

## Research Article

# Screening of Tomato Varieties for Resistance to Tomato Leaf Curl Viral Disease under Field Conditions

Sajad Ali Solangi<sup>1</sup>, Jamal-U-Ddin Hajano<sup>1\*</sup>, Rehana Naz Syed<sup>1</sup>, Sohail Ahmed Otho<sup>2</sup>, Khadim Hussain Wagan<sup>1</sup>, Agha Mushtaque Ahmed<sup>2</sup>, Fahad Nazir Khoso<sup>2</sup>, Aftab Raza Jarwar<sup>3</sup> and Suman Tarique Qazi<sup>1</sup>

<sup>1</sup>Department of Plant Pathology, Faculty of Crop Protection, Sindh Agriculture University, Tandojam 70060, Pakistan; <sup>2</sup>Department of Entomology, Faculty of Crop Protection, Sindh Agriculture University, Tandojam 70060, Pakistan; <sup>3</sup>Department of Plant Protection, Faculty of Crop Protection, Sindh Agriculture University, Tandojam 70060, Pakistan.

**Abstract** | Tomato (*Lycopersicon esculentum* Mill.) is important vegetable in Pakistan. Tomato leaf curl viral disease caused by *tomato leaf curl virus* (TLCV) (genus: *Begomovirus*, family: *Geminiviridae*) and transmitted by whitefly (*Bemisia tabaci*) is considered as the most devastating one. Recently, available tomato varieties are not screened against this disease in the agro-ecosystem of Sindh Province of Pakistan. Therefore, in this study 12 commercial varieties of tomato such as, TO-1057, Advanta-1225, T-1359, Yaqui, Sahil, Ayushman, Early king, Advanta-1211, Kiara, Lima, Advanta-1209 and Ashoka were screened against the disease under field conditions during Rabi and Kharif growing season 2017-18. Observations were taken on disease incidence, severity and whiteflies population at interval of week after date of transplantation. Additionally, relationship among the disease and vector insect was determined. The minimum incidence of the disease was recorded in variety Advanta-1211 (13.85%) and Lima (18.85%) followed by T-1359 (23.30%), Early king (25.51%), TO-1057 (27.21%), Advanta-1225 (29.41%). Minimum 1-rating score was recorded in Advanta-1211, Lima and T-1359 varieties. Significantly minimum number of whiteflies was recorded in variety Lima (2.3 whiteflies), Advanta-1209 (2.3 whiteflies), Kiara (2.4 whiteflies) followed by Advanta-1211 (2.5 whiteflies). There was non-significant relationship of vector insect with both incidence as well severity of tomato leaf curl disease,  $r^2 = 0.07068$ ,  $P = 0.8272$  and  $r^2 = 0.2869$ ,  $P = 0.3660$ , respectively. Based on the results, it is concluded that the minimum incidence and severity of tomato leaf curl disease was recorded in variety Advanta-1211, Lima and T-1359. In rabi season the disease intensity was lower as compare to kharif season. Therefore, it is suggested that variety Advanta-1211, Lima and T-1359 should incorporated in the disease management plan.

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\***Correspondence** | Jamal-U-Ddin Hajano, Department of Plant Pathology, Faculty of Crop Protection, Sindh Agriculture University, Tandojam 70060, Pakistan; **Email:** hajanojamal@gmail.com; jhajano@sau.edu.pk

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## Introduction

Tomato (*Lycopersicon esculentum* Mill.) belongs to the family Solanaceae and is a popular grown vegetable and rank third of worldwide vegetable production (Sadaf *et al.*, 2012). Tomato is a good source

of vitamins (A and C) and minerals. It is one of the most widely grown vegetable crops, highly popular due to its high nutritive value, taste and versatile use in various foods. In Pakistan tomato crop is cultivated on 58.4 thousand hectares, with production of 551.0 thousand tonnes and per hectare yield is estimated

9.4 thousand tonnes (GoP, 2018). However, tomato crop in Sindh is grown on area of 25.0 thousand hectares which produced 182.2 thousand tonnes with average yield per hectare is 7.3 thousand tonnes (GoP, 2018). Sindh province ranks first in Pakistan with reference to area under cultivation and total production (GoP, 2018). However, yield per hectare is lower as compare to Punjab, Balochistan and KPK province, respectively (GoP, 2018). Tomato production is reducing due to abiotic and biotic factors which prerequisite to boost up crop yield in Pakistan. Among biotic factors, plant viruses attract considerable attention for vegetable production because they impose significant production constraints. Tomato crop is susceptible to approximately 136 viruses under natural or artificial conditions (Dallwitz, 1980; Dallwitz *et al.*, 1993; Brunt *et al.*, 1996). Viral diseases of tomatoes are causing serious damages and large economic losses. The amount of loss depends on the viral disease involved, the strain of the virus, the variety of tomato, the age of the plant at infection time, the presence of other diseases, and the extent that viruses have spread during the planting of the crop (Walkey, 1985).

Approximately 13 plant viruses are known to infect tomato crop in Pakistan. Most of tomatoes infecting viruses are predominantly transmitted by white fly, aphids and some are mechanically transmitted (Hassan and Thomas, 1985; Hassan *et al.*, 1993). Among these viral pathogens, *tomato leaf curl virus* (TLCV, genus: *Begomovirus*, family: *Geminiviridae*) causing tomato leaf curl viral disease (TLCVD) is considered as the most devastating one (Nono-womdim, 2001; Zeshan *et al.*, 2016). TLCV is consisting on ssDNA (+/-) genome and two incomplete icosahedral geminate particles. Up to 100 % yield losses in tomato crop are documented due to this problem (Shelat *et al.*, 2014). Whitefly (*Bemisia tabaci*) has been shown to transmit TLCV in persistent circulative manner (Zeshan *et al.*, 2016).

Such viral pathogens could be controlled by the use of chemical against the vector insects, but the chemical can create hazards to human health and can produce undesirable side effects on non-targeted organisms. Although development of resistant varieties is time consuming strategy but is the most effective method of controlling many viral diseases. Additionally, this strategy is easy to and cost effective. Therefore, available varieties are screened on regular basis to assess their potential to specific viral pathogen. For such

purpose previously, Hameed and Khalid (1996) collected tomato varieties from AVRDC for screening resistance to TLCV, only Tyking (a Hybrid cultivar), *L. hirsutum* (LA-1777) and *L. chilense* (LA-1969) are resistant to the virus. Similarly, Zeshan *et al.* (2016) screened twenty-seven tomato varieties/lines against TLCVD, number of highly susceptible, susceptible, moderately susceptible, moderately resistant and resistant were three, six, four, six and eight, respectively. Highly resistant and immune varieties/lines against TLCVD were not found in the study. However, with passage of time and change in ecological conditions resistance equilibrium in varieties can fluctuate therefore there is needed to assess tomato varieties. Purpose of the study was to determine the resistance potential of different commercially grown tomato varieties against TLCVD in agro-ecological zone of Sindh and to analyze the relationship between the disease intensity with vector population.

## Materials and Methods

### Experimental sites

Experiments were conducted in open field at vicinity of Tandojam.

### Planting material and experimental design

Twelve commercial varieties of tomato were tested against the TLCVD under natural inoculation conditions (Table 1). Trials were conducted in rabi (winter) and kharif (summer) seasons during 2017 and 2018, respectively. A total 27 plants of each variety were grown with three replications (9 per repeat, 3 repeats= 27 plants) in complete randomize block design in same experimental plot.

**Table 1:** Details of tomato varieties used in this study.

S. No.	Variety	Distributor
1	TO-1057	Syngenta
2	Advanta 1225	ICI
3	T-1359	Syngenta
4	Yaqui	Seminis
5	Sahil	Syngenta
6	Ayushman	Seminis
7	Early king	Millan Agro Seed
8	Advanta 1211	ICI
9	Kiara	Siddique sons
10	Lima	Haji sons
11	Advanta 1209	ICI
12	Ashoka	Seminis

*Observation and measurements*

Observations were taken on the disease incidence, severity and whiteflies population at interval of week after date of transplantation. Percent of the disease incidence was determined by dividing number of tomato plants showing leaf curling symptoms with total number of plants examined for the disease. A 0-5 rating scale was used to measure the disease severity (Zeshan *et al.*, 2016) where, 0 is indicating all plants free from disease symptoms, 1 = 1-20 % infection, 2 = 21-40 % infection, 3 = 41-60 % infection, 4 = 61-80 % infection and 5 = 81-100 % infection. Whiteflies population (both adults & nymphs) was recorded from three randomly selected plants of each replication at upper leaf (first plant), middle leaf (second plant), and lower leaf (third plant) during the time of visual disease assessment (Perveen *et al.*, 2010; Akram *et al.*, 2013). Each plant was rated and then averaged in the group of 9 plants to represent one replication and there were three such replications of that variety.

*Statistical analysis*

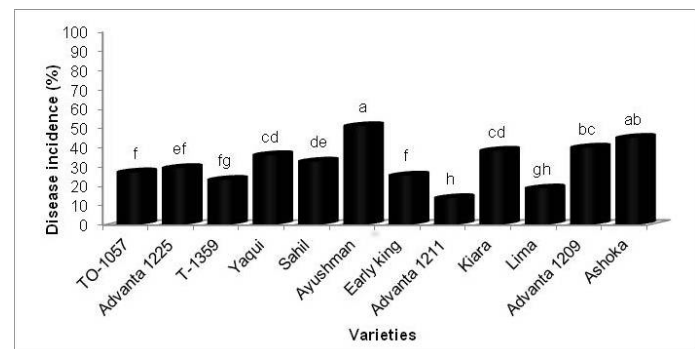
A multifactorial ANOVA was performed to analyze difference in the disease incidence and whiteflies in interaction of varieties × season × Time of assessment using LSD test ( $\alpha = 0.05$ ) of completely randomized design using STATISTIX v. 8.1 software (Analytical Software). Nonparametric spearman test at 95% confidence interval was used to analysis correlation of the disease incidence and severity with vector population.

**Results and Discussion**

*Incidence of the tomato leaf curl disease in different tomato varieties*

The incidence of TLCVD was recorded in different commercial tomato varieties under natural inoculum in field conditions during rabi and kharif growing season 2017-18. On average the minimum incidence of the disease was recorded in variety Advanta-1211 (13.85%) and Lima (18.85%) followed by T-1359 (23.30%), Early king (25.51%), TO-1057 (27.21 %), Advanta-1225 (29.41%) (Figure 1). Similarly, average maximum incidence of TLCVD was recorded in variety Ayushman (51.13%) and Ashoka (45.07%) followed by Advanta-1209 (40.01%), Kiara (38.38 %), Yaqui (36.17 %) and Sahil (32.77%) (Figure 1). Variety Advanta-1211 showed significantly lower incidence 6.60 % of the disease during rabi growing season followed by TO-1057 (9.90 %), Early king (14.30 %) and T-1359 (12.10 %), whereas, during same

growing season Ashoka variety showed maximum incidence of the disease 40.0 % followed by Ayushman (31.13 %), Kiara (30.07 %) and Advanta-1225 (21.10 %) (Table 2). During Kharif growing season, minimum tomato leaf curling was recorded in Advanta-1211 (21.10 %) followed by T-1359 (34.50 %), Early king (36.73 %) and Advanta-1225 (37.73 %), while maximum incidence of the disease during kharif season was recorded in Ayushman variety (71.13 %) followed by Ashoka (50.13 %), Sahil (47.83 %), Kiara (46.70 %) and TO-1057 (44.53 %) (Table 2). Generally, the disease incidence was higher in kharif as compare to rabi season but in variety Yaqui, Lima and Advanta-1209 the situation was vice versa. Variety Lima showed 9.90 and 27.80 % leaf curling in kharif and rabi season, respectively (Table 2). There was non significant variation in the disease incidence % recorded in Yaqui variety even it was higher (36.67 %) during rabi season as compare to kharif (35.57 %) (Table 2). Similarly, Advanta-1209 variety showed higher incidence in the rabi season and lower (38.87 %) in kharif growing season (Table 2). However, variety Lima showed minimum incidence of curling symptoms during both growing seasons as compare to other tested varieties.

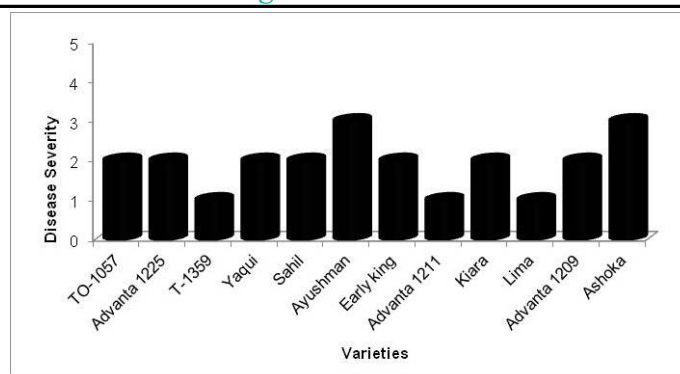


**Figure 1:** Average incidence of tomato leaf curl disease in different tomato varieties.

The disease appeared at 3<sup>rd</sup> week after transplantation of seedlings in the variety Advanta-1225, T-1359, Ayushman, Kiara, Advanta-1209 and Ashoka (Table 3). The disease was gradually increasing till the time of last assessment. Significantly minimum (38.8 %) incidence of the disease was recorded in variety Advanta-1211 followed by Lima (44.3 %) at 9<sup>th</sup> and 10<sup>th</sup> week after transplantation (Table 3). Maximum 89.0 % disease incidence was recorded in the variety Ayushman and Advanta-1209 followed by Kiara (83.5 %) at 9<sup>th</sup> and 10<sup>th</sup> week after transplantation (Table 3). Whereas variety Yaqui showed 77.8 and 83.3 % incidence of the disease at 9<sup>th</sup> and 10<sup>th</sup> week after transplantation, respectively (Table 3).

**Table 2:** Incidence of tomato leaf curl disease in different tomato varieties during kharif and rabi growing season 2017-2018.

Varieties	Season	Incidence (%)	
TO-1057	Kharif	44.53	b-e
	Rabi	9.90	lm
Advanta 1225	Kharif	37.73	d-h
	Rabi	21.10	lk
T-1359	Kharif	34.50	f-i
	Rabi	12.10	k-m
Yaqui	Kharif	35.57	e-i
	Rabi	36.67	e-i
Sahil	Kharif	47.83	bc
	Rabi	17.70	kl
Ayushman	Kharif	71.13	a
	Rabi	31.13	g-i
Early king	Kharif	36.73	e-i
	Rabi	14.30	k-m
Advanta 1211	Kharif	21.10	jk
	Rabi	6.60	m
Kiara	Kharif	46.70	b-d
	Rabi	30.07	h-j
Lima	Kharif	9.90	lm
	Rabi	27.80	ij
Advanta 1209	Kharif	38.87	c-h
	Rabi	41.17	b-f
Ashoka	Kharif	50.13	b
	Rabi	40.00	c-g
LSD ( $\alpha= 0.05$ )		9.0892± 4.6257	



**Figure 2:** Average severity of tomato leaf curl disease in different tomato varieties.

*Severity of the leaf curl disease in different tomato varieties*

Severity of the TLCVD was recorded using 0-5 rating scale. Minimum 1-rating score was recorded in T-1359, Advanta-1211 and Lima varieties (Figure 2). Maximum severity score 3 was recorded in Ayushman and Ashoka varieties (Figure 2). All the remaining varieties showed 2-severity score (Figure 2). During rabi growing season severity score-1 of the disease was recorded in varieties like TO-1057, Advanta-1225, T-1359, Sahil, Early king and Advanta-1211 (Table 4). Yaqui and Advanta-1209 varieties showed severity score-2 during both growing seasons (Table 4). Ayushman variety showed maximum severity 4-score during kharif growing season followed by TO-1057, Sahil, Kiara and Ashoka variety with 3-score (Table 4). Severity score-2 was recorded in variety Advanta-1225, T-1359 and Early king during kharif growing season (Table 4). Ayushman, Lima and Ashoka varieties showed 2-score severity during

**Table 3:** Incidence of tomato leaf curl disease in different tomato varieties over the growth period.

Varieties	Weeks after transplanting									
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	7 <sup>th</sup>	8 <sup>th</sup>	9 <sup>th</sup>	10 <sup>th</sup>
TO-1057	0.0 n	0.0 n	0.0 n	16.6 k-n	22.1 j-m	33.3 h-k	44.5 f-i	50.0 e-h	50.0 e-h	55.5 d-g
Advanta-1225	0.0 n	0.0 n	11.0 l-n	11.0 l-n	11.0 l-n	33.1 h-k	44.5 f-i	50.0 e-h	61.1 c-f	72.3 a-d
T-1359	0.0 n	0.0 n	5.5 mn	5.5 mn	11.1 l-n	22.1 j-m	33.3 h-k	38.8 g-j	55.5 d-g	61.0 c-f
Yaqui	0.0 n	0.0 n	0.0 n	11.0 l-n	22.1 j-m	50.0 e-h	50.0 e-h	66.8 b-e	77.8 a-c	83.3 ab
Sahil	0.0 n	0.0 n	0.0 n	22.1 j-m	27.6 i-l	33.3 h-k	50.0 e-h	61.1 c-f	66.6 b-e	66.6 b-e
Ayushman	0.0 n	0.0 n	22.1 j-m	39.0 g-j	61.1 c-f	66.6 b-e	72.1 a-d	72.1 a-d	89.0 a	89.0 a
Early king	0.0 n	0.0 n	0.0 n	0.0 n	11.0 l-n	38.8 g-j	38.8 g-j	50.0 e-h	55.5 d-g	61.0 c-f
Advanta-1211	0.0 n	0.0 n	0.0 n	5.50 mn	5.5 mn	5.5 mn	16.6 k-n	27.6 i-l	38.8 g-j	38.8 g-j
Kiara	0.0 n	0.0 n	11.1 l-n	11.1 l-n	16.6 k-n	44.3 f-i	61.1 c-f	72.3 a-d	83.5 ab	83.5 ab
Lima	0.0 n	0.0 n	0.0 n	0.0 n	5.5 mn	22.1 j-m	33.3 h-k	38.8 g-j	44.3 f-i	44.3 f-i
Advanta-1209	0.0 n	0.0 n	5.5 mn	16.5 k-n	22.0 j-m	44.5 f-i	61.3 c-f	72.3 a-d	89.0 a	89.0 a
Ashoka	0.0 n	0.0 n	11.1 l-n	27.8 i-l	44.3 f-i	55.6 d-g	72.3 a-d	72.3 a-d	83.5 ab	83.5 ab
LSD ( $\alpha= 0.05$ )	20.324± 10.343									

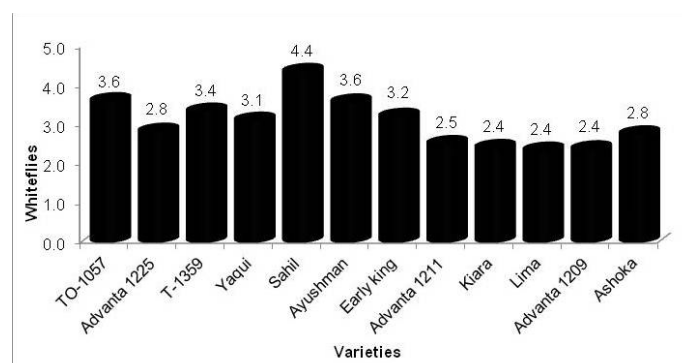
**Table 4:** Severity of tomato leaf curl disease in different tomato varieties during kharif and rabi growing season 2017-2018.

Varieties	Season	Severity
TO-1057	Kharif	3
	Rabi	1
Advanta 1225	Kharif	2
	Rabi	1
T-1359	Kharif	2
	Rabi	1
Yaqui	Kharif	2
	Rabi	2
Sahil	Kharif	3
	Rabi	1
Ayushman	Kharif	4
	Rabi	2
Early king	Kharif	2
	Rabi	1
Advanta 1211	Kharif	1
	Rabi	1
Kiara	Kharif	3
	Rabi	2
Lima	Kharif	1
	Rabi	2
Advanta 1209	Kharif	2
	Rabi	2
Ashoka	Kharif	3
	Rabi	2

**Table 5:** Severity of tomato leaf curl disease in different tomato varieties over the growth period.

Varieties	Weeks after transplanting									
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	7 <sup>th</sup>	8 <sup>th</sup>	9 <sup>th</sup>	10 <sup>th</sup>
TO-1057	0.0	0.0	0.0	1	1	2	3	3	3	3
Advanta 1225	0.0	0.0	1	1	1	2	3	3	4	4
T-1359	0.0	0.0	1	1	1	1	2	2	3	3
Yaqui	0.0	0.0	0.0	1	1	3	3	4	4	4
Sahil	0.0	0.0	0.0	1	2	2	3	3	4	4
Ayushman	0.0	0.0	1	2	3	4	4	4	5	5
Early king	0.0	0.0	0.0	0.0	1	2	2	3	3	3
Advanta 1211	0.0	0.0	0.0	1	1	1	1	2	2	2
Kiara	0.0	0.0	1	1	1	3	4	4	5	5
Lima	0.0	0.0	0.0	0.0	1	2	2	2	3	3
Advanta 1209	0.0	0.0	1	1	1	3	4	4	5	5
Ashoka	0.0	0.0	1	2	3	3	4	4	4	4

rabi season (Table 4). During kharif growing season minimum 1-score of the severity was recorded in variety Advanta-1211 and Lima (Table 4). Kiara variety during rabi season showed 2-score of the severity (Table 4). Similar as the disease incidence, severity of the disease was also recorded in 3<sup>rd</sup> week after transplantation in few varieties such as Advanta-1225, T-1359, Ayushman, Kiara which were showing 1severity score (Table 5). Severity of the disease showed increase till 9<sup>th</sup> and 10<sup>th</sup> week of observation, however, at last assessment of the disease variety Advanta-1211 showed minimum 2-score whereas maximum 5-score was recorded in Ayushman, Kiara and Advanta-1209 varieties (Table 5). Varieties such as TO-1057, T-1359, Early king and Lima showed 3-severity score at 10<sup>th</sup> week after transplantation and remaining Advanta-1225, Yaqui, Sahil and Ashoka showed 4 severity score (Table 5).



**Figure 3:** Average whiteflies population in different tomato varieties.

*The vector population in different tomato varieties and its correlation with tomato leaf curl viral disease incidence and severity*

Maximum vector population was recorded in variety Sahil (4.3 whiteflies) followed by TO-1057 (3.6 whiteflies), Ayushman (3.6 whiteflies), T-1359 (3.3 whiteflies), Early king (3.2 whiteflies), Yaqui (3.1 whiteflies), Advanta-1225 (2.8 whiteflies) and Ashoka (2.8 whiteflies) (Figure 3). Significantly minimum number of whiteflies was recorded in variety Lima (2.3 whiteflies), Advanta-1209 (2.3 whiteflies), Kiara (2.4 whiteflies) followed by Advanta-1211 (2.5 whiteflies) (Figure 3). Maximum vector population (5.9 whiteflies) was recorded in Sahil variety followed by TO-1057 (5.0 whiteflies), Ayushman (4.2 whiteflies) during kharif growing season (Table 6). Whereas minimum vector population was recorded in variety Lima (1.8 whiteflies) during rabi season (Table 6). Maximum 5.7 whiteflies were recorded at 10<sup>th</sup> week after transplantation in variety Ayushman followed by

**Table 6:** *Whiteflies population in different tomato varieties during kharif and rabi growing season 2017–2018.*

Varieties	Season	Whiteflies	
TO-1057	Kharif	5.0	ab
	Rabi	2.2	f
Advanta 1225	Kharif	3.3	c-f
	Rabi	2.3	d-f
T-1359	Kharif	3.8	b-d
	Rabi	2.9	c-f
Yaqui	Kharif	3.7	b-e
	Rabi	2.4	d-f
Sahil	Kharif	5.8	a
	Rabi	2.8	c-f
Ayushman	Kharif	4.2	bc
	Rabi	2.9	c-f
Early king	Kharif	2.1	f
	Rabi	4.2	bc
Advanta 1211	Kharif	2.2	ef
	Rabi	2.7	c-f
Kiara	Kharif	2.3	d-f
	Rabi	2.5	d-f
Lima	Kharif	1.8	f
	Rabi	2.9	c-f
Advanta 1209	Kharif	2.5	d-f
	Rabi	2.2	f
Ashoka	Kharif	2.6	d-f
	Rabi	2.9	c-f
LSD ( $\alpha=0.05$ )		1.5190± 0.7731	

8<sup>th</sup> week in variety Early King (5.1) and 3<sup>rd</sup> week after transplantation in variety T-1359 (Table 7). Whereas minimum (0.5) vector population was recorded at 2<sup>nd</sup> week after transplantation in Kiara variety (Table 7).

Relationships of vector population with incidence and severity of TLCVD was determined using PRISM v. 5.01 (Graph Pad Software). There was non-significant relationship of vector insect with both incidences as well severity of tomato leaf curl disease,  $r^2= 0.07068$ ,  $P= 0.8272$  and  $r^2= 0.2869$ ,  $P= 0.3660$ , respectively (Table 8).

The disease appeared at 3<sup>rd</sup> week after transplantation of seedlings in the variety Advanta-1225, T-1359, Ayushman, Kiara, Advanta-1209 and Ashoka. The disease was gradually increasing till the last assessment. Such trend has been observed in other vector transmitted plant viral diseases (Khoso *et al.*, 2021). These results are accordance with Zhang *et al.* (2008) who observed that first symptom of the disease can be appear 15 days after transplantation, which are related with longer period till the end of crop. The minimum incidence of the disease was recorded in variety Advanta-1211 (13.85%) and Lima (18.85%) followed by T-1359 (23.30%), Early king (25.51%), TO-1057 (27.21 %), Advanta-1225 (29.41%). Whereas minimum 1-rating score was recorded in T-1359, Advanta-1211 and Lima varieties. Generally, the disease incidence was higher in kharif as compare to rabi season but in variety Yaqui, Lima and Advanta-1209 the situation was vice versa. This season variation in the

**Table 7:** *Whiteflies population in different tomato varieties over the growth period.*

Varieties	Weeks after transplanting									
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	7 <sup>th</sup>	8 <sup>th</sup>	9 <sup>th</sup>	10 <sup>th</sup>
TO-1057	2.0 c-k	4.6 b-f	4.0 b-i	3.8 b-j	4.5 b-f	2.5 b-k	3.8 b-j	5.0 b-d	3.0 b-k	2.8 b-k
Advanta 1225	1.6 d-k	2.0 c-k	2.6 b-k	2.5 b-k	3.6 b-j	3.0 b-k	2.8 b-k	3.6 b-j	2.3 b-k	4.0 b-i
T-1359	2.1 c-k	2.5 b-k	5.1 bc	3.6 b-j	4.6 b-f	4.1 b-h	3.8 b-j	2.8 b-k	2.1 c-k	2.3 b-k
Yaqui	2.0 c-k	2.5 b-k	3.8 b-j	3.3 b-k	3.6 b-j	3.1 b-k	3.8 b-j	3.8 b-j	2.3 b-k	2.6 b-k
Sahil	11.6 a	2.5b-k	2.8 b-k	4.8 b-e	3.1 b-k	3.8 b-j	3.3 b-k	2.8 b-k	3.8 b-j	4.8 b-e
Ayushman	0.8 h-k	1.8 c-k	4.3 b-g	3.1 b-k	4.6 b-f	3.3 b-k	3.8 b-j	4.1 b-h	4.0 b-i	5.6 b
Early king	0.8 h-k	1.3 f-k	3.0 b-k	2.8 b-k	3.3 b-k	4.1 b-h	3.1 b-k	5.1 b-c	4.3 b-g	4.0 b-i
Advanta 1211	0.6 i-k	1.3 f-k	3.5 b-j	2.3 b-k	3.0 b-k	3.3b-k	2.6 b-k	2.8 b-k	2.3 b-k	3.1 b-k
Kiara	1.0 g-k	0.5 j-k	2.0 c-k	2.5 b-k	3.0 b-k	2.7 b-k	3.8 b-j	3.3 b-k	2.8 b-k	2.5 b-k
Lima	0.0 k	0.7 i-k	1.7 d-k	2.3 b-k	2.8 b-k	3.7 b-j	4.1 b-h	3.3 b-k	1.8 c-k	3.0 b-k
Advanta 1209	0.8 h-k	2.1c-k	2.7 b-k	2.8 b-k	2.1 c-k	2.7 b-k	3.0 b-k	3.0 b-k	3.0 b-k	1.5 e-k
Ashoka	1.3 f-k	2.7 b-k	3.0 b-k	3.1 b-k	3.7 b-j	4.0 b-i	2.3 b-k	2.0 c-k	2.3 b-k	3.1b-k
LSD ( $\alpha=0.05$ )	3.3966±	1.7286								

intensity of the TLCVD is attributed with higher temperature range (Iftkhar *et al.*, 2021). In the geographic area of current study temperature remains higher in the kharif growing season.

**Table 8:** Relationships of vector population with intensity of tomato leaf curl disease.

Particular of analysis	Disease incidence (%)	Disease severity
Spearman r	0.07068	0.2869
95% confidence interval	-0.5385 to 0.6313	-0.3607 to 0.7478
P	0.8272	0.3660
$\alpha$	0.05	

These results are in accordance with Channarayana and Shivashank (1992) screened 1200 cultivars, breeding lines and wild species of tomato for resistance to tomato leaf curl disease, which all were less or more susceptible to the disease, one three lines of *L. hirsutum* and one of *L. peruvianum* accessions showed apparent resistance to the disease. Similarly, Hameed and Khalid (1996) collected tomato cultivars from AVRDC for screening resistance to TLCV, only Tyking (a Hybrid cultivar), *L. hirsutum* (LA-1777) and *L. chilense* (LA-1969) are resistant to the virus. Singh (2014) screened 32 tomato genotypes against TLCVD under greenhouse out of which three genotypes showed resistant reaction and eight genotypes found moderately resistant. Zeshan *et al.* (2016) in their study concluded that number of highly susceptible, susceptible, moderately susceptible, moderately resistant and resistant to TLCVD were three, six, four, six and eight, respectively. Highly resistant and immune varieties/lines against TLCVD were not found in the study.

Maximum vector population was recorded in variety Sahil followed by TO-1057, Ayushman, T-1359, Early king, Yaqui, Advanta-1225 and Ashoka. Significantly minimum number of whiteflies was recorded in variety Lima, Advanta-1209, Kiara followed by Advanta-1211. There was non-significant relationship of vector insect with both incidences as well severity of tomato leaf curl disease,  $r^2 = 0.07068$ ,  $P = 0.8272$  and  $r^2 = 0.2869$ ,  $P = 0.3660$ , respectively. Such findings are previously reported by Ssekyewa *et al.* (2007) who assessed a negative relationship between number of plants infected with tomato yellow leaf curl virus and percentage marketable tomato yield. Tomato maturity was inversely proportional to whitefly infestation. Later on, Ssekyewa *et al.* (2010) reported that inci-

dence of tomato yellow leaf curl disease was lower, whereas the vector population was higher at seedling stage. It is well documented that a single individual of insect vector can transmit the virus to a single or dozen of susceptible plants. Under circumstance single individual of insect Therefore under this circumstance non-significant variation might be associated with such characteristic of whitefly that single individual of whitefly may sufficiently transmit the TLCV to susceptible tomato plant. However, further studies are needed to explore this phenomenon.

## Conclusions and Recommendations

Based on the obtained results it is concluded that the minimum incidence and severity of tomato leaf curl disease was recorded in variety Advanta-1211, Lima and T-1359. In rabi season the disease intensity was lower as compare to kharif season. Maximum vector population was recorded in variety Sahil followed by TO-1057, Ayushman, T-1359, Early king, Yaqui, Advanta-1225 and Ashoka. The disease intensity was not dependent to the vector population. Therefore, these varieties should incorporate in the disease management plan. Same set of varieties should also be tested under challenged inoculation and different isolates may test for more authenticate the results. Impact of environmental conditions may be studies for furthermore in detail to understate the epidemic parameters of the disease.

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## Author’s Contribution

**Sajad Ali Solangi:** Performed Experiments and collected data.

**Jamal-U-Ddin Hajano, Rehana Naz Syed, Sohail Ahmed Otho, Fahad Nazir Khoso, Agha Mush-taque Ahmed and Khadim Hussain Wagan:** Performed Analysis.

**Sajad Ali Solangi, Suman Tarique Qazi and Aftab Raza Jarwar:** Wrote first draft of the manuscript.

All authors contributed to the study conception and design and commented on final versions of the man-

uscript. All authors read and approved the final manuscript.

### Conflict of interest

The authors have declared no conflict of interest.

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