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Impact of weather-related variables on the development of *Phomopsis vexans* (Sacc. and Syd.)-induced brinjal fruit rot

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Abstract
The impact of weather-related factors such as temperature, relative humidity, total rainfall, wind speed, and sunshine hours in the progression of fruit rot in brinjal caused by *Phomopsis vexans* (Sacc. and Syd.) Harter during 2021 was studied by performing correlation, regression analysis and calculation of apparent infection rate (AIR) and area under the disease progression curve (AUDPC). Disease severity recorded was correlated with the weather factors and were subjected to regression analysis. The correlation of disease severity with the weather parameters revealed the significant but negative correlation between percent disease intensity and temperature (minimum) and bright sunshine hours. The percent disease severity and relative humidity (morning and evening) showed a significant and positive correlation with each other. According to the regression analysis, the combined impact of meteorological factors and brinjal fruit rot disease severity was moderately significant and accounted to 60% for the late transplanted crop. The crop that was transplanted on July 15, 2021, had the lowest AUDPC value (2201.50), while it was maximum in the crop transplanted on August 11, 2021 (2421.65), whereas, the highest and lowest value of AIR were recorded in the crops transplanted on August 11 and July 15, 2021, respectively.

Keywords: Brinjal, fruit rot, disease severity, weather parameters, *Phomopsis vexans*

Introduction
Brinjal or eggplant (*Solanum melongena* L.), is a member of the *Solanaceae* family and is mostly grown in tropical and sub-tropical regions worldwide. Due to its extensive use in Indian foods, brinjal is considered the most significant vegetable in India and is referred to as the "king of vegetables" (Choudhary and Gaur, 2009) [4]. At different phases of growth, the brinjal crop is susceptible to a various biotic and abiotic stresses. The most damaging and significant of them is fruit rot disease, which is caused by *Phomopsis vexans* (Sacc. and Syd.) Harter.

Phomopsis vexans is a deuteromycetes fungal pathogen and its anamorph is *Diaporthe vexans.* The fruit rot disease incited by *Phomopsis vexans*, is most destructive and regarded as a significant disease because it limits the usage of brinjal in terms of nutrition, health, and income generation by rendering the fruit unmarketable and inedible. There is a 40-70% reduction in production of brinjal due to fruit rot disease (Cristina, 2002) [5]. The pathogen adversely affects the market value as well as the nutritive value of the brinjal (Bhale *et al.*, 2001) [2].

In addition to plants, climate also impact diseases, insect pests, and weeds, which lowers crop output (Anderson *et al.*, 2004) [1]. According to the classical disease triangle, if the meteorological conditions are not conducive to the development of the disease, no virulent infection may cause disease, even in highly susceptible hosts (Ziska and Runion, 2007) [19]. The purpose of the current study was to determine the effect of climatic factors, including temperature (maximum and minimum), relative humidity (morning and evening), total rainfall (mm), wind speed, and sunshine hours on the development of brinjal fruit rot disease.

Materials and Methods

The role of weathor factors was studied on the development and progression of brinjal fruit rot disease by transplanting a susceptible variety (Pusa purple long) on three different dates *viz*., 15th July, 29th July and 11th August, 2021 with 60×60 cm spacing in plots measuring 3×2.4 m^2. All agronomic practices were followed at regular intervals. A (0-5) rating scale (Islam *et al*., 1990) [8] was used to record the disease severity at weekly intervals after the appearance of the disease. The scale is given as Grade = Hull rot%: 0 = 1, 1 = 1-10, 2 = 10-15, 3 = 15-30, 4 = 30-40, 5 = 50 and above.

The formula given by McKinney (1923) [3] was used to calculate the disease severity (%).

$$\text{Disease severity (\%)} = \frac{\text{Sum of all the disease ratings}}{\text{Total number of plants examined} \times \text{maximum rating grade}} \times 100$$

The individual as well as combined effect of weather factors on disease progression was studied by computing simple correlation and stepwise multiple regression analysis. Infection rate and AUDPC were also calculated. For correlation and regression analysis, the weekly average data on weather parameters *viz*., temperature (maximum and minimum), relative humidity, rainfall, wind speed, and sunshine hours recorded by Agro Meteorological Observatory, CCSHAU, Hisar during the crop growth period was used.

The apparent infection rate of the disease was calculated by using the formula given by Vander Plank (1963) [18].

$$r = \frac{2.3}{(t_2-t_1)} \left\{\log_e \frac{x_2}{1-x_2} - \log_e \frac{x_1}{1-x_1}\right\}$$

where,

r = apparent infection rate at log phase of epidemic development

t_1 = time at x_1 value of disease severity

t_2 = time at x_2 value of disease severity

The value of area under disease progress curve was calculated by the formula given by Vander Plank (1963) [18].

$$AUDPC = \sum_{i=1}^{k} \tfrac{1}{2} (y_i + y_{i+1}) \times (t_{i+1}-t_i)$$

where,

k = number of successive evaluations

y_i = value of disease severity at t_i

y_{i+1} = value of disease severity at t_{i+1}

t_i = time at y_i value of disease severity

t_{i+1} = time at y_{i+1} value of disease severity

Experimental results

Correlation and stepwise multiple regression analysis were performed to evaluate the effect of weather-related factors on the disease progression of brinjal fruit rot during *Kharif* 2021. The value of disease severity (%) was maximum in the crop transplanted on the first fortnight of August ranging from 13.6-85.7 percent, in the crop transplanted on second fortnight of July, disease severity varied from 15.0-82.0 percent, whereas, it ranged from 19.5-75.5 percent in the crop transplanted on the first fortnight of July as revealed in Table 1. Amongst all the three dates of transplanting, the third date (August 11, 2021) had the highest disease severity (85.7%), followed by the second date (82.0%), while the minimum disease severity (75.0%) was recorded in the first date of the transplanting.

The disease severity showed a significant increase in all three dates of transplanting of brinjal from 36 to 43 Standard Meteorological Weeks (SMW). The highest temporal progress of disease severity was recorded when maximum temperature ranged between 31.8-34.8 °C, minimum temperature 21.6-25.2 °C with relative humidity morning 86.2-92.6 percent and evening 36.9-75.8 cent, average wind speed 1.9-6.5 km/h, sunshine 4.7-8.2 hours/day and total rainfall 0-142 mm during SMW 37 to 38 and 40 to 41 on pusa purple long transplanted on 15th July, 2021. During 2nd and 3rd transplanting (29th July, 2021, 11th August), the maximum percent disease severity was recorded when maximum temperature ranged between 31.8-34.8˚C, minimum temperature between 21.6-25.8˚C, relative humidity (morning) between 86.2-94.6%, relative humidity (evening) between 36.9-75.8%, average wind speed between 1.9-6.5 km/h, sunshine between 4.3-8.2 hours/day and total rainfall between 0-142 mm during SMW 36 to 41.

Correlation analysis was used to determine the quantitative relationship between the weather variables and disease severity for different dates of transplanting. With correlation coefficient values of-0.925, -0.952, and-0.936, a significant but negative correlation between the percent disease severity and the minimum temperature was recorded on 1st, 2nd and 3rd dates of transplanting, respectively. The morning average relative humidity had a substantial and positive correlation with the percent disease severity, with correlation coefficient values of 0.778, 0.736, and 0.772 on 1st, 2nd and 3rd dates of transplanting, respectively. Likewise, with correlation coefficient values of 0.883, 0.794, and 0.872, respectively, the evening average relative humidity demonstrated a significant and positive correlation with the percent disease severity. There was a non significant and negative correlation between disease severity and average wind speed with correlation coefficient values of-0.652, -0.517 and-0.621 on 1st, 2nd and 3rd dates of transplanting, respectively. With correlation coefficient values of-0.774, -0.660, and-0.775 on 1st, 2nd and 3rd dates of transplanting, respectively, there was a significant but negative correlation between the percent disease severity and sunshine hours, whereas, significant and positive correlation of disease severity with total rainfall was observed with the correlation coefficient values of 0.722, 0.713 and 0.726 on 1st, 2nd and 3rd dates of transplanting, respectively as depicted in Table 2.

Table 1: Effect of weather-related factors on the progression of brinjal fruit rot

Dates of Observation	Standard Meteorological weeks (SMW)	Disease severity (%) Dates of Transplanting			Temperature (°C)		Relative Humidity (%)		Average wind speed (km/h)	Sunshine (h)	Total Rainfall (mm)
		15-07-21	29-07-21	11-08-21	Max.	Min.	M	E			
07-09-2021	36	19.5 (25.9)*	15.0 (21.4)	13.6 (21.4)	32.7	25.8	94.6	75.4	4.8	4.3	100.2
15-09-2021	37	20.5 (26.5)	16.0 (22.1)	14.4 (22.0)	31.8	25.2	89.2	71.8	6.5	4.7	44.3
22-09-2021	38	25.0 (29.2)	19.0 (25.9)	22.5 (26.6)	32.3	25.2	89.5	75.8	5.8	6.1	142
29-09-2021	39	37.0 (39.2)	26.5 (31.3)	32.0 (33.4)	31.9	25.4	90.5	71.3	3.7	5.7	126
06-10-2021	40	42.0 (41.9)	38.3 (40.3)	42.8 (40.8)	33.3	25.3	92.6	65.7	3.1	6.7	5.5
15-10-2021	41	58.5 (48.9)	44.75 (42.4)	60.2 (48.7)	34.8	21.6	86.2	36.9	1.9	8.2	0
22-10-2021	42	74.0 (59.1)	80.5 (63.1)	81.5 (63.6)	31.3	18.4	85.5	50	2.8	6.3	0
30-10-2021	43	75.5 (61.8)	82.0 (64.2)	85.7 (67.1)	29.8	15.9	86	44.4	4.4	7.8	0
CD (p = 0.05)		3.57	3.94	2.95							

*Figures in parentheses represents angular transformed values

Table 2: Correlation matrix between weather factors and disease severity (%) at all three dates of transplanting

Weather Parameters	Correlation Coefficients		
	15-07-2021	29-07-2021	11-08-2021
Temperature (maximum)	-0.297	-0.455	-0.321
Temperature (minimum)	-0.925	-0.952	-0.936
Relative Humidity (morning)	0.778	0.736	0.772
Relative Humidity (evening)	0.883	0.794	0.872
Average Wind Speed	-0.652	-0.517	-0.621
Sunshine hours	-0.774	-0.660	-0.775
Total Rainfall	0.722	0.713	0.726

Table 3: Multiple regression equation for progression of fruit rot disease in relations to weather factors

Dates of Transplanting	Multiple Regression Equation	R square Value
15-07-2021	Y = 37.14-3.62 Tmax.-17.37 Tmin + 0.16 RHm + 8.19 RHe-11.24 WS-29.02 BSH + 10.971 Rain	0.59
29-07-2021	Y = 42.61-3.95 Tmax.-19.58 Tmin + 6.76 RHm + 8.32 RHe-21.78 WS-39.25 BSH + 20.78 Rain	0.44
11-08-2021	Y = 58.24-4.62 Tmax.-19.54 Tmin. + 3.46 RHm + 9.10 RHe-16.36 WS-36.17 BSH + 15.76 Rain	0.60

The combined effect of weather parameters, including temperature (maximum and minimum), relative humidity (morning and evening), total rainfall, average wind speed, and sunshine hours, on the severity of brinjal fruit rot was found to be moderately significant with values 59.0, 44.0, and 60.0% for 1st, 2nd and 3rd dates of transplanting, respectively according to the multiple linear regression analysis as depicted in Table 3.

The summary of disease progression of fruit rot disease over a period of time was computed using AUDPC. The highest values of AUDPC were observed during 42 SMW in all three dates of transplanting with values 568.75, 523.25 and 585.38 on 1st, 2nd and 3rd dates of transplanting, respectively. When AUDPC was statistically analyzed based on the disease progression, it was observed that the crop transplanted on July 15, 2021, had the lowest total AUDPC value (2201.50), while the crop transplanted on August 11, 2021, had the highest total AUDPC value (2421.65) as depicted in Table 4.

Table 4: Area under disease progress curve (AUDPC) on different dates of transplanting

Dates of Observations	Standard Meteorological Week (SMW)	AUDPC Dates of Transplanting			Mean
		15-07-2021	29-07-2021	11-08-2021	
07-09-2021	36	108.50	140.00	98.00	115.50
15-09-2021	37	122.50	159.25	129.15	136.97
22-09-2021	38	159.25	217.00	190.75	189.00
29-09-2021	39	226.63	276.50	261.80	254.98
06-10-2021	40	290.50	351.75	360.50	334.25
15-10-2021	41	438.38	463.75	495.95	466.03
22-10-2021	42	568.75	523.25	585.38	559.13
30-10-2021	43	287.00	264.25	300.13	283.79
AUDPC		2201.50	2395.75	2421.65	2339.63

The disease spread based on the apparent infection rate was calculated by using the formula given by Vanderplank (1963) [18]. With a mean of 0.010-0.162 from SMW 36 to 43, Table 5 shows that the apparent infection rate varied from 0.009-0.100, 0.011-0.232, and 0.009-0.153 on the 1st, 2nd, and 3rd dates of transplanting, respectively. The crop transplanted on August 11, 2021 recorded the highest apparent infection rate (0.067), while the crop transplanted on July 15, 2021 recorded the lowest AIR (0.047).

Table 5: Apparent infection rate (AIR) on different dates of transplanting

Dates of Observations	Standard Meteorological Week (SMW)	Apparent Infection rate (r)			Mean
		Dates of Transplanting			
		15-07-2021	29-07-2021	11-08-2021	
07-09-2021	36	0.009	0.011	0.009	0.010
15-09-2021	37	0.037	0.030	0.078	0.048
22-09-2021	38	0.081	0.061	0.069	0.070
29-09-2021	39	0.030	0.077	0.066	0.058
06-10-2021	40	0.095	0.038	0.100	0.078
15-10-2021	41	0.100	0.232	0.153	0.162
22-10-2021	42	0.011	0.014	0.044	0.023
30-10-2021	43	0.009	0.015	0.013	0.012
Mean		0.047	0.060	0.067	

Summary and Discussion

The disease severity was minimum in the crop transplanted on 15th July (75.5%) and maximum in the crop transplanted on 11th August (85.7%) *i.e.*, late transplanted crop.

The percent disease severity showed a significant but negative correlation with minimum temperature and bright sunshine hours, whereas significant and positive correlation with relative humidity (morning and evening) and total rainfall. However, the correlation of percent disease severity was non significant and negative with temperature (maximum) and average wind speed.

The value of AUDPC was minimum in the crop transplanted on July 15, 2021, whereas the crop transplanted on August 11, 2021 recorded the highest value of AUDPC (2421.65). Likewise, the value of AIR was lowest in the crop transplanted on first fortnight of July (0.047), while it was highest in the crop transplanted on the first fortnight of August with the value 0.067.

These results are in conformity with the research findings of Panwar and Chand (1968) [14], Chaudhary and Hasija (1979) [3], Singh (1987) [17], Islam and Pan (1992) [7], Kaushal (1992) [10], Manna *et al.*, (2004) [12], and Kumar and Sugha (2006) [11], who emphasized the impact of temperature and relative humidity on the progression of fruit rot disease in brinjal. Likewise, Sharma and Razdan (2013) [16] found a negative but significant association between the percent disease severity and the temperature (maximum and minimum). According to Kaniyassery *et al.*, (2024) [9], there is a substantial but negative correlation between the minimum temperature and the occurrence of brinjal leaf spot disease.

Conclusion

This study extended our knowledge on the role of different meteorological parameters and time of transplanting on the development of brinjal fruit rot disease. The meteorological conditions in Haryana had a significant impact on the development of brinjal fruit rot. Thus, in order to prevent the vulnerable stage of the disease from occurring under favourable weather circumstances, it is therefore recommended that the crop should be transplanted during the first fortnight of July.

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