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Short Communication

Influence of agro-meteorological variables on downy mildew development in pearl millet (*Pennisetum glaucum* (L.) R. Br.)

SARAH MURRIA[1*], NAMARTA GUPTA[1], PK KINGRA[2], ANJU BALA SHARMA[3], RUCHIKA BHARDWAJ[3] and NIRMALJIT KAUR[1]

[1]*Dept of Botany, Punjab Agricultural University, Ludhiana, India*
[2]*Dept of Climate Change & Agril Meteorology, Punjab Agricultural University, Ludhiana, India*
[3]*Dept of Plant Breeding & Genetics, Punjab Agricultural University, Ludhiana, India*
[*]***Corresponding author email :*** sarahmurria1994@gmail.com

In India, nearly 6.93 million hectare area is under pearl millet cultivation with an annual production of 8.61 million tonnes (Anon, 2020). Due to its exceptional fodder and grain yielding potential, pearl millet is the most important dual purpose crop cultivated worldwide. Downy mildew caused by *Sclerospora graminicola* (Sacc.) J. Schroet is an oomycetous fungal pathogen which can cause upto 30 *per cent* economic losses to the pearl millet during the years of severe attack with losses reaching nearly 100 *per cent* in individual fields (CGIAR, 2006). 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). 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.

Field trials were conducted during *Kharif* 2019 and 2020 at Forage, Millet and Nutrition Research Farm, Punjab Agricultural University, Ludhiana, located at 30.90° N, 75.80° E at an altitude of 247 m. Seeds of the highly susceptible pearl millet inbred line PIB 1614 were sown in a randomized block design (RBD) with three replications by following standard package of practices (Row to row spacing = 50 cm and plant to plant spacing = 10 cm). Fungicides which could affect downy mildew disease were not applied. The experiment was laid out in a sick plot maintained by adding dried and downy mildew infected pearl millet plants in every season frequently for the providing the source of *S. graminicola* inoculum. For recording downy mildew incidence (DMI), ten plants per plot in three replicates were assessed after crop emergence from 32nd standard meteorological week (SMW) by using standard following formula given by Thakur *et al*., (2011):

$$\text{DMI (\%)} = \frac{\text{Number of diseased plants}}{\text{Total Number of plants}} \times 100$$

Weather data and downy mildew incidence (DMI) was recorded at weekly interval from July to October, when the disease appeared till the occurrence of maximum DMI. Weekly means of data on temperature (°C), relative humidity (%), rainfall (mm), number of rainy days, sunshine hours per day and evaporation (mm) were obtained from the nearby Agrometeorological Observatory, Punjab Agricultural University, Ludhiana for the period of study. The DMI of 10 plants were averaged to get weekly DMI means for each assessment date. The agro-meteorological indices of one week preceding the assessment date were taken as independent variables to evaluate their influence on the dependent variable, DMI through correlation and regression analysis. The prediction

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Table 1: Mean weekly weather variables and downy mildew progression in pearl millet (Pooled data of 2019 and 2020)

Standard Met Week	Mean DMI	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	No. of rainy days	Evaporation (mm)	Sunshine (hrs)
		Max	Min	Morning	Evening				
29	0.35	33.4	26.8	84	68	70.2	5	31.7	5.3
30	0.88	34.9	28.0	82	67	24.5	1	30.5	6.0
31	2.75	32.6	26.6	86	73	130.6	4	30.9	4.6
32	7.67	33.5	26.2	85	64	19.1	1	29.6	8.5
33	16.52	33.6	26.4	86	65	63.4	2	25.8	6.3
34	20.97	34.2	25.9	88	63	22.0	1	27.2	6.7
35	31.42	34.9	26.3	86	58	3.0	0	24.8	7.8
36	34.98	34.1	25.0	85	57	1.9	0	25.5	8.4
37	46.59	32.2	23.2	88	65	61.9	2	26.3	5.9
38	53.82	32.1	19.7	90	45	0.0	0	26.2	8.5
39	61.65	32.7	18.8	92	41	0.0	0	21.1	8.9
40	68.19	31.8	16.7	86	34	0.0	0	21.1	7.4
41	71.35	30.8	14.6	87	32	0.0	0.0	20.6	7.8
42	76.48	29.1	13.7	91	35	0.0	0.0	15.2	3.6
43	81.98	28.0	11.9	87	32	0.0	0.0	14.5	6.0
44	87.53	25.0	12.3	91	46	7.3	0.5	11.4	4.3
45	93.37	23.6	8.8	92	37	0.5	0.0	6.8	6.6
46	95.77	23.4	11.1	94	46	0.0	0.0	6.3	6.2

Table 2: Pearson correlation coefficients between weather variables and downy mildew incidence

S.No.	Weather variables	r (correlation coefficient)
1	Maximum temperature	-0.84**
2	Minimum temperature	-0.97**
3	Morning relative humidity	0.79**
4	Evening relative humidity	-0.88^{NS}
5	Rainfall	-0.64**
6	Number of rainy days	-0.64**
7	Evaporation	-0.93*
8	Sunshine hours	-0.07^{NS}

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed), NS Non-significant at 0.01 level

model based on DMI (dependent variable) and weather parameters (independent variables) were generated using multiple regression analysis for *Kharif* 2019 and 2020, separately as well as of pooled data. Statistical analysis was carried out using Statistical Analysis Software (SAS) version 9.4 for Windows.

The pooled data for weekly mean values of weather variables and downy mildew incidence (DMI) in the pearl millet inbred line PIB 1614 for the *kharif* seasons 2019 and 2020 revealed that downy mildew incidence (DMI) occurred from 29th to 46th standard meteorological week (SMW) during both the crop seasons (Table 1). The average maximum and minimum temperature ranged from 23.4°C to 34.9°C and 11.1°C and 26.3°C, respectively with 84 and 51 per cent of mean morning and evening relative humidity (RH), during 2019 and 2020.

The initiation of downy mildew disease in the field was observed in the 29th SMW (0.35 *per cent* DMI) when the maximum temperature was high (33.4°C). It was in the 37th SMW when the maximum temperature dropped (32.2°C) and DMI reached upto 46.6 *per cent* depicting the progression and spread of downy mildew disease in pearl millet with the decrease in maximum temperature. The DMI peaked in the 46th SMW (95.77 *per cent*) when the maximum temperature dropped (23.4°C) critically. Similar patterns on downy mildew disease progression were observed with minimum temperature. Sangeetha and Siddaramaiah, (2007) reported maximum downy mildew incidence in mustard when minimum and maximum temperature were 26^{o}C and 29^{o}C, respectively. Atri and Singh (2019) while analysing the effect of weather variables on downy mildew progression in pearl millet 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 SMW when the disease incidence was at its peak (95.77 %). Sangeetha and Siddaramaiah (2007) observed that downy mildew infested mustard when the mean relative humidity was more than 65 per cent. The present results are in consonance with the findings of Daunde *et al*., (2017) and Atri and Singh (2019) who reported increment in downy mildew disease of cucumber and pearl millet, respectively, from 28th SMW with high morning and evening relative humidity.

The high rainfall of 130.6 mm during 31st SMW favoured the progression and spread of disease during the initial period after crop emergence (Table 1). An increase in downy mildew incidence with the decrease in evaporation was observed (Table 1). When the evaporation rate was 31.7 mm in 29th SMW, the disease incidence was at its minimum (0.35%) which substantially increased and reached its peak in 46th SMW (95.8 %) at the time of minimum evaporation rate (6.3 mm). These observations on contribution of rainfall and evaporation in disease incidence are in consonance with the results of Ghule *et al.,* (2015) and Atri and Singh (2019) for downy mildew in grapes and pearl millet, respectively.

Pearson correlation coefficients between downy mildew incidence (DMI) and weather variables over the two cropping seasons were computed (Table 2). The results revealed a significant negative correlation between DMI and minimum temperature (r = -0.97**) followed in descending order by evaporation (r = -0.93*) and maximum temperature (r = -0.84**). Rainfall and number of rainy days also had negatively significant correlation (r= -0.64** and -0.64**, respectively) with DMI. A positive and significant correlation of DMI was found only with morning relative humidity (r = 0.79**). The correlation analysis depicted that maximum and minimum temperature, morning relative humidity, rainfall and evaporation played an important role in downy mildew development and progression in pearl millet. Dhaliwal *et al*., (2018) also reported negative and significant correlation of temperature and rainfall with maize stem borer incidence. Kandalkar *et al*., (2000) reported *C. partellus* infestation in sorghum having negative and significant correlation with minimum temperature. However, hot and dry weather conditions under which pearl millet can thrive well might not be conducive for sporangial survival. Hence, pearl millet cultivation can be preceded in early summers prior to monsoons to avoid downy mildew infestation. Similar positive correlation between morning relative humidity and disease development was observed by Ghule *et al*., (2015) and Atri and Singh (2019) in grape anthracnose and pearl millet downy mildew, respectively.

A multiple regression analysis for the prediction of downy mildew incidence in pearl millet was computed using the two year pooled data keeping DMI as dependent variable and weather variables as independent variables. The computed regression equation is as under:

$$Y = -247.438 - 48.095X_1 - 26.114X_2 + 6.234X_3 + 6.726X_4 - 0.520X_5 + 0.866\ X_6 - 3.244X_7 + 1.666X_8, \text{ with } R^2 = 0.987^{**}$$

where,

Y = Downy mildew incidence (DMI), X_1 = Maximum temperature (°C), X_2 = Minimum temperature (°C), X_3 = Morning relative humidity (%), X_4 = Evening relative humidity, X_5 = Rainfall (mm), X_6 = Number of rainy days, X_7 = Evaporation and X_8 = Sunshine hours per day.

The pooled results of multiple regression model exhibited a positive correlation of DMI with morning and evening relative humidity, number of rainy days and sunshine hours, whereas negative correlation with maximum and minimum temperature, rainfall and evaporation. The results revealed that all the weather variables accounted for 98 *per cent* variation (R^2 = 0.98) in downy mildew incidence in pearl millet inbred lines. It is evident that one unit change in maximum temperature, minimum temperature and morning and evening relative humidity might cause probable change of 48.095, 26.114, 6.234, 6.726 units in downy mildew incidence, respectively. The downy mildew incidence in pearl millet inbred lines in *Kharif* 2019 showed high variation as indicated by R^2 value (93%). It was revealed that the downy mildew incidence in pearl millet in *Kharif* 2019 peaked to 98.2 per cent due to decrease of 10.4 and 25.2°C of maximum and minimum temperature, respectively. Similarly, DMI in *Kharif* 2020 peaked to 93.3 per cent by 15.8 and 16.6°C variation in maximum and minimum temperature, respectively. On the basis of pooled analysis in the present study, it was found that increase of 6.23 and 6.72 per cent morning and evening relative humidity, respectively increased downy mildew incidence in pearl millet. The pooled analysis of *Sclerospora graminicola* incidence in both the seasons (2019 and 2020) revealed that DMI can be decreased by 1.23 per cent decrease in rainfall. The present study is in conformity with that of Atri and Singh (2019) who reported a positive correlation of DMI in pearl millet with maximum temperature, morning and evening relative humidity and negative correlation with minimum temperature and rainfall.

It may be concluded here that *S. graminicola* was active during *Kharif* season when the temperature and relative humidity was favourable for the survival of the downy mildew pathogen. High rainfall after the first week of emergence of the crop led to incidence and spread of downy mildew in pearl millet. During the later growth stages of development, morning RH, few sunshine hours, less evaporation and cooler nights led to downy mildew progression. Incidence pattern of pathogen may not be restricted due to changing environmental conditions. Thus, it can be inferred that only in the favourable environment *viz.,* during cool and humid conditions with fewer sunshine hours per day, *S. graminicola* actively infests the pearl millet crop. Thus, multiple regression model is a significant tool for the prediction of downy mildew incidence in pearl millet in Ludhiana region of Punjab.

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

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