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# Fungicidal effects of *Commiphora swynnertonii* (Burrt.) and *Synadenium glaucescens* (Pax.) against tomato fusarium wilt disease

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ABSTRACT

Tomato fusarium wilt disease is an important soil-borne disease caused by *Fusarium oxysporum f. sp. Lycopersici* (*FoL*) worldwide. The disease causes yield losses of about 90% worldwide. This study aimed to evaluate the extracts of *C. swynnertonii* (resins) and *S. glaucescens* (latex, fresh and dry leaves) for their efficacy against FoL. In the laboratory, a 4 × 4 factorial experiment in a Complete Randomized Design (CRD) was carried out to evaluate resins, latex, fresh, and dry leaves each in four concentrations (0.01 g/ml, 0.05 g/ml, 0.1 g/ml and 0.15 g/ml). The negative and positive controls were Sterile Distilled Water (SDW) and a Linkmil 72 WP (Mancozeb 64% + Metalaxyl 8%) respectively. In a screenhouse, resins, latex, and fresh and dry leaves, each at 0.15 g/ml were applied on pre-inoculated tomato plants to manage TFW disease. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. The negative and positive controls were the untreated soil and soil treated with Linkmil 72 WP respectively. The differences between extracts in the inhibition of radial mycelial growth of the pathogen were highly significant ($p = 0.000$). The efficacy of the plant extracts against in vitro growth of FoL was significantly dependent on the application dose. The inhibition of mycelial growth caused by latex and dry leaves was higher than that of Linkmil 72 WP (23.58%) and SDW (0%) by 41% and 65% respectively. Findings show that there was a TFW disease reduction of 72.92% 68.75% and 56.25% in plants treated with dry leaves, the latex of *S. glaucescens*, and resin of *C. swynnertonii* in that order. Plant extracts had significant effects ($p = 0.000$) on plant growth. The plants treated with dried leaf powder attained the highest height, the number of branches/plant, leaves/plant, and leaf area of 85.85 cm, 19.25,99.5 and 59.39 respectively. The findings benchmark the fungicidal potential of *C. swynnertonii* and *S. glaucescens*.

## 1. Introduction

Tomato fusarium wilt (TFW), a soil borne fungal disease, is a serious problem of tomatoes associated with up to 90% yields losses worldwide (Singh and Kamal, 2012; Ramaiah and Garampalli, 2015). It is caused by *Fusarium oxysporum* f. sp. *lycopersici* (Ohunakin and Bolanle, 2017). Although the fungus survives in different soil types, it thrives well in sandy soils (Larkin and Fravel, 2002) especially when the soil and air temperatures are withing room temperature range (25–28 °C) (Arici et al., 2018). Under field condition the fungus is disseminated by infected planting materials, watering, equipment and human movement (Ajilogba and Babalola, 2013; Bawa, 2016).

The symptom of the tomato fusarium wilt begins as slight vein clearing on the outer portion of the young leaves followed by chlorosis in the older leaves normally begins on one side of the plant before wilting of that foliage (Tistisgiannis et al., 2008). As the disease progresses the entire plant becomes chlorotic and wilts to death or becomes severely stunted. A longitudinal dissection into the xylem of the stem base shows a dark-brown to red discolouration which can be used for disease identification (Mishra et al., 2014).

Various strategies have been proposed for the management of TFW including the use of resistance cultivars and fungicides (Nirmaladevi et al., 2016; Cueto-Wong et al., 2010). Unfortunately, no one method has proved to permanently ameliorate the TFW problem. Although the use of genetic resistance is considered effective and cheap, resistance breaking is common depending on environment and pathogen variability (Kutama et al., 2013). Moreover, synthetic fungicides have a negative impact on the environment and human health and some plant pathogenic fungi have developed resistance (Dias, 2012). The use of botanical pesticides as an alternative to the conventional chemical

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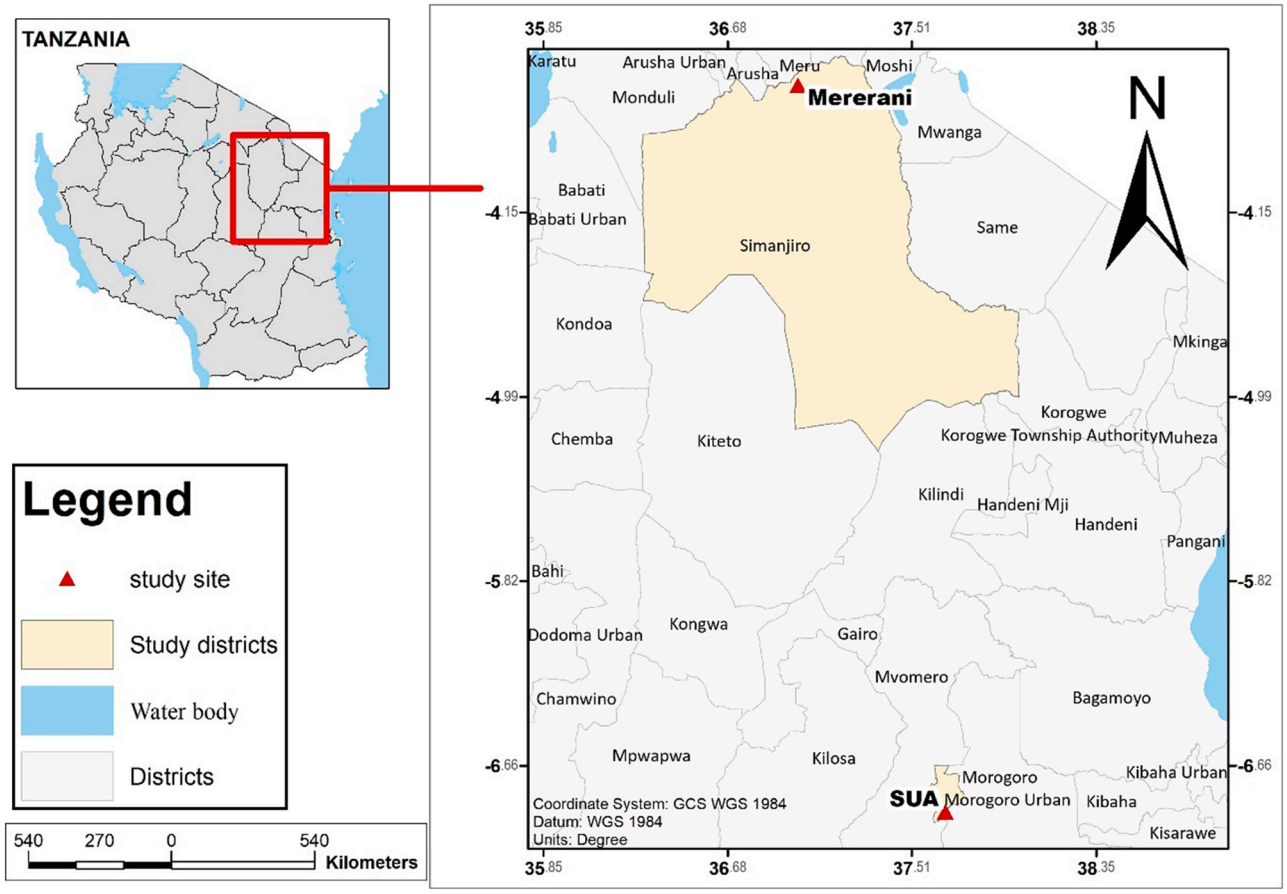


**Fig. 1.** Map of Tanzania showing Mererani and SUA from which experimental materials were collected.


**Fig. 2.** Shade drying of S. glaucescens leaves [A]; grounded dried leaves [B], blended fresh leaves [C] and latex [D] of S. glaucescens and resin of C. swynnertonii [E].

pesticides in agriculture is gaining renewed interest worldwide as it has proved to be friendly to public and environmental health (Ramaiah and Garampalli, 2015).

The commonly used phytofungicidal plant species include *Azadirachta indica, Ageratum conyzoides* and *Datura metel* which have shown antifungal activities against *F. oxysporum* f. sp. *spinaciae* (Hadian, 2012: Mishra, 2014; Rinez et al., 2013). Other reports show that *Commiphora* species like *Commiphora stoksiana* can inhibit the radial growth *F. oxysporum* f. sp. *spinaciae* (Bhale et al., 2005). Limited information are available on the effectiveness of *C. swynnertonii* and *S. glaucescens* in managing TFW disease caused by *F. oxysporum* f. sp. *lycopersici.* This study was conducted to evaluate four plant extracts from *C. swynnertonii* and *S. glaucescens* for their activities against the growth of the pathogen and development of the TFW disease.

## 2. Materials and methods

### 2.1. Mobilizing experimental materials

Collection of resins of *C. swynnertonii* (*Cs*) was done at Simanjiro District in Manyara Region (4° 0′ 0 S, 36° 30′ 0 E: 1 009 m a.s.l) (Fig. 1). Latex and leaves of *S. glaucescens* (*Sg*) were collected at the Edward Moringe Campus of the Sokoine University of Agriculture (SUA), Morogoro, Tanzania (6° 85′ S, 37° 65′ E; 556 m a.s.l). Linkmil 72 WP and tomato seeds c.v. Cal J were purchased locally in Morogoro town.

Potato Dextrose Agar (PDA), Sodium hypochlorite, and Tween 20were supplied by Jakovic General Supplies Ltd, Morogoro, Tanzania.

### 2.2. Preparation crude plant extracts

Resin of Cs, latex and leaves of Sg were harvested, packed in an airtight bottle (Fig. 2D and E), kept in a cool box and transported to the laboratories of the Department of Physics and Chemistry of SUA. In the laboratory, the resin and latex were stored in the refrigerator at 4 °C. About 1 kg of fresh leaves of *Sg* were harvested and the samples were brought to the laboratory for washing under running water in order to remove sticking dirt, insects, and plankton followed by rinsing in distilled water. About 0.5 kg of the fresh leaves were finely blended using an electric blender (Kenwood, Model BL 490, China) and the blend was kept in an airtight bottle (Fig. 2C) and the other 0.5 was dried under shade (Fig. 2A) for a week before being ground into powder through a 1.5 mm sieve (Fig. 2B).

### 2.3. Preparation of crude plant extract-dilutions

Resins, latex, blended fresh leaves and leaves powder were reconstituted to concentrations of 0.01 g/ml, 0.05 g/ml, 0.1 g/ml and 0.15 g/ml respectively by weighing 1 g, 5 g, 10 g, and 15 g in that order (Fig. 2). Each extract was put in a beaker in which sterile distilled water was added to the 100 ml mark. The mixture in the beaker were vigorously mixed by vortexing and left to stand for 24 h. After 24 h, the mixture was filtered using Whatman No.1 filter paper and the filtrate was stored at 4 °C in airtight bottles until used.

### 2.4. Collection and preparation fungal inoculum

Selected tomato growing fields in Mlali village of Morogoro region in Tanzania were surveyed to identify fields with wilt-infected plants from where TFW symptomatic plants were collected. To isolate *Fusarium oxysporum* from wilted tomato plants, stem tissues were washed under running tap water to remove dirt, rinsed in distilled water followed by surface sterilisation in 1% NaOCl (Sodium hypochlorite) solution for 2 min. After surface sterilization, the tissues were double rinsed in sterile distilled water and dried between sterile filter papers. Pieces (< 5 mm) of surface disinfected tissues were placed on Potato Dextrose Agar (PDA) plates according to Landschoot et al. (2011). The plates were incubated at room temperature for 7–10 days to allow white mycelial growth of *Fusarium oxysporum* before they are subcultured onto PDA slants. Pure cultures were maintained on PDA slants at 4 °C. The isolates were observed for cultural characters and morphology of the conidia. Colonies exhibiting the taxonomic features of *F. oxysporum* were identified according to Nelson et al. (1983). Morphological identification was based on characteristics of the macroconidia, phialides, microconidia, chlamydospores and colony growth traits.

#### 2.4.1. Identifying formae speciales

To establish Koch's postulates, eleven *F. oxysporum* isolates were subjected to a pathogenicity test according to Twizeyimana et al. (2013). Each isolate was inoculated to 4 healthy tomato plants using a standard root dip method. Briefly, the seedlings were uprooted carefully without damaging the roots, were shaken to remove the adhering particles before washing gently under running tap water. About 1 cm of the root apex was trimmed using a pair of sterile scissors and submerged in a suspension of the conidial of each isolate for 30 min. Other seedlings were dipped in sterile distilled water to be used as a control. Fifteen centimeters (15 cm) diameter minipots were surface sterilized using 0.1% mercuric chloride and then they were filled with sterilized soil and sand at a ratio of 1:1. Five inoculated seedlings and control were transplanted into each pot. The plants were maintained in a greenhouse in which the day and night temperatures varied between 25 and 30 °C. The seedlings were irrigated daily and fertilized once with NPK (24 − 8 − 16). After transplanting, an assessment of disease severity was done from 14th to 45th day. The disease severity index was calculated based on disease severity scores determined using a scale that ranged from 0% to 100% (0- healthy plant; 25- initial symptoms of leaf chlorosis; 50- severe leaf chlorosis and initial symptoms of wilting; 75- severe wilting symptoms and leaf chlorosis; 100-plant totally wilted, leaves completely necrotic). Stem longitudinal dissection was also done to observe discoloration of the vascular tissue as confirmation of TFW internal symptoms. The pathogen was reisolated to confirm identity and similarity with the originally inoculated isolate and the disease symptoms were compared to those from the field records. (Fig. 3).

### 2.5. Effects of Sg and Cs against growth of F. oxysporum f. sp. lycopersici

#### 2.5.1. Experimental design

A 4 × 4 factorial (4 plant extracts each in 4 concentrations) experiment in a completely randomized design (CRD) with three replications was established to determine the bioactivity of Cs and Sg extracts against *F. oxysporum* f. sp. *Lycopersici (FoL)* using poisoned food technique (Adedeji and Aduramigba, 2016). A 2 ml of each extract at 0.01 g/ml (EC1), 0.05 g/ml (EC5), 0.1 g/ml (EC10) and 0.15 g/ml (EC15) were added in 20 ml of sterilized PDA. From an actively growing

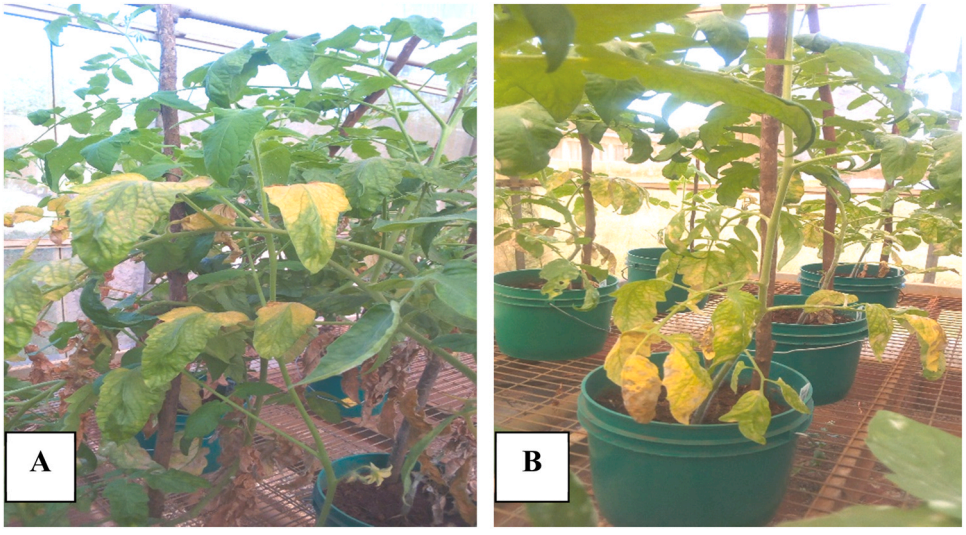


**Fig. 3.** Chlorosis of one side of tomato plant [A]; Chlorosis of older leaves of tomato plant [B].

7 days old culture of *FoL*, a 5 mm diameter of mycelium disc was placed at the centre of the petri dish using a sterile cork borer. The none poisoned PDA and PDA mixed with Linkmil 72 WP at 3 g/l were maintained as a negative and positive control, respectively. The cultures were incubated at 24 °C for eight days.

#### 2.5.2. Data collection

Colony radii were measured 2, 4, 6 and 8 days after inoculation (DAI). The percent inhibition was determined according to Ogbebor and Adekunle (2005) (Eq. (1))

$$\text{Inhibition}(\%) = \frac{\text{Radial growth in control} - \text{Radial growth in treatment}}{\text{Radial growth in control}} x \quad 100 \tag{1}$$

### 2.6. Effects of Cs and Sg against TFW

#### 2.6.1. Experimental design

A single factor experiment in RCBD with four replications was established to determine the effects of Cs and Sg extracts on TFW disease development according to Sharma et al. (2017) with few modifications. Under screen house condition, tomato seeds of the cultivar Cal J were sown on seedling trays filled with compost and watered daily to establish seedlings to be used as test plants. From the in vitro experiment, for all tested plant extracts, a concentration of 0.15 g/ml of SDW was seen as the most efficacious in terms of inhibiting mycelial growth of *FoL* to be used in this in vivo experiment. The *FoL* inoculum was prepared by culturing the fungi in sterilized sorghum grains and kept in darkness at 25 °C for two weeks. Tomato growth medium was prepared as a mixture of steam-sterilized soil, FYM and rice husks at a ratio of 4:2:1. After two weeks of culture, the inoculated sorghum grains were then incorporated in the growth medium at the rate of 25 g inoculum per kg of growth medium and incubated for 5 days to allow re-establishment of the fungi in this mixture. The soil mix was treated with aqueous crude plant extracts each at a concentration of 0.15 g/ml were applied into the inoculated growth medium at a rate of 5.0 ml per150 $cm^3$ of the medium. Dry leaf powder was applied at 20 g/kg soil. The treated growth medium was transferred in 4 L- plastic pots and incubated for 48 h before the tomato seedlings at 3 – 5 leaf stage were transplanted into the pots. The untreated pots with only fungus inoculated growth medium were maintained as negative control and the pots treated with Linkmil 72 WP was kept as a positive control. Ten potted tomato plants constituted one experimental unit.

#### 2.6.2. Disease incidence and severity

For 8 weeks consecutively, TFW disease the number of infected plants was recorded. Disease incidence and severity were recorded weekly. The disease severity was scored on a scale of 0 – 4 as described by Grattidge and O'Brien (1982). The disease incidence (DI), Disease severity, disease severity index (DSI) and disease reduction (DR) were determined based on Sharma et al. (2017) as in Eqs. (2) – (5) respectively

$$\text{Disease incidence}(\%) = \frac{\text{Number of infected plants X100}}{\text{Total number of plants assessed}} \tag{2}$$

$$\textit{Diseaseseverity}(\%) = \sum((n \times V)/(9 \times N))x100 \tag{3}$$

Where Σ = summation, n = number of plants within each infection score, V = numerical values of infection scores, N = total number of plants examined, and 4 is a constant and the highest score value.

$$\text{DSI}(\%) = \frac{\Sigma(\text{grade x number of plants in that grade})}{(\text{maximum grade x total number of assessed plants})} x100 \tag{4}$$

$$\text{DR}(\%) = \frac{(\text{DSI of negative control} - \text{DSI of treatment})}{(\text{DSI of negative control})} x100 \tag{5}$$

### 2.7. Growth parameters

Two months after inoculation the heights of two randomly sampled plant were measured from the ground to the tip. The number of branches leaves were recorded for each treatment. Leaf length was measured followed by measuring the leaf width at the middle then the values were multiplied according to Awal et al. (2004) to determine the leaf area.

### 2.8. Data analysis

Data collected were subjected to analysis of variance using GenStat software 15th Edition (VSN International Ltd. UK). Post hoc tests were done where ANOVA showed significant effects of the treatments at $p \leq 0.05$.

## 3. Results

### 3.1. Effect of plant extracts on F. oxysporum f. sp. lycopersici mycelia growth

Fig. 6 presents the pictorial view on variability in the radial mycelial growth of *FoL* in PDA medium augmented with plant extracts of *S. glaucescens* and C. *swynnertonii*. Type of plant extracts showed a highly significant effect ($p < 0.001$) on inhibiting the radial mycelia growth of *FoL* (Fig. 4 A). Significant differences in radial mycelial growth of *FoL* were observed between plant extract and the positive (Linkmill 72WP)

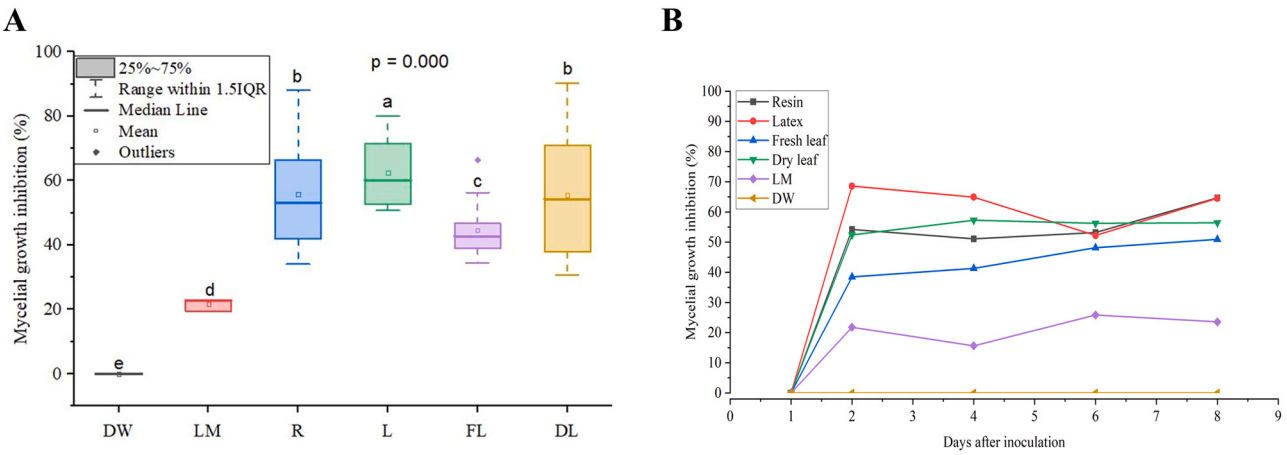


**Fig. 4.** (A) Effects of type of plant extract on mycelial growth inhibition, and (B) the persistence of efficacy over time after inoculation.

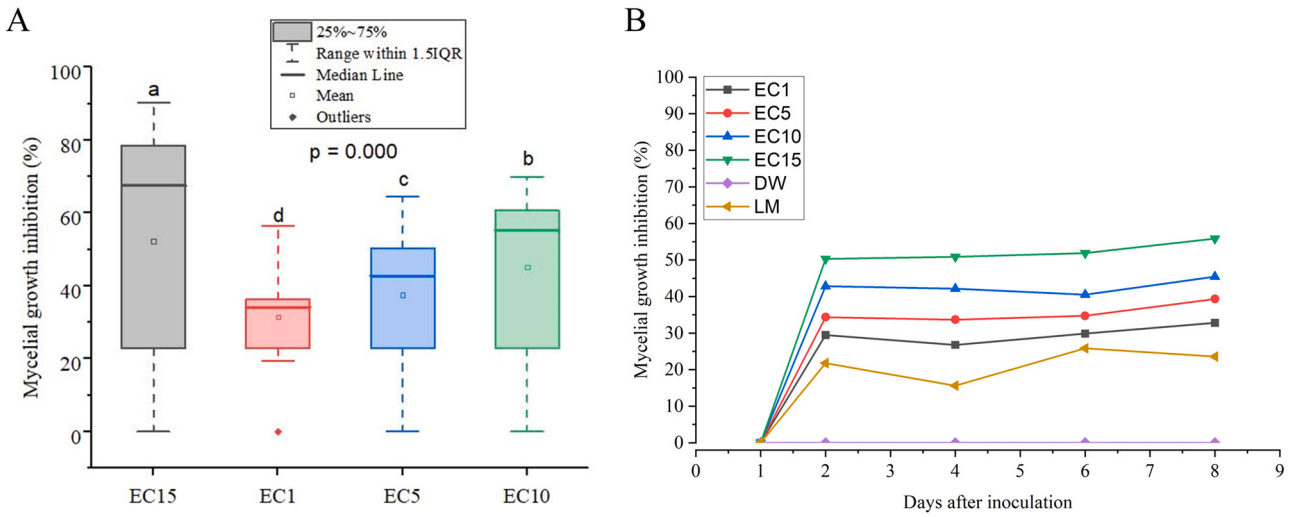


**Fig. 5.** Effects of Plant extract (PE) concentration on mycelial growth inhibition (A) and the persistence of efficacy at each PE concentration (EC1 = 0.01 g/ml, EC5 = 0.05 g/ml, EC10 = 0.1 g/ml and EC15 = 0.15 g/ml).

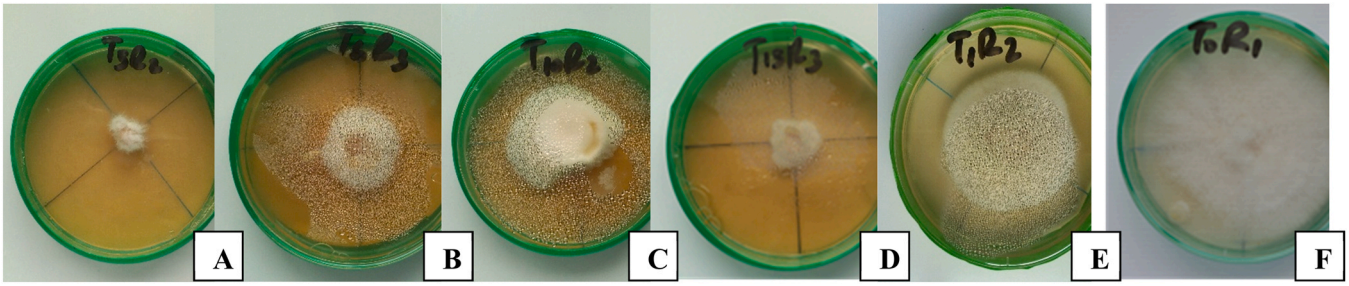


**Fig. 6.** Effect of different treatments on mycelia radial growth inhibition of F. oxysporum f. sp. lycopersici after incubation for 8 days (A = Resin, B = Latex, C = Fresh leaves, D = Dry leaves, E = Linkmil 72WP and F = negative control).

as well as the negative (distilled water) controls. Latex of *S. glaucescens* caused the highest (62.5%) inhibition. This was followed by dry leaves (55.56%) and Resin of *C. swynnertonii* (55.78%) while the application of fresh leaves caused the lowest inhibition (44.70%) on the growth of fungal mycelia. However, the effects of plant extracts on the growth of fungal mycelia were significantly higher than the effects due to both negative (distilled water) and positive (Linkmill 72WP) controls which caused mycelial growth inhibition of 0% and 21.7% respectively. Findings in Fig. 4B show that, 8 days after inoculation, the efficacy of plant extracts against *FoL*, did not deteriorate significantly except Latex of *S. glaucescensn* whose inhibitory effects dropped from 70% at the second day after inoculation to near 50% on the 6th day after inoculation.

### *3.2. Effect of concentration of plant extracts on F. oxysporum f. sp. lycopersici mycelia growth*

Fig. 7 presents the pictorial view of the effects of concentration of latex, a plant extract of *S. glaucescent* on the radial mycelial growth of *FoL* grown in PDA medium. It was observed that, the concentrations of plant extracts had a highly significant effects ($p < 0.001$) on the inhibition of radial mycelia growth of *FoL* (Fig. 5A). There levels of inhibition were varying with a concentration whereby plant extracts at a concentration of 0.15 g/ml (EC15) showed the highest inhibiting capacity (52.2%) against radial mycelial growth of *FoL* followed by EC10 (42.7%) and EC5 (35.5%) while the concentration of 0.01 g/ml had the lowest overall inhibitory effect of 29.7%. For each plant extract concentration, the effectiveness of plant extracts against *F FoL* did not vary with time (Fig. 5B).

### *3.3. Interaction effect of plant extracts and concentrations on F. oxysporum f. sp. lycopersici mycelia growth*

The result in Fig. 8 shows that the effects of plant extracts on inhibiting the mycelial growth of *FoL* were significantly ($p = 0.000$) dependent on their concentration. It is clear from this study that, inhibitory effects due to plant extracts on mycelial growth of *FoL* improved with increasing concentration from 0.01 to 0.15 g/ml. The highest inhibitory effects were observed with dry leaves (DL) as it improved from 37.7% inhibition when applied at 0.01 g/ml to 80.04% inhibition when 0.15 g of dry leaves of *S. glaucescens* was applied as a mixture in one milliliter of water. These results were not statistically different from those observed for Resins of *C. swynnertonii* which when applied at the same dosage, the inhibitory effects improved from 34.79% inhibition at a dose of 0.01 g/ml to 78.61% inhibition when applied at 0.15 g/ml.

### *3.4. Effect of crude plant extracts on incidence and severity of TFW disease under screen house condition*

Significant effects ($p = 0.002$) of the type of plant extract on the incidence of fusarium wilt in tomato plants were observed (Fig. 9A). Lowest tomato fusarium wilt (TFW) disease incidences of 47.56% and 46.87% were observed on tomato plants treated with dry leaves and latex of *S. glaucescens* respectively. The TFW disease incidences in tomato plants growing on soils treated with fresh leaves of *S. glaucescens* (74.87%) and the resins of *C. swynnertonii* (73.13%) did not vary statistically with the 75.77% TFW incidence on plants growing under positive control (Linkmil 72WP). Similarly, the type of plant extracts

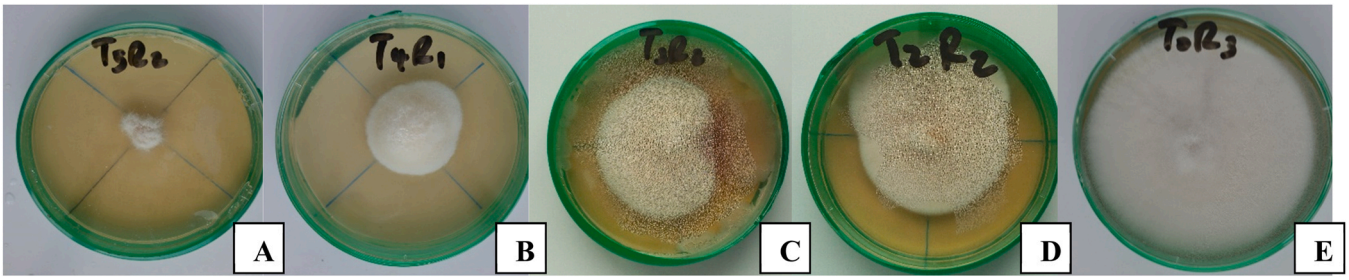


**Fig. 7.** The effect of different concentrations of latex (S. glaucescens) on mycelia radial growth inhibition of F. oxysporum f. sp. lycopersici (A = 0.15 g/ml, B = 0.1 g/ml, C = 0.05 g/ml and D = 0.01 g/ml and E = negative control).

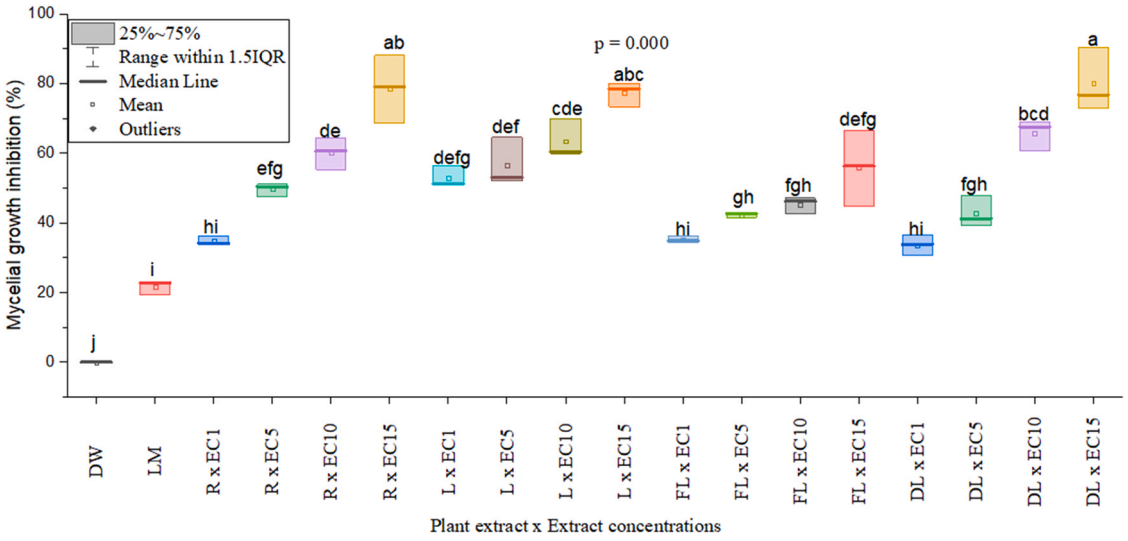


**Fig. 8.** Interaction effects of Plant extracts and the plant extract concentration on the mycelial growth inhibition (A) and the persistence of their effects over time (B).

had significant (p = 0.001) effects on the severity of tomato fusarium wilt disease (Fig. 9B). Lowest TFW disease severity was observed on tomato plants that were grown on soils treated with fresh leaves (14.5%), dry leaves (12.76%) and latex (13.23%) of *S. glaucescens*. These findings were significantly lower than TFW disease severity on tomato plants growing on soils treated with resins of *C. swynnertonii* (20.22%). The TFW on tomato plants grown in soil treated with the different plant extracts were significantly lower than the severity of the same disease on plants grown on both positive (30.15%) and negative controls (42.56%) (Fig. 9B).

### *3.5. Effects of type of plant extracts on TFW disease progress under screen house condition*

Disease progress curves for the plants grown on soils treated with the four plant extracts in the screen house show that over time, the disease intensity varied with type treatment (Fig. 10). Conducive conditions facilitated early disease initiation, rapid disease development and highest disease pressure in the untreated plants (negative control) during all the eight weeks of evaluation. Delayed disease initiation, slower rates of disease development, and lower final disease severities

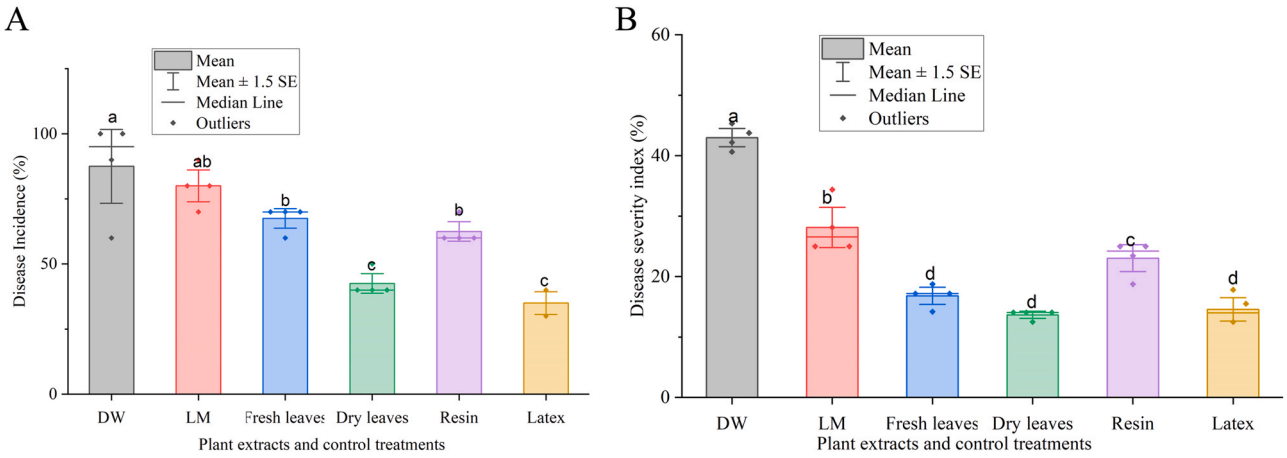


**Fig. 9.** Effects of type of plant extract on incidence and severity of fusarium wilt under screenhouse condition.

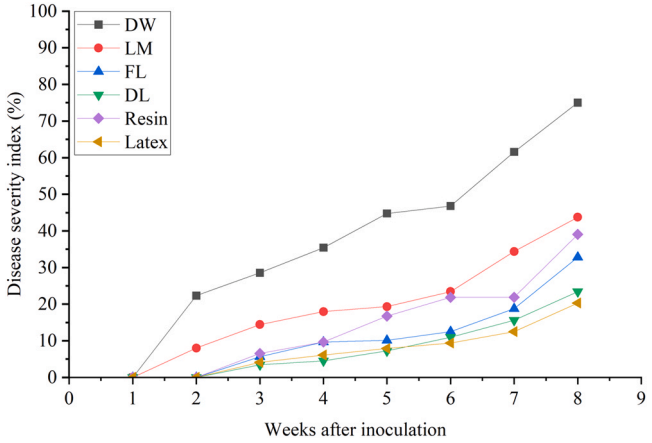


**Fig. 10.** Tomato fusarium wilt disease progress curves on plants grown in soils treated with four plant extracts.

were recorded on plants that were grown on soils treated with plant extracts especially dry leaves and latex, both of *S. glaucescens*. Disease severities in plant under the negative and positive control treatments were significantly higher than the severities recorded on plants under plant extracts.

### *3.6. Effect of plant extracts on tomato fusarium wilt disease reduction*

Significant differences ($p = 0.002$) between plant extracts were observed regarding their ability to reduce plant disease severity in tomato plants (Fig. 11). Disease reduction of 70% and 66% were attained in plants which were treated with latex and dry leaves respectively. About 50% and 43% disease reductions were attained with fresh leaves and resins applications respectively and the two were not statistically different from the positive control (Linkmil 72WP) and were different from negative control. All treatment attained an increasing disease reduction with time except the negative control. For the tomato plants treated with latex, a maximum of about 80% disease reduction was attained at the 5th week after inoculation followed by 64% disease reduction attained at the 7th week after inoculation in the plants treated with dry leaves. A maximum of 42.4% diseases reduction was attained at the 8th week after inoculation in the plants which were treated with positive control.

### *3.7. ffect of crude plant extracts on growth parameters of tomato*

There was a significant difference ($p = 0.001$) between plant extracts in leaf surface area, plant height, number of branches per plant and number of leaves per plant (Table 1). Plants treated with dried leaves powder of *S. glaucescens* were the longest (85.85 cm), had the largest number of branches per plant (19.25), the largest number (99.50) of leaves per plant and greatest leaf area (59.39 $cm^2$). Of the four plant extracts, plants treated with resins of *C. swynnertonii* had the shortest plants (38.22 cm), smallest number (9.5) of branches per plant, smallest number (46.50) of leaves per plant and lowest leaf area (33 $cm^2$). For all the growth parameters measured in this study, the growth performance of plants grown in soils treated with resins of *C. swynnertonii* was generally lower than the growth performance in both positive and negative controls.

## 4. Discussion

Under laboratory conditions, plant extracts of both *S. glaucescens* and *C. swynnertonii* showed effectiveness as an antifungal against *F. oxysporum* f. sp. *Lycopersici (FoL)*. This is the first report establishing the potential of *S. glaucescens* and *C. swynnertonii* in the management of *FoL* pathogen. The pathogen is a notorious soil-borne fungus which under favourable conditions can cause up to 100% tomato yield losses and is associated with significant economic losses in tomato production. Previously, numerous studies have reported the medicinal value of *S. glaucescens* and *C. swynnertonii* against viruses, bacteria, and insect parasites of animals (Max et al., 2014, Vitus et al., 2016, Credo et al., 2022, Nyigo et al., 2022, Ochola et al., 2022). Of all these, none had reported the fungicidal potential of *S. glaucescens* and *C. swynnertonii*. Other plants like *Tephrosia vogelii* (Hook f.), *Vernonia amygdalina* (Delile), *Lippia javanica* (Burm.f.) Spreng., *Tithonia diversifolia* (Hemsl.) A. Gray, *Bidens pilosa* L., *Ageratum conyzoides* L and *Lantana camara* L. have been tested for their pesticidal potentials including antifungal activities (Tembo et al., 2018, Danish et al., 2020, Schoss et al., 2022).

Of the four plant extracts used in this study, Dry leave powder and latex both of *S. glaucescens* were the most effective in inhibiting the mycelial growth of *FoL* followed by the resinous extract of *C. swynnertonii.* The difference between the two plants can be linked to their differences in the biochemical composition of the secondary metabolites which act against the fungal pathogen. *Commiphora* species contain terpenoids and phenolic compounds that serve as defensive compounds against biotic and abiotic stresses. *Synadenium* species contain flavonoids, saponins, diterpenes and phorbol esters for the same purpose (Nyigo et al., 2016). These compounds interfere physiological activities of different pests including fungi. These findings are supported by results of tests which previously investigated the pesticidal potential of other plants. Hadian (2012) tested neem seed extracts against *FoL* and found 98% growth inhibition. Neem seeds contain secondary metabolite *azadiractin* which affects the mycelial growth of the pathogen (El-Wakeil, 2013). Beg et al. (2011) reported that the aqueous extract of

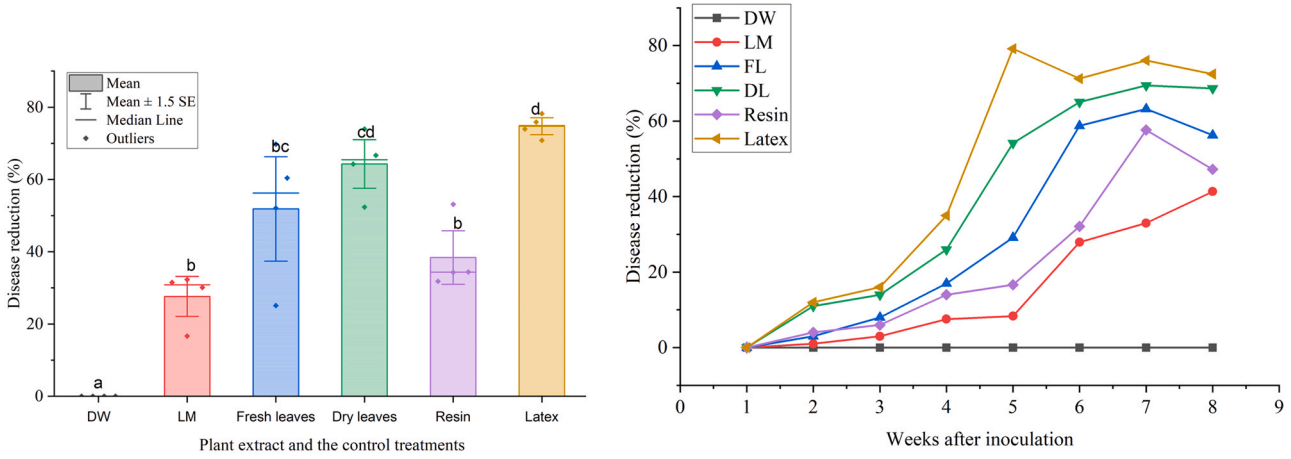


**Fig. 11.** Effect of Plant extracts on disease reduction (DR) of tomato fusarium wilt. (DW = distilled water and LM = Linkmil 72WP).

**Table 1**
Effect of crude plant extracts on growth of tomato plant.

| Treatments | Plant height (cm) | No. of branches/plant | No. of leaves/plant | Leaf area ($cm^2$) |
|---|---|---|---|---|
| Resin | 38.22a | 9.50a | 46.50a | 33.00a |
| Latex | 77.65d | 18.50c | 86.25b | 51.27 cd |
| Fresh leaves | 73.40 cd | 16.00 BCE | 82.25b | 45.53 BCE |
| Dry leaves | 85.85e | 19.25c | 99.50c | 59.39d |
| Linkimil 72 WP | 71.25c | 15.75 BCE | 77.50b | 41.18abc |
| Negative control | 62.92b | 12.25ab | 76.75b | 38.23ab |
| Mean | 68.22 | 15.21 | 78.10 | 44.80 |
| CV% | 5.80 | 17.60 | 9.30 | 16.00 |
| S.E | 1.99 | 1.34 | 3.63 | 3.58 |
| *p-value* | < 0.001 | < 0.001 | < 0.001 | 0.001 |

Means followed by the same letter in the same column are not significantly different at $p \leq 0.05$ according to DMRT.
CV% = Coefficient of variation, S.E = Standard errors of means.

*Blumea lacera* had positive activity against *F. oxysporum* f. sp. *Lycopersici*. The extract inhibited 78% of the mycelial growth of the fungus.

It is also established that, the bioactivity of plant extracts against *FoL* was highly dependent on the concentration of the extract. The higher the concentration the higher the bioactivity of each plant extract, but the study could not establish how would the response look like beyond the concentration of 0.15 g/ml. These findings are in agreement with Danish et al., 2021 who found that the antifungal and antibacterial activity of Aloe vera happened in a concentration-dependent manner. All plant extracts were more effective at the highest application dose of 0.15 g/ml and vise versa was in line with previous studies (Efenberger-Szmechtyk et al., 2021; Schoss et al., 2022). The plant extracts showed stable bioactivity as the inhibition of mycelia growth did not vary significantly up to six days after inoculation. These results suggest that formulations of plant extracts at any given concentration remain effective long time without compromising bioactivity. This implies that there could be an insignificant change in their biochemical composition during that period.

The findings obtained in the screen house experiment are in agreement with the findings attained under laboratory conditions. It was established that all the plant extracts (fresh leaf, dry leaf, resin and latex) had the ability to suppress the development of tomato fusarium wilt disease, although at varying levels of disease incidence, severity, disease progress, and hence disease reduction. Dry leaves and latex extracted from *S. glaucescens* suppressed tomato fusarium wilt. The efficacy of plant extracts and their mode of action are extensively summarized in Gurjar et al. (2012) but in the list, *S. glaucescens* and *C. swynnertonii* are not included suggesting the novelty of the current study.

In the screenhouse experiment, disease incidence, disease intensity (severity), disease progress and growth performance of plants were monitored. The findings suggest that the extracts of *S. glaucescens* and *C. swynnertonii* have capacity to significantly suppress the development of tomato fusarium wilt caused by *FoL*. The findings are in agreement with the findings in Esther et al. (2016) who reported that these two plants showed sufficient insecticidal effects under field conditions. The findings are not far from a common knowledge that pesticidal plants have been used to control plant diseases caused by fungi, bacteria, nematodes and insect pests since time immemorial (Kumar et al., 2014; Din et al., 2016; Dutta et al., 2019; Khan et al., 2017). However, in this study the dry leaves powder and latex of *S. glaucescens* were found to be the most effective in reducing disease incidence and severity of tomato fusarium wilt (Waterman, 2007).

Previous studies have indicated that differences in fungicidal activities as shown in this study could be linked to phytochemical differences of *Synadenium* species especially the composition of their phenolic compounds and phorbol esters (Hassan et al., 2012). Singha et al. (2011) reported that crude extracts from leaves of *Piper beetle* showed a significant fungicidal effect against the *FoL*. Studies by Rinez et al. (2013) demonstrated that aqueous extract of *Datura metel* had fungicidal properties which could be used in managing *FoL* because the plant extract inhibited mycelial growth by 69%.

The disease reduction caused by the resinous extract of *C. swynnertonii* was lower than the disease reduction due to dry leaves powder and latex of *S. glaucescens*. Unfortunately, the resinous extract of *C. swynnertonii* inhibited tomato plant growth. Such inhibition on tomato plant could be associated with the phytotoxic effect of resins on plant growth in line with Sharma et al. (2017) who established that clove oil at a high dose (10%) caused phytotoxic effects to the growth of tomato plants. Similarly, the aqueous methanol extracts of *Ocimum tenuiflorum* plant at concentrations higher than 10 mg/ml had inhibitory activity on the shoot and root growth of *Lactuca sativa*, *Lepidium sativum*, *Medicago sativa, Lolium multiflorum*, *Echinochloa crus-galli* and *Phleum pretense* (Islam and Kato-Noguchi, 2014). Ibanez and Blazquez (2019) observed that extract from *Lavandula angustifolia* caused phytotoxicity against tomato seed germination.

The tested plant extracts from *S. glaucescens* did not only reduce disease development but also had positive impacts on the growth and development of tomato plants. Generally, the plants which were growing in soils treated with extract of *S. glaucescens* were more vigorous than those growing on soils treated with the resinous extract of *C. swynnertonii*. These results are in agreement with the findings that, *C. swynnertonii* has inhibitory effects on plant growth possibly due to its biochemical nature according to Sharma et al. (2017). Dry leaf powder from *S. glaucescens* causes greater plant vigour in terms of plant height, number of leaves, number of branches and leaf area. Such good performance was followed by plants that were grown in soils treated with latex of *S. glaucescens*. The ability of dry leaf and latex of *S. glaucescens* to inhibit fungal growth and hence suppress disease development could be ascribed to the observed good plant growth because they were less affected by tomato fusarium wilt disease. Whether these extracts provided nutritional support to the plant could not be established in this study. However, like other plants that are used as soil amendments, extracts from *S. glaucescens* could have played multiple roles including soil conditioning and supply of mineral nutrients upon decomposition.

## 5. Conclusion

The study has established that the plant extracts of *S. glaucescens* and *C. swynnertonii* had significant inhibitory effects on radial mycelial growth of *FoL* a pathogen causing fusarium wilt disease in tomato. The inhibition power of each plant extract was dependent on the concentration whereby at 0.15 g/ml the dry leaves and latex extracts of *S. glaucescens* caused the highest inhibition of mycelia growth of the pathogen. Also, the application of dried leaves powder had positive effects on tomato plant growth. Further studies are needed to verify the current findings but also to determine the most effective formulation against *FoL* for commercially managing TFW without compromising the agronomic performance of the tomato crop plant.

## CRediT authorship contribution statement

Richard R. Madege processed and analysed the data and drafted the manuscript Said Babu implemented the experiment and collected the data, Faith Mabiki Conceived the research and supervised and co-ordinated the research, Both Hosea Mtui, Abdul Kudra Supervised the implementation of the research.

## Data availability

Data will be made available on request.

## Conflict of interest

The authors and funders of the research declare no conflict of interest in publishing this article.

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