Original Research Article

Effect of weather parameters on development of powdery mildew of ber (*Ziziphus mauritiana*) caused by *Oidium erysiphoides*

Abstract

India's one of the most popular fruits is the ber (*Ziziphus mauritiana* Lamk.). *Ziziphus mauritiana* is sometimes referred to as Indian plum or desert apple. *Oidium erysiphoides* f. sp. *Ziziphi*, which causes powdery mildew of ber, is more common and a threat in northern states. The white powdery coating on leaves and fruits affects the photosynthesis and growth & development, respectively. This disease results in 50-60% loss in fruit yield and reduces market value of the produce. In the present study, the effect of abiotic environmental elements such as temperature, relative humidity, wind speed, and others were observed and they had a significant impact on the progression of powdery mildew disease. In the study, which was carried out on two ber cultivars *viz.*, Gola and Kaithali, the disease progression on both cultivars showed a significantly negative correlation with maximum (Tmax) and minimum temperature (Tmin) and a significantly positive correlation with morning (RHm) and evening relative humidity (RHe). The favourable weather variables were observed *viz.*, Tmax above 20.3 °C, Tmin around 9.9 °C and RHm was more than 80%. Theber cultivar Gola was more susceptible to disease development than Kaithali, with Gola having the highest disease intensity.

Keywords: Ber, Powdery mildew, Disease index, correlation, Gola and Kaithali

Introduction

In semi-arid and dry regions of India and a select few other nations, the ber (*Ziziphus mauritiana* Lamk) fruit crop has been cultivated for thousands of years. Although it is a little fruit in India, its production and acreage have recently expanded since it has become a significant cash crop in several regions. Indian Ber or ber (*Ziziphus mauritiana*Lamk.) is one of the most common fruits consumed in India and adjoining areas of China. *Ziziphus mauritiana*, is also known as ber, desert apple or Indian plum. Because of its potential for high yield and strong financial returns for growers, the cultivation of ber has experienced significant growth as a commercial crop in North India, particularly in Punjab, Haryana, and Rajasthan. The fruits being palatable, delicious, highly nutritive and are rich in vitamin A, B complex and contains high amount of vitamin C, per 100 g of pulp (39-166 mg of ascorbic acid), considered higher than citrus and apple. The fruits can be used to make drinks, eaten fresh, dried, canned, or pickled. Fruits of some species begin to ripen in October, others between mid-February and mid-March, and still others between March or mid-March and the end of April (Morton, 1987). Powdery mildew is more common and a threat in northern states. Mitter and Tondon originally reported powdery mildew of ber in India from Allahabad in 1930. Later reports came from numerous locations, including Pune in Maharashtra (Uppal *et. al.*, 1935). It results in 50-60% loss in fruit yield and reduces market value of the produce. The disease often affects plants and fruits starting in October and is most prevalent from November to April. The fungus, an obligate parasite, generates white upright conidiophores from ectophytic septate mycelium (Arjunan *et. al.*, 1999) and it survives in the bud wood of the host plant or in some additional host plants.The severity of the disease depends not only on the stage of infection but also on pruning periods and weather conditions (Jamadar and Jahagirdar, 2004). White flecks covering the diseased areas can be seen. When the condition is advanced, patches eventually become larger, cover the entire surface of the parts, and change colour to a greyish brown hue. The fruit may become deformed, corky, and sunken with dark brown areas on the surface, while the leaves grow dwarfed, twisted, and malformed. In other words, the fruits' and leaves' white powdery coatings have an impact on growth and development and photosynthesis, respectively. Earlier studies on the relationship of weather parameters with disease development and progression depictsthat the maximum and minimum temperature were significantly correlated with powdery mildew during fruiting season of ber (Singh *et al.*,2019), whereasin a field experiment conducted by Jat and Goyal (2009) to determine the impact of various abiotic environmental factors on the development of the powdery mildew disease on a susceptible ber cultivar, it was found that the disease first appeared when relative humidity levels in the morning and evening were 76% and 42%, respectively, and that the maximum and minimum temperatures were 32 and 14 °C respectively, during the ber fruiting season.

Materials and Methods

Layout and location of experimental field:

The investigation took place in the experimental orchard at CCS Haryana Agricultural University, Regional Research Station, Bawal (28.08 °N 76.58 °E and 266 meters elevation above mean sea level) during the crop season 2020–21. In the investigation, for the fulfillment of the objectives, two cv(s) of ber plantation Gola and Kaithali were selected. The design of the experimental field was randomized block design (RBD).

To study the role of weather variables in the progress of powdery mildew disease of ber

From October 2020 to February 2021, different meteorological variables were examined weekly. For correlation with the percent disease index, weekly meteorological data of the following weather attributes were collected from R.R.S., Bawal observatory.

- Maximum Temperature (Tmax) and Minimum Temperature(Tmin)
- Morning relative humidity (RHm)
- Evening relative humidity (RHe)
- Windspeed
- Sun shine hours
- Total rainfall
- Number of rainy days

Disease assessment:

After the onset of the disease, the percent disease index (PDI) of powdery mildew of ber was measured at weekly intervals. Three replications of two ber were used. The data was collected from the 43rd week of 2020 to the 5th week of 2021. Twenty leaves and fruits were randomly selected from each tagged branch of ber plants and graded using the scale below (Anonymous, 1985):

Table: 1. The per cent disease index (PDI) of powdery mildew of ber was calculated according to the following scale:

Rating Scale	Area (%) covered by disease
0	No disease
1	1-10% areas of leaves and fruits affected
2	11-20% areas of leaves and fruits affected
3	21-50% areas of leaves and fruits affected
4	51-75% areas of leaves and fruits affected
5	76-100% areas of leaves and fruits affected

I. The per cent disease index was calculated using the following formula given by McKinney (1923):

$$\text{Per cent disease index (PDI)} = \frac{\text{Sum of all numerical ratings}}{\text{Total no. of leaves and fruits} \times \text{Number of ratings}} \times 100$$

II. Per cent disease control was calculated by the following formula:

$$\text{Per cent disease control} = \frac{\text{Disease intensity in treatment} - \text{Disease intensity in control}}{\text{Disease intensity in control}} \times 100$$

Statistical analysis: Statistical package of programs OPSTAT was used to analyze the data in the investigation (Sheoran*et al.*, 1998).

Results and Discussion:

Role of weather variables in the progress of powdery mildew disease of ber

For both cultivars, the data in Tables 2indicates PDI as well as meteorological factors. The maximum PDI was recorded in cv. Gola (31.3%) and relatively less PDI was observed in cv. Kaithali (19.6%).

Effect of weather variables in the progress of powdery mildew disease on cv(s). Gola and Kaithaliof ber (2020-21)

According to Table 2, the disease in cv(s). Gola and Kaithali started in the 43rd week of the year 2020 and spread quickly over time as a result of favourable environmental conditions. The table shows weekly averages for the maximum (Tmax) and minimum (Tmin) temperatures, the morning (RHm) and evening (RHe) relative humidity, the average wind speed, the number of sunshine hours, the total amount of precipitation, and the number of wet days. A hike in disease severity was observed when RHm increased and Tmindroped.Between the 46^{th} and 50^{th} meteorological weeks, the disease increased significantly from 11.0 to 24.0% in Gola and 6.3 to 14.3% in Kaithali, and thereafter disease progressed at slower rate. The favourable weather variables were observed *viz*; Tmax above 20.3 °C, Tmin around 9.9 °C and RHm was more than 80%.The disease was additionally aided by average wind speed (2.66 km h^{-1}), sun shine hours (5.67 hrs), and intermittent winter rains (1.4 mm).

Figures 1 and 3 show the link between PDI and Tmax&Tmin graphically, and from that it is possible to infer that with the decline in Tmax and Tmin PDI in cv(s). Gola and Kaithali increased within a 15-week period. Over the course of the investigation, Tmax was above 20.3 °C and overall Tmin remained around 9.9 °C indicating that the disease had progressed to a significant extent due to prevailing favourable temperature. Figure 2 and 4 depicts the association of PDI with average morning (RHm) and evening (RHe) relative humidity, indicating that PDI increased with increasingRHm.

Table: 2 Effect of weather variables in the progress of powdery mildew disease on cv(s). Gola and Kaithaliof ber (2020-21)

Date of observations	Standard Meteorological Weeks	Disease index (%) (Kaithali)	Disease index (%) (Gola)	Weather Data: Avg. Temperature (°C) Max	Avg. Temperature (°C) Min	Avg. relative humidity (%) Morn.	Avg. relative humidity (%) Even.	Avg. wind speed (Km h^{-1})	Sun shine hours	Total rainfall (mm)	No. of rainy days
27th Oct	43	0.0	2.3	34.3	13.0	70	14	2.2	7.2	0	0
3rd Nov	44	1.6	4.0	31.0	9.5	66	12.1	2.9	7.5	0	0
10th Nov	45	4.0	6.6	30.6	9.0	76	17	2.0	3.2	0	0
17th Nov	46	6.3	11.0	25.0	10.2	87	43	2.1	4.4	1.4	1
24th Nov	47	9.6	15.3	24.6	7.3	86	27	2.6	6.6	0	0
1st Dec	48	10.6	18.0	25.1	9.1	82	28	2.9	6.1	0	0
8th Dec	49	12.3	21.3	24.2	8.9	87	31	1.7	6.6	0	0
15th Dec	50	14.3	24.0	20.3	9.9	90	53	3.0	4.3	0	0
22nd Dec	51	15.0	24.6	19.3	3.9	73	31	3.7	6.6	0	0
31st Dec	52	15.6	25.3	19.4	2.6	92	38	2.6	6.0	0	0
7th Jan	1	16.3	26.0	18.2	5.3	96	70	4.5	1.6	33.4	4
14th Jan	2	17.3	27.6	17.9	4.8	93	54	3.9	5.2	0	0
21st Jan	3	18.3	28.3	18.2	4.7	97	60	3.9	4.3	0	0
28th Jan	4	18.6	30.0	18.9	5.2	91	47	4	6	0	0
4th Feb	5	19.6	31.3	23.8	4.7	91	37	2.5	7.1	0	0

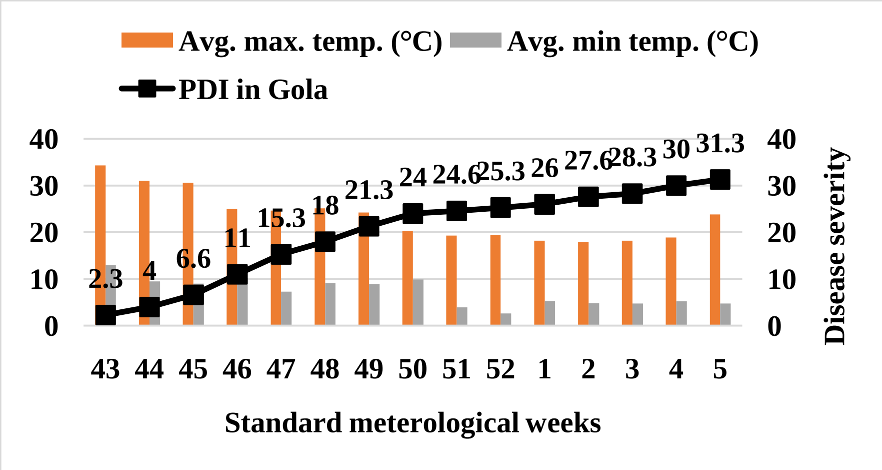

Figure 1: Effect of temperature in the progress of powdery mildew disease (cv. Gola)

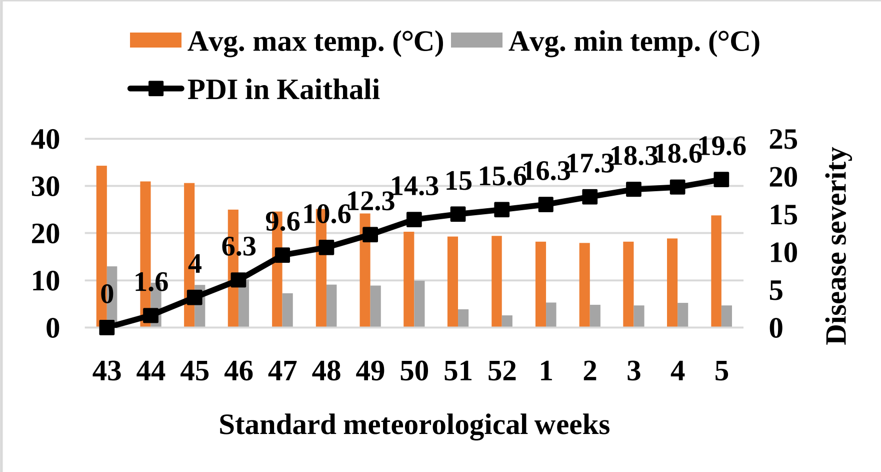

Figure 3: Effect of temperature in the progress of powdery mildew of ber (cv. Kaithali)

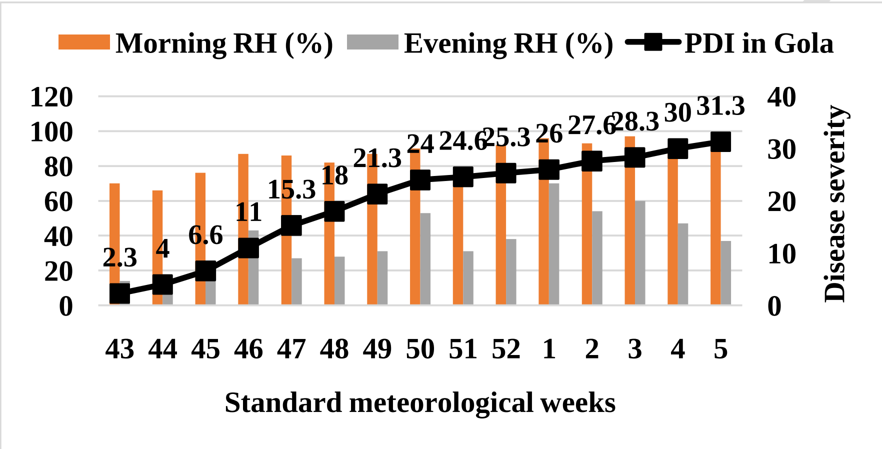

Figure 2: Effect of relative humidity in the progress of powdery mildew disease (cv. Gola)

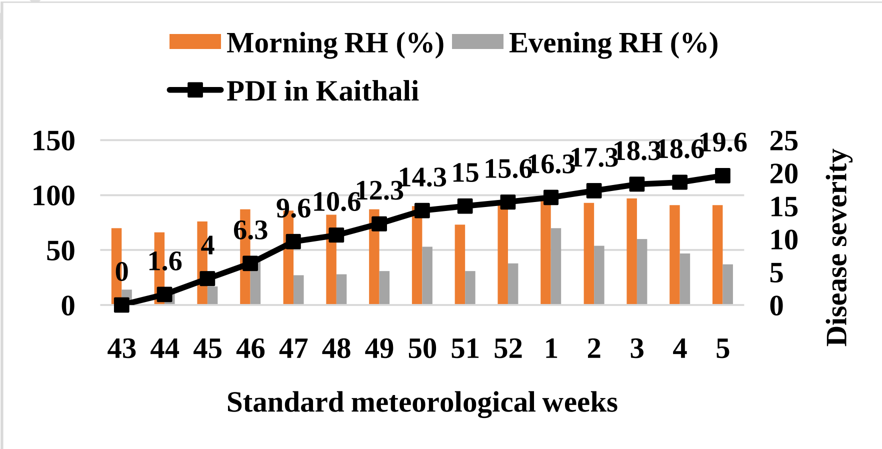

Figure 4: Effect of relative humidity in the progress of powdery mildew of ber (cv. Kaithali)

Correlation and multiple regression between weather parameters and per cent disease severity in cv(s). Gola and Kaithali

Correlation and regression analysis were used to determine the quantitative association between disease intensity of powdery mildew of berand weather variables. The association of the PDI with corresponding meteorological factors is shown in Table 3. Disease severity was inversely related with temperature and Sun shine hours, but positively correlated with relative humidity, wind speed, rainfall, and number of rainy days.

Tmax (which varied from 17.9 to 34.3 ℃) and disease severity had a significant negative correlation (at 5% level),in both cultivars, Tmin (ranging from 2.6 to 13.0 ℃) had a significant negative relation with powdery mildew disease development. The average relative humidity (RHm and RHe) had a positive and substantial correlation with disease severity. Wind speed was found to be positively linked with significance at 1%. Total rainfall and the number of rainy days did, however, exhibit a positive and non-significant relationship with PDI. Sun shine hours showed negative and non-significant correlation with disease intensity.

Table: 3 Correlation matrix between weather parameters and per cent disease severity in cultivars Gola and Kaithali

Cultivars	Avg. temperature °C		Avg. relative humidity (%)	Avg. relative humidity (%)	Avg. Wind Speed	Sun Shine Hours	Total Rainfall (mm)	No. of rainy days
	Max	Min	Morning	Evening				
Gola	-0.906**	-0.797**	0.790**	0.750**	0.576*	-160	0.170	0.116
Khaithli	-0.911**	-0.817**	0.802**	0.759**	0.591*	-187	0.178	0.125

Significance: *at 1%; ** at 5%

For both cultivars, Table 4 illustrates multiple regression generated for disease severity and meteorological factors. The equations for both cultivars were statistically significant, according to multiple regression, with R^2 values more than 0.93. The prediction equations explained 93.0% (cv. Gola) and 93.63% (cv. Kaithali) of disease progress as influenced by maximum (X_1) and minimum (X_2) temperature, morning (X_3) and evening (X_4) relative humidity, wind speed (X_5), Sun shine hours (X_6), total rainfall (X_7), and the number of rainy days (X_8).

Table: 4 Multiple regression equations for per cent disease severity w.r.t weather parameters for cultivars Gola and Kaithali (2020-21)

Cultivars	Regression equation	R^2 Value
Gola	Y_1= 23.473 - 0.691 X_1 – 0.857 X_2 + 0.057 X_3 + 0.350 X_4 - 2.565 X_5 + 1.603 X_6 + 1.122 X_7 – 9.710 X_8	0.93
Kaithali	Y_2= 10.031 - 0.359 X_1 - 0.677 X_2 + 0.083 X_3 + 0.201 X_4 - 1.197 X_5 + 0.829 X_6 + 0.642 X_7 - 5.770 X_8	0.9363

Y_1 – PDI in Gola, Y_2 – PDI in Kaithali, X_1 – Avg. maximum temperature, X_2 – Avg. minimum temperature, X_3– Avg. morning relative humidity, X_4 – Avg. evening relative humidity, X_5 – wind speed, X_6 – Sun shine hours, X_7 – Rainfall, X_8– No. of rainy days.

Area under disease progress curve (AUDPC) of powdery mildew on ber cultivars Golaand Kaithali

AUDPC was calculated for the powdery mildew disease progression over time for bothcultivars and presented in Table 5. On the basis of disease severity and weather data, the maximum AUDPC of powdery mildew was recorded as 1951.6 in cv. Gola, while it was 1187.2 in cv. Kaithali.

Table: 5Area under disease progress curve(AUDPC) of powdery mildew on ber cultivars Gola and Kaithali (2020-21)

Cultivars	Area under disease progress curve
Gola	1951.6
Kaithali	1187.2

Conclusion

The disease development under field conditions is influenced by various environmental factors, the type of the host cultivar and availability of inoculum load. Abiotic Weather factors play an important role in the severity of powdery mildew of ber, which governs the variability inonset of the disease and epidemics development.The disease had commenced from 43rd week of the year 2020 in Gola cultivar of ber whereas it was observed in the 44th week in Kaithali and the disease had increased with time due to presence of favourable environmental conditions. The intensity of the disease increased with increase in RHm and decrease in Tmin. At that period, the PDI increased rapidly from 11.0 to 24.0% in cv. Gola and from 6.3 to 14.3% in cv. Kaithali between 46th and 50thmeteorological weeks and thereafter the rate of disease progression decreased beyond 5th meteorological week.

In the period of rapid disease development, the favourable weather variables were observed *i.e.*,Tmax above 20.3 °C, Tmin around 9.9 °C and RHm was more than 80%. The aforementioned results are found in resemblance with the results of Gupta (1985) and Prakash and Jhooty (1987) who had reported the congenial range of temperature to be 20-25 ºC with >90% relative humidity for spore germination and disease development. Yadav *et al.*, (1980) reported that the powdery mildew disease starts in October month in dry weather at 16-32 ºC accompanied by >90% relative humidity. Prakash and Jhooty (1987) observed that the favourable range for disease progression was 20-25 ºC temperature with 64-84% relative humidity in the month of October in Punjab state. Jat and Goyal (2009) recorded that, temperatures between 13.8-32.0 ºC and relative humidity 41.4-75.8% with rainfall 4.0 mm during 39^{th} to 46^{th} meteorological weeks favoured the higher incidence of disease with its peak in the month of December.

Future Prospects

- The data showing close association of disease development with different meteorological parameters would be beneficial for creating a forecasting system for ber powdery mildew based on weather variables and disease indices that would assist farmers in taking timely and effective management measures.
- Identifying optimal climatic conditions for ber powdery mildew growth and development, as well as investigating the possibilities of applying climate change scenarios to anticipate the disease's future distribution and severity.
- Evaluating the efficiency of various fungicides and biocontrol agents against ber powdery mildew under various weather conditions, as well as improving treatment methods and timings for improved disease control.
- Understanding the co-evolutionary dynamics and adaption mechanisms of the pathogen-host system under varied meteorological parameters, as well as the genetic diversity and population structure of *Oidium erysiphoides* and its host *Ziziphus mauritiana*.
- Screening and breeding for disease resistance in ber cultivars, and investigating the molecular and physiological basis of resistance to ber powdery mildew under different weather parameters.

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