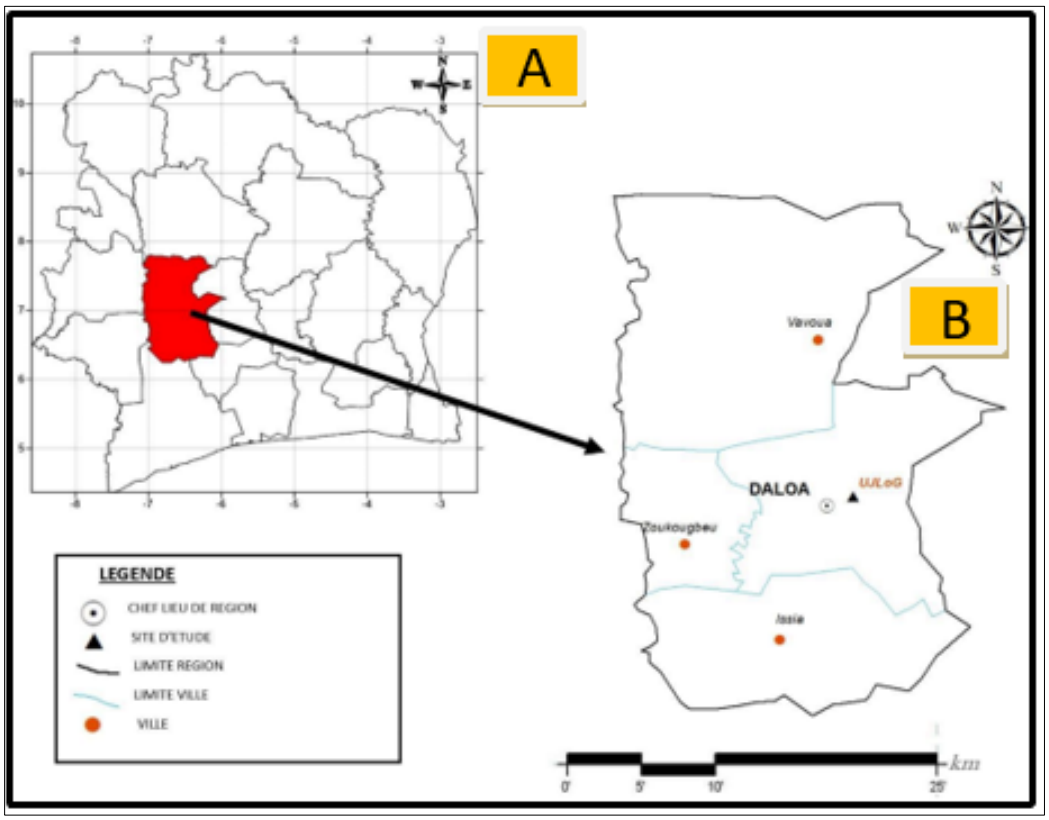
plantations is limited to prophylactic measures and the use of synthetic pesticides [3 ; 4]. However, the use of synthetic chemical pesticides poses problems for both human health and the environment. Residues of active substances have been found in various horticultural products, sometimes exceeding the maximum residue limits (MRLs) established by the Codex Alimentarius of the European Union [5 ; 6]. Furthermore, the use of chemical pesticides promotes the emergence of resistant strains in agrosystems. To mitigate the impact of chemical control in agroecosystems, adopting biological control as an alternative method is crucial for safeguarding the health of producers and consumers, as well as protecting the environment. The aim objectif of this study is to find an efficacy plant extract to control the soil-borne fungal pathogens of tomato and eggplant. Specifically, the aim is to identify the mycopathogens responsible for the death of tomato and eggplant plants and to evaluate the fungicidal activity of aqueous extracts of *Securidaca* sp and *Solanum* sp species, followed by the essential oils of *Ocimum canum* and *Ocimum gratissimum*, on soil-borne fungal pathogens of tomato and eggplant *in situ*.

2. Materials and methods

2.1. Study site

The work was carried out at Jean LOROUGNON GUEDE University in Daloa, a city located in the centre-west of Côte d'Ivoire. It is located at a latitude of 6°53' north and a longitude of 6°27' west. The city is the capital of the Haut-Sassandra Region and covers an area of 15,200 km^2, with an estimated population of over 1 430 960 [7]. The climate of this Region is Sudano-Guinean, with four distinct seasons. The long rainy season runs from April to mid-July, while the short dry season runs from mid-July to mid-September. The short rainy season runs from mid-September to mid-November, and the long dry season runs from December to March. Temperatures range from an average of 24.65°C to 27.75°C during the dry and wet seasons. It is a humid tropical zone with dense forest vegetation [8]. The soil of Daloa is composed of granite from old Precambrian bedrock. The region's soils are mainly ferralitic. They are generally very deep with a high organic matter content. They are well suited to all types of agriculture [9]. The river system is dominated by the Sassandra River. The Lobo is this river's main tributary and the second most important watercourse [10].



Map of Côte d'Ivoire (A) and Map of Haut-Sassandra (B)

Figure 1 Map of the study area [10]

2.2. Materials

This study required a variety of equipment, including plant material, biological control agents, and both field and laboratory equipment. The plant material comprised two improved tomato cultivars (Petomech and F1 Cobra 26) and one eggplant cultivar (N'drowa). These cultivars were sourced from Callivoire in Daloa. The biological control agents were aqueous extracts from the leaves of *Securidaca* and *Solanum* species, as well as essential oils from *Ocimum canum* and *Ocimum gratissimum*. The synthetic fungicide Mancozeb was used as a positive control. The technical field equipment comprised tools for cultivating the soil and for measuring the height of the tomato and eggplant plants. Technical laboratory equipment included devices such as an autoclave, a magnetic stirrer, an oven, an electronic balance and an electron microscope.

3. Methods

3.1. Experimental setup

The experimental setup consisted of four Fischer blocks, each with four completely randomised replicates (Figure 2). This was implemented on a 500 m^2 plot. The blocks were separated by one metre. Within each block, a total of 18 ridges were created, each measuring 250 cm in length and 70 cm in width. The distance between two ridges was one metre. Each ridge had a planting density of 10 tomato or eggplant plants arranged in rows of five, with 50 cm between each plant and between each row.

3.2. Production of tomato and eggplant nurseries

The soil used for the nursery beds was taken from a low-lying area within the university grounds. It was then sterilised in a 25-litre metal bucket using steam for two hours. It was then left to cool for 24 hours in a basin, covered with a plastic sheet. The sterilised soil was divided into 10-dm^2 trays, with 100 tomato or eggplant seeds sown per tray. The nurseries were watered regularly, twice a day, for 21 days for the tomato and 30 days for the eggplants.

3.3. Production of aqueous extracts and essential oils

3.3.1. Production of aqueous extracts

The *Securidaca* sp and *Solanum* sp leaves were harvested in Korhogo and Daloa, respectively, in Côte d'Ivoire. They were then left to dry at ambient temperature in a laboratory. The dried leaves were crushed and the resulting powder was sieved. One hundred grams of this sieved powder were macerated in one litre of distilled water for 24 hours. The mixture was blended for 15 minutes, then filtered and studied over three days at 40 °C. The dried aqueous filtrate, constituting the aqueous extract, was recovered and weighed to determine its yield.

3.3.2. Production of essential oils

The fresh leaves of *Ocimum gratissimum* and *Ocimum canum* were harvested in Daloa in September. The essential oils were extracted from the leaves using hydrodistillation with a Clevenger-type device. For each extraction, 4 kg of leaves were weighed using an electronic balance before being placed in a pressure cooker containing 2 litres of water. The pressure cooker was placed on a hotplate set to 370 °C at the start of distillation. After 15 minutes of heating, the temperature was reduced to 225 °C. Extraction lasted for three hours.

3.4. Isolation of soil fungi

A microbiological study of the soil in the experimental plot was conducted. For this analysis, a composite soil sample was taken from both diagonals. Soil samples were taken at a depth of 30 cm using a probe. The composite sample was then dried at room temperature in the laboratory. After drying, the soil was manually ground to obtain a fine powder. This fine powder was then used to prepare the aliquots. A stock solution was prepared by emulsifying 100 g of the powder in one litre of sterile distilled water. This solution was then used for a series of 1/10 dilutions on PDA culture medium. Four drops of the aliquot were placed equidistant from each other on the PDA medium in Petri dishes. The dishes were then sealed, dated, and incubated at 27 ± 2 °C until fungal colonies proliferated.

3.5. Transplanting and treatment of tomato and eggplant plants

Tomato and eggplant plants, aged 30 and 37 days respectively, were transplanted onto the ridges within each block. The plants were transplanted according to the experimental design. The treatments were coded as follows: T0 for the blank control (distilled water); T1 for the aqueous extract of *Securidaca* sp; T2 for the aqueous extract of *Solanum* sp; T3 for the essential oil of *Ocimum canum*; T4 for the essential oil of *Ocimum gratissimum*; and T5 for the synthetic

fungicide mancozeb (positive control). The varieties were coded as follows: V1 for the 'N'drowa' eggplant variety; V2 for the 'Petomech' tomato variety; and V3 for the 'F1 Cobra 26' tomato variety.

3.6. Application of products to plants

The aqueous extracts of *Securidaca* sp and *Solanum* sp were prepared by adding 100 g of powder to 1 litre of distilled water. The powders were weighed using an electronic balance, then mixed and homogenised in distilled water for 30 minutes. The essential oils of *Ocimum gratissimum* and *Ocimum canum* were diluted to 500 µL in 5 ml of Tween 20 per litre of distilled water. A micropipette was used to sample the oils. The synthetic fungicide Mancozeb was used at a concentration of 10 g/L. The plants were treated with 100 ml of solution containing the aqueous extracts, essential oils or synthetic fungicide. The solution was sprinkled at the base of each plant. This process was repeated three times, with an interval of 21 days between each application.

3.7. Maintenance and health monitoring of tomato and eggplant plants

After transplanting, the plants were watered daily with tap water. This was done in the morning and evening until the harvest was finished. Weeds were removed from the plot regularly. Staking was carried out from the third week after transplanting until flowering.

3.8. Evaluation of health parameters on tomato and eggplants in situ

3.8.1. Incidence of diseases

Attacks were counted by recording the number of diseased plants per treatment and per variety in the plot. Records were taken once a week until the plants flowered. The incidence was calculated using the following formula of [11].

$$I = \frac{NBPm}{NBP} * 100$$

With

I: Incidence of attack; NBPm: Number of diseased plants per variety; NBP: Total number of plant per variety.

3.8.2. Severity index

The disease severity index was determined using a 0–3 rating scale [12].

- 0: healthy plant
- 1: slight yellowing of the plant
- 2: severe yellowing of the plant
- 3: dead plant

The following formula was used to calculate the severity index per treatment and per variety:

$$Is = \sum (Xi.ni) / (N.Z) * 100$$

With

- IS: Severity index;
- Xi: Score assigned to the diseased plant;
- ni: Number of diseased plants with the same score xi;
- N: Total number of plants and
- Z: Highest score.

3.9. Mortality rate

The number of dead plants was assessed on the plot every fortnight. The mortality rate was calculated per treatment and per variety according to the formula below:

$$TM = \frac{NBPm}{NBTp} \times 100$$

TM: Mortality rate; NBPm: Number of diseased plants; NBTp: Total number of plants.

3.10. Identification of fungal isolates associated with symptoms in dead plants

Isolations were carried out on PDA medium, which consisted of 20 g of agar, 5 g of potato flakes, and 5 g of glucose dissolved in 1 litre of distilled water. The medium was homogenised using a magnetic stirrer, then autoclaved at 1 bar and 121 °C for 30 minutes. The isolations were carried out using dead plants taken from the experimental plot. The roots were sectioned, rinsed with tap water, and then soaked in a 70% sodium hypochlorite solution for three minutes. The explants were then rinsed three times with sterile distilled water. The cleaned explants were then dried on blotting paper in a fume hood. Inoculation was then performed in the fume hood using Petri dishes containing frozen PDA medium. Four explants from the same plant were placed equidistant from each other in the same Petri dish. The Petri dishes were then sealed with parafilm, numbered and dated, and incubated at 27 ± 2 °C until the colonies had proliferated. Purification consisted of removing part of the mycelium from the outgrowth zone of the seeded Petri dish and transplanting it into the centre of a new Petri dish containing frozen PDA medium. The macroscopic characteristics of the fungal isolates were determined by staining the mycelium and observing its appearance on the PDA medium. Microscopic characteristics were determined using a photonic microscope. Observation focused on the mycelium, spore shape, conidia and conidiophores, according to the identification key [13].

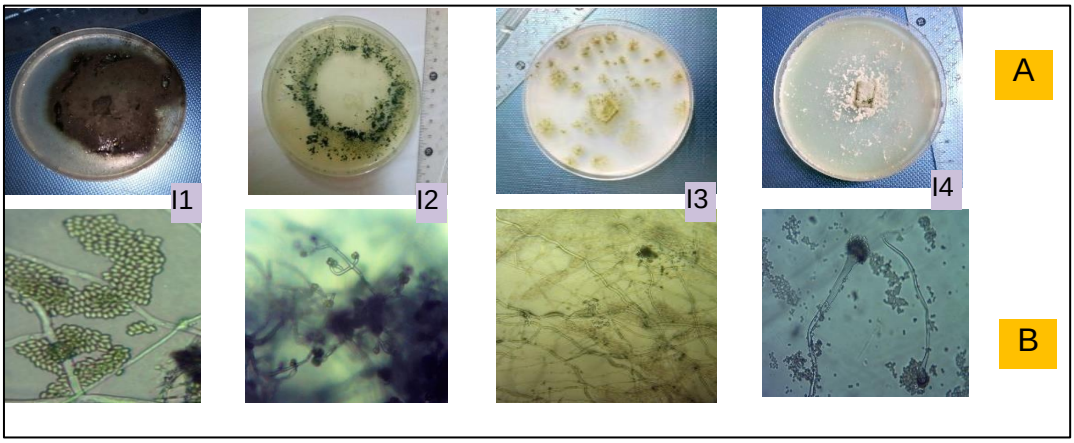
3.11. Statistical analysis of data

The data was entered into an Excel spreadsheet. Statistica 7.1 software was then used to analyse the data statistically. The normality and the homogeneity of the data was respectively verified using the Shapiro–Wilk test and Bartlett test. The data were subjected to analysis of variance (ANOVA). The means were classified using the Newman-Keuls test (%).

4. Results

4.1. Fungi isolated from the soil

Four fungal isolates were obtained from soil samples using the successive dilution technique. They were labelled I1, I2, I3 and I4 (Figure 2). Isolate I1 produced greyish-green mycelium with powdery aerial growth on PDA medium. The conidia were irregularly shaped and dark in appearance. I1 is a *Botrytis* sp and has a partitioned mycelium ending in clustered conidiospores. Isolate I2 is a *Trichoderma* sp. Initially, it has a cottony white thallus, which is covered by numerous green spores after a week. It has a septate mycelium with numerous round conidia. These conidia are produced at the end of phialides, which are borne by conidiospores. Isolate I3 exhibits the characteristics of *Sclerotium rolfsii*. It has a dense, milky-white thallus and grows rapidly on PDA medium. Its mycelium is septate and produces ovoid, yellowish-grey macrosclerotia measuring a millimetre in size. *Aspergillus* sp corresponds to isolate I4. Its hyphae are grey, septate and flaky. The sporocystophores are simple or branched, ending in a globular vesicle of variable size, from which various fruiting bodies grow.

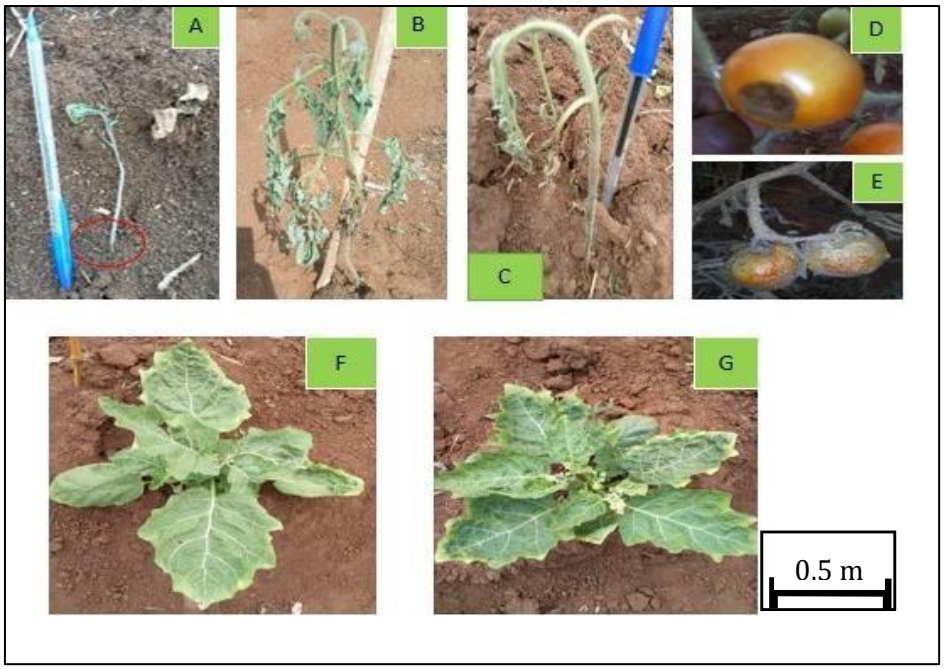


Botrytis sp (I1); *Trichodema* sp (I2); *Sclerotium rolfsii* (I3) and *Aspergillus* sp (I4) (x 400) Macroscopic aspects (A) and microscopic aspects (B).

Figure 2 Morphology of fungi isolated from the soil of the experimental plot

4.2. Symptoms observed on tomato and eggplant plants

The various organs of the tomato and eggplant plants showed symptoms of disease (Figure 3). Health monitoring identified three symptoms of disease on tomato plants. Seedling damping-off was observed on a tomato plant three days after transplanting. Young plants affected by damping-off died at the base of the stem. Affected seedlings died within 5 days. Apical wilt in tomato plants begins with the withering of a leaflet or leaf, progressing throughout the entire plant. The plant dies 3 days after widespread wilting. Plants affected by grey mould exhibit circular, damp patches on the leaflets that develop rapidly, causing the leaf blade to dry out. The leaf rots and the lesion spreads to the stem, turning it grey. Fruit affected by grey rot is covered in grey felting. The fruit wilts and loses its vigour. Apical necrosis of the fruit begins with the appearance of a black dot at the tip. This necrotic area then enlarges, deforming the fruit. Three types of symptoms have been observed on eggplant plants. These include yellowing of leaf margins, leaf blistering and leaf curling.

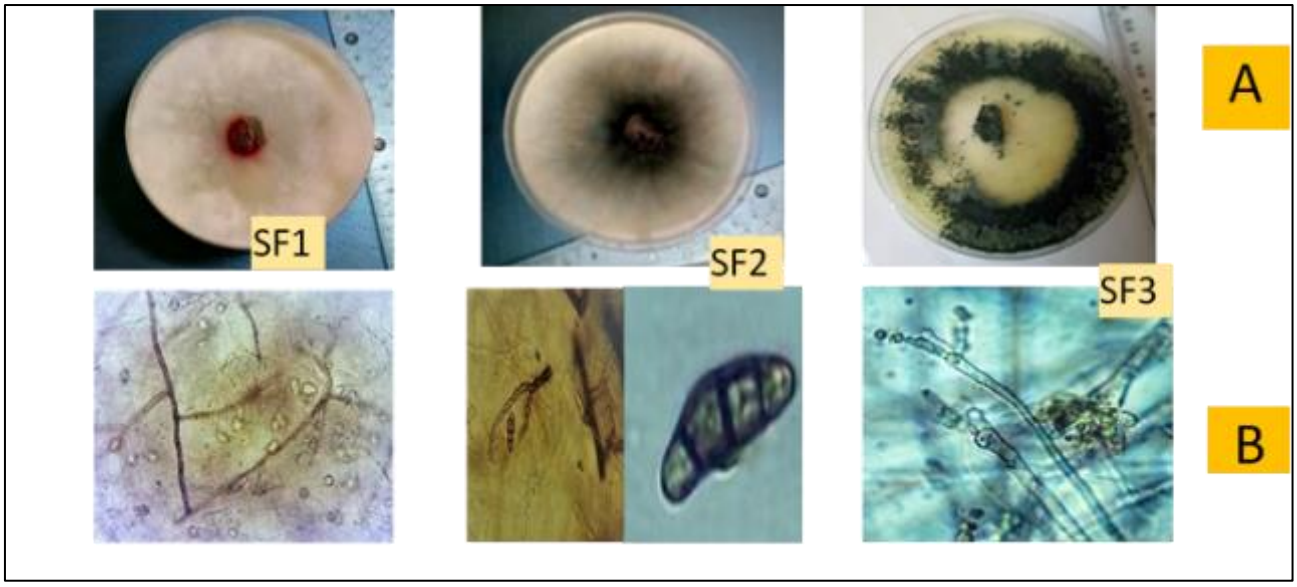


Seedling blight on tomato plants (A); Apical wilt on eggplant plants (B); Grey rot on tomato plants (C); Apical necrosis on tomato fruit (D); Grey rot on tomato fruit (E); Blistering and curling of eggplant leaves (F and G).

Figure 3 Symptoms of diseases observed on tomato and eggplant plants

4.3. Identification of fungal isolates associated with dead plants

Microbiological analysis of the samples enabled three fungal genera to be isolated. (Figure 4). These three isolates were coded SF1, SF2 and SF3. On PDA medium, isolate SF1 (*Phytophthora* sp) produced white, cottony mycelium with a reddish centre. The sporocystophores are similar to the mycelium and have vesicles along the branches. Isolate SF2 is *Alternaria* sp and has a whitish mycelium for the first three days. After one week in the oven, the mycelium turns black. The hyphae of the mycelium are septate with monoseptate or biseptate spores. The SF3 isolate, *Trichoderma* sp, has greyish-green mycelium with powdery aerial felting. After 3 to 5 days, it produces dark, irregularly shaped sclerotia. The mycelium is compartmentalised and branched, ending in a conidiospore in the form of a cluster.



Phytophtora sp (SF1); *Alternaria* sp (SF2) and *Trichoderma* sp (SF3). (X400) Macroscopic aspects (A) and microscopic aspects (B).

Figure 4 Morphology of fungi isolated from diseased tomato and eggplant plants

4.4. Effect of plant extracts on tomato pathogen parameters

Treated tomato plants were more resistant to disease than untreated plants, regardless of variety (Table 1). The results demonstrate that the incidence of attacks varied according to the treatments applied to the two cultivars. Petomech plants treated with the aqueous extract of *Securidaca* sp experienced a 25% reduction in the incidence of attack. Plants treated with the synthetic fungicide mancozeb showed an incidence of 35%. The highest incidence was recorded in untreated Petomech plants. Petomech plants treated with the aqueous extract of *Securidaca* sp had the lowest severity index of 15.5%, while those treated with Mancozeb had a severity index of 15.8%. The highest severity index, at 18.8%, was recorded in untreated Petomech plants. The lowest Petomech mortality rate of 22% was obtained by plants treated with the *Securidaca* sp extract, while plants treated with Mancozeb had a mortality rate of 52%. The highest mortality rate (60%) was recorded in untreated Petomech plants (Table 1). The lowest incidence, 21.33%, was observed in F1 Cobra 26 plants treated with an aqueous extract of Solanum sp. An incidence of 36.33% was observed in F1 Cobra 26 plants treated with Mancozeb. The highest incidence, at 85%, was recorded in untreated F1 Cobra 26 plants. The lowest severity index, 0.5%, was obtained in F1 Cobra 26 plants treated with the aqueous extract of *Solanum* sp, while the severity index was 8.2% in F1 Cobra 26 plants treated with Mancozeb. The highest severity index, 18.7%, was recorded in untreated plants. The lowest mortality rates of 17% and 18%, respectively, were obtained by F1 Cobra 26 plants treated with the aqueous extracts of *Solanum* sp and *Securidaca* sp, while F1 Cobra 26 plants treated with Mancozeb recorded a mortality rate of 22%. The highest mortality rate of 22% was obtained in untreated F1 Cobra 26 plants.

Table 1 Tomato cultivars' sensitivity

Varieties and treatements	Incidence (%)	Severity index (%)	Mortality rate (%)
V2T0	66.67	18.8	60
V2T1	25.00	11.5	22
V2T2	26.67	14.5	27
V2T3	30.00	12.2	38
V2T4	32.00	12.0	33
V2T5	35.00	15.8	52
V3T0	85.00	18.7	57
V3T1	26.00	6.7	18
V3T2	21.33	5.0	17

V3T3	34.67	6.0	18
V3T4	29.00	10.5	33
V3T5	36.33	8.2	22

Values in the same column followed by the same letter are not significantly different according to the Newman-Keuls test at $p < 0.05$.
V2T0: Untreated Petomech plants; **V2T1:** Petomech plants treated with *Securidaca* sp aqueous extract; **V2T2:** Petomech plants treated with *Solanum* sp aqueous extract; **V2T3:** Petomech plants treated with *O. canum* essential oil; **V2T4:** Petomech plants treated with *O. gratissimum* essential oil and **V2T5:** Petomech plants treated with Mancozeb. **V3T0:** Untreated F1 Cobra 26 plants; **V3T1:** F1 Cobra 26 plants treated with *Securidaca* sp aqueous extract; V3T2: F1 Cobra 26 plants treated with *Solanum* sp aqueous extract; **V3T3:** F1 Cobra 26 plants treated with *O. canum* essential oil; **V3T4:** F1 Cobra 26 plants treated with *O. gratissimum* essential oil; **V3T5:** F1 Cobra 26 plants treated with Mancozeb.

4.5. Effect of plant extracts on eggplant pathogen parameters

The treated plants were more resistant to disease compared to the untreated plants (Table 2). The lowest incidence (8.33%) was recorded for N'drowa plants treated with the aqueous extract of *Securidaca* sp, while plants treated with Mancozeb recorded an incidence of 36.67%. The highest incidence, at 78.33%, was recorded in untreated N'drowa plants. The lowest severity index, at 2.1%, was recorded in N'drowa plants treated with the aqueous extract of *Securidaca* sp, while plants treated with Mancozeb had an index of 6.2%. The highest severity index, at 12.2%, was recorded in untreated N'drowa plants. There was no mortality recorded in N'drowa plants treated with the aqueous extract of *Securidaca* sp, whereas N'drowa plants treated with the aqueous extract of *Solanum* sp had a mortality rate of 4%. The mortality rate in plants treated with Mancozeb was 17%. The highest mortality rate (23%) was obtained in untreated N'drowa plants.

Table 2 Eggplant sensitivity

Varieties and treatements	Incidence (%)	Severity index (%)	Mortality rate (%)
V1T0	78.33	12.2	23
V1T1	8.33	2.1	0
V1T2	26.67	2.6	4
V1T3	20.00	3.3	7
V1T4	22.33	4.3	8
V1T5	36.67	6.2	17

Values in the same column followed by the same letter are not significantly different according to the Newman-Keuls test at $p < 0.05$.
V1T0: Untreated N'drowa plants; **V1T1:** N'drowa plants treated with aqueous extract of *Securidaca* sp; **V1T2:** N'drowa plants treated with aqueous extract of *Solanum* sp; **V1T3:** N'drowa plants treated with essential oil of *O. canum*, **V1T4:** N'drowa plants treated with essential oil of *O. gratissimum* and **V1T5:** N'drowa plants treated with Mancozeb.

5. Discussion

A preliminary study of the soil microflora of the experimental plot revealed a variety of fungal isolates. Four fungal genera were isolated from the plot soil: *Botrytis* sp, *Trichoderma* sp, *Sclerotium* sp and *Aspergillus* sp. These soil fungi are phytopathogenic. In the absence of favourable conditions, their presence in the soil would serve as a means of conservation. This corroborates the findings of [13], who also detected fungi in samples from various tomato production areas in Côte d'Ivoire.

Microbiological analysis of samples taken from diseased tomato and eggplant plants revealed the presence of *Phytophthora* sp, *Alternaria* sp and *Botrytis* sp, with the exception of *Trichoderma* sp, which is an hyperparasite. All of the isolates identified are pathogenic to tomato and eggplant. This result reflects the susceptibility of these crops to the various identified pathogens. This susceptibility is thought to be due to the inefficiency of the defence systems that these crops have evolved to combat fungal attacks. Phytopathogenic fungi are believed to possess enzymatic molecules that allow them to bypass the defence systems of various plant species. The products applied had no effect on the mycopathogens isolated from the plants. These mycopathogens were resistant to the products applied. These results are consistent with those of [14 ; 15], who demonstrated that the efficacy of an antifungal extract can vary depending on the fungal strain. They demonstrated that the aqueous extract of *Xylopia aethiopica* (Dunal) A. Rich. (Annonaceae) inhibits the germination of *Colletotrichum destructivum* spores and the growth of its colonies. However, no fungicidal effect was observed for this same aqueous extract on *Sclerotium rolfsii*, in contrast to the essential oil, which was highly

effective against the same fungus. The presence of *Botrytis* sp in dead plants could be explained by its diverse habitat. It is a polyphagous fungus that can spread on plant debris.

The plant extracts had different effects on the sensitivity of tomato and eggplant plants. This difference in efficacy could be explained by the nature of their physicochemical composition. This composition varies from one plant species to another, which could explain this difference in efficacy. Aqueous extracts reduced the incidence of fungal attacks more in the three cultivars. The effectiveness of the aqueous extracts may be due to the fact that they contain residues that remain in contact with the treated plants for longer. These results corroborate those of [14], who demonstrated that aqueous extracts offer greater protection to tomato plants against fungal attacks. These results also align with those of [16], who demonstrated that *Xylopia aethiopica* extracts mitigate tomato disease incidence in Côte d'Ivoire.

Essential oils were less effective in reducing the incidence of attacks. This is thought to be due to the nature of the emulsifier used and the persistence of the oils at the base of the treated plants. Essential oils are rich in phenolic compound [17]. They are also highly volatile, and application at high temperatures reduces their effectiveness at the base of the plants [18].The severity of fungal diseases in tomato and eggplant varied according to the treatments. The lowest indices were obtained with the aqueous extract of *Securidaca* sp at N'drowa and Petomech, and with the aqueous extract of *Solanum* sp at F1 Cobra 26. All of the aqueous extracts were more effective than the positive control (Mancozeb). The efficacy of the aqueous extracts compared to synthetic fungicides can be attributed to their high content of phenolic compounds, which stimulate plant defence mechanisms. This includes strengthening cell walls through lignin deposition or defence protein synthesis [19]. Previous studies have demonstrated the ability of plant extracts to protect cultivated plants against attacks by microorganisms. *Alchornea cordifolia* (Schum. and Thonn.) and *Mezoneuron benthamianum* (Baill.) extracts are rich in phenolic compounds, including alkaloids, flavonoids, and saponins. They also contain amides, which are products of organic matter decomposition [20].

The mortality rate of tomato and eggplant plants varied according to the treatment applied. No mortality was observed at N'drowa with the aqueous extract of *Securidaca* sp, in contrast to the results obtained with the essential oils. The lowest mortality rate was obtained with the aqueous extract of *Solanum* sp, indicating that aqueous extracts improve eggplant tolerance to fungal attack. Regarding tomato cultivars, the lowest mortality rate was recorded with the aqueous extracts of *Securidaca* and *Solanum*, and this rate was lower in the F1 Cobra 26 variety than in the Petomech variety. These results suggest that the F1 Cobra 26 variety is less susceptible to fungal attack than the Petomech variety. This difference in susceptibility could be explained by the genetic makeup of the different tomato cultivars. The F1 Cobra 26 variety may naturally secrete substances that inhibit the development of fungi that attack different cultivars.

6. Conclusion

Studying the soil microflora of market garden crops at the Université Jean LOROUGNON GUEDE (UJLoG) in Daloa revealed its fungal diversity. Six pathogenic fungal isolates and one hyperparasite of the *Trichoderma* genus were found in the soil and in dead tomato and eggplant seedlings. Mortality rates were higher for tomato than eggplant in the soil. Plant extracts used to control mycopathogens in tomato and eggplants showed that aqueous extracts were more effective than essential oils or the synthetic fungicide Mancozeb.

The aqueous extract of *Securidaca* sp was the most effective biofungicide in reducing the incidence and mortality rates of tomato and eggplant plants. Their efficacy compared with the positive control (Mancozeb) makes these aqueous extracts an alternative to synthetic chemical pesticides. They could therefore be recommended for use on vegetable crops. However, further efficacy tests will need to be carried out on farms.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding the publication of this paper.

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