



Role of abiotic factors on disease progression of Spot blotch of Wheat

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Abstract

Spot blotch of wheat caused by *Bipolaris sorokiniana* appears at all growth stages, though susceptibility increases with increase in plant age. Every year disease causes high yield losses even up to 60% depending on the wheat variety and weather factors. The cultivation of wheat in North Eastern Plains Zone (NEPZ) of India is increasing, but the crop yield is low due to warm and humid climate which increase diseases like spot blotch. Considering significant impact of the spot blotch on crop yield, an experiment was conducted during *rabi* seasons of 2015–2016 and 2016–2017 to evaluate the effect of different abiotic factors on spread of the disease, as well as development of a predictive model to predict the disease severity in a set of 12 wheat varieties. Statistical analysis proved that all the thermic variables like temperature (maximum and minimum) and soil temperature are significantly correlated with diseases initiation across growth stages of the crop. Step-wise regression showed high R^2 values like, 0.99, 0.97, 0.96, 0.96, 0.98, 0.96, 0.99, 0.98, 0.96, 0.98, 0.98, 0.98 for the predicative model of spot blotch in PBW 343, HD 2733, PBW154, Raj4015, KALYAN SONA, SONALIKA, LERMA RAJO, DBW39, UP301, HD2009, NP114, NP718 respectively.

Keywords Abiotic factors · Disease progression · Plant growth stage · Prediction model · Spot blotch · Wheat

Introduction

The year 2019 India witnessed an outstanding output in food grain production where wheat contributes 36% of share with an annual estimated wheat production of 103.60 million tons from 29.32 million hectare registering an all-time highest crop productivity of 3533 kg/ha (Annual Report 2019). Increase in production of wheat as compared to last year was marginal, and it may also to attribute to percentage decline in acreage. In NEPZ the area under wheat cultivation was restricted as in some areas of West Bengal, wheat holiday was observed to avoid occurrence of wheat blast disease which was reported from the neighboring country (ICAR-IIWBR 2018). The wheat scenario in NEPZ of India is in stressed condition due to higher intensity of spot blotch which further adds to yield losses depending on the selection of cultivars and weather factors. Spot blotch is one of

the destructive fungal diseases that affects wheat and several other small grains worldwide. In the eastern part of the Indian subcontinent, on-farm studies indicated crop losses up to 16% in Nepal and 15% in Bangladesh. Grain yield losses between 20 and 80% have been reported by Duveiller and Gilchrist (1994). The average yield loss estimated to be 18–50% under favourable weather conditions (Singh et al. 2015). Grain yield loss due to spot blotch in South Asia ranged from 04 to 38% and 25 to 43% in the year 2004 and 2005, respectively (Sharma and Duvellier 2005). Even every 1% increase in disease severity have a significant impact on seed yield (Devi et al. 2018). Globally spot blotch is a common disease which is widespread across the globe with its incidence reported from all the wheat growing continents (Gupta et al. 2018). Acharya et al. (2011) has reported the disease to occur in more than 32 wheat growing countries.

Spot blotch is considered to contribute significantly low average yield of wheat crop under warm and humid conditions. High relative humidity, which allows the canopy to remain wet for a prolonged period, is particularly favourable for infection and pathogen growth (Acharya et al. 2011). The severity of spot blotch disease is largely dependent on environmental conditions like low temperature and frequent rainfall during dough stage (Wang et al. 2002). High temperature

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and high relative humidity favour the outbreak of the disease particularly in South-Asia's intensive irrigated rice–wheat production systems (Aggarwal et al. 2000). Infection of *B. sorokiniana* increased with increase in Temperature, bright sunshine hour and with dew point (morning) although relative humidity (both maximum and minimum) had a negative correlation with its progression (Devi et al. 2018). Changes in pathogen virulence due to climate change, emergence of new races of pathogen and lack of effective durable resistance, lead to loss of resistance in the wheat varieties and hence there is always a need for identification and characterization of new sources of resistance (Kumar et al. 2019, 2020; Mahapatra et al. 2020). To develop an effective forecasting system for the spot blotch of wheat, it is essential to evaluate relation between weather and diseases is key factors involved in the disease initiation and progress. Understanding of weather conditions is prerequisite for prognostic purpose of the disease pressure. Keeping this fact in view, in this experiment we develop a weather based prediction equation that will helpful for the farmers of Indo–Gangetic plains of India for Spot blotch of wheat.

12 wheat varieties viz PBW343, HD2733, PBW154, RAJ4015, Kalyansona, Sonalika, Lerma Rojo, DBW39, UP301, HD2009, NP114 and NP718 were selected for conducting field experiment during rabi 2015–2016 and 2016–2017. The varieties selected for this experiment have known to occupy a large area under cultivation in the eastern plains of India and have ruled the farmers' fields at the time of their cultivation. Some have become mega varieties while others are the first genotypes received from CIMMYT in early 1960s and have made a mark in the at wheat improvement program. Few lines were also taken from the pre-green revolution era to make the experimental set a diverse one. Experiment was conducted at instructional farm Jaguli of Bidhan Chandra Krishi Viswavidyalaya (BCKV) Nadia, West Bengal, India. The climate of the region is subtropical humid. The selected varieties were sown during 3rd week of November. The experiment was laid out in randomized block design with three replications. The date of first appearance of the disease was recorded on onset time and the percent disease severity was worked out at every subsequent seven day interval before harvesting of the crop. The standard evaluation scale (0–9) was used. Evaluation was done on randomly selected plants in each replicated block for measuring the disease progress.

The proposed rating system has the digits rating 0–9 and severity is recorded on the top two leaves of the plant at 59–65 growth stages of Zadok's scale. The spot blotch severity is taken in percent leaf area covered separately for flag (F) and leaf below (F-1) and rating is done as by following double digit scale (Singh and Kumar 2005). The calculation of disease severity was done as diseased leaf area percentage (DLA%). The ten plants per replication

were randomly selected and DLA% per replication will be calculated by using the following formula by Sharma and Duveiller (2003),

$$\text{Percent diseased leaf area, DLA\%} = \frac{a}{9} \times \frac{b}{9} \times 100.$$

Then the disease severity records were averaged over the three replications and disease progress curves were plotted. For each replication the area under disease progress curves (AUDPC) were calculated. The formula used as follows:

$$\text{AUDPC} = \Sigma[(Y_i + 1 + y_i)/2(X_i + 1 - X_i)]$$

where, $i = 1$, Y_i is the severity at 1st observation, X_i is the time (days) at first observation, N is the Total number of observation.

The following weather parameters were collected during the course of experiment, Maximum temperature ($^{\circ}\text{C}$) (T_{max}), Minimum temperature ($^{\circ}\text{C}$) (T_{min}), Maximum Relative humidity (%) (RH_{max}), Minimum Relative humidity (%) (RH_{min}), Bright sunshine hours (BSH) Soil temperature (St) and Wind speed (km/h) (Wv). These data were collected from the Department of Agricultural Meteorology and Physics of BCKV, Mohanpur, Nadia, West Bengal. Seven days mean of those weather parameter (variables) were calculated for the entire period of disease assessment were worked out.

The experimental results were statistically interpreted through calculating the “Analysis of variance” by standard method of error mean square by Fischer and Syndecor's F test at probability level 0.05. For determination of critical difference (CD at 5% level significant) Fisher's and Yate's table were consulted.

The disease severity in the leaves was changing day to day following development of initial foci (onset time). If this variable considered being a dependable variable with weather parameters being independent variables, then regression equation will describe the relationship. The disease severity is called the dependent (response) variable Y and is said to regress on the weather parameters are called the independent (determining) variables X . For calculation of correlation of both variables need to be normally distributed whereas for regression this is necessary only for dependent variables. For study of the multiple effects on dependent variables the multiple regression analysis is done (MRA) as a predictive equation:

$$\hat{Y} = b_0 + b_1x_1 + b_2x_2 + \dots b_nx_n$$

where, \hat{Y} is the predicted disease severity, b_0 is the intercept, $b_1b_2\dots b_n$ is the regression co-efficient $x_1x_2\dots x_n$ is the independent variable.

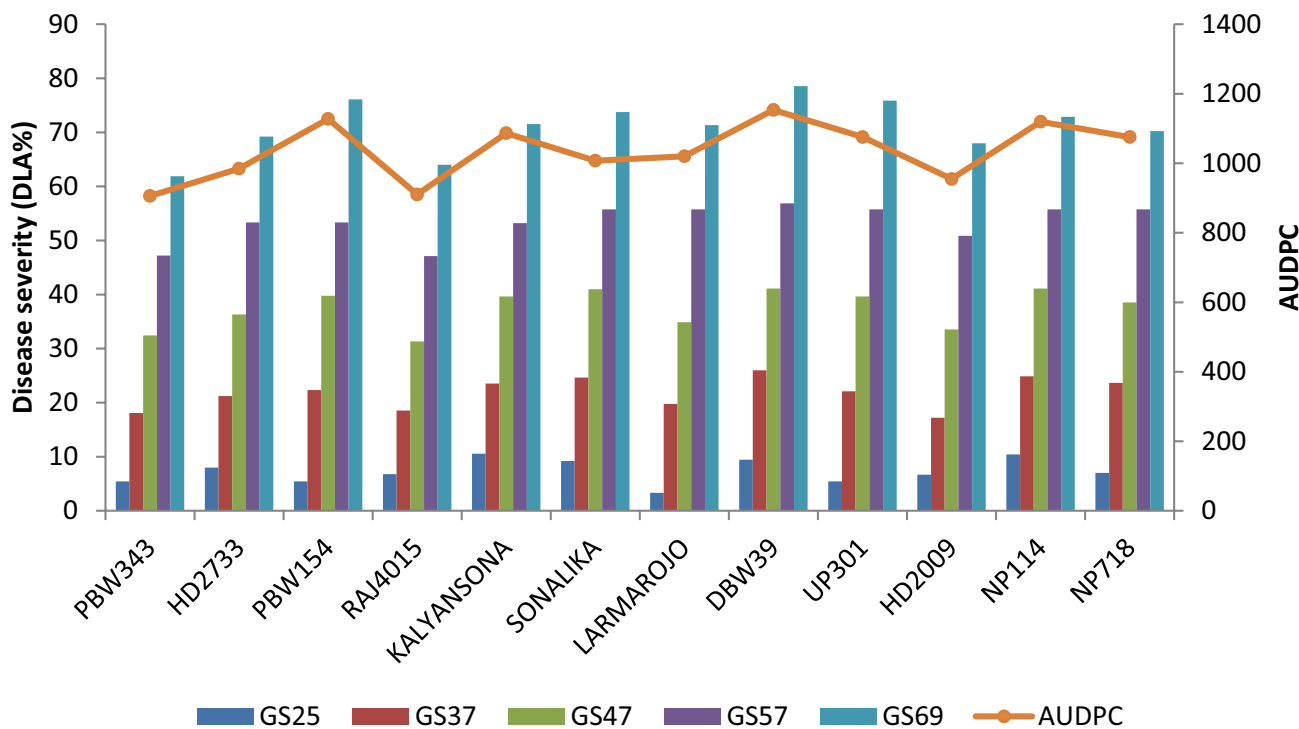
At initial growth stages (25) maximum disease severity was recorded in Kalyansona (10.55) statistically at parwith NP114 (10.44), DBW39 (9.44), Sonalika (9.22),

HD2733 (8.00), Raj4015 (6.77), NP718 (7.3), HD2009 (6.67), UP301 (5.44), PBW154 (5.44) and PBW343 (5.44). The minimum disease severity was noticed in Larmarojo (3.33) statistically at par with PBW 343 (5.44), PBW154 and UP301 (Fig. 1).

At 37 growth stage the diseases severity was increased significantly and maximum was recorded in DBW39 (26.0) statistically at par with NP114 (24.55), Sonalika (24.66), NP718 (23.66), Kalyansona (23.55) and minimum in HD2009 (17.22) statistically at par with PBW343 (18.11), Raj4015 (18.55) and Larmarojo (19.77). At growth stage of 57 the disease severity was increased significantly and it was observed that maximum was recorded in DBW39 (56.88) and statistically at par with all the other varieties except Raj4015 (47.11) and PBW343 (47.22) which produced less disease severity. In that growth stage it was observed that except two varieties Raj4015 and PBW343 all other ten varieties showed no significant difference in disease reaction. At last 69 growth stages minimum disease severity was recorded in PBW343 (61.88) statistically at par with Raj4015 (64.00) and HD2009 (68.00) whereas the other nine varieties showed no significant differences in disease severity and they produced disease varied from 70.22 to 78.55. The increase in disease severity at different growth

stages were reflected in AUDPC values. Twelve varieties were different in their AUDPC values and their differences were statistically significant. Though the AUDPC value with regards to disease severity was minimum in PBW343 (906) followed by Raj4015 (910.38) and HD2009 (954.83) and their differences were not statistically significant. But it was also observed that all the eleven varieties were statistically at par in disease severity except DBW39 which produced maximum AUDPC (1153.61).

All the disease severity data of different varieties were correlated with meteorological parameters like maximum temperature (°C) (T_{max}) minimum temperature (°C) (T_{min}), soil temperature (St), maximum relative humidity (%) (RH_{max}), minimum relative humidity (RH_{min}), Bright sunshine hours (BSH) to find out relationship between increase in disease and how much it is influenced by above meteorological parameters on twelve different varieties (Table 1). In both the *rabi* seasons disease was appear at GS25 and GS37 depends on resistance within the selected varieties when crop approaching to its tillering stage and T_{max} (28.4–33.6 °C), T_{min} (14.6–19.9 °C), St (17.8–22.9 °C) and RH (90–92%) so all these were critical factor for disease initiation and at this diseases initiation time, maximum disease scored was in HD2733 and



Notes: GS= Zadok’s growth stage, AUDPC= Area under diseases progress curve.

Fig. 1 Progression of disease severity of leaf blotch of wheat at different growth stage of the plant. GS Zadok’s growth stage, AUDPC area under diseases progress curve

Table 1 Effect of different weather factors on the severity of Spot blotch of wheat

Growth stage	Disease severity on different varieties											Weather variables						
	PBW 343	HD 2733	PBW 154	RAJ 4015	Kalyansona	Sonalitka	Lermarojo	DBW 39	UB 301	HD 2009	NP 114	NP 718	T _{max}	T _{min}	RH _{max}	RH _{min}	BSH	St
GS 25	01	12	00	12	00	00	01	12	00	13	12	01	28.4	14.6	92	60	4.0	17.8
GS 37	23	24	12	13	00	01	23	23	12	12	24	23	33.6	19.9	90	45	6.5	22.9
GS 47	35	35	23	24	22	45	45	35	22	35	35	34	31.8	20.3	97	59	7	21.9
GS 57	46	45	35	46	34	57	57	45	45	46	46	57	33.8	21.8	91	49	6.8	23.5
GS 69	57	56	46	68	57	67	68	68	56	56	68	79	34.1	20.7	88	42	7.4	23.9

GS Zadok's growth stage, T_{max} maximum temperature, T_{min} minimum temperature, RH_{max} maximum relative humidity, RH_{min} minimum relative humidity, BSH bright sunshine hours, St soil temperature

NP114 (Table 1). Then the diseases progresses gradually as crop growth stages progresses, but sharply increased at GS 57–69. But at that time highest diseases scored in DBW39 (68), Sonalika (67), Raj4015 (68). This coincides with T_{max} (33.8–34.1 °C), T_{min} (20.7–21.8 °C), St (23.5–23.9 °C) and RH (88–91%), means all parameters were quite high.

Four different meteorological factors (T_{max}, T_{min}, RH_{max} and RH_{min}) were considered for predicting the occurrence of spot blotch of wheat on twelve different varieties and results were discussed separately.

In case of variety PBW343 (V₁), 99% change in disease severity was due to increase in T_{min} (25.59 units) and RH_{max} (7.99 units) in combination with the decrease of T_{max} (29.54 units) and RH_{min} (7.97 units) and it was confirmed by high R² value (0.99). The equation was, Y = 21.47–29.54 T_{max} + 25.59 T_{min} + 7.99 RH_{max} – 7.97 RH_{min}, R² = 0.99. whereas in case of HD2733 (V₂) the prediction equations showed that more than 90% due to decrease in T_{max} and RH_{min} in combination with in decrease in T_{min} and RH_{max}. The prediction equation showed that 97% disease severity was change due to decrease in T_{max} (36.14 units) and RH_{min} (11.11 units) in combination with increase in T_{min} (35.51 units) and RH_{max} (12.43 units) and it was confirmed by high R² value (0.97). The equation was, Y = – 269.75 – 36.14 T_{max} + 35.51 T_{min} + 12.43 RH_{max} – 11.11 RH_{min}, R² = 0.97.

The variety PBW154 (V₃) showed the 96% change in disease severity due to decrease in T_{max} (37.09 units), and RH_{min} (11.23 units) in combination with increase in T_{min} (37.06 units) and RH_{max} (12.38 units) which was confirmed by high R² value (0.96). The prediction equation was, Y = – 272.31 – 37.09 T_{max} + 37.06 T_{min} + 12.38 RH_{max} – 11.23 RH_{min}, R² = 0.96 and in case of Raj4015 (V₄), the predicted disease severity was due to decrease in T_{max} (17.42 units) and RH_{min} (5.56 units) in combination with increase in T_{min} (19.64 units) and RH_{max} (5.74 units) and this probable measurement was confirmed up to 96% which was confirmed by high R² value (0.96). The prediction equation was, Y = – 132.86 – 17.42 T_{max} + 19.64 T_{min} + 5.74 RH_{max} – 5.56 RH_{min}, R² = 0.96.

In case of Kalyansona (V₅), the change of prediction equations was also due to change in exposure of different weather factors in different age of crop plants during the infection process which was confirmed by high R² value (0.98). The prediction equation was, Y = – 442.18 – 20.21 T_{max} + 28.03 T_{min} + 9.04 RH_{max} – 7.87 RH_{min}, R² = 0.98. In case of Sonalika (V₆) showed that with decrease in T_{max} and RH_{min} in combination with increase in T_{min} and RH_{max} three was a significant increase in disease severity which was confirmed by high R² value. The prediction equation was, Y = 1200.37 – 76.13 T_{max} + 49.33 T_{min} + 10.08 R_{max} – 15.56 RH_{min}, R² = 0.98.

Table 2 Correlation coefficient value of DLA of different varieties against meteorological factors

Variety	T _{max}	T _{min}	St	RH _{max}	RH _{min}	BSH
V ₁ (PBW 343)	0.748	−0.903	0.912	0.401	−0.588	0.716
V ₂ (HD 2733)	0.850	−0.883	0.845	0.449	−0.497	0.672
V ₃ (PBW 154)	0.825	−0.888	0.868	0.442	−0.516	0.678
V ₄ (RAJ 4015)	0.816	−0.848	0.869	0.512	−0.453	0.618
V ₅ (KALYANSONA)	0.806	−0.897	0.888	0.421	−0.538	0.682
V ₆ (SONALIKA)	0.743	−0.812	0.911	0.542	−0.434	0.562
V ₇ (LERMARAJO)	0.800	−0.866	0.882	0.481	−0.495	0.650
V ₈ (DBW 39)	0.859	−0.918	0.827	0.373	−0.557	0.734
V ₉ (UP 301)	0.848	−0.875	0.848	0.463	−0.483	0.657
V ₁₀ (HD 2009)	0.863	−0.867	0.841	0.466	−0.456	0.628
V ₁₁ (NP 114)	0.836	−0.898	0.862	0.421	−0.527	0.689
V ₁₂ (NP 718)	0.842	−0.858	0.843	0.498	−0.461	0.644

T_{max} maximum temperature, T_{min} minimum temperature, RH_{max} maximum relative humidity, RH_{min} minimum relative humidity, BSH bright sunshine hours, St soil temperature

In variety Lermarajo (V₇), the prediction equation indicated that with decrease in T_{max} (0.59 units) and RH_{min} (13.65 units) in combination with increase in T_{min} (46.15 units) and RH_{max} (12.15 units) there was 99% probable change in disease severity which was confirmed by high R² value (0.99). The prediction equation was, $Y = 394.39 - 59.19 T_{max} + 46.15 T_{min} + 12.15 RH_{max} - 13.65 RH_{min}$, R² = 0.99. Also in case of DBW39 (V₈) 98% probable change in disease severity was due to negative influence of T_{max} (19.76 units) and RH_{min} (6.78 units) in combination of positive influence of T_{min} (24.87 units) and RH_{max} (8.35 units) and it was confirmed by high R² value (0.98). The equation was, $Y = -392.28 - 19.76 T_{max} + 24.87 T_{min} + 8.35 RH_{max} - 6.78 RH_{min}$, R² = 0.98.

In case of UP301 (V₉) among the four meteorological two meteorological parameters T_{max} and RH_{min} were negatively and T_{min} and RH_{max} positively influence in disease progression and it was confirmed by high R² value (0.96). The equation was, $Y = -322.38 - 34.74 T_{max} + 35.45 T_{min} + 12.21 RH_{max} - 10.82 RH_{min}$, R² = 0.96. Whereas in case of HD2009 (V₁₀), the disease progression was due to negative influence of T_{max} (30.93 units) and RH_{min} (10.81 units) in combination with the positive influence of T_{min} (33.23 units) and RH_{max} (11.54 units) which was confirmed by high R² value (0.98). (The prediction equation was, $Y = -310.86 - 30.93 T_{max} + 33.23 T_{min} + 11.54 RH_{max} - 10.81 RH_{min}$, R² = 0.98.

In variety NP114 (V₁₁), the predicted disease severity was depend on due to negative influence of T_{max} (22.74 units) and RH_{min} (7.34 units) in combination with the positive influence of T_{min} (26.89 units) and RH_{max} (8.79 units). The predicted data will be valid up to the probability of 98%. It was confirmed by high R² value (0.98). The prediction equation was, $Y = -348.98 - 22.74 T_{max} + 26.89 T_{min} + 8.79 RH_{max} - 7.34 RH_{min}$, R² = 0.98. Whereas in

NP718 (V₁₂) it was also observed that the disease severity was depends on negative influence of T_{max} and RH_{min} in combination with positive influence of T_{min} and RH_{max}. It was confirmed by high R² value (0.98). The prediction equation was, $Y = -91.27 - 49.59 T_{max} + 43.62 T_{min} + 14.10 RH_{max} - 13.34 RH_{min}$, R² = 0.98.

This study clearly indicated that at early stages of wheat crop all the varieties produced different disease reactions and their differences significantly varied. The results were prominent at early growth stage, whereas with increase in growth stages the differences in disease severity were greatly reduced. Here among the twelve varieties tested in regards to disease reaction it was noticed that except PBW343 and Raj4015 all other varieties were statistically at par in producing maximum disease severity. Different weather parameters studied were also correlated with the disease incidence and its spread. The correlation analysis of various factors with disease severity showed that, T_{max}, T_{min}, St were positively correlated with disease severity, whereas RH_{min} was negatively correlated with diseases (Table 2). Similar result was observed by Malik et al. (2010) who reported that a temperature of 25 °C with relative humidity below 90% favour spot blotch infection. Akram and Singh (2003) found that the temperature range of 14.06 to 27.6 °C and a relative humidity of 46.8–86.4% favours the spot blotch infection. Prates and Fernandez (2001) reported that nocturnal and diurnal temperature 23 °C and 30 °C respectively were favourable for lesion expansion of *Bipolaris sorokiniana*. Thermic variables (atmospheric, canopy and soil temperature) along with age of crop in the selected varieties were shown to have significant positive correlation with stripe rust severity in wheat (Gupta et al. 2017). Similarly, Singh and Tewari (2001) confirmed that the temperature above 27 °C and below 30 °C increases the leaf blight of wheat. The step down multiple regression equation confirmed the above result for the 12

tested varieties. It was further stated that only four variables were investigated but to provide greater accuracy of prediction of leaf blight disease of wheat, the variables other than those investigated can also be tested. These equations can be considered to be primary and simple prototype that provide solid ground work for future improvement. A forecasting infection model helps to develop the initiation of the diseases that useful to take proper management in time (Viani et al. 2017).

The global climate changes, mean temperature rise expected to be range of 0.5–2.0 °C at the end of this century (IPCC 2013). These changes ultimately make an impact on diseases triangle i.e. pathogen, host and environment and their interactions. The effect of such unknown weather variables and their effect on diseases severity and prediction of diseases now become compulsory to give time to time forewarning against the diseases (Mahapatra et al. 2018). Previous studies indicated that spot blotch infection in wheat as highly influenced by weather factors like temperature and relative humidity (Senthil 2004). In this study influences of some other factors also recorded like soil temperature, bright sunshine hour. Similar kind of observations also found that the effect of abiotic factors on diseases reaction may vary due to variation in light quantity, temperature and relative humidity. However very less information regarding small changes in abiotic factors impacts on diseases scoring in respect to different varieties. If weather is congenial and inoculums level is high then it can break all kind of resistance within the plant genome. Also plant growth stage is another critical factor for diseases development when the day temperature and night temperature were increasing above 14–34 °C and relative humidity 42–97% in the Gangetic plains of West Bengal.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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