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Influence of weather factors on severity of rhizoctonia aerial blight of soybean

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Abstract
The current investigation was conducted on the soybean crop against rhizoctonia aerial blight during the *Kharif* seasons of 2021 and 2022 at the soybean pathology block of the Crop Research Centre, GBPUA&T, Pantnagar, Uttarakhand. The data from the two crop seasons showed that the most favourable time for the development of RAB in soybeans is between the months of September and October. During both years of the experiment, the minimum atmospheric temperatures and relative humidity of evening were highly significant and inversely connected with the onset of disease. While maximum temperature, the number of rainy days and evaporation showed a non-significant and negative correspond with disease index. The morning relative humidity, wind speed, and rainfall showed a significant and positive correlation with disease index. Sunshine hour showed a weak and favourable connection with the disease index. According to the R^2 values, the correlation between meteorological characteristics and disease severity in 2021 was between 85 and 87 percent, while in 2022 it was between 81 and 90 percent.

Keywords: Rhizoctonia aerial blight, soybean, epidemiology, correlation, regression

Introduction

One of the oldest and most significant *Kharif* oilseed crops is soybean (*Glycine max* (L.) Merill), which is grown all over the world in tropical, subtropical, and temperate settings. It is a high-value crop with numerous uses in food, feed, and industry and is essential to India's agricultural economy. On a dry weight basis, it has 40–42% protein and 20–22% edible oil. The presence of several bacterial and fungal diseases, such as seed and seedling rots, bacterial pustules, bacterial leaf blight, aerial blight, anthracnose, charcoal rot, soybean yellow mosaic, and soybean mosaic, might be blamed for the crop's reduced productivity (Mathpal and Singh, 2017) [15]. The most severe disease to afflict the crop is aerial blight, which is brought on by the fungus *Rhizoctonia solani* Kuhn (Teleomorph: *Thanatephorus cucumeris* (Frank) Donk), which covers the leaves and weakens and incapacitates the plant (Hartman *et al.* 2011) [13]. According to reports, the disease reduces crop yield by around 80% (Bharma *et al.*, 2022) [3]. Due to increased soybean production and the spread of the crop to new areas, the disease's significance has increased. The present environmental circumstances have a big impact on how severe aerial blight is. The onset and progression of plant disease throughout time are greatly influenced by a variety of environmental conditions, including temperature, relative humidity, intense sunlight hours, and rainfall (Jeena *et al.*, 2022) [2]. For a disease to develop, a combination of favourable environmental factors and a plant's vulnerable developmental stage are required (Joshi *et al.*, 2018) [14]. During the crop's flowering stage, the aerial blight fungus's mycelium begins to grow on the stem and leaves of the plant and travels from plant to plant using aerial mycelia. Rainfall during the crop's blossoming stage has been linked to the disease's high severity (Yang *et al.*, 1990) [5]. In order to estimate and predict crop losses and establish management strategies for the disease, it may be useful to study the interaction of weather factors that led to the development of the disease. This will allow researchers to keep apprised of when plant diseases epidemics occur in nature. Thus, the goal of this investigation was to examine the relationship between meteorological variables and the severity of aerial blight in order to determine particular weather patterns are responsible for the disease's severe occurrence under epiphytic settings.

Materials and Methods

For two consecutive crop seasons, 2021 and 2022, seeds of four soybean cultivars PK-262, NRC 7, Monetta, and Panjab 1 were sown in replicated plots at Pathology Block, Department of Plant Pathology farm in Pantnagar on June 30 and July 5, respectively, to study the influence of meteorological factors on disease development. In a randomized block design (RBD) with three replications, the seeds were prepared with Rhizobium and sown in plots measuring 4 x 1.5 m^2 with a row-to-row distance of 45 cm and a plant-to-plant distance of 10 cm. The experiment was carried out in an epiphytotic environment to investigate how diseases spread naturally in the natural environment. Every week between the first week of September and the third week of October in both years, the intensity of aerial blight was observed. Using the Mayee and Datar (1986) [6] 0–9 scale of disease severity, the disease reaction of genotypes was recorded. Then, using the following formula provided by Wheeler (1969) [7], the disease index of Rhizoctonia aerial blight (RAB) in various cultivars was calculated:

$$\text{Percent disease index (PDI)} = \frac{\text{Sum of individual ratings}}{\text{Total number of units assessed x Maximum disease grade}} \text{x } 100$$

The apparent infection rate (r), which was calculated using the logistic equation according to Vanderplank's (1963) [8] approach, and the area under the disease progress curve (AUDPC), which was calculated using Shanner and Finney's (1977) [9] equation, were both used to measure the progression of the disease are as follows:

$$\text{Apparentinfection rate (r)} = \frac{2.3}{t_2 - t_1} \log 10 \frac{x_2(1 - x_1)}{x_1(1 - x_2)}$$

Where, r = the apparent infection rate, t_1 = the time of the first measurement, t_2 = is the time of the second measurement, X_1 = the proportion of infection measured at time t_1, X_2 = the proportion of infection measured at time t_2.

$$\text{AUDPC} = \sum_{i=1}^{n} \frac{1}{2}(Si + (Si + 1))(Ti - (Ti + 1))$$

Where, Si = Per cent disease index at the end of time i, k = Number of successive evaluations, Ti-(Ti + 1) = Timeinterval between two evaluations i and i-1 of the disease. Simultaneously, meteorological data on temperature, relative humidity, rainfall, bright sunshine hours, wind velocity and evapotranspiration were collected from the meteorological station at GBPUA&T, Pantnagar. The correlation was calculated using the Karl Pearson’s correlation coefficient. The total effect of all the elements that led to the development of disease was ascertained using SPSS 16.0 software's multiple regression analysis (Butt and Royle, 1974) [10] employing meteorological characteristics as an independent variable. To determine the respective contributions of these factors in the spread of disease, the multiple correlation was calculated individually for both years.

Results and Discussion

The disease ratings were obtained in the field under epiphytic circumstances as Pantnagar is one of the areas where aerial blight of soybeans is most common. Multiple environmental variables have been proven to have an impact on disease development in natural environments. In 2021 and 2022, the symptoms of the diseases began to manifest during the last week of August. During the two crop seasons when the disease first appeared in the field, temperatures ranged from 31 to 33 °C at its highest and 25 °C at its lowest, with relative humidity between 80 and 91 percent and rainfall between 57.8 and 60.4 mm. This suggests that a warm, humid climate promotes the beginning of aerial blight in the field. The disease's severity increased quickly over time, reaching in the first week of October when the highest temperature was around 32 °C, the minimum temperature was between 22 and 23 °C, the relative humidity was around 90%, and there was no rain to be found at this time. The data from the two crop seasons showed that the development of soybean aerial blight is most likely to occur between the months of September and October. Table 1 shows the disease response, infection rate, and area under the disease progress curve (AUDPC) of aerial blight on soybean cultivars that was recorded during the week of October for two consecutive years of study. For two successive growth seasons of soybean, the relationship between the RAB severity index and environmental factors including maximum and minimum temperatures, relative humidity, wind speed, bright sunlight hours, and evapotranspiration was calculated. For the purposes of correlation study, the disease index was recorded on four different soybean response cultivars. The interpretation of association between the individual parameters on the development and progress of the disease led to the culminated that the correlation analysis among the disease severity and weather parameters revealed that the minimum temperature (T_{min}) and evening relative humidity had highly significant (p<0.001) negative correlation with the disease severity during the criticalperiod from the last week of August (34th SMV) to the last week of October (43th SMV), with ‘r’ values ranging from (-0.722) to (-0.80), (-0.739) to (-0.878) in 2021 and r’ values ranging from (-0.862) to (-0.901), (-0.533) to (-0.673) in 2022 data from two consecutive crop season. In two years observation, morning relative humidity (RH) and rainfall was found to be highly significantly but negatively correlated (p<0.001) with disease development in both the year 2021 and 2022 (r = 0.734 to 0.891, 0.739 to 0.878 and r = 0.862 to 0.901, 0.728 to 0.810). The correlation for the maximum temperature (T_{max}), no. of rainy days and evaporation to the disease index was found to be negative ranging from (-0.640) to (-0.753), (-0.279) to (-0.633) and (-0.041) to (-0.524), respectively during the experiment years. The percent disease index exhibited a very weak positive correlation (-0.002) to (-0.526) with sunshine hours in consecutive two seasons and correlation with wind velocity was also positive and significantly correlated (p<0.005) with ‘r’ values ranging from -0.573 and -0.755 (Table 2).

The current results are in agreement with the finding of Surbhi and Singh, (2020) [1]. With "r" values ranging from 0.743 to 0.798 in 2016, they reported that the maximum and minimum atmospheric temperatures were significantly negatively correlated with the onset of disease during the critical period (from the 3rd week of September to the 3rd week of October). However, in 2017, the correlation was also negative (0.938 and 0.968) with the minimum temperature, but the maximum temperature showed a positive correlation (r = 0.110-0.247). In 2016 and 2017, respectively, there was a statistically negative correlation between the mean relative humidity and the development of disease (r = 0.781 to 0.815

and 0.664 to 0.761, respectively). Similar to this, Mathpal (2016) [11] found a strong association between the relative humidity and temperature of the atmosphere and the severity of the aerial blight disease. Similar observations were made during this present investigation, which indicated a strong and adverse association between the average ambient temperature and relative humidity and the severity of aerial blight. According to the results, it is evident that for the disease to start, soybean aerial blight needs a warm, humid environment. However, as the crop developed, the disease's severity increased as temperature and relative humidity decreased, reaching its peak in the third week of October. Similar findings were found during the present investigation, where it was discovered that the association between ambient temperature and the severity of aerial blight was substantial and negatively connected, whereas the correlation between relative humidity and RAB severity was highly significant and positively correlated. It is apparent from the results that aerial blight of soybeans requires a warm and humid environment for the disease to start, but as the crop grew to maturity, the percent disease index of aerial blight increased with decreases in temperature (maximum and minimum) and relative humidity, causing the disease to become the most severe in the third week of October.

Table 1: Disease reaction, infection rate and area under disease progress curve (AUDPC) of *Rhizoctonia* aerial blight on soybean cultivars recorded during the disease progress for two consecutive years of study

S. No.			Percent disease index (%)		Infection rate (r)		AUDPC	
			2020	2021	2020	2021	2020	2021
1	PK 262	Moderately Resistance	7.20	9.75	0.003	0.011	49.77	65.80
2	NRC 7	Moderately Susceptible	17.68	21.28	0.005	0.004	121.80	147.00
3	Monetta	Susceptible	43.15	40.68	0.009	0.010	296.27	278.88
4	Punjab 1	Highly Susceptible	64.08	58.18	0.024	0.018	434.28	396.13

Table 2: Correlation co-efficients of disease index of Rhizoctonia aerial blight (YLD) in relation to weather variable during the two years of study.

Environmental variables	Cultivar							
	PK 262		NRC 7		Monetta		Panjab 1	
	2021	2022	2021	2022	2021	2022	2021	2022
Maximum temp (°C)	-0.722	-0.753	-0.640	-0.735	-0.739	-0.746	-0.641	-0.747
Minimum temp (°C)	-0.880**	-0.862**	-0.830**	-0.901**	-0.883**	-0.891**	-0.722**	-0.891**
Morning RH (%)	0.734**	0.767**	0.891**	0.722**	0.812**	0.837**	0.785**	0.794**
Evening RH (%)	-0.742	-0.673	-0.647	-0.565	-0.613	-0.533	-0.711	-0.624
Rainfall (mm)	0.739**	0.810**	0.860**	0.728**	0.829**	0.730**	0.878**	0.766**
No. of rainy days	-0.441	-0.041	-0.524	-0.100	-0.464	-0.075	-0.449	-0.068
Sunshine hours	0.473	0.041	0.526	0.054	0.473	0.020	0.467	0.002
Wind velocity (km/hr)	0.670*	0.687*	0.632*	0.755*	0.648*	0.629*	0.673*	0.728*
Evaporation (mm)	-0.326	-0.633	-0.279	-0.563*	-0.352	-0.537	-0.381	-0.608

*Significant at p=0.05 (2-tailed) ** Significant at p=0.01 (2-tailed)

For the years 2021 and 2022, the multiple linear regression of the percent disease index in relation to weather parameters (minimum temperature, relative humidity, rainfall, wind velocity) revealed R^2 values of 0.85 to 0.87 and 0.81 to 0.90, respectively (Table 3). According to the R2 values, the correlation between meteorological characteristics and disease severity in 2021 was between 85 and 87 percent, while in 2022 it was between 81 and 90 percent. It can be revealed from Table 3 that minimum temperature, relative humidity, rainfall and wind velocity explained 85, 86, 87 and 86 percent variability in PK 262 (R^2= 0.85, F_{cal}= 6.69), NRC 7 (R^2=0.86, F_{cal}= 7.84), Monetta (R^2=0.87, F_{cal}=8.08) and Panjab (R^2=0.86, F_{cal}=7.91) cultivars, respectively in 2021. In 2022, minimum temperature, relative humidity, rainfall and wind velocity explained 88, 81, 87 and 90 percent variability in PK 262 (R^2= 0.88, F_{cal}= 9.46), NRC 7 (R^2=0.81, F_{cal}= 5.07), Monetta (R^2=0.87, F_{cal}=8.14) and Panjab 1 (R^2=0.90, F_{cal}=10.63) cultivars, respectively. Through a multiple regression analysis equation of disease development with weather parameters, Surbhi and Singh (2020) [1] also came to similar conclusions and showed that weather variables accounted for more than 60% of variation in disease. Later, Bara (2007) [12] examined the web blight of urdbean and made comparable findings using multiple regression analysis of disease intensity with weather variables. He reported that the coefficient (R^2) indicated that the combined effect of various weather variables favored the development of the disease, causing 57 percent variations in the disease's intensity. The findings of the study supported by the results presented by Amrate *et al.* (2021) [4]. According to them, a regression-based model with three explanatory variables - Mean RH, Rainfall, and Minimum Temperature - was most effective in predicting the severity of aerial blight disease (R^2=0.946). Weather variables, such as rainy days and rainfall, also contributed to the variability of disease severity by 71.7 percent (R^2 = 0.717) across different experiment years. The most favourable field conditions for the rapid progression of the soybean aerial blight disease were found to be the overall average maximum temperature (27 to 30ºC) and mean RH (80 to 90%) in the present week combined with more rainfall and wet days in the previous week.

Table 3: Multiple regression equation for prediction of rhizoctonia aerial blight disease on different cultivars of soybean during 2021 and 2022.

Cultivar	Prediction model		2021			2022		
	2020	2021	R^2	Adjusted R^2	F_{cal}	R^2	Adjusted R^2	F_{cal}
PK 262	$y=21.512 - 0.356x_1 + 0.001x_2 - 0.144x_3 - 0.007x_4 - 0.479x_5$	$y=26.780 - 1.110x_1 - 0.057x_2 + 0.118x_3 + 0.008x_4 + 0.112x_5$	0.89	0.79	9.46	0.85	0.72	6.69
NRC 7	$y=53.488 - 0.653x_1 - 0.004x_2 - 0.419x_3 - 0.017x_4 - 1.115x_5$	$y=70.471 - 2.109x_1 - 0.186x_2 + 0.016x_3 + 0.025x_4 + 0.268x_5$	0.81	0.65	5.07	0.87	0.76	7.84
Monetta	$y=115.367 - 2.246x_1 + 0.144x_2 - 0.806x_3 + 0.040x_4 - 2.356x_5$	$y=134.683 - 3.922x_1 - 0.375x_2 + 0.014x_3 + 0.550x_4 + 0.627x_5$	0.87	0.76	8.14	0.87	0.76	8.08
Punjab 1	$y=182.932 - 4.444x_1 + 0.004x_2 - 0.808x_3 + 0.053x_4 - 1.248x_5$	$y=123.871 - 6.297x_1 + 0.003x_2 + 0.622x_3 + 0.029x_4 + 0.350x_5$	0.90	0.81	10.63	0.87	0.75	7.91

x_1: Min temperature (ºC), x_2: Morning relative humidity (ºC) x_3: Evening relative humidity (%), x_4: Rainfall (mm), x_5: Wind velocity (km/hr)

Conclusion

Weather conditions have a significant impact on the spread of plant diseases, and comprehending the interactions of different weather variables that can cause severe aerial blight infections in the field can help to develop prediction models for the disease's progression so that crucial management techniques can be implemented during a favourable time. Applying management practices in early stages will assist reduce the need for chemical sprays, prevent serious disease outbreaks, and reduce yield losses. The present study's findings can help in disease prediction based on the analysis of two crop seasons, allowing for the appropriate planning of management practices to prevent catastrophic yield losses brought on by aerial blight.

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