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Evaluation Resistance of Fifteen Tomato Varieties to Fusarium Wilt caused by Fusarium Oxysporum. F. Sp. *Lycopersici*

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Abstract

Fusarium oxysporum f.sp. lycopersici (Fol), is a detrimental pathogen to tomato (Solanum lycopersicum L.) and the first factor challenges for production of tomato crops world-wide. Tomato Varieties were evaluated as a source of resistance pathoginic wilt incidence caused by (Fol).The fifteen varieties were examined to ensure their relative resistance or susceptibility to (Fol) under the conditions of the semi-field experiment at the Kfar-yahmool Research Station.The results showed Varieties lama And Zomrot their disease incidence (80% and 60%)respectively and disease severity was (40% and 55%) respectively, they were considered as moderate resistance. And Varieties: Ruby, Leo, Kapprov, Carnival, Lamar, Redsun, Shaba and Royal 777), moderately susceptible with disease incidence rang (60-100) % and disease severity rang (55-75) %. but Varieties Noskan, Alwahi, Guitar, Ragad, Norshan were considered as susceptible for Fusarium with disease incidence (100) % and disease severity rang (80-85) %. And depending on the disease index values none of the varieties are resistant against Fusarium wilt infection. And varieties, Lama and Zomrot, shows moderate resistance with disease index (32%and 33%) respectively. And cultivars (Ruby, Leo, Kapprov, Carnival, Lamar, Redsun, Shaba and Royal 777) are susceptibility, disease index of (42%, 44%, 48%, 48%, 48%, 48%,48% and52%) respectively. but varieties (Noskan, Raghad, Guitar, Al-Wahi and Norshan) they are highly susceptibility to infection with Fusarium Wilt, the average disease index reaching (75%, 80%, 80%, 85% and 85%) respectively. Where The infection date appeared early in the second week after the artificial infection of the varieties (Noskan, Al-Wahi, Raghad). Later, the infection appeared on the varieties (Leo, Redsun, Royal 777, Kemper, Guitar, Lamar) at the end of the third week. As for the varieties that are resistant to or tolerant to Fusarium wilt, infection symptoms were delayed in appearing until the fourth week.

Keywords: Fusarium wilt- Tomato Cultivars - Fusarium oxysporum f.sp. lycopersici.

Introduction

Tomato (*Solanum lycopersicum* L) is one of the most important vegetables in the world (Dayab and El – Gariani, 2019) and it plays the vital important role in the diet for human

(Manaa et al.,2014) Tomato is the second most cultivated vegetables plant in the horticultural crops after potato in Syria. Tomato varieties are often susceptible to the pests and pathogens, which cause huge losses in tomato production (Ozbay and Newman, 2004).

The fungus *Fusarium oxysporum*. f.sp. *lycopersici* (*Fol*), is a detrimental pathogen to tomatoes (Yonggang, 2011; Elias and Schneider,1991). It challenges for production of tomato crops worldwide, these pathogens are causing extensive losses to the greenhouse- and field-cultivated vegetable crops, resulting in major drops in tomato yield (McGovern,2015). Sometimes causing extensive field losses reach 47% (Enespa, 2014**)**. and sometimes huge losses (Özer and Soran, 1991) up to 80% of production.

The fungus is widespread and occur in soils as saprophytes (Ilyaas et al., 2020; Al-Maghribi et al., 2018). however, some of its strains can be phytopathogenic(Bao et al., 2002; Marlatt et al., 1996) and even host-specific (Panina et al.,2007). *F. oxysporum* can survive for long periods without the presence of the host (Ignjatov et al., 2012(, particularly as chlamydospores (Pietro et al.,2003). The pathogen, is spread by (water, wind, shoes, and equipment) (McGovern, 2015). The pathogen causes Fusarium wilt, Fusarium crown, and damping off diseases in tomato seedlings. They can also cause stunting, yellowing, and wilting, especially during warmer temperatures. (McGovern, 2015).

Fungicides, such as Triazoles, have been commonly used to control Fusarium Wilt by preventing the growth and spread of the *Fusarium* fungi (Cendoya et al., 2019; Neringa et al., 2024). Many chemical pesticides have been used to control this disease but no effective fungicides have been controlling this disease.

Soil sterilization is an impractical and expensive application, in addition to the ability of chlamydospores to persist alive in the soil for seven years or Moreover, the wide host range of this fungus made it difficult to control, and important to search for resistant varieties. Despite its high effectiveness, it is considered dangerous effects on the environment and humans (Pest, 2017), which made international attention turn towards safe agriculture, including the use of organic materials by adding them to the soil for fertility, and its decomposition results in a change in the physical and chemical properties of the soil. Relationship in reduction or minimizing plant diseases (Fichtner et al., 2004**).**

Many microorganisms have been used as biological control agents against soil diseases, such as *Bacillus* sp., *and Trichoderma* sp. (Akrami, 2015; Karima and Ibrahim. 2016; Al**-**Fadhal et al**.,** 2019).

The better way to reduce the wilting danger is by Tomato Cultivars**,** therefore, Ten Tomato cultivars were evaluated to infection by the most virulent isolate (*Fol*). the results indicated that Cultivar (CV. Super-Strain B) was the highest susceptible, whereas Cultivar (CV. Super-Marmand) was the lowest one (Saleh et al., 2016).

In other search studies, The resistance of the six commercial cultivars of tomato to the *(Fol)* by dipping roots of the seedlings in spore suspension of five *(Fol)* isolates, the results were cultivars (Dotaerangmaster, Supersunload) resistant to *(Fol)* (Myung et al., 2012). And (Şerife Evrim et al., 2018) found fifteen Varieties to be resistant to (*Fol*) and no symptom of diseases was observed, whereas, Three Varieties were susceptible.

The varieties were classified into five groups: immune, resistant, moderately resistant, susceptible, and very susceptible (Akram et al., 2014), And he refers that None of the varieties was completely resistant or immune against *(Fol)*, Three varieties were

classified moderately resistant (Pride Burn, Red Power, Sun Grape), All other varieties were either susceptible or very susceptible against *(Fol)*.

(Al-Maghribi et al., 2016) showed that the hybrid Ergwan was susceptible, and the isolate FO7 had the most effects with an injury severity of 100%. The researcher Khafta (2019) found Tomato hybrids had different responses to Fusarium wilt, Domina hybrid was more susceptible, the infection percentage was (13%), followed by lina (9%) then Saly (2.3%), while the Yosra hybrid was the most tolerant with infection percentage (0%).

In wild tomatoes (*Solanum pennelli)*, resistance genes against (*Fol*) are found and they are called I (for immunity), I-2, and I-3, which have been introgressed into some commercial cultivars (Gonzalez-Cendales et al., 2016; Catanzariti et al., 2015). In turn, (*Fol*) encodes a virulence gene that is recognized by-product of I genes. Some mutations in avr genes overcome I-mediated resistance giving rise to (*Fol*) pathogenic races (López et al., 2021). And depending on this result all tomato varieties were placed in three different groups to identify all *(Fol)* isolates (Akram et al., 2014). Whereas in Jordon Under greenhouse conditions four Local tomato cultivars were tested for resistance to *(Fol)* using the standard root dip method inoculated in fungal suspensions from race 1, and race 2. The result was 60% of the inoculated varieties showed different levels of resistance to race 1; however, some of the resistant varieties under greenhouse conditions were susceptible in the field, but all varieties were susceptible to race 2 (Al-Khatib., 2006).

Other hand both tomato varieties (Chondrokatsari and Messinias) were susceptible to *(Fol)*, but they were less susceptible compared to (Katsari Santorinis) (Darras et al., 2017).

But As a result found by (Okocha et al., 2023) when he tested twenty Tomato varieties, all the varieties recorded an average wilt severity of 15% when the red cherry tomato had wilt severity (40.0%), while *Tropimech* (75.6%) and Alausa (75.5%), Whereas Four varieties selected (Onityre, Zumoured, Roma savanna and Riogrande) to be subjected to further pot and field evaluations to determine the effects of the pathogens on their growth and yield parameters.

Maurya et al (2023) using eleven Tomato varieties (Pusa ruby, Tycon, Sulabh, Sarathi, Shakti, To- 1057, NHT-1813, MAHY-302, Emrol, Arka samrat, KSP-1154) the incidence wilting range was from 10.03% to 85.0% And the variety Arka samrat incidence wilting (10.03 %) showed highly resistant and Tycon incidence wilting (27.50 %) showed moderately resistant while Emrold incidence wilting (85.00 %) and Sarathi incidence wilting (75.02 %) were highly susceptible to *(Fol)* and no variety was immune**.**

This search aimed to Evaluate the sensitivity or resistance of some tomato varieties to Fusarium wilt caused by (*Fol*) grown in Idlib Governorate.

Materials and Methods

2.1. Tomato varieties used in the search:

The tomato varieties grown in Idlib Governorate were obtained, and they are the most widespread in agricultural pharmacies and the most varieties in the governorate, Table 1.

Table (1). Tomato varieties for testing susceptibility to Fusarium wilt

Number	Variety	Seed source	the production company
1	Shahba	Turkey	Antalia Turket
2	Ruby	California USA	Castle seeds
3	Noskan	U S A	Teta Lohum

4	Leo	Sanlus USA	Catalyst seeds
5	Redsun	Tiland	Green Global seeds
6	Alwahi	USA	Catalyst seeds
7	Carnival	Turkey	Best seeds
8	Royal777	Tiland	Monsarlo Holland BV
9	Kemper	California USA	Catalyst seeds
10	Guitar	Turkey	Onemliuyarii
11	Ragad	Syria	Local
12	Lamar	Turkey	Best seeds
13	Lama	California USA	Catalyst seeds
14	Norshan	Amman- Jordan	Millinium seeds
15	Zomrot	Turkey	Best seeds

Isolate the pathogen

samples of diseased plant Appearance collected from fields and brought to the library and the isolation was carried out from the stems, the roots, and the color of the samples showing symptoms of the disease. The samples were washed with tap water to remove soil, and freshly infected tissue was selected for isolation. The infected tissue was cut into small pieces 5 mm long, disinfected with 5%NaOCl for 3 min, then rinsed with distilled water and dried for 4 minutes on an absorbent water paper (sterilized). Small pieces were placed on a PDA medium (Potato Dextrose Agar 250 g of potato broth, 20 g agar, and 20 g of Dextrose per liter of distilled water). were incubated at at25C° for 7 days like the manner of (Sharma et al., 2010).

Identification of isolates:

The species *Fusarium oxysporum* is distinguished from other species of *Fusarium* in the production of microconidia, macroconidia and chlamydospores and pink purple color of the colony (Sidawi et al., 2015). The isolates were recultured on carnation leaf agar and observed to be producing macroconidia and microconidia were identified according to the keys of *Fusarium oxysporum* (Dayab and El–Gariani, 2019). Only isolates with these characteristics are considered to belong to *Fusarium oxysporum*.(Fig 1).

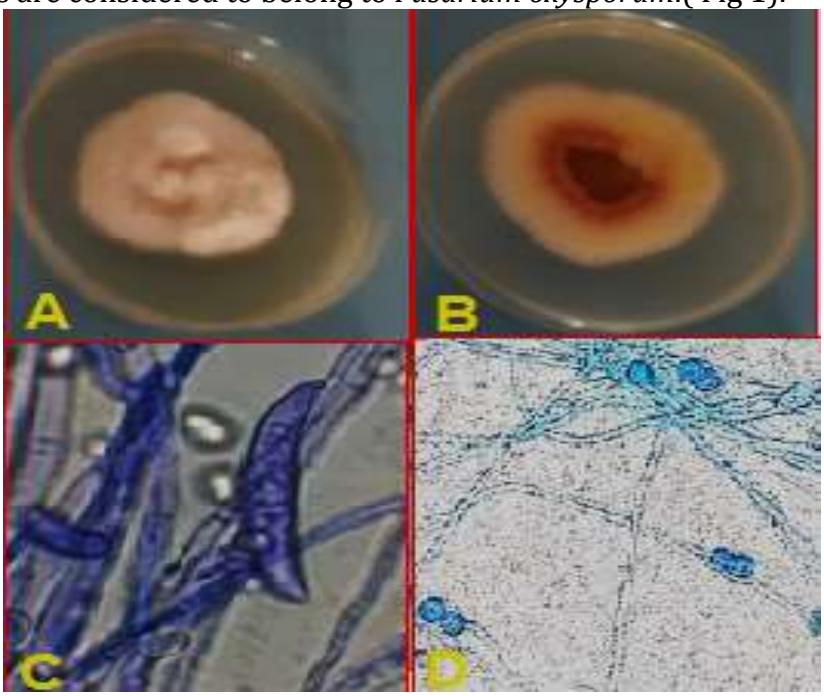

Fig (1). A: Colony from the upper surface, B: Colony from the lower surface, C: Macroconidiaspores and Microconidiaspores, D: Chlamydial spores.

2.4. Seedling preparation:

The Tomato varieties (Shahba, Ruby, Noskan, Leo, Redsun, Alwahi, Carnival, Royal Royal 777, Zomrot, Guitar, Kaprof, Ragad, Lamar, Lama, and Norshan) evaluated to their susceptible to *(Fol*). The seeds were first disinfected with sodium hypochlorite to 2% for 3min then rinsed in sterile distilled water three times and placed in a sterile Tourb (organic soil) was used for planting seeds. Seed Sowing was made at the rate of one seed per eye in the planting tray. The trays were placed in a lighted greenhouse at 20 to 22 C° under daylight illumination. Watering was made daily, with tap water until they were 25 days.

2.5. Preparation of the conidia suspension:

(Fol) isolates to be tested were incubated at 25C° for 12 days on PDA medium. The spores were scraped from the surface of the culture and introduced into 10 ml of sterile distilled water. Concentration was determined by hemocytometer under an optical microscope. The suspension adjusted to the concentration of 10^6 spores/ml.

(López et al., 2018).

2.6. Inoculation:

Inoculation was performed at the four-true-leaf stage of plantlets (25 days after sowing), the root system was cut to 10 mm below the side then dipped in a suspension of the isolate of (*Fol*). After 30 minutes inoculated plants were replanted into pots (Rose and Punja**.** 2004), and every pot arrogation with 10 m from the suspension. The test was performed at a rate of 5 replicates for each cultivar, and 5 plants were inoculated in distilled water as control.

2.7. Estimating the incidence and severity:

After 2 weeks, a Symptom assessment was performed based on a rating scale comprising 5 symptom scores: from 0 to 4 ordinal scale as with some modifications (A Reis et al., 2004), (0 = asymptomatic, 1 = yellowing,

2 = vascular discoloration, 3 = wilting, 4 = plant dead).

The infection rate was calculated according to the formula

$$The\ infectionate = \frac{n}{N} \times 100$$

n*:* Number of infected plants*,* N*:* Total number of plants

The disease severity was evaluated using Townsend and Heuberger's (1943) formula:

$$\text{Severity} = \frac{\Sigma\ (a \times 1b1 + a2 \times b2 \ldots.)}{N \times K} \times 10 - 0$$

a: Degree of infection, b: Severity of infection, N: Highest degree of incidence,K: Total number of plants

2.8. Evaluation of sensitivity of varieties:

The susceptibility of the varieties to (*Fol*) was indexed by used scale with 5 levels (Maurya et al., 2023), which were: Resistant (R), moderate Resistant (MR), moderate Susceptibility (MS), Sensitive (S), and Highly Susceptible to infection (HS). The susceptibility index for

the varieties was calculated the same formula as (Cachinero et al., 2002) with little amendment using the average and the formula was as follows:
Susceptibility index= (I×S)÷ 100

I: average infection rate, S: average infection severity.

The variety was considered highly sensitive at a sensitivity(HS) index of 81-100. The variety was considered susceptible to infection with a sensitivity (S) index of 61-80. The variety was considered moderately susceptible (MS) at a sensitivity index of 41-60. The variety was considered moderately resistant (MR) to infection at a sensitivity index of 21-40. The variety was considered resistant (R) to the infection with an index of 0-20. The time of occurrence of the infection and its development during the trial period were also recorded every week.

2.9. Statistical Analyses:

Data were analyzed by analysis of variance (ANOVA) to detect differences between

Tomato varieties. all statistical tests were conducted at a probability level of $P \leq 0.05$. All analyses were performed using the GenStat 12 software.

Results and Discussion

3.1. Incidence rate and disease severity of Fusarium wilt:

Fifteen grown tomato varieties varied in their response to inoculation with the local race of (*Fol*). Disease reactions are shown in (Table 2). The variety lama with an incidence of 80% and severity of 40%, And Zomrot with an incidence of 60% and severity of 55%, were considered as moderate resistance, and This is consistent with (Okocha et al., 2023). The other varieties : Lamar , Kemper ,Royal Royal 777, Carnival , Redsun, leo, Ruby and Shaba, moderately susceptible with a disease incidence range (60-100)% and severity range (55-75)%, and this going with (Bonger et al.,2016) who refers that the disease wilt severity on tomato was an indication of the pathogen virulence on the tested Tomato varieties marking that (resistant /moderately resistant) varieties, and agreements for Ruby cultivar with (Maurya et al., 2023). Other hand the varieties Noskan, Alwahi, Guitar, Ragad, and Norshan were considered highly susceptible to Fusarium Wilt with an incidence (100) % and a severity range (80-85)%.

Tablet (2): Disease (*Fol)* Incidence and Severity in Tomato varieties

Number	Variety	Incidence%	Severity%
1	Shahba	80	60b
2	Ruby	60	70c
3	Noskan	100	80d
4	Leo	80	55ab
5	Redsun	80	60b
6	Alwahi	100	85d
7	Carnival	80	60b
8	Royal 777	80	65b
9	Kemper	80	60b
10	Guitar	100	75c
11	Ragad	100	80d
12	Lamar	80	60b
13	Lama	80	40a
14	Norshan	100	85d
15	Zomrot	60	55a
L S D (0.05)			**14.6**

3.2. Screening of tomato varieties resistant or sensitive to Fusarium wilt disease:

After classifying the varieties on the basis of infection rate and average disease severity, none of the varieties were immune or resistant against Fusarium wilt infection, as shown by the disease index values (Table 3).

It agreements with (Akram et al., 2014).

Two varieties, Lama and Zomrot, show moderate resistance to Fusarium wilt disease, with an average disease index (32% and 33%) respectively.

Eight varieties (Ruby, Leo, Kapprov, Carnival, Lamar, Redsun, Shaba, and Royal 777) are susceptible to Fusarium wilt with an average disease index of (42%, 44%, 48%, 48%, 48%, 48%,48% and 52%) respectively. As for the last varieties (Guitar, Noskan, Raghad, Al-Wahi and Norshan) they are highly susceptible to infection with Fusarium Wilt. And the average disease index for varieties (Guitar, Noskan, Raghad, Al-Wahi, and Norshan) reached (75%, 80%, 80%, 85%, and 85%) respectively.

Table (3): Average of (Incidence and Severity) of Disease (*Fol*) and disease index in cultivated Tomato varieties in Idlib

Number	Variety	Average Incidence%	Average Severity%	disease index	Wilt responses
1	Shahba	80	60	48	MR
2	Ruby	60	70	42	MR
3	Noskan	100	80	80	HS
4	Lieo	80	55	44	MR
5	Redsun	80	60	48	MR
6	Alwahi	100	85	85	HS
7	Carnival	80	60	48	MR
8	Royal777	80	65	52	MR
9	Kaprof	80	60	48	MR
10	Guitar	100	75	75	S
11	Ragad	100	80	80	HS
12	Lamar	80	60	48	MR
13	Lama	80	40	32	R
14	Norshan	100	85	85	HS
15	Zomrot	60	50	30	R

3.3. Determining the date of the first appearance of wilt symptoms on the tested tomato varieties and development severity:

Tomato varieties grown in Idlib showed a difference in the speed of disease occurrence in plants after industrial infection and a difference in the speed of disease development in the tissues of the roots and stem of the plant. The infection appeared early in the second week after the artificial infection of the varieties (Noskan, Al-Wahi, Raghad). (Table .4)

The infection developed slowly for these varieties in the third week, then it increased severely in the fourth week, and the plants died at the beginning of the eighth week and before reaching the fruiting stage.

Later, the infection appeared on the varieties (Lieo, Redsun, Royal Royal 777, Kemper, Guitar, Lamar) at the end of the third week and gradually developed to reach advanced stages in the eighth week and caused the death and wilting of some
plants, but others remained in significant stages of the severity of the infection. (Table .4)

As for the varieties that are resistant to or tolerant to Fusarium wilt, infection symptoms were delayed in appearing until the fourth week. It was found that the varieties (Shahba, Ruby, Carnival, Lama, and Zomrot) that were tolerant to the infection developed their infections gradually during the following weeks, but they did not wilt and die in the eighth week, and the infection reached advanced levels. Except for the variety (Lamma), which remained at the same level for the next 4 weeks. This means that tomatoes are greatly affected by the age of the plant, and thus the sensitivity of tomato varieties varies depending on their growth stage or age, and this is consistent with (Agrios, 2005).

Table (4). Date Appearance of Disease (*Fol)* and development severity on cultivated Tomato varieties in Idlib every week.

Number	Variety	Week number							
		W1	W2	W3	W4	W5	W6	W7	W8
1	Shahba	0	0	0	1*	2	2	3	3
2	Ruby	0	0	0	0	1	1	2	3
3	Noskan	0	1	1	1	2	3	3	4
4	Lieo	0	0	1	1	1	2	2	3
5	Redsun	0	0	0	1	1	2	3	3
6	Alwahi	0	1	1	2	2	3	4	4
7	Carnival	0	0	0	0	1	2	3	4
8	Royal 777	0	0	0	1	1	2	3	4
9	Kemper	0	0	1	2	2	3	3	3
10	Guitar	0	0	1	1	2	2	3	4
11	Ragad	0	1	1	2	3	3	4	4
12	Lamar	0	0	0	1	1	2	3	3
13	Lama	0	0	0	0	1	2	2	2
14	Norshan	0	1	1	2	2	3	3	4
15	Zomrot	0	0	0	1	1	2	2	3

* **Severity of Disease**

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