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RESEARCH ARTICLE

Determination and Pathogenicity of *Verticillium dahliae* Isolates Obtained from Tomato Plants (*Solanum lycopersicum* L.) in the Iğdır Province

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ABSTRACT

This study was carried out to identification of Vegetative Compatibility Groups (VCGs) and pathogenicity of *Verticillium dahliae* isolates obtained from tomato plants in Iğdır province. As a result of survey studies conducted in 18 different regions, 14 isolates were obtained from 629 diseased tomato plants. In the complementation test, the seven isolates were found as VCG2A and VCG2B by using international reference isolates. VCGs of other isolates were not identified. Assessment of the aggressiveness of the KRS-2, YC-13, YY-14, and MLK3-4 isolates was evaluated on tomato (cv. Super). The disease severity was between 15-45% and MLK3-4 isolate had the highest disease severity (45%). Additionally, the effect of temperature on the growth of *V. dahliae* isolates (TSD-1, MLK3-4 and YY-14) was determined. The isolates showed optimal growth temperatures ranging from 20 to 25 °C (except for TSD-1). In control of fungal diseases, it is very important to describe the disease and pathogen. Therefore, the results of the study are important for tomato growers and researchers.

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1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most popular vegetables all over the world (Schreinemachers et al., 2018; Famuyini et al., 2020). The tomato plants are attacked by many biotic and abiotic disease during the production stage which it is known to be threatened by more than 200 diseases (Panno et al., 2021). Fungi constitute the most significant group of plant pathogens that causes economic damage in tomato. Specially, soil-borne fungal pathogens cause important yield loss in tomato (Yucel et al., 2008). Verticillium wilt caused by *Verticillium dahliae* Kleb. is a soil-borne pathogen serious threat to tomato cultivation areas all around the world. The pathogen causes disease in 14 families from 4 different continents (Inderbitzin et al., 2011), and it causes billions of dollars of damage to various agricultural products (Pegg & Braddy, 2002; Klosterman et al., 2008; Inderbitzin et al., 2011). Although *Verticillium isaacii* Inderb. et al., *Verticillium nonalfalfae* Inderb. et al., *Verticillium tricorpus* Isaac and *Verticillium zaregamsianum* Inderb. et al. are known to cause vascular wilt diseases (Inderbitzin & Subbarao, 2014), *V. dahliae* is the most important and common species of the *Verticillium* genus on tomato (Li et al., 2022).

Initial symptoms of Verticillium wilt diseases on tomato include yellowing of the lower leaves, wilting and stunted

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growth (Kumar et al., 2018). The yellowing between the veins of the leaves with increasing wilt gradually becomes dry and brown (Senthamilselvi & Victoria, 2019). Generally, one side of the leaves remains green while other parts show typical wilt symptoms (Fradin & Thomma, 2006; Gazozcuzade, 2010), and causes V-shaped lesions on lower leaves. In the later stages of the disease, yellowing and stunting start from the lower leaves and gradually progresses to the upper leaves. Brown discoloration observed in the vascular tissues in the part close to the soil surface (Fradin & Thomma, 2006; Kumar et al., 2018).

Vegetative compatibility is used to determine the similarities and differences in the population of a species (Leslie, 1993; Burgess et al., 2009). The determination of Vegetative Compatibility Groups (VCGs) is approaching effectively for examine the genetic structure of soil-borne pathogens (Bao et al., 1998) and this method is commonly used in the genetic characterization of *V. dahliae* (García-Carneros et al., 2014). *V. dahliae* obtained from different hosts were determined five VCGs as VCG1, VCG2, VCG3, VCG4 (Joaquim & Rowe, 1990) and VCG6 (Bhat et al., 2003). VCG1 (VCG1A, VCG1B), VCG2 (VCG2A, VCG2B) and VCG4 (VCG4A, VCG4B) groups were categorized as two subgroups (Klosterman et al., 2009). VCGs of *V. dahliae* isolates obtained from various hosts have been studied by many researchers in Türkiye. This is known as VCGs; VCG1, VCG2A, VCG2B and VCG4B from cotton and cotton seeds (Göre, 2007; Göre et al., 2014), VCG1A, VCG2A, VCG2B and VCG4B from eggplant (Dervis et al., 2009), VCG1, VCG2A, VCG2B and VCG4B from chrysanthemum (Göre, 2009), VCG2B and VCG4B from weeds (Demirci & Genc, 2009), VCG1A, VCG2A and VCG4B from olive (Dervis et al., 2010), VCG2B and VCG4B from potato (Dane & Demirci, 2012), VCG2A, VCG2B and VCG4B from strawberry (Genc Kesimci & Demirci, 2020).

The tomato production is one of the most significant agricultural activities for growers in Iğdır province. It has been determined that there are important fungal diseases both in the survey studies carried out and in the diseased samples brought by the farmers. Therefore, studies were planned to identify fungal diseases that cause disease in tomato plants. We conducted this study: (i) to determination of *V. dahliae* isolates obtained from the tomato plants in Iğdır province (ii) to assess VCGs diversity of isolates *V. dahliae* (iii) to determine the virulence of isolates with pathogenicity test and (iv) to determine the effect of temperature on the growth of *V. dahliae* isolates.

2. Materials and Methods

2.1. Survey Studies

Survey studies were conducted in the tomato field of the Iğdır province and districts between August and November 2014-2016. Diseased tomato plants were randomly collected from in the field (5-6 steps). The plants were taken in plastic bags and transported to the laboratory.

2.2. Isolations from Tomato Plants

Tomato plants were brought to the laboratory were washed with tap water and cleaned from the soil. For isolations, the root and stem tissues were cut in 1.5 cm size, surface sterilized in 2% NaOCl solution for 2-3 minutes, and then rinsed in sterile water 3 times. The plant parts were dried on the sterile paper for 15-20 minutes and were transferred 4 pieces (2 stems and 2 root collars) on each Petri plates (9 cm diameter) onto Water Agar (WA; 15 g agar per liter) amended with 50 mg L^{-1} streptomycin sulfate. The plates were incubated at 25 °C for 3-7 days. The colonies were examined under the microscope and conidia were transferred for pure growth with a sterile needle on WA or Potato Dextrose Agar (PDA). The isolates were stored +5 °C for use in the study.

Serial dilution method used for single spores. Firstly, isolates were grown at 25 °C for 7-10 days. Sterile water (1000 µL) was transferred in the first eppendorf tube (2 mL), and 900 µL sterile water was transferred in the 2nd, 3rd and 4th eppendorf tubes. A mycelial disc (5 mm diameter) of fungus grown on PDA was transferred in the first eppendorf tube. This eppendorf tube was vortexed for 1 min and then 100 µL conidial suspension was transferred from tube 1 to tube 2. After the eppendorf tube 2 was vortexed for 1 minute, 100 µL of taken was transferred from tube 2 to tube 3. The eppendorf tube 3 was vortexed for 1 min and the tube 3 containing spore concentration prepared as $1x10^3$. The spore suspension (1000 µL) was poured into an empty the Petri plate (9 cm) and on top of this was added PDA slightly colder than the normal pouring temperature. The Petri were developed at 25 °C for 2-3 days and this pure colony was transferred to PDA. The isolates were kept in the slant test tubes +5 °C (Genc, 2012).

2.3. Morphological and Molecular Characterization

Verticillium dahliae (TSD-1, MLK3-4 and YY-14) isolates were grown on WA and PDA for morphological observations. The isolates were observed under the microscope and determined according to conidia and microsclerotia (Goud et al., 2003; Jabnoun-Khiareddine et al., 2010; Inderbitzin et al., 2011).

In the molecular test, two isolates (YY-14 and TSD-1) were selected. The isolates were grown to be used in DNA isolation in the Petri plates containing PDA 7-10 days at 25 °C and were identified using ribosomal DNA (rDNA)-ITS (Internal Transcribed Spacer) regions (ITS1, 5.8, ITS2) using ITS1 and ITS4 primers were performed by REFGEN (Ankara University Teknokent, Ankara, Türkiye). Genomic DNA isolation, PCR amplification using ITS1 and ITS4 primers (White et al., 1990), sequence analysis performed as described by Genc Kesimci et al. (2022).

2.4. Generation and Characterization of *nit* Mutants

Previous method of Korolev and Katan (1997) was modified for the determination VCGs of *V. dahliae* isolates. In this method, 30-50 g L^{-1} potassium chlorate ($KClO_3$) and 0.2 g L^{-1} glucose were added to 17 g L^{-1} Corn Meal Agar (CMA) or 15 g L^{-1} WA. *Verticillium dahliae* isolates were grown on PDA and 5 mm mycelial discs taken from the isolates were transferred to each Petri plate (9 cm) as 6-8 pieces on Corn Meal Chlorate Agar (CMCA) or Water Agar Chlorate medium (WAC). The Petri plates were kept at 25 °C for 1-2 weeks. Each isolate was made in two replications. After the incubation period, fast and thin-growing sectors resistant to $KClO_3$ were transferred to Czapex Dox Agar (CDA) and were determined as *nit* mutants. Then, sodium nitrate (0.5 g L^{-1}) ($NaNO_3$), sodium nitrite (0.5 g L^{-1}) ($NaNO_2$) and hypoxanthine (0.2 g L^{-1}) were added separately to CDA (45.4 g L^{-1}) and the phenotype of *nit* mutants were classified according to aerial mycelium growth in the presence of different nitrogen sources (Correll et al., 1987; Korolev & Katan, 1997).

2.5. Complementation Tests with Tester Isolates

Complementation tests were maintained on CDA using a method modified from Korolev and Katan (1997) and Korolev et al. (2000). All of the *nit* mutants obtained in this study with *nit* mutants of the international *V. dahliae* tester isolates were compared (*nit*1x*nit*M or *nit*Mx*nit*M) 1 to 1.5 cm apart on plates at least twice, and plates were incubated for 14-28 days at 25 °C in the dark. The complementations were characterized by growth at the contact zone between the two complementary *nit* mutants (Korolev et al., 2000).

2.6. Effect of Temperature on the Mycelial Growth

The optimal temperature of isolates *V. dahliae* was determined using a method modified from Bhat et al. (2003). TSD-1, MLK3-4 and YY-14 isolates were grown on PDA (9 cm) and were taken from 7-day-old colonies of each isolate mycelial plugs (5 mm in diameter) that transferred to PDA (9 cm). The petri were incubated at temperatures ranging from 5, 10, 15, 20, 25, 30 and 35 °C. Three replicates of each isolate and the sizes of the colony growth of each petri were measured as mm 7^{th}, 14^{th} and 21^{st} days.

2.7. Pathogenicity Test

KRS-2, YC-13, YY-14 and MLK-3-4 isolates were selected for pathogenicity test. All isolates were cultured on PDA for 15 days. Surface disinfection of tomato seeds (cv. Super) were made in 70% alcohol for 3 min, rinsed with water three times and air-dried on filter paper. For each isolates were sown with 3 seeds in each pot (15-cm-diameter) filled with autoclaved torf/perlit soil mixture (2:1, v v^{-1}). The seeds were reduced to one seedling in each pot. The concentration of conidia in the suspension was adjusted to 10^6 conidia ml^{-1} using a hemocytometer. The tomato plants (2-3 leaf) were inoculated by flooding the soil around the roots with 10 ml spore suspensions for each isolate (Gong et al., 2017). The control plants were inoculated with sterile distilled water (10 ml). Hoagland solution added three times each 15 days (10, 20 and 30 mL). Plants were grown at 25±1 °C with a photoperiod of 24 h for 75 days. Five pots of tomato were used for each isolates and control. The scale was used according to the modified 0-4 scale of Hunter et al. (1968). The disease severity were calculated according to Townsend Heuberger's formula. As a result of pathogenicity test, were measured fresh weight and height of all tomato plants. Dry weight of the plants was calculated after drying at 80 °C for 48 h (Isaac et al., 2018). Re-isolations were made to complete Koch's postulate with the procedure of isolation. The data obtained as a result of study were subjected using the Statistical Package for the Social Sciences (SPSS) version 17.0 ($p<0.05$).

3. Results

3.1. Survey, Isolation and Identification

In this study, surveys were conducted from districts and villages in Iğdır province (Akyumak, Bayraktutan, Centre, Gölbaşı, Hakmemet, Küllük, Melekli, Obaköy, Yaycı, Yukarıçarıkçı, Kasımcan, Kuzugüden, Özdemir, Sarıçoban, Yüzbaşılar, Karakoyun, Taşburnu and Aralık). Isolations were performed from sypmtomatic 629 tomato plants. A total of 14 isolates of *V. dahliae* were obtained from the plants (Table 1). *Verticillium dahliae* could not be isolated from other regions except Aralık, Melekli, Taşburnu, Yukarıçarıkçı and Yaycı. The majority of the isolates were collected from stems (8 isolates), and remaining the isolates were isolated from root collar. *Verticillium dahliae* were also occured in the complex with other pathogens as *Rhizoctonia* spp. and *Fusarium* spp. which were significantly higher observed.

In morphological characterization, length and width of conidia and microsclerotia of *V. dahliae* isolates were measured (Table 2). Conidia arise singly at the apices of the phialides, irregularly sub-cylindirical, ellipsoidal. All of the isolates produced verticillate conidiophore. Microsclerotia is very variable in shape (irregular and elongated shaped or more spherical and scattered). Chlamydospores were not observed. Colonies has white then varied from white to black with the produced of microsclerotia during the 6-7 day incubations.

Table 1. Isolate code and location of *Verticillium dahliae* isolates obtained from root collar and stem of tomato plants in Iğdır province.

Species	Isolate code	Location	Plant colonization	
			Root collar	Stem
Verticillium dahliae	KRS-2	Aralık		+
	MLK1-D1	Melekli		+
	MLK1-D2	Melekli		+
	MLK1-D5	Melekli		+
	MLK3-D3	Melekli	+	
	MLK3-D4	Melekli	+	
	MLK3-D8	Melekli	+	
	TSD-1	Taşburnu	+	
	TS-ZE-8	Taşburnu	+	
	YC-1	Yukarıçarıkçı		+
	YC-13	Yukarıçarıkçı		+
	YC-14	Yukarıçarıkçı		+
	YC-16	Yukarıçarıkçı		+
	YY-14	Yaycı	+	
Total			6	8

Table 2. Isolate code, conidia-microsclerotia length and width of *Verticillium dahliae* isolates.

Species	Isolate code	Conidia length/ width*(µm)	Microsclerotia length/ width*(µm)
Verticillium dahliae	TSD-1	3-10 (5.7)/1.5-4.0 (3.0)	15-80 (37.4)/16-44 (28.8)
	MLK3-D4	3-7 (5.1)/1.5-3.5 (2.4)	17-70 (37.3)/16-40 (27.1)
	YY-14	3.5-10 (6.3)/1.5-4 (2.5)	15-59 (30.5)/13-45 (30.1)

*: Minimum-Maximum (Average).

In the molecular characterization, *V. dahliae* isolates (YY-14 and TSD-1) were performed by sequence analysis of the ITS regions of the ribosomal DNA (rDNA). BLAST analysis of the sequences obtained in the study was performed in NCBI, and the base sequences of the isolates were registered in the GenBank. The Accession number of TSD-1 and YY-14 was obtained as OR734907 and OR734908 (Sequence similarity of 100%), respectively.

3.2. Generation and Characterization of *nit* Mutants

Colonies that showed thin and expansive growth on CDA were determined as *nit* mutants. A total of 24 *nit* mutants from the nine isolates were obtained and phenotypes were identified (Table 3). Most mutants classified as *nit*1 (18). *nit*3 mutants could not be obtained. The other five isolates were not obtained *nit* mutant despite being repeated numerous times.

Table 3. Number of *nit* mutants and types of *Verticillium dahliae* isolates.

Isolate No	*nit*1	*nit*M	Total
MLK1-D1	1	-	1
MLK3-D3	-	2	2
MLK3-D4	2	-	2
MLK3-D8	2	1	3
TSD-1	3	1	4
TS-ZE-8	2	1	3
YC-1	5	-	5
YC-16	2	-	2
YY-14	1	1	2
Total	18	6	24

3.3. Vegetative Compatibility Groups

In the VCGs test, some of the isolates giving '+' reaction (Figure 1a) with reference test isolates and were included in a group. MLK1-D1, MLK3-D4, MLK3-D8, TS-ZE-8, YC-1 and YY-14 isolates were compatible with reference tester isolates (VCG2B Q115 and 39/5) and determined as VCG2B. Also, some of the isolates made '+/-' reaction (Figure 1b) with other groups. The weakly cross-reactions were observed between VCG2B (MLK3-D4, MLK3-D8, YC-1 and YY-14) and tester isolate of VCG2A PH. Similarity, VCG2A isolate (TSD-1) and all of the VCG2B isolates were made'+/-' with VCG4A BB, except VCG2B MLK3-D4 isolate. Two isolates (MLK3-D3 and YC-16) were incompatible and '-' reaction (Figure 1c) with tester isolates and VCGs could not be determined (Table 4).

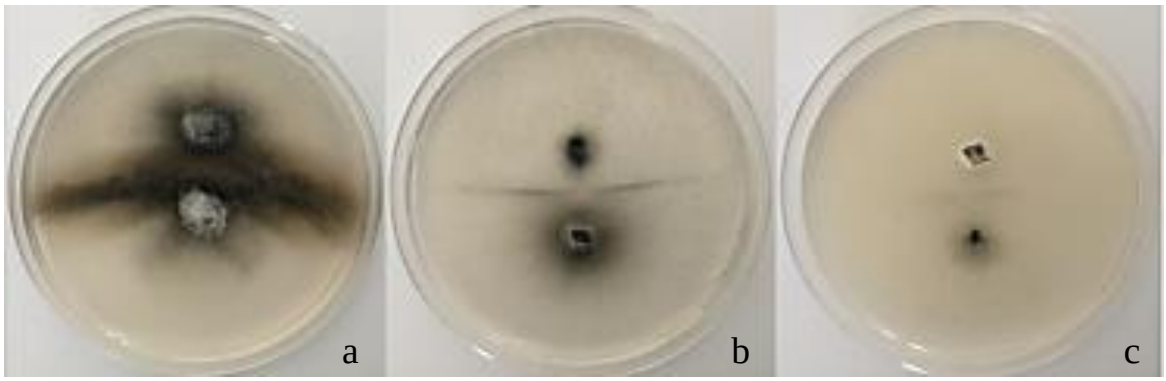

Figure 1. The degree of complementation; (a) '+' reaction; (b) '+/-' reaction; (c) '-' reaction.

Table 4. The reaction with test isolates of isolates *Verticillium dahliae*.

Isolate code	Mutant type	Tester isolates							VCGs
		VCG2A	VCG2B		VCG4A		VCG4B		
		PH	Q115	39/5	P103	BB	S39	MT	
MLK1-D1	1	-	+	+	-	+/-	-	-	2B
MLK3-D3	M, M	-	-	-	-	-	-	-	-
MLK3-D4	1, 1	+/-	+	+	-	-	-	-	2B
MLK3-D8	M, M	+/-	+	+	-	+/-	-	-	2B
TSD-1	M, 1	+	-	-	-	+/-	-	-	2A
TS-ZE-8	M, 1	-	+	+	-	+/-	-	-	2B
YC-1	1,1	+/-	+	+	-	+/-	-	-	2B
YC-16	1,1	-	-	-	-	-	-	-	-
YY-14	M, 1	+/-	+	+	-	+/-	-	-	2B

3.4. Effect of Temperature on the Colony Growth of Isolates *Verticillium dahliae*

TSD-1, MLK3-4 and YY-14 isolates were investigated for growth rate at seven temperatures (5 to 35 °C) *in vitro* conditions. The growth characteristics of the three isolates varied during the 1, 2 and 3-week incubation. The isolates showed optimum growth temperatures, ranging from 20 to 25 °C (except for TSD-1). None of the isolates *V. dahliae* grew at 5 °C and 35 °C for 7, 14 or 21 consecutive days (Figure 2).

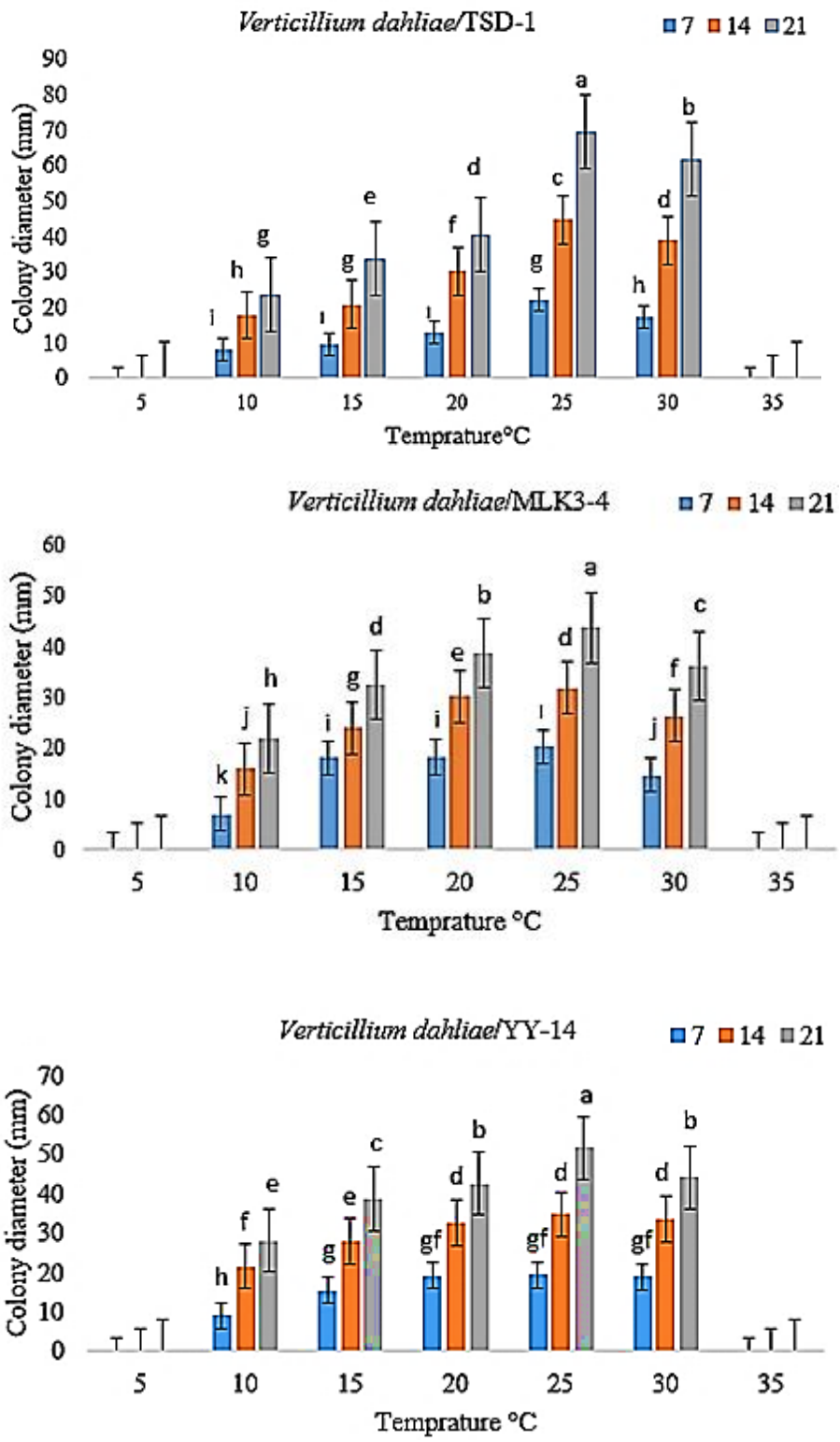

Figure 2. Colony growth of *Verticillium dahliae* isolates at different growth temperatures.

3.5. Pathogenicity Test

Pathogenicity test was established with 4 isolates selected from *V. dahliae* isolates. As a result of the pathogenicity test of isolates *V. dahliae* was determined on differential virulence to the tomato plants. MLK3-4 isolate had the highest disease severity (45%); however, the KRS-2 isolate had the lowest disease severity (15%). The effects of all isolates on tomato plants (height, root length and fresh weight) were found to be statistically insignificant (Table 6). The control plants were observed any disease symptoms.

Table 6. Results of pathogenicity test of *Verticillium dahliae* isolates.

Species	Isolate codes	Height* (cm)	Root length (cm)	Fresh weight (g)	Dry weight (g)	Disease severity (%)**
Verticillium dahliae	KRS-2	37.4±6.36	18.8±3.36	8.1±1.14	1.1±0.19b	15±6.12b
	YC-13	37.8±3.74	17.4±0.92	8.4±1,04	1.3±0.15ab	35±6.12a
	YY-14	45.6±0.81	15.6±1.28	7.4±1.20	1.7±0.13a	40±10.0a
	MLK-3-4	39.8±1.39	19.4±2.52	8.8±1.49	1.7±0.10a	45±5.00a
	Control	35.6±3.64	16.0±1.51	7.1±0.66	1.1±0.10b	0±0.0b

*: Mean+/-standard error: Different letters indicate the difference between the averages (Duncan test, $p<0.05$).
**: Disease severity was calculated as a percentage on a 0-4 scale using the Tawsend-Hauberger formula.

4. Discussion

The determination of disease-causing pathogens is necessary for an effective control strategy and reduction of pathogen damage (Martinelli et al., 2015). In the current study, the presence of *V. dahliae* in tomato plants was investigated in Iğdır province and the pathogen was determined as associated with Verticillium wilt of tomato. The morphological identification is the first step in the classification of fungal pathogens (Sunpapao et al., 2022). *Verticillium* spp. have a resting structure characteristic as dark resting mycelium, chlamydospores and microsclerotia. The structures play an significant role both in the biology and taxonomy of the genus and was characteristic in distinguishing the species (Inderbitzin, 2011). All isolates obtained from this study showed the general characteristic features of *V. dahliae* by producing verticillate conidiophore and microsclerotia in morphological determination. The morphological identification was also confirmed by molecular identification of the selected isolates in the study.

Genetic variation is a significant concept in the life history of asexually reproducing plant pathogens. VCGs are the most effective method in the determination of the genetic relationships in *V. dahliae* population (McDonald & Linde, 2002). Also, knowledge of the variation within the pathogen groups is essential for improve the control strategy (Collado-Romero et al., 2008). VCGs test were applied to *V. dahliae* isolates obtained in this study and the VCGs of the isolates were determined as VCG2A and 2B which VCG2B isolates were isolated more frequently from tomato plants. The VCG2B is considered likely to be present in any *Verticillium* soil (Zeise & Von Tiedemann, 2002). Similarly, VCG2B is reported to be the most common group isolated from a variety of hosts (Bhat & Subbarao, 1999; Korolev et al., 2000). VCGs associated with tomato have been determined as VCG2A, VCG2B, and VCG4B at the International level. Different from our study, some studies were reported that VCG4B is the dominant group in tomato in South Africa, Greece and Israel. On the other hand, they showed that VCG2B had a limited distribution (Korolev et al., 2000; Papaioannou et al., 2013; Retief et al., 2023). Also, Akar et al. (2024) reported that VCG1A isolates are dominant group from grafted tomatoes in Antalya, Türkiye.

In this study, pathogenicity of one isolate was found to be different in levels of virulence of the other isolates used in the pathogenicity test. Other studies have shown that *V. dahliae* isolates have different virulence in various hosts (Tjamos, 1981; Joaquim & Rowe, 1991; Tsror et al., 2001; Sanei et al., 2008). A study conducted that by Genc Kesimci and Demirci (2020) were determined the disease severity between 27.5% and 75% on strawberry. Tjamos (1981) found that were differences found in the pathogenicity of tomato. Retief et al. (2023) reported that the aggressiveness of *V. dahliae* isolates varied between 2.08% and 51.94% on tomato. There are two races of *V. dahliae* infections on tomato, race 1 carries the avirulence gene VdAve1 and race 2 is not carrying (Panno et al., 2021). Fradin et al. (2009) observed that Ve gene provides resistance against race 1 of *V. dahliae* isolates. Therefore, it is considered that virulence differences may occur, especially in tomato. Also, the ability toxin production of isolates are very important (lead to necrosis and wilting) which the toxic metabolites and/or phytotoxins may induce plant defense mechanisms (Zhen & Li, 2004). Genetic exchange between isolates belonging to the same VCGs may lead to the emergence of more virulent isolates as it will provide diversity (Bhat et al., 2003; Jiménez-Díaz et al., 2006). At the same time, large number of host species may be effect the degree of virulence (Pegg & Brady, 2002).

The growth and distribution of fungi are affected by different environmental factors (Alsohaili & Bani-Hasan, 2018). Temperature is one of the most important environmental factors affecting the development of fungal diseases. In this study, temperature effect on radial growth of isolates *V. dahliae* was investigated *in vitro*. The colonies of *V. dahliae* well grown on PDA at 20-25 °C, and the optimal temperature was 25 °C. *Verticillium dahliae* not grown at 5 °C and 35 °C. These results were similar to with previous studies. Pegg and Brady (2002) has been reported that the optimal growth temperature of isolates as 22 and 25 °C. Jing et al. (2018) also found that the colony growth of isolates *V. dahliae* increased at 25 °C. Rampersad (2010) demonstrated that *V. dahliae* was grown at 25 and 30 °C, but not at 15 and 35 °C. In addition, Jabnoun-Khiareddine et al. (2006) found that *V. dahliae* was more greater disease higher temperatures (21 to 30 °C) than the lower

temperatures (17 to 21 °C) and adapted to higher temperatures in tomato plants.

5. Conclusion

Verticillium dahliae is one of the most common pathogens that causes yield and quality losses in tomato worldwide. In this study, we investigated to VCGs and pathogenicity of *V. dahliae* isolates obtained from tomato plants in Iğdır province. As a result of the study, VCGs were determined as VCG2A and VCG 2B. Also, variation in the pathogenicity of the isolates was observed. With the data obtained, a source was created for further studies to be carried out in tomato plants. The management of Verticillium wilt recommends control methods such as soil solarization, soil fumigation, and crop rotation, but the methods are inadequate to manage of the disease. Developing pathogen-specific control strategies such as selection of resistant varieties can contribute to more successful results.

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Conflict of Interest

The author has no conflict of interest to declare.

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