International Journal of Environment and Climate Change

Volume 14, Issue 8, Page 182-188, 2024; Article no.IJECC.120579
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Effect of Weather Parameters on Disease Severity and Progression of *Fusarium* Wilt in Chilli (*Capsicum anuum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijecc/2024/v14i84340

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/120579

Original Research Article

Received: 28/05/2024
Accepted: 30/07/2024
Published: 05/08/2024

ABSTRACT

Fusarium wilt incited by *Fusarium oxysporum* is an economically damaging disease of chilli (*Capsicum anuum* L.). Field experiments on epidemiological studies were conducted using susceptible variety (Pusa Jwala) to study the effect of weather parameters on the progression of the disease. The study revealed that transplanting chilli during the first half of July reduced the disease severity compared to earliest transplant dates. The area under disease progress curve (AUDPC) and the apparent infection rate were lowest in the crop transplanted on 15th July, 2022 while they were highest in the crop transplanted on 15th June, 2022. The correlation analysis showed a positive correlation between disease severity and bright sunshine hours, and a negative correlation

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Cite as: *Gupta, Priyanka, Pooja Sangwan, Manjeet Singh, Vinod Kumar Malik, and Sapna. 2024. "Effect of Weather Parameters on Disease Severity and Progression of Fusarium Wilt in Chilli (Capsicum Anuum L.)". International Journal of Environment and Climate Change 14 (8):182-88. https://doi.org/10.9734/ijecc/2024/v14i84340.*

with the other weather parameters. The R^2 value obtained from multiple regression equations revealed that the combined effect of weather parameters could explain the prediction of a disease level of 83-86 per cent at all three transplant dates.

Keywords: Chilli; Fusarium wilt; disease progression; weather parameters; disease severity.

1. INTRODUCTION

Chilli (*Capsicum anuum* L.) is the most important vegetable and spice crop in India which covers about 75% of total cultivated area. The total area devoted to chilli cultivation in Haryana is estimated at 13,290 hectares with a production of 1,41,650 tons (First advance estimate, NHB, [1]). Chilli fruit contains significant number of essential vitamins (A, B and C), providing sufficient ascorbic acid and carotene (contributor of vitamin A) to poor people in India [2]. *Fusarium* wilt caused by *Fusarium oxysporum* f. sp. *capsici* is one of the most devastating diseases inflicting yield losses of up to 10-80 per cent worldwide [3].

Fusarium oxysporum is a soil borne fungus that belongs to the domain Eukarya, kingdom *Fungi*, phylum *Ascomycota*, subphylum *Pezizomycotina* and the class of *Fusarium* is *Sordariomycetes*. It belongs to order *Hypocreales* and family *Nectriaceae*. *Fusarium oxysporum* plays a significant role in development of wilt symptoms at high temperature and high moisture [4]. The germination of *Fusarium* conidia is highly influenced by environmental factors like temperature and water potential [5]. The growth of *Fusarium* is favored at a temperature between 25-28 °C and the maximum growth is generally obtained at 28°C, inhibited above 33°C and not favored below 17 °C. Dry weather condition and excessive soil moisture also enhance the disease development [6].

Transplanting of chilli varieties at different times subjects the vegetative and reproductive stages to various temperature, rainfall and solar radiation. The interaction of three factors *viz.*, the host's resistance level, the pathogen's virulence level and the predisposing factors exerted by the prevailing environmental conditions influence the total outcome of disease [7]. Multivariate analysis of the disease progress curve highlights the phase during which maximum rate of pathogen multiplication takes place and helps to discern the structure of the epidemic [8].

For sustainable chilli production, it is advisable to identify strategies that can limit the farmer's need for fungicide application. A meagre information is available on disease progression in chilli varieties with varied date of transplanting under field conditions. Thus, the present research was framed to study the effect of transplanting time and weather parameters on disease severity and progression. The proportion of *Fusarium* wilt epidemic and temporal development can be determined by manipulating environmental conditions or by adjusting the date of transplanting in susceptible variety of chilli *i.e.*, Pusa Jwala.

2. MATERIALS AND METHODS

2.1 Experimental Setup

The field experiment was conducted to study the effect of weather parameters such as Temperature (^oC) (Maximum and Minimum), Relative Humidity (%) (Morning and Evening), Rainfall (mm), Wind Velocity and bright sunshine (hours) on the progression of *Fusarium* wilt of chilli. A *Fusarium* wilt susceptible variety of chilli *i.e.*, Pusa Jwala was grown in an infected sick plot at experimental area of CCS HAU, Hisar. The seeds of above-mentioned cultivar were transplanted in plots of $3\times2.4m^2$ with a row to row and plant to plant spacing of 60 and 45 cm, respectively, on three different dates of transplanting *viz.*, 15th June, 25th June and 15th July, 2022. A Randomized Block Design (RBD) with five replications of each transplant date was used.

2.2 Disease Assessment

Development of disease in terms of severity was recorded at weekly intervals on five randomly selected plants per plot starting from disease appearance to crop maturity using 0-5 rating scale. Area under disease progress curve (AUDPC) and apparent infection rate were also calculated. The weather data of *kharif* season of 2022 was obtained from the nearby Agro-Meteorological Observatory situated in the research farm of CCS Haryana Agricultural University, Hisar. The disease severity (%) was calculated by using formula given by Jamil et al. [9] (Table 1).

$$\text{Disease severity (\%)} = \frac{\text{Sum of all disease ratings}}{\text{Total no. of disease ratings} \times \text{maximum disease grade}} \times 100$$

Table 1. Scale for scoring *Fusarium* wilt of chilli [9]

Grade	Description
0	0% infection or no wilt
1	1-20% infection
2	21-40% infection
3	41-60 % infection
4	61-80% infection

2.3 Statistical Analysis

The disease development of *Fusarium* wilt was assessed by calculating area under the disease progress curve (AUDPC) by adopting standard procedure given by Van der Plank [7]. Coefficient of correlation for disease severity index was calculated with the weather variables namely, Temperature (°C) (Maximum and Minimum), Relative Humidity (%) (Morning and Evening), Rainfall (mm), Wind Velocity and bright sunshine (hours) for different transplanting dates. The correlation coefficient was figured out by performing correlation analysis using OPSTAT software. Multivariate regression analysis was performed with disease severity (%) as dependent variable for the regression equation. The value of coefficient of determination (R^2) was used to obtain the combined effect of temperature, relative humidity, average wind speed, sunshine and rainfall for the prediction of disease level in all three dates of transplanting.

3. RESULTS AND DISCUSSION

The development and progression of *Fusarium* wilt of chilli were studied on Pusa Jwala variety of chilli transplanted on three different dates *viz.*, 15th June, 25th June and 15th July, 2022 (Table 2). The disease first appeared in the third week of July. Disease severity progression was observed up to 14th October, 2022. During that period, temperature ranged between 27-36.6°C (maximum) and 20.4-27.9°C (minimum), while Relative humidity ranged between 84.4-94.9 per cent (morning) and 48.4-83 per cent (evening). The average wind speed, bright sunshine hours and total rainfall ranged between 2.4-8.1 km/h, 3.5-8.7 hours and 0-146.5 mm, respectively. The per cent disease severity was recorded maximum in 1st date of transplanting ranging from 8.8-88.8 per cent. In 2nd date of transplanting per cent disease severity varied from 0-86.2 per cent and in 3rd date of transplanting per cent disease severity varied from 0-85.6 per cent. Among three different dates of transplanting maximum disease severity (88.8 per cent) was observed in 1st date of transplanting *i.e.*, 15th June, 2022 followed by 86.2 per cent in 2nd date of transplanting and the minimum *i.e.*, 85.6 per cent in 3rd date of transplanting. Progression of per cent disease severity was measured and correlated with the environmental factors starting from the appearance of the disease. Per cent disease severity increased in all three dates of transplanting of chilli crop from 29 to 41 Standard Meteorological Weeks (SMW). The maximum temporal progress of per cent disease severity was recorded during SMW 30 to 32 on Pusa Jwala transplanted on 15th June, 25th June and 15th July, 2022. The maximum temperature ranged between 32.2-33.6°C, minimum temperature 26.4-27.6°C with relative humidity (morning) 85.7-94.9 per cent and (evening) 65.0-83.0 per cent, average wind speed 3.3-7.1 km/h, bright sunshine 3.6-5.9 hours/day and total rainfall 2.4-132.1 mm. Cook [10] stated that weather affects the incidence and disease severity during infection, systemic infection and wilting symptom development. Rishbeth [11] noted temperature to be critical factor in the development of wilt disease. Therefore, Khan et al*.* [6] also observed the growth of *Fusarium* at temperature between 25 to 28°C and found that maximum growth is generally obtained at 28°C, inhibited above 33°C and not favoured below 17°C. Kumar et al*.* [12] reported that the most favourable temperature is 25-30°C for the growth of *Fusarium* spp. Similarly, Chen et al*.* [13] showed that *F. oxysporum* was able to grow at wide temperature range, and the highest growth rate was observed at 23-24°C.

The maximum AUDPC (623) was found in 1st date of transplanting followed by 2nd date of transplanting (605.5) on 41 SMW. The value of AUDPC with respect to average of three dates of transplanting was maximum (609.58) in 41st SMW and minimum (38.73) in 29th SMW. The total mean AUDPC with respect to average of three dates of transplanting was recorded 5423.48 from 29-41 SMW. Based on the disease progression, AUDPC was statistically analysed. It was found that the value of AUDPC was lowest in the crop transplanted on 15th July, 2022 (5270.65) while it was maximum in the crop transplanted on 15th June, 2022 (5500.60) (Fig. 1).

Table 2. Effect of weather parameters on the development of *Fusarium* wilt disease

Dates of Observations	Standard Meteorological weeks (SMW)	Disease severity (%) Dates of Transplanting			Temperature (°C)		Relative Humidity (%)		Average wind speed (km/h)	Bright sunshine hours (h)	Total Rainfall (mm)
		15-06-2022	25-06-2022	15-07-2022	Max.	Min.	M	E			
22-07-2022	29	8.8	0.0	0.0	35.2	26.6	89.4	73.0	6.3	4.6	101.0
29-07-2022	30	12.8	11.6	0.0	33.0	26.9	89.9	77.0	7.1	5.0	17.6
05-08-2022	31	28.0	32.0	26.8	32.2	26.4	94.9	83.0	3.3	3.6	132.1
12-08-2022	32	43.2	45.6	42.4	33.6	27.6	85.7	65.0	5.5	5.9	2.4
19-08-2022	33	56.8	60.8	55.2	33.4	26.1	88.0	63.5	8.1	6.9	55.0
26-08-2022	34	60.0	65.6	59.2	34.3	26.0	89.8	64.1	6.1	8.1	0.0
02-09-2022	35	65.6	68.8	64.0	35.5	25.6	85.9	53.0	4.9	8.5	0.0
09-09-2022	36	68.0	70.4	66.4	36.6	25.2	84.4	48.4	4.6	8.7	0.0
16-09-2022	37	70.4	72.8	72.8	35.2	27.9	85.3	58.4	7.6	6.5	1.2
23-09-2022	38	75.2	76.0	73.6	34.6	24.6	88.7	65.2	5.0	5.5	44.3
30-09-2022	39	82.4	82.4	80.8	30.2	24.0	92.8	69.0	2.4	5.1	146.5
07-10-2022	40	85.6	84.0	83.2	33.5	23.3	84.2	51.6	3.8	8.2	0.0
14-10-2022	41	88.8	86.2	85.6	27.0	20.4	93.8	72.0	4.2	3.5	1.3

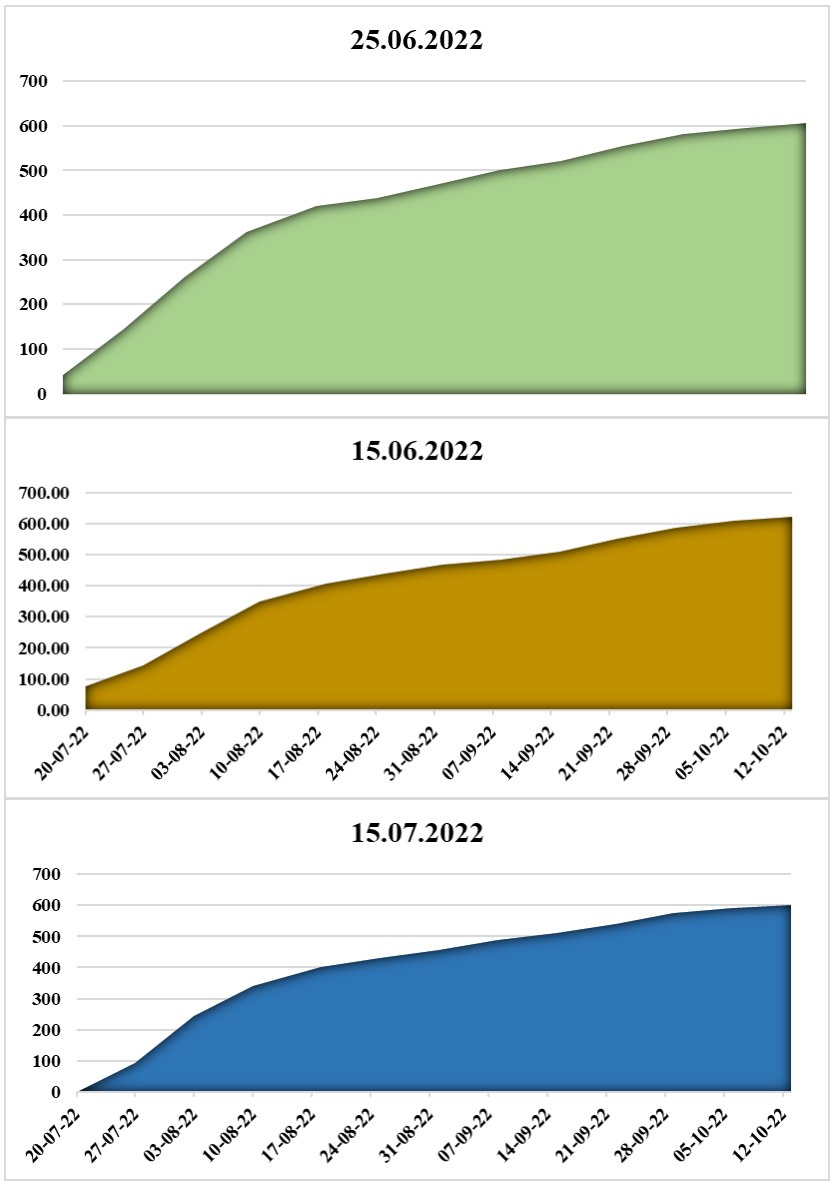

Fig. 1. Area under disease progress curve (AUDPC) for different dates of transplanting

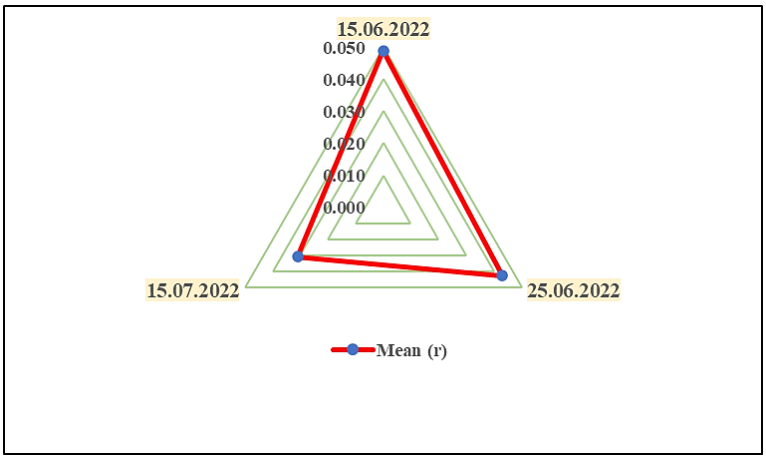

Fig. 2. Apparent infection rate (r) on different dates of transplanting

Table 3. Correlation matrix between weather parameters and per cent disease severity at different dates of transplanting

Weather Variables	Correlation		
	15-06-2022	25-06-2022	15-07-2022
Temp. Max.	-0.270	-0.247	-0.235
Temp. Min.	-0.650*	-0.598*	-0.594*
RH (M)	-0.177	-0.185	-0.189
RH (E)	-0.575*	-0.575*	-0.583*
Wind speed	-0.383	-0.364	-0.374
Sunshine	0.341	0.359	0.354
Rainfall	-0.296	-0.304	-0.285

**Correlation is significant at the 0.05 level*

Table 4. Multiple regression equations for prediction of progress of *Fusarium* wilt of chilli in different dates of transplanting in relation to weather parameters

Date of transplanting	Regression equation	R2 Value
15-06-2022	$Y= 0.62 – 5.19 X_1 + 1.81 X_2 + 6.17 X_3 – 4.98 X_4 + 0.006 X_5 – 6.38 X_6 + 0.621 X_7$	0.86
25-06-2022	$Y= –86.27 – 5.98 X_1 + 3.77 X_2 + 7.24 X_3 – 5.43 X_4 – 0.39 X_5 –6.36 X_6 – 0.048 X_7$	0.83
15-07-2022	$Y= –116.13 – 5.88 X_1 + 4.21 X_2 + 7.99 X_3 – 6.08 X_4 – 0.41 X_5 – 8.25 X_6 – 0.039 X_7$	0.84

where, X_1=Maximum temperature, X_2=Minimum temperature, X_3=Relative humidity (morning), X_4=Relative humidity (evening), X_5=Wind speed, X_6=Bright sunshine hours, X_7= Total rainfall

The apparent infection rate (Fig. 2) ranged from 0.006-0.139, 0.000-0.169 and 0.000-0.100 on 1st, 2nd and 3rd dates of transplanting respectively with mean of 0.006-0.103 from SMW 29 to 41. The apparent infection rate was highest in the crop transplanted on 15th June (0.049) and it was lowest in the crop transplanted on 15th July (0.031).

3.1 Correlation Analysis

The quantitative relationship between the disease severity and weather variables for different dates of transplanting was obtained by performing correlation analysis (Table 3). The values indicated a non- significant but negative correlation of per cent disease severity with maximum temperature with value of correlation coefficient -0.270, -0.247 and -0.235 and significant but negative correlation of per cent disease severity with minimum temperature with value of correlation coefficient -0.650, -0.598 and -0.594. The morning average relative humidity showed non-significant but negative correlation with per cent disease severity in all dates of transplanting with correlation coefficient value -0.177, -0.185 and -0.189 respectively. The evening average relative humidity showed significant but negative correlation with per cent disease severity with correlation coefficient value -0.575, -0.575 and -0.583 respectively. The wind speed also showed non-significant negative correlation with per cent disease severity with correlation coefficients of -0.383, -0.364 and -0.374 respectively. Non-significant but positive correlation of per cent disease severity with bright sunshine hours with correlation coefficient value of 0.341, 0.359 and 0.354 was recorded. The rainfall showed non-significant but negative correlation with per cent disease severity with correlation coefficient -0.296, -0.304 and -0.285.

3.2 Multiple Regression Equations for Prediction of Progress of *Fusarium* Wilt in Chilli

Multiple regression equations were calculated for Pusa Jwala variety with three dates of transplanting and are presented in Table 4. On the basis of multiple regression analysis considering the collective effect of all the weather factors, variability in per cent disease severity could be accounted for upto 86 per cent. The value of R^2 (Table 4) revealed that the combined effect of temperature, relative humidity, average wind speed, sunshine and rainfall could explain the prediction of disease level of 83-86 per cent in all three dates of transplanting.

4. CONCLUSION

In conclusion, this study expanded the knowledge on the role of weather variables and sowing time in *Fusarium* wilt development in chilli. Development of *Fusarium* wilt in chilli under Haryana conditions was influenced by transplant dates and prevailing weather conditions during the season. Thus, it would be advisable to transplant the crop during first half of July rather than in the month of June to enable escape or

non-coincidence of the susceptible stage with favourable weather conditions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENTS

Authors are highly thankful to Department of Agrometeorology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India for providing weather data of *kharif* season of 2022 and Department of Plant Pathology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India for providing required facilities to carry out the research work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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