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Relationship of Meteorological variables with an Epiphytotic of Powdery Mildew Disease of Okra

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ABSTRACT: Powdery mildew (*Erysiphe cichoracearum* DC) is a serious disease of okra and causes heavy losses both in the field. The damage caused by powdery mildew may be manifested as a direct fall in the yield, because of suppression or distortion of plant growth. There is no definite evidence available regarding the conditions which help the outbreak of okra mildew. Therefore, okra powdery mildew disease development and progress in relation to meteorological factors were studied in a natural/field condition. Amidst the twelve factors, the mean temperature, maximum temperature, GDD, AGDD, bright sun shine hours and crop age shown significantly positive correlation while, significantly negative correlation was shown by morning relative humidity, afternoon relative humidity, mean relative humidity and minimum temperature with the powdery mildew intensity of okra, in *Kharif* season. Through the regression analysis it was found that mean relative humidity, afternoon relative humidity and crop age were the crucial factors for the spread of powdery mildew during *Kharif* season.

Keywords: Meteorological variables, *Abelmoschus esculentus*, powdery mildew.

INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench], crop is suitable for cultivation as a garden crop as well as on large commercial farms. This crop is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. In India okra is cultivated in an estimated area of 526.00 (000 ha) with production of 6460.00 (000 MT) & productivity of 12.10 MT/ha (Anonymous, 2018). In Gujarat, okra is mainly grown in Vadodara, Surat, Junagadh, Banaskantha and Bhavnagar districts throughout the year providing continuous and good source of income to the farmers. In Gujarat, it is grown on an area of 75.27 thousand hectares with a production of 921.72 thousand metric tonnes having average productivity of 10.90 MT/ha (Anonymous, 2018).

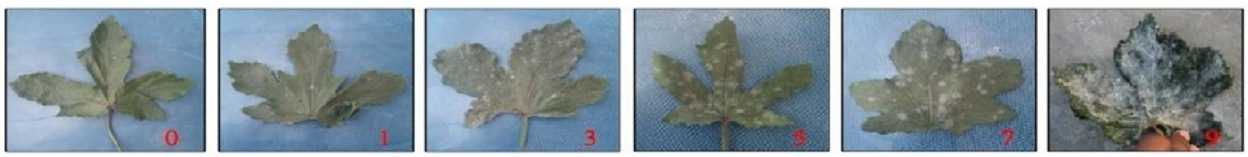
Amongst various factors diseases are major constraints for low yield of okra (Sastry, 1974). A number of viral, fungal and bacterial diseases of okra have been reported in India. powdery mildew caused by *Erysiphe cichoracearum* DC is most important among the fungal diseases affecting okra crop, as it causes considerable yield losses. In India, the disease has been reported from Delhi (Prabhu *et al*., 1971) followed by Karnataka (Sohi and Sokhi, 1973), Maharashtra (Jambhale and Nerkar 1983) and Himachal Pradesh (Raj *et al*., 1992). The occurrence of the disease has also been reported from Mexico (Diaz-Franco, 1999). The symptoms of the disease appears as white powdery minute patches first on the upper surface of lower older leaves and then spreads to younger ones. In severely affected leaves grayish white powdery coating is visible and leaves show necrosis resulting in withering, drying and defoliation. (Sridhar and Sinha, 1989) reported yield losses to the tune of 17 to 86.6 per cent due to powdery mildew in affected plants of all growth stages. If the infection takes place in early stages of plant growth the crop yield losses are significantly more under favourable weather conditions (Gupta and Thind, 2006). In southern regions of the state and other parts of the country this powdery mildew pathogen is known to produce only the conidial or anamorphic stage. The identification of the pathogen is therefore done only on the basis of the anamorphic stage.

Powdery mildew causing fungi are very fast growing pathogens, having 4 to 5 days of latent period therefore, timely decision is important for their management **(**Sinha *et al.*, 2001). For crops, there is no appropriate forewarning system for powdery mildews except for grapes and mango. In the absence of any forewarning information, growers suffer heavy yield loss.

According to (Singh, 1996) epidemiology includes the study of the factors associated with disease development. The five major components of the disease *viz.*, susceptible host, virulent pathogen and favourable weather with time and space causes epidemic. Accurate forecast of the crop age at first appearance of the disease and the risk of a mildew epidemic would enable farmers to decide on optimum timing of fungicide sprays and to avoid unnecessary pesticide application. Hence, the present study was undertaken to find out the relationship of meteorological parameters with disease development.

MATERIAL AND METHOD

The field experiment was conducted at research farm, N.M. College of Agriculture., N.A.U., Navsari during *Kharif* 2014. The experiment was kept totally unprotected without any application of fungicides /botanicals. All the good agricultural practices were followed as per the recommendation.



To determine the influence of various physical factors of environment on the development of the powdery mildew of okra, the data on powdery mildew intensity were correlated with different meteorological parameters *viz.,* morning relative humidity (RH1), afternoon relative humidity (RH2), average relative humidity, maximum temperature (Max. Temp.), minimum temperature (Min. Temp.), average temperature (Av. Temp.), rain fall (RF), sunshine hours (SH) and wind speed (WS) through analysis of correlation regression. The corresponding data on various weather parameters were collected from meteorology department of university. The powdery mildew intensity was recorded at weekly interval adjusting standard week in the field of susceptible variety Gitanjali. The per cent disease intensity for powdery mildew were recorded by using formula proposed by Wheeler (1969). Powdery mildew intensity observed during the crop season at standard week's interval was correlated with the D-7 (Days prior to observation) weather parameters. For the regression equations, the multiple step wise regression analysis was carried out.

Disease rating scale for powdery mildew

0 = No symptoms on the leaf

1 = Small powdery specks on the leaves covering 1% or less area

3 = Small powdery patches, scattered, covering 1-10% of leaf area

5 = Large powdery patches, scattered, covering 11-25% of the leaf area

7 = Large powdery patches coalescing, covering 26-50% of leaf area

9 = Powdery growth covering 51% or more of leaf area. Leaves tum yellow and dry up.

RESULTS AND DISCUSSION

Severity and Progress of powdery mildew: The observations of powdery mildew intensity were recorded at weekly interval from initiation of disease on susceptible variety Gitanjali of okra grown at N. M. C. A. farm, Navsari during kharif 2014-15 (Table 1). The initiation of the disease was first noticed after 59 days of sowing (0.67%). After that, the linear progress of the disease was observed up to the maturity of the crop. The disease was appeared (0.67%) at flowering stage (35th SMW) and found highest (68.44 %) at maturity (42nd SMW). The disease development was recorded higher during 38th to 41st SMW. The disease progress was found higher during 66 to 87 days of crop age *i.e*. at fruiting period.

Table 1: Meteorological parameters and Powdery mildew intensity and AUDPC on okra cv. Gitanjali.

SMW	PDI	AUDPC	Tmax (°C)	Tmin (°C)	Mean Temp.	RH %		Mean RH%	WS (km/hrs)	BSSH	Rf (mm)	GDD	AGDD	Crop age
						Morning	Afternoon							
34	0.00	0.00	32.2	25.6	28.88	94.5	77.1	85.8	2.6	3.9	24.0	129.7	129.7	52
35	0.67	2.33	29.7	24.3	27.00	96.9	85.5	91.2	3.1	0.7	120.0	120.75	250.45	59
36	2.44	10.89	29.8	25.3	27.51	93.1	83.0	88.1	9.4	3.5	61.0	119.3	369.75	66
37	8.00	36.56	29.7	24.2	26.92	95.9	78.1	87.0	4.1	2.8	278.0	121.7	491.45	73
38	13.56	75.44	32.0	24.3	28.13	90.5	70.4	80.4	3.6	6.4	1.0	126.9	618.35	80
39	23.56	129.89	34.4	24.6	29.46	89.8	68.2	79.0	2.7	6.4	0.0	139.5	757.85	87
40	40.67	224.78	36.7	24.4	30.54	83.1	40.9	62.0	3.1	8.1	0.0	143.4	901.25	93
41	56.89	341.44	36.4	22.5	29.44	85.5	42.2	63.8	3.4	8.6	0.0	132.85	1034.1	100
42	68.44	438.67	36.4	22.5	29.41	87.8	47.8	67.8	2.9	9.8	0.0	138.5	1172.6	107

DAS- Days after sowing and SMW- Standard Meteorological Week

Correlation: The extent of association between PDI with different meteorological factors, heat unit and crop age are given in correlation coefficient values of Table 2. Out of twelve factors, significantly positive correlation was shown by the mean temperature (0.695), maximum temperature (0.890), bright sun shine hours (0.902), GDD (0.710), AGDD (0.957) and crop age (0.942) whereas, minimum temperature (-0.840), morning relative humidity (-0.845), afternoon relative humidity (-0.922) and mean relative humidity (-0.905) shown significantly negative correlation with the per cent disease intensity. Similarly, the significant and positive correlation of AUDPC with mean temperature (0.678), maximum temperature (0.879), GDD (0.693), AGDD (0.947), bright sun shine hours (0.890) and crop age (0.931) were found to have significantly positive correlation with the progress of the disease while, morning relative humidity (-0.787), afternoon relative humidity (-0.898), minimum temperature (-0.864) and mean relative humidity (-0.879) were noted to have significantly negative correlation.

Table 2: Relationship of powdery mildew intensity with different variables.

Sr. No.	Variables	Correlation coefficient "r" Kharif (2014-15)
1.	Maximum temperature (°C)	0.890
2.	Minimum temperature (°C)	-0.856
3.	Mean temperature (°C)	0.695
4.	Morning relative humidity (%)	-0.816
5.	Afternoon relative humidity (%)	-0.922
6.	Mean relative humidity (%)	-0.905
7.	Wind Speed (km/hrs)	-0.325 ^{NS}
8.	Bright Sun Shine Hours	0.902
9.	Rainfall (mm)	-0.479 ^{NS}
10.	GDD	0.710
11.	AGDD	0.957
12.	Crop age (DAS)	0.942

Critical value (0.05) = +/- 0.666 (Kharif)

Regression: The various meteorological factors, heat unit (GDD and AGDD) and crop age were assessed to formulate the simple and effective linear regression equation for powdery mildew disease prediction. The mean, maximum and minimum temperature replaced by GDD and AGDD when heat unit were used in regression analysis. An independent variable *viz*., average of 7 previous days (D-7) of meteorological factors from initiation to maturity of crop heat unit (GDD and AGDD) and crop age with dependent variable PDI and AUDPC at respective SMW were analyzed by multiple step wise regression analysis.

Generally, under the congenial environmental conditions the pathogen becomes most active over the susceptible host. These important factors were critically studied during kharif 2014-15. The data presented in Table 3 showed, meteorological factors *viz*., mean relative humidity (X6), afternoon relative humidity (X5) and crop age (X10) were found as a most crucial factors for the disease development under natural conditions in kharif season. 97.5 per cent (R^2 = 0.975) variation was found by this regression equation. So, mean relative humidity, afternoon relative humidity and crop age were found most responsible factors for the development of okra powdery mildew during kharif season. The obtained regression equation for the prediction of PDI (Y) is as under:

$$Y = -168.2943 – 3.4904 (X5) +4.552 (X6) -0.8580 (X10) \quad (1)$$

Data of regression analysis on an average heat index (GDD and AGDD) of D-7, meteorological factors and crop age, with Per cent disease intensity during kharif season are given in Table 4, showed that AGDD, afternoon relative humidity and crop age (as independent variable) with PDI (as dependent variable), were crucial factors contributing in powdery mildew epidemics development. Regression equation R^2 value of 0.984 indicates that 98.4 per cent of the variation of the disease recorded by these three variables. So, AGDD, afternoon relative humidity and crop age were found as most responsible factors, which can predict the PDI (Y) of okra powdery mildew under natural conditions. The obtained equation is :

Y= 20.5474 – 0.7997 (X2) -0.0144 (X8) + 0.8299 (X9) (2)

Table 3: Regression analysis of per cent disease intensity of powdery mildew with different meteorological factors and crop age in kharif season (Average of D-7).

Sr. No.	Independent Variables	Constant	Regression* coefficient 'b'	R^2
1	X5 = Afternoon relative humidity (%)	-168.2943	-3.4904 (1.5447)	0.975
2.	X6 = Mean relative humidity (%)		4.5522 (2.4505)	
3.	X10 = Crop age (DAS)		0.8580 (0.2114)	

Standard error of est.= 5.3923

*'b' significant at 5% level and std. error of variable is given in parentheses

Table 4: Regression analysis of per cent disease intensity of powdery mildew with different meteorological factors, heat index and crop age in kharif season (Average of D-7).

Sr. No.	Independent Variables	Constant	Regression* coefficient 'b'	R^2
1	X2 = Afternoon relative humidity (%)	20.5474	-0.7997 (0.1841)	0.984
2.	X8 = AGDD		-0.0144 (0.0049)	
3.	X9 = Crop age (DAS)		0.8299 (0.1665)	

Standard error of est.= 4.2507

The data obtained from Present study are in confirmation with the several reports of earlier workers. Solanki *et al.* (1999) was given similar confirmation who found that powdery mildew intensity proportional with the crop age in powdery mildew of mustard and found that mean temperature, GDD, AGDD, bright sun shine hours and crop age were significantly and positively correlated with powdery mildew disease intensity. These results are also in similarity with the observations of Kohire *et al.* (2008) and Gupta *et al.*, (2001). The result is moderately similar with the confirmation of Singh *et al.*, (2008) who found that maximum temperature were significantly and positively correlated, whereas bright sun shine hours and wind speed negatively correlated with powdery mildew disease intensity and AUDPC. Similarly, Vikas and Ratnoo (2013) observed that rainfall and sunshine hours significantly negatively correlated with powdery mildew intensity. According to Singh and Pannu (2013) minimum temperature, Maximum temperature, morning relative humidity, afternoon relative humidity and rainfall significantly positively correlated with powdery mildew disease intensity.

Moreover, there was negligible rainfall occurred in kharif during fruiting stage. In high rainfall areas and periods, powdery mildews decrease as rainfall increases (Agrios, 2005) but other diseases become more prevalent. High spore dispersal is aided by light rainfall. Two main mechanisms are involved, the splash effect (Gregory, 1961) and the rain tap and puff effect (Hirst & Stedman, 1963). The rain tap effect in case of okra powdery mildew is important both quantitatively and qualitatively for two reasons. First, presence of free water negatively affects the germination of conidia (Willocquet and Clerjeau 1998). Second, on the lower surface of leaves powdery mildew colonies are mostly located, especially at the onset of the growing season. Since, rain drops are not going to hit these colonies, the rain tap effect becomes the most important mechanism of spore dispersal by rain. Thus light rainfall can be considered as favourable to the fungus in case of okra, as it would allow dispersal without the drawbacks associated with heavy or continuous rain.

The conidial stock is likely to decrease under continuous rain and conidia may be washed off from leaves, leading to a decrease in spore concentration. Decrease in various other powdery mildews due to rain have also been reported (Willocquet and Clerjeau 1998; Hammett & Manners 1971; Sutton & Jones 1979; Pauvert, 1986). Continuous rainfall causes physical damage to leaf surface mycelium and conidiophores leading to unfavourable conditions for okra powdery mildew. Iqbal *et al*. (1996) stated that powdery mildew of cucurbits in India occurred when temperature was 20 to 30 °C with rain free weather. In present study the optimum maximum and minimum temperature for maximization of powdery mildew severity on okra leaves were 36.7 and 22.5°C for kharif under field conditions was in confirmation to Bhattacharya and Shukla (2002) who have pointed out that optimum temperature for development of powdery mildew severity were 37.4 and 21.4°C under irrigated conditions. *E. cichoracearum* from cantaloupe showed a temperature optimum of 25° to 28°C on the basis of in vivo length of hyphae reported by Yarwood *et al.* (1954). They also observed that growing mycelia are apparently more sensitive to high temperature than are quiescent conidia. The LD 50 of 37°C air temperature for a 3-day infection of *E. cichoracearum* on cucumber was about 10 hours, while with freshly inoculated leaves it was about 20 hours.

The short life of powdery-mildew conidia is associated with their high water content (Yarwood, 1950). But *E. cichoracearum* is more tolerant of high temperature than other *Erysiphe* spp. because it has lowest water containing conidia among the powdery mildews and has the longest-lived conidia at ordinary temperatures (Yarwood, 1954).

Wide variation (10-15°C) in the maximum and minimum temperature and day and night relative humidity (30-40%) increases powdery mildew intensity in cucumber (Gupta *et al*., 2001). They also reported that too high and too low temperature did not favour powdery mildew development. The optimum temperature and relative humidity for conidial germination is 25°C and 100 per cent, respectively.

At 20°C conidia production is optimal and declines rapidly above and below that temperature (Ward and Manners, 1974). Conidia are capable of disseminating the fungus long distances although they survive only for few days. Repeating cycles of spores are provided as new pustules with conidia are produced every seven to ten days at optimal conditions. Conidia germination at 97 to 100 per cent relative humidity is found to be most rapid, but they germinate when humidity declines below 50 percent. However, below 92 per cent relative humidity germ tube growth and appressorium production are greatly reduced (Friedrich and Boyle, 1993).

According to Jyothi (2014) conidia of powdery mildew germinated at 65 per cent and 100 per cent humidity, indicated the ability of fungus to infect both under dry and humid conditions. Similarly, Jacob et al. (2008) and Gupta and Sharma (2009) reported that conidia of *Oidium lycopersici* germinate well at 65 to 100% RH and best at 95%. They also reported that low light intensity was associated with optimal germination. The bright sunny periods militate against the development of the fungus, and have a lethal effect on detached spores (Peries, 1965). Bhattacharya and Shukla (2002) concluded that increase in temperature and sunshine duration had positive effect on powdery mildew severity, whereas, relative humidity was negative under both irrigated and rainfed conditions. High association of powdery mildew severity with sunshine duration could be possible by its indirect effects as has been suggested by Calhoun (1973) or due to changes in sun's inclination resulting increase in temperature with sunshine duration and evapo-transpiration (Rotem, 1978). Germination decreased or was delayed in the presence of free water demonstrated by Butt (1978). While, according to Kohire *et al*., (2008) dry and cool environmental conditions that means temperature range between 12.2 to 22.8°C and low relative humidity from 30.2 to 48.8 % ideal for conidial germination. The result was also more or less similar with the findings of Vikas and Ratnoo (2013); Singh *et al*. (2008).

CONCLUSION

From the results of the present investigation, it is very clear that in Navsari district powdery mildew of okra is high to moderately occurring throughout the year. In the presence of favourable climatic conditions the infection on leaf recorded very huge quantity of inoculums. Due to presence of heavy load of inoculum, the pathogen attacked on all the leaves (Lower, Middle and Upper, respectively). So, the weather during the period between 38^{st} to 42^{nd} SMW were very congenial for powdery mildew development in okra and afternoon relative humidity, mean relative humidity and crop age were the crucial factors for the development of powdery mildew during *Kharif* season.

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Conflict of Interest. None.

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