



Weather-based models to forecast spot blotch disease (*Bipolaris sorokiniana*) of wheat (*Triticum aestivum*) in North Bengal

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ABSTRACT

Experiment was laid with wheat (*Triticum aestivum* L.) genotypes Sonalika (susceptible check) and HD 2967 (popular variety) at Pundibari, Coochbehar, India (26°23'52"N, 89°23'26"E) on two dates of post-rainy (*rabi*) seasons of 2018 and 2019 at one-year interval. Data of experiments conducted previously at Pundibari were also used. Correlation values indicated that percent disease severity and Area under Disease Progress Curve on cv. Sonalika and HD 2967 had significant ($P < 0.1$) correlations with maximum temperature and morning relative humidity. Weighted interactions between maximum temperature and morning relative humidity, maximum temperature and rainfall, minimum temperature and afternoon relative humidity, minimum temperature and rainfall, morning and afternoon relative humidity were also significant ($P < 0.1$). Cultivar-specific models were developed to predict the severity of the spot blotch disease (*Bipolaris sorokiniana*) on the crop. This will allow the growers to make need-based timely effective application of fungicides prior to inception of the disease. Here we report only the models that were found effective based on validation in the two years. As per available literature, this report seems to be the first of its kind for forecasting spot blotch of wheat.

Keywords: *Bipolaris sorokiniana*, Epidemiology, Forecasting models, Spot blotch disease, *Triticum aestivum*, Weather

Wheat (*Triticum aestivum* L.), a major cereal crop cultivated in India and around the world (GoI 2020), suffers from an important constraint spot blotch disease caused by *Bipolaris sorokiniana* affecting approximately 25 m ha (Chowdhury 2021) globally of which about 40% area is in the Indian subcontinent (Joshi *et al.* 2007 and Jamil *et al.* 2020). In northern parts of West Bengal, the crop loss due to the disease was 43% in susceptible varieties (Chowdhury *et al.* 2008). The timing and severity of infestation caused by *B. sorokiniana* on wheat differ among seasons and regions. In absence of host resistance to the spot blotch disease, fungicides remain the only effective means for its management (Gianessi 2014). About two-thirds of Indian wheat growers resort to 1-2 calendar foliar sprays of fungicides during post-flowering stage to safeguard the crop from avoidable losses in yield (Sharma-Poudyal *et al.* 2016, Yadav and Dutta 2019). Thus, crops requiring treatment are

left unsprayed and others sprayed unnecessarily, which leads to waste of chemical fungicides, environmental pollution due to avoidable application(s) of the fungicide(s) as also ineffective management of the disease. In India, wheat is sown in November-December while harvest occurs during March-May. Harboring of the spot blotch pathogen by wheat and alternative hosts (Acharya *et al.* 2011 and Manamgoda *et al.* 2011) could be the reason for carryover of *B. sorokiniana* from one crop to another.

Knowledge of tripartite relationship among pathogen, plant and environmental conditions is limited (Joshi *et al.* 2007, Viani 2014, Chattopadhyay *et al.* 2020). Efficient and eco-friendly management of the disease could be obtained through knowledge of its severity and timing of attack in relation to weather factors, which may help forecast its occurrence to enable growers initiate timely efficient action for better crop management. No system to forecast spot blotch of wheat exists at present. Hence, the present study was undertaken to assess the correlation of weather parameters with the occurrence of spot blotch of wheat and develop models to forecast severity of the disease.

MATERIALS AND METHODS

Experiment was laid out with wheat cv. Sonalika (released in 1971, susceptible check with negligible area)

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and HD 2967 (Singh *et al.* 2019) at Pundibari, Coochbehar, India (26°23'52"N, 89°23'26"E), on two dates of post-rainy (*rabi*) seasons of 2018 and 2019 at one-year interval. The genotypes were grown following standard agronomic practices (Kumar *et al.* 2014) and without application of potassium fertilizer and fungicides.

Visual disease scoring on a modified 0-9 scale for spot blotch of wheat (Saari and Prescott 1975, Eyal *et al.* 1987) was carried out for recording disease scores thrice at 10-day intervals. For calculating Area Under Disease Progress Curve (AUDPC), disease scores were converted to percent disease severity (Wilcoxson *et al.* 1975 and Sharma *et al.* 2007).

Correlations were derived of the weather parameters, viz. weekly average of maximum (X1) and minimum (X2) temperature, morning (recorded at 0700 hr local apparent time/LAT, X3), afternoon (recorded at 1400 hr LAT, X4) relative humidity and rainfall (X5) at Coochbehar (secured from the Indian Meteorological Department, Government of India) for 12 crop seasons (2004-05 to 2016-17) with percent spot blotch disease severity (vertical and horizontal, Saari and Prescott 1975, Eyal *et al.* 1987) and AUDPC recorded on cv. Sonalika at Pundibari (data for which was available at the Department of Plant Pathology, Uttar Banga Krishi Viswavidyalaya). Similarly, correlations were also investigated for the same five weather parameters for five crop seasons (2012-13 to 2016-17) with disease severity and AUDPC recorded on cv. HD 2967 at Pundibari.

For developing forecasting models for spot blotch of wheat, a technique based on relatively smaller number of model parameters accounting for distribution of weather parameters over time could be achieved by taking weighted accumulation of weather variables, weights being derived from correlation coefficients between variables to forecast and weather variables considered as the indicators of relative importance in respective weeks. In this approach, two indices were developed for each weather variable; one as total value of weather variables and the second one as weighted total, weights being correlation coefficients between variables to forecast and weather variables in respective weeks. The first index represents the total of different weather variables received by the crop during the period under consideration while the other one takes care of distribution of weather variables with special reference to its importance in different weeks in relation to the variables to forecast. Likewise, for joint effects of weather variables, weather indices were developed as weighted accumulations of product of weather variables (taking two at a time), weights being correlation coefficients between variables to forecast and product of weather variables considered in respective weeks (Chattopadhyay *et al.* 2005). Stepwise regression technique is an improvement over forward/backward selection process in the sense that it re-checks at each step the importance of all previously included variables. The partial correlation for each variable in the regression equation at any stage is evaluated for significance. Further, any variable that provides non-significant partial correlation value is removed from the

model. The process is continued till no variable is either admitted to the equation or any variable is rejected.

The forecasting models for prediction of highest severity of spot blotch disease of wheat were developed for Pundibari using weather data for the five parameters from 47th Standard Meteorological Week (SMW) to 4th SMW. For this, historical data on disease severity and weather variables for corresponding years were utilized for wheat cv. Sonalika and HD 2967. The data for disease severity of the horizontal and vertical observations of the modified scale of Saari and Prescott (1975) were first converted into percentage, which was then arc-transformed and then the process of development of models was initiated; after development of models, the data output (Y) were re-transformed to horizontal and vertical percentage disease severity. The data was analysed using the software SAS version 9.3.

RESULTS AND DISCUSSION

Correlation structure of spot blotch of wheat with indices of different weather parameters along with interaction on percent disease severity (vertical, horizontal and AUDPC) on cv. Sonalika and HD 2967 showed that the correlations with weighted indices are more important than unweighted (not multiplied with any correlation coefficient) indices (Table 1). In most of the cases, high relative humidity was found to have significant influence on disease severity as it allows the canopy to remain wet for a prolonged period that provides favourable environment to pathogen for growth and infection (Acharya *et al.* 2011). Spot blotch infection is most severe with periods of continued (>18 h a day) leaf wetness, high temperature (>18°C; >26°C) and the crop's late post-anthesis phase coinciding with a period of high relative humidity (Duveiller *et al.* 2005, Viani 2014, Chattopadhyay *et al.* 2020).

The models thereby devised forecasted vertical spot blotch severity on cv. Sonalika (Table 2) which was not close enough to observed values for years of validation 2018-19, 2019-20, where the weather parameters entered were primarily afternoon relative humidity (X4) as interacted with maximum temperature (X1) along with an added interaction with minimum temperature (X2). The coefficients of determination (R^2) were also of a level that were comparatively lower than those encountered in case of models for forecasting horizontal severity of spot blotch on cv. Sonalika. Among the different models attempted for forecasting severity of spot blotch on cv. Sonalika, the forecasted horizontal spot blotch severity was closest to the observed values as depicted by the close difference between values of 2018-19 and 2019-20, more so for the model that forecasted using the data for 47th to 4th SMWs (Table 2). Even, the models that used data for 47th to 3rd, 47th to 2nd and for 47th to 1st SMWs could also provide a reasonably good forecast for all practical purposes. The R^2 were also of a level that provides confidence to a forecaster. Notably, the models mostly relied on the interaction of the maximum temperature (X1) either with the morning relative humidity

Table 1 Correlation of weather indices during Standard Meteorological Week (SMW) 47 to SMW 6 with percent disease severity for spot blotch of wheat on cv. Sonalika and HD 2967

Weather parameter, interaction	Percent disease severity Vertical [#]						Percent disease severity Horizontal [#]						AUDPC	
	cv. Sonalika			cv. HD 2967			cv. Sonalika			cv. HD 2967			cv. Sonalika	cv. HD 2967
	Wt	Unwt	Wt	Unwt	Wt	Unwt	Wt	Unwt	Wt	Unwt	Wt	Unwt	Wt	Unwt
Max Temp	0.49**	-0.44	0.69	0.42	0.76	-0.21	0.56	-0.3	0.79**	-0.55*	0.72	-0.36		
Min Temp	0.79**	-0.04	0.90*	0.90*	0.46	-0.17	0.85*	0.05	0.91**	0.71**	0.64	0.37		
RH Morn	0.28	-0.06	0.83*	0.97**	0.67*	0.31	0.76	0.4	0.69*	0.54*	0.86*	0.78		
RH Aft	0.40	-0.12	0.93*	0.07	0.33	0.04	0.85*	0.65	0.65*	-0.60*	0.92	0.69		
Rainfall	0.51*	0.42	0.93*	0.07	0.51	0.13	0.85*	0.65	0.52*	0.54*	0.92*	0.69		
Interaction of Max Temp and Min Temp	0.73**	-0.41	0.77	0.73	0.53*	-0.29	0.89*	-0.21	0.78**	0.23	0.47	-0.06		
Interaction of Max Temp and RH Morn	0.59*	-0.42	0.82*	0.69	0.68*	0.12	0.90*	-0.13	0.56*	0.238	0.74	-0.07		
Interaction of Max Temp and RH Aft	0.32	-0.21	0.69	0.62	0.41	-0.01	0.98**	-0.02	0.69*	-0.67*	0.71	-0.1		
Interaction of Min Temp and RH Morn	0.46	-0.05	0.90*	0.94*	0.59*	0.07	0.69	0.16	0.79**	0.67*	0.66	0.5		
Interaction of Min Temp and RH Aft	0.52*	-0.17	0.93*	0.77	0.58*	-0.04	0.81*	0.32	0.73**	-0.43	0.67	0.59		
Interaction of RH Morn and RH Aft	0.49	-0.21	0.88*	0.64	0.49	0.20	0.93*	0.66	0.74**	-0.51*	0.95*	0.92*		
Interaction of Max Temp and Rainfall	0.51*	0.42	0.69	0.62	0.52	0.14	0.98**	-0.02	0.53*	0.54*	0.71	-0.1		
Interaction of Min Temp and Rainfall	0.51*	0.44	0.92*	0.77	0.53	0.11	0.81*	0.32	0.52*	0.54*	0.67	0.59		
Interaction of RH Morn and Rainfall	0.50*	0.42	0.88*	0.64	0.50*	0.14	0.93*	0.66	0.53*	0.53*	0.95*	0.92*		
Interaction of RH Aft and Rainfall	0.51*	0.42	0.93*	0.07	0.52*	0.13	0.86*	0.65	0.53*	0.54*	0.93*	0.69		

[#]Modified scale of Saari and Prescott (1975); AUDPC: Area Under Disease Progress Curve; Max Temp: Maximum temperature; Min Temp: Minimum Temperature; RH Morn: relative humidity at 0700 hr (local apparent time/LAT); RH Aft: relative humidity at 1400 hr LAT; * P<0.1; ** P<0.01, wt: weighted; unwt: unweighted

Table 2 Models for forecasting of spot blotch severity of wheat cv. Sonalika and HD 2967

Data used for model development	Disease severity (Vertical)*			Disease severity (Horizontal)*			Disease severity (AUDPC)			Crop Season
	Model	Observed	Forecasted	Model	Observed	Forecasted	Model	Observed	Forecasted	
47 th to 4 th SMW (cv. Sonalika)	Y= 115.61761 + 9.0325Z ₂₁ + 0.90028Z ₄₁ - 0.06384Z ₂₄₁ (R ² : 0.60)	69.1	98.4	Y= 131.60433 + 1.63879Z ₁₁ + 0.01476Z ₁₃₁ + 0.07299Z ₂₅₁ (R ² : 0.80)	77.8	83.6	Y= 1553.50880 - 0.16318Z ₁₄₀ + 0.27884Z ₂₄₀ (R ² : 0.55)	453.7	933.9	2018-19
47 th to 3 rd SMW (cv. Sonalika)	Y= 107.72655 + 8.68505Z ₂₁ + 0.87555Z ₄₁ - 0.05235Z ₂₄₁ (R ² : 0.62)	53.1	98.1	Y= 129.61858 + 2.22962Z ₁₁ + 0.01385Z ₁₃₁ + 0.39317Z ₂₅₁ (R ² : 0.86)	77.8	82.2	Y= 1253.09286 - 0.21821Z ₁₄₀ + 0.43215Z ₂₄₀ (R ² : 0.69)	267.9	211.0	2019-20
47 th to 2 nd SMW (cv. Sonalika)	Y= 78.96359 + 16.07637Z ₂₁ + 0.78164Z ₄₁ - 0.07851Z ₂₄₁ (R ² : 0.74)	69.1	98.1	Y= 128.19749 + 2.23887Z ₁₁ + 0.01389Z ₁₃₁ + 0.39344Z ₂₅₁ (R ² : 0.86)	77.8	88.3	Y= 1210.25328 - 0.24494Z ₁₄₀ + 0.48867Z ₂₄₀ (R ² : 0.70)	453.7	767.0	2018-19
47 th to 1 st SMW (cv. Sonalika)	Y= 71.99585 + 18.79882Z ₂₁ + 0.94994Z ₄₁ - 0.11370Z ₂₄₁ (R ² : 0.77)	69.1	98.5	Y= 132.70217 + 2.19773Z ₁₁ + 0.01455Z ₁₃₁ + 0.44732Z ₂₅₁ (R ² : 0.87)	77.8	87.9	Y= 1441.31549 - 0.24719Z ₁₄₀ + 0.44252Z ₂₄₀ (R ² : 0.64)	453.7	901.7	2018-19
47 th to 1 st SMW (cv. HD 2967)	Y= 51.57308 + 0.32608Z ₄₁ (R ² : 0.86)	63.0	59.8	Y= -588.43013 + 2.88288Z ₄₁ (R ² : 0.73)	75.3	100.0	Y= -2664.16997 + 16.06668Z ₄₁ (R ² : 0.85)	395.1	267.9	2019-20
		42.0	63.2		70.3	12.8		200.0	186.0	2019-20

*Modified scale of Saari and Prescottt (1975)

(X3) or with minimum temperature (X2) and rainfall (X5) (Table 2). However, the attempt for devising models to forecast severity of spot blotch on cv. Sonalika using values of AUDPC was not so successful (Table 2), the forecasted values being quite distant from those observed while the R^2 were lower than those encountered in other models. Thus, from the above, it is evident that the models to forecast severity of spot blotch of wheat could be worked on with horizontal values as the most preferred one followed by the vertical values for cv. Sonalika of wheat.

Since longer-term historical data was available for cv. Sonalika, the models to forecast severity of spot blotch on the variety was attempted, which were also found to be reasonably effective to start with as they provided a foundation for relevant interaction among the host, pathogen and different weather parameters. However, due to the advantages discussed above, an attempt was taken to devise models to forecast severity of spot blotch on the cv. HD 2967 as well even with the meagre data available. Among the different models attempted for forecasting severity of spot blotch on cv. HD 2967, the forecasted horizontal and vertical spot blotch severity were comparable to the observed values of 2018-19 and 2019-20, where the R^2 for vertical spot blotch severity was of a level that provided confidence to a forecaster (Table 2). Models that entered were based on the data for 47th to 1st SMW, which were built on interaction of maximum temperature (X1) with afternoon relative humidity (X4) and the ones for vertical spot blotch severity seemed to have parity between observed and forecasted values, whereby the models were validated with reasonable success. Though the models were unique in their nature, the weather variables considered matched those of *Alternaria* blight of mustard (Chattopadhyay *et al.* 2005), possibly due to the fact that both occurred in post-rainy season and were caused by dematiaceous hyphomycetes. However, the models attempted for forecasting severity of spot blotch on cv. HD 2967 based on values of AUDPC had poor efficacy for parity with observed values, which thereby may not be of any use for further application for forecasting severity of spot blotch in farmers' fields.

There have been a few attempts to forecast diseases of wheat, viz. rusts (Nagarajan and Singh 1990), etc. Though the need for models to forecast the spot blotch of wheat has been suggested very recently (Chowdhury 2021), as per available literature, this report seems to be the first of its kind for forecasting spot blotch of wheat using both the susceptible cv. Sonalika and the popular cv. HD 2967. The cultivar-specific models validated in this study could be further refined to enable wider application to forecast spot blotch of wheat with improved precision for enabling better management of the disease in North Bengal.

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