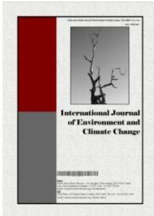

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Impact of Agro-met Conditions and Crop Growth Stages on the Progression of Brown Spot Disease in Basmati Rice

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study was carried out at Crop Research Centre of SVPUAT Meerut, U.P during three cropping seasons i.e. 2018, 2019 and 2020 using basmati rice as test cultivar. The study was primarily focused upon the combined effect of weather parameters and crop growth stages of rice crop on the progression of brown spot disease. It was noticed that disease was first observed at late vegetative stage in every cropping season *viz.* 2018, 2019 and 2020 and reached its maximum towards maturity phase of the crop by obtaining total AUDPC'S of 1049.3, 1170.74 and 852.6 respectively. A significant negative correlation between weekly percent disease index (PDI) and T-

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max & T-min was obtained recording correlation coefficients (r) of (- 0.71 & - 0.98), (- 0.88 & - 0.98) and (- 0.63 & - 0.98) during 2018, 2019 and 2020 respectively indicating decline in maximum and minimum temperatures at the terminal stages of the crop can greatly favor disease progression. A non-significant positive correlation was obtained between weekly m-RH and PDI to the end of every crop season. During the year 2020, a highly significant negative correlation was obtained between weekly a-RH and PDI (r = - 0.803) in contrast with the years 2018 (r = - 0.55) and 2019 (r = -0.477) exhibiting non-significant negative correlation which might be the reason for low PDI during the year 2020 due to greater decline in relative humidity to the end of the crop season. Although, a non-significant negative correlation between weekly PDI and RF (rainfall) and partial positive correlation with weekly bright sunshine hours (BSS) was obtained during all three crop seasons, high intermittent rainfall from late vegetative to reproductive stage during 2018 and 2019 might be responsible for large amount of spore dispersal (high inoculum pressure) leading to greater disease progression. The regression model developed using 2018, 2019 and 2020 meteorological data, which was validated with disease severity data of 2019 yielded significant R^2 value of 0.98 using observed and predicted values.

Keywords: Brown leaf spot of rice; crop growth phase; temperature; relative humidity; rainfall; bright sunshine hours; percent disease index.

ABBREVIATIONS

PDI : Percent disease index
SNC : Significant negative correlation
SPC : Significant positive correlation
NSNC : Non-significant negative correlation
NSPC : Non-Significant negative correlation
T-max : Maximum temperature
T-min : Minimum temperature
a-RH : after noon relative humidity
m-RH : morning relative humidity
RF : Rainfall, BSS: Bright sunshine hours

1. INTRODUCTION

Brown spot disease of rice caused by *Bipolaris oryzae* (*Helminthosporium oryzae*) is one of the most important diseases of rice worldwide, which is known to cause significant amount of quantitative and qualitative losses greatly reducing the grain yield. Rice brown spot is known to infect all growth stages of rice. At the early stage, symptoms of brown spot mainly appear on the leaves. Leaf lesions reduce nutrient absorption and photosynthesis, which result in less tillering, whereas, infection at later stage may result in reduced grainfilling, discolored, spotted and shriveled grains as well. It causes severe damage under cool conditions of summer and especially under nutrient deficient soils and that is the reason it is also known as poor farmers disease [1]. Yield losses could be as high as 45 percent in severe infection and 12 percent in moderate infection In Asia, the disease is known to cause yield losses ranging from 6 to 90 percent [2]. Brown spot disease progression is very high under favorable weather and field conditions. Even minor changes and deviation in weather factors like temperature and relative humidity may greatly affect the disease progress. High humidity (>92.5 percent), leaf wetness and temperatures ranging from 24 to 30°C are highly favorable conditions for disease development [3]. Wind and rainfall can assist in the dispersal of spores from infected plant to healthy plants. During the years of heavy rainfall, the disease is known to occur with very less intensity [4,5] whereas seasons with limited rainfall, drought like conditions and heavy dew are conducive for severeepidemics. Prolonged duration of leaf wetness in rice canopy, generally leads to increased lesion density. Successful inoculation by conidia requires a relative humidity of more than 89 per cent at 25°C and infection is favored by free water on leaf surface [6]. So keeping this fact in view, the present study was undertaken to study theeffect of weather and crop growth stages on brown spot disease progression in basmati rice growing areas.

2. MATERIALS AND METHODS

Field experiments were conducted during three cropping seasons of kharif (2018, 2019 and 2020) at the Crop Research Centre, Chirodi, SardarVallabhbhai Patel University of Agricultural Sciences and Technology, Meerut. Basmati rice variety PB 1121 which is susceptible to brown spot disease was selected for the present investigation. Transplantation of basmati rice was carried out in plots having size of $18m^2$ (6mx3m) at five different locations in the field during the month of July in three consecutive crop seasons i.e. 2018, 2019 and 2020. Plant population in each plot was maintained by following the Plant-row spacing of 15 cmx20 cm. Standard agronomical practices were followed during every year for proper crop establishment. The disease severity was recorded at weekly intervals from ten randomly selected plants from each sampling unit following SES scale [7] starting from the initial infection of the disease until terminal disease severity. After scoring the percent brown leaf spot disease severity, the per cent disease index (PDI) was calculated using the following formula:Percent disease index (PDI) = (Total grade points/Number of leaves observed) ×(100/Maximum grade observed). The weekly percent disease index (PDI) was recorded and correlated with meteorological parameters like maximum and minimum temperatures (°C), morning and evening relative humidity (percentage), sunshine hours (hours per day) and total rainfall (mm) which were collected from the Agro-meteorological observatory, SVPUAT for the entire period of experimentation. Area under disease progress curve (AUDPC) which gives a quantitative measure of disease development and disease intensity was estimated using the following formula as given by Simko and Piepho, [8].

$$AUDPC = \sum_{i=1}^{n-1} [(Y_{i+1} + Y_i)\, 0.5]\, (T_{i+1} - T_i)$$

Where, $Y_I = Y\ (T_i)$, n is the number of assessments, Y is the brown leaf spot disease severity (as percentage), $(Y_{i+1} + Y_i)$ 0.5 is the average of two consecutive assessments and $(T_{i+1}–T_i)$ is the interval (days) between two consecutive assessments.

2.1 Analysis of Data

The disease severity data with respect to crop growth stages and meteorological parameters were analyzed using SPSS software [9]. Effect of different meteorological parameters viz. weekly maximum temperature (Tmax), minimum temperature (Tmin), morning relative humidity (m-RH), afternoon relative humidity (a-RH), bright sunshine hours (BSS) and total rainfall (RF) on disease severity was determined by correlation analysis. Brown leaf spot prediction model was developed based on pooled severity index data (2018, 2019 and 2020) and meteorological parameters using regression analysis and was validated using meteorological data of 2019 season. The relationships were developed between observed and predicted disease level [10,11].

3. RESULTS AND DISCUSSION

3.1 Crop Growth Stages and Disease Progression

Data obtained during the three consecutive crop seasons *viz.* 2018, 2019 and 2020 revealed that the incidence of disease was first noticed in late stages of vegetative growth which culminated in peak levels at maturity stage with sharp increase from reproductive phase to ripening phase. The first appearance of disease occurred at the end of 33rd standard week during the year 2019 with Disease Index (DI) of 0.13 percent followed by 0.10 percent in 34th and 0.05 percent in 35th standard weeks of 2018 and 2020 respectively. Disease progression significantly varied among these three years while highest disease progression was noticed during 2019 with maximum DI of 39.5 percent and AUDPC (Area under disease progress curve) of 1170.74 followed by the year 2018 with maximum DI of 36.3 percent and AUDPC of1049.3. Whereas, least DI of 30.2 percent was noticed during the year 2020 with AUDPC of 852.6 (Fig 1, 2).These results were in agreement with the findings of Biswas *et al*. 2018 who reported the initial incidence of brown spot disease during 30th standard week and increased disease progression thereafter towards maturity recording maximum DI of 21.3%. Development of rice brown leaf spot disease increased from vegetative phase to the ripening phase of the cropespecially during the term of September to early October at normal prevailing conditions of relative humidity where the crop is tend to becomemoresusceptibleto the disease at that stage [5,12].

3.2 Disease Correlation with Temperature and Relative Humidity

Increase in disease intensity was observed to the end of cropping seasons with corresponding decrease in weekly maximum temperatures (T-max)during all the three consecutive years registering significant negative correlation (SNC) coefficients (r) of -0.723, -0.883 and -0.635 during 2018,2019 and 2020 respectively. Similarly, highly SNC was found between disease intensity and weekly minimum temperature (T-min) yielding coefficients of (r) *viz.*- 0.986, - 0.987, - 0.980 during 2018,2019 and 2020 respectively (Fig 3A-C). From the above findings, it was observed that decrease in both T-max and T-min to the end of cropping seasons favored the progression of brown leaf spot disease in rice during all the three consecutive years. Dhaliwal *et al*. 2019 also reported highly SNC of brown spot disease with both weekly T-max and T-min to the end of cropping seasons, which were in agreement with the present findings. An aggravation of brown leaf spot diseasein rice was noticed with the fall in minimum temperatures during September and October months [5].

Despite having non-significant positive correlation (NSPC) between weekly morning relative humidities (m-RH's) and disease intensities to the end of crop seasons during all the consecutive years *viz.* 2018 (r = 0.069), 2019 (r = 0.170) and 2020 (r = 0.162), consistently high weekly m-RH's throughout the cropping period were noticed during the years 2019 (> 93 percent) and 2018 (85-93 percent) in contrast with low weekly m-RH's observed during the year 2020 (< 85 percent) (Fig 4A-C). On the other hand, afternoon relative humidities (a-RH's) exhibited partially SNC and NSNC (Non-significant negative correlation) with disease intensitiesduring the years 2018 (r =- 0.558) and 2019 (r = - 0.447) respectively. Whereas, highly SNC (r = - 0.803) between a-RH and disease intensity was noticed during 2020 indicating greater decline in a-RH to the end of crop season.

From these results, it was evidenced that prolonged high weekly m-RH's and a-RH's accompanied by decreased weekly T-max and T-min to the end of crop seasons in 2019 and 2018 were responsible for greater disease progression in these years compared to those values of 2020 recording very less weekly m-RH's and a-RH's. Choudhury et al. [13] reported similar findings that the incidence of disease in the field was at peak in the years with high RH especially during the month of October. Leaf wetness due to high humidity (>92.5 percent) is highly conducive for brown spot disease development [3,12]. Similar findings were also reported by Minnatullah and Sattar, [14] that when crop moves from vegetative to reproductive phase, the temperature becomes comparatively cooler and brown spot disease was found to be favored by relatively cooler temperature and wet weather conditions. A decrease in daily T-min accompanied by high RH or dew point in the form of leaf wetness helps promote infection efficiency and spread of spores which leads to severe epidemics of brown leaf spot disease due to well established host-pathogen interaction [15].

3.3 Disease Correlation with Rainfall and Bright Sunshine Hours

Correlation analysis of disease progression with weekly rainfall (RF) and bright sunshine hours (BSS) to the end of crop seasons recorded NSNC and NSPC respectively during 2018 (r =- 0.421 & 0.452), 2019 (r =- 0.494 & 0.346) and 2020 (r =- 0.426& 0.32) (Fig 5A-C; Fig 6A-C). Despite non-significant correlation of rainfall with the disease progression to the end of crop seasons, continual intermittent drizzles especially from late vegetative stage to early reproductive stage during 2019 and 2018 should have been responsible for greater spore dispersal (high inoculum pressure) leading to higher PDI in those years in contrast with the year 2020 with no precipitation in those stages.

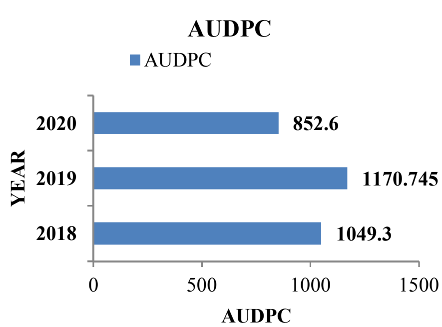

Fig. 1.

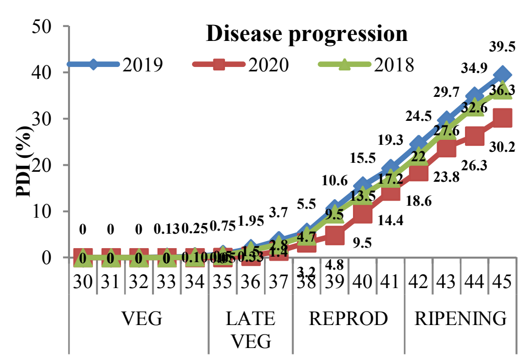

Fig. 2.

Fig. 1. Area under disease progression during the years 2018, 2019 and 2020; Fig 2. Disease index percentages at various crop growingphasesduring the years 2018, 2019 and 2020

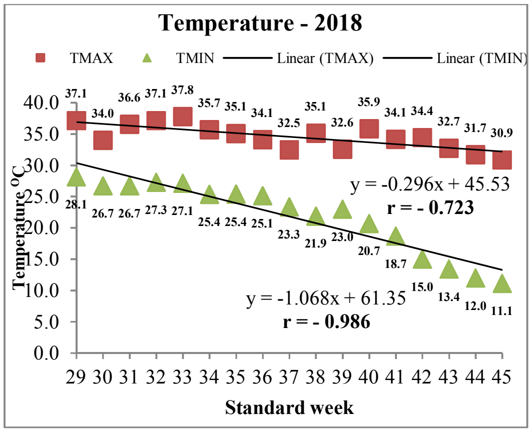

Fig. 3A.

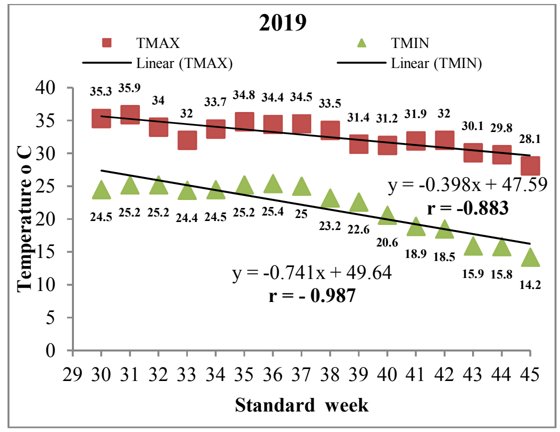

Fig. 3B.

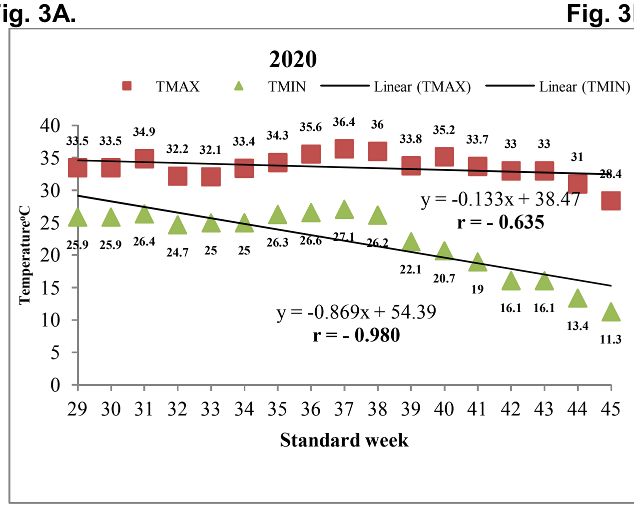

Fig. 3C.

Trend of maximum and minimum temperatures to the end of crop seasons during 2018 (Fig. 3A), 2019 (Fig. 3B), 2020 (Fig. 3C)

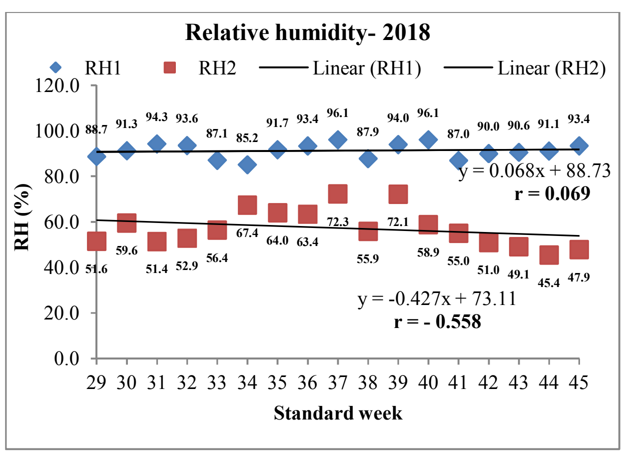

Fig. 4A.

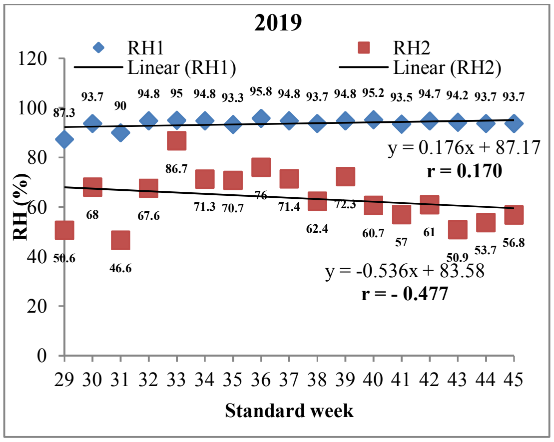

Fig. 4B.

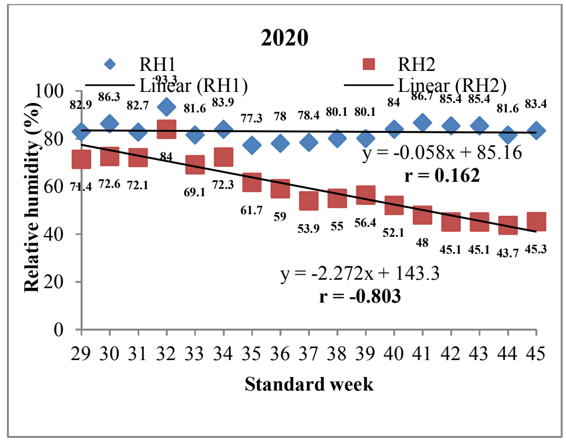

Fig. 4C.

Trend of morning and afternoon relative humidities to the end of crop seasons during 2018 (Fig. 4A), 2019 (Fig. 4B), 2020 (Fig. 4C)

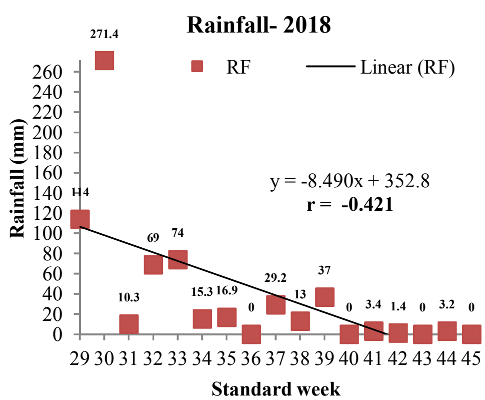

Fig. 5A.

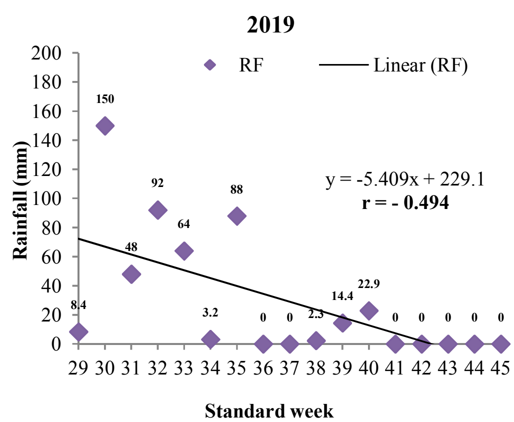

Fig. 5B.

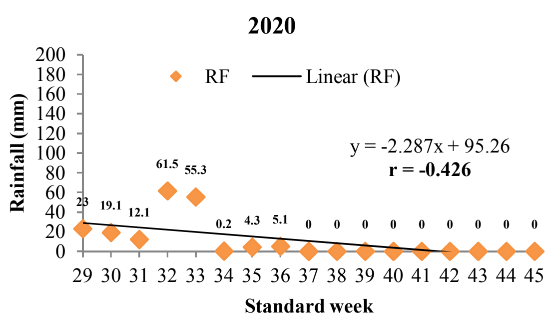

Fig. 5C.

Trend of rainfall to the end of the crop season during 2018(Fig. 5A), 2019(Fig. 5B), 2020(Fig. 5C)

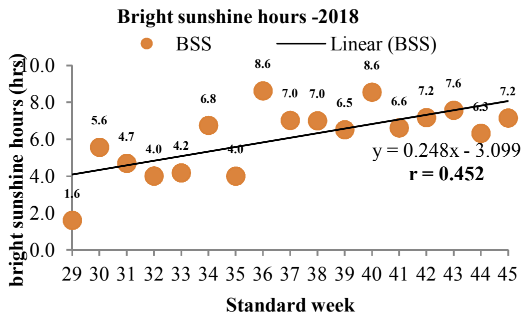

Fig. 6A.

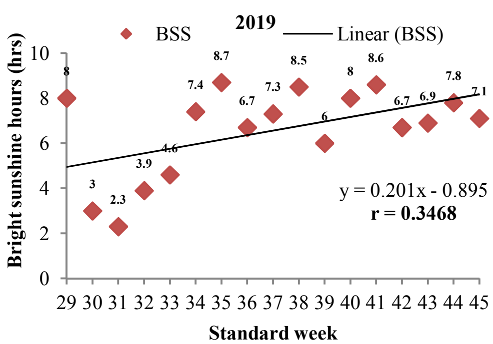

Fig 6B

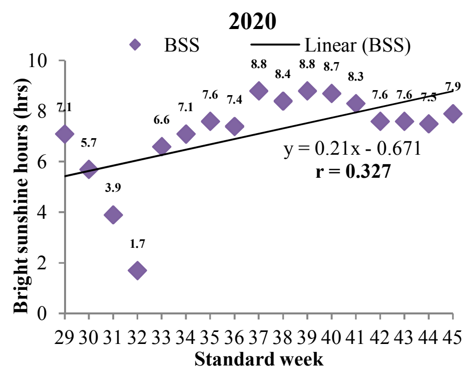

Fig 6C

Trend of bright sunshine hours to the end of crop seasons during 2018(Fig. 6A), 2019(Fig. 6B), 2020(Fig. 6C)

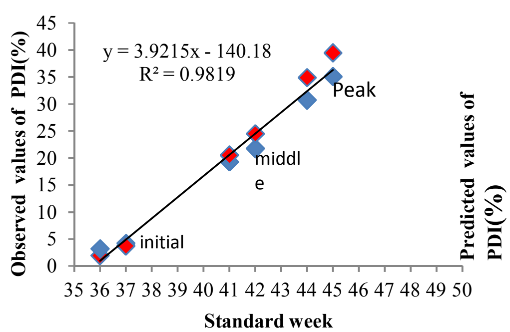

Fig. 7. Validation of regression model by using predicted (indicated in blue) and observed (indicated in red) values during the initial, mid and peak periods of 2019

Singh *et al.,* 2005 previously reported that intermittent rainfall could spread the spores to other organs of the same plant as well as other neighboring plants. They also reported that seasons with limited rainfall accompanied by heavy dew conditions are conducive for break of severe epidemics, which were in agreement with our present findings. Favorable temperatures and relative humidity accompanied by moderate rainfall have been found suitable for maximum increment of PDI in brown leaf spot disease of rice [16]. In the case of BSS, Dhaliwal *et al*. 2019 reported a partial positive correlation of brown spot disease severity with sunshine hours which is similar to our present findings.

3.4 Calibration and Validation of Regression Model

Using pooled data of disease severity for three consecutive years (2018, 2019, 2020), the multiple linear regression analysis was performed to estimate the prediction model equation of brown leaf spot infection in percentage terms as detailed below;

Y= 74.53 - 2.103 (T-max) - 0.975 (T-min) + 0.757 (m-Rh) - 0.514 (a-Rh) - 1.162(BSS)-0.034 (RF) at R^2= 0.98 where, Y= Brown leaf spot percent disease index. The developed equation was then validated with 2019 meteorological data, which showed 0.5-5 percent variability between observed and predicted values of disease severity. The observed and predicted disease severity values (at initial, mid and peak period) revealed 98.1 percent variation of disease severity (dependent variable) as explained by independent variables (Fig 7).

4. CONCLUSION

It was found that brown leaf spot disease mostly attacks at late vegetative stages and becomes severe from reproductive stage towards maturity affecting the photosynthetic activity where maximum translocation of sugars occurs from leaves to grains and thereby responsible for formation of lightweight shriveled/ chaffy grains and reduction in yield. The development and severity of brown leaf spot is greatly influenced by different meteorological factors like temperature, relative humidity, amount and time of rainfall received at different stages during the crop season. From the present findings it can be concluded that increase in the age of the crop, decrease in maximum and minimum temperatures, increase in morning and afternoon relative humidities to the end of crop seasons followed by intermittent drizzles will greatly favor the progression of brown leaf spot disease in rice. Data related to meteorological parameters can be used to predict disease epidemic using prediction model and proper spray scheduling as a disease management practice can be implemented or suggested to farmers to reduce the progression of disease without incurring any extra costs.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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