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Regression models for prediction of downy mildew progression in pearl millet var. HB 3 based on weather parameters*

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ABSTRACT

The downy mildew constitutes an important group of plant diseases affecting plant species. The data of 10 years (1991-2000) of downy mildew in pearl millet var. HB 3 recorded at the experimental field of CCS Haryana Agricultural University, Hisar were taken to develop the regression models for prediction of downy mildew progression in the crop based on weather parameters. Weather data for the same period (maximum, minimum and mean temperature, morning and evening relative humidity, sunshine hours, rainfall, rainy days, wind speed and rate of evaporation) were used for epidemiological study of downy mildew in pearl millet. Disease intensity values were transformed using Logistic, Gompertz, Monomolecular and Von Bertalanffy-Richard disease progression models. Growing degree days and vapour pressure deficit were computed using daily weather data. Disease intensity (%) and transformed values by different models were correlated with weather parameters. Among the disease progression models, disease intensity transformed by Logistic model showed the best association with weather parameters. Mean temperature, wind speed and growing degree day were collectively explained upto 72% variability in downy mildew disease progression.

Key words : Downy mildew, pearl millet, regression models, weather parameters

The fungi responsible for initiating downy mildew belong to the family ‘Peronosporaceae’, order ‘Peronosporales’ which are obligate parasites in nature. Downy mildew is an economically important disease of pearl millet crop, which causes a sizeable loss in grain yield in many pearl millet growing countries of the world. Rainfall, temperature, humidity, wind speed and direction, dew, cloudiness and its duration, quality and intensity of radiation are the important weather parameters, which play an important role in the initiation and spread of plant diseases (Colhoun, 1973; Thind *et al.,* 2008). Host, physical environment, edaphic and biotic factors influence the processes involved from oospore infection to zoospore infection, which ultimately determine the level of infection. A good deal of work has been done on the effect of important weather parameters i. e. temperature and humidity on these processes (Appaji *et al*., 1989; Singh and Gopinath, 1990; Mehta *et al*., 2008), but relatively a few studies have been conducted on the influence of other environmental factors on development and spread of downy mildew disease in pearl millet crop. Considering the importance of pearl millet cultivation in arid and semi arid zones of Haryana, it is imperative that intricacies of weather parameters and progression of downy mildew need more investigations. Therefore, an attempt was made to develop multiple regression models for downy mildew disease progression in pearl millet based on weather parameters.

MATERIALS AND METHODS

The epidemiological study of downy mildew in pearl millet var. HB 3 was undertaken at Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar (29°10′N, 75°46′E, Altitude 215.2 m). The data of 10 years (1991-2000) on downy mildew recorded at 30 and 60 days after sowing in pearl millet crop were collected. Daily weather data for the same period on maximum and minimum temperature, morning and afternoon relative humidity, actual vapour pressure, sunshine hours, rainfall, rainy days, wind speed and rate of evaporation were taken from Agro-meteorological Observatory located at university research field and used for computation of agrometeorological indices.

The per cent disease incidence (PDI) was calculated as :

$$PDI = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

Disease intensity values were transformed using the following disease progression models :

Logestic model (LM) : $Y=\ln(y/1-y)$

Gompertz model (GM) : $Y=-\ln[-\ln(y)]$

*Papers presented at and reviewed for proceeding of national seminar on "Agrometeorology-Needs, Approaches and Linkages for Rural Development" held at CCSHAU, Hisar during 26-27 November 2009.

Table 1: Correlation coefficient between transformed value of downy mildew by different models of disease progression and weather parameters in pearl millet variety HB-3

Weather parameters	LI	GM	MM	VBRM	PDI
T_{MAX}	-0.74*	-0.67*	-0.63*	-0.50*	-0.64*
T_{MIN}	-0.73*	-0.70*	-0.68*	-0.59*	-0.70*
T_{ME}	-0.80*	-0.78*	-0.76*	-0.65*	-0.77*
RH_M	0.67*	0.64*	0.59*	0.48*	0.59*
RH_E	0.23	0.27	0.19	0.16	0.22
RH_{ME}	0.64*	0.59*	0.53*	0.40	0.55*
WS	-0.73*	-0.72*	-0.69*	-0.65*	-0.72*
SS	0.21	0.15	0.13	0.17	0.19
EP	0.66*	0.66*	0.61*	0.56	0.61*
RF	0.06	0.06	0.04	0.03	0.08
RD	0.09	0.08	0.07	0.05	0.08
GDD	0.77*	0.76*	0.72*	0.63*	0.74*
HTU	0.16	0.20	0.12	0.08	0.02
VPD_M	-0.27	-0.25	-0.22	-0.26	-0.25
VPD_E	-0.64*	-0.64*	-0.60*	-0.59*	-0.60*
VPD_{ME}	-0.33	-0.23	-0.21	-0.22	-0.22

*Significant at P<0.05[r=0.48, n=17).

Where, T_{MAX}–Maximum temperature, T_{MIN}– Minimum temperature, T_{ME}–Mean temperature, RH_M–Morning relative humidity, RH_E– Evening relative humidity, RH_{ME}–Mean relative humidity, WS–Wind speed, SS–Sun shine hours, EP–Evaporation, RF–Rainfall, RD –Rainy days, GDD–Growing degree days, HTU–Helio thermal units, VPD_M–Morning sturation vapour deficit, VPD_E– Evening sturation vapour deficit,VPD_{ME}–Mean sturation vapour deficit, LI–Logistic model, GM–Gompertz model, MM–Monomolecular model, VBRM–Von Bertalanffy-Richards model and PDI– Per cent disease incidence.

Monomolecular model (MM) : $Y=\ln [1/(1-y)]$

Von Bertalanffy-Richards : model (VBRM) $Y=\ln[1/(y^{1-m}-1)]$

Where,

Y=Transformed value of disease intensity

y=Disease intensity in fraction

m=Shape parameters that can range from 0 to infinity, here value of m=3

ln = Logarithm with base e.

The daily weather data were used to compute the different agrometeorological indices viz : growing degree days (GDD, ^{0}C day) and Heliothermal unit (HTU). The difference between saturation vapour pressure and actual vapour pressure the vapour pressure deficit (VPD) was calculated.

Correlation and regression analyses were carried out between weather parameters and disease progression. Multiple regression models were developed by clubbing significant weather parameters using regression analysis.

RESULTS AND DISCUSSION

Correlations

Correlation coefficients obtained between weather parameters and downy mildew disease incidence are presented in Table 1. Maximum, minimum and mean air temperatures, wind speed and morning, evening and mean vapour pressure deficit were negatively correlated with disease intensity irrespective of disease progression models used for transformation. Whereas other weather parameters viz., morning, evening and mean relative humidity; sunshine hours, evaporation rate, rainfall, rainy days, growing degree days and helio-thermal units showed a positive association with disease intensity. However, correlation coefficients in respect of only some of the above said parameters are significant (P=0.05).

Among the disease progression models, disease intensity transformed by Logestic model showed the highest values of correlation coefficients and followed disease intensity transformed by Gompertz, Monomolecular and Von Bertalanffy-Richard models. However, disease intensity showed higher association as compared to Monomolecular

Table 2 : Response function of downy mildew disease progression by different models with weather parameters in pearl millet var. HB-3

Models	Polynomial equations	R^2
LM	$Y=0.0039(T_{ME})^2 -0.712T_{ME}+19.191$	0.55
	$Y=0.001(GDD)^2 -0.182GDD+7.605$	0.59
	$Y=0.0338(WS)^2 -0.862WS+5.847$	0.53
	$Y=-0.0226(VPD_E)^2+1.026VPD_E -8.583$	0.41
GM	$Y=-0.0018(T_{ME})^2 -0.36T_{ME}+14.01$	0.45
	$Y=0.0008(GDD)^2 -0.124GDD+4.25$	0.58
	$Y=0.0568(WS)^2 -1.199WS+7.151$	0.52
	$Y=-0.0525(VPD_E)^2+2.732VPD_E -32.551$	0.41
MM	$Y=0.0153(T_{ME})^2 -1.359T_{ME}+27.752$	0.25
	$Y=0.0016(GDD)^2 -0.334GDD+17.505$	0.40
	$Y=0.0646(WS)^2 -1.314WS+6.714$	0.42
	$Y=-0.0467(VPD_E)^2+2.394VPD_E -28.426$	0.35
VBRM	$Y=-0.0044(T_{ME})^2 -0.174T_{ME}+10.899$	0.40
	$Y=0.0009(GDD)^2 -0.174GDD+8.107$	0.52
	$Y=0.0525(WS)^2 -1.114WS+6.916$	0.48
	$Y=-0.0302(VPD_E)^2+1.486VPD_E -15.233$	0.36
PDI	$Y=-0.664(T_{ME})^2 +33.144T_{ME}-318.52$	0.41
	$Y=-0.0085(GDD)^2+3.392GDD-222.63$	0.55
	$Y=0.255(WS)^2 -8.257WS+123.67$	0.52
	$Y=-0.3251(VPD_E)^2+15.682VPD_E -95.159$	0.36

Where, Y–Transformed value of disease progression, T_{ME}–Mean temperature, WS–Wind speed, GDD- Growing degree days, VPD_E–Evening vapour pressure deficit, LM–Logistic model, GM–Gompertz model, MM–Monomolecular model, VBRM–Von Bertalanffy-Richards model and PDI–Per cent disease incidence.

and Von Bertalanffy-Richard transformations and showed lower association with weather parameters in comparison with Logestic and Gompertz transformations. The correlation coefficients in case of significant weather parameters ranged between 0.44 and 0.80.

Simple regression models

The weather parameters such as mean temperature, growing degree days, wind speed and evening vapour pressure deficit showed a polynomial response with disease progression by Logestic model and presented in Table 2. This response of downy mildew disease was parabolic and its second degree regression coefficient was positive with mean temperature, growing degree days and wind speed, but it was negative with evening vapour pressure deficit. Growing degree days explained the maximum variation in disease progression i. e. 59% followed by mean air temperature, wind speed and evening vapour pressure deficit.

The downy mildew disease progression by Gompertz model showed parabolic polynomial response and its second degree regression coefficient was positive with growing degree days and wind speed (Table 2), whereas it was negative with mean air temperature and evening vapour pressure deficit. The R^2 values ranged between 0.41 and 0.58. The growing degree days explained the maximum variability in disease progression (58%) and minimum variation was explained by evening vapour pressure deficit (41%).

The per cent disease progression showed parabolic response and its second degree regression coefficient was negative with mean air temperature, growing degree days and evening vapour pressure deficit, while it was positive in case of wind speed with disease progression. The growing degree days also explained the highest variability (55%) in disease progression (Table 2).

Disease progression by Monomolecular model exhibited similar polynomial response with weather parameters (Table 2). Mean air temperature and evening vapour pressure deficit showed parabolic response and its second degree regression coefficient was negative. Whereas the second degree regression coefficient of this equation was positive with growing degree days and wind speed. Among these weather parameters, growing degree days explained the highest variation in disease progression (52%).

Table 3. Multiple regression equations for downy mildew disease progression by different models in pearl millet var. HB-3 with weather parameters

Models	Regression equations	R^2
LM	$Y=3.692-0.307\,T_{ME}+0.052GDD$	0.69
	$Y=3.895-0.223T_{ME}-0.191WS+0.041GDD$	0.72
GM	$Y=13.267+0.323T_{ME}+0.289WS$	0.64
	$Y=3.980-0.206T_{ME}-0.254WS+0.041GDD$	0.68
MM	$Y=4.313-0.282T_{ME}+0.044GDD$	0.54
	$Y=4.547-0.185T_{ME}-0.221WS+0.032GDD$	0.64
VBRM	$Y=11.627-0.299T_{ME}-0.269WS$	0.56
	$Y=3.923-0.201T_{ME}-0.239WS+0.034GDD$	0.59
PDI	$Y=218.625-4.073T_{ME}-2.745WS$	0.60
	$Y=218.706-4.071T_{ME}-2.744WS-0.002VPD_E$	0.63

Where, Y–Transformed value of disease progression, T_{ME}–Mean temperature, WS–Wind speed, GDD–Growing degree days, VPD_E–Evening vapour pressure deficit, LM–Logistic model, GM–Gompertz model, MM–Monomolecular model, VBRM–Von Bertalanffy-Richards model and PDI–Per cent disease incidence.

Disease progression by Von Bertalanffy-Richard model also showed polynomial response with weather parameters (Table 2). The second degree regression coefficient of the parabolic equation was positive with mean air temperature, growing degree days and wind speed, while it was negative with evening vapour pressure deficit. Although R^2 values were low, yet growing degree days explained maximum variation in disease progression.

Multiple regression models

Based on significant correlation coefficients of selected weather parameters were clubbed together for developing multiple regression models for prediction of disease progression using step-wise regression technique. The best fit models based on two or more weather parameters are presented in Table 3. Among the various models of disease progression used, the disease progression by Logistic model showed the highest R^2 values. Based on two weather parameters such as mean temperature and growing degree days, the regression model explained the variability in disease progression upto 69%. With the addition of wind speed, the model further explained 3% more variation in disease progression. These weather parameters explained more variability in disease intensity as compared to disease progression by Monomolecular and Von Bertalanffy-Richards model and explained lower variability in comparison with the disease progression by Logistic and Gompertz models.

Among the various models of disease progression used, the disease progression by Logistic model showed highest R^2 values. This might be due to better linearization of disease progress curve by logistic transformations. In this cultivar, 74% variability in disease was explained by mean temperature, growing degree days, wind speed and evening saturation deficit. Appaji *et al.* (1989) also observed that actual vapour pressure, mean air temperature, relative humidity and minimum air temperature explained the variability in downy mildew disease incidence upto 46-48%, when 10 years (1977-1988) disease incidence and weather data were analyzed. However, they reported that 84-85% of the disease variability was explained by mean air temperature, saturation vapour pressure and growing degree days, when the disease data were utilized from field experiment conducted in 1987 and 1988. The study conducted by Shaw *et al.* (1995) revealed that 46.1 to 54.6% variability in bacterial blight of cowpea could be explained by maximum temperature, minimum temperature, morning and evening relative humidity.

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