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Influence of weather parameters on powdery mildew of mango inflorescence in humid tropics of South Gujarat

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ABSTRACT

The influence of environmental parameters on the development of powdery mildew caused by *Oidium mangiferae* Berthet on mango inflorescence was studied for seven consecutive years (2012-18) in humid tropics climatic conditions of South Gujarat. The disease incidence and severity (DIS), area under disease progress curve-AUDPC (A-value) and apparent infection rate (r-value) were recorded at panicle and fruit setting stages of the tree at weekly intervals. The correlation studies showed that incidence and severity of powdery mildew significantly negative relationship with morning relative humidity ($r = -0.631$; $p<0.05$ and $r = -0.721$; $p<0.01$) and average relative humidity ($r = -0.766$ and $r = -0.787$; $p<0.01$). Temperature (maximum and average) and evaporation showed positive relationship with incidence and severity of powdery mildew. Further, stepwise linear regression model indicated that average relative humidity as single predictor independent variable had the strongest relationship disease incidence and severity, which explained 59 percent disease incidence and 62 percent for disease severity variability. This forewarning model can be useful for efficient management of powdery mildew disease of mango and as well as agro advisory services to farmers.

Key words: Climate, weather, epidemiology, powdery mildew, disease severity, validation

Mango (*Mangifera indica* L.), considered as 'king of fruits" is an important fruit crop in tropical and sub-tropical regions of India. It is known for its delicious taste, attractive colour, savoring flavour and high nutritive value *viz.* vitamins A and C, mineral and fibre content. The area under mango cultivation in India is 2.20 million hectares with total production of 18.64 million tonnes, contributing to 40 per cent of the total world mango production (NHB, 2015). Among Indian states, Gujarat covers 150-thousand-hectare area with total 1.24 million tones of production and 8.10 tonnes/ha productivity (NHB, 2015). India is the largest producer of mango but per ha productivity is low. Various biotic and abiotic stresses play an important role for its low productivity in India. Disease and insect-pest infestations are the major biotic stress causing factors reported in India (Choudhary *et al.,* 2017; Gundappa *et al.,* 2018).

Mango suffers from diseases at its all development stages. Among them, powdery mildew, *Oidium mangiferae* Berthet is an important, serious and widespread disease in India and causes up to 90 percent loss when observed in epidemic (Misra *et al.,* 2016; Nelson, 2008; Prakash and Srivastava, 1987). Symptoms of this disease can be noticed on leaves, inflorescences and young fruits (Nelson, 2008). The typical symptom of powdery mildew disease is characterized by appearance of white superficial powdery growth of the fungus on affected plant parts resulting in shedding of flowers and pea size fruits at later stage. The affected flowers usually fail to open and may fall prematurely resulting into no fruit set on diseased inflorescence stalk (Palti *et al.,* 1974). Southern part of Gujarat, is considered as major production hub of delicious alphonso and kesar varieties of mango in western India where powdery mildew is one of major disease reported (Chavan *et al.,* 2009; Raut *et al.,* 2017).

Several reports have been published from different parts of India on influence of weather parameters on development of powdery mildew disease on mango (Gupta, 1979; Misra *et al.,* 2016; Shukla *et al.,* 2016) but completely missing from southern part of Gujarat. Hence, seven-year consecutive study was carried out to understand the epidemiology of disease and to analyse the factors affecting the development of powdery mildew on mango under South

Gujarat conditions for its effective management.

MATERIALS AND METHODS

The present study was conducted at 26 fixed orchards located in Valsad district of South Gujarat during 2012 to 2018. Powdery mildew incidence and severity was recorded each orchard by selecting five trees (four were from four corners and one from the centre). Two rows of trees alongside of boundary of orchard in all directions were selected for observations. The tree selections for disease observations during each weekly visit were random and it was not the fixed trees in an orchard that would be sampled continuously. In each of the selected trees, the observations were made from four directions *viz.,* East, South, West and North to avoid direction biasness in the observations (NICRA team of Mango Pest Surveillance, 2011). The data from ten inflorescences from each tree were recorded at each standard meteorological week (SMW) started from panicle initiation to flowering cum fruit setting stages (1^{st} -15^{th} SMW). The observations were taken on lower canopy of mango tree (2-3 meters height from ground level) (NICRA team of Mango Pest Surveillance, 2011). The, per cent disease incidence was calculated as number of panicles infected out of total numbers of panicles observed.

Per cent disease index (PDI) was recorded by scoring all the individual ten panicles on each plant on a 0–4 scale (0= no disease, 1=<25% of the inflorescence covered by disease, 2=25-50% of the inflorescence covered by disease in panicles, 3=51-75% of the inflorescence covered by diseases and 4=>75% of the inflorescence covered by disease (NICRA team of Mango Pest Surveillance, 2011). Further, the PDI was calculated using the formula of McKinney (1923).

$$PDI(\%) = \frac{\text{Sum of all the disease ratings (£N)}}{\text{No. of panicles observed x Maximum disease rating}} \times 100$$

The area under disease progress curve (AUDPC) and apparent infection rate (AIR) were also calculated using the formula given by Van der Plank (1963) and Shaner and Finney (1977), respectively.

$$AUDPC = \sum_{i=1}^{n-1} [(X_{i+1}+X_i)/2][t_{i+1}-t_i]$$

Where, x_i= the portion of host tissue damaged at the i^{th} dayt^i=the time in days after appearance of the disease at the i^{th} day$n$=the total number of observations

$$ARI = 2.3/t_2-t_1 \{\log X_2/X_1\}$$

Where, X_1 = PDI at time t_1 X_2 = PDI at time t_2 t_2-t_1 = time interval in days between two observations

The data on weather parameters *viz.,* temperature (maximum and minimum), relative humidity (morning and evening), rainfall, wind speed, and evaporation rates were recorded in each Standard Meteorological Week (SMW) from meteorological observatory located within the experimental site of Agriculture Experimental Station, Navsari Agricultural University, Paria (20°26'N, 72°58'E, 16 m at altitude). Statistical analysis of the data and graphs were drawn using Microsoft Excel program. The model fitting and prediction accuracy performance measures were evaluated by calculating Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE) parameters.

RESULTS AND DISCUSSION

Epidemiology of powdery mildew

The weather conditions of South Gujarat played an important role in the development of the powdery mildew. The maximum and minimum temperatures varied from 30.64 to 36.61°C and 9.89 to 19.78°C, respectively during the study periods. Average temperature ranged from 20.42 to 27.87°C. Minimum and maximum relative humidity was ranged between 35.52 to 87.54%, with an average value of 60.72%. Wind velocity varies from 1.54 to 3.58 km/hr. Average evaporation rate was 4.51 mm/24hrs noticed during the observation periods.

The initial symptoms of powdery mildew disease were noticed from initiation of panicles on mango plants which lasted up to setting of fruits in the panicles. The maximum incidence and severity of disease was noticed in 2012 as compared to the succeeding years of observations. In 2012, infection started at 6^{th} standard meteorological week (SMW) which attained its peak at 12^{th} SMW (12.23%) followed by 13^{th} SMW (9.31% incidence and 5.63% severity). Thereafter, incidence and severity started declining gradually (Fig. 1). On the basis of pooled results, it is evident that maximum incidence (2.71%) was recorded at 12^{th} SMW when the prevailing maximum, minimum and average temperature, relative humidity (morning, evening and average), wind velocity and evaporation were 36.32, 16.41 and 26.36ºC, 74.17, 36.97 and 55.57%, 2.50 km/hrs and 5.62 mm/24 hrs followed by 11^{th} SMW (2.60 %) and 8^{th} SMW (2.30%), respectively. Whereas, maximum severity of powdery mildew was recorded in 13^{th} SMW (1.08%) followed by 12^{th} (1.01%) and 11^{th} SMW (0.77%), respectively. It was evident to

Table 1: Correlation between powdery mildew incidence and severity with weather parameters under south Gujarat during 2012-18

Weather parameters	Correlation coefficient (r)	
	Disease incidence (%)	Powdery mildew severity (%)
Max. Temp.	0.710**	0.747**
Min. Temp.	0.394^{NS}	0.499^{NS}
Avg. Tem.	0.539*	0.617*
Morning RH	-0.631*	-0.721**
Evening RH	-0.349^{NS}	-0.222^{NS}
Avg. RH	-0.766**	-0.787**
Rainfall	0.100^{NS}	0.029^{NS}
Wind velocity	0.338^{NS}	0.372^{NS}
Evaporation	0.567*	0.608*

** Significant at 0.01 level, * Significant at 0.05 level, NS=Non-significant

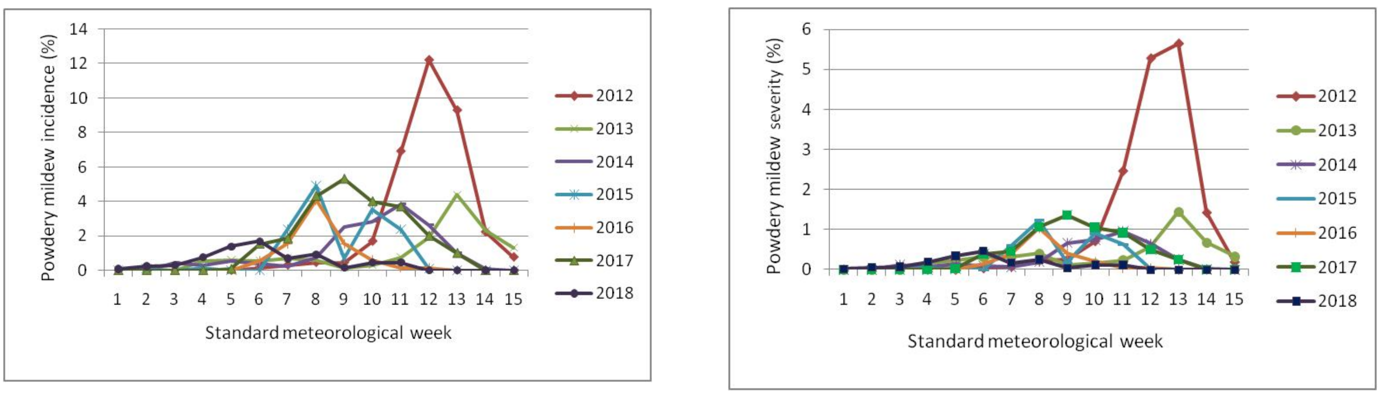


Fig.1: Incidence and severity pattern of powdery mildew in south Gujarat agro-climatic conditions during 2012-18

increase with increased temperature up to 36.61ºC and relative humidity decreased till 75.50% (Fig. 3). Evaporation rate was found on an average 4.51 mm/day which seemed to be favourable for multiplication of powdery mildew. Raut *et al.,* 2017 reported that symptoms of powdery mildew initiated in 4th SMW and attained peak status on 14th SMW at Vengurle conditions of Maharashtra.

Area under disease progress curve (AUDPC) and apparent infection rate (AIR)

The results showed that maximum area under disease progress curve was observed in 11th SMW (18.62 & 6.20 % DIS) followed by 12th (17.35 & 7.31) and 10th SMW (15.82 & 6.20) while maximum apparent rate of infection was observed in 2nd SMW (r = 0.20 DIS) followed by successive SMW *i.e.* 3rd (r = 0.13) and 4th SMW (r= 0.13 & 0.12), respectively. Disease is reported to increase with initiation of flower panicles (Shukla *et al.,* 2016; Raut *et al.,* 2017) which could be the reason for higher frequencies of disease initiation on flower panicles. Higher disease severity was observed on 11th and 12th SMW (flowering cum fruit setting stages) on flower panicles as coincided with the vulnerable weather conditions (low average relative humidity). The values of AUPDC and AIR show a greater role of weather parameters and phenological stages of mango for disease infection and further development.

Relationship between powdery mildew and weather parameters

The results from pooled data showed that powdery mildew incidence was significantly negative relationship with relative humidity of morning hours and also with averaged relative humidity ('r' = -0.631, P<0.05 & -0.766, P<0.01). Temperature (maximum and average) and evaporation showed positive significant with powdery mildew incidence ('r'=0.710, p<0.01 & 0.539, p<0.05 and 'r'=0.567, p<0.05). Other weather parameters were showed non-significant relationship with powdery mildew incidence. On the other hand, disease severity significantly positive

Table 2: Stepwise liner regression analysis between powdery mildew incidence and severity with weather parameters during 2012-18

Fit statistic	PM incidence (%)	PM severity (%)
Regression equation	$Y=19.93-0.310_{(Avg.\ RH)}$	$Y=7.38-0.115_{(Avg.\ RH)}$
R-squared	0.59	0.62
F value	18.41**	21.08**
MSE	0.39	0.05
RMSE	0.62	0.22
MAE	0.43	0.16
MAPE	263.79	393.79

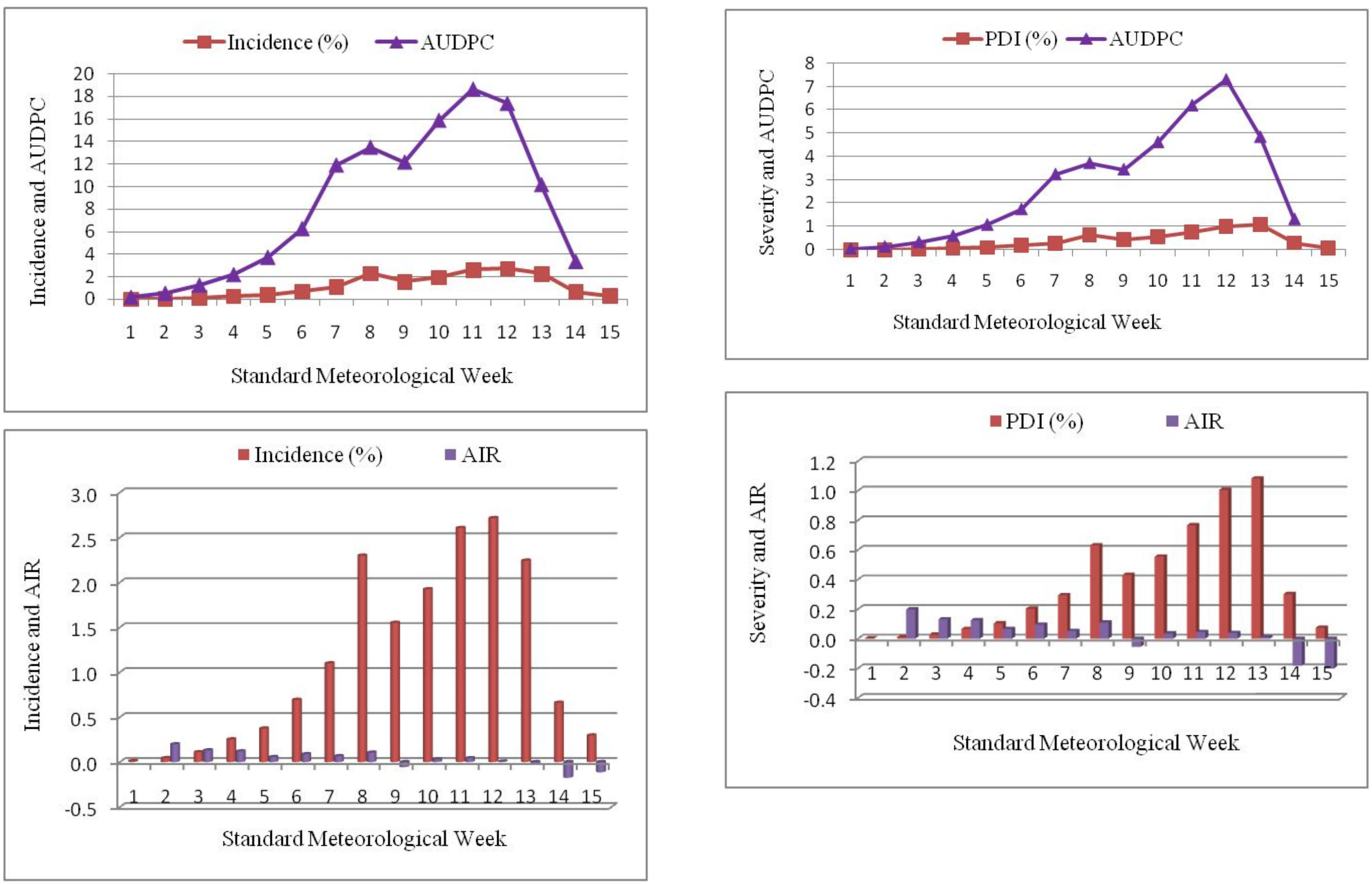
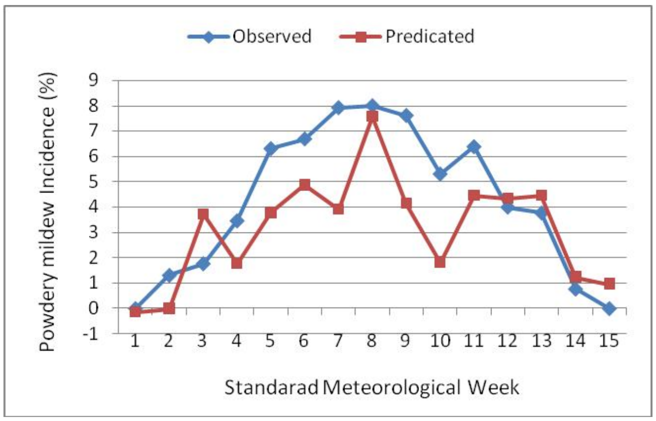


Fig.2: Area under disease progress curve (AUDPC) and apparent infection rate (AIR) for incidence and severity of powdery mildew during 2012-18

correlated with temperature (maximum and average temperature) and evaporation (‘r’= 0.747, P<0.01 & 0.617, p<0.05 and 0.608, p<0.05). Morning and average relative humidity showed negative significant with powdery mildew severity (‘r’ = -0.721 & -0.787, p<0.01). Other weather parameters *viz*., minimum temperature, evening relative humidity, rainfall and wind velocity did not play any significant role in powdery mildew disease development (Table 1). Weather factor based study of powdery mildew disease development from mango growing belt of Uttar Pradesh showed that high wind velocity for 3-4 days with maximum temperature of 35°C, minimum temperature of 15°C, minimum relative humidity of 23.4-25.5% and maximum relative humidity of 73.3-83.9% were favorable for the rapid disease development (Misra and Prakash, 1988). Temperature and humidity were considered as an important factor for appearance and development of powdery mildew diseases (Misra and Prakash, 1988; Gupta,

Table 3: Models performance results in the validation (2019) part of powdery mildew incidence and severity prediction

Prediction Statistical error	PM incidence (%)	PM severity (%)
R^2	0.46	0.52
MSE	4.28	0.24
RMSE	2.07	0.49
MAE	1.68	0.41
MAPE	47.06	58.64



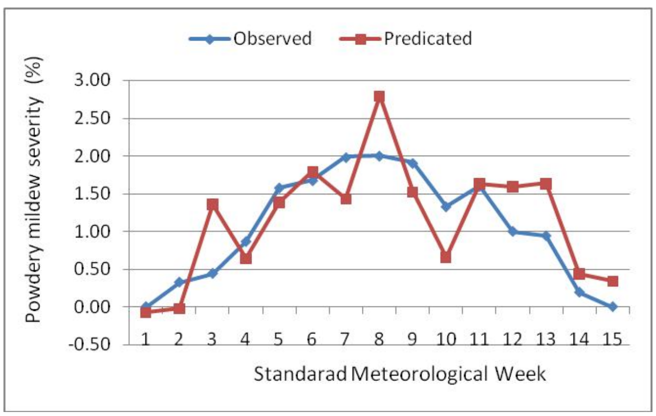


Fig.3: Validation of observed and predicted incidence and severity of powdery mildew during the year 2019

1979). Present finding further revealed that maximum temperature of 35°C played crucial role in the epidemics of powdery mildew. Schoeman *et al.,* 1995 fully support the present finding wherein severity of powdery mildew was observed during cool and dry weather indicating positive correlation with temperature and negative with humidity. Pandey *et al.,* (2004) reported that higher humidity (85-90%) and moderate temperature (33-34°C) provided favourable conditions for the initiation of Ber powdery mildew disease. Gupta (1989) further reported that rainfall did not play any significant role in disease development whereas dry weather favoured the development of disease. Based on region specific findings, some are not supportive to the present findings. Contrary result from different location was reported by Raut *et al.,* 2017 that powdery mildew positively significant with minimum temperature at Vengurle, Maharashtra conditions. Disagreement from different locations indicated that location specific studies are required to understand the disease incidence and further development of disease.

Stepwise linear regression model was developed for prediction of disease progression and results are presented in Table 2 which indicated that up to 59 and 62 per cent variation explained in powdery mildew incidence and severity, respectively due to single predictor *i.e.* average relative humidity. The model resulted out in present study considerably based on high R^2 value with minimum standard error. Models, $Y=19.93-0.310_{(Avg. RH)}$ and $Y=7.38-0.115_{(Avg. RH)}$ was considered as optimized model with minimum mean square error (0.39 & 0.05), root mean absolute error (0.62 & 0.22), mean absolute error (0.43 and 0.16) and mean absolute percentage error (263.79 and 393.79) for incidence and severity of powdery mildew of mango in humid tropic of South Gujarat agro-climatic conditions. The prediction error of model in fitting part (2012-18) and validation part (2019) was showed in Table 3 as MSE, RMSE, MAE and MAPE. The model curve displays the point to point comparison of actual incidence and severity of powdery mildew predicted in stepwise regression model (Fig. 3). In the year 2019, pattern of maximum incidence and severity of powdery mildew predicted in SMW 8 by stepwise linear regression model was identical with the actual data (Fig.3). So, it is suggested that increase in incidence and severity of powdery mildew in mango were associated mainly with humidity and appeared to be the regulatory factor South Gujarat agro-climatic conditions.

CONCLUSIONS

The present study clearly indicated that relative humidity and temperature played a significant role and offered congenial atmospheric condition for the incidence and maximum development of powdery mildew of mango in humid tropic agro-climatic conditions of South Gujarat. The present study also suggested that powdery mildew disease incidence and development in mango orchards of South Gujarat can be determined through single weather factor (relative humidity). The present results may use for better decision making well in advance to check the incidence and disease development in order with congenial weather conditions.

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