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INFLUENCE OF ENVIRONMENTAL FACTORS ON DEVELOPMENT OF DOWNY MILDEW (*SCLEROSPORA GRAMINICOLA*) IN PEARL MILLET

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ABSTRACT

The present study was undertaken during *kharif*, 2022 to find out the effect of different weather variables on the development of downy mildew in pearl millet. The data of downy mildew incidence for consecutive one year revealed that the mean weekly disease incidence in 7042 S ranged from 5.45 to 81.82 per cent indicating the highly susceptible response. The second fortnight of August to the first fortnight of September can be considered as window period for downy mildew incidence. The disease incidence in cultivar 7042 S was correlated highly significantly and positive correlation with maximum temperature (r = 0.753**), highly significantly and negative correlation with total rainfall (r = -0.744**). Evening relative humidity (r = -0.602*), morning relative humidity (r = -0.625*) and rainy days (r =-0.624*) was significant and negatively correlated with downy mildew incidence. The minimum temperature showed non-significant and negative correlation (-0.309) with downy mildew disease incidence. It has been observed that multiple correlation (R) value 0.941 indicating a strong association between per cent disease incidence and weather parameters. The co-efficient of determination (R^2) of 0.886 proved the significance of overall regression model accuracy. Predict the occurrence of downy mildew with R^2 = 0.886, indicating that all weather parameters contributed 88.6 per cent towards disease development.

Key words: Downy mildew, pearl millet, disease incidence, weather variables, correlation, regression

Introduction

Pearl millet (*Pennisetum glaucum* L.) is a monocot species belongs to the family *Poaceae* and sub family *Penicedae*, having diploid genome (2n= 2x =14). It is locally known as Bajra, is also known as bulrush millet, cat tail or spiked millet (Verma *et al*., 2021a, Reddy *et al*., 2021). India is the largest country in Asia in terms and area of 6.55 m ha, production of 9.64 MT and productivity of 1471 kg/ha (Anon. 2025a). Rajasthan is the leading state with an area of 4.26 m ha with a production of 5.07 MT and productivity of 1191 kg/ha (Anon. 2025b). Pearl millet is the most drought tolerant crop among cereals and millets. It grows in warm and dry climatic conditions, where annual rainfall is 150-700 mm and ideal temperature for growth is 20-28 ^{o}C. Moist weather is advantageous during its vegetative growth. Bajra can be grown in a wider range of soil but thrives best in black cotton soil, sandy loam soil having well drainage (Harinarayana *et al*., 1999). Pearl millet is infected with a large number of diseases caused by fungal and bacterial pathogens. Downy mildew (*Sclerospora graminicola* (Sacc.) Schroet), blast (*Pyricularia grisea* (Cke.) Sacc), smut (*Moesziomyces penicillariae* (Bref.) Vanky), ergot (*Claviceps fusiformis* (Loveless)) and rust (*Puccinia substriata* Ellis & Barthstriata) are the most important fungal diseases of pearl millet. *Sclerospora graminicola* is caused by systemic infection by the obligate biotrophic pseudo-fungus, first reported on pearl millet in India by Butler (1907) and he described that disease in poorly drained areas where it developed into severe epidemics. Under favourable environmental conditions the disease may cause up to 65 per cent

Table 1: Effect of meteorological parameters on downy mildew development on highly susceptible cultivar (7042 S) of pearl millet (*kharif*, 2022).

Date of Observation	Meteoro-logical Standard Week	Temperature		Rain-fall (mm)	Rainy days (No.)	Relative humidity		Observed* disease incidence (%)	Predicted disease incidence (%)
		Min. (°C)	Max. (°C)			Evening (%)	Morning (%)		
		X1	X2	X3	X4	X5	X6	Y	$\hat{Y}$
30 Jul – 05 Aug	31th	24.1	32.03	4	0	55.74	68.47	5.45	16.53
06 Aug – 12 Aug	32th	22.7	32.29	78.2	3	55.29	75.23	9.09	7.08
13 Aug – 19 Aug	33th	21.56	31.81	74.3	4	71.19	87.39	10.91	12.93
20 Aug – 26 Aug	34th	20.59	29.2	48	4	71.19	85.29	20.00	19.21
27 Aug – 02 Sep	35th	21.21	32.07	0	4	53.53	71.49	50.00	50.27
03 Sep – 09 Sep	36th	21.4	36	0	0	45.2	70.37	62.73	81.97
10 Sep – 16 Sep	37th	22.16	36.43	0	0	53.31	71.97	72.73	73.50
17 Sep – 23 Sep	38th	22.7	35.09	0	0	49.55	70.61	77.27	56.56
24 Sep – 30 Sep	39th	21.53	33.9	0	0	50.89	68.56	80.00	68.64
01 Oct – 07 Oct	40th	21.14	34.43	0	0	57.04	64.27	81.82	83.30

* Per cent disease incidence was calculated as per rating scale mentioned in the material and method
* Mean of three observations per week

reduction in the yield (Thakur *et al*., 1978). Gupta and Singh (1996) reported 57 per cent reduction in the yield besides heavy losses in the fodder yield. Subsequent to this epidemic, grain yield losses continue to occur quite frequently due to downy mildew epidemics in India (Singh *et al*., 1987). It has been demonstrated that the losses in yield can be directly proportional to disease severity (Williams and Singh, 1981). The soil-borne oospores or sexual spores of *S. graminicola* are the primary source of inoculum for the development of downy mildew. Climatic variables play a major role in the initiation and spread of plant diseases. Host, climate, biotic and edaphic factors influence the process involved in pathogenesis. During cool and humid nights, systemically downy mildew infected leaves produce abundant sporangia on the abaxial surface. However, the hot and dry environmental conditions favourable for pearl millet growth may not be conducive for sporangial production and survival (Singh *et al*., 1993). Environmental factors like temperature, rainfall, relative humidity, wind, dew, cloudiness and duration, quality and intensity of radiation play an important role in the development and spread of downy mildew (Gupta and Singh, 2000). The contribution of temperature and humidity on the incidence and spread of downy mildew in pearl millet was surveyed by Atri and Singh (2019) in Punjab. They developed a weather prediction model for downy mildew incidence and suggested its usefulness in forecasting the occurrence of disease. This offers a holistic view to take pre-emptive decisions for the prevention of disease occurrence and determine appropriate management practices under given environmental conditions. Keeping in view the losses incurred due to downy mildew in pearl millet and importance of weather variables on this disease, the present investigation was undertaken to develop a prediction model for downy mildew progression in pearl millet.

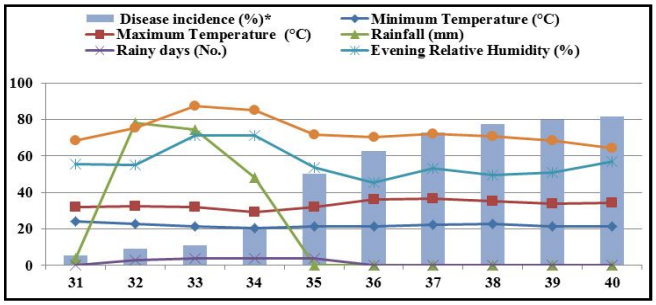

Fig. 1: Effect of meteorological parameters on downy mildew development on highly susceptible cultivar (7042 S) of pearl millet during *kharif*, 2022.

Materials and Methods

The downy mildew incidence was recorded to know the period and crop stage for initiation and progress of downy mildew during the entire crop season. One highly susceptible cultivar *i.e.* 7042 S was selected to record the influence of epidemiological factors on the progression of the disease under field conditions. The experimental trials on epidemiological studies were conducted at ICAR-AICRP on pearl millet field Mandor, during *kharif*, 2022. The crop was sown on 10th July, 2022 by adopting all

Table 2: Correlation of pearl millet downy mildew incidence with weather parameters on highly susceptible cultivar (7042 S) during *kharif*, 2022.

Temp. in (°C)		Rainfall (in mm)	No. Rainy days	Relative humidity	
Min.	Max.			Evening	Morning
-0.309	0.753**	-0.744**	-0.624*	-0.602*	-0.625*

* Significant at 5%; ** Significant at 1%

Table 3: Multiple linear regression equation for pearl millet downy mildew and different weather parameters on susceptible cultivar (7042 S) during *kharif*, 2022.

Multiple linear regression equation $\hat{Y}1 = a+b1X1+b2X2+.....+bnXn$	Multiple R	Co-efficient of Determination (R^2)
$\hat{Y}1=221.05 + (-15.39)(x1) + (6.73)(x2) + (-0.26)(x3) + (2.24)(x4) + (0.21)(x5) + (-0.87)(x6)$	0.941	0.886*

standard agronomical practices. The field was kept free from any fungicidal spray. The plants were sown in plot size 4 × 3 m^2 and 45×15 cm row to row and plant to plant spacing. For recording the downy mildew incidence and its development, after germination, ten plants were selected randomly and labeled.

The observations (thrice in a week at two days' interval) on individual labeled plant were recorded from 31th to 41th standard meteorological week till maturity of crop. There after a correlation, simple regression and multiple regression study was made between the progressive development of disease and respective weather parameters *viz.*, temperature (minimum and maximum), relative humidity (evening and morning), rainfall, number of rainy days, were symbolized as X1, X2, X3, X4, X5, and X6 respectively and recorded periodically from experimental field. The per cent disease incidences were calculated as per formula given by (Mayee and Datar, 1986).

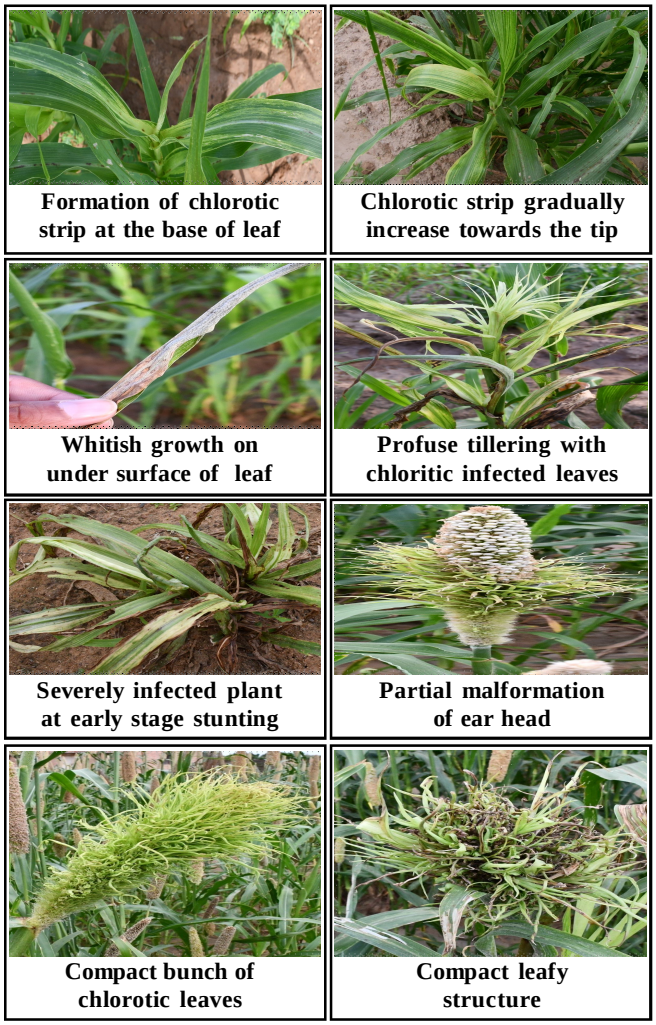

Plate 1: Progressive development of downy mildew in pearl millet under natural conditions.

$$\text{Percent disease incidence} = \frac{\text{Total no. of infected plants}}{\text{Total no. of plants}} \times 100$$

Results and Discussion

The progress of downy mildew incidence in one cultivar of pearl millet 7042 S (highly susceptible) in relation to weather variables were studied in *Kharif*, 2022 under field conditions. The first downy mildew incidence was recorded from initiation of disease *i.e.* 21 days after sowing (31th meteorological standard week) of crop season and continued up to maturity 7th October (40th meteorological standard week). For disease incidence, three observations were recorded in each week at two days' interval and the average weekly disease incidence was calculated. The weather variables *viz.*, minimum temperature (X1), maximum temperature (X2), total rainfall (X3), rainy days (X4), evening relative humidity (X5) and morning relative humidity (X6) were recorded periodically from experimental field for the entire cropping season starting from the germination to the harvesting of the crop.

The data of downy mildew incidence for consecutive one year revealed that the mean weekly disease severity in 7042 S ranged from 5.45 to 81.82 per cent indicating the highly susceptible response. The downy mildew incidence progressively increased during the observation period *i.e.* 30th July to 7th October in the crop seasons. However, in the crop seasons (*Kharif*, 2022) the maximum downy mildew incidence was recorded during 35th and 36th meteorological weeks (27th August to 9th September) (Table 1 & Plate 1 and Fig. 1). The incidence of downy mildew disease was increased progressively. Environmental factors play a great role in buildup pathogen population and subsequent disease development. Hence, the second fortnight of August to the first fortnight of September can be considered as window period for downy mildew incidence.

Correlation analysis

In the crop season (*Kharif*, 2022) the disease incidence in cultivar 7042 S was correlated highly significantly and positive correlation with maximum temperature (r = 0.753**). However, highly significantly

and negative correlation with total rainfall (r = -0.744**). Evening relative humidity (r = -0.602*), morning relative humidity (r = -0.625*) and rainy days (r =-0.624*) was significant and negatively correlated with downy mildew incidence. The minimum temperature showed non-significant and negative correlation (-0.309) with disease (Table 2). The analysis of data depicted that the above said weather parameters played key role on downy mildew disease development. Since the disease development is a cumulative process, once per cent disease incidence attained its peak, maintained a gradual but steady increase with morning relative humidity and minimum temperature during entire crop season.

Multiple regression analysis

The regression co-efficient based on multiple linear regression analysis for per cent downy mildew incidence of pearl millet with respect to six weather parameters have been worked out. The predicted downy mildew incidence explained by the function of weather parameters as evident from multiple linear regression equation shown as under:

$$\hat{Y} = a + b1X1 + b2X2 + b3X3 + b4X4 + b5X5 + b6X6$$

$\hat{Y}$ = predicted downy mildew severity

a = constant (intercept)

b1, b2, b3, b4, b5 and b6 = partial regression co-efficient

X1, X2, X3, X4, X5 and X6 = weather parameters (independent variables)

It has been observed that multiple correlation (R) value 0.941 indicating a strong association between per cent disease incidence and weather parameters. The co-efficient of determination (R^2) of 0.886 proved the significance of overall regression model accuracy.

The multiple linear regression equation for *Kharif*, 2022:

$$\hat{Y}1=221.05+(-15.39)(x1)+(6.73)(x2)+(-0.26)(x3)+(-2.24)(x4)+(0.21)(x5)+(-0.87)(x6)$$

The observed and predicted downy mildew incidence clearly indicated (Table 4.2) that the lines during entire crop season were closer justifying the validity of the regression equations formulated. These models (equations) can be used to forecast for pearl millet downy mildew disease in the field. The potential figure in a particular season can, therefore, be worked out by substituting the values of five climatic factors for the preceding week in the model. It may be the most reliable and useful for forecasting for pearl millet downy mildew during *Kharif* season. The loss caused by the downy mildew may be saved by forewarning and thereby controlling the same at proper time.

Many scientists had made several successful endvours in epidemiological studies, there seems to be an agreement that temperatures between 15-25°C is favourable for the formation of the sporangial stage (Safeeulla & Thirumalachar, 1956). Suryanarayana (1965) considered temperature as low as 10°C favourable. Suryanarayana (1965), Bonde *et al*., (1978), Gilijamse *et al*., (1997), Singh *et al*., (1987) and Sangeetha and Siddaramaiah (2007) were considered that the relative humidities above 75 per cent was necessary for the stimulation of sporangial production. However, in general a saturated atmosphere with film of water on the leaves is considered an optimum combination of high humidity and the favourable temperature range (minimum temperature of 14-16ºC and maximum temperature of 26-29ºC) taking place usually in July, August and September in north India and hence the disease is more commonly seen during these months. Atri and Singh (2019) analysed the effect of weather variables on downy mildew progression in pearl millet and revealed that a decrease in temperature within a favourable range might cause a rapid increase in pathogen growth rate. A high variation in the morning (94 %) and evening relative humidity (46%) was observed in the 46th stranded metrological week (SMW) when the disease incidence was at its peak (95.77%). Murria *et al*., (2022) reported that downy mildew incidence of pearl millet in *Kharif* season reached at maximum of (98.2%) due to a decrease of 10.4 and 25.2 °C in maximum and minimum temperature respectively.

Conclusion

The maximum downy mildew severity was recorded during 35th and 36th meteorological weeks (27th August to 9th September). Hence, the second fortnight of August to the first fortnight of September it can be considered as window period for downy mildew incidence.

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Conflict of Interest Statement: The author(s) declare(s) that there is no conflict of interest.

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