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Epidemiological factors responsible for powdery mildew disease in okra, green gram, black gram and wild poinsettia

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Abstract
The studies on effect of weather factors on development of disease revealed that the powdery mildew disease index during late *kharif* season was found higher at 49th SMW of 2019 in okra (88.7%), at 2nd SMW of 2020 in green gram (85.6%) and black gram (82.5%) respectively and in the case of wild poinsettia (98.2%) it was found higher at 8th SMW of 2020. There was a negative correlation between the disease index and all weather parameters except bright sunshine hours in okra and wild poinsettia and wind speed in the case of green gram and black gram, respectively. The multiple linear regression of PDI of powdery mildew in relation to weather parameters and crop age indicated that crop age in okra, minimum temperature and crop age in the case of green gram, black gram and wild poinsettia, respectively were most responsible for the disease development.
The aerobiological studies on effect of weather factors on the development of spore load of *E. cichoraearum*, *E. polygoni* and *Leveillula clavata* indicated that more conidial counts were observed during November and December in *E. cichoraearum* and *E. polygoni* while it was during November to January in the case of *Leveillula clavata*.
Viability of conidia of *Erysiphe* and *Leveillula* were observed up to 16 and 17 weeks in freeze condition followed by 13 and 15 weeks under tree shade condition. Under field condition, it was noticed up to 11 and 13 weeks and in room temperature viability was up to 10 and 11weeks, respectively.

Keywords: Epidemiological factors, powdery mildew disease, okra, green gram, black gram

1. Introduction
Powdery mildew disease, caused by various fungal pathogens within the order Erysiphales, poses a significant threat to a wide range of plant species, including crops, ornamentals and trees. Its characteristic white, powdery fungal growth on leaves, stems, and fruits can devastate agricultural yields and landscape aesthetics. The epidemiology of this disease is a complex interplay of factors that influence its occurrence, severity and spread.
This study focuses on understanding the epidemiological factors associated with powdery mildew disease in okra, green gram, black gram crops and wild poinsettia weed—commonly grown plants in the Navsari Agricultural University farm. These factors encompass environmental conditions, host plant susceptibility, pathogen survival structures, cultural practices and the potential for fungicide resistance. Of particular importance are weather conditions, host plant characteristics and pathogen survival mechanisms, all of which contribute to disease development. By unraveling these intricacies, researchers, farmers and plant pathologists can develop informed strategies to mitigate the impact of powdery mildew, ultimately ensuring sustainable plant health and agricultural productivity.

2. Materials and Methods
2.1 Effect of weather parameters on disease development
The study, conducted at College Farm, N.M.C.A., N.A.U., Navsari, aimed to investigate the relationship between meteorological factors and powdery mildew disease development in okra, green gram, black gram crops and wild poinsettia weed. The research involved unprotected crops without any fungicide or botanical application. Powdery mildew intensity was observed weekly from September throughout one cropping season, and disease intensity was calculated using Wheeler's (1969) [25] formula.

$$\text{Per cent disease index (PDI)} = \frac{\text{Sum of the individual disease ratings}}{\text{Total number of leaves observe} \times \text{Maximum grade}} \times 100$$

2.2 Correlation of powdery mildew intensity with weather parameters
The study aimed to assess the impact of various environmental factors on the development of powdery mildew disease in crops such as okra, green gram, black gram, and wild poinsettia. Meteorological parameters, including maximum temperature (Max. Temp.), minimum temperature (Min. Temp.), average temperature (Av. Temp.), morning relative humidity, evening hours, wind velocity, and sunlight, corresponding to disease observations, were analyzed using correlation and regression techniques. Powdery mildew intensity was recorded using Wheeler's (1969) [25] formula at regular weekly intervals throughout the crop season. The data from the observations were correlated with weather parameters obtained from the meteorological department at N.M.C.A., NAU, Navsari. Powdery mildew severity was assessed using a 0-9 scale (Mayee and Datar, 1986) [13] on five randomly selected and labeled plants for each crop (Table 1).

Table 1: The disease rating scale for powdery mildew (Mayee and Datar, 1986) [13]

Sr. No.	Powdery mildew severity	Score/grade
1.	No symptoms on the leaf	0
2.	Small powdery specks on the leaves covering 1% or less area	1
3.	Powdery lesions small, scattered covering 1-10% of leaf area	3
4.	Powdery patches big, scattered covering 11-25% of the leaf area	5
5.	Powdery patches big, coalescing covering 26-50% area	7
6.	Powdery growth covering 51% or more of leaf area. Leaves turn yellow and dry up.	9

2.3 Aerobiological studies on spore load of okra, green gram, black gram and wild poinsettia
Epidemiological study was conducted by applying aerobiological techniques. Spore trap or aeroscope for exposure of stationary slide smeared with a thin layer of vaseline was mounted at a height of 1.5 m during the cropping seasons of okra, green gram and black gram in the field and crop cafeteria for throughout the season. Disease severity, spore load was correlated with weather parameters. Average number of spores per microscopic field was recorded under low power projective (10x) by taking count of ten microscopic fields in each slide. Appearance of powdery mildew disease on these crops in the aeroscope installed field and crop cafeteria was recorded. Meanwhile, the weather data *viz*., maximum and minimum temperature, morning and evening relative humidity and wind speed received during the period of aerobiological studies were recorded.

2.4 Viability and survival of spores of *Erysiphe* and *Leveillula*
Freshly harvested powdery mildew-infected leaves from okra, green gram, black gram, and wild poinsettia were collected and stored under varying conditions: freezing, under tree shade, room temperature, and field conditions. Conidia germination percentages were recorded before storage, and conidia viability was periodically assessed by microscopic examination.

$$\text{Per cent germination(PG)} = \frac{A}{B} \times 100$$

Where,
PG = percent germination
A = Number of conidia germinated
B = Total number of conidia examined

3. Results
3.1 Effect of weather parameters on disease development
The observations of powdery mildew intensity were recorded at weekly interval from September 2019 onwards on okra, green gram, black gram and wild poinsettia. The weekly observations on powdery mildew intensity was recorded for one cropping seasons (late *kharif* season) right from the initiation of disease to maturity stage of the crop, N. M. C. A. Farm, Navsari.
The initiation of the disease was first observed on 40th standard meteorological week when the crop age was between 64 days after sowing of okra. The severity increased slowly and reached the incidence as high as 88.74 percent during 49th standard meteorological week. During the 48th week, maximum temperature of 33.1 °C and minimum temperature was 17.9 °C with morning relative humidity of 90.1 percent

and evening relative humidity of 59.9 percent followed by no rainfall (Table 2) (Fig.1a).

In green gram and black gram, the powdery mildew symptoms were first observed on 46th standard week when the crop age was 28 DAS. The minimum temperature of 20.5 °C and maximum temperature of 32.3 °C, morning relative humidity of 96.1 and evening relative humidity of 70.6 percent were prevailed during previous week. Severity increased slowly and reached maximum incidence of 85.6 percent and 82.5 during 2nd standard week of 2020 in green gram and black gram, respectively (Table 3) (Fig. 1b and Fig. 1c).

The powdery mildew symptoms on wild poinsettia (*E. geniculata*) were first observed on 38th standard week. The severity increased slowly and reached the incidence as high as 98.2 percent during 8th SMW of 2020 after which it started decreasing. During the previous week, maximum temperature of 32.9 °C and minimum temperature was 18.6 °C with morning relative humidity of 79.6 percent and evening relative humidity of 39.4 percent with no rainfall (Table 4) (Fig. 1d).

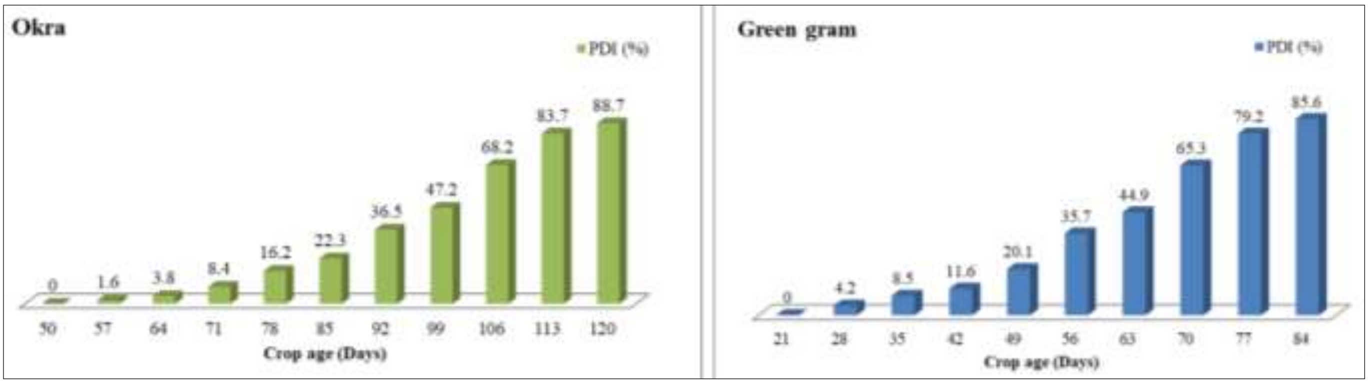
In okra crop disease progress was found higher during 110-120 days after sowing, in green gram and black gram it was between 70-84 DAS. In wild poinsettia the disease progress higher during 130-185 days.

Table 2: Meteorological parameters and percent disease index (PDI) of powdery mildew on okra during the late *kharif* 2019-2020

SWM (week)	PDI (%)	Tmax (°C)	Tmin (°C)	RH%		WS (km/hrs)	BSSH (hrs)	Rf (mm)	Crop age (days)
				Morning	Evening				
39	0	31.8	22.7	93.3	86.0	3.9	3.8	54	50
40	1.6	32.0	21.9	91.4	74.7	2.2	6.5	32	57
41	3.8	34.7	21.7	87.1	64.2	1.1	8.5	0	64
42	8.4	34.6	20.9	82.4	64.4	1.9	6.6	0	71
43	16.2	31.7	21.9	89.9	72.3	3.9	1.8	27	78
44	22.3	34.0	21.7	92.0	67.8	1.6	6.3	47	85
45	36.5	32.3	20.5	96.1	70.6	0.9	6.0	15	92
46	47.2	33.8	18.8	90.4	60.2	1.2	8.0	0	99
47	68.2	33.3	17.5	86.5	59.9	1.2	7.6	0	106
48	83.7	33.1	17.9	90.1	59.9	0.9	6.6	0	113
49	88.7	32.0	19.3	76.4	55.6	2.4	5.5	0	120

Table 3: Meteorological parameters and percent disease index (PDI) of powdery mildew on green gram and black gram during the late *kharif* 2019-2020

SWM (week)	PDI (%) Green gram	PDI (%) Black gram	Tmax (°C)	Tmin (°C)	RH%		WS (km/hrs)	BSSH (hrs)	Rf (mm)	Crop age (days)
					Morning	Evening				
45	0	0	32.3	20.5	96.1	70.6	0.9	6.0	15	21
46	4.2	3.8	33.8	18.8	90.4	60.2	1.2	8.0	0	28
47	8.5	9.4	33.3	17.5	86.5	59.9	1.2	7.6	0	35
48	11.6	15.1	33.1	17.9	90.1	59.9	0.9	6.6	0	42
49	20.1	27.7	32.0	19.3	76.4	55.6	2.4	5.5	0	49
50	35.7	39.7	31.3	13.8	89.1	63.3	1.7	7.5	0	56
51	44.9	44.6	30.7	15.6	90.8	68.6	1.5	5.9	0	63
52	65.3	59.5	18.3	9.4	59.5	47.4	0.3	3.6	0	70
1	79.2	74.4	28.0	11.6	88.1	61.4	1.6	6.8	0	77
2	85.6	82.5	29.8	14.2	80.2	52.5	2.2	7.1	0	84



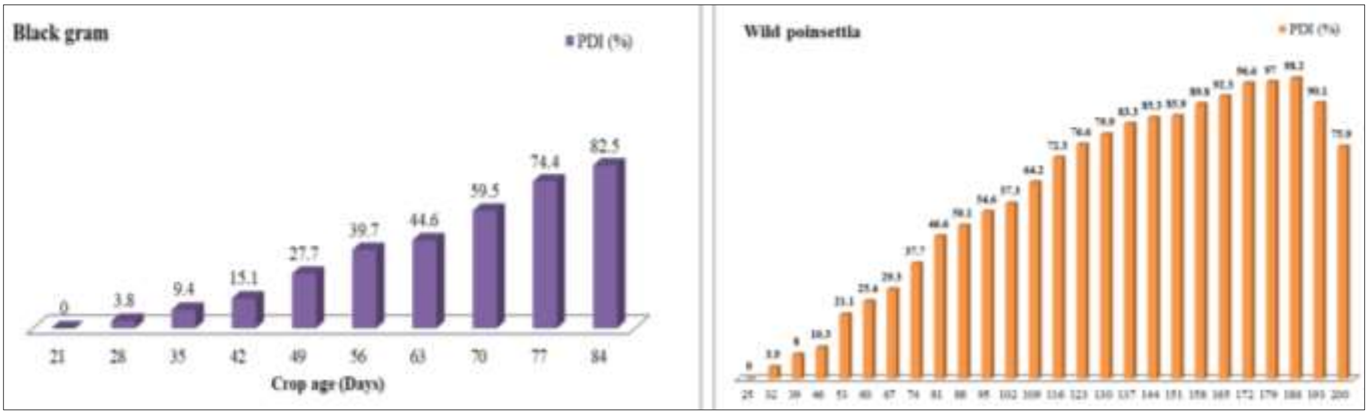


Fig 1: Percent disease index of powdery mildew on a) okra b) green gram c) black gram and d) wild poinsettia in relation to crop age in late *kharif* season

Table 4: Meteorological parameters and percent disease index (PDI) of powdery mildew on wild poinsettia during late *kharif* 2019-20

SWM (week)	PDI (%)	Tmax (°C)	Tmin (°C)	RH%		WS (km/hrs)	BSSH (hrs)	Rf (mm)	Crop age (days)
				Morning	Evening				
37	0	29.3	23.4	97.5	90.3	2.7	1.0	226.0	25
38	3.9	32.5	22.7	93.4	81.4	1.8	4.3	107.0	32
39	8.0	31.8	22.7	93.3	86.0	3.9	3.8	54.0	39
40	10.3	32.0	21.9	91.4	74.7	2.2	6.5	32.0	46
41	21.1	34.7	21.7	87.1	64.2	1.1	8.5	0.0	53
42	25.4	34.6	20.9	82.4	64.4	1.9	6.6	0.0	60
43	29.3	31.7	21.9	89.9	72.3	3.9	1.8	27.0	67
44	37.7	34.0	21.7	92.0	67.8	1.6	6.3	47.0	74
45	46.6	32.3	20.5	96.1	70.6	0.9	6.0	15.0	81
46	50.1	33.8	18.8	90.4	60.2	1.2	8.0	0.0	88
47	54.6	33.3	17.5	86.5	59.9	1.2	7.6	0.0	95
48	57.3	33.1	17.9	90.1	59.9	0.9	6.6	0.0	102
49	64.2	32.0	19.3	76.4	55.6	2.4	5.5	0.0	109
50	72.3	31.3	13.8	89.1	63.3	1.7	7.5	0.0	116
51	76.6	30.7	15.6	90.8	68.6	1.5	5.9	0.0	123
52	79.9	18.3	9.4	59.5	47.4	0.3	3.6	0.0	130
1	83.3	28.0	11.6	88.1	61.4	1.6	6.8	0.0	137
2	85.3	29.8	14.2	80.2	52.5	2.2	7.1	0.0	144
3	85.9	27.5	8.4	86.7	53.8	1.6	8.0	0.0	151
4	89.8	31.5	13.4	89.0	53.2	1.0	7.5	0.0	158
5	92.3	28.8	11.8	89.8	47.4	1.6	8.3	0.0	165
6	96.6	30.1	13.4	82.2	39.9	2.2	9.2	0.0	172
7	97.0	32.9	18.6	79.6	39.4	0.8	7.5	0.0	179
8	98.2	34.4	15.0	90.2	41.1	0.6	8.7	0.0	186
9	90.1	34.0	16.2	79.1	41.8	0.7	9.6	0.0	193
10	75.9	30.7	17.0	91.0	51.4	3.1	8.4	0.0	200

SMW- Standard Meteorological Week; PDI- Percent Disease Index; Tmax- Maximum temperature; Tmin- Minimum temperature; RH-Relative humidity; WS- Wind speed; BSSH- Bright sun shine hours; Rf-Rainfall

3.2 Correlation and multiple linear regression analysis

The analysis was made to study the relationship between weather factors *viz*., maximum (X_1) and minimum temperatures (X_2), morning (X_3) and evening relative humidity (X_4), bright sun shine hours (X_5), wind speed (X_6), rainfall (X_7) and crop age (X_8) with percent disease index (PDI) of disease in okra, green gram, black gram and wild poinsettia through correlation and multiple linear regression analysis.

Correlation coefficient values are presented in Table 5 which indicated the extent of association between PDI of okra crop with different meteorological factors and crop age. The disease development was positively correlated with bright sun shine hours, crop age and negatively correlated between all other weather parameters and significant correlation coefficient was observed with minimum temperature (r= -0.886), evening relative humidity (r= -0.745) and crop age (r= 0.965).

Table 5: Correlation of powdery mildew disease index with weather variables during late *kharif* season and crop age on okra

Sr. No.	Variables	Correlation coefficient "r"
1.	Maximum temperature (°C)	-0.102
2.	Minimum temperature (°C)	-0.886 **
3.	Morning relative humidity (%)	-0.403
4.	Evening relative humidity (%)	-0.745**
5.	Wind Speed (km/hrs)	-0.394
6.	Bright Sun Shine Hours	0.193
7.	Rainfall (mm)	-0.566
8.	Crop age (DAS)	0.965**

* = Significant at 5 %
**= significant at 1% and 5%

The multiple linear regression of PDI of powdery mildew of okra in relation to weather parameters and crop age indicated that the regression coefficient for crop age (X_8) were most responsible for the disease development (Table 6). The obtained regression equation for the prediction of PDI (Y) is as under: $Y= -102.43 + 1.381X_8$

Variation accounted by this regression equation was 92.3 percent ($R^2 = 0.923$). So, the crop age was identified as crucial factors for the development of powdery mildew in late *kharif* season on okra.

Table 6: Regression analysis of PDI of powdery mildew in okra with different meteorological factors and crop age in late *kharif* season

Sr. No.	Independent variable	Constant	Regression coefficient "b"	R2
1.	X_8 = Crop age	-102.43	1.381 (0.126)	0.923

Standard error of est. = 9.221
*'b' significant at 5% level and std. error of variable is given in parentheses

Correlation coefficient values were presented in Table 7 which indicated the extent of association between PDI of green gram crop with different meteorological factors and crop age. The disease development was positively correlated with wind speed (r= 0.238) and crop age (r= 0.976).Negative correlation was found with maximum temperature (r= -0.637), minimum temperature (r= -0.842), morning relative humidity (r= -0.466), evening relative humidity (r= -0.459), bright sun shine hours (r= -0.256) and rainfall (r= -0.391). Significant correlation was noticed with minimum temperature and crop age.

Table 7: Correlation of powdery mildew disease intensity of green gram with different variables during late *Kharif* season

Sr. No.	Variables	Correlation coefficient "r"
1.	Maximum temperature (°C)	-0.637
2.	Minimum temperature (°C)	-0.842**
3.	Morning relative humidity (%)	-0.466
4.	Evening relative humidity (%)	-0.459
5.	Wind Speed (km/hrs)	0.238
6.	Bright Sun Shine Hours	-0.256
7.	Rainfall (mm)	-0.391
8.	Crop age (DAS)	0.976**

* = significant at 5 %
**= significant at 1% and 5%

The multiple linear regression of PDI of green gram powdery mildew in relation to weather parameters and crop age indicated that the regression coefficients for minimum temperature (X_2) and crop age (X_8) were most responsible for the disease development (Table 8).

The obtained regression equation for the prediction of PDI (Y) is as under: $Y= 38.418 - 3.298X_2 + 0.893X_8$

Variation accounted by this regression equation was 93.33 percent ($R^2 = 0.933$). So, the minimum temperature (X_2) and crop age (X_8) were identified as crucial factors for the development of powdery mildew in late *kharif* season.

Table 8: Correlation of powdery mildew disease intensity of black gram with different variables during late *kharif* season

Sr. No.	Variables	Correlation coefficient "r"
1.	Maximum temperature (°C)	-0.599
2.	Minimum temperature (°C)	-0.812**
3.	Morning relative humidity (%)	-0.464
4.	Evening relative humidity (%)	-0.463
5.	Wind Speed (km/hrs)	0.316
6.	Bright Sun Shine Hours	-0.245
7.	Rainfall (mm)	-0.425
8.	Crop age (DAS)	0.990**

= significant at 5 %
**= significant at 1% and 5%

The multiple linear regression of PDI of black gram powdery mildew in relation to weather parameters and crop age indicated that the regression coefficient for minimum temperature (X_2) and crop age (X_8) were most responsible for the disease development (Table 9).
The obtained regression equation for the prediction of PDI (Y) is as under

$$Y = 28.107 - 2.587X_2 + 0.875X_8$$

Variation accounted by this regression equation is 94.00 percent ($R^2 = 0.940$). So, the minimum temperature (X_2) and crop age (X_8) were identified as crucial factors for the development of powdery mildew in late *kharif* season.

Table 9: Regression analysis of PDI of powdery mildew in black gram with different meteorological factors and crop age in late *kharif* season

Sr. No.	Independent variable	Constant	Regression coefficient "b"	R2
1.	X_2 = minimum temperature	28.107	-2.587 (0.720)	0.940
2.	X_8 = Crop age		0.875 (0.83)	

Standard error of est. = 7.89
*'b' significant at 5% level and std. error of variable is given in parentheses

Correlation coefficient values were presented in Table 10 which indicated the extent of association between PDI of wild poinsettia with different meteorological factors and crop age. The disease development was positively correlated with bright sun shine hours, crop age and negatively correlated between all the other weather parameters and significant correlation coefficient was observed with minimum temperature (r= -0.835), morning relative humidity (r=-0.440), evening relative humidity (r= -0.893), wind speed (r= -0.454), rainfall (r= -0.643) and crop age (r= 0.951).

Table 10: Correlation of powdery mildew disease intensity of wild poinsettia with different variables during late *kharif* season

Sr. No.	Variables	Correlation coefficient "r"
1.	Maximum temperature (°C)	-0.271
2.	Minimum temperature (°C)	-0.835**
3.	Morning relative humidity (%)	-0.440*
4.	Evening relative humidity (%)	-0.893**
5.	Bright Sun Shine Hours	0.619**
6.	Wind Speed (km/hrs)	-0.454*
7.	Rainfall (mm)	-0.643**
8.	Crop age (DAS)	0.951**

* = significant at 5 %
**= significant at 1% and 5%

The multiple linear regression of PDI of wild poinsettia powdery mildew in relation to weather parameters and crop age indicated that the regression coefficient for minimum temperature (X_2) and crop age (X_8) were most responsible for the disease development (Table 11).
The obtained regression equation for the prediction of PDI (Y) is as under: $Y = 46.649 - 2.187X_2 + 0.445X_8$
Variation accounted by this regression equation was 93.90 percent ($R^2 = 0.939$). So, the minimum temperature (X_2) and crop age (X_8) were identified as crucial factors for the development of powdery mildew in late *kharif* season.

Table 11: Regression analysis of PDI of powdery mildew in wild poinsettia with different meteorological factors and crop age in late *kharif* season

Sr. no.	Independent variable	Constant	Regression coefficient "b"	R2
1.	X_2= minimum temperature	46.649	-2.187 (0.545)	0.939
2.	X_8 = Crop age		0.445 (0.44)	

Standard error of est. = 8.011
*'b' significant at 5% level and std. error of variable is given in parentheses

In present study the optimum maximum and minimum temperature for maximization of powdery mildew severity on okra were 34.4-17.5 °C for late *Kharif* under field conditions was in confirmation to Bhattacharya and Shukla (2002) [2] who had pointed out that optimum temperature for development of powdery mildew severity were 37.4 and 21.4 °C under irrigated conditions.
The results of present studies on powdery mildew incidence have similarity with findings of various workers (Yarwood, 1957, Prabhu *et al*., 1971 and Sokhi and Sohi, 1975) [26, 17, 20] who reported higher incidence of disease under low relative humidity (<80%) and low temperature ranges (18-28 °C). Moreover, Gupta and Thind (2006) [5] reported that temperature ranges in between 18-24 °C and relative humidity level in between 60-80 percent was favorable for the disease development. Sunshine hours also showed a significant and positive correlation with disease development and the findings are corroborating with Morrison (1964) [14] who reported that continuous light period increases the conidial germination. In current studies negative and non significant correlation was noted between disease severity and rainfall which are in line with the findings of Sokhi and Sohi (1975) and Pathania (2015) [20, 16] who observed that low rainfall led to the increase in disease severity.
The severity had a high significant positive correlation with crop age (r = 0.984) and maximum temperature (r = 0.657). Non-significant correlation was observed between severity and rest of the independent variables. These observations are in agreement with the findings of Thakur and Agarwal (1995) [23]; Solanki *et al*. (1999) [21]; Yarwood (1957) [26]; Bhattacharya and Shukla, (2002) [2]; Gupta and Sharma, (2016) and Kanzaria *et al*. (2013) [8]. The maximum temperature during the period of occurrence of powdery mildew up to last observation on severity was in the range of 30.9 °C-33.8 °C and is well within the favourable range of 28 °C- 36 °C for powdery mildew (Delp, 1954; Schnathorst, 1960; Manners *et al*., 1963, Korra and Kumar., 2018) [18, 3, 12, 10]. Hence, the maximum temperature showed a strong positive influence on powdery mildew severity.
The best fit equation showed 92.3, 93.33, 94.00 and 93.00 percent role of tested independent variables on okra, green gram, black gram and wild poinsettia powdery mildew severity. Results were in accordance with the reports of earlier workers (Solanki *et al*., 1999; Bhattacharya and Shukla, 2002; Gupta and Sharma, 2016; Kanzaria *et al*., 2013) [21, 2, 8]. Similarly, minimum temperature was favourable for disease development as reported by earlier findings (Yarwood *et al*., 1957) [26]. Wind speed effected an instantaneous dispersal of conidia of *Erysiphe polygoni* which was reported by Hammett and Manners (1974) [6].

3.3 Aerobiological studies using spore trap

As a part of epidemiological studies of powdery mildew disease, aerobiological studies using spore trap or aerospore was conducted to know the appearance of spore load *of E. cichoraearum* on okra, *E. polygoni* on green gram and black gram and *L. clavata* on wild poinsettia and progress of the disease.

The investigation on sampling of air borne conidia of these pathogens was carried out from September 2019 to March 2020 in crop cafeteria and from the experimental plots of Department of plant pathology, N.M.C.A, NAU under different environmental conditions. The data on spore load and weather parameters are presented in (Table 12 – 16). The results revealed that the average number of spores trapped weekly varied as the disease severity progressed.

The weekly average spore load of *E. cichoraearum* on okra increased progressively from 35th to 47th SMW of 2019. Later on, it decreased gradually to 10.2 during 2th SMW of 2020. In general, the spore catch was higher by the end of November, 2019. The maximum spore load was 58.8 at 47th week. During 46th (previous) meteorological week, the weather conditions such as maximum temperature, minimum temperature, morning and evening relative humidity and wind speed were 33.8 °C, 18.8 °C, 90.4 percent, 60.2 percent and 1.2 (km/hrs), respectively (Table 12).

Table 12: Development of weekly spore load of powdery mildew on okra caused by *E. cichoraearum* and meteorological parameters associated during 2019 -2020

SMW (week)	Weekly average no. of spores/ slide	Temperature (°C)		Relative Humidity (%)		Ws (km/hrs)
		Tmax	Tmin	Morn	Eve	
35	0.4	30.1	23.1	97.7	88.4	2.8
36	1.6	30.1	23.1	98.4	91.7	4.1
37	2.2	29.3	23.4	97.5	90.3	2.7
38	4.8	32.5	22.7	93.4	81.4	1.8
39	8.6	31.8	22.7	93.3	86.0	3.9
40	12.4	32.0	21.9	91.4	74.7	2.2
41	18.0	34.7	21.7	87.1	64.2	1.1
42	27.2	34.6	20.9	82.4	64.4	1.9
43	33.8	31.7	21.9	89.9	72.3	3.9
44	39.2	34.0	21.7	92.0	67.8	1.6
45	49.8	32.3	20.5	96.1	70.6	0.9
46	54.2	33.8	18.8	90.4	60.2	1.2
47	58.8	33.3	17.5	86.5	59.9	1.2
48	46.6	33.1	17.9	90.1	59.9	0.9
49	37.6	32.0	19.3	76.4	55.6	2.4
50	34.0	31.3	13.8	89.1	63.3	1.7
51	33.8	30.7	15.6	90.8	68.6	1.5
52	28.2	18.3	9.4	59.5	47.4	0.3
1	19.4	28.0	11.6	88.1	61.4	1.6
2	10.2	29.8	14.2	80.2	52.5	2.2

SMW- Standard Meteorological Week; Tmax- Maximum temperature; Tmin- Minimum temperature; RH-Relative humidity; WS- Wind speed

The weekly average spore load of *E. polygoni* on green gram increased gradually from 38th to 52nd SMW of 2019. Later on, it decreased gradually to 6.2 during 4th SMW of 2020. In general, the spore catch was higher by the end of December, 2019. The maximum spore load was 56.6 at 52nd week. During 51st SMW the weather conditions such as maximum temperature, minimum temperature, morning and evening relative humidity and wind speed were 30.7 °C, 15.6 °C, 90.8 percent, 68.6 percent and 1.5 (km/hrs), respectively (Table 13).

Table 13: Development of weekly spore load of powdery mildew on green gram and black gram caused by *E. polygoni* and meteorological parameters during 2019-2020

SMW (week)	Weekly average no. of spores/ slide (green gram)	Weekly average no. of spores/ slide (black gram)	Temperature °C		Relative Humidity (%)		Ws (km/hrs)
			Tmax	Tmin	Morn	Eve	
38	0.2	0.4	32.5	22.7	93.4	81.4	1.8
39	0.6	0.8	31.8	22.7	93.3	86.0	3.9
40	1.2	2.2	32.0	21.9	91.4	74.7	2.2
41	2.8	3.2	34.7	21.7	87.1	64.2	1.1
42	3.6	4.6	34.6	20.9	82.4	64.4	1.9
43	4.6	5.8	31.7	21.9	89.9	72.3	3.9
44	5.8	6.4	34.0	21.7	92.0	67.8	1.6
45	7.9	11.2	32.3	20.5	96.1	70.6	0.9
46	13.4	14.8	33.8	18.8	90.4	60.2	1.2
47	18.2	16.6	33.3	17.5	86.5	59.9	1.2
48	21.9	19.6	33.1	17.9	90.1	59.9	0.9
49	42.6	30.9	32.0	19.3	76.4	55.6	2.4
50	50.8	44.8	31.3	13.8	89.1	63.3	1.7
51	53.4	52.6	30.7	15.6	90.8	68.6	1.5
52	56.6	54.6	18.3	9.4	59.5	47.4	0.3
1	39.7	50.2	28.0	11.6	88.1	61.4	1.6

2	32.2	36.5	29.8	14.2	80.2	52.5	2.2
3	15.8	27.8	27.5	8.4	86.7	53.8	1.6
4	6.2	12.6	31.5	13.4	89.0	53.2	1.0

SMW- Standard Meteorological Week; Tmax- Maximum temperature; Tmin- Minimum temperature; RH-Relative humidity; WS- Wind speed

The weekly average spore load of *E. polygoni* on black gram increased gradually from 38th to 52nd SMW of 2019. Later on, it decreased gradually to 12.6 during 4th SMW of 2020. In general, the spore catch was higher by the end of December, 2019. The maximum spore load was 54.6 at 52nd week, during 51st SMW the weather conditions such as maximum temperature, minimum temperature, morning and evening relative humidity and wind speed were 30.7 °C, 15.6 °C, 90.8 percent, 68.6 percent and 1.5 (km/hrs), respectively (Table 13).

The weekly average spore load of *L. clavata* increased gradually from 35th to 4th SMW of 2019-2020. Later on, it decreased gradually to 10.4 during 10th SMW of 2020. In general, the spore catch was higher by the end of January, 2020. The maximum spore load was 40.4 at 4th week. During 3rd SMW the weather conditions such as maximum temperature, minimum temperature, morning and evening relative humidity and wind speed were 27.5 °C, 8.4 °C, 86.7 percent, 53.7 percent and 1.5 (km/hrs), respectively (Table 14).

Table 14: Development of weekly spore load, disease incidence of powdery mildew of wild poinsettia caused by *L. clavata* and meteorological parameters during 2019-2020

SMW	Weekly average no. of spores/ slide	Temperature (°C)		RH (%)		Ws (km/hrs)
		Tmax	Tmin	Morn.	Even.	
35	1.4	30.1	23.1	97.7	88.4	2.8
36	2.0	30.1	23.1	98.4	91.7	4.1
37	3.6	29.3	23.4	97.5	90.3	2.7
38	5.4	32.5	22.7	93.4	81.4	1.8
39	8.8	31.8	22.7	93.3	86.0	3.9
40	9.8	32.0	21.9	91.4	74.7	2.2
41	11.4	34.7	21.7	87.1	64.2	1.1
42	13.6	34.6	20.9	82.4	64.4	1.9
43	16.2	31.7	21.9	89.9	72.3	3.9
44	18.6	34.0	21.7	92.0	67.8	1.6
45	20.8	32.3	20.5	96.1	70.6	0.9
46	22.2	33.8	18.8	90.4	60.2	1.2
47	25.6	33.3	17.5	86.5	59.9	1.2
48	27.4	33.1	17.9	90.1	59.9	0.9
49	28.8	32.0	19.3	76.4	55.6	2.4
50	30.8	31.3	13.8	89.1	63.3	1.7
51	32.0	30.7	15.6	90.8	68.6	1.5
52	35.4	18.3	9.4	59.5	47.4	0.3
1	37.2	28.0	11.6	88.1	61.4	1.6
2	38.8	29.8	14.2	80.2	52.5	2.2
3	39.4	27.5	8.4	86.7	53.8	1.6
4	40.4	31.5	13.4	89.0	53.2	1.0
5	38.2	28.8	11.8	89.8	47.4	1.6
6	35.8	30.1	13.4	82.2	39.9	2.2
7	33.6	32.9	18.6	79.6	39.4	0.8
8	28.0	34.4	15.0	90.2	41.1	0.6
9	25.2	34.0	16.2	79.1	41.8	0.7
10	10.4	30.7	17.0	91.0	51.4	3.1

SMW- Standard Meteorological Week; Tmax- Maximum temperature; Tmin- Minimum temperature; RH-Relative humidity; WS- Wind speed

The relationship between spore load of *E. cichoracearum* on okra and weather factors during 2019 (Table 15) indicated significant negative correlation with evening relative humidity and wind speed. Maximum temperature, minimum temperature, morning relative humidity, evening relative humidity showed non- significance with negative relationship.

Table 15: Correlation between weekly spore loads of *E. cichoracearum* on okra in relation to weather parameters

Sr. No.	Variables	Correlation coefficient "r"
1.	Maximum temperature (°C)	-0.240
2.	Minimum temperature (°C)	-0.312
3.	Morning relative humidity (%)	-0.225
4.	Evening relative humidity (%)	-0.619**
5.	Wind speed	-0.560**

During 2019-2020, negative relationship was observed between spore load and weather parameters on green gram, but significant negative correlation coefficients were observed with maximum temperature (-0.600), minimum temperature (-0.662), morning (-0.568) and evening relative humidity (-0.531) (Table 16).

Table 16: Correlation between weekly spore loads of *E. polygoni* on green gram in relation to weather parameters

Sr. No.	Variables	Correlation coefficient "r"
1.	Maximum temperature (°C)	-0.600**
2.	Minimum temperature (°C)	-0.662**
3.	Morning relative humidity (%)	-0.568*
4.	Evening relative humidity (%)	-0.531*
5.	Wind speed	-0.290

In black gram, the spore load and weather parameters showed negative correlation with all the weather parameters. The significant correlation coefficients were observed with maximum temperature (-0.675), minimum temperature (-0.798), morning (-0.524) and evening relative humidity (-0.577) (Table 17)

Table 17: Correlation between weekly spore loads of *E. polygoni* on black gram in relation to weather parameters

Sr. No.	Variables	Correlation coefficient "r"
1.	Maximum temperature (°C)	-0.675**
2.	Minimum temperature (°C)	-0.798**
3.	Morning relative humidity (%)	-0.524*
4.	Evening relative humidity (%)	-0.577*
5.	Wind speed	-0.328

The relationship between spore load of *L. clavata* and weather factors during 2019-2020 indicated significant negative correlation with minimum temperature (-0.878), morning (-0.553) and evening relative humidity (-0.781) except wind speed (0.566) which had a positive correlation (Table 18).

Table 18: Correlation between weekly spore loads of *L. clavata* on wild poinsettia in relation to weather parameters

Sr. No.	Variables	Correlation coefficient "r"
1.	Maximum temperature (°C)	-0.294
2.	Minimum temperature (°C)	-0.878**
3.	Morning relative humidity (%)	-0.553**
4.	Evening relative humidity (%)	-0.781**
5.	Wind speed	0.566**

* = significant at 5 %
**= significant at 1% and 5%

In the present study, the vaseline coated glass slide kept in stationary aeroscope / spore trap was used to catch the conidia of *E. cichoracearum*, *E. polygoni* and *L. clavata*, respectively. Similarly, in order to find out the spore load, several techniques had been used from simple glass slide (Mehta, 1940) [14] to Burkard volumetric spore trap (Kulkarni, 1982) [11]. Similar technique had been used earlier to trap the uredospores of *Puccinia arachidis* (Sunkad, 2004) [22], *Phakopsora pachyrhizi* (Hegde, 2001) [7] and conidia of *L. taurica* (Ashtaputre, 2006).

3.4 Survival and viability of conidia

The powdery mildew infected leaves of okra, green gram, blackgram and wild poinsettia were collected and stored under different study conditions to study the viability of conidia of *Erysiphe* and *Leveillula*. The conidial germination at different weekly intervals was recorded that the conidia of *Erysiphe* remained viable up to 10 weeks when stored under field conditions. While, they remained viable upto 11 weeks at room temperature. The conidia remained viable upto 13 weeks when the infected leaves were kept under tree shade. However, under freeze conditions, the conidia were viable up to 16 weeks.

On wild poinsettia the results revealed that the conidia remained viable up to 11 weeks when kept under field condition, whereas they remained viable for 13 weeks stored at room temperature. The viability of spore remained up to 15 weeks under tree shade condition, but maximum period of viability of spores remained for 16 weeks under freeze conditions at 17 weeks of storage. This study indicated that conidia of powdery mildew pathogen were short lived on the host debris under natural conditions.

Table 19: Effect of different storage conditions on the viability of conidia of *Erysiphe*

Sr. No.	Storage condition	Viability after weeks of storage in (*Erysiphe*)																
		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.	Field	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
2.	Room	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
3.	Tree shade	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-
4.	Freeze	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-

Table 20: Effect of different storage conditions on the viability of conidia of *Leveillula*

Sr. No.	Storage condition	Viability after weeks of storage in (*Leveillula*)																
		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.	Field	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
2.	Room	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-
3.	Tree shade	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
4.	Freeze	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-

It can be noted that the method employed for testing the survival of the fungus permits only the conidia and not the dormant mycelium. It is possible that while conidia have a shorter longevity and the fungus may be persisting as dormant mycelium for longer periods. However, further investigations are required to verify this hypothesis in detail. This is in agreement with the reports of several workers (Wankhade and Peshney, 1992, Ashtaputre, 2006 and Karuna *et al*., 2015) [24, 9]. As host penetration and infection depends on the process of germination. So, germination of infectious propagules is an important process in the life cycle of pathogenic fungi and disease development and spread of the disease which has significant role in the epidemiology of the disease.

4. Conclusion

Crop age is crucial factor in okra crop where as minimum temperature and crop age are crucial factors in green gram, black gram and wild poinsettia with respect to environmental factors for powdery mildew disease.

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