ENVIRONMENTAL SCIENCE ARCHIVES
ISSN: 2583-5092
Volume III Special Thematic Issue 1, 2024
www.envsciarch.com

RESEARCH PAPER OPEN ACCESS

Serological Detection of Viruses causing Tomato Mosaic Disease

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Received: 2024/05/01
Accepted: 2024/05/28
Published: 2024/06/02

Abstract

Tomato (*Solanum lycopersicum* L.) belongs to solanaceous family and is sensitive to many plant viruses during the different crop stages and viruses are spread by insect vectors. Mostly plant viruses with ss-RNA infect the crop vulnerability and cause huge losses, including Tomato mosaic virus (ToMV), Cucumber mosaic virus (CMV), and Potato mosaic virus (PVY). The survey was conducted in the subtropical climate zone of Jammu province in different locations viz. Gajansoo, Pinjore, and Lalyal from Marh, Badayal Brahmna, Laswara and Purobana from RS Pura, Makhanpur, Salehar, and Kothe from Bishnah and Chatha Farm during 2020 and 2021. It was observed that the overall incidence of disease in Marh was 32.44% in Gajansoo and a minimum (16.67%) in Makhanpur of Bishnah during 2020 while during 2021, a maximum disease incidence of 30.66% was recorded from Gajansoo of Marh and minimum (15.75%) was recorded from Purobana of RS Pura. Host resistance for different plant viruses has always been a successful management strategy in the control of plant viral diseases, which are ecologically and economically valid. Twenty germplasms of tomato viz. Pusa Ruby, EC-620406, Arka Vikas, EC-771607, EC-676791, Hisar Anmol, EC- 514109, EC- 514109, EC-677191, EC-677049, EC- 677123, Avinash 2, Arka Sourabh, Kashi Vishes, Local, Kajal, Hiasr Arun, Money Maker, EC-620417, Arka Ananya, EC-617048 obtained from NBPGR were screened against ToMV, CMV and PVY under field conditions to know the host resistance to three plant viruses which are detected serologically through DAS-ELISA.

Keywords: Tomato Mosaic Disease; Tomato; Viruses; Serological; Detection; Solanaceous; Plant virus

Introduction

Tomato is an economically important crop grown in India which belongs to the Solanaceae family, including more than 3000 plant species. Tomatoes are employed as a vital nutritional component due to being rich in minerals, vitamins, proteins, amino acids (leucine, threonine, valine, histidine, lysine, and arginine), carotenoids, and phytosterols. Lycopene consumption reported that these are effective for myocardial health issues which are cognitive in function. The tomato plant constitutes the main host for many pathogens which cause biotic stress and hinders the plant production (Blancard, 2012). Tomato crop is more prone to many viral diseases which affect the physiology and fruit quality and it affects the crop by affecting the quality of tomatoes and more than 100 types of plant viruses are infecting the crop (Hančinský et al., 2020). Tobamoviruses group such as Tomato mosaic virus, Tobacco mild green mosaic virus and Tobacco mosaic virus (TMV), Tomato brown rugose fruit virus (ToBRFV), and Tomato mottle mosaic (ToMMV) naturally infect tomato crops (Hančinský et al., 2020). Tobamoviruses group are unusual plant viruses due to transmission of viruses abiotically but they are still infective under soil and plant debris (Almeida et al., 2018). Potato X virus, a member of the genus Potexvirus, predominately affects solanaceous plants (Verchot, 2022). Double infection of Potato X virus and Tobacco mosaic virus in tomato plants synergistically decreased the concentration of TMV and increased Potato X virus in inoculated plants was detected through DAS-ELISA (Balogun et al., 2002).

Long-term activity of Cucumber mosaic virus in plants' photosynthetic ability and respiration rates, the viral infection load increases the electron transport and also doubles H_2O_2 in the plant cell (Song et al., 2009). The most important serological techniques in detecting the plant viral infection with ToMV through the development and characterization of polyclonal antibodies in serological detection through ELISA was performed (Mrkvová et al., 2022).

Serological detection of different surveyed samples from 2011-2012 identified different tomato samples from different localities in 18 districts of Serbia was carried out. Cucumber mosaic virus (CMV), Potato virus Y (PVY), Alfalfa mosaic virus (AMV), Tomato spotted wilt virus (TSWV), Tomato mosaic virus (ToMV) and Tobacco mosaic virus (TMV) were detected in 42.1, 40, 11, 8.6, 2.3 and 1.3 percent of the total tested samples, respectively. CMV and PVY, apart from being predominant, two plant viruses that are most common and widely spread in dual combination were found through ELISA (Nikolić et al., 2018). The present study was conducted through the major tomato cultivating areas of Jammu sub-tropic to detect the major viral infections in tomato plants based on the characteristic viral symptoms of tomato plants from the surveyed areas and also to know the extent of viral infection disease incidence among the fields along with possible vial combination infections (Sulistyowati et al., 2004).

Materials and Methods

Sample Collection

A survey was undertaken to detect the presence of three different tomato plant viruses: ToMV, CMC and PYV from different areas of Jammu district viz. Gajansoo, Pinjore, and Lalyal from Marh, Badayal Brahmna, Laswara, and Purobana from RS Pura, Makhanpur, Salehar and Kothe from Bishnah and Chatha Farm. Plants were from selected plot area (10 m x 10 m) from different fields and the number of plants showing characteristic symptoms such as yellowing and green patches, mosaic, mottling and distortion of leaves were recorded separately to calculate percent disease incidence. The percentage of disease incidence was calculated by observing the number of diseased plants showing characteristic symptoms of virus infection using the following formula:

$$\text{Percent Disease incidence} = \frac{\text{No. of infected plants}}{\text{Total No. of plants observed}} \times 100$$

$$\text{Percent Disease Index (PDI)} = \frac{\text{Sum of all numerical ratings}}{\text{Maximum disease grade x Total Number of plants observed}} \times 100$$

Twenty tomato germplasm/ varieties/ cultivar viz., Pusa Ruby, EC-620406, Arka Vikas, EC-771607, EC-676791, Hisar Anmol, EC- 514109, EC-677191, EC-677049, EC- 677123, Avinash 2, Arka Sourabh, Kashi vishes, kajal, Hiasr Arun, Money maker, EC-620417, Arka ananya and EC-617048 collected from National Bureau of Plant Genetic Resources and from local market, Jammu were screened for determining resistance against tomato mosaic disease under natural conditions. Disease incidence was calculated based on viral symptoms observed and serological sap detection from the infected leaf samples confirmed the presence of viral infection.

Detection of viruses through serological methods (ELISA)

All the samples collected from different locations in Jammu were brought under laboratory conditions for confirmation of the pathogens by DAS-ELISA. Three antibodies viz. cucumber mosaic virus (CMV), potato virus Y (PVY) and tomato mosaic virus (ToMV) were used to test the presence or absence of respective causal viruses, as the disease is caused by these viruses. Double antibody sandwich ELISA method as described by Clark and Adams (1977) was used to detect the virus infection from the samples and coated with 100µl coating buffer. After coating with buffer plates were incubated at 37 ° C for 4 hours followed by washing with PBST (1x) three to four times at 5 minutes intervals. Fresh leaf samples were cut into small pieces and ground into a fine paste with mortar and pestle in the presence of phosphate buffer, extracted sap was filtered through multilayered muslin cloth. ELISA plates are coated with the antigens from the extracted buffer at 100µl along with buffer and healthy samples. Plates were incubated at 16 hours at 6 °C followed by washing with 100µl of enzyme conjugate diluted at 1:200 was added in each well and incubated

for 4 hours at 37°C. Finally, substrate buffer containing PNPP (p-nitro phenyl phosphate) was added to different wells at the rate of 100µl and incubated at room temperature (25°C) for 2 hours and the reaction was visually observed and read at 405 nm in ELISA reader.

Results

Survey was carried out in different areas of Jammu district *viz*., Gajansoo, Pinjore and Lalyal from Marh, Badayal Brahmna, Laswara, and Purobana from RS Pura, Makhanpur, Salehar and Kothe from Bishnah and Chatha Farm. The disease incidence was recorded based on symptomatology and then confirmed in the laboratory by using the serological detection method. During the cropping season of 2020, it was observed that in Marh maximum disease incidence was recorded from Gajansoo (32.44%) followed by Pinjore (30.33%) and the minimum was recorded from Lalyal (28.75%) while in RS Pura the maximum incidence of the disease was recorded from Badayal Brahmna (25.00%) followed by Purobana (18.75%) and Laswara (17.85%). In Bishnah the maximum incidence of the disease (21.42%) was recorded from Salehar followed by kothe (20.00%) and Makhanpur (16.67%) while in Chatha Farm the incidence of the disease was 29.98 percent. The mean percentage of incidence of the disease was 25.09 percent with an overall range of 16.67-32.44 percent (Table 1).

During the cropping season 2021, the overall range of disease incidence was 15.75 - 30.66 percent while the overall mean of disease incidence was 24.52 percent. However, in Marh, the maximum disease incidence was recorded in Gajansoo (30.66%) followed by Lalyal (30.33%), and Marh (29.66%) having the mean disease incidence of 30.21 percent. In RS Pura the maximum disease incidence of 23.66 percent was observed in Badayal Brahmna followed by Laswara (18.33%) and Purobana (15.75%). In Bishnah, the maximum disease incidence recorded was in Salehar (23.45%) followed by Kothe (21.66%), and Makhanpur (17.85%). However, in Chatha farm it was 27.66% (Table 1).

Table 1. Disease incidence of tomato virus in different locations of Jammu

Location		Disease Incidence		
Marh	**Village**	**2020**	**2021**	**Pooled**
	Gajansoo	32.44	30.66	31.55
	Pinjore	30.33	29.66	29.99
	Lalyal	28.75	30.33	29.54
RS Pura	Badayal Brahmna	25	23.66	24.33
	Laswara	17.85	18.33	18.09
	Purobana	18.75	15.75	17.25
Bishnah	Makhanpur	16.67	17.85	17.26
	Salehar	21.42	23.45	22.43
	Kothe	20	21.66	20.83
Chatha	Chatha farm	29.98	27.66	28.82

ToMV, CMV, and PVY were used to test the presence or absence of respective causal viruses as the disease is caused by these viruses. During the cropping season of 2020, It was observed that samples collected from Gajansoo, Pinjore, Lalyal, Badayal Brahmna, Makhanpur, Kothe and Chatha Farm were found infected with Tomato mosaic virus (ToMV). Sample collected from each location were loaded with different wells of ELISA plate coated with specific antibodies. Healthy tissue and buffer were also used as controls. The absorbance values of ToMV, CMV and PVY samples collected from different locations of Marh, RS Pura, Bishnah and Chatha were measured. The absorbance value in Gajansoo (0.3546-2.5953), Pinjore (0.2868-1.5426), Lalyal (0.1436-0.7846), Badayal Brahmna (0.3882-0.8756), Makhanpur (0.0962-0.2736), Kothe (0.1536-0.7642) and Chatha Farm (0.2756-1.4563) was recorded. However, the wells that were charged with healthy tissue and buffer showed absorbance values of 0.0467 and 0.0370 respectively at 405nm.

Cucumber mosaic virus (CMV) which is also responsible for disease development was found in samples collected from Gajansoo, Pinjore, Badayal Brahmna, Laswara, Purobana, Kothe and Chatha with the absorbance value of 1.3667-1.8406 (Gajansoo), 0.9801-1.7145 (Pinjore), 0.8975-1.1855 (Badayal Brahmna), 0.3403-0.1312 (Laswara), 0.0891-0.3116 (Purobana), 0.5081-1.0093 (Kothe), and 1.6002-1.9835 (Chatha Farm). While presence of PVY in response to disease development was also confirmed from Gajansoo, Lalyal, Salehar, Kothe and Chatha Farm with OD values of 0.4352-0.6785, 0.2670-0.3684, 0.1683-0.3227, 0.0837-0.2163 and 0.5361-1.7703 respectively. However, in healthy tissue and buffer-charged wells, the OD value was 0.0394-0.0463 respectively at 405 nm (Table 2).

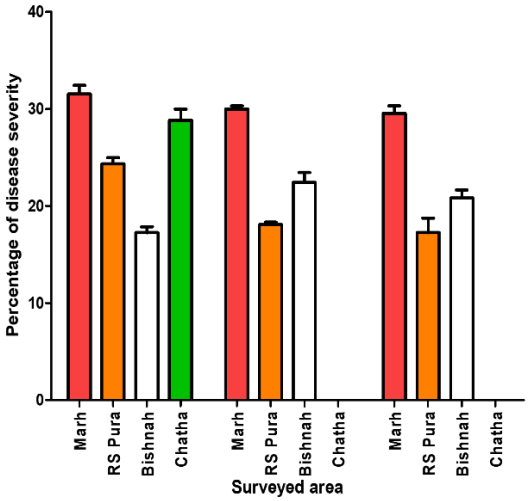


Fig. 1. Graphical representation of Tomato viral disease symptoms from different locations (Marh, RS Pura, Bishnah, Chatha)

During the cropping season of 2021, the absorbance value of ToMV in Gajansoo (0.2685-1.341), Pinjore (0.1986-1.4563), Lalyal (0.1125-0.5789), Badayal Brahmna (0.1564-0.5687), Makhanpur (0.0867-0.4532), Kothe (0.2567-0.9765) and Chatha Farm (0.4589-1.2456) was recorded. However, the wells that were charged with healthy tissue and buffer showed absorbance value of 0.0356 and 0.0320 respectively at 405nm. The absorbance value of CMV was 1.5682-1.9865 (Gajansoo), 1.3242-1.9872 (Pinjore), 1.2589-1.4682 (Badayal Brahmna), 0.8654-0.2543 (Laswara), 0.3685-0.7532(Purobana), 0.7804-1.1783 (Kothe), and 1.6543-2.0654 (Chatha Farm). While presence of PVY in response to disease development was also confirmed from Gajansoo, Lalyal, Salehar, Kothe and Chatha Farm with OD values of 0.3567-0.9741, 0.2349-0.3321, 0.2582-0.3480, 0.1132-0.3269 and 0.3241-1.9863 respectively. However, in healthy tissue and buffer charged wells the OD value waso.0245-0.0532 respectively at 405 nm (Table 2).

Serologically detected viruses through surveyed samples

Different virus-infected samples from different locations in Jammu were analyzed through DAS-ELISA methods. The different combinations of viral infections observed in different locations. Single viral infection with CMV, ToMV and PVY was observed under different frequencies 34 percent for CMV, 62 percent for PVY and 73 percent for ToMV. The combined infection of CMV+PVY with the frequency of 54 percent, CMV+ToMV with 54 percent, PVY+ToMV with 55 percent and finally multiple infections of three viruses together with a frequency of 70.34 percent. The percentage of disease incidence among PVY+ToMV, CMV+PVY+ToMV, CMV+ PVY recorded highest given in table 3 and Fig 1.

Serological detection of CMV, ToMV and PYV in screened germplasm during 2020-21

Twenty different germplasms were screened and tested serologically by DAS-ELISA to ascertain the detection of viruses during the 2017 and 2018 cropping seasons. The samples collected during screening were loaded into different wells of the ELISA plate coated with specific antibodies. The result showed a negative result in the case of EC-771607 and Hisar Anmol which confirmed that

there was no presence of CMV, ToMV, and PYV in this germplasm. Multiple infections of viral disease with three viruses were observed in ten germplasm with plant disease incidence during 2017-18 viz., Pusa Ruby, EC-620406, EC- 514109, EC-677191, EC-677049, Avinash 2, Local, Money Maker, EC-620417, EC-617048. Only dual viral infection was observed in Arka Vikas, and Kashi Vishes. Single viral infection was observed in EC-676791, EC- 677123, and Kajal. Viral infection with disease severity was observed in EC-771607, Hisar Anmol, Arka Sourabh. The percentage of the disease severity was given in Table No. 3. along with viral infection and disease incidence. A percentage of samples from symptomatic tomato plants analyzed did not react with the antisera against any of the 3 viruses. The absence of positive reactions may be due to infection of the plants with other viruses.

Table 2: Survey areas and serologically detected plant viral infections in selected locations of Jammu-sub tropics

Jammu	Locations	OD value of ToMV at 405nm		Presence (+) or absence (-) of virus	OD value of CMV at 405nm		Presence (+) or absence (-) of virus	OD value of PVY at 405nm		Presence (+) or absence (-) of virus
		2020	2021		2020	2021		2020	2021	
Marh	Gajansoo	0.3546-2.5953	0.2685-1.341	+	1.3667-1.8406	1.5682-1.9865	+	0.4352-0.6785	0.3567-0.9741	+
	Pinjore	0.2868-1.5426	0.1986-1.4563	+	0.9801-1.7145	1.3242-1.9872	+	0.1436-0.3763	0.1690-0.5430	-
	Lalyal	0.1436-0.7846	0.1125-0.5789	+	0.0804-0.0818	0.0654-0.0765	-	0.2670-0.3684	0.2349-0.3321	+
RS Pura	Badayal Brahmna	0.3882-0.8756	0.1564-0.5687	+	0.8975-1.1855	1.2589-1.4682	+	0.0473-0.0631	0.0176-0.0327	-
	Laswara	0.0532-0.0610	0.0356-0.0432	-	0.3403-0.1312	0.8654-0.2543	+	0.0452-0.0216	0.0219-0.0134	-
	Purobana	0.0443-0.0632	0.0356-0.0546	-	0.0891-0.3116	0.3685-0.7532	+	0.0732-0.0154	0.0436-0.0098	-
Bishnah	Makhanpur	0.0962-0.2736	0.0867-0.4532	+	0.0381-0.0536	0.0269-0.0326	-	0.0113-0.0372	0.0368-0.0541	-
	Salehar	0.0532-0.0610	0.0254-0.0345	-	0.0434-0.0635	0.0146-0.0569	-	0.1683-0.3227	0.2582-0.3480	+
	Kothe	0.1536-0.7642	0.2567-0.9765	+	0.5081-1.0093	0.7804-1.1783	+	0.0837-0.2163	0.1132-0.3269	+
Chatha	Chatha farm	0.2756-1.4563	0.4589-1.2456	+	1.6002-1.9835	1.6543-2.0654	+	0.5361-1.7703	0.3241-1.9863	+
	Healthy tissue	0.0467	0.0356	-	0.0323	0.0135	-	0.0394	0.0245	-
	Negative control	0.0370	0.0320	-	0.0352	0.0257	-	0.0463	0.0532	-

Table 3. Serologically detected virus infections from the commonly collected samples from different locations of Jammu

S.no	Virus infection	No. of collected samples	No. of infected samples	Frequency	Disease incidence
1	**CMV**	200	68	34	43.4
2	**PVY**	200	96	48	62
3	**ToMV**	200	73	36.5	58.34
4	**CMV+ PVY**	200	112	56	65.24
5	**CMV+ToMV**	200	108	54	73.4
6	**PVY+ToMV**	200	55	27.5	75.3
7	**CMV+PVY+ToMV**	200	83	41.5	70.34

Discussion

Tomato crop is susceptible to several viral diseases, which cause huge losses affecting the quality and quantity of crop and act as the main constrain in the cultivation of tomato crops globally (Panno et al., 2021). Plant viral diseases are transmitted through sap-sucking insect vectors which are soft insects (Ghosh et al., 2019; Sarwar, 2020). Difficulties in determining the relation between the viral infection and the growth stages of tomato and infection rate, cucumber mosaic virus (CMV) and ToMV were detected through DAS -ELISA in lower rates in cherry tomatoes as 24 and 8 percent.(Park and Cha, 2002).Quality of seed is more important in the control of viral infection

of plants the seed transmission of cucumber mosaic virus transmitted through seed acts as primary inoculum in the solanaceous plants (Ali and Kobayashi, 2010).

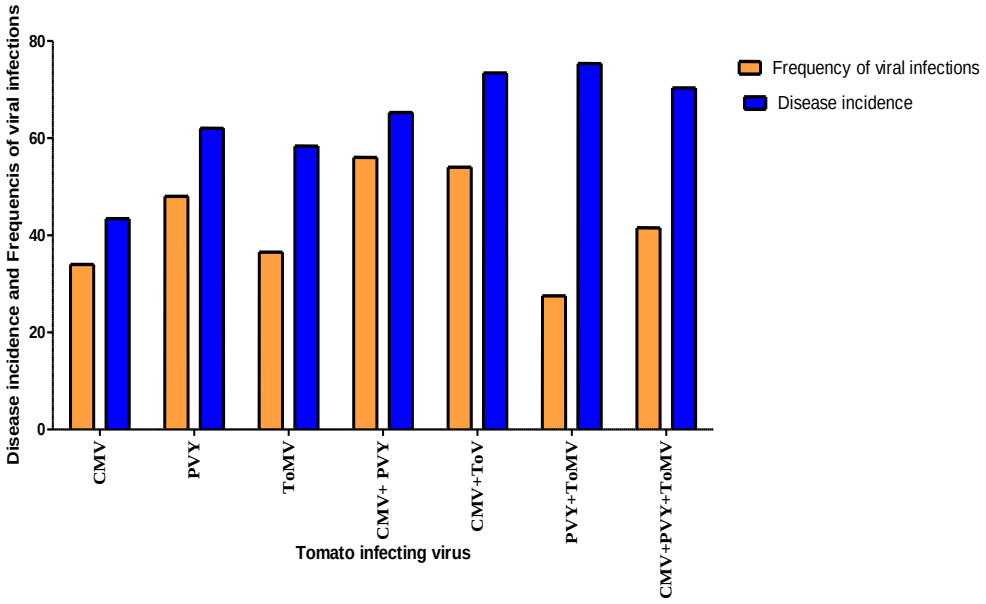
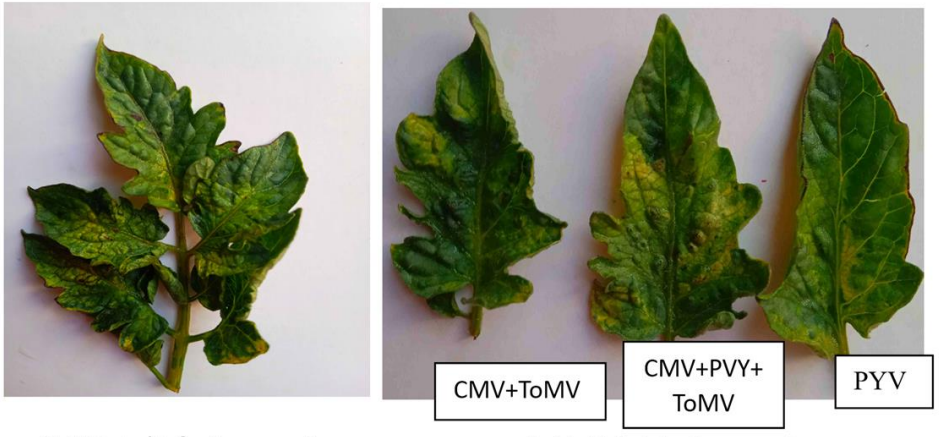


Fig. 2. Disease incidence and frequency of viral infections



a. ToMV viral infection symptoms

b. Multiple infection symptoms

c. CMV symptoms in tomato

d. Potato Y virus symptoms

Fig. 3. Detected symptoms in tomato plants

Table 4. Screened germplasm for the detection of CMV, ToMV and PVY through DAS -ELISA readings

S No	Germplasm	OD Value of ToMV at 405nm		Presence (+) or Absence (-) of Virus	OD Value of CMV at 405nm		Presence (+) or Absence (-) of Virus	OD Value of PVY at 405nm		Presence (+) or Absence (-) of Virus	DI	VIO
		2020	2021		2020	2021		2020	2021			
1	Pusa Ruby	1.9835-2.6439	2.3245-2.9438	+	0.1931-0.2744	0.2765-0.3687	+	0.1620-0.2481	0.1983-0.3235	+	65.32	3
2	EC-620406	0.7907-1.0183	1.2431-1.5974	+	0.2540-0.5267	0.3567-0.6320	+	0.3447-0.5362	0.1324-0.6579	+	75.2	3
3	Arka Vikas	0.2540-0.5267	0.3421-0.7632	+	0.3247-0.5543	0.1456-0.5408	+	0.0342-0.0427	0.0432-0.0543	-	49.2	2
4	EC-771607	0.0381-0.0411	0.0253-0.0578	-	0.0439-0.0565	0.0321-0.0654	-	0.0359-0.0652	0.0432-0.0654	-	0	0
5	EC-676791	0.0285-0.0342	0.0267-0.0430	-	0.2503-0.3532	0.3752-0.5432	+	0.0425-0.0498	0.0321-0.0567	-	25.3	1
6	Hisar Anmol	0.0358-0.0468	0.0386-0.0521	-	0.0463-0.0604	0.0379-0.0567	-	0.0475-0.0603	0.0234-0.0506	-	0	0
7	EC- 514109	0.2083-1.2350	0.1792-0.9203	+	0.1842-0.2856	0.2358-0.3256	+	0.3437-0.5303	0.2657-0.4568	+	56.43	3
8	EC-677191	0.2343-0.7302	0.2805-0.8754	+	0.2117-0.3632	0.2765-0.3986	+	0.4261-0.6832	0.3456-0.7632	+	38.43	3
9	EC-677049	0.3027-0.5011	0.4597-0.7531	+	0.3785-0.4658	0.5783-0.8654	+	0.6543-0.8291	0.4321-0.8641	+	33.3	3
10	EC- 677123	0.0423-0.0446	0.0124-0.0324	-	0.2851-0.6175	0.1983-0.8543	+	0.0354-0.0632	0.0356-0.0567	-	17.86	1
11	Avinash 2	0.4565-1.0235	0.3274-0.9875	+	0.3017-0.8524	0.2189-0.6342	+	0.2117-0.3684	0.1987-0.2654	+	47.89	3
12	Arka Sourabh	0.0297-0.0567	0.0376-0.0648	-	0.0384-0.0562	0.0234-0.0276	-	0.0482-0.0571	0.0345-0.0654	-	0	0
13	Kashi Vishes	0.2365-0.5472	0.1983-0.6431	+	0.0408-0.0510	0.0389-0.0326	-	0.2847-0.3681	0.1765-0.2349	+	62.43	2
14	Local	0.2887-1.0224	0.2345-1.2341	+	0.2704-0.3542	0.1467-0.3257	+	0.4564-1.0281	0.2345-1.2561	+	78.39	3
15	Kajal	0.3011-0.5432	0.2789-0.7531	+	0.0254-0.0326	0.0368-0.0526	-	0.0392-0.0421	0.0235-0.0342	-	33.3	1
16	Hiasr Arun	0.0468-0.0635	0.0234-0.0365	-	0.3471-0.7867	0.1673-0.5931	+	0.0265-0.0394	0.0324-0.0543	-	25.3	1
17	Money Maker	0.6572-1.2568	0.8651-1.3652	+	0.3037-0.8514	0.2861-0.9431	+	0.2997-1.0125	0.3456-1.2459	+	56.85	3
18	EC-620417	0.2335-0.7556	0.2568-0.6532	+	0.3835-0.4778	0.1569-0.5792	+	0.1858-0.3428	0.2365-0.5467	+	70.78	3
19	Arka Ananya	0.0267-0.0394	0.0156-0.0356	-	0.2018-0.3105	0.1567-0.4352	+	0.0382-0.0563	0.0365-0.0654	-	27.64	1
20	EC-617048	0.3561-0.6872	0.4321-0.7659	+	0.2741-0.8175	0.2342-0.9821	+	0.6542-0.9801	0.4571-0.8567	+	48.3	3
Healthy tissue		0.0232	0.0165	-	0.0384	0.0256	-	0.0337	0.0276	-	0	-
Buffer		0.045	0.0354	-	0.0428	0.0329	-	0.0398	0.0267	-	0	-

CMV, Cucumber mosaic virus; ToMV, Tomato Mosaic virus, PVY, Potato Y virus; +/- Presence and absence of viral infection; VIO, Viral Infections observed; DI, Disease Incidence; OD, Optical density of observed samples under ELISA

Multiple viral infections of plants always have synergistic effects on enhancing the plant susceptibility to viral infections, Cucumber mosaic virus (CMV) and Potato Y (PVY) viruses are predominant combinations of viral infections (Nikolić et al., 2018) .Synergistic effect of plant viruses on plant height of tomato affects the plant height and also has relatively higher disease severity when compared single viral infections (Nazir et al., 2018). In our present survey, the highest frequency of the samples collected was observed at 27.5 with 75.2 percent disease severity. Similar ToMV and PVY combination of viral infection accounts for a higher percentage (Soler *et al.*, 2010). CMV+PVY+ToMV triple infection in the surveyed samples with 41.5 and 70.4 percent of disease intensity, similar type mixed viral infection in tomato was previously infected and detected through serologically by double -antibody sandwich by monoclonal antibodies of (DAS)-ELISA using specific antibodies to Cucumber mosaic virus (CMV), Potato virus X (PVX), Potato virus Y (PVY), Tomato mosaic virus (ToMV) (Herrera-Vasquez et al., 2009). ToMV plant viruses are generally transmitted in more than any other single viral infection as ToMV was mechanically transmitted (Tolin and Fayad, 2016).

Screening of tomato germplasm for single, dual and multiple infections and viral detection was done through serologically DAS-ELISA. Cucumber mosaic virus infection was observed in dual combination along with either ToMV or PYV virus. Optical density readings A_{405} readings of different germplasm result positive optical density up to 0.525 (Shehata et al., 2023) and a similar trend of results was observed in the germplasm with positive for CMV with optical density values

in germplasm Pusa Ruby, EC-620406, and Arka Vikas. Pusa Ruby, EC-620406, EC- 514109, EC-677191, EC-677049, Avinash 2, Local, Money Maker, EC-620417, EC-617048 resulted positive for the CMV, PYV and ToMV with optical density values of range 0. 0.1931 to 0.6234, optical density at 405 nm above 2.0 associated with the non-inoculated leaves from infected plants indicated that viral progenies (Faurez et al., 2012). Germplasm with neither single nor any of mixed viral infection was observed with optical density A_{405} at 0.0297 to 0.0654, with similar optical density values observed for plant samples detected for various viral combinations (Kang et al., 1982; Nadeem et al., 2022).

Conclusion

The present study focused on detecting the viral infection that occurred under Jammu sub-tropical climate and to know the extent of the viral disease which common, was concluded that tomato mosaic virus was detected serologically in Gajansoo, Pinjore, Lalyal, Badayal Brahmna, Makhanpur, Kothe and Chatha, while CMV was detected in Pinjore, Gajansoo, Badayal Brahmna, Laswara, Purobana, Kothe and Chatha however PVY was detected in Lalyal, Salehar, Gajansoo, Kothe and Chatha. The two germplasm EC-771607 and Hisar Anmol were found resistant to the entire three viruses and these resistant lines/varieties can further be exploited in tomato breeding programs. There is an extent of single, dual or mixed viral infections observed in different samples detected through DAS-ELISA in surveyed areas.

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Author Contributions
All authors conceived the concept, wrote and approved the manuscript.

Acknowledgements
Not applicable.

Funding
There is no funding source for the present study.

Availability of data and materials
Not applicable.

Competing interest
The author declares no competing interests.

Ethics approval
Not applicable.

Citation: Diskit S, Ravishankar LV, Singh R, Rasool B, Choskit D, Dar NA, Vaid A, Gupta S and Summuna B (2024) Serological Detection of Viruses causing Tomato Mosaic Disease. Environ Sci Arch 3(STI-1): 27-36.