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Brown Rust (*Puccinia melanocephala*) Development in Sugarcane in Relation to Weather Parameters in Western Maharashtra

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ABSTRACT

The intensity of brown rust disease (*Puccinia melanocephala*) on sugarcane variety CoC 671 was recorded at D Block, Central Sugarcane Research Station Padegaon, Dist. Satara in Maharashtra for consecutive eight years. Based on the data on different weather parameters and the intensity of common rust on sugarcane, following multiple linear regression equation was developed for effective prediction of the occurrence and intensity of common rust on sugarcane.

PDI (%) = -162.67 + 0.109 x T_{max} – 0.068 x T_{min} + 1.776 x RH-I – 0.088 x RH-II – 0.035 x RF

[Where, PDI=Percent disease index, T_{max} = Maximum temperature (°C), T_{min} = Minimum temperature (°C), RH-I = Morning relative humidity (%), RH-II = Afternoon relative humidity (%) and RF = Rainfall (mm)]. The studies revealed that the maximum temperature of 28.3 to 31.7 °C, minimum temperature of 11.2 to 23.0 °C, morning relative humidity of 95 to 98 % and afternoon relative humidity of 52 to 87 % coupled with intermittent rainfall contributed significantly for the disease incidence and its further build-up. The data were subjected to step down regression analysis by eliminating the non-significantly related factors for predicting common rust on sugarcane using linear model. By employing this equation, the incidence of common rust on sugarcane could be predicted with an accuracy of 78.4 %. The actual observed (2014-15) and predicted values of PDI of common rust on sugarcane were compared. The standard residuals of PDI of common rust of sugarcane lied between -2.12 to +2.03 indicating high degree of accuracy of the model in predicting PDI of common rust of sugarcane. The linear regression equation developed was also validated with the disease data of the year 2015-16. The observed and predicted values of PDI of common rust of sugarcane were compared with Chi-square test for goodness of fit. The χ^2_{Cal} was less than χ^2_{Tab} for linear model indicating the best fitness of the equation. The standard residuals of PDI of common rust of sugarcane lied between -1.84 to +1.97 indicating high degree of accuracy of the model. Forecasting the incidence and spread of common rust of sugarcane helps in adopting effective fungicidal spray schedule. Hence, this model can be utilized in Agro-Advisories for predicting the occurrence of the common rust disease of sugarcane.

Key words: *Brown rust, Puccinia melanocephala, Sugarcane, Forecasting*

Introduction

Sugarcane (*Saccharum officinarum* L.) is a highly versatile C_4 plant grown all the year round and can be cultivated successfully under tropical and subtropical area for sugar and bio-energy. In Maharashtra, sugarcane is cultivated on an area of 11.63 lakhs hectares with total production of 924.43 lakh tonnes

([1]Research Scholar, [2]Associate Professor) and productivity of about 79.50 t/ha (Anonymous, 2018).

Brown rust of sugarcane, which was a minor and less significant disease earlier, is now emerging as serious threat to sugarcane production because of its shift to the major disease due to changing environment and cultivation practices and the susceptibility of the presently grown varieties. It causes 18 to 20% reduction in cane yield, 24 to 25% reduction in commercial cane sugar (CCS) yield and reduces sugar recovery by 1 to 1.25% in western Maharashtra.

Brown rust of sugarcane, caused by *Puccinia melanocephala*, is an economically important disease of sugarcane infecting the crop in almost all sugarcane growing areas throughout the world (Raid and Comstock, 2000). India was the first country to report brown rust on sugarcane in 1950 (Patel *et al.*, 1950) which later on spread to Southeast Asia, Africa, Southern Asia and Australia (Glynn *et al.*, 2010). Brown rust epidemic occurred in Australia, Taiwan and United State during 1970s (Dean and Purdy, 1984) which still continues as a great challenge for sugarcane production. The typical brown rust symptoms on sugarcane consist of reddish-brown lesions or pustules found on the younger, upper leaves than on the older, lower leaves. Numerous coalescing rust pustules cause premature tissue death of even young leaves i.e. leaf necrosis. It can cause substantial yield losses to sugarcane crop (Comstock, *et al.*, 1992; Comstock, *et al.*, 1994 and Hoy and Hollier, 2009) and has been responsible for the withdrawal of commercial cultivars in most sugarcane growing regions of the world (Sood *et al.*, 1992). The disease became prevalent due to environmental conditions being ideal for rust development (Cadet *et al.*, 2003) and a possible change in the pathogen population (Pillay *et al.*, 2005). Brown rust is now present in all areas of the sugar industry and yield losses are estimated to be as high as 12–26 % in susceptible sugarcane varieties (Rutherford *et al.*, 2003 and McFarlane *et al.*, 2006). *Puccinia melanocephala* causes reduced plant growth as experienced by the reduction of the length and number of stalks per plant (Hoy and Hollier, 2009).

The weather conditions play a predominant role and contribute significantly for the disease incidence and spread. If the information about time of disease incidence, disease severity and outbreak of disease are available in advance, timely control measures can be taken up and further yield losses may be reduced. Hence, an attempt was made to study the role of different weather parameters *viz.*, rainfall, relative humidity and temperature in the infection and development of brown rust (*Puccinia melanocephala*) of sugarcane and secondly to develop regression equation for forecasting the occurrence of brown rust of sugarcane in advance as forewarning of disease is important for crop production management and taking timely plant protection measures.

Materials and Methods

A field experiment was conducted for eight consecutive years from 2006-07 to 2013-14 at D Block of Plant Pathology Section, Central Sugarcane Research Station Padegaon, Dist. Satara in Maharashtra state, India. The rust susceptible sugarcane cultivar, CoC- 671 was planted during mid-January every year on plot size of 10 x 10 m (100 m^2 area). No plant protection measures were taken up in this plot. Manuring and fertilizer application and all other cultural practices were followed as per the recommended best management practices for Sugarcane.

For studying the effect of different weather parameters on the incidence and development of brown rust disease of sugarcane, the weekly observations on all the weather parameters *viz.*, maximum temperature (°C), minimum temperature (°C), morning relative humidity (%), afternoon relative humidity (%) and rainfall (mm) were recorded during the crop growth period at the meteorological observatory of CSRS, Padegaon. For recording the rust severity observations, initially the sugarcane plants were observed for first appearance of brown rust disease; ten randomly selected clumps on which the brown rust appeared were tagged for further periodical observations. The observations on the brown rust disease severity were recorded on 10 randomly selected leaves from each of the 10 selected clumps staring from the first appearance of disease till harvesting of the crop at weekly interval.

The severity of brown rust disease was recorded using the 1-9 scale (Barbosa, 2014) on 10 leaves on each of the 10 randomly selected clumps at weekly intervals from July (MW 27) to March (MW 9) and the per cent severity of brown rust disease was calculated by using the following formula.

$$\text{Disease severity (\%)} = \frac{\text{Sum total of all numerical ratings}}{\text{Total no. of leaves observed x maximum rating}} \times 100$$

The average brown rust disease severity across eight years was calculated from the weekly average severity of brown rust disease on the crop during 2006-07 to 2013-14 from MW 27 to MW 9. Similarly the averages of all the weather parameters *viz.*, maximum temperature (°C), minimum temperature (°C), morning relative humidity (%), afternoon relative humidity (%) and rainfall (mm) were calculated for MW 27 to MW 9. The rate of increase or decrease in average weekly brown rust disease severity and the weekly averages of all these weather parameters of eight years from MW 27 to MW9 were subjected to correlation analysis. The data were further subjected to step-down multiple linear regression analysis by eliminating the non significant factors and including only significant factors and the following multiple linear regression equation was developed for short-term prediction of the brown rust disease on sugarcane.

$$Y = a + b1X1 + b2X2 + b3X3 + b4X4 + b5X5$$

Where,

Y = Dependent variable (Severity of brown rust of sugarcane)

a = Constant

b1 = Regression coefficient for maximum temperature (X1)

b2 = Regression coefficient for minimum temperature (X2)

b3 = Regression coefficient for morning relative humidity (RH-I) (X3)

b4 = Regression coefficient for afternoon relative humidity (RH-II) (X4)

b5 = Regression coefficient for rainfall (X5)

The actual observed per cent severity of common rust on sugarcane during 2014-15 and the predicted values of disease severity as per the derived regression equation were compared and the standard residuals were calculated for knowing the degree of accuracy of the model in predicting the occurrence and severity of common rust of sugarcane. The multiple linear regression equation developed based on past 8 years data (2006-07 to 2013-14) was also validated with the rust disease severity data of 2015-16. The observed and predicted values of severity of common rust of sugarcane were compared by calculating the standard residuals and using the Chi-square test for testing the goodness of fit of the equation for predicting the severity of common rust of sugarcane.

Results and Discussion

Correlation studies

The average data on the severity of brown rust of sugarcane and different weather parameters were subjected to correlation analysis and the Karl Pearson's correlation coefficients obtained are presented in Table 1. The disease appeared on the crop during 1st week of July (27 MW). The test of significance of the correlation coefficients indicated that the rainfall showed a significant positive correlation (r = +0.363), the minimum temperature (r = +0.473) and RH-I (r = +0.531) and RH-II (r = +0.616) had a highly significant positive correlation while the maximum temperature (r = -0.477) had a highly significant negative correlation with the rate of increase/ decrease in the severity of brown rust disease on sugarcane. The studies revealed that the maximum temperature of 28.3 to 31.7 °C, minimum temperature of 11.2 to 23.0 °C, morning relative humidity of 95 to 98 % and afternoon relative humidity of 52 to 87 % coupled with intermittent rainfall contributed significantly for the disease incidence and its further build-up.

Sanjel *et al*. (2019) reported that maximum severity of brown rust of sugarcane was correlated with the number of hours at night with an average temperature of 20 to 22.2 °C in one season. Slightly higher correlation was obtained when relative humidity above 90% was included in the number of hours at night with an average temperature 20 to 22.2 °C. At least 97 % relative humidity and temperature between 17 and 24 °C were found to be the most conducive conditions for orange rust in Australia (Magarey *et al.*, 2004). In Florida, temperature between 20 and 25 °C and more than 8 hrs leaf wetness were necessary for development of sugarcane orange rust in a growth chamber experiment (Martins *et al.*, 2010).

Regression equation for forewarning brown rust on sugarcane in western Maharashtra

Based on the data available on weather parameters and the intensity of brown rust on sugarcane for the past 8 years, i.e. from 2006-07 to 2013-14, a multiple linear regression equation was developed (Table 2) for effective prediction of the occurrence and intensity of brown rust on sugarcane.

The data were subjected to step down regression by eliminating the non-significant factors and including only significant factors for predicting the incidence of brown rust on sugarcane under western Maharashtra using linear model. Coefficient of determination (R^2) was improved significantly under linear regression model for predicting the incidence of brown rust on sugarcane. By employing step down linear regression models, the incidence of brown rust on sugarcane can be predicted to an extent of 78.4 % (Table 3). The actual observed (2014-15) and predicted values of PDI of brown rust on sugarcane are depicted in Table 4. The standard residuals of severity of brown rust of sugarcane (Figure 1) lied between -2.12 to +2.03 indicating high degree of accuracy of the model in predicting the severity of brown rust of sugarcane.

Validation of disease forewarning model

The linear regression equation developed for predicting the intensity of brown rust of sugarcane based on past 8 years data (2006-07 to 2013-14) was also validated with the disease severity data of the year 2015-16. The observed and predicted values of

Table 1. Effect of weather parameters on severity of brown rust of sugarcane during 2006-07 to 2013-14 (average of eight years)

MW	PDI	Rate of increase/ decrease	Rainfall	T_{max} (°C)	$T_{min.}$ (°C)	RH-I (%)	RH-II (%)
27	0.25	0.20	15.03	29.24	22.70	95.96	81.90
28	0.50	0.25	10.83	29.23	22.39	95.34	82.23
29	0.92	0.42	13.43	29.43	22.50	97.20	83.50
30	1.00	0.08	26.05	28.75	21.89	96.80	84.94
31	1.46	0.46	16.40	28.29	21.94	96.16	87.08
32	2.13	0.67	19.26	28.39	22.01	97.33	85.81
33	2.71	0.59	8.80	29.38	22.08	96.55	83.21
34	3.00	0.29	22.96	29.74	21.56	96.81	78.91
35	3.54	0.54	28.48	29.63	21.91	97.41	81.53
36	3.96	0.42	33.96	29.61	22.95	97.45	81.53
37	4.38	0.42	49.36	30.06	21.29	98.35	81.24
38	3.58	-0.79	30.94	29.81	21.05	97.10	81.33
39	5.08	1.50	14.49	31.00	21.06	97.21	73.13
40	5.63	0.54	39.19	30.75	21.34	98.18	74.11
41	5.88	0.25	12.70	31.39	20.79	97.31	70.31
42	6.13	0.25	9.83	31.71	19.19	97.15	66.14
43	6.54	0.41	3.14	31.15	17.66	95.41	63.94
44	6.79	0.25	3.54	30.71	16.66	96.86	62.55
45	7.04	0.25	7.51	30.43	19.68	97.73	63.78
46	7.29	0.25	14.59	29.79	18.15	97.19	63.54
47	7.50	0.21	2.93	29.79	17.04	96.96	59.64
48	7.75	0.25	0.80	29.64	15.84	97.11	60.30
49	7.92	0.16	0.35	29.04	14.76	97.48	58.33
50	8.17	0.25	0.00	29.69	12.99	97.13	58.40
51	8.21	0.04	0.09	28.60	11.60	97.10	58.74
52	8.09	-0.12	0.00	29.25	11.45	97.51	52.16
1	8.38	0.29	0.00	29.50	12.46	97.59	53.09
2	8.33	-0.04	0.00	28.81	11.15	97.53	53.31
3	7.92	-0.42	0.00	29.89	11.31	97.40	52.16
4	7.58	-0.34	0.00	29.75	11.25	97.66	51.16
5	7.54	-0.04	0.01	30.64	12.31	96.99	51.64
6	5.25	-2.29	0.00	30.80	14.44	96.38	44.41
7	3.25	-2.00	0.00	31.56	13.85	95.31	47.20
8	1.12	-2.13	0.00	32.88	14.04	94.38	45.55
9	0.00	-1.12	0.76	33.63	13.86	93.18	47.94
			0.363*	**-0.477****	**0.473****	**0.531****	**0.616****

Table r at n-2 (35-2 = 33) dfat 5 % = 0.334, at 1 % = 0.430

Table 2. Constant, regression coefficients and coefficient of determination (R^2) for predicting brown rust of sugarcane (2006-07 to 2013-14)

Parameters	Regression coefficient (with significantly correlated parameters)
Constant (a)	-162.670
Maximum temperature (T_{max})	+0.109
Minimum temperature (T_{min})	-0.068
Morning Relative Humidity (RH-I)	+1.776
Afternoon Relative Humidity (RH-II)	-0.088
Rainfall	-0.035

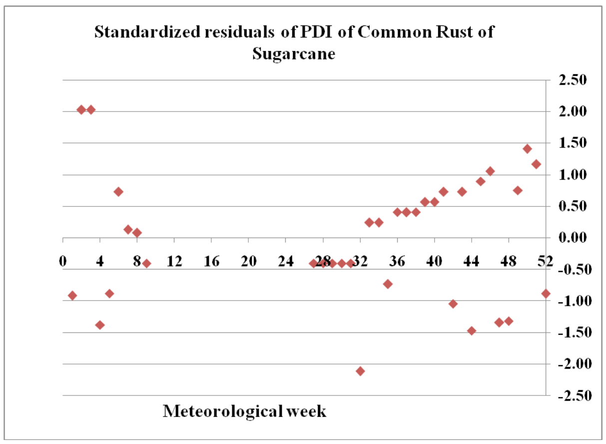

Fig. 1. Distribution plot depicting the standard residuals of severity of brown rust of sugarcane (2006-07 to 2013-14) compared with data of 2014-15

severity of brown rust of sugarcane (Table 5) were compared with Chi-square test for goodness of fit. The $\chi2$ Cal was less than the table value of $\chi2$ for linear model developed (Table 6). Hence the equation derived seemed to be best fit. The standard residuals of severity of brown rust of sugarcane (Figure 2) lied between -1.84 to +1.97 indicating high degree of accuracy of the model in predicting the severity of brown rust of sugarcane.

Paswan *et al*. (2018) studied the effect of different weather parameters on the incidence of red rot disease of sugarcane and developed a multiple regression equation for disease prediction. The coefficient of determination (R^2) of the model was able to explain about 71 per cent variables in the incidence of red rot disease involving maximum and minimum

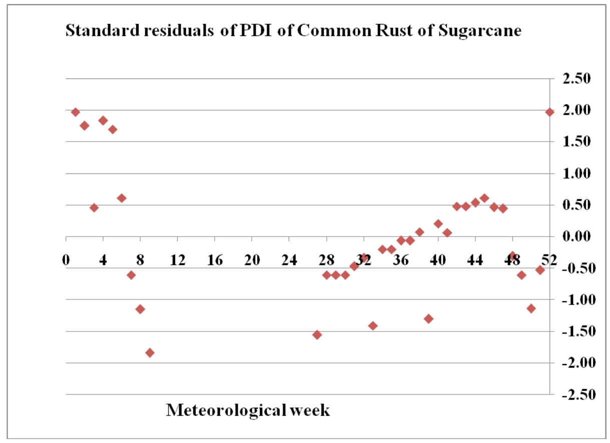

Fig. 2. Distribution plot depicting the standard residuals of PDI of brown rust of sugarcane (2006-07 to 2013-14) validated with data of 2015-16

temperature, morning and afternoon relative humidity, rainfall and bright sunshine hours. The R^2 value of the model was significant at 5 per cent level of significance. The brown rust severity depends on length of cool (mean daily temperature of around 20°C) and humid (70-90% RH) weather condition, especially when these coincide with susceptible plant growth stages (Comstock and Ferreira, 1986).

Conclusion

The brown rust on sugarcane is very much favoured by congenial climatic conditions like temperature, relative humidity and rainfall in western Maharashtra. The following multiple linear regression equation based on weather parameters for short term forewarning (prior to one week) of the brown rust occurrence and severity in sugarcane is recommended for the western Maharashtra. Forecasting the incidence and spread of brown rust of sugarcane helps in adopting effective fungicidal spray schedule. The correlation and regression analysis clearly indicated the importance of weather factors in the prediction of brown rust of sugarcane. The linear regression model was found more precise (R^2 = 0.784) for predicting brown rust incidence and further spread. Hence, this model can be utilized in agro-advisories for predicting the occurrence of the brown rust disease of sugarcane.

Table 3. Multiple linear regression equation for brown rust of sugarcane

Multiple linear regression equation	R^2 value
PDI (%) = -162.67 + 0.109 x T_{max} – 0.068 x T_{min} + 1.776 x RH-I – 0.088 x RH-II – 0.035 x RF	0.784

Table 4. Actual observed (2014-15) and estimated severity of brown rust of sugarcane using multiple linear regression equation

Time interval (7 days)	Percent Disease Index (PDI)		
	Actual (2014-15)	Final predicted	Standard residual
1	0.00	0.00	-0.41
2	0.00	0.00	-0.41
3	0.00	0.00	-0.41
4	0.00	0.00	-0.41
5	0.00	0.00	-0.41
6	1.33	4.84	**-2.12**
7	1.33	0.00	0.24
8	1.33	0.00	0.24
9	1.33	2.01	-0.74
10	1.67	0.00	0.41
11	1.67	0.00	0.40
12	1.67	0.00	0.41
13	2.00	0.00	0.57
14	2.00	0.00	0.57
15	2.33	0.00	0.73
16	2.33	3.65	-1.05
17	2.33	0.00	0.73
18	2.67	4.85	-1.47
19	2.67	0.00	0.89
20	3.00	0.00	1.05
21	3.67	5.59	-1.34
22	3.67	5.55	-1.32
23	4.00	1.62	0.75
24	5.33	1.60	1.41
25	5.67	2.45	1.16
26	5.67	6.66	-0.89
27	5.33	6.38	-0.92
28	5.00	0.00	2.03
29	5.00	0.00	**2.03**
30	5.00	7.00	-1.38
31	4.67	5.64	-0.88
32	2.33	0.00	0.73
33	1.33	0.23	0.13
34	1.00	0.00	0.08
35	0.00	0.00	-0.41

Table 6. Chi-square ($\chi 2$) test for goodness of fit for linear model

1. Cal χ^2 = 0.00
   Tab χ^2 for 0.05 level of significance and 34 df = 21.66

PDI (%) = -162.67 + 0.109 x Tmax – 0.068 x Tmin + 1.776 x RH-I – 0.088 x RH-II – 0.035 x RF

[Where, PDI=Percent disease index, Tmax = Maximum temperature (°C), Tmin = Minimum temperature (°C), RH-I = Morning relative humidity (%), RH-II = Afternoon relative humidity (%) and RF = Rainfall (mm)].

Table 5. Validation of multiple linear regression model for predicting severity of brown rust of sugarcane during 2015-16

Time interval (7 days)	Percent Disease Index (PDI)		
	Actual (2015-16)	Final predicted	Standard residual
1	0.00	0.00	-1.56
2	2.33	0.00	-0.61
3	2.33	0.00	-0.61
4	2.33	0.00	-0.61
5	2.67	0.00	-0.47
6	3.00	0.00	-0.34
7	3.00	2.63	-1.41
8	3.33	0.00	-0.20
9	3.33	0.00	-0.20
10	3.67	0.00	-0.06
11	3.67	0.00	-0.06
12	4.00	0.00	0.07
13	4.00	3.37	-1.30
14	4.33	0.00	0.20
15	4.67	0.69	0.06
16	5.00	0.00	0.48
17	5.00	0.00	0.48
18	5.33	0.19	0.53
19	5.33	0.00	0.61
20	5.67	0.71	0.46
21	6.33	1.42	0.44
22	6.67	3.61	-0.31
23	7.33	4.99	-0.61
24	7.67	6.65	-1.14
25	8.67	6.15	-0.53
26	8.67	0.00	**1.97**
27	8.67	0.00	1.97
28	8.33	0.19	1.75
29	8.33	3.37	0.46
30	8.33	0.00	1.83
31	8.00	0.00	1.70
32	5.33	0.00	0.61
33	2.33	0.00	-0.61
34	1.00	0.00	-1.15
35	0.00	0.70	**-1.84**

Conflict of Interest- None

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