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Agro-morphological traits and some bacterial leaf pathogens susceptibility in local super tomato genotypes

Yerel süper domates genotiplerinde tarımsal morfolojik özellikler ve bazı bakteriyel yaprak patojenlerine duyarlılık

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ABSTRACT

This study aimed to characterize the morphological traits of Super tomato genotypes grown widely in Iğdır plain and to determine the reaction of the Super tomato genotype to bacterial diseases caused by *Pseudomonas syringae* pv. *tomato* (*Pst*) and *Xanthomonas euvesicatoria* pv. *perforans* (Xep). Super tomato genotypes were collected from 20 different regions in the harvest season in 2021-2022. Morphological and physiological measurements in the laboratory were taken on tomato genotypes to characterize plant traits. Also, pot experiments were carried out in a plant growth chamber to assess the reaction of Super tomato to infection by *Pst* and *Xep*. Data on plant morphology and growth were obtained, including measurements of plant heights (136.9-88.7 cm), root lengths (69.0-46.3 cm), stem diameters (2.17-1.52 cm), plant fresh weights (596-426 g), plant dry weights (127.6-94.0 g), root fresh weights (74.5 to 51.8 g), root dry weights (24.3-11.9 g), yield per plant (4717.3-2906.5 g), mean fruit weight (385.2-223.7 g), fruit length (55.5-50.3 mm), and mean fruit diameter (96.0-81.1 mm). In terms of the physiological properties of tomato fruits, the water-soluble dry matter content ranged from 4.55% to 4.11%, fruit juice pH from 4.69 to 4.43, titratable acidity from 3.16 to 2.93 mval 100 ml^{-1}, vitamin C content from 26.63 to 17.80 mg/100 g, lycopene content from 2951.1 to 2629.5 ng/µl, and β-carotene content from 272.55 to 228.82 ng/µl. Additionally, pot experiments demonstrated that the super tomato genotype exhibited moderate susceptibility to both *Pst* and *Xep* infections, with disease severity index (DSI) of 2.4 and 2.2, respectively.

INTRODUCTION

Tomato (*Solanum lycopersicum* L., Solanaceae) ranks among the most economically important cultivated plants globally, exhibiting high production, consumption, and trade (Keskin and Gül 2004). Turkiye is the world's third-largest tomato producer, contributing 6.99% of the global output. According to FAO (2022) data, Turkiye produced 13 million

tons of tomatoes annually, trailing only China (68.2 million tons) and India (20.7 million tons). Tomato cultivation in Turkiye is versatile, with production occurring in the field and controlled environments such as greenhouses.

Based on Turkish Statistical Institute (TUIK) data from 2022, most tomatoes (61.2%) were cultivated for direct consumption as table tomatoes. Processing tomatoes (paste tomatoes) constituted the remaining 38.8% of production. Notably, 32% of the table tomato crop was grown in greenhouses. Tomato production in Turkiye utilizes sophisticated agricultural practices. Furthermore, the industry has undergone a structural change, moving from a predominantly small-scale, family-based model to a larger, corporate structure characterized by advanced agricultural practices. Despite these agricultural improvements, the risk of crop damage or destruction caused by pests, diseases, and adverse weather conditions has escalated. Such challenges lead to considerable tomato quality and quantity losses within our country (Yucel et al. 2008).

Tomatoes are infected by over 200 pathogens, with bacterial species from the genera *Xanthomonas*, *Pseudomonas*, *Clavibacter*, *Pectobacterium*, and *Dickeya* posing significant economic losses to tomato cultivation (Horuz and Serin 2024). Pathogenic bacteria belonging to the genera *Pseudomonas* (Canzoniere et al. 2021, Silvera-Pérez et al. 2023) and *Xanthomonas* (Abrahamian et al. 2021, Osdaghi et al. 2017) have been reported to cause substantial economic losses in tomato cultivation. Bacterial speck, caused by *Pseudomonas syringae* pv. tomato (Okabe) Young, Dye & Wilkie, and bacterial spot, a complex disease primarily caused by *Xanthomonas euvesicatoria* pv. euvesicatoria, *X. euvesicatoria* pv. *perforans* (Jones et al.) Constantin et al., *X. hortorum* pv. *gardneri*, and *X. vesicatoria*, are among the most economically devastating bacterial diseases affecting global tomato production (Canzoniere et al. 2021, Constantin et al. 2016, Jones et al. 2004, Morinière et al. 2020).

The symptoms of these two diseases first appear on the leaves, as the disease progresses, lesions spread to the stems, petioles, and flowers. Yield reductions may also occur due to reduced photosynthetic capacity of infected leaves, leaf drops, flower drops, and fruit lesions. Bacterial speck is more severe in cool, moist conditions, while bacterial spot symptoms generally appear more severe in warm, wet weather (Ji et al. 2006). Current strategies for controlling both diseases are known to be of limited effectiveness. Cultural practices alone cannot adequately control diseases and are generally not adopted by commercial growers. Copper compounds, alone or often combined with the ethylene bisdithiocarbamate (EBDC) fungicides, were the primary method of disease control in tomato cultivation. However, the widespread development of copper resistance among pathogen populations has rendered these treatments increasingly ineffective in many regions. Furthermore, the potential risks associated with pesticide residues have stimulated research into alternative or supplementary disease management strategies (Lai et al. 2021, McLeod et al. 2017, Potnis et al. 2015).

Host plant resistance offers a cost-effective and efficient strategy for disease management (Zhan et al. 2014). Despite the potential benefits, bacterial spot-resistant tomato cultivars are currently commercially unavailable. Breeding programs have encountered difficulties in developing varieties with sufficient resistance (Sharma and Bhattarai 2019). This is primarily due to the pathogen's rapid evolution and the complex nature of quantitative resistance (Qiao et al. 2020). Several wild and cultivated tomato plants exhibit resistance to the bacterial speck. Most studies suggest that this trait is inherited simply (Yang and Francis 2007). Breeding tomatoes for genetic resistance to bacterial diseases is a crucial and promising endeavour (Kozik and Sobiczewski 2007).

Biodiversity is a broad term that includes the variety of life on Earth, from wild species to cultivated plants. This diversity also encompasses the genetic resources that form the foundation of our planet's genetic pool (Dal et al. 2017). Turkiye ranks among the world's leading countries regarding genetic resources and diversity. The sustainability of plant diversity depends on the effective discovery, collection, and conservation of genetic resources.

A single plant species can exhibit significant variation through its varieties and genotypes. Therefore, it's crucial to conserve plant genetic resources and to identify the varieties with the widest diversity (Gross et al. 2006, Karagöz et al. 2010, Karataş et al. 2017). In other words, to fully utilize genetic resources, it's essential to understand the range of variation within plant species (Bode et al. 2013, Che et al. 2003).

Local genotypes were formed by a process of continuous selection for superior qualities tailored to the region, coupled with successive generations of breeding and the influence of natural selection (Dal et al. 2017). For breeding studies, local varieties are crucial, and they can be successfully crossed with cultivated varieties (Eser et al. 2005). Plant breeders extensively utilize morphological and agronomic data to characterize and assess plant genetic diversity. Modern plant science involves collecting genotypes of various plant species, identifying similarities to eliminate redundancies, and creating focused core collections for breeding programs. Breeders must thoroughly understand their genetic material, including morphological, phenological, and agronomic

traits (Madakbaş and Ergin 2011). Physiological and molecular advances have made substantial contributions to accurate variety classification. Iğdır plain's low altitude and high temperatures contribute to its status as one of Turkiye's largest microclimatic regions. Both cultivated crops and native plants are represented in abundance within this area. Tomatoes are the leading edible vegetable in Iğdır plain, with an annual production of 35.217 tons cultivated across approximately 8.915 decares (TUIK 2022). Roughly one-third of the region's tomato production is attributed to the Super tomato genotype, a locally cultivated large-fruited variety renowned for its exceptional flavour and aroma (Özden and Akbaba 2023).

This study characterized the morphological traits of the Super tomato genotypes, a commercially prominent variety cultivated extensively in the Iğdır plain. Additionally, this study assessed the susceptibility of the local Super tomato genotype to both bacterial speck and bacterial spot diseases caused by *P. syringae* pv. *tomato* and *X. euvesicatoria* pv. *perforans*, respectively.

MATERIALS AND METHODS

Plant material

Super tomato plant samples were examined during the peak harvest season of 2021-2022 (June-July). Samples were collected from 20 different regions. Measurements were taken from 5 plants within each area, and the results were averaged. Testing was conducted at the Vegetable and Seed Physiology Laboratory of Iğdır University. Also, to evaluate the Super tomato genotype's response to pathogens, the H2274 variety was included as a comparative control.

Bacterial material

P. syringae pv. *tomato* DO24 (Akbaba et al. 2023) and *X. euvesicatoria* pv. *perforans* XCV2 (Akbaba et al. 2025, in press), previously characterized strains from the Iğdır University phytopathology laboratory, were used as pathogens in this study.

Collection of plant samples

Using portable scales, uprooted plants were immediately weighed in the field to minimize water loss. Weighted plant samples were transported to the laboratory between damp coarse filter paper to maintain moisture. For further analysis, the plant samples were transported in cool bags to the lab (Mumtaz et al. 2021). The identical procedure was applied to fruit samples. Morphological and physiological measurements were taken from tomato samples.

Morphological and physiological analysis

Plants were chosen to reflect the typical characteristics of their respective regions. Five plants were examined per region.

- *Plant height (PH)*: The height of each uprooted plant was determined by measuring the distance from the root collar to the plant apex using a meter, and the results were recorded in centimeters.
- *Root length (RL)*: Root damage was minimized during the field studies. The roots were extracted by cutting at the root collar, thoroughly cleaned in water, and then measured from the root collar to the radicle tip using a meter to determine root length in centimeters.
- *Stem diameter (SD)*: The mean diameter of the main stem was determined using a digital caliper and recorded in millimeters.
- *Plant fresh weight (PFW) and Dry weight (PDW):* The plants were cut at the crown region with a knife, and the upper part of the plant was weighed on a coarse scale in grams. The plants with calculated fresh weight were dried in ventilated ovens at 65 °C for 6 hours, and then the dry weights of the plants were calculated.
- *Root fresh weight (RFW) and dry weight (RDW):* The plants removed from the field were cut at the crown region using a knife, and the root part of the plant was weighed on a coarse scale in grams. The roots with calculated fresh weight were dried in ventilated ovens at 65 °C for 6 hours, and then the dry weights of the roots were calculated.
- *Yield per plant (Y):* Fruits were harvested at the pink-red stage of maturity. The total weight of fruits per plant was recorded in grams to calculate yield.
- *Fruit weight (FW):* To calculate average fruit weight, 10 fruit samples were taken to represent the plants in that region for each replicate and weighed. The mean value was recorded in grams.
- *Fruit length (FL):* To calculate average fruit length, 10 fruit samples were taken to represent the plants in that region for each replicate and measured longitudinally with the help of a digital caliper. The mean value was recorded in millimeters.
- *Fruit diameter (FD):* To calculate average fruit diameter, 10 fruit samples were taken to represent the plants in that region for each replicate and measured from the equatorial parts with the help of a digital caliper. The mean value was recorded in millimeters.
- *Water-soluble dry matter content (Brix%):* Five fruits per replicate were homogenized. The homogenate was filtered using Whatman No. 4 filter paper. The (Brix%) of the

obtained fruit juice was measured with a refractometer (Digital Abbe Refractometer).

- *Fruit juice pH measurement (pH):* The pH of the fruit juices prepared for the water-soluble dry matter measurement was measured using a pH electrode (Titrette).

- *Titratable acidity (TA):* It was determined by titrating 10 ml of fruit juice with a 0.1 N sodium hydroxide (NaOH) solution until the pH value reached 8.1 using a pH meter. The results were calculated as citric acid based on the amount of base (NaOH) used and expressed as a percentage (Cemeroğlu 1992).

- *Determination of ascorbic acid (Vitamin C):* 100 g of the fruit sample was mixed with an equal amount of 2% oxalic acid solution and homogenized. Then, 30 g of this sample was taken and diluted to 100 ml with 2% oxalic acid solution. After vortexing the samples, they were filtered. From the filtered samples, 10 ml was taken and titrated with a 2,6-dichlorophenolindophenol solution until a pink color appeared. The amount of ascorbic acid was calculated using the formula below (Cemeroğlu 1992).

  Ascorbic acid (mg/100g) = V x F x 100 W (2)

  V: The amount of 2,6-dichlorophenolindophenol solution used in the titration (ml)

  F: The factor of the 2,6-dichlorophenolindophenol solution, i.e., the amount of ascorbic acid (mg) equivalent to 1 ml of this solution

  W: The amount of sample contained in the filtrate used in the titration (g)

- *Determination of lycopene and β-carotene:* 1 g tomato samples were homogenized for 5 minutes with a 16 ml mixture of acetone (4:6) in a homogenizer. The hexane phase at the top of the prepared extraction was collected using a micropipette, and readings were taken at wavelengths of 663, 645, 505, and 453 nm using a spectrophotometer. After completing the readings, the amounts of lycopene and β-carotene were calculated according to Nagata and Yamashita (1992) and the results were expressed as mg/100g.

Experimental design for the control and pathogen treatments

In-pot experiments were conducted in the growth chamber. Sterile peat was used as a growth medium in 0.38 liter disposable thermoform pots (8x8x9 cm). Seeds were sown in these pots and placed in the growth chamber. Throughout the experiment, tomato plants were maintained in a controlled environment (for approximately 45 days) with a 16-hour light, 8-hour dark photoperiod, 60% relative humidity, and a day/night temperature regime of 24 °C and 20 °C, respectively. Tomato seedlings were inoculated with pathogenic bacteria at the 3-5 leaf stage (day 25). The experimental design consisted of a randomized complete block arrangement with five replications, each containing a single plant. This experiment was replicated twice.

Bacterial strain cultivation, inoculum preparation, and disease assessment

In this study, Pst strain DO24 and Xep strain XCV2 were used as pathogenic bacterial strains. Bacterial cultures stored at -80 °C were streaked onto Nutrient Agar (NA) in petri dishes and incubated at 24 ± 2 °C for 48–72 h. The grown bacterial colonies were stored at 4 °C for subsequent experiments. Inoculum for tomato seedlings, prepared by suspending bacterial colonies in sterile distilled water from NA medium growth for 48-72 hours at 24 ± 2 °C. Bacterial suspensions were adjusted to OD600nm: 0.2 for Pst and 0.1 for *Xep* (approximately 108 and 107 CFU/ml, respectively) using spectrometry. One or two drops of Tween 20 surfactant were added to the bacterial suspensions. Plants were inoculated by spraying bacterial suspensions onto the undersides of fully developed leaves. To maintain high humidity, the treated seedlings were placed in polyethylene bags and the environment was adjusted to a relative humidity of 80-90%. Following a 48-hour incubation period in polyethylene bags, the plants were transferred back to the growth chamber, where they were maintained at approximately 60% relative humidity. Tomato seedlings were treated with distilled water as the negative group (-), and those inoculated solely with the pathogenic bacterial suspension were considered the positive control group (+). Standard variety H2274 was used as a control for comparing Super tomato disease resistance. Fourteen days after inoculation with Pst, disease severity was evaluated using a modified Chambers and Merriman (1975) disease rating 0-4 scale (0= no lesions, 1= 1-10 lesions, 2= 11-20 lesions, 3= 21-40 lesions, 4= 40 and more for per plant) (Ekici and Baştaş 2014). The disease symptoms were evaluated on a scale of 0-4 based on the scale described by Al-Dahmani et al. (2003) with a slight modification on the 21st day after Xep's inoculation. The modified scale is as follows: 0= symptomless, 1= one to five lesions per leaflet, 2 = many lesions and some coalesced lesions, 3 = coalesced lesions and some necrotic leaflets, and 4 = dead leaflets. The DSI value was calculated from the sum of the data classified by scale values obtained from five replicates (two experiments n=10) divided by the replication number for each cultivar (Eenink 1981). Ekici and Baştaş (2014) described 5 resistance classes

following: Resistant; R (DSI:0), Moderately Resistant; MR (DSI:1), Moderately Susceptible; MS (DSI: 2), Susceptible; S (DSI:3) and Highly Susceptible; HS (DSI:4).

Plant growth analysis

For both disease-inoculated and control plants, leaf number (LN), plant fresh weight (PFW), plant dry weight (PDW), root fresh weight (RFW), and root dry weight (RDW) were determined using previously described methods. Chlorophyll concentration (CC) was measured using a portable chlorophyll meter (Minolta SPAD-502+) (Fischer 2001). Chlorophyll content was determined by taking three replicate measurements from the lower, middle, and upper leaves of each plant under bright afternoon light conditions (14:00-16:00). The average SPAD value for each plant was calculated by combining data from the three-leaf positions and the replicate measurements.

The efficacy (%) of pathogen infection on growth parameters of different tomato cultivars is also calculated according to Abbott's formula* (Akbaş et al. 2009) as follows:

*Efficacy (%) = (C – T) / C × 100 Where C refers to the measurement of the control (-), and T refers to the measurement of the relevant treatment (*Pst* or *Xep* for this study).

Statistical analysis

The experimental groups were compared using one-way variance analysis coupled with Duncan's multiple range test ($P < 0.05$) (SPSS 26 Package program).

RESULTS

Morphological outputs

Examination of Super tomato genotypes collected from 20 different regions within the Iğdır plain revealed substantial variation in vegetative characteristics. Plant height (PH) exhibited regional variation, ranging from 136.9 to 88.7 cm across regions. The Akyumak region exhibited the maximum plant height, whereas the Bayraktutan region displayed the minimum plant height value. Root length (RL) exhibited variation among genotypes, with measurements spanning from 69.0 cm to 46.3 cm. Similar to the pattern observed for plant height, the Akyumak region displayed the maximum root length value, whereas Taşburun, Yüzbaşılar, Özdemir, and Bayraktutan regions exhibited the minimum root length values. The stem diameter (SD) varied between 2.17 cm and 1.52 cm. The largest stem diameter values were measured in the Akyumak, Obaköy, Yaycı and Küllük regions, while the smallest stem diameter values were determined in the Taşburun, Yüzbaşılar, Özdemir, Hakmehmet and Bayraktutan regions (Table 1).

In addition to length measurements, plant fresh and dry weights were determined. Plant fresh weight (PFW) ranged from 596 g to 426 g. Akyumak had the highest fresh weight, while Bayraktutan had the lowest. Plant dry weights (PDW) varied between 127.6 and 94.0 among the regions. The highest PDW was measured in Obaköy, Akyumak and Küllük, and the lowest in Taşburun, Yüzbaşılar, Özdemir and Bayraktutan. Root fresh weights (RFW) ranged from 74.5 g to 51.8 g. Akyumak and Obaköy had the highest root fresh weight, while Taşburun had the lowest. Root dry weights (RDW) ranged from 24.3 g to 11.9 g. Akyumak and Obaköy had the highest DWW values, while Taşburun, Hakmehmet, and Bayraktutan had the lowest (Table 1).

Fruit characteristics exhibited significant variation among regions. The average yield (per plant) varied between the sites from 4717.3 g to 2906.5 g. Akyumak had the highest yield, while Bayraktutan had the lowest. Average fruit weights (FW) varied between 385.2-223.7 g. The highest fruit weight was determined in the Akyumak and Alikamerli regions, while the lowest was determined in the Bayraktutan region (Table 2). Fruit lengths (FL) varied between 55.5 and 50.3 mm depending on the region. The Küllük region had the highest fruit length, while the Hakveyis region had the lowest. Fruit diameters (FD) varied between 81.1 and 96.0 mm depending on the region. Fruit diameter (MD) was highest in the Akyumak, Obaköy, Yaycı, and Alikamerli regions, but lowest in the Taşburun, Mirhanlı, and Bayraktutan regions (Table 2).

Physiological outputs

In addition to yield parameters, some physiological properties of the fruits were measured. Water-soluble dry matter content (Brix%) ranged from 4.11% to 4.55% across regions. Evci and Obaköy had the highest water-soluble dry matter content (Brix%), while Alikamerli, Kasımcan, Kuzugüden, and Bayraktutan had the lowest. Fruit pH ranged from 4.43 to 4.69. The Yaycı region had the highest pH value, while Taşburun and Mirhanlı regions had the lowest. Titratable fruit acidity (TA) ranged from 2.93 to 3.16 mval 100 ml-1. The Özdemir region had the highest titratable acidity, while the Taşburun region had the lowest (Table 3). There is a wide variation in vitamin C (VitC) content between regions. Vitamin C (VitC) content ranged from 17.80 to 26.63 mg/100g. The Küllük region had the highest vitamin C content, while the Zülfikar region had the lowest. Lycopene content ranged from 2629.5 to 2951.1 ng/µl. The Evci and the Obaköy regions had the highest lycopene content, while the Hakmehmet region had the lowest. Beta-carotene (β-carotene) content ranged from 228.82 to 272.55

Table 1. Vegetative growth parameters (plant height, root length, stem diameter, fresh and dry weights of plant and root) of Super tomato genotypes across different regions

Genotype	PH (cm)	RL (cm)	SD (cm)	PFW (g)	PDW (g)	RFW (g)	RDW(g)
Taşburun	91.1 lm ±2.8	46.9 j ±0.7	1.52 h ±0.017	444.4 m ±3.9	95.6 h ±0.9	51.8 j ±0.8	12.6 g ±0.4
Mirhanlı	104.5 i ±0.6	50.9 i ±0.6	1.68 fg ±0.015	494.7 i ±2.1	102.1 g ±1.0	60.5 fg ±0.4	15.5 f ±0.2
Zülfikar	111.8 gh ±0.8	53.5 fg ±0.8	1.79 de ±0.015	520.6 fg ±1.6	105.5 fg ±0.4	64.7 de ±1.2	17.9 de ±0.4
Evci	115.8 ef ±1.3	58.6 d ±0.8	1.80 de ±0.023	522.4 fg ±2.9	107.5 ef ±1.1	69.2 c ±0.4	19.3 cd ±0.5
Pinazar	98.8 j ±0.4	51.9 g-i ±0.4	1.61 gh ±0.021	477.8 j ±1.5	102.4 g ±1.4	56.0 hi ±1.3	15.2 f ±0.3
Melekli	113.9 fg ±0.9	55.7 e ±0.5	1.76 d-f ±0.024	524.8 f ±1.9	105.5 fg ±0.6	68.3 cd ±1.0	18.2 d ±0.3
Akyumak	136.9 a ±0.8	69.0 a ±0.1	2.14 a ±0.045	596.0 a ±3.6	125.6 a ±0.6	74.3 a ±0.5	22.9 a ±0.9
Enginalan	117.1 e ±1.1	61.5 c ±0.4	1.85 cd ±0.021	529.6 f ±2.2	110.2 de ±0.3	69.8 bc ±0.8	21.1 b ±0.4
Yüzbaşılar	95.0 k ±0.8	46.6 j ±0.8	1.54 h ±0.047	453.4 l ±2.0	94.0 h ±0.8	55.3 h-j ±0.3	16.0 f ±0.1
Özdemir	93.1 kl ±0.4	47.6 j ±0.9	1.57 h ±0.039	468.3 k ±3.6	97.6 h ±2.6	55.1 ij ±4.0	15.1 f ±0.2
Hakveyis	109.2 h ±0.6	51.2 hi ±0.6	1.71 ef ±0.018	515.4 g ±2.4	111.4 de ±0.9	63.7 ef ±0.7	16.5 ef ±0.3
Obaköy	130.9 b ±0.4	67.4 a ±1.2	2.17 a ±0.052	575.0 c ±1.7	125.2 a ±0.6	74.5 a ±0.9	24.3 a ±1.3
Yaycı	122.7 cd ±0.6	64.8 b ±0.3	2.13 a ±0.038	559.8 d ±2.6	117.5 bc ±1.2	69.5 c ±0.8	20.6 bc ±0.4
Alikamerli	121.0 d ±0.8	62.6 bc ±0.2	1.97 b ±0.042	559.5 d ±2.9	118.7 b ±1.0	66.4 c-e ±0.4	19.4 cd ±0.2
Kasımcan	117.4 e ±0.2	60.9 c ±0.8	1.93 bc ±0.042	542.0 e ±1.7	114.0 cd ±0.8	65.3 de ±0.6	19.0 d ±0.3
Kuzugüden	105.7 i ±0.9	53.2 gh ±1.3	1.60 gh ±0.026	521.8 fg ±2.0	108.5 ef ±0.5	63.1 ef ±1.0	15.5 f ±0.3
Hakmehmet	102.8 i ±0.7	49.8 i ±0.3	1.57 h ±0.025	481.1 j ±3.9	101.8 g ±1.1	58.9 gh ±0.5	13.0 g ±0.3
Küllük	124.3 c ±1.0	63.8 b ±0.8	2.13 a ±0.026	584.5 b ±3.5	127.6 a ±1.1	73.1 ab ±0.8	20.7 bc ±0.3
Çarıkçı	112.0 gh ±0.8	55.4 ef ±1.1	1.76 d-f ±0.018	503.4 h ±2.2	105.2 fg ±1.4	65.5 de ±1.0	18.2 d ±0.4
Bayraktutan	88.7 m ±1.2	46.3 j ±0.5	1.57 h ±0.012	426.0 n ±5.3	96.6 h ±4.0	53.0 ij ±0.9	11.9 g ±0.7
Mean	110.63	55.88	1,79	515.02	108.63	63.90	17.64

Means with different letters in the same column denote significant difference at P <0.05. The error bars represent ± SEM. ns: non-significant.

Table 2. Yield (per plant), fruit weight, length, and diameter of Super tomato genotypes across different regions

Genotype	Y (g)	FW (g)	FL (mm)	FD (mm)
Taşburun	3069.9 j ±34.0	249.4 k ±1.8	51.2 gh ±0.6	81.1 g ±0.2
Mirhanlı	3562.7 h ±13.1	306.9 gh ±1.8	52.7 e ±0.1	81.0 g ±0.3
Zülfikar	4276.7 de ±25.6	319.1 f ±1.6	52.4 ef ±0.2	87.7 e ±1.1
Evci	4479.7 bc ±23.4	337.7 de ±6.9	55.1 ab ±0.1	91.7 c ±0.3
Pinazar	3323.1 i ±17.5	288.3 i ±4.0	51.0 gh ±0.3	84.1 f ±0.3
Melekli	4239.4 e ±21.5	329.2 e ±3.0	52.5 e ±0.4	93.5 b ±0.2
Akyumak	4717.3 a ±34.2	385.2 a ±5.8	54.0 cd ±0.4	96.0 a ±0.3
Enginalan	4319.2 de ±10.8	340.6 d ±5.1	53.2 de ±0.2	91.5 c ±0.3
Yüzbaşılar	3101.9 j ±8.1	270.0 j ±0.9	52.7 e ±0.3	83.2 f ±0.5
Özdemir	3147.2 j ±27.4	277.8 j ±1.2	51.4 fg ±0.3	83.2 f ±0.1
Hakveyis	4261.7 de ±29.1	314.0 fg ±1.2	50.3 h ±0.5	89.5 d ±0.5
Obaköy	4531.2 b ±19.3	364.7 bc ±4.5	54.6 a-c ±0.4	96.4 a ±0.3
Yaycı	4326.9 d ±13.8	369.2 b ±0.6	54.3 bc ±0.3	96.0 a ±0.5
Alikamerli	4346.0 d ±47.4	382.3 a ±3.6	53.9 cd ±0.1	95.8 a ±0.1
Kasımcan	4073.5 f ±33.9	359.7 bc ±2.5	54.7 a-c ±0.3	94.0 b ±0.1
Kuzugüden	4096.3 f ±21.9	313.3 fg ±1.3	52.3 ef ±0.1	89.6 d ±0.5
Hakmehmet	3771.7 g ±35.2	303.0 h ±2.5	51.2 gh ±0.3	83.6 f ±0.2
Küllük	4450.5 c ±32.1	355.0 c ±2.8	55.5 a ±0.2	93.7 b ±0.9
Çarıkçı	4316.2 de ±18.5	316.0 fg ±1.1	54.1 cd ±0.4	91.2 c ±0.3
Bayraktutan	2906.5 k ±30.0	223.7 l ±2.8	50.6 gh ±0.4	81.6 g ±0.3
Mean	3965.87	320.25	52.88	89.22

Means with different letters in the same column denote significant difference at P <0.05. The error bars represent ± SEM. ns: non-significant.

Table 3. Regional distribution of water-soluble dry matter content, pH, titratable fruit acidity, vitamin C, Lycopene and β-Carotenoid contents in Super tomato fruits

Genotype	Brix (%)	pH	TA (mval 100 ml^{-1})	VitC (mg 100 g-1)	Lycopene (ng/µl)	β-carotene (ng/µl)
Taşburun	4.36 de ±0.017	4.43 l ±0.038	2.93 h ±0.012	20.95 h ±0.61	2648.1 hi ±14.2	232.49 j ±0.4
Mirhanlı	4.37 d ±0.015	4.43 l ±0.012	3.04 ef ±0.007	19.62 jk ±0.15	2684.4 h ±4.1	239.22 i ±0.4
Zülfikar	4.22 f ±0.015	4.53 i-k ±0.018	3.04 ef ±0.006	17.80 n ±0.09	2793.7 ef ±6.5	240.20 i ±0.9
Evci	4.60 a ±0.015	4.62 cd ±0.015	3.08 cd ±0.001	25.61 b ±0.20	2951.1 a ±9.4	271.82 a ±0.7
Pinazar	4.20 f ±0.015	4.50 k ±0.012	3.05 ef ±0.009	18.19 mn ±0.22	2757.1 fg ±23.7	248.82 gh ±0.2
Melekli	4.35 de ±0.003	4.59 d-g ±0.003	3.11 b ±0.007	22.61 fg ±0.29	2908.3 bc ±4.7	265.07 b ±0.5
Akyumak	4.44 bc ±0.018	4.57 e-h ±0.012	2.97 g ±0.012	24.33 d ±0.17	2862.0 d ±12.1	262.32 c ±0.6
Enginalan	4.46 b ±0.026	4.55 g-i ±0.015	2.95 gh ±0.003	25.61 b ±0.25	2939.0 ab ±2.9	272.55 a ±1.4
Yüzbaşılar	4.35 de ±0.003	4.51 jk ±0.009	3.09 b-d ±0.007	20.05 ij ±0.05	2734.9 g ±9.3	232.42 j ±0.7
Özdemir	4.31 e ±0.012	4.53 i-k ±0.001	3.16 a ±0.010	18.94 kl ±0.28	2668.1 hi ±18.9	228.82 k ±0.6
Hakveyis	4.25 f ±0.015	4.61 c-e ±0.012	3.02 f ±0.023	22.82 ef ±0.42	2853.4 d ±20.6	253.41 e ±0.3
Obaköy	4.55 a ±0.015	4.64 bc ±0.007	3.10 bc ±0.009	25.09 bc ±0.10	2946.3 a ±7.6	265.48 b ±0.6
Yaycı	4.44 bc ±0.024	4.69 a ±0.003	3.04 ef ±0.003	24.52 cd ±0.08	2864.0 d ±11.3	253.29 e ±0.7
Alikamerli	4.14 g ±0.032	4.55 g-i ±0.012	3.11 b ±0.012	20.62 hi ±0.08	2784.6 ef ±9.7	259.83 d ±0.2
Kasımcan	4.12 g ±0.026	4.56 f-i ±0.012	3.06 de ±0.003	20.65 hi ±0.10	2806.3 e ±5.3	248.08 h ±0.1
Kuzugüden	4.13 g ±0.017	4.66 ab ±0.009	2.93 h ±0.007	20.19 ij ±0.34	2882.4 cd ±2.1	250.90 f ±0.5
Hakmehmet	4.20 f ±0.033	4.57 e-h ±0.003	3.04 ef ±0.006	22.03 g ±0.26	2629.5 i ±15.4	250.53 fg ±0.5
Küllük	4.38 cd ±0.015	4.67 ab ±0.007	2.97 g ±0.015	26.63 a ±0.13	2903.2 bc ±3.2	259.67 d ±0.1
Çarıkçı	4.45 b ±0.020	4.61 c-e ±0.003	3.04 ef ±0.018	23.35 e ±0.13	2772.1 e-g ±8.6	247.79 h ±0.4
Bayraktutan	4.11 g ±0.003	4.54 h-k ±0.013	3.09 b-d ±0.003	18.75 lm ±0.07	2661.1 hi ±23.2	252.33 ef ±0.5
Mean	4,32	4,57	3,04	21,92	2802,49	251,75

Means with different letters in the same column denote significant differences at P <0.05. The error bars represent ± SEM. ns: non-significant.

ng/µl across regions. The Evci and the Enginalan regions had the highest beta-carotene content, while the Özdemir region had the lowest (Table 3).

Reaction of the Super tomato genotype to Pst and Xep

The Super tomato genotype (Küllük) and H2274 cultivar were evaluated for disease severity in this study 14 days after Pst and 21 days after Xep inoculation (Figure 1).

Figure 1. Disease symptoms in Super tomato genotype following *Pseudomonas syringae* pv. *tomato* (*Pst*) and *Xanthomonas euvesicatoria* pv. *perforans* (*Xep*) inoculation: a: control (-), b: Pst (+), c: bacterial speck on tomato, d: control (-), e: Xep (+), f: bacterial spot on tomato

H2274 and the Super tomato genotype both exhibited moderate susceptibility to Pst infection (DSI: 2.7 and 2.4, respectively). However, H2274 demonstrated moderate resistance to *Xep* infection (DSI: 1.3), while the Super tomato remained moderately susceptible (DSI: 2.2) (Table 4).

Effects of pathogens on plant growth parameters

It was investigated the impact of *Pst* and *Xep* on tomato plant growth parameters, including leaf number (LN), plant and root fresh (PFW, RFW) and dry weights (PDW, RDW), and chlorophyll content (C) in this study. Both Super tomato and H2274 genotypes exhibited significant reductions in plant growth parameters following Pst infection compared to healthy controls. Super tomato displayed decreases of 8.06% (LN), 28.03% (SFW), 35.25% (SDW), 39.77% (RFW), 50.57% (RDW), and 9.37% (C) at a disease index of 2.4. H2274 showed more severe reductions, with decreases of 20.31% (LN), 50.86% (SFW), 35.75% (SDW), 42.17% (RFW), 57.21% (RDW), and 1.4% (C) at a disease index of 2.7 (Table 5). Super tomato genotypes infected with Xep (disease index: 2.2) exhibited significant reductions in leaf number (1.32%), plant fresh weight (18.06%), plant dry weight (46.18%), root fresh weight (41.28%), root dry weight (25.98%), and chlorophyll content (0.95%) compared to healthy controls. H2274 plants with a disease index of 1.3 showed decreases in SDW (1.61%) and RDW (2.46%), but increases in LN (1.35%), SFW (13.63%), RFW (21.11%), RDW (2.46%), and C (2.67%) (Table 6).

DISCUSSION

This study examined the plant characteristics of Super tomato genotypes collected from 20 regions in the Iğdır Plain. In the study conducted in Iğdır Plain, when parameters such as plant height, root length, and stem diameter were examined, higher plant development values were reached in the central regions of the plain. These values were lower in the eastern, northern and western parts of the plain. Plant weights (SFW, SDW, RFW, RDW) were higher in the central and southern than in other parts of the plain (Table 1). Healthy plants typically exhibit optimal vegetative growth and root development. Özenç and Şen (2017) reported tomato plant heights ranging from 193 cm to 156 cm in their study. In the other study, Tezcan et al. (2022) found plant height, stem diameter, and root projection area to be 35-20 cm, 12.3-9.1 mm, and 1405-322 cm², respectively. Super tomato

Table 4. Disease severity index (DSI) values of tested tomato genotypes/varieties and number of plants in infection class (0-4)

Pathogens	Genotype	Number of plants in infection class					DSI	Resistance classes*
		0	1	2	3	4		
Pst strain	Süper			6	4		2.4	Moderately Susceptible
DO24	H2274			3	7		2.7	Moderately Susceptible
Xep strain	Süper			8	2		2.2	Moderately Susceptible
XCV2	H2274		7	3			1.3	Moderately Resistant

* Resistance classes described by Ekici and Baştaş (2014); *0: Resistant; 1: Moderately Resistant, 2: Moderately Susceptible, 3: Susceptible, 4: Highly Susceptible

Table 5. Effects of *Pseudomonas syringae* pv. *tomato* (Pst) inoculation on tomato plant growth parameters, including leaf number (LN), plant and root fresh (SFW, RFW) and dry weights (SDW, RDW), and chlorophyll content (C)

Genotype	Pathogens*	LN (Adet)	SFW (g)	SDW (g)	RFW (g)	RDW (g)	C (g)
Super	*Pst* strain DO24	5.7	4.06	0.24	0.32	0.02	25.45
	C (-)	6.2	5.64	0.37	0.53	0.04	28.08
	Efficacy (%) **	-8.06	-28.03	-35.25	-39.77	-50.57	-9.37
H2274	*Pst* strain DO24	5.1	4.17	0.24	0.38	0.02	24.67
	C (-)	6.4	8.49	0.37	0.66	0.04	25.02
	Efficacy (%) **	-20.31	-50.86	-35.75	-42.17	-57.21	-1.4

* Data were collected 14 days post-inoculation. Results represent the mean of 10 observations (5 replicates x 2 experiments).
** A negative sign (-) was used to indicate a reduction in plant parameters compared to the pathogen-free control.

Table 6. Effects of *Xanthomonas euvesicatoria* pv. *perforans* (Xep) inoculation on tomato plant growth parameters, including leaf number (LN), plant and root fresh (SFW, RFW) and dry weights (SDW, RDW), and chlorophyll content (C)

Genotype	Pathogens*	LN (Adet)	SFW (g)	SDW (g)	RFW (g)	RDW (g)	C (g)
Süper	*Xep* strain XCV2	7.70	12.11	0.57	0.64	0.07	30.31
	C (-)	7.60	14.78	1.06	1.08	0.10	30.60
	Etki (%) **	1.32	-18.06	-46.18	-41.28	-25.98	-0.95
H2274	*Xep* strain XCV2	7.50	15.32	0.73	1.04	0.07	26.88
	C (-)	7.40	13.48	0.75	0.86	0.07	26.18
	Etki (%) **	1.35	13.63	-1.61	21.11	-2.46	2.67

* Data were collected 21 days post-inoculation. Results represent the mean of 10 observations (5 replicates x 2 experiments).
** A negative sign (-) was used to indicate a reduction in plant parameters compared to the pathogen-free control.

genotypes cultivated on the Iğdır plain exhibit significantly larger fruit and more robust, expansive plants compared to those reported in the literature.

While commercial producers prioritize hybrid tomatoes for yield and quality, consumers increasingly favor local genotypes due to perceived taste, naturalness, and support for local producers. Our research findings show that the average yield per plant is 3965.9 g. In the literature, yield values per plant in tomatoes vary considerably. According to Özbay and Ateş (2015), this value is between 7.02-2.44 kg, while Tosun and Aktaş (2022) reported that this range is 4.89-1.20 kg. Our results indicated that the Super tomato is a medium-yielding genotype with consistent yield performance, as reflected by the narrow range between maximum (4717.3 g) and minimum (2906.5 g) yields. Additionally, the average fruit weight across all regions was determined to be 320.3 g. Researchers reported that fruit weights of tomato genotypes varied between 118.5-55.3 g (Paksoy 2003), 332.45 -18.18 g (Turhan and Şeniz 2009), 324.25-15.5 g (Aoun et al. 2013), 58.67-22.33 g (Kathayat et al. 2015), 112.50-47.16 g (Singh and Goswami 2015) and 529.56-60.22 g (Tosun and Aktaş 2022). Based on our findings, the Iğdır Super tomato genotype can be characterized by its relatively large fruit size. Fruit diameters (FD) among Super tomato genotypes ranged from 96.0 mm to 81.1 mm across different regions. Aydın and Aktaş (2023) reported that fruit length in cherry and cocktail tomato genotypes varied between 57.59 mm and 23.42 mm, while fruit diameter ranged from 52.1 mm to 18.1 mm. Super tomato genotypes generally produced large, beef-type fruit with diameters exceeding length. This is a common characteristic of large-fruited species (Renna et al. 2019).

The Brix level is a crucial factor in classifying tomato varieties as either table or industrial. Our results indicate a regional average Brix of 4.32%, classifying this as a table variety. The Iğdır Super tomato's market share is diminishing due to its excessive juiciness and rapid spoilage resulting from its delicate skin. Previous studies on tomato Brix ratios reported a range of 8.6-3.6% (Hanson et al. 2004), 4.36-3.96% (Giorio et al. 2007), 5.98-4.36% (Al-Aysh et al. 2012), 6.03-3.50% (Pal et al. 2018), 4.71-3.12% (Raj et al. 2018), and 4.91-2.50% (Tosun and Aktaş 2022).

The pH level of fruit juice significantly impacts its overall flavor profile, contributing to both taste and aroma perception. Previous studies have reported pH values for tomatoes ranging from 4.58 to 4.37 (Figueiredo et al. 2017), 4.6 to 4.1 (Liu et al. 2017), and 4.49 to 4.24 (Peixoto et al. 2018). Our findings align with previous research, indicating a slightly acidic fruit juice pH range of 4.69-4.43.

Tomatoes are rich in vitamin C, whose content can fluctuate based on various factors, and are also a significant source of the antioxidant pigments lycopene and beta-carotene, responsible for their color and known for their phenolic properties. These phytochemicals may vary widely depending on cultivar, cultivation methods, and environmental conditions. Aydın and Aktaş (2023) reported vitamin C, lycopene, and β-carotene contents in tomato fruits ranging from 60.0-4.9 mg/100 g, 18.6-0.31 mg/100 g, and 6.29-0.75 mg/100 g, respectively. Average vitamin C, lycopene, and β-carotene contents in tomato fruits are reported to range from 67-15 mg/100 g, 25-0.5 mg/100 g, and 6.2-0.3 mg/100 g, respectively (Felföldi et al. 2022, Renna et al. 2019). Compared to literature values, Super tomato genotypes from the Iğdır plain exhibited typical vitamin C levels but were notably high in lycopene and β-carotene.

Our study investigated the vegetative characteristics of the local Super tomato genotype and evaluated its susceptibility to bacterial spot and speck diseases. The local genotype of Super tomato exhibited moderate susceptibility to *Xep*, whereas the H2274 variety demonstrated moderate resistance. A field study in Mysore, India, screened 20 tomato cultivars for resistance to bacterial spot disease caused by *X. axonopodis* pv. *vesicatoria*. Cultivars were categorized as highly resistant (Safal), resistant (Indam, Vignesh, Rasi, Pradhan, Naveen, Pioneer seeds), susceptible (Rukshita, Marglobe, PKM-1, Rohini, SCL-4, Utsav, Leadbeter, Arka vikas), and highly susceptible (Madanapalli, Heemsona, Vajra, Amar, Golden). These twenty cultivars exhibited varying levels of resistance to the pathogen. This variation correlated with the activation of cinnamyl alcohol dehydrogenase (CAD), a key enzyme in plant defence. The researchers emphasized CAD's direct role in lignification and its contribution to bacterial spot resistance (Umesha and Kavitha 2011). Tomato varieties with complete resistance to bacterial spot disease remain elusive. Breeding programs have had limited success in developing acceptably resistant cultivars (Sharma and Bhattarai 2019), primarily due to the emergence of new pathogen strains that overcome existing resistance genes and the complex genetic nature of resistance (Hutton et al. 2010).

Both the local Super tomato genotype and the H2274 variety exhibited moderate susceptibility to infection by *Pst*. A study conducted in the Aegean region of Turkiye reported varying bacterial spot resistance levels among tomato varieties. Marmara and 144 were classified as highly resistant, Beril and Selin as moderately resistant, Dorit and 5656 as susceptible, and Newton as highly susceptible (Bakır et al. 2012). An investigation of 50 tomato varieties cultivated in Turkiye's Mediterranean and Central Anatolia regions reported 15 carrying the *Pto* gene, conferring resistance to *Pst*. These varieties include T-6, Kutlu, OD-8, Impala, H2274, 144, Gülhan, OD-5, Gözde, T-3, Erdem, Ebia, Konya, Çiğdem, and Natura sırık. Despite carrying the Pto resistance gene, the H2274 variety exhibits susceptibility to *Pst* (Ekici and Baştaş 2014). Kozik (2002) observed numerous necrotic lesions on tomato varieties possessing the *Pto* gene. Previous findings indicate that tomato resistance to *Pst* is a complex trait controlled by multiple genes rather than a single gene (Roberts 2002). The study also assessed the impact of disease agents on tomato plant growth, examining parameters such as leaf numbers, plant and root fresh and dry weights, and chlorophyll content.

The moderately susceptible Super tomato genotype exhibited significant reductions in leaf number, plant mass, root biomass, and chlorophyll content following both pathogen infections. The H2274 variety, being moderately susceptible to *Pst* to our findings, experienced significant reductions in leaf number, plant, and root weight following pathogen infection. However, the H2274 variety's moderate resistance to *Xep* mitigated its negative impact on plant growth parameters. These findings demonstrate a clear correlation between varietal resistance levels and their effect on plant growth parameters when challenged by pathogen infection. These diseases alter the host's physiology, biochemistry, and structure, resulting in changes in plant phenotypes (e.g., decreased photosynthetic capacity of diseased foliage, defoliation, flower abortion, and fruit lesions). Ultimately, they result in yield reductions of susceptible varieties due to the damage caused to plants and fruits (Reis Pereira et al. 2023).

Plant genetic resources serve as a crucial repository for genes conferring resistance to diseases and pests, enabling the development of superior crop cultivars (Salgotra and Chauhan 2023). Local plant genotypes such as Super tomatoes constitute a valuable genetic reservoir for developing crop varieties with enhanced disease and pest resistance, as well as increased yield. This study will contribute significantly to tomato breeding programs in terms of developing productive, disease-resistant and consumer-preferred varieties. Further studies should be conducted in the field or in the greenhouse to confirm these findings.

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Author's Contributions

Authors declare the contribution of the authors is equal.

Statement of Conflict of Interest

The authors have declared no conflict of interest.

ÖZET

Bu çalışmada Iğdır Ovası'nda yaygın olarak yetiştirilen Süper domates genotiplerinin morfolojik özelliklerinin karakterize edilmesi ve Süper domates genotipinin *Pseudomonas syringae* pv. *tomato* (*Pst*) ve *Xanthomonas euvesicatoria* pv. *perforans* (*Xep*)'in neden olduğu bakteriyel hastalıklara reaksiyonunun belirlenmesi amaçlanmıştır. Süper domates genotipleri, 2021-2022 hasat sezonununda 20 farklı bölgeden toplanmıştır. Bitki özelliklerini karakterize etmek için domates genotiplerinden laboratuvarda morfolojik ve fizyolojik ölçümler alınmıştır. Ayrıca, Süper domatesin *Pst* ve *Xep* enfeksiyonuna reaksiyonunu değerlendirmek için bitki yetiştirme odasında saksı denemeleri gerçekleştirilmiştir. Analizlerin sonucunda, bitki morfolojisi ve büyümesine ilişkin veriler elde edilmiştir. Bu veriler arasında bitki boyları (136.9-88.7 cm), kök uzunlukları (69.0-46.3 cm), gövde çapları (2.17-1.52 cm), bitki taze ağırlıkları (596-426 g), bitki kuru ağırlıkları (127.6-94.0 g), kök taze ağırlıkları (74.5-51.8 g), kök kuru ağırlıkları (24.3-11.9 g), bitki başına verim (4717.3-2906.5 g), ortalama meyve ağırlığı (385.2-223.7 g), meyve uzunluğu (55.5-50.3 mm) ve ortalama meyve çapı (96.0-81.1 mm) ölçümleri yer almıştır. Domates meyvelerinin fizyolojik özellikleri açısından, suda çözünür kuru madde içeriği %4.55 ile %4.11 arasında, meyve suyu pH'ı 4.69 ile 4.43 arasında, titrasyon asitliği 3.16 ile 2.93 mval 100 ml^{-1} arasında, C vitamini içeriği 26.63 ile 17.80 mg/100 g arasında, likopen içeriği 2951.1 ile 2629.5 ng/µl arasında ve β-karoten içeriği 272.55 ile 228.82 ng/µl arasında değişmiştir. Ayrıca, saksı denemeleri, Süper domates genotipinin hem *Pst* hem de *Xep* enfeksiyonlarına karşı orta düzeyde duyarlılık gösterdiğini, hastalık şiddeti endekslerinin (DSI) sırasıyla 2.4 ve 2.2 olduğunu göstermiştir.

Anahtar kelimeler: Süper domates, bakteriyel leke, bakteriyel benek, *Xep*, *Pst*, Iğdır.

REFERENCES

Abrahamian P., Klein-Gordon J.M., Jones J.B., Vallad G.E., 2021. Epidemiology, diversity, and management of bacterial spot of tomato caused by *Xanthomonas perforans*. Applied Microbiology and Biotechnology, 105 (16-17), 6143–6158.

Akbaba M., Dönmez M.F., Hürkan K., 2025. Characterization of causal agents of bacterial spot on tomato fields in Iğdır Plain (Turkiye). Journal of Agricultural Science and Technology, 0-0. (Accepted for publication, in press)

Akbaba M., Hürkan K., Özcan O., 2023. Characterization of causal agents of bacterial canker on apricot plantations and risk mapping using GIS in Aras Basin (Türkiye). Journal of Phytopathology, 171 (10), 517-536.

Akbaş B., Kunter B., Ilhan D., 2009. Influence of leafroll on local grapevine cultivars in agroecological conditions of Central Anatolia region. Horticultural Science, 36 (3), 97-104.

Al-Aysh F., Kutma H., Serhan M., Al-Zoubai A., Al-Naseer M.A., 2012. Genetic analysis and correlation studies of yield and fruit quality traits in tomato (*Solanum lycopersicum* L.). New York Science Journal, 5 (10), 142-145.

Al-Dahmani J.H., Abbasi P.A., Miller S.A., Hoitink H.A., 2003. Suppression of bacterial spot of tomato with foliar sprays of compost extracts under greenhouse and field conditions. Plant Disease, 87 (8), 913-919.

Aoun A.B., Lechiheb B., Benyahya L., Ferchichi A., 2013. Evaluation of fruit quality traits of traditional varieties of tomato (*Solanum lycopersicum*) grown in Tunisia. African Journal of Food Science, 7 (10), 350-354. https://doi.org/10.5897/AJFS2013.1067

Aydın G., Aktaş H., 2023. Bazı kiraz ve kokteyl domates hatlarının biyokimyasal içeriklerinin belirlenmesi. Türk Bilim ve Mühendislik Dergisi, 5 (2), 97-111.

Bakır V., Özdemir Z., Yardım H., 2012. Reaction of some popular hybrid tomato cultivars grown in Aegean region to bacterial speck disease and determination of disease incidence in Şahnalı, Aydın. The Journal of Turkish Phytopathology, 41 (1-2-3), 37-42.

Bode D., Elezi F., Gixhari B., 2013. Morphological characterisation and interrelationships among descriptors in *Phaseolus vulgaris* accessions. Agriculture and Forestry-Poljoprivreda i šumarstvo, 59 (2), 175-185.

Canzoniere P., Francesconi S., Giovando S., Balestra G., 2021. Antibacterial activity of tannins towards P*seudomonas syringae* pv. *tomato*, and their potential as biostimulants on tomato plants. Phytopathologia Mediterranea, 60 (1), 23-36. https://www.jstor.org/stable/27248654

Cemeroğlu B., 1992. Meyve ve Sebze İşleme Endüstrisinde Temel Analiz Metotları. Ankara, Biltav Yayınları, No:02-2

Chambers S.C., Merriman P.R., 1975. Perennation and control of *Pseudomonas syringae* pv. *tomato* in Victoria. Australian Journal of Agricultural Research, 26, 657-663.

Che K., Liang C., Wang Y., Jin D., Wang B., 2003. Genetic assessment of watermelon germplasm using the AFLP technique. Hortscience, 38 (1), 81-84.

Constantin E.C., Cleenwerck I., Maes M., Baeyen S., Van Malderghem C., De Vos P., Cottyn B., 2016. Genetic characterization of strains named as *Xanthomonas axonopodis* pv. *dieffenbachiae* leads to a taxonomic revision of the *X. axonopodis* species complex. Plant Pathology, 65 (5), 792–806. https://doi.org/10.1111/PPA.12461

Dal Y., Kayak N., Kal Ü., Seymen M., Türkmen Ö., 2017. Yerel kavun (*Cucumis melo* L.) genotiplerinin bazı morfolojik özellikleri. Akademik Ziraat Dergisi, 6 (Özel Sayı), 179-186.

Eenink A.H., 1981. Partial resistance in lettuce to downy mildew (*Bremia lactucae*). 1. Search for partially resistant genotypes and influence of certain plant characters and environments on the resistance level. Euphytica, 30, 619-628.

Ekici O., Baştaş K., 2014. Determination of the resistance reactions of some tomato cultivars against bacterial speck disease. Selcuk Journal of Agriculture and Food Sciences, 28 (2), 42-51.

Eser B., Saygılı H., Göçgol A., İlker E., 2005. Tohum Bilimi ve Teknolojisi, Ege Üniversitesi Tohum Teknolojisi Uygulama ve Araştırma Merkezi, İzmir, Cilt 1, Yayın no:3.

FAO, 2022. Tomatoes, Food and Agriculture Organization of the United Nations (FAO), https://www.fao.org/faostat/en/#data/QCL/visualize (accessed date: 07.05.2024).

Felföldi Z., Ranga F., Roman I.A., Sestras A.F., Vodnar D.C., Prohens J., Sestras R.E., 2022. Analysis of physico-chemical and organoleptic fruit parameters relevant for tomato quality. Agronomy, 12 (5), 1232.

Figueiredo-González M., Valentao P., Pereira D.M., Andrade P.B., 2017. Further insights on tomato plant: cytotoxic and antioxidant activity of leaf extracts in human gastric cells. Food and Chemical Toxicology, 109, 386-392.

Fischer R.A., 2001. Selection traits for improving yield potential. In: Application of Physiology in Wheat Breeding, Reynolds, A.P., Ortiz-Monasterio, J.I., McNab, A., (Eds.), CIMMYT, Mexico, 148-159.

Giorio G., Stigliani A.L., D'Ambrosio C., 2007. Agronomic performance and transcriptional analysis of carotenoid biosynthesis in fruits of transgenic highcaro and control tomato lines underfield conditions. Transgenic Research, 16 (1), 15–28. https://doi.org/10.1007/s11248-006-90253

Gross T., Johnston S., Barber C.V., 2006. The convention on biological diversity: understanding and ınfluencing the process, United Nations University Institute of Advanced Studies, COP Secretariat, Ministry of the Environment, p 70.

Hanson P.M., Yang R.Y., Wu J., Chen J.T., Ledesma D., Tsou S.C., Lee T.C., 2004. Variation for antioxidant activity and antioxidants in tomato. Journal of the American Society for Horticultural Science, 129 (5), 704-711.

Horuz S., Serin M., 2024. Occurrence and pathogenicity of *Stenotrophomonas* spp. and *Paenibacillus* spp. on tomato plants in Turkey. Journal of Plant Pathology, 106, 191–201. https://doi.org/10.1007/s42161-023-01540-9

Hutton S.F., Scott J.W., Yang W., Sim S.C., Francis D.M., Jones J.B., 2010. Identification of QTL associated with resistance to bacterial spot race T4 in tomato. Theoretical and Applied Genetics, 121, 1275-1287.

Ji P., Campbell H.L., Kloepper J.W., Jones J.B., Suslow T.V., Wilson M., 2006. Integrated biological control of bacterial speck and spot of tomato under field conditions using foliar biological control agents and plant growth-promoting rhizobacteria. Biological Control, 36 (3), 358-367.

Jones J.B., Lacy G.H., Bouzar H., Stall R.E., Schaad N.W., 2004. Reclassification of the Xanthomonads associated with bacterial spot disease of tomato and pepper. Systematic and Applied Microbiology, 27 (6), 755–762. https://doi.org/10.1078/072320204236988432

Karagöz A., Zencirci N., Tan A., Taşkın T., Köksel H., Sürek M., Toker C., Özbek K., 2010. Bitki Genetik Kaynaklarının Korunması ve Kullanımı. Ziraat Mühendisliği VII. Teknik Kongresi. 11-15 Ocak 2010, Ankara, 155-177.

Karataş A., Büyükdinç D.T., İpek A., Yağcıoğlu M., Sönmez K., Ellialtıoğlu Ş.Ş., 2017. Türkiye'de fasulyede yapılan morfolojik ve moleküler karakterizasyon çalışmaları. Türk Bilimsel Derlemeler Dergisi, 10 (1), 16-27.

Kathayat K., Singh A., Rawat M., 2015. Morphological characterization of tomato (*Solanum lycopersicum* L.) germplasm in Tarai region of Uttarakhand. HortFlora Research Spectrum, 4 (3), 220-223.

Keskin G., Gül U., 2004. Domates, Tarımsal Ekonomi Araştırma Enstitüsü, T.E.A.E-Bakış, Sayı:5, Nüsha:13, Ankara.

Kozik E.U., 2002. Studies on resistance to bacterial speck (*Pseudomonas syringae* pv. *tomato*) in tomato cv. Ontario 7710. Plant Breeding, 121 (6), 526-530.

Kozik E.U., Sobiczewski P., 2007. Assessment of inoculation techniques suitability for determination of tomato plants resistance to bacterial speck (*Pseudomonas syringae* pv. *tomato*). Phytopathologia Polonica, 44, 17-25.

Lai Y.R., Lin C.H., Chang C.P., Ni H.F., Tsai W.S., Huang C.J., 2021. Distribution of copper resistance gene variants of *Xanthomonas citri* subsp. *citri* and *Xanthomonas euvesicatoria* pv. *perforans*. Plant Protection Science, 57 (3), 206-216.

Liu X., Wang L., Zhang H., Li Y., Yang W., 2017. Genetic and fruit trait differences between Chinese elite lines/varieties and American varieties of processing tomato. Scientia Horticulturae, 224, 251-257. https://doi.org/10.1016/j.scienta.2017.06.023

Madakbaş S.Y., Ergin M., 2011. Morphological and phenological characterization of Turkish bean (*Phaseolus vulgaris* L.) genotypes and their present variation states. African Journal of Agricultural Research, 6 (28), 6155-6166.

McLeod A., Masimba T., Jensen T., Serfontein K., Coertze S., 2017. Evaluating spray programs for managing copper resistant *Pseudomonas syringae* pv. *tomato* populations on tomato in the Limpopo region of South Africa. Crop Protection, 102, 32-42.

Morinière L., Burlet A., Rosenthal E.R., Nesme X., Portier P., Bull C.T., Lavire C., Fischer-Le Saux M., Bertolla F., 2020. Clarifying the taxonomy of the causal agent of bacterial leaf spot of lettuce through a polyphasic approach reveals that *Xanthomonas cynarae* Trébaol et al. 2000 emend. Timilsina et al. 2019 is a later heterotypic synonym of *Xanthomonas hortorum* Vauterin et al. 1995. Systematic and Applied Microbiology, 43 (4), 126087. https://doi.org/10.1016/J.SYAPM.2020.126087

Mumtaz S., Hameed M., Ahmad F., Ahmad M.S.A., Ahmad I., Ashraf M., Saleem M.H., 2021. Structural and functional determinants of physiological pliability in *Kyllinga brevifolia* rottb. for survival in hyper-saline salt marshes. Water, Air, & Soil Pollution, 232, 1-21.

Nagata M., Yamashita I., 1992. Simple method for simultaneous determination of chlorophyll and carotenoids in tomato fruit. Nippon Shokuhin Kogyo Gakkaishi, 39 (10), 925-928.

Osdaghi E., Taghavi S.M., Hamzehzarghani H., Fazliarab A., Lamichhane J.R., 2017. Monitoring the occurrence of tomato bacterial spot and range of the causal agent *Xanthomonas perforans* in Iran. Plant Pathology, 66 (6), 990-1002.

Özbay N., Ateş K., 2015. Bingöl ili ekolojik şartlarına uygun sofralık domates çeşitlerinin belirlenmesi. Türk Tarım ve Doğa Bilimleri Dergisi, 2 (2), 226-236.

Özden E., Akbaba M., 2023. Determination of some morphological, viability and physiological characteristics of Iğdır super tomato local genotype seeds. 13 th International Conference on Agriculture, Animal Science and Rural Development, November 28-29, 2023 Uşak / Türkiye, 636-650 pp.

Özenç D.B., Şen O., 2017. Farklı gelişim dönemlerinde uygulanan deniz yosunu gübresinin domates bitkisinin gelişim ve bazı kalite özelliklerine etkisi. Akademik Ziraat Dergisi, 6 (özel sayı), 235-242.

Paksoy M., 2003. Konya ekolojisinde değişik ekim dikim zamanlarında yetiştirilen bazı sanayilik domates çeşitlerinde verim ve kalite özelliklerinin incelenmesi. Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi, 17 (32), 6-9.

Pal R.S., Hedau N.K., Kant L., Pattanayak A., 2018. Functional quality and antioxidant properties of tomato genotypes for breeding better quality varieties. Electronic Journal of Plant Breeding, 9 (1), 1-8. https://doi.org/10.5958/0975-928X.2018.00001.7

Peixoto J.V.M., Garcia L.G.C., Nascimento A.D.R., Moraes E.R.D., Ferreira T.A.P.D.C., Fernandes M.R., Pereira V.D.A., 2018. Post-harvest evaluation of tomato genotypes with dual purpose. Food Science and Technology, 38 (2), 255-262. https://doi.org/10.1590/1678-457X.00217

Potnis N., Timilsina S., Strayer A., Shantharaj D., Barak J.D., Paret M.L., Vallad G.E., Jones J.B., 2015. Bacterial spot of tomato and pepper: Diverse *Xanthomonas* species with a wide variety of virulence factors posing a worldwide challenge. Molecular Plant Pathology, 16 (9), 907-920. https://doi.org/10.1111/mpp.12244

Qiao K., Liu Q., Huang Y., Xia Y., Zhang S., 2020. Management of bacterial spot of tomato caused by copper-resistant *Xanthomonas perforans* using a small molecule compound carvacrol. Crop Protection, 132, 105114. https://doi.org/10.1016/j.cropro.2020.105114

Raj T., Bhardwaj M.L., Pal S., 2018. Performance of tomato hybrids for quality traits under Mid-hill conditions of Himachal Pradesh. International Journal of Chemical Studies, 6 (4), 2565-2568.

Reis Pereira M., Dos Santos F.N., Tavares F., Cunha M., 2023. Enhancing host-pathogen phenotyping dynamics: early detection of tomato bacterial diseases using hyperspectral point measurement and predictive modeling. Frontiers in Plant Science, 14, 1242201. https://doi.org/10.3389/fpls.2023.1242201

Renna M., D'Imperio M., Gonnella M., Durante M., Parente A., Mita G., Santamaria M., Serio F., 2019. Morphological and chemical profile of three tomato (*Solanum lycopersicum* L.) landraces of a semi-arid mediterranean environment. Plants, 8 (8), 273. https://doi.org/10.3390/plants8080273

Roberts P.A., 2002. Concepts and consequences of resistance. In: Plant resistance to parasitic nematodes. Starr, J.L., Cook, R., Bridge, J., (Eds.), CABI Publishing, UK.pp. 23-42. https://doi.org/10.1079/9780851994666.0023

Salgotra R.K., Chauhan B.S., 2023. Genetic diversity, conservation, and utilization of plant genetic resources. Genes, 14 (1), 174. https://doi.org/10.3390/genes14010174

Sharma S., Bhattarai K., 2019. Progress in developing bacterial spot resistance in tomato. Agronomy, 9 (1), 26. https://doi.org/10.3390/agronomy9010026

Silvera-Pérez E., Maeso D., Catara V., Rubio L., Leoni C., Amaral J., Estelda C., Hernández M., Bóffano L., González P., 2023. *Pseudomonas* spp. associated with tomato pith necrosis in the Salto area, Northwest Uruguay. European Journal of Plant Pathology, 165 (4), 715-724.

Singh B., Goswami A., 2015. Morphological and molecular characterization of tomato (*Lycopersicum esculentum* Mill) genotypes. Vegetos, 28 (4), 67-75.

Tezcan O.S., Tütüncü A.Ç., Ay A., Özer H., 2022. Aşılı domates fidesi üretiminin domates bitkilerinin kalitesine etkileri. Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi, 8 (3), 423– 429. https://doi.org/10.24180/ijaws.1163857

Tosun K., Aktaş H., 2022. Ebeveyn potansiyeli yüksek bazı domates hatlarının verim ve meyve kalite niteliklerinin belirlenmesi. Türk Bilim ve Mühendislik Dergisi, 4 (2), 100-113. https://doi.org/10.55979/tjse.1187438

Turhan A., Şeniz V., 2009. Türkiye'de yetiştirilen bazı domates gen kaynaklarının verim, meyve ve morfolojik özelliklerinin belirlenmesi. Selcuk Journal of Agriculture and Food Sciences, 23 (50), 52-59.

TUIK, 2022. Bitkisel Üretim İstatistikleri: Domates Üretimi. https://data.tuik.gov.tr/Kategori/GetKategori?p=tarim-111anddil=1 (accessed date: 07.05.2024. (In Turkish)

Umesha S., Kavitha R., 2011. Induction of cinnamyl alcohol dehydrogenase in bacterial spot disease resistance of tomato. Journal of Bacteriology Research, 3 (2), 16-27.

Yang W.C, Francis D.M., 2007. Genetics and breeding for resistance to bacterial diseases in tomato: prospects for marker assisted selection. In: Genetic Improvement of Solanaceous Crops, 1, Tomato. Razdan M.K., Mattoo A.K. (Eds.), Science Publishers, New Hampshire, USA, pp. 379-419.

Yucel S., Can C., Yurtmen M., Cetinkaya-Yildiz R., Aysan Y., 2008. Tomato pathology in Turkey. The European Journal of Plant Science and Biotechnology, 2 (1), 38-47.

Zhan J., Thrall P.H., Burdon J.J., 2014. Achieving sustainable plant disease management through evolutionary principles. Trends in Plant Science, 19 (9), 570-575.