Research Article

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Effects of Potato Virus Y Strains on Local Tomato Genotype "Sazlıca"

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ABSTRACT

The aim of this study was to investigate incidence of PVY and the effect of PVY strains on the yield and fruit quality of local tomato genotype "Sazlıca", which is important for local producers and farmers at different stages of development. Symptomatic samples were collected from Sazlıca region to investigate PVY infection incidence and 10 % of samples were found positive by DAS-ELISA analysis. Seedlings were mechanically inoculated with two different PVY strains in three combinations ($PVY^{NW,}$ $PVY^{NTN,}$ and $^{NW+NTN}$) at four different growth stages (7, 14, 21 and 28 days old) for the assessment of PVY strains' effects on plants. PVY susceptible commercial tomato cultivar H2274 was used as control. Among the PVY strains, PVY^{NW} alone has shown the maximum infection rates in the replications and varieties. Moreover, 7 days old inoculated plants have displayed the maximum PVY infections as expected, whereas only one infection was observed in 28 days old plants. There were no symptoms detected on fruits for all replications. In the fruit quality and yield parameters, the highest fruit number, length, width, weight, and brix value were observed on PVY^{NW+NTN} within 21 days plants. PVY infections on Sazlıca tomatoes were proven and PVY^{NW} was found to be the most effective strain for the yield and fruit quality of Sazlıca tomatoes among the tested strains. Based on the data provided by this study, it is thought that it will be possible to develop more effective management methods for PVY virus.

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Introduction

Tomato (*Solanum lycopersicum* L.) plant is a family member of Solanaceae, including more than 3000 species with many economically important plants. Due to their morphological and ecological differences, *Solanum* species can be found on all warm and tropical continents. [1].

It arises from Andean land presently covering in part of Chile, Ecuador, Bolivia, Colombia and Peru. In Turkey, Adana province had the highest tomato production at the beginning of

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the 19th century. Therefore tomato production has great contribution in Turkey's economy [2, 3]. In 2017 tomato production was 182.302.395 million tons whereas tomato harvested area was 4.848.384 worldwide [4]. Being the most grown vegetable in the whole world adds up to its the importance. First countries in both fresh and paste tomatoes production are USA, Italy followed by Turkey. In 2017, the production potential of Turkey was of 187,070 tons [5]. There are certain factors with key roles for the advancement of tomato production in Turkey, such as appropriate ecological conditions, income source for growers, and increase in public demand [6]. Comparing the other vegetables and fruits processed, tomato paste furnishes the greatest amount of foreign exchange earned by our country. Tomato processing also creates employment which is a great economical support for agriculture [7]. It also has a significant economic value as frozen food, canned product, pickles, fruit juice, paste, and ketchup.

This economical plant has many threats in nature lowering its agricultural yield and quality. *Potato virus Y* (PVY) is the most harmful virus found in tomato and other *Solanaceous* crops production areas [8]. PVY has a broad host range normally infecting plants of more than nine families, containing 14 genera of the *Solanaceae*, including tomato, pepper, tobacco, and eggplant [9]. This virus spreads with the help of small insects called aphids. Aphids are the most important and hazardous vectors of potato viruses with more than 40 species transmitting PVY in natural conditions [10]. The current classification of PVY isolates are carried out based on primary hosts, symptoms caused in various plants, and serological response to monoclonal antibodies. These isolates have been categorized in three major strains; PVY^N, PVY^O and PVY^C [11]. Strains of PVY includes PVY^N (Tobacco venial necrosis strains), PVY^O (Ordinary stains), and PVY^C (Stipple-streak strain, including potato virus C). The major diseases caused by PVY consist of mild to harsh leaf mottling, leaf-drop streak (PVY^O) with necrosis along the veins of underside the leaflets (PVY^N), and stipple streak (PVY^C) [12]. Making comparison to other Solanaceae crops, tomato appears to be insufficiently selective considering symptoms caused by diverse PVY isolates [13]. PVY^C, PVY^O and PVY^N strains infect tomato plant [14] while PVY^O and PVY^C strains infect pepper only [15]. Severe mosaics, frequently followed by interveinal yellow and whitish spots on potato fruits indicate infections by PVY^N strains. In the past 20 years, two

new PVY variants were identified and assorted as subgroups of PVY^{N} strain, PVY^{NTN} and PVY^{NW} (In North America named $PVY^{N:O}$). PVY^{NTN} is the causal agent of potato tuber necrotic ring spot disease and PVY^{NW} was found in Poland in 1984 [16].

Control of the economic damages caused by this viral pathogen is a burning question in the agricultural practices of 21st century. Moreover, to ensure an effective control strategy of this pathogen there are certain features that pointed out, such as its unique nature as its mode and site of infection, favorable environmental conditions, different biotic and abiotic factors, and age of infection. Infection of PVY in different growth age of tomato hinders the total quality of the products. Hence, this pathogen causes great damage in both small fields and large scale productions areas. As a result of extreme nature and huge losses, PVY is ranked at 5th position in term of worldwide economic damages among crop pathogens [17].

Sazlıca tomato is one of the most consumed tomatoes in Sazlıca town and Niğde province. It is also source of income in Niğde. It is known to be rich in salt compared to other local tomato varieties. There is no study on PVY incidence and its effects on this local important tomato genotype Sazlıca reported up to date. The purpose of this research is to investigate PVY incidence and the effect of PVY infection at different developmental stages (after 7, 14, 21 and 28 days germination) on yield and fruit quality of local tomato genotype *"*Sazlıca" in Sazlıca town and Niğde region.

Materials and Methods

Materials for the study

Plant materials

To evaluate the effects of PVY infection at different growth stages "Sazlıca" genotype (168 plants), along with PVY susceptible H2274 commercial tomato (174 plants) were tested. The seeds of Sazlıca tomato were collected from various commercial companies in Niğde town, while the seeds of H2274 were obtained from the faculty of Agricultural Science particularly the Department of Plant Production and Technologies.

Virus isolates

PVY isolates from *Potato virus* Y^{NW} *and Potato virus* Y^{NTN} strains were used in the experiment. Tobacco plants inoculated with these isolates were obtained from Prof. Dr. Çiğdem Ulubaş Serçe (NOHU).

Field survey

The survey was conducted during the summer growing season especially between June and July in 2018. A total of 50 leaf samples showing suspicious virus symptoms were randomly collected from different fields in Sazlıca town. Each field a number of samples were obtained; Field 1 (7 samples), Field 2 (11), Field 3 (14 samples) and Field 4 (18 samples). The samples were collected by plastic bags and instantly stored in a cooling box and later transferred in to laboratory refrigerator under -80 °C until testing time.

Experimental design

To evaluate the effects of virus infection time at different growth stages on local cultivar Sazlıca tomato, seeds were germinated in plastic pods at greenhouse condition. As a control, commercial tomato variety H2274 was used. Each plot was included fifteen plants with three replications. After 7 days, 14 days, 21 days and 28 days of germination, two virus strains were used for inoculation in three different combinations; PVY^{NW}, PVY^{NTN} and PVY^{NTN+NW} with uninfected controls.

Mechanical inoculation of virus

During the growing stages of tomato plants, the PVY virus strains (PVY^{NW} and PVY^{NTN}) were inoculated on tobacco plants and these plants were later used for inoculation source for tomato plants. Virus inoculation for tomato plants was carried out by mechanical virus inoculation method. Leaf extract was added, PVY inoculation buffer (pH: 7.4) including 0.199 g/l KH_2PO_4, 1.14 g/l Na_2HPO_4, 0.1% Na_2SO_3, and 1% PVP-40 were used. Infected tobacco plant materials were ground in mortal and pestle to macerate the tissue and it was the initiating step in the preparation of plant leaf extract for inoculation. The plants were kept in shade for 24 hr in order to sensitize them for the virus and following day virus inoculating on plants' leaves were performed. At the starting point, carborundum was sprinkled on to the leaves and the virus preparation was rubbed on tomato leaf surface in such a way as to break the surface cells without making too much mechanical damage. The

leaves were rinsed with tap water soon after 2-3 hours of inoculation. Then, inoculated plant leaf samples were collected representing whole plant part. These inoculations were repeated at 7^{th}, 14^{th}, 21^{st}, and 28^{th} days.

Double antibody sandwich enzyme-linked immune sorbent assay (DAS-ELISA)

PVY presence was tested on the samples collected from the department's greenhouse and the survey samples collected from Sazlıca town area by using DAS-ELISA, according to the instructions of antisera's manufacturer (Bioreba AG, Switzerland) corresponding to the PVY polyclonal antisera [18]. Before samples analyzed, each sample was transferred into new 2 ml tube and added with extraction buffer; 200 µl of sample juice and 200 µl of extraction. In the first step of DAS-ELISA, coating was done with 40 µl of IgG in 40 ml of coating buffer and 200 µl were added to each well. The plates were covered tightly and incubated 30 °C for 4 hours. Then plates were washed with washing buffer three times. Each well was covered with 200 µl of sample and placed in a humid box and left at 4 °C for overnight. Following day plates were washed as in step one, then 200 µl of 40 µl of enzyme conjugate in 40 ml of conjugate buffer solution was added into each well. Plates were placed in humid box and incubated at 30 ℃ for 5 hours. Then the plates were washed as described previously and 200 µl of dissolved pNPP (Para-nitro phenyl-phosphate) at 0.04 mg in 40 ml of substrate buffer was added into each well along with positive and negative control samples and extraction buffer were added on each well. This procedure was repeated in triplicates. The plates were incubated at room temperature (20-25 ℃) for 2 hours. ELISA result was visually observed based on yellow color development in the plates and then measured at 405 nm on Biotek EL800 ELISA reader.

Calculation of PVY infection rate

In order to determine the percentage of PVY in inoculated tomato plants, the following formula were used:

$$\textbf{\% PVY incidence} = \frac{\textbf{Tomato samples confirmed positive by ELISA}}{\textbf{Total tomato samples tested}} \times \mathbf{100}$$

Yield and fruit quality parameters

Ripen fruits from each sampling in the three different replication (stages) were collected with clean plastic bags by hand and were stored in a refrigerator at +4 °C until the study was conducted. These different parameters such as fruit length (FL), fruit width (FW^{th}) and fruit weight were observed and fruits were also measured for their soluble-solid content (Brix content) by using A. KRÜSS Optronic GmbH, AR-2008.

Data analysis

The samples were also compared to present the variance among replications and strains. The fruit quality parameters were analyzed by using post hoc, Duncan, the software IBM SPSS statistical 25 version.

After all analysis, all the infected samples were autoclaved for the control of contamination.

Results

Field survey

During the survey, different virus symptoms were observed in the tomato fields at Sazlıca town. The tomato plants showing viral infection symptoms were collected and tested by DAS-ELISA. The symptoms we focused on include leaf rolling, necrotic, yellow leaf curl, and stunting. Five samples in the fields located in Sazlıca have shown positive results. The highest number of PVY positive reactions was observed with the samples collected from Field 1; 14%, in comparison to the samples collected from Field 4, Field 2, and Field 3 with 11%, 9%, and 7% infection rates respectively from Sazlıca town. The average percentage of PVY positive samples of the fields from Sazlıca town were 10%.

Mechanical inoculation

The symptoms appearance on tomato leaves varied according to inoculation time, PVY strain, plant age, and environmental conditions. PVY symptoms usually became visible four to five weeks after inoculation (Figure 1). Samples were collected from all inoculated plants along with controls, and were tested for the presence of PVY using DAS-ELISA. The main symptoms observed on the plants during infection development are shown in Figure 1.

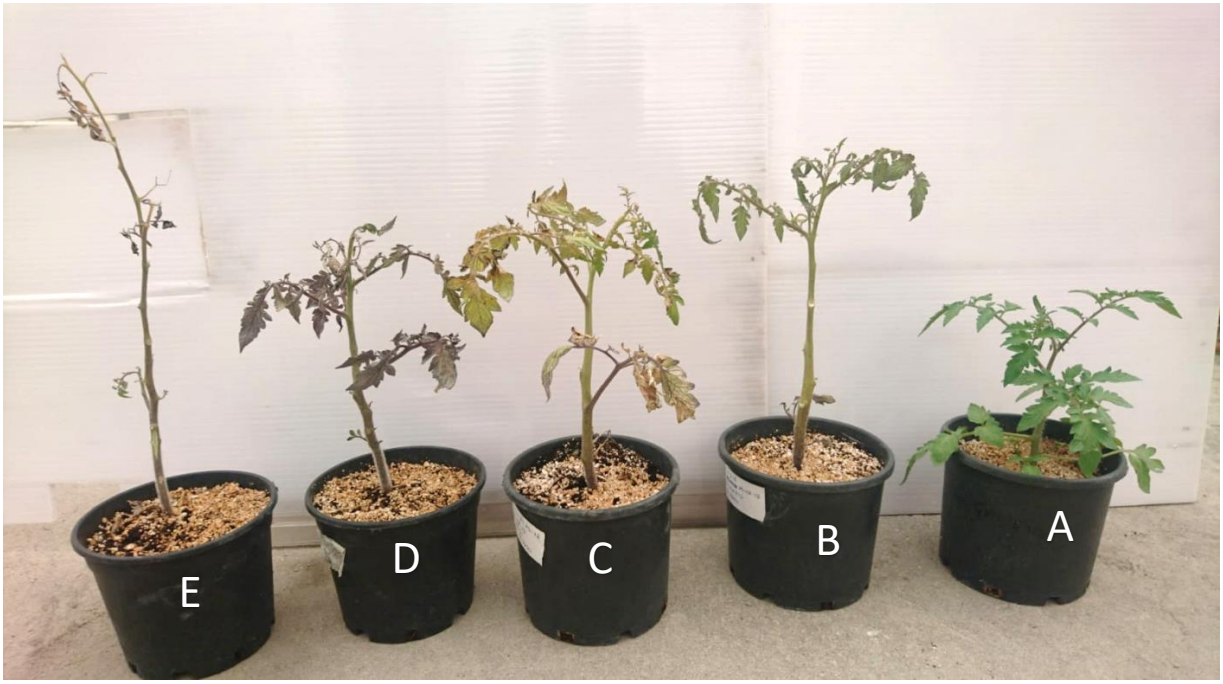

Fig 1 (**A**) Healthy plant, (**B**) leaf rolling and yellowing (**C**) Leaf yellowing and terminal leaves dying (**D**) severe yellowing and slight dark brown color (**E**) Dark brown color and all leaves dying.

DAS-ELISA

The samples of local genotype "Sazlıca" and H2274 plants inoculated by $PVY^{NW,}$ PVY^{NTN}, and mixed of PVY^{NW}+PVY^{NTN} have shown negative and positive reactions. All control plants were negative. PVY have been identified in 112 out of 392 inoculated samples. The result of DAS-ELISA was visually observed with yellow color development in the wells of ELISA plates. On seven days inoculated plants, the maximum ELISA positive result was recorded for H2274 with mixed PVY strains (PVY^{NW+} $PVY^{NTN)}$ (84.62%), followed by Sazlıca with PVY^{NW} strain (72.72%). In fourteen days inoculated plants, the maximum ELISA positive results were achieved by Sazlıca with the PVY^{NW} strain (53.53%). In twenty-one days inoculated plants, the maximum ELISA positive results were obtained by H2274 with PVY^{NTN} (46.67%). In twenty-eight days inoculated plants, only one positive sample was found and it was Sazlıca with PVY^{NW}. The details of all ELISA positive results are also summarized in Table 1.

Table 1 The details of ELISA result in Sazlıca and H2274 varieties and PVY strains in 7 days, 14 days, 21 days and 28 days inoculations' during the current study

Variety	Inoculation date	Total # of tested samples	Total # of infected samples	PVY strains	Infection rate (%)
Sazlıca	7 days	33	8	PVY^{NW}	72.72%
		(11 plants per strain)	7	PVY^{NTN}	63.63%
			5	PVY^{NW+NTN}	45.45%
H2274		39	9	PVY^{NW}	69.23%
		(13 plants per strain)	5	PVY^{NTN}	38.46%
			11	PVY^{NW+NTN}	84.62%
Sazlıca	14 days	45	8	PVY^{NW}	53.33%
		(15 plants per strain)	7	PVY^{NTN}	46.67%
			7	PVY^{NW+NTN}	46.67%
H2274		45	8	PVY^{NW}	53.33%
		(15 plants per strain)	7	PVY^{NTN}	46.67%
			6	PVY^{NW+NTN}	40%
Sazlıca	21 days	45	3	PVY^{NW}	20%
		(15 plants per strain)	2	PVY^{NTN}	13.33%
			2	PVY^{NW+NTN}	13.33%
H2274		45	7	PVY^{NW}	46.67%
		(15 plants per strain)	6	PVY^{NTN}	40%
			3	PVY^{NW+NTN}	20%
Sazlıca	28 days	45	1	PVY^{NW}	6.67%
		(15 plants per strain)	0	PVY^{NTN}	0%
			0	PVY^{NW+NTN}	0%
H2274		45	0	PVY^{NW}	0%
		(15 plants per strain)	0	PVY^{NTN}	0%
			0	PVY^{NW+NTN}	0%

Yield and fruit quality parameters

The effect of PVY at different growth stages on yield of local tomato genotype “Sazlıca” and H2274 variety on fruit length, weight, width and brix were analyzed. The results obtained were analyzed with variance test in post hoc, Duncan, SPSS and are summarized in Table 2.

Table 2 Fruit quality parameters results of 7 days, 14 days and 21 days inoculated plants (the average of infected plants along with control plants)

Tomato /virus strain	7 days inoculated plants				14 days inoculated plants				21 days inoculated plants			
	Fruit length (cm)	Fruit weight (g)	Fruit width (cm)	Brix (%)	Fruit length (cm)	Fruit weight (g)	Fruit width (cm)	Brix (%)	Fruit length (cm)	Fruit weight (g)	Fruit width (cm)	Brix (%)
H2274 PVY^{NTN}	3.64	27.08	4.03	5.91	3.55	17.83	2.32	3.50	3.62	21.45	3.75	4.50
H2274 PVY^{NW}	4.03	34.29	3.30	5.24	2.47	28.58	3.57	4.58	1.83	12.01	1.50	1.73
H2274 PVY^{NTN+NW}	3.78	18.80	4.00	5.42	3.35	27.64	4.05	5.73	1.16	6.11	1.33	1.83
Sazlıca PVY^{NTN}	1.77	17.21	2.39	3.27	3.34	27.32	3.56	4.48	3.66	20.16	4.16	4.26
Sazlıca PVY^{NW}	2.31	18.11	2.90	3.94	2.97	20.55	2.94	4.56	1.50	13.70	1.66	1.90
Sazlıca $PVY^{NTN+}PVY^{NW}$	2.40	26.36	3.70	5.16	3.88	26.38	4.27	5.58	4.16	38.39	4.50	6.16
H2274 Control	4.35	39.44	4.00	6.32	4.70	45.38	4.50	6.26	4.10	48.20	4.30	6.60
Sazlıca Control	4.60	30.60	3.85	5.56	4.50	42.66	3.90	6.30	4.80	47.31	4.10	6.50

Fruit quality parameters of seven, 14 and 21 days old inoculated plants

The H2274 variety with PVY^{NW}+PVY^{NTN} and PVY^{NW} in 7 days and H2274 variety with PVY^{NW+NTN} and PVY^{NW} in 21 days inoculated plants obtained the maximum fruit length of 5.5 cm while Sazlıca genotype with PVY^{NTN} and PVY^{NW+NTN} in 14 days inoculated plants obtained the highest height of 5 cm. Both H2274 variety with PVY^{NTN} in 14 days inoculated plants and Sazlıca genotype with PVY^{NW+NTN} in 21 days inoculated plants are recorded with the maximum fruit with of 5.5 cm. The H2274 variety with PVY^{NW} in 7 days inoculated plants achieved the maximum fruit weight of 55.80 g/plant. On the other side Sazlıca genotype with PVY^{NTN} in 14 days inoculated plants showed maximum fruit weight as 51.08 g/plant. The H2274 with PVY^{NTN} in 14 days inoculated plants are observed with maximum fruit brix as 8.1%, while Sazlıca genotype with PVY^{NW} in 14 days inoculated plants showed maximum fruit brix of 6.8% (Table 2).

Discussion

PVY is the most economically important disease problem in tomato plants in many places through the world. This virus is responsible for decrease in yield and quality and causes serious diseases in cultivated hosts, such as tomato, potato, tobacco, and pepper. A total of 392 tomato plant from local genotype “Sazlıca” and PVY susceptible H2274 commercial tomato varieties were mechanically inoculated with PVY strains at different times (7 days, 14 days, 21 days and 28 days). After 6-8 weeks, samples were collected from inoculated plants along with 50 survey samples and tested by DAS-ELISA. The positive result was variable based on the replications, varieties and effect of PVY infection. Based on the survey studies in Sazlıca region, some virus specific symptoms were observed on tomato plants and the results indicate PVY incidence in the region. Due to the high amount of potato and other *Solanecous* plant production in the area, PVY could be easily transmitted to Sazlıca tomato genotype as well. Therefore it has crucial importance to successfully to prevent from and control PVY infections in Sazlıca tomatoes.

Effects of PVY strains on Sazlıca tomatoes were tested with mechanical inoculations under greenhouse conditions. Although the varieties (Sazlıca and H2274), have shown a close positive result, H2274 is found to be more susceptible to PVY infection than Sazlıca

genotype. In seven days inoculated H2274 plant, 25 out of 39 samples has shown positive, whereas Sazlıca have indicated 20 out of 33 samples as positive. In fourteen days inoculated plants, 22 out of 45 Sazlıca samples were positive, while H2274 has shown 21 positive samples out of 45 samples. In twenty-one days inoculated plants, H2274 has shown 16 positive samples out of 45 samples whereas Sazlıca has displayed 7 samples out of 45 samples. In twenty-eight days inoculated plants, Sazlıca has only 1 positive sample out of 45 samples and H2274 has not indicated any positive sample in all samples.

*Among the PVY strains, PVY^{NW} has shown the highest positive reaction in the varieties and the replications except PVY^{NW+NTN} in seven days inoculated plants. PVY^{NW+NTN} showed the highest infection rate in seven days inoculated plants. The infection of PVY^{NW} in Sazlıca seven days inoculated plants was 72.72% compared PVY^{NTN} (63.63%) and PVY^{NW+NTN} (45.45%). While in H2274 seven days inoculated plants, PVY^{NW+NTN} (84.62%) has shown the highest infection rate compared with PVY^{NW} (69.23%) and PVY^{NTN} (38.46%). In Sazlıca fourteen days inoculated plants; PVY^{NW} was the highest percentage which was 53.33%, whereas PVY^{NTN} and PVY^{NW+NTN} had reached a similar percentage which was 46.67%. On the other hand, H2274 fourteen days inoculated plants, PVY^{NW} had the maximum infection rate which was 53.33% compared with PVY^{NTN} (46.67%) and PVY^{NW+NTN} (40%). In Sazlıca twenty-one days inoculated plants, PVY^{NW} had the maximum infection rate which was 20%, whereas the two other strains (PVY^{NTN} and PVY^{NW+NTN}) had similar infection rate (13.33%). No symptoms were observed on fruits for all replications. Therefore, it can be concluded that the PVY^{NW} strain has an importance in management of PVY in Sazlıca tomatoes.

In H2274 twenty-one days inoculated plants, the PVY^{NW} was also had the highest infection rate which was 46.67% compared with PVY^{NTN} (40%) and PVY^{NW+NTN} (20%). In the last inoculated plants, which were after twenty-eight days, only Sazlıca had shown one positive sample and this was from the PVY^{NW} (6.67%) strain while the other strains did not indicate any positive reaction.

The age of the plant is an important factor that takes part the susceptibility of the plants to the viruses. As the age of the plant was older, the effects of the virus were lower. The plants that inoculated after seven days were the most susceptible ones to virus when compared to

other plants inoculated later. The plants inoculated after twenty-eight days were affected by other factors and did not show infection for the virus except one sample which indicates the importance of plant age for infections.

The most previous studies focused on the resistance of plant to the virus and the virus vector. The symptoms of PVY infection differ with varieties, PVY strain, plant age and environmental conditions. A biological assay resulted that cv. Agria is more susceptible to $PVY^{N\text{-}Wi}$ than to PVY^{NTN}, whereas cv. Charlotte is susceptible to both strains. The biological (inoculation) assay also displayed that the expression of symptoms on varieties is strain-dependent. These shows stress the main role of the resistance profile of varieties to explain the balance of the PVY strains in potato crops [19]. The occurrence of PVY on potato plants were investigated and samples were collected from main tomato growing fields in west-bank Palestine by utilizing serological, biological and molecular methods. In DAS-ELISA method, the occurrence of PVY virus was identified at an average of 15.29% and also confirmed by RT-PCR analysis and bioassay test [20]. Researchers studied the distribution and percentage of PVY strains (PVY^{N}, PVY^{O}, PVY^{C}) along with other viruses such as PLRV and PVS and seed tubers were used for sowing materials in the significant potato producing provinces in Turkey [21]. The symptoms induced by single or mixed infection were observed under field conditions. At first, virus-specific polyclonal antibodies were used to analyze a total of 880 leaf samples and almost 83 samples were detected the presence of PVY infection of the first result were re-analyzed by utilizing PVY^{O}, PVY^{N}, PVY^{C}-virus-specific monoclonal antibodies. The ELISA result showed seed potato tubers utilized for the planting materials were infected with the percentage of PVY (17.7%), PLRV (14.2%), PVS (4.6%) and PVX (11.8%). Another group found that all PVY isolates infecting tomato and pepper as a positive for the normal strains of PVY^{O} both ELISA and RT-PCR whereas PVY isolates infecting potato have more heterogeneous and consisted of PVY^{N}, PVY^{NTN} and $PVY^{N\ Wilga}$ strains and some cases mixed infection shown [22]. However, our research had several limitations which are fruit quality parameters and have showed a non-significant in statistical analyzing. In our findings, the PVY susceptible commercial H2274 tomato variety is more susceptible to PVY^{NW} than to PVY^{NTN} and PVY^{NW+NTN}. It is reported that infection rate was higher for plants inoculated at pre-

flowering relative to those inoculated at the post-flowering and the replication different for mechanical inoculation, the interaction of strain and genotype was not statistically significant [23]. Mature-plant resistance can also inhibit PVY^{N} infections but plants need to be physiologically old at the time of highest infection pressure in the late season. Therefore, the use of chatted seed linked with planting as early as possible and early haulm destruction could together be a helpful part of an approach to manage PVY^{N} [24]. The current study also showed us that the infection rate was higher to the plants inoculated seven days when compared to the plant inoculated later and this indicates the importance of plant age for virus infection.

In the fruit quality parameters, among the three replications (seven days, fourteen days and twenty-one days), varieties and strains, the highest fruit length is achieved by Sazlıca PVY^{NW+NTN} which is recorded for 4.16 cm in twenty-one days inoculated plants. The highest fruit weight is reached by Sazlıca PVY^{NW+NTN} which is recorded for 38.29 g/plant in 21 days inoculated plants whereas the minimum fruit is obtained by seven days inoculated plants. On fruit width, the maximum fruit width among the replications, tomato varieties and strains are obtained by Sazlıca PVY^{NW+NTN} with the maximum average of 4.5 cm in twenty-one days inoculated plants. For fruit total soluble solid content (brix), Sazlıca PVY^{NW+NTN} has the maximum average of 6.16% in twenty-one days inoculated plants when compared with other replications. After seven days inoculated plants yielded smaller and produced less tomato compared to 14 days and 21 days plants. In general fruit brix, the fourteen days inoculated plants obtained the maximum fruit brix with the number of 6.8 % (Sazlıca) and 8.1 % (H2274) when compared the seven days and twenty-one days inoculated plants. On the other hand, control plant all of them are closer and have shown a higher percentage when compared with infected plants. Only one infection was observed on 28 days inoculated plants even for repetitions. The findings also showed us that the survey samples have infections and at least one positive sample was found in each field and this indicates how PVY exists in Sazlıca town area. The twenty-eight days inoculated plants also had not produced any infections due to age and physiological conditions of plants. The mechanical inoculation methods were more effective than virus vector transmissions because of the virus was directly transmitted to plants through leaves with high

concentrations. This study is a base for future study of the effect of PVY strains at different growth stages on yield and fruit quality of local genotype in Turkey particularly Sazlıca town/Niğde region.

Conclusion

Tomato is one of the most important vegetable grown worldwide and is now the fourth most saleable fresh-market vegetable after potatoes, lettuce, and onions. Turkey ranks as the 4th biggest producers of tomatoes around the world. Infection of PVY in different strains and growth ages of tomato hinders the total quality-based production of tomato. The current study has importance for knowing the effects of PVY strains on local tomato genotype Sazlıca and this research can be used as starting point for effect of PVY strains on tomato at different growth stages (after 7,14,21 and 28 days). The farmers in Sazlıca area are recommended to remove host plants to minimize or eliminate virus inoculum sources and they should take necessary precautions to prevent from aphids spread which is the most dangerous vector of PVY in early stages of tomato plantlets to decrease the PVY incidence. The farmers are also recommended to plant susceptible crops away from each other, to use certified seeds, to select resistant varieties and to avoid mechanical transmissions.

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