International Journal of Agriculture, Environment and Biotechnology
Citation: IJAEB: 9(6): 1117-1124, December 2016
DOI: 10.5958/2230-732X.2016.00141.8

AGRICULTURAL STATISTICS

Weather based Statistical Modelling for Forecasting of Yearly Spot Blotch Severity in different Growth Stages of Wheat

Anil Kumar Pant[1], G.C. Mishra[1*], Ramesh Chand[2], V.K. Mishra[3]

[1]Section of Statistics, Department of Farm Engineering, [2]Department of Mycology and Plant Pathology, [3]Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221005, India

Corresponding author: gcmishrabhu@gmail.com

Paper No. 544 Received: 27 August 2016 Accepted: 17 December 2016

Abstract

The Objective of the present study was to develop regression models for forecasting spot blotch severity in susceptible and resistant genotypes of wheat crop under Irrigated timely sown condition (ITS), Irrigated late sown condition (ILS) and Rainfed timely sown condition (RFTS). CRI, tillering, jointing, flowering, milking and dough stages of wheat were considered for studying the effect of weather parameters on yearly spot blotch severity. Yearly disease severity data and weekly weather data during the period 1975 to 2012 of North eastern plains zones of India were used for this purpose. On the basis of 37 years data, the correlation coefficients between the yearly spot blotch severity and weekly weather parameters (Maximum temperature, maximum relative humidity and their joint effects) were calculated for measuring the quantitative relationship between these variables. These values of correlation coefficients were used for developing weighted weather indices of weather parameters. Values of r_{Tw} and r_{TRHw} were found higher and positive in between jointing stage and flowering stage in both the genotypes. The lower RMSE value of MLR models at jointing stage suggested that forecasted value at jointing stage is more precise than other stages.

Highlights

- Duration between 8th week and 11th week from the date of sowing was found critical for the spot blotch progression in wheat. In this consideration best management practices are required during this duration to restrict the progression of spot blotch. The forecasted values of yearly spot blotch severity in susceptible genotype for the period 2016-17 were obtained as 73.08 %, 75.01% and 52.00% for ITS, ILS and RFTS sowing conditions respectively. For the same period forecasted values of spot blotch disease severity were obtained as 37.95 %, 43.91 % and 38.60 % for ITS, ILS and RFTS conditions respectively in the case of resistant genotypes.

Keywords: Regression models, Sowing conditions, Spot blotch severity, Weather parameters, Growth stages

Wheat (*Triticum aestivum*) is the main source of nutrients and energy in the Indian diet. It is not only rich source of minerals but high content of antioxidant is also found in the Wheat grain, which provides additional health benefits (Rosegrant *et al*., 1995). Rice being the first and wheat is the second most important crop of the country, which contributes nearly one – third of the total food grain production. The area under wheat has steadily gone up since the start of the green revolution in 1965 and its production and productivity have increased tremendously. The wheat area has increased from 12.8 million-ha in 1966-67 to 29.8 million-ha in 2015-16. During the same period productivity and production of this staple food has been increased by 263% and 711% respectively. With the record production of 95.85 million tonnes of wheat in 2013-14, India ranked second in wheat production after china in the world. Besides these achievements, less productivity of wheat is also a serious concern for

India. India produced 2.95 ton wheat in a hectare against 5.34 ton by china in 2015-16.

Several biotic and abiotic stresses are responsible for less productivity of wheat in India. Spot blotch caused by *Bipolaris sorokiniana* emerged as a major threat to wheat production in North eastern plains zones (NEPZ) of India, which has the second highest share in the total wheat production in India (Dubin, 1984; Gilchrist and Pfeiffer, 1991; Joshi *et al.*, 2002). The risk of Spot blotch epidemics is high in areas characterized by average temperature greater than 17° C during night of the coolest months, with high relative humidity. Disease severity increases with crop growth stage and is generally devastating after flowering (Joshi *et al.*, 2007). The centres under NEPZ are eastern Utter Pradesh, Bihar, Jharkhand, West Bengal and plains of far eastern states. These regions are characterized by high temperature and humidity at the late 'growth stage', which are very favourable conditions for spot blotch progression in wheat.

Reliable forecast for disease and yield is necessary for taking timely action regarding disease control and for assessing losses (Zhang *et al*., 2003; Ho *et al.*, 2002; Mishra and Singh, 2013; Kumari *et al*., 2013, Kumari *et al*., 2014; Shukla *et al*., 2015). Weather parameter contributes a major role in the development of different growth stages of crop and infestation of pest and diseases (Nema and Joshi, 1973, Paul *et al*., 2013). In this consideration statistical models based on weather parameters are very efficient for forecasting purposes.

The objective of the present study was to develop weather based multiple linear regression (MLR) models for forecasting yearly spot blotch severity at different growth stages of wheat crop viz.CRI, tillering, jointing, flowering, milk and dough, for North eastern plains zone (NEPZ) of India. Studies reveals that the nature of genotypes and showing date also influences the progression of disease (Sharma and Duveiller, 2004; Duveiller *et al.*, 2005), for this consideration susceptible and resistance genotypes of wheat crop and three sowing conditions i.e. irrigated timely sown (ITS), irrigated late sown (ILS) and rainfed timely sown (RFTS) conditions were considered in the present study.

Materials and Methods

Data Set

Time series data of yearly spot blotch severity during wheat crop seasons 1975-1976 to 2011-2012, related to genotypes of wheat in NEPZ of India , at different sowing conditions i.e. ITS, ILS and RFTS, was collected from annual reports of Institute of Wheat and Barley Research Karnal (Indian Council of Agricultural Research) India.

Previous studies revels that weather parameters such as high temperature and high relative humidity are very favourable for progression of Spot blotch (van Ginkel and Rajaram, 1993). In the light of this fact weekly data related to maximum temperature and maximum relative humidity, during 1975 to 2012 were collected from India Meteorological Department, New Delhi (India).

Development of weighted indices of weather parameters

Weather indices were computed from weekly weather parameters, where weights being correlation coefficient between yearly spot blotch severity and weather parameters with respective week's. Equation (2.1) and (2.2) represents the mathematical form of weather indices:

$$Z_{i,j} = \sum_{w=1}^{m} r_{iw}^{j} X_{iw} \tag{2.1}$$

$$Z_{i,i',j} = \sum_{w=1}^{m} r_{ii'w}^{j} X_{iw} X_{i'w} \tag{2.2}$$

Where,

J =0, or 1 (where, '0' represents un-weighted indices and '1' represents weighted indices), w represents week number (1, 2... m)

r_{iw} is the Correlation coefficient between disease severity and i^{th} weather variable in w^{th} week, $r_{ii'w}$ is Correlation coefficient between disease severity and the product of i and i'^{th} weather variable of w^{th} week X_{iw} is the i weather variables in w^{th} week respectively.

MLR Model

The mathematical equation of multiple linear regression (MLR) model, as follows:

$$Y = A_0 + \sum_{i=1}^{p}\sum_{j=0}^{1} a_{i,j}Z_{i,j} + \sum_{i\neq i'=1}^{p}\sum_{j=1}^{1} a_{i.i'.j}Z_{i,i',j} + e \qquad (2.3)$$

Where,

$Z_{i,j}$ and $Z_{i,i',j}$ weather indices obtained by equation (2.1) and (22) , i,i': 1, 2, …p

p: Number of weather variables under study

Y: Dependent Variable

A_0: Intercept

e: Error term normally distributed with mean zero and constant variance .

Accuracy Measurement of the Model

To make comparison of forecasting ability among models is Root mean square Error (RMSE) given as:

$$RMSE = \sqrt{\frac{\Sigma\left(P_t - A_t\right)^2}{T}} \qquad (2.4)$$

Where, T: Total number of observations in the time series.

P_t: Predicted Value at time t.

A_t: Actual value at time t.

Results and Discussion

Three type of sowing conditions are more common in North eastern plains zones of India for wheat cultivation i.e. Rainfed timely sown conditions (sowing time: between last week of October and 12 November), Irrigated timely sown conditions (sowing time: between 10 November and 30 November) and Irrigated late sown condition (sowing time: between 25 November and last week of December). In the collection phase of spot blotch severity data, a problem regarding sowing dates has been experienced for each sowing conditions. It was found that in many years, sowing date of a particular year was different than sowing date of its previous and next year. In this study, 1 November for RFTS, 15 November for ITS and 1 December for ILS, has been considered as a sowing dates in model building process (Since these dates were the most common sowing dates during 37 years at the particular sowing conditions). Crown root initiation (CRI), Tillering, Jointing, Flowering, Milking and Dough growth stages of wheat crop were considered for studying the behaviour of disease.

Time series data, during the crop seasons 1975-76 to 2011-12, of the monthly average maximum temperature (˚C), monthly average maximum relative (%) and yearly spot blotch disease severity (%) in susceptible and resistant genotypes at ITS, ILS and RFTS conditions was shown in Fig. 1. Based on the 37 year data, the correlation coefficients between the yearly spot blotch severity and weekly weather parameters were calculated for measuring the quantitative relationship between these variables .These values of correlation coefficients were used for developing weighted weather indices of weather parameters with the help of procedure mentioned in material and method section.

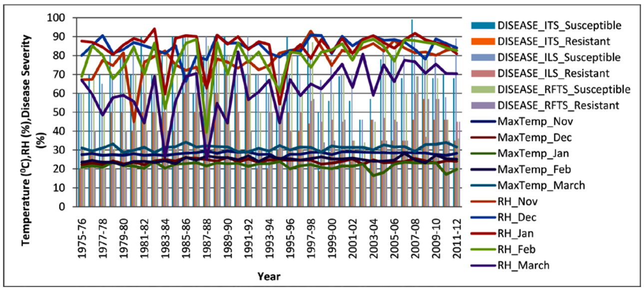

Fig. 1: Time series data of the monthly average maximum temperature (˚C), monthly average maximum relative (%) and yearly spot blotch disease severity (%) in susceptible and resistant genotypes at ITS, ILS and RFTS conditions

Table 1, 2 and 3 represents the values of correlation coefficients between the yearly disease severity and weekly weather parameters at RFTS, ITS and ILS conditions respectively. In these tables symbol r_{Tw} used for the values of correlation coefficients between disease severity and maximum temperature in w^{th} week, symbol r_{RHw} used for the values of correlation coefficients between disease severity and maximum relative humidity in w^{th} week. Symbol r_{TRHw} used for the values of correlation coefficients between disease severity and the product of maximum temperature and maximum relative humidity of w^{th} week. In other words r_{TRHw} used for the values of correlation coefficients between disease severity and joint effect of maximum temperature and maximum relative humidity.

In this study tabulated in Table 1, 2 and 3, it was found that at each sowing condition value of r_{Tw} was found higher in the jointing stage for both genotypes. This high positive correlation indicates that temperature at jointing stage is severely affects the rate of disease progression. The values of r_{RHw} were found negative for each week of crop season

Table 1: Correlation coefficient between yearly disease severity and weekly weather parameters for susceptible and resistant genotypes at RFTS condition

Weeks	Growth stage of wheat	Values of correlation coefficient between yearly disease severity and weekly weather parameters					
		Susceptible Genotype			Resistant Genotype		
		r_{Tw}	r_{RHw}	r_{TRHw}	r_{Tw}	r_{RHw}	r_{TRHw}
3	CRI	-0.12	-0.04	-0.07	0.17	0.02	0.06
4		0.08	-0.09	-0.06	0.08	0.02	0.04
5		-0.08	-0.13	-0.17	-0.10	-0.12	-0.16
6	Tillerig	0.21	-0.07	0.03	0.01	0.12	0.10
7		-0.06	-0.04	-0.08	0.29	-0.05	0.12
8	Jointing	0.10	-0.26	0.03	0.29	-0.31	0.11
9		0.49	-0.27	0.06	0.40	-0.49	0.23
10	Flowering	0.21	-0.35	0.10	0.17	-0.28	0.11
11		0.30	-0.35	0.24	0.21	-0.28	0.13
12	Milking	0.22	-0.07	0.15	0.27	0.05	0.30
13		0.12	-0.01	0.10	0.23	0.05	0.19
14	Dough	0.28	-0.19	-0.23	0.21	-0.02	0.03
15		-0.01	-0.17	-0.15	0.09	-0.01	0.15
16		0.05	-0.28	-0.24	0.22	0.07	0.13
17		0.22	-0.11	-0.01	0.20	0.08	0.09

Table 2: Correlation coefficient between yearly disease severity and weekly weather parameters for susceptible and resistant genotypes at ITS condition

Weeks	Growth stage of wheat	Values of correlation coefficient between yearly disease severity and weekly weather parameters					
		Susceptible Genotype			Resistant Genotype		
		r_{Tw}	r_{RHw}	r_{TRHw}	r_{Tw}	r_{RHw}	r_{TRHw}
3	CRI	-0.08	0.04	0.02	0.02	0.10	0.10
4		0.21	0.08	0.14	0.20	0.04	0.10
5		0.06	-0.10	-0.08	0.22	-0.23	-0.16
6	Tillerig	0.06	-0.05	-0.01	0.04	-0.04	-0.02
7		-0.27	-0.04	-0.01	-0.11	-0.03	0.01
8	Jointing	0.27	-0.02	0.14	-0.10	-0.12	0.11
9		0.41	-0.19	0.28	0.46	-0.36	0.12
10	Flowering	0.05	-0.23	0.29	0.10	-0.22	0.01
11		0.15	-0.23	0.10	0.11	-0.22	0.10
12	Milking	0.08	0.10	0.16	0.01	0.01	.029
13		-0.19	0.18	0.21	-0.20	0.11	.098
14	Dough	-0.13	0.07	0.01	0.11	0.08	0.13
15		0.14	0.04	0.11	0.23	0.13	0.21
16		-0.13	-0.17	-0.19	0.04	-0.13	-0.05
17		-0.11	-0.08	0.15	-0.20	0.01	-0.04

Table 3: Correlation coefficient between yearly disease severity and weekly weather parameters for susceptible and resistant genotypes at ILS condition

Weeks	Growth stage of wheat	Values of correlation coefficient between yearly disease severity and weekly weather parameters					
		Susceptible Genotype			Resistant Genotype		
		r_{Tw}	r_{RHw}	r_{TRHw}	r_{Tw}	r_{RHw}	r_{TRHw}
3	CRI	0.09	-0.26	0.08	0.07	-0.30	0.05
4		0.11	-0.33	-0.16	0.26	-0.40	-0.12
5		0.15	-0.13	0.05	0.24	-0.09	0.16
6	Tillerig	0.14	-0.13	0.08	0.11	-0.09	0.07
7		0.13	-0.06	0.05	0.08	-0.11	0.02
8	Jointing	0.28	-0.15	0.10	0.11	-0.13	0.02
9		0.16	-0.14	0.14	0.43	-0.17	0.02
10	Flowering	0.27	-0.11	0.10	0.30	-0.08	0.16
11		0.17	-0.08	0.11	0.35	-0.12	0.07
12	Milking	0.08	-0.03	0.01	0.16	-0.16	-0.09
13		0.12	-0.15	-0.04	0.29	-0.31	-0.16
14	Dough	0.04	-0.05	-0.04	0.03	-0.16	-0.16
15		0.16	-0.27	-0.11	0.29	-0.35	-0.20
16		0.12	-0.09	-0.07	0.33	-0.08	-0.03
17		0.11	-0.02	0.01	0.05	-0.04	-0.02

at RFTS and ILS conditions in susceptible genotypes (Table 1 and 3). However values of r_{TRHw} were found higher and positive in between jointing stage and flowering stage in both the genotypes. This indicates that, the relative humidity is not alone responsible for progression of disease severity. This is the temperature, whose joint effect with relative humidity is responsible for progression of disease severity.

Regression models for forecasting yearly spot blotch severity

CRI, tillering, jointing, flowering, milking and dough stages of wheat crop have been used for developing relationship between weather parameters and spot blotch severity. Three weighted indices for weather parameters ($Z_{1,1}$ for maximum temperature, $Z_{2,1}$ for maximum relative humidity and $Z_{12,1}$ for joint effect of maximum temperature and maximum relative humidity) have been obtained for each growth stages of wheat crop. Multiple linear regression (MLR) model was used for establishing the relationship between weather indices ($Z_{1,1}$, $Z_{2,1}$ and $Z_{12,1}$) and yearly spot blotch severity (Y). Table 4 and Table 5 represents the weather based MLR models for forecasting yearly spot blotch severity in different growth stages of wheat at ITS, ILS and RFTS sowing conditions in susceptible and resistant genotypes respectively.

Forecasted yearly spot blotch severity for season 2015-16 and 2016-17

Autoregressive Integrated Moving Average (ARIMA) technique was used for forecasting weather conditions of year 2015-16 and 2016-17. Based on these forecasted values of weather conditions, value of disease severity has been estimated during these period with the help of regression models mentioned in materials and methods section. Table 6 represents the forecasted values of yearly spot blotch severity obtained by, MLR models discussed in Table 4 and 5, for the crop seasons 2015-16 and 2016-17. It was found from Table 4 and 5 that for both the genotypes at each sowing conditions the RMSE values of the MLR models at the jointing stage was minimum compared to other growth stages. The lower RMSE value at jointing stage indicates that, forecasted value at this stage is more precise than any other stage value. On this consideration forecasted

Table 4: Weather based MLR models for forecasting of spot blotch in different growth stages of wheat at ITS, ILS and RFTS sowing conditions in susceptible genotypes

Stage	MLR models for forecasting disease severity	RMSE
	Irrigated Timely Sown Condition	
C.R.I	$Y = 20.00 + 8.90Z_{1,1} + 3.11Z_{2,1} + .005Z_{12,1}$	12.15
Tillring	$Y = 97.45 + 0.58Z_{1,1} + 2.87Z_{2,1} - .004Z_{12,1}$	13.05
Jointing	$Y = 100.8 + 2.29Z_{1,1} + 0.87Z_{2,1} - .029Z_{12,1}$	11.31
Flowering	$Y = 37.41 + 0.87Z_{1,1} + 0.34Z_{2,1} + .008Z_{12,1}$	11.71
Milking	$Y = 101.0 + 1.21Z_{1,1} + 0.78Z_{2,1} - .014Z_{12,1}$	13.72
Dough	$Y = 132.5 + 0.96Z_{1,1} + 0.68Z_{2,1} + .002Z_{12,1}$	11.88
	Irrigated Late Sown Condition	
C.R.I	$Y = 111.6 + 1.47Z_{1,1} + 0.81Z_{2,1} - .010Z_{12,1}$	12.20
Tillring	$Y = 80.95 + 2.537Z_{1,1} + 0.51Z_{2,1} - .034Z_{12,1}$	12.83
Jointing	$Y = 170.2 - 3.15Z_{1,1} + 0.60Z_{2,1} + .037Z_{12,1}$	11.18
Flowering	$Y = 48.83 + 2.79Z_{1,1} + 0.26Z_{2,1} - .037Z_{12,1}$	12.70
Milking	$Y = 56.56 + 2.01Z_{1,1} + 0.33Z_{2,1} - .027Z_{12,1}$	12.87
Dough	$Y = 34.93 + 1.95Z_{1,1} + 0.31Z_{2,1} - .025Z_{12,1}$	11.70
	Rainfed Timely Sown Condition	
C.R.I	$Y = 173.9 + 24.4Z_{1,1} + 1.55Z_{2,1} - .023Z_{12,1}$	15.04
Tillring	$Y = 120.3 + 3.02Z_{1,1} + 1.81Z_{2,1} - .052Z_{12,1}$	15.93
Jointing	$Y = 64.7 + 4.11Z_{1,1} + 0.67Z_{2,1} - .030Z_{12,1}$	13.16
Flowering	$Y = 106.6 + 2.14Z_{1,1} + 0.51Z_{2,1} - .001Z_{12,1}$	13.76
Milking	$Y = 80.76 + 2.45Z_{1,1} + 0.45Z_{2,1} - .010Z_{12,1}$	15.50
Dough	$Y = 52.51 + 2.42Z_{1,1} + 0.34Z_{2,1} - .007Z_{12,1}$	15.92

Table 5: Weather based MLR models for forecasting of spot blotch in different growth stages of wheat at ITS, ILS and RFTS sowing conditions in resistant genotypes

Stage	MLR models for forecasting disease severity	RMSE
	Irrigated Timely Sown Condition	
C.R.I	$Y = 10.61 + 3.79Z_{1,1} + 2.88Z_{2,1} + .025Z_{12,1}$	12.06
Tillring	$Y = 101.9 + 0.87Z_{1,1} + 3.05Z_{2,1} - .008Z_{12,1}$	12.16
Jointing	$Y = 88.18 + 1.75Z_{1,1} + 1.01Z_{2,1} - .023Z_{12,1}$	11.15
Flowering	$Y = 71.96 + 1.90Z_{1,1} + 0.99Z_{2,1} - .026Z_{12,1}$	12.32
Milking	$Y = 88.85 + 1.16Z_{1,1} + 1.02Z_{2,1} - .014Z_{12,1}$	12.84
Dough	$Y = 126.6 + 0.30Z_{1,1} + 0.93Z_{2,1} - .001Z_{12,1}$	11.22
	Irrigated Late Sown Condition	
C.R.I	$Y = 52.54 + 1.04Z_{1,1} + 0.79Z_{2,1} - .040Z_{12,1}$	11.38
Tillring	$Y = 59.84 + 2.98Z_{1,1} + 0.66Z_{2,1} - .034Z_{12,1}$	11.44
Jointing	$Y = -28.9 + 2.7Z_{1,1} + 0.23Z_{2,1} - .029Z_{12,1}$	10.03
Flowering	$Y = -37.4 + 2.2Z_{1,1} + 0.32Z_{2,1} - .022Z_{12,1}$	11.96
Milking	$Y = -54.6 + 1.7Z_{1,1} + 0.23Z_{2,1} - .001Z_{12,1}$	10.38
Dough	$Y = -51.0 + 1.5Z_{1,1} + 0.20Z_{2,1} - .009Z_{12,1}$	10.55

	Rainfed Timely Sown Condition	
C.R.I	$Y = -1.6 + 10.2Z_{1,1} - 0.85Z_{2,1} - .135Z_{12,1}$	12.28
Tillring	$Y = 115.3 - 1.92Z_{1,1} + 2.35Z_{2,1} + .034Z_{12,1}$	11.90
Jointing	$Y = 96.13 - 1.12Z_{1,1} + 0.73Z_{2,1} - .009Z_{12,1}$	10.12
Flowering	$Y = 118.4 - 0.16Z_{1,1} + 0.80Z_{2,1} - .012Z_{12,1}$	10.94
Milking	$Y = 95.13 + 0227Z_{1,1} + 0.80Z_{2,1} + .007Z_{12,1}$	13.71
Dough	$Y = 86.65 + 0.42Z_{1,1} + 0.83Z_{2,1} + .004Z_{12,1}$	13.52

Table 6: Forecasted values of yearly spot blotch severity (%) for cropping season 2015-16 and 2016-17

Growth stages	Forecasted values of spot blotch severity (%) in Susceptible Genotypes					
	ITS		ILS		RFTS	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
CRI	74.50	74.57	72.78	72.63	63.11	62.93
Tillering	72.12	72.10	71.95	71.85	64.50	64.39
Jointing	**73.09**	**73.08**	**75.32**	**75.01**	**52.13**	**52.00**
Milking	71.67	71.61	72.70	72.63	62.15	61.97
Flowering	70.82	70.72	74.45	73.01	64.00	63.85
Dough	67.07	66.80	75.67	75.01	67.18	67.32
	Forecasted values of spot blotch severity (%) in Resistant Genotypes					
	ITS		**ILS**		**RFTS**	
	2015-16	**2016-17**	**2015-16**	**2016-17**	**2015-16**	**2016-17**
CRI	43.08	44.17	44.01	43.91	45.33	45.54
Tillering	38.13	37.98	43.33	43.39	39.15	39.09
Jointing	38.10	**37.95**	**43.99**	**43.91**	**38.69**	**38.60**
Milking	41.19	41.12	46.16	46.34	39.40	39.40
Flowering	37.65	37.50	45.48	45.60	40.10	40.08
Dough	37.86	38.06	45.01	46.0	40.37	40.34

value of yearly spot blotch severity in susceptible genotypes for the period 2016-17 obtained as 73.08% (with RMSE value 11.31), 75.01 % (with RMSE value 11.18) and 52.00 % (with RMSE value 13.16) at ITS, ILS and RFTS conditions respectively.

In the same cropping season forecasting value of yearly spot blotch severity in resistant genotype obtained as 37.95% (with RMSE value 11.15), 43.91% (with RMSE value 10.03) and 38.60% at ITS, ILS and RFTS conditions respectively.

Conclusion

The higher values of r_{Tw} and r_{TRHw} between the jointing and flowering growth stages indicates that duration between 8th week and 11th week from the date of sowing is very critical for the spot blotch progression in wheat. Therefore, proper care is required in this duration to restrict the progression of spot blotch. On the basis of lower RMSE value at jointing stage forecasted values of yearly spot blotch severity in susceptible genotype for the period 2016-17 were obtained as 73.08 %, 75.01% and 52.00% for ITS, ILS and RFTS sowing conditions respectively. For the same period forecasted values of spot blotch disease severity were obtained as 37.95 %, 43.91 % and 38.60 % for ITS, ILS and RFTS conditions respectively in the case of resistant genotypes.

Acknowledgements

The authors are thankful to the ICAR-Indian Institute of Wheat and Barley Research Karnal

(Indian Council of Agricultural Research) India and India Meteorological Department, New Delhi (India) for providing data to carry out the present study.

References

Dubin, H.J. 1984. Regional and in-country activities: Andean region, *Report on wheat improvement 1981*. CIMMYT, Mexico D.F.:102-104

Duveiller,E., Kandel, Y.R., Sharma, R.C. and Shrestha, S.M. 2005. Epidemilogy of Foliar Blights (Spot Blotch and Tan Spot) of wheat in Plains Bordering the Himalayas. *Phytopathology* **95**:248-256.

Gilchrist, L.I. and Pfeiffer, W.H. 1991. Resistant to *Helminthosporium sativum* in bread wheat: Relation ship of infected plant parts and the association of agronomic traits :Wheat for the Nontraditional, Warm Areas, D.A. saunders, ed, CIMMYT, Mexico, D.F.:473-476

Ho, S.L., Xie, M. and Goh, T.N. 2002. A comparative study of neural network and Box-Jenkins ARIMA modeling in time series prediction. *Computers and Industrial Engineering* **42**:371– 375.

Joshi, A.K., G.Ortiz-Ferrara J. Crossa, R. Chand, G. Alvarado, M.R. Bhatta, E. Duveiller, G. Singh, R.C. Sharma, D.B. Pandit, M.M.A.B. Siddique, S.Y. Das and Sharma, R.N. 2007. Associations of environments of South Asia based on spot blotch disease of wheat caused by *Bipolaris sorokiniana. Crop Sciences* **43**:1071- 1081.

Joshi, A.K., Chand, R. and Arun, B. 2002. Relation of plant height and days to maturity with resistant to spot blotch in wheat (*Triticum aestivum*). *Euphytica* **123**: 221-278.

Kumari, P., Mishra, G.C. and Srivastava C.P. 2013. Forecasting of productivity and pod damage by *Helicoverpa armigera* using Artificial neural network model in Pigeonpea (*Cajanus cajan*). *International Journal of Agriculture, Environment and Biotechnology* **6**: 335-340.

Kumari, P., Mishra G.C .and Srivastava, C.P. 2014. Time series forecasting of losses due to pod borer, pod fly and productivity of pigeonpea (*Cajanus cajan*) for North West Plain Zone (NWPZ) by using artificial neural network (ANN). *International Journal of Agricultural and Statistical Science* **10**: 15-21.

Mishra,G.C. and Singh, A. 2013. A study on forecasting, prices of groundnut oil in Delhi by ARIMA methodology and Artificial Neural Networks. *AGRIS online papers in Economics and Informatics* **5**: 25-34.

Nema, K.G. and Joshi, L.H. 1973. Spot blotch disease of wheat in relation to host age, temperature and moisture. *Indian Phytopathol.*, **26**:41-48.

Paul R.A., Prajneshu and Ghosh, H. 2013. Statistical modelling for forecasting of wheat yield based on weather variables. *Indian Journal of Agricultural Sciences* **83**: 60-63.

Rosegrant, M.W., Agcaoili-Sombilla, A. and Perez, N. 1995. Global food projections to 2020. Discussion paper 5. Washington, D.C: IFPRI.

Sharma, R.C. and Duveiller, E. 2004. Effect of Helminthosoporium leaf blight on performance of timely and late seeded wheat under optimal and stressed levels of Soil fertility and moisture. *Field Crop Research* **89**: 205-218.

Shukla, G., Mishra, G.C. and Singh, S.K. 2015. Kriging approach for estimating deficient micronutrients in the soil: A case study. *International Journal of Agriculture, Environment and Biotechnology* **8**: 309-314.

Van Ginkel, M. and Rajaram, S. 1998. Breeding for resistance to spot blotch in wheat: Global perspective. In: Duveiller E, Dubin HJ, Reeves J, McNab A (eds) Helminthosporium Blights of Wheat: Spot Blotch and Tan Spot. CIMMYT, Mexico DF. Pp. 162-169.

Zhang, G.P. 2003. Time series forecasting using a hybrid ARIMA and neural network model. *Neurocomputing* **50**: 159–175.