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Correlation and Regression Analysis for Assessing Wheat Yellow Rust Severity using Relevant Weather Data in Jammu Subtropics of India

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Various meteorological variables were used to assess their effect on yellow rust severity of wheat varieties Agra local and PBW-343 at research station, SKUAST-J, Chatha. Disease severity was recorded in the plots following modified Cobb's scale at different dates. The disease severity data was correlated with various meteorological variables viz., T_{max} (maximum temperature), T_{min} (minimum temperature), T_{ave} (average temperature), R_{Hmax}(maximum relative humidity), RH_{min} (minimum relative humidity), RH_{ave} (average relative humidity) and Rainfall. There was significantly positive correlation between disease severity and minimum, maximum and average temperature, whereas, minimum, maximum and average relative humidity showed negative though significant correlation. The rainfall of 20.7 mm, T_{ave} 14.6°C and RH_{ave} of 85.5% were found conducive for disease development. The regression model depicted that the weather parameters taken under study contributed more than 80.2 and 81.1 per cent in the development of yellow rust in Agra local and PBW-343, respectively.

Key words: Yellow rust, *Puccinia striiformis*, Weather, Correlation, Regression, Infection rate.

Wheat (*Triticum aestivum* L.) is one of the most economically important and the world's most widely cultivated crop which serves as the staple food for about 40% of the world's population[1]. It is predicted that in order to meet human demand in 2050, crop production must increase annually by 2% on the same area of cultivated land[2]. Rust diseases of wheat can cause significant damage throughout the world, however, yellow rust caused by *Puccinia striiformis* West. f.sp. *tritici* is a major threat to global wheat production, resulting both in yield losses and downgrading the grain quality[3, 4]. In most wheat-producing areas, yield losses caused by yellow rust have ranged from 10 to 70 per cent depending on susceptibility of the cultivar, earliness of the initial infection, rate of disease development, and duration of disease[5]. Yellow rust is one of the most damaging diseases of wheat and its distribution depends much upon climatic factors such as rainfall, humidity, temperature, etc[6]. The most important weather variable for the progress of yellow rust is temperature, followed by dew period and light quantity[7]. The temperature from February to June is the most influential factor for an epidemic as well as for disease severity of yellow rust[8]. In India, yellow rust is restricted in its distribution to cooler parts of North–West region as well as Nilgiri hills in South, where conditions are favorable for rust development[9]. The development of yellow rust epidemics in addition to favorable weather depends upon the level of cultivar susceptibility, which

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affects the disease occurrence and its progress[10]. Crop-weather models for forecasting various parameters of wheat crop have been developed and are being used in various agro-meteorological regimes. Changes in pathogen virulence and the lack of effective durable resistance support the need for forecasting model. These models are needed if fungicides are to be effective and economical in reducing crop losses that may be attributed to new races of the pathogen[11]. With the introduction of high yielding varieties the disease has gained importance and shifted its status from minor to major disease in subtropics and intermediate zones of Jammu and Kashmir

MATERIALS AND METHODS

The effects of different weather factors such as temperature, relative humidity and rainfall on the development of yellow rust of wheat were studied under field conditions during the 2009-2010 crop seasons. Wheat varieties Agra local and PBW-343 highly susceptible to yellow rust were selected. The experiment was laid out in RBD with three replications and each variety was planted in $3m^2$ plots consisting of 8 rows in each plot. The crop was sown on 15th of November 2009 with row spacing of 22.5cm. Theurediospores of yellow rust (concentration= 6×10^5/ml of water) were sprayed in January (10th) on the two test varieties (Agra local and PBW-343) at tillering stage. The field was irrigated after inoculation to maintain proper humidity. Disease observations were taken at weekly intervals from 3rd week of January till the crop attained maturity using modified Cobb's scale[12] and disease severity was calculated based on the leaf area covered with rust pustules. Rate of disease progress was calculated using the formula given below[13]:

$$r = \frac{2.3}{t_2 - t_1} \log_{10} \frac{X_2}{X_1}$$

where, r= rate of disease progress or infection rate.

$t_2 - t_1$ = Time interval

X_1 = Disease at time t_1

X_2 = Disease at time t_2

Correlation analysis

Analysis of correlation between weather data (collected from the observatory of Agro-Meteorology, Section of the University, SKUAST-J,Chatha, Jammu) and disease severity was determined using Minitab software. The regression and coefficient of multiple determination (R^2) values were also analyzed to find out the effect of single as well as combination of different meteorological factors on disease development. All simple correlations were calculated between variables Y and weather factors X_1, X_2, X_3…..X_5, where, disease severity (%), rainfall, relative humidity maximum and minimum, temperature maximum and minimum is represented by Y, X_1, X_2, X_3, X_4 and X_5, respectively. The test of significance for simple correlation was carried out using Student's t- test[14]. To study the cumulative effect of different variables (independent variables) in disease development (disease severity) and multiple correlation coefficient were carried out and linear multiple regression model was developed for prediction of disease development. The coefficient of multiple determinations was used for the adequacy of regression equations.

Regression model

Linear multiple regression analysis were used to find out the effect of various environmental factors on disease progress by using prediction equation as:

$$Y = b_0 + b_1X_1 + b_2X_2 + \ldots\ldots\ldots\ldots + b_5X_5$$

RESULTS AND DISCUSSION

The data in Table 1 revealed that in the wheat varieties Agra local and PBW-343, under the field conditions, the disease initiation took place 8 days after inoculation during the 3rd week of January, when the maximum and minimum temperature for seven days was 14.9 and 4.3°C (Tave of 9.6°C) and maximum and minimum relative humidity for the seven days was 92 and 68 per cent, (RH_{ave} 80%) respectively. Subsequently, due to the rise in minimum relative humidity and rainfall in the month of February, a sharp rise in disease severity was recorded. The sharp rise in disease severity on wheat varieties Agra local (from 19.23 to 37.67%) and PBW-343 (from 16.32 and 33.21%) was observed between 5th and 6th standard week when Tave in 5th and 6th standard weeks were 13.45 and 14.6 °C (period of seven days), with maximum and minimum temperature of 20.8 and 6.1°C in 5th

standard week and 19.4 and 9.8°C in 6th standard weeks. RH_{ave} in 5th standard and 6th standard weeks were 66.6 and 85.5 % respectively with maximum relative humidity of 87 and 87% in 5th and 6th standard week respectively, and minimum relative humidity 46 and 84% in 5th and 6th standard week respectively. From 11th to 13th standard week the disease incidence and severity increased very slowly due to the rise in temperature and from 13th standard week onwards it remained more or less constant. Nagarajan and Joshi (1978) reported positive correlation between number of rainy days and buildup of brown and yellow rusts over N.W. India[15]. The temperature is the most influential factor for disease severity and epidemics buildup in wheat in United Kingdom[8]. Similar observations were made by Papastamati and Vandan (2007) during a study at Rothamsted Research, Hertfordshire in England, who have reported that the most important weather variable for the progress of yellow rust was temperature, followed by dew and light quantity[7]. The activity of *P. striiformis*, including germination, penetration and development are limited due to rise in environmental temperature in late April which prevented further disease development as a result of heat and dryness[16]. A correlation between weather factors and disease severity on wheat varieties, Agra local and PBW-343, revealed that per cent disease severity was non-significant but negatively correlated with rainfall with a value of r =-0.161 and -0.115(non signigicant), respectively. Mostly rainfall shows the positive correlation with the yellow rust, but during the course of the growing season, there were not ample rains and the disease increased due favourable humidity and temperature till 12th standard week. Hailua and Finishab (2006) also reported high yellow rust severity in less rainfall season at Sinana, in Ethopia[17]. The maximum (14.9 to 38.3 °C) minimum (4.3 to 21.6 °C) and average temperatures (9.6 to 29.5 °C) had significant and positive correlation with disease development with the values of r = 0.859 ($p \leq 0.01$), 0.862($p \leq 0.01$) and 0.875 $p \leq 0.05$) in Agra local and 0.875($p \leq 0.01$), 0.866($p \leq 0.01$) and 0.998($p \leq 0.05$) in PBW-343, respectively (Table 2). Similarly, the maximum (84 to 92%), minimum(22 to 84 %) and average relative humidity had significant and negative correlation with disease development, with the values of r = - 0.739 ($p \leq 0.05$),-0.728 ($p \leq 0.05$), -0.729 ($p \leq 0.05$) and -0.645, -0.621 ($p \leq 0.05$), -0.709 ($p \leq 0.05$) for the varieties PBW-343 and Agra local, respectively. A study in Denmark showed that the temperature in January and February is positively correlated with yellow rust severity[18]. Disease severity did not show negative correlation with

Table 1. Effect of abiotic factors on the severity of yellow rust of wheat in Jammu subtropics, during 2009-10

Standard week	Date of observation	Disease severity (%)		Infection Rate		Rainfall (mm)	Temperature (°C)			Relative Humidity (%)		
		Agra local	PBW -343	Agra local	PBW -343		Min	Max	Ave	Min	Max	Ave
3rd	18-01-2010	5.21	5.00	-	-	0.0	4.3	14.9	9.6	68	92	80
4th	25-01-2010	10.32	9.75	0.098	0.096	0.0	4.3	20.6	12.45	48	89	68.5
5th	01-02-2010	19.23	16.32	0.089	0.074	3.2	6.1	20.8	13.45	46	87	66.5
6th	08-02-2010	37.67	33.21	0.096	0.102	20.7	9.8	19.4	14.6	84	87	85.5
7th	15-02-2010	41.54	39.13	0.014	0.024	0.0	7.6	19.9	13.75	40	83	61.5
8th	22-02-2010	46.43	45.00	0.016	0.020	0.0	8.6	24.8	16.7	46	84	65
9th	01-03-2010	50.67	48.57	0.013	0.011	0.0	11.3	26.1	18.7	45	84	64.5
10th	08-03-2010	53.33	52.53	0.007	0.011	0.0	9.8	26.5	18.15	46	81	63.5
11th	15-03-2010	55.01	54.33	0.004	0.005	0.0	11.8	30.6	21.2	41	77	59
12th	22-03-2010	56.43	55.57	0.004	0.003	0.0	15.1	34.0	24.55	39	82	60.5
13th	29-03-2010	60.33	59.86	0.010	0.011	2.7	15.3	34.2	24.75	36	71	53.5
14th	05-04-2010	60.45	60.04	0.000	0.000	0.0	16.3	35.4	25.85	22	61	41.5
15th	12-04-2010	61.34	60.39	0.002	0.001	0.0	17.2	38.3	27.75	20	54	37
16th	19-04-2010	61.89	60.73	0.001	0.001	0.8	21.6	37.4	29.5	29	54	41.5

Table 2. Correlation of different abiotic factors with disease severity

Weather parameter	Disease severity (%)	
	PBW -343	Agra local
Rainfall (mm)	-0.161	-0.115
Min Temperature (^{O}C)	0.866*	0.862 *
Max Temperature (^{O}C)	0.875*	0.859*
AveTemperature (^{O}C)	0.998**	0.875**
Min Relative Humidity (%)	-0.645**	-0.621**
Max Relative Humidity (%)	-0.739*	-0.728*
Ave Relative Humidity (%)	-0.729**	-0.709**

* Significant at 1% probability level** Significant at 5% probability level

temperature in March because relative humidity seldom goes below 80 per cent. Furthermore, yellow rust epidemic is halted by periods of hotweather[8]. Multiple correlation coefficients indicated strong relationship between disease and the weather variables taken under the study, thereby establishing that rainfall, maximum relative humidity, maximum temperature and minimum temperature during the course of disease development contributed more than 81.1 and 80. 2 % variations in yellow rust on varieties PBW-343 and Agra local, respectively, during the 2009-2010 crop season. The regression equation $\hat{Y}_1$ = - 60.2 + 0.46X_1 + 2.68X_2 + 1.10X_3 - 0.357X_4 + 0.737 X_5 for PBW-343

Table 3. Multiple Regression model of disease severity

Variety	Multiple correlation coefficient	Coefficient of multiple determination	Regression model
PBW-343	0.901	0.811*	= - 60.2 + 0.46 X1 + 2.68 X2 + 1.10X3 - 0.357 X4 + 0.737 X5
Agra local	0.896	0.802**	= - 56.8 + 0.74 X1 + 2.96 X2 + 0.84X3 - 0.466 X4 + 0.816 X5

, = Disease severity X1 = Rainfall (mm) X2 = Min Temperature (oC); X3 = Max Temperature (oC) X4 = Min Relative Humidity X5 = Max Relative Humidity
* Significant at 1% probability level; ** Significant at 5%

depict that unit increase in rainfall (X_1), minimum temperature (X_2), maximum temperature (X_3), and minimum relative humidity (X_5) increased the disease severity by 0.46, 2.68, 1.10 and 0.737 units,respectively. The unit increase in minimum relative humidity (X_4) decreased the disease severity by 0.357 units. Similarly, the regression equation $\hat{Y}_2$ = - 56.8 + 0.74X_1 + 2.96X_2 + 0.84X_3 - 0.466X_4 + 0.816X_5 for Agra local predict that increase in rainfall (X_1), minimum temperature (X_2), maximum temperature (X_3), and maximum relative humidity (X_5) increased the disease severity by 0.74, 2.96, 0.84 and 0.81 units, respectively. The unit increase in minimum relative humidity (X_4) decreased the disease severity by 0.466 units. Thus, the regression model developed for predicting unit increase/decrease in disease showed that different weather variables could influence disease severity to a given extent if the given weather conditions prevailed in an area over a specific period of time (Table 3).

CONCLUSION

Weather factors play an important role in the occurrence and severity of yellow rust of wheat as multiple correlation coefficient indicated strong relationship between disease and weather factors, thereby established that rainfall, relative humidity and temperature contribute significantly in variations of the disease. Therefore, understanding the epidemiology of the pathogen is of utmost importance in managing the disease and will surely help to devise a strategy for the timely application of the fungicides, thereby reduce the loss of fungicides and save the time.

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