Management of the tomato diseases in vitro using safe and eco-friendly natural plant extracts

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Abstract

A field survey was conducted in 27 locations across five districts in Sulaimani and Halabja (July 2024) to evaluate the incidence and severity of major fungal diseases affecting tomato plants. Thirty-one fungal isolates were obtained and identified as Rhizoctonia, Aspergillus, Penicillium, Rhizopus, and Cladosporium based on macroscopic and microscopic characteristics. The isolates showed wide variation in their effects on tomato seed germination, such as highly stimulatory isolates (Iso.7, Iso.8, Iso.19, Iso.20, and Iso.21) enhanced germination and seedling vigor, whereas strongly inhibitory isolates (Iso.2, Iso.5, Iso.6, Iso.13, and Iso.15) suppressed germination completely. A quick pathogenicity test on seedlings narrowed the selection to six pathogenic isolates for further study. Two in vitro techniques were used to assess the antifungal activity of four plant extracts (ginger, Al-sahbah, garlic, and willow). Garlic exhibited the highest inhibition of colony growth in the first technique (0.25–0.75 ml), followed by ginger and Al-Sahbah. In the second method, the different rates of water and alcohol with plant extracts also suppressed fungal growth. Al-Sahbah showed the highest activity and caused complete inhibition of several isolates. Garlic showed the least amount of overall activity in alcohol extracts; however, ginger was very effective. These results show the potential of various plant extracts, especially Al-sahbah and ginger, as strong natural antifungal agents for managing pathogenic fungi; however, the kind of solvent, plant extract species, and fungal isolate all had significant effects on the degree of inhibition.

Keywords: Tomato diseases, fungal isolates, pathogenic, plant extracts, Survey.

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the vegetable crops produced all over the world [1], recognized for its wide use in the food industry and high nutritional value. However, several diseases cause significant economic damages in addition to decreasing tomato yield and quality [2, 3]. It was reported that about 200 tomato diseases worldwide caused by different pathogens [4]. Fungi are the most com-

mon parasitic organisms found on seeds. Diseased seeds are a major source of primary infection and the primary cause of plant diseases. As a result, they have an adverse effect on seed health, lowering early seedling growth parameters like germination capacity and poor seedling quality, transferring fungus to the growing seedlings, and increasing infection in storage [5]. It was decided to conduct this review in order to identify the most significant fungi that cause diseases in tomato seeds and to disseminate information that can help fight these diseases, since fungal diseases are the primary causes of losses in agriculture and are made worse when they occur in seeds [6].

Fungi causes seed infections, such as seed rotting, necrosis, seed toxification, and seed abortion, which causes the fruit to decay during harvest, transportation, and storage [7]. Among these, species from the genera *Rhizoctonia*, *Aspergillus*, *Penicillium*, and *Cladosporium* are known to be significant contributors to losses both pre- and postharvest. *Aspergillus niger* and *Aspergillus flavus* are typical soil-borne fungus that cause black and yellow mold rots, respectively, when tomato fruits are handled and stored. In addition to causing physical degeneration, these fungi create mycotoxins including ochratoxins and aflatoxins, which is of a risk concern to humans [8]. The soil-borne disease *Rhizoctonia solani* mostly damages tomato plants' roots and stems, resulting in damping-off, stem canker, and root rot, which eventually limits plant growth and lowers production [9].

Environmental conditions, cultivar susceptibility, and postharvest handling techniques are some of the variables that affect the occurrence and severity of these fungal infections. Sustainable tomato production and food safety depend on an understanding of the pathogenic mechanisms and control techniques for *Aspergillus*, *Rhizopus*, *Penicillium*, and *Rhizoctonia* species.

Over-reliance on chemical treatments has led to a number of issues, such as pest populations becoming resistant to pesticides, environmental damage, and serious health risks for farmers such pesticide poisoning [10]. Many farmers continue to use pesticides as the primary choose for pest management despite being aware of these concerns. This is mostly attributed to their lack of education, ignorance of their risk, and their limited ability to access to the alternative options [11]. There are some trees in Kurdistan that people or farmer not aware to using it in common such as Alsahbah, and willow, using these tree as organic pesticides to control Tomatoes disease was the main purpose for using it in Kurdistan. The aim of this study was to reduce pesticide use, which pollutes the environment and impacts biodiversity due to excessive application by farmers, by shifting towards natural organic alternatives like plant extracts for disease control, as these are environmentally safe.

Materials and Methods

Disease survey and collecting infected tomato samples

A survey on tomato diseases was carried out in 27 locations across 5 districts in the primary tomato cultivation regions of the Sulaimani and Halabja governorates

during July 2024-2025 to evaluate the incidence and severity of tomato diseases. Randomly a number of tomato fields that are cultivated by tomato were selected from the studied region, and the plant samples were collected from which at different growth stages, seedlings, vegetative, floral, and fruit-setting, which are infected with the pathogens. Five locations in each tomato field were inspected using a 1 m² diagonal walk in order to avoid bias in the disease recording [12]. The survey was conducted in 27 tomato farms, which were inspected across the assessed five districts during the survey. Three tomato samples that explored soil-borne symptoms were collected from each location. Using a 0-5 severity scale (Table 1) based on the percentage of foliar tissue exhibiting wilt symptoms, disease severity and incidence were measured in 1 m² as described by [13].

Table (1): Screening of tomato diseases using disease severity scale based on plant diseased percentage [13].

score	Disease Responses	Percent of wilt
0	Highly Resistant (HR)	No disease
1	Resistant (R)	1-10% of plants wilted
2	Moderately Resistant (MR)	10.1-20% of plants wilted
3	Moderately Susceptible (MS)	20.1-30% of plants wilted
4	Susceptible (S)	30.1-50% of plants wilted
5	High Susceptible (HS)	51% or more of plants wilted

Disease incidence (DI) calculated using equations as follows:

DI % = (Number of infected plants per 1 m² ×100) /Total number of plants inspected per 1 m² [14].

Disease severity (DS) was determined by applying the formula provided by the analysis severity scores as described by [15].

DS= (Σ number of plants within each infection score × numerical values of infection scores) /maximum score scale x Total number of plants.

Isolation, purification and identification of pathogens

The pathogen was isolated from roots and shoots of infected plants Figure 1. Diseased plant samples were collected and mixed to form a composite sample for each area under evaluation. Placed in clean paper bags and labeled, then transported to the plant diseases laboratory of Sulaimani Agricultural Research Directorate. Samples were washed, surface-sterilized with 1% NaOCl, rinsed, dried, and cut into (3–5) mm pieces. Tissues were plated on PDA medium with 250 ppm streptomycin and incubated for seven days at (25 ± 2) °C. Hyphal tip isolation was used to purify the fungal colonies, which were stored on PDA slants at 4°C [16]. Isolates were diagnosis as fungal species using macroscopic and microscopic criteria in vitro.

Figure (1): Blackening of internal stem due to tomato fungal disease

Germination parameters, and seed vigor

The agar plate method was used to evaluate seed health and detect internal seed-borne diseases [17]. Then the inoculation discs (5) mm from seven-day-old fungal cultures were placed onto PDA plates until each isolate covered 75% of the medium. Sterilized tomato seeds were then sown around the hyphal tips (10 seeds per plate, three replicates) and incubated for (5–7) days at 25°C [18]. Germination parameters measured included germination percentage, speed, energy, and vigor index [19].

$$\text{Germination percentage (G\%)} = \frac{\text{A number of seeds germinated}}{\text{Total number of seed sown}} \text{ x } 100$$

$$\text{Germination Speed (GS)} = \frac{\text{Number of seeds germinated in 72 hours}}{\text{Number of seed germinated in 168 hours}} \text{x } 100$$

Germination Energy (GE) = %of seed germinated in 72 hr.
Vigor Index (VI) = Seedling length (Root length + Shoot length) × Germination Percentage (G %) [18].

Pathogenicity test

This test was conducted using a single local tomato variety; after 15 days, tomato seedlings were immersed in the spore suspension [20]. After adjusting the concentration of conidia in the suspension to the suggested concentration 10^6 CFU/ml^{-1} (the used concentration of conidia ranged from 6-490*10^6 CFU/ml^{-1}). Spore suspensions of each pathogen were added to sterile containers containing 250 g of sterile parrot moss and mechanically agitated prior to inoculation, whereas the control treatment contained only PDA without inoculation [21,22]. The infected seedlings were immediately tested under an optical microscope to check for any fungal development in the plant tissue once symptoms began to appear. The infections and the diseased seedlings were once again isolated in order to prove Koch's postulate [23]. Disease severity (DS) was determined by applying the formula provided by the analysis severity scores as described by [15].
DS= (Σ number of plants within each infection score × numerical values of infection scores) /maximum score scale x Total number of plants.

Preparation of aqueous plant extracts involved several steps

For preparing plant extracts, 20 g of ground pomegranate peel were separately soaked in 100 ml solvents. The extract was prepared in four types of solvents

First method, Al-Sahbah (*Milia azedarach*), Garlic (*Allium sativum*), Ginger (*Zingiber officinale*), and Willow (*Salix alba*) leaves were thoroughly cleaned with tap water, and Garlic bulbs. After removal from the bulb, each clove was manually peeled [24]. Then, they were surface sterilized using a 1% NaOCl solution and washed multiple times with sterilized distilled water. Afterward, the plant materials were left to air dry. To create the extracts, 20 ml of sterile water and 20 g of plant material were carefully well mixed. The mixture was then grinded using a pestle and mortar. All the chosen plant components were combined to form a 100% w/v stock solution. This stock solution was filtered using muslin cloth and Whatman filter paper No. 1. The obtained extracts were centrifuged for (5) min at 10,000 rpm. The supernatant was then sterilized for (10 min) at 40°C and stored in a freezer to be used later [25,26].

Second method, i.e. 100% ethanol100%, water, and 50 % ethanol: 50 % water.

The samples were incubated at 37°C for 24 hr. in a shaking incubator with 200 rpm. After that, the samples were filtered with Whatman no. 1 filter paper and filtrate was stored in the incubator at 4°C and stored in a freezer to be used later [27].

Results and Discussion

Disease survey and collecting infected tomato samples

Results showed that most of the fields surveyed were infected with the tomato disease. Both of Hayas in Said Sadiq district and the Gurgadar area of Sharbazher district had the highest disease severity and incidence rates at 100% and 100%, but Qalachualan in Sharbazher district had the lowest disease severity and incidence rate in the area at 0.00% and 0.00%. (Table 2). The main reason for the infection fields is attributed to that those fields were cultivated with tomatoes in the previous seasons. The increased incidence and severity of diseases in tomato fields may be due to several factors, such as continuous cultivation of tomatoes on the same land; For example, one of the most well-known regions for producing tomatoes is Penjwen. Thus, it will lead to the pathogen accumulation year after year in the fields due to the development of favorable environmental conditions to increase the probability of infection and the transmission of the disease from both incidence and severity in those areas. After harvesting the crops, the farmers left the residues of tomato and other plants from the previous season on or near the fields, which are thought to be the primary source of infection of diseases that can resume in the next season.

Table (2): Tomato wilt disease incidence and severity in various tomato production areas within Sulaimani, and Halabja governorates during July, 2024.

Region	District	Location	Dates of survey	No. of Surveyed fields	No. of Infected field	Types of tomato	Disease incidence (%)	Disease severity (0-5) Scale	Disease Responses
Sulaimani	Penjwen	Brahimawa	22/7/2024	2	1	Nobel	80	70	HS
		Nzara	22/7/2024	1	1	Rozya	90	70	HS
		Darbankarty1	22/7/2024	1	1	Sofia	70	50	HS
		Barawa	22/7/2024	1	1	Salma	55	40	S
		Tatan1	22/7/2024	1	1	Sofia	75	50	HS
		Tatan2	22/7/2024	1	1	Kurdi	50	35	S
		Shale1	22/7/2024	1	1	Sofia	30	25	MS
		Shale2	22/7/2024	1	1	Wady	45	30	S
		Kelw	6/8/2024	1	1	Sofia	45	30	S
		Kanyshaban	6/8/2024	1	1	Sofia	30	25	MS
		Qzalja	6/8/2024	1	1	Sofia	25	15	MR
	Bazian	Kanyshynkan	24/7/2024	1	1	Kurdi	30	25	MS
		Kopala	24/7/2024	1	1	Ancon	35	30	S
		Lazyan	24/7/2024	1	1	Kurdi	80	60	HS
	Sharbazher	Sitak	29/7/2024	1	1	Kurdi smal l	10	5	R
		Tagaran	29/7/2	1	1	An-	50	5	MS

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		Qal-achwa-lan	29/7/2024	1	0	8320	0	0	HR
		Kanyshexan	29/7/2024	1	1	Kurdi	5	5	R
		Gwrgadar	29/7/2024	1	1	Kurdi	100	100	HS
		Parazan	29/7/2024	1	1	Kurdi	60	50	HS
	Said-sadq	Hayas	31/7/2024	1	1	Kurdi pink	100	100	HS
Hala-bja	Hala-bja	Halabja	31/7/2024	1	1	So-fia	50	40	S
		Qayafary	31/7/2024	1	1	Kurdi	20	10	MR
		Tapakwra	31/7/2024	2	2	Kurdi	100	75	HS
		Shatwan	31/7/2024	1	1	Ancon	50	35	S
Total	5	23	-	27	25	-	51.4	39.2	-

Isolation, purification and identification of pathogens

Major disease symptoms, such as wilting, withering, and yellowing of plants, browning of vascular bundles, drying and the leaves become yellowish from base to top, all these symptoms are indicators of tomato plants infection with diseases in the field. The stem and root surfaces of affected seedlings do not deteriorate. However, when cut or split open vertically from the collar downward, the tissues within the stems exhibit a dark color ranging from dark brown to black. IKR, especially in the provinces of Sulaimani and Halabja, identified 31 isolates from 27 regions of infected tomato crops spread over five districts (Table 2). Based on descriptions, growth rate, and culture appearance, the isolated organisms were determined to be Rhizoctonia, Aspergillus, Penicillium, Rhizopus and Cladosporium. Both macroscopic and microscopic criteria were used in vitro to identify isolates as fungal species.

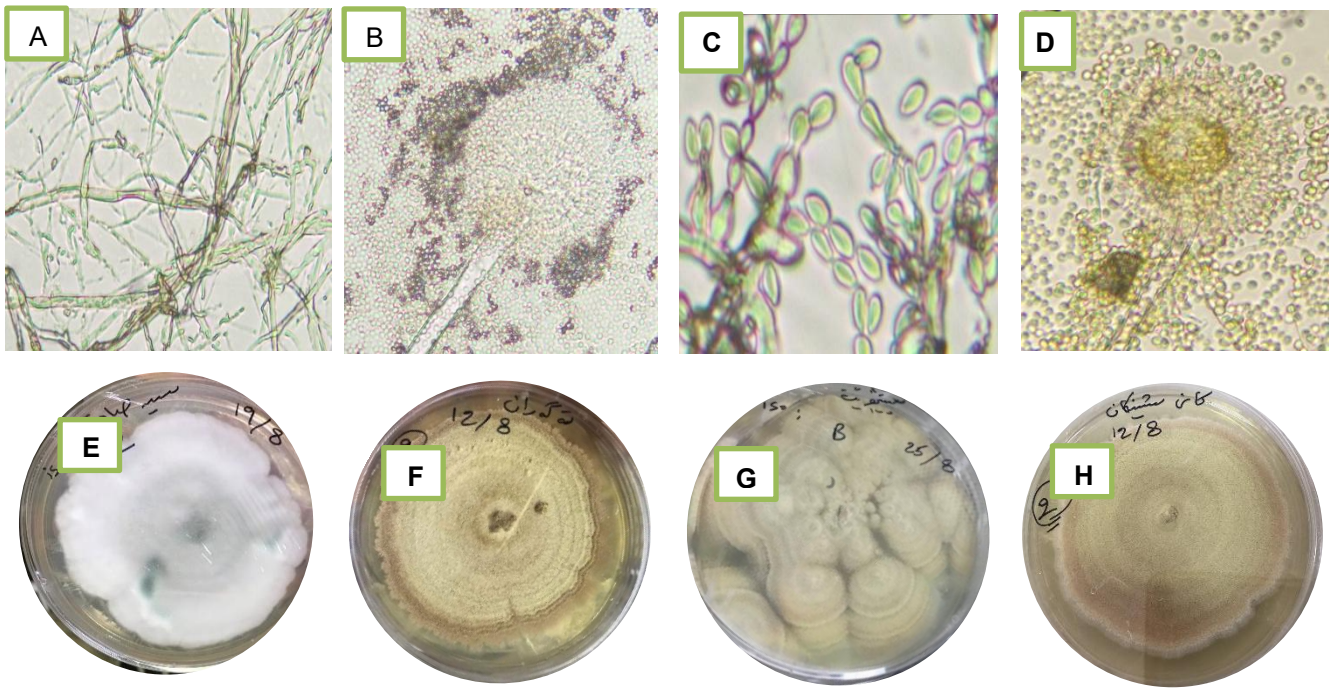

Figure (2): Morphology of some isolates of tomato diseases in Sulaimani, and Halabja governorates. (a) *Rhizoctonia solani* mycelium on PDA 7days 27°c, (b) *Aspergillus niger* conidiophore, (c) *Cladosporium sp.* spores, (d) *Aspergillus flavus* conidiophore, (e) *Rhizoctonia solani* colonies, (f) *Aspergillus niger* colonies, (g) *Cladosporium sp.* colonies, (h) *Aspergillus flavus* colonies.

Germination parameters, and seed vigor

Tomato seed germination and early seedling growth varied widely among isolates (Table 3). Germination ranged from 0–100%, with several isolates (Iso.2, Iso.5, Iso.6, Iso.13, Iso.15) completely inhibiting germination, while Iso.12 showed the highest rate (100%), followed by Iso.7 and Iso.29 (95 and 85) %, respectively. In addition, local tomato seeds (Kurdish) recorded a high germination rate (95%). Speed of germination is strongly correlated with germination rate, That is, isolates that inhibited seed germination have zero germination energy.

Germination speed values ranged from (0-94.74). High germination speed was observed in Iso.7 (94.74), Iso.1 (94.12), local (94.12), and the control (94.12), demonstrating rapid and uniform germination. The isolates that completely inhibited germination correspondingly exhibited a speed value of 0. Several isolates, such as Iso.17, Iso.18, Iso.19, Iso.20, and Iso.21, recorded moderate to high germination speed, indicating a positive influence on seed metabolic activation.

The root/shoot length ratio also differed significantly between isolates. Ratios ranged from 0 in treatments where germination was fully inhibited to values above 7 in Iso.21 (7.33) and Iso.24 (7.38). These two isolates induced markedly higher root development relative to shoot growth, suggesting improved root system establishment. Many isolates produced moderate ratios (1.0–5.0), while a few, such as Iso.14 and Iso.17, showed reduced root elongation.

Seedling vigor exhibited the greatest variability among treatments, with values ranging from 0 to over 590. The highest vigor indices were observed in Iso.8 (592.2) and the local (593.75), indicating robust combined germination and seedling growth. Other isolates with high vigor performance included Iso.20 (350.55) and Iso.21 (162.05). However, isolates that totally prevented germination also generated a vigor index of 0, indicating that they had a negative impact on the establishment of seedlings.

Table (3): Effect of different treatment on germination and seedling growth parameters.

Isolations	Germination %	Germination Speed	Germination Energy	Root/Shoot Length Ratio	Seedling Vigor Scale
1	85^{bcd}	94.12^{ab}	80^{ab}	1.15^{ijkl}	276.25^{f}
2	0^{n}	0^{m}	0^{f}	0^{l}	0^{w}
3	65^{fghi}	61.54^{j}	40^{e}	2^{hijk}	97.5^{t}
4	85^{bcd}	82.35^{ef}	70^{bc}	1.3^{ijkl}	97.75^{t}
5	80^{cde}	87.5^{cde}	70^{bc}	4.27^{def}	166.4^{op}
6	0^{n}	0^{m}	0^{f}	0^{l}	0^{w}
7	95^{ab}	94.74^{ab}	90^{a}	6.35^{bc}	219.93^{i}
8	90^{abc}	100^{a}	90^{a}	5.61^{cd}	592.2^{a}
9	90^{abc}	100^{a}	90^{a}	4.9^{de}	185.85^{m}
10	75^{def}	93.33^{bc}	70^{bc}	4.58^{def}	167.25^{o}
11	80^{cde}	75^{gh}	60^{cd}	3.72^{efg}	143.6^{r}
12	100^{a}	90^{bcd}	90^{a}	4.52^{def}	320^{e}
13	0^{n}	0^{m}	0^{f}	0^{l}	0^{w}
14	80^{cde}	50^{k}	40^{e}	1.25^{ijkl}	108^{s}
15	0^{n}	0^{m}	0^{f}	0^{l}	0^{w}
16	90^{abc}	100^{a}	90^{a}	1.91^{hijk}	172.8^{n}
17	55^{jk}	90.91^{bcd}	50^{de}	0.98^{ijkl}	228.8^{h}
18	90^{abc}	66.67^{ij}	60^{cd}	2.42^{ghi}	332.55^{d}
19	90^{abc}	77.78^{fg}	70^{bc}	1.33^{ijkl}	209.7^{j}
20	90^{abc}	44.44^{l}	40^{e}	7.38^{b}	350.55^{c}
21	70^{efg}	85.71^{de}	60^{cd}	2.31^{hij}	162.05^{pq}
22	70^{efgh}	71.43^{hi}	50^{de}	4.49^{def}	159.6^{q}
23	75^{def}	53.33^{k}	40^{e}	2.05^{hijk}	87^{u}
24	85^{bcd}	70.59^{hi}	60^{cd}	4.51^{def}	210.8^{j}
25	80^{cde}	87.5^{cde}	70^{bc}	2.28^{hij}	199.2^{l}
26a	40^{m}	100^{a}	40^{e}	0.91^{jkl}	227.8^{h}
26b	50^{kl}	100^{a}	40^{e}	0.91^{jkl}	262.25^{g}
27	60^{gij}	80^{fg}	40^{e}	9.49^{a}	55.6^{v}
28	80^{cde}	66.67^{ij}	60^{cd}	0.61^{kl}	204.8^{k}

29	0^{n}	61.54^{j}	40^{e}	0^{l}	0^{w}
30	45^{lm}	63.16^{j}	60^{cd}	0^{l}	0^{w}
Control	85^{bcd}	94.12^{ab}	80^{ab}	1.53^{ijkl}	418.63^{b}
Local (Kurdish tomato)	95^{ab}	94.12^{ab}	80^{ab}	3.17^{fgh}	593.75^{a}

Duncan Multiple Range Test < 0.001 Completely Randomized Design Analysis (CRD). By SPSS. There are high significant differences between isolates in terms of disease production regardless of the site of testing.

Pathogenicity test

A quick pathogenicity test was conducted on tomato seedlings utilizing the conidial concentration of 31 pure isolates (*Rhizoctonia*, *Aspergillus*, *Penicillium*, *Rhizopus*, and *Cladosporium*) from different tomato fields in the provinces of Sulaimani and Halabja. As indicated in Table 4, the isolates were classified into four groups based on the results of the rapid pathogenicity evaluation. Group 1, the highly pathogenic isolates, includes Iso.2, Iso.9, Iso.12, Iso.19, Iso.26b, and Local (Kurdish tomato), which shows disease symptoms on tomato seedlings after 48 hr. Group 2, the pathogenic group that shows disease symptoms on tomato seedlings after 72 hr. The pathogenic group includes Iso.1, Iso.3, Iso.5, Iso.8, Iso.11, Iso.16, Iso.17, Iso.18, Iso.22, Iso.24, Iso.25, Iso.26a, Iso.27, and Iso.28 that showed pathogenicity on tomato seedlings, respectively. Group 3 Iso.4, Iso.6, Iso.10, Iso.13, Iso.14, Iso.15, Iso.20, Iso.21, Iso.23, and Iso.29 showed pathogenicity on tomato seedlings, while Group 4, the weak pathogenic group, which includes Iso.7 and Iso.30, showed no symptoms on the seedlings within 96 hours. Due to the isolates' pathogenicity on the seedlings, only six of the 31 tested isolates were selected for further investigation. *Rhizoctonia*, *Aspergillus*, *Penicillium*, *Rhizopus*, and *Cladosporium* isolates were found to be significantly different from the control treatment.

Table (4): Quick pathogenicity test of different isolates collected from various tomato growing areas in Sulaimani and Halabja governorates during the growing season 2024/25.

Isolates	pathogen	Pathogenicity on tomato seedlings	Isolates	pathogen	Pathogenicity on tomato seedlings
1	*Penicillium sp.*	++*	18	*Rhizoctonia sp.*	++
2	*Aspergillus flavus*	+++	19	*Aspergillus niger*	+++
3	*Aspergillus niger*	++	20	*Aspergillus fumigatus*	+
4	*Aspergillus niger*	+	21	*Aspergillus sp.*	+

5	*Aspergillus niger*	++	22	*Aspergillus niger*	++
6	*Aspergillus niger*	+	23	*Aspergillus niger*	+
7	*Aspergillus niger*	-	24	*Rhizoctonia sp.*	++
8	*Cladosporium sp.*	++	25	*Aspergillus sp.*	++
9	*Aspergillus niger*	+++	26a	*Cladosporium sp.*	++
10	*Aspergillus niger*	+	26b	*Cladosporium sp.*	+++
11	*Aspergillus niger*	++	27	*Aspergillus sp.*	++
12	*Rhizoctonia sp.*	+++	28	*Aspergillus sp.*	++
13	*Aspergillus niger*	+	29	*Aspergillus sp.*	+
14	*Aspergillus niger*	+	30	*Aspergillus sp.*	-
15	*Aspergillus niger*	+	control	-	-
16	*Rhizopus sp.*	++	Local (Kurdish tomato)	*Aspergillus flavus*	+++
17	***Penicillium sp.***	++			

+++ = Tomato seedlings showed signs of a highly virulent disease after 48 hr.
++ = Tomato seedlings developed pathogenic disease symptoms after 72 hr.
+ = Tomato seedlings showed weak pathogenic disease signs after 96 hr.
- = Non-pathogenic, tomato seedlings show no symptoms after 96 hr.

Preparation of aqueous plant extracts involved several steps.

First method, figure 3 and 4 show the results of the effects of ginger, Al-Sahbah, garlic, and willow extract on the mycelial growth of the isolates (6 quick pathogenic isolates) after seven and fifteen days. The extracts were found to have a significant effect at different concentrations (0.25, 0.50, and 0.75) ml on the growth of the pathogens assessed after 7 and 15 days of incubation at 27ºC. There was a progressive decreasing trend in the pathogen colony diameter.

Effect of Plant Extracts on Fungal Colony Diameter after 7 days

Aqueous plant extracts were tested for their antifungal activity against six fast-growing pathogenic isolates. Figures 3 and 4 show that ginger, Al-sahbah, garlic, and willow extracts significantly reduced mycelial growth at concentrations of 0.25, 0.50, and 0.75 ml after 7 and 15 days at 27°C, with colony diameters decreasing as extract

concentration increased. After 7 days (Figure 3), control plates showed the largest colony diameters (70–83) mm. Garlic extract produced the strongest inhibition, followed by ginger and Al-sahbah, while willow showed moderate effects. Iso.12 and Iso.26b were the least affected, whereas Iso.19 showed strong growth suppression across all treatments.

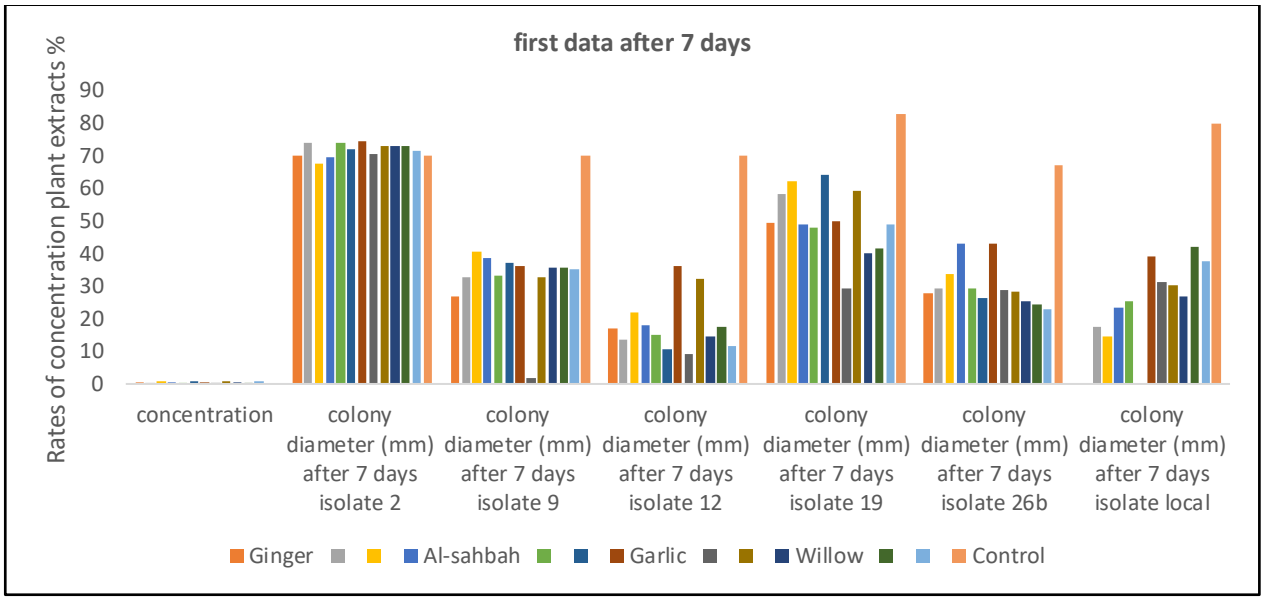

Figure (3): Effect of Plant Extracts on Fungal Colony Diameter after 7 days in first method

Effect of plant extracts on fungal colony diameter after 15 days

After 15 days of incubation, colony diameters increased across all treatments and isolates, over time (Figure 4). However, treatment effects observed at 7days remained consistent. However, the control had the largest colony diameter, typically between (75 and 90) mm, confirming the absence of growth restriction. Garlic extract again had the strongest inhibitory effect, maintaining the minimum colony diameter in most isolates. Ginger and al-Sahbah extracts continued to reduce growth effectively, although to a lesser extent than garlic. Willow extract showed little inhibition of medium, compared to the control but the colony diameter of the isolates was higher than the other extracts. Our findings indicate that all plant extracts differed significantly and had the greatest effect on isolate diameter growth. According to all three explanations, plant extracts had a significant effect on the growth of Iso.12 and local when compared to other isolates and the control; however, it had minimal effect on the diameter growth rate of Iso.2 and Iso.19 when compared to other isolates and the control. The plant extracts also had a moderate effect on the growth of Iso.9 and Iso.26 when compared to the control and each other.

The most successful single treatment was the "Al-sahbah" extract at a 0.75 concentrations, which totally stopped the growth of the "local" isolate, resulting in a colony diameter of 0 mm. Iso.12 is a sensitive isolate because all extracts were affected and the least colony diameter developed; For example, when willow concentrations

of 0.25 was used, the colony diameter was 28 mm, and when ginger concentrations of 0.75 was used, the colony grew to 30.33 mm. Al-sahbah at 0.25 concentrations for Iso.19 (74 mm) and garlic at 0.25 concentrations for Iso.2 (80 mm) were two of the least effective treatments; the results were almost the same as the control values, but Iso.2 showed the highest diameters among all isolates for many treatments (e.g., 80 mm with Ginger, Al-sahbah, and Garlic 0.25 concentrations), suggesting it was the most resistant.

Higher concentrations (0.75) often perform better than lower concentrations (0.25). Ginger concentrations at 0.75 provided slightly better results than 0.25 or 0.5 across most isolates. Al-Sahbah concentrations at 0.75 were clearly optimal at local colony diameters (0 mm). Garlic concentrations at 0.75 were generally more effective than the others. Willow concentrations at 0.75 were the most effective in reducing colony diameter compared to the lower concentrations.

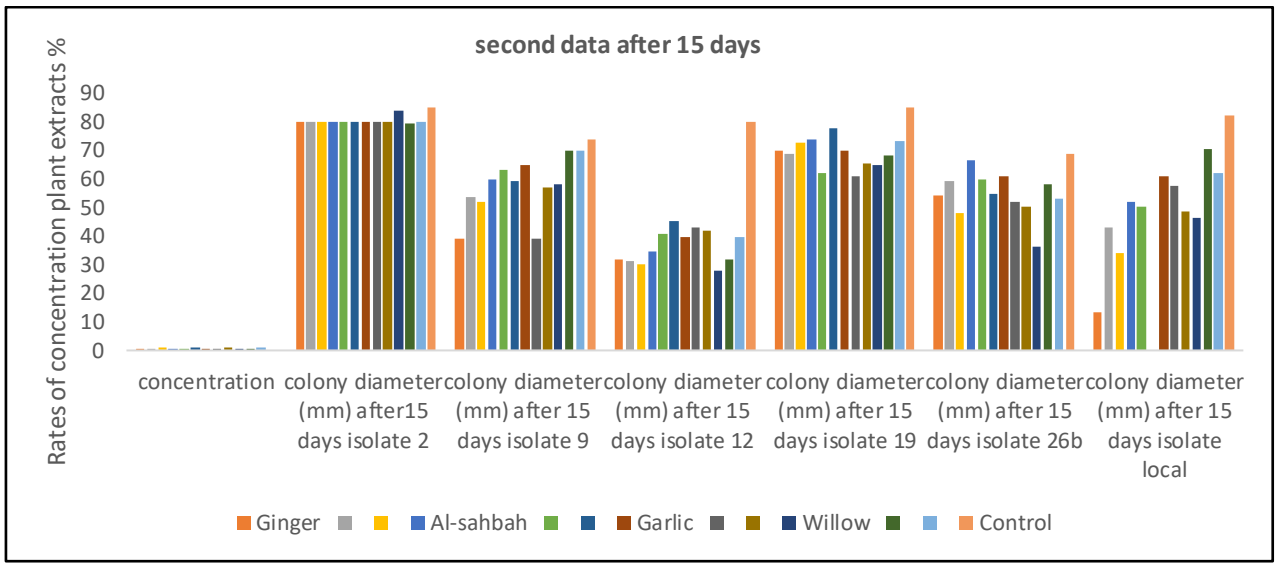

Figure (4): Effect of plant extracts on fungal colony diameter after 15 days in first method

Second method, This study evaluated the antifungal effectiveness of different plant extracts (ginger, Al-sahbah, garlic, and willow) prepared in 100% water, 50% alcohol, and 100% alcohol against six fungal (Iso.2, Iso.9, Iso.12, Iso.19, Iso.26b, and local). The efficiency of the plant extracts was measured by the colony diameter (mm) after 7 days, where the smaller colony size indicated to the stronger antifungal activity. The control showed the largest colony diameters, confirming normal fungal growth (Figure 5). The antifungal activity of four plant extracts (Ginger, Al-sahbah, Garlic, and Willow) prepared using two solvent with different concentration alone and in combination which were (100% water, 50% alcohol, and 100% alcohol) was evaluated against six fungal isolates (Iso.2, Iso.9, Iso.12, Iso.19, Iso.26b, and local). Fungal growth was determined by measuring the colony diameter following seven days. Higher antifungal activity was seen in reduced colony diameters across all treatments. Normal fungal development was confirmed by the control, which had the

highest colony diameters (69–84) mm. Alcohol-based extracts outperformed water in ginger's moderate to strong inhibitory effects. The growth of isolates Iso.2, Iso.9, and Iso.26b was significantly inhibited by the 50% and 100% alcohol extracts. Iso.12 was completely inhibited in the 50% and 100% alcohol treatments (0 mm). The local isolate only partially inhibited colony growth (9.33 mm), despite the 100% alcohol extract reducing colony growth across the majority of isolates.

Overall, ginger extracts showed strong antifungal action, especially when combined with alcohol. Among all the plant materials studied, al-sahbah showed the most potent and reliable antifungal action. Iso.12 (0 mm) was totally inhibited by extracts containing 50% alcohol and 100% water. The same treatments nearly completely (0–0.33) mm inhibited Iso.26b. Although the effects varied considerably across the other isolates, the 100% alcohol extract also maintained a high inhibition on Iso.12 (0 mm). Al-sahbah extracts demonstrated significant efficacy by generally producing the smallest colony diameters across treatments. The inhibitory performance of garlic was the lowest. Colony diameters were similar to the control and remained high for all isolates and solvents. Even the 100% alcohol extract only slightly decreased the colony diameter. In all garlic treatments, Iso.12 colony diameter was between (13–27.33) mm, indicating limited susceptibility. Overall, there was little antifungal action in garlic extracts. Depending on the solvent, different inhibitions were induced by willow extracts. The 100% water extract showed significant inhibition of Iso.9 (2.33 mm), Iso.19 (5 mm), and Iso.26b (1 mm). The 50% and 100% alcohol extracts, however, showed less inhibition for a number of isolates and were less reliable. Iso.12 was more successfully suppressed by the 100% alcohol extract (12.67 mm), although Iso.9 and Iso.19 were less effectively inhibited.

Thus, among the willow therapies, willow water extract proved to be the most successful. When compared to the untreated control, all plant extracts dramatically decreased colony diameter, demonstrating detectable antifungal efficacy. However, the degree of inhibition differed significantly depending on the fungal isolate, solvent type, and plant species. Al-sahbah demonstrated the strongest antifungal potential of all the therapies, with ginger and willow coming in second and garlic last. Iso.12 consistently showed the highest inhibition, with total suppression over several administrations. Iso.26b was likewise quite vulnerable, particularly to extracts from willow and Al-sahbah. These findings suggest that the kind of plant extract and the solvent system are important factors in determining the effectiveness of antifungals.

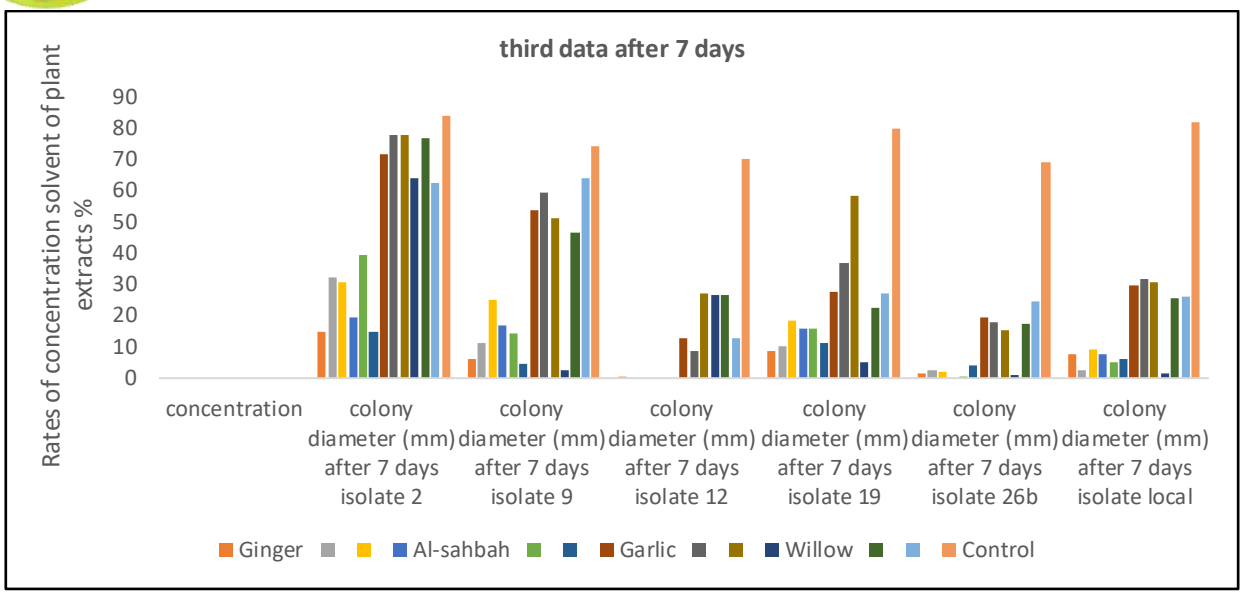

Figure (5): Effect of Plant Extracts on Fungal Colony Diameter after 7 days in second method

After 15 days of incubation against six fungi (Iso.2, Iso.9, Iso.12, Iso.19, Iso.26b, and local), the antifungal activity of ginger, Al-sahbah, garlic, and willow extracts made in 100% water, 50% alcohol, and 100% alcohol was assessed. Fungal growth was measured by colony diameter, with the untreated control exhibiting the highest diameters (69–85) mm, indicating normal fungus growth for comparison (Figure 6). Across isolates, ginger exhibited moderate antifungal activity, with discernible heterogeneity based on the kind of extract. Iso.12 (1.33 mm) and Iso.26b (4.00 mm) colony growth was significantly decreased by 100% water extract, but Iso.9 and Iso.19 colony growth was somewhat inhibited. Strong suppression of Iso.12 (1.00 mm) was maintained, while inhibition for the local isolate (10.00 mm) was enhanced by 50% alcohol extract. Iso.9 and Iso.19 (60.00 and 43.67) mm showed the least effectiveness from the 100% alcohol extract, while Iso.12 (1.67 mm) was still suppressed. In general, ginger had the greatest impact on Iso.12, but other isolates, depending on the solvent, showed intermediate resistance.

Al-sahbah extracts exhibited potent and reliable antifungal efficacy against almost all isolates. Iso.12 (0.00 mm) was totally inhibited by 100% water extract, and isolates Iso.26b (9.33 mm) and Iso.19 (37.33 mm) also showed significant decreases. Similar suppression was shown by a 50% alcohol extract, which significantly inhibited Iso.2, Iso.9, and Iso.26b. The most effective extract was 100% alcohol, which completely suppressed isolate 26b (0.00 mm) and nearly completely inhibited Iso.9 (8.00 mm) and Iso.19 (28.33 mm). Among all the isolates, al-sahbah was the most effective plant extract, particularly at higher alcohol concentrations.

In comparison to the other plant extracts, garlic showed poor antifungal efficacy, because colony diameters in all three solvent types are near proximity to untreated controls. Colony diameters in Iso.12 demonstrated a significant increase (23.00–45.67) mm, suggesting low susceptibility. In the 100% alcohol extract, Iso.26b was

the only isolate to exhibit moderate inhibition (15.00 mm), however this was still significantly greater than values found for Ginger, Willow, or Al-sahbah. After 15 days of incubation, garlic extracts showed very little inhibitory action. With high inhibition for some isolates and poor performance for others, willow demonstrated selective antifungal efficacy. Strong inhibition against Iso.19 (10.00 mm) and Iso.26b (1.67 mm) was demonstrated by 100% water extract, indicating its best effectiveness. With colony diameters ranging from (36.00-78.33) mm among isolates, 50% alcohol extract had the least amount of activity. Iso.12 (27.00 mm) was better suppressed by 100% alcohol extract, whereas Iso.9 and local (76.33 and 46.33) mm were weakly suppressed. Willow water extract worked well, especially for Iso.19 and Iso.26b. With the exception of garlic, all extracts decreased colony diameter in comparison to the control. For Iso.9, Iso.12, and Iso.19 isolates, the control treatment consistently yielded the largest diameters (80–85) mm. Garlic had no effect, whereas extracts from ginger, al-sahbah, and willow exhibited significant suppression.

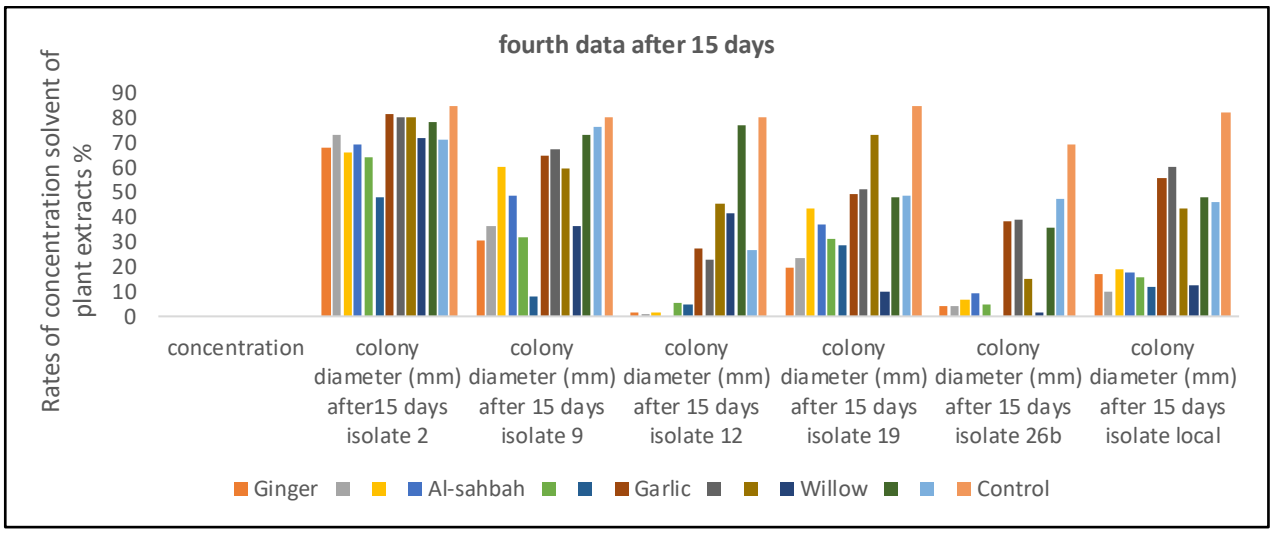

Figure (6): of Plant Extracts on Fungal Colony Diameter after 15 days in second method

Effective control of tomato-damaging fungal infections requires a multimodal approach. Among the suggested practices are seed treatment, nursery bed treatment, timely fungicide application, crop rotation, and sanitation. As the world becomes aware of the detrimental consequences of synthetic fungicides, interest in safer, non-synthetic alternatives is rapidly growing. Currently, researchers are looking for components that are safe for both people and the environment (El-Mohamady et al., 2014). The results of the effects of plant extracts (ginger, Al-Sahbah, garlic, and willow) on the mycelial growth of the 6 quick pathogenic isolates. The extracts were found to have a significant effect at different concentrations (0.25, 0.50, and 0.75) ml on the growth of the pathogens assessed after 7 and 15 days of incubation at 27ºC. There was a progressive decreasing trend in the pathogen colony diameter.

At both times, the results demonstrate that all tested plant extracts possessed

measurable antifungal activity. Inhibition effects increase over time (differences between treatments are larger at 15 days). The following general trends were observed: Garlic extract was the most effective inhibitor of fungal colony growth across all isolates and both time points. Ginger and Al-sahbah showed strong and consistent antifungal effects. Willow extract provided moderate inhibition. Differences in colony diameter among isolates indicate strain-dependent variation in susceptibility to plant-derived antifungal compounds. Growth suppression persisted from (7- 15) days, indicating the extracts' long-term inhibitory activity, but Control treatments always resulted in the largest colony diameters, confirming the effectiveness of the extracts. But in the second method, which used different rates of solvents, Al-sahbah emerged as the most potent antifungal extract, maintaining high activity across time and solvents. Willow water extract selectively inhibited colony diameter, while ginger showed stable and targeted inhibition, especially against Iso.12. Garlic extracts produced limited inhibition and low activity in long-term exposure. These findings highlight the potential of Al-sahbah, Ginger, and Willow as natural sources of antifungal compounds.

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