

Research Paper

Effect of meteorological parameters on Karnal bunt incidence in wheat under different agroclimatic zones of Punjab

SARABJOT KAUR SANDHU^{1*}, ANURAG ATTRI¹ and RITU BALA²

¹Dept of Climate Change & Agricultural Meteorology, PAU, Ludhiana, India

²Dept of Plant Breeding and Genetics, PAU, Ludhiana, India

*Corresponding author email : skchahal@pau.edu

ABSTRACT

To quantify the effect of meteorological parameters on incidence of Karnal bunt in wheat crop, an investigation was done using 9 to 12 season's data of Bathinda and Ludhiana stations of Punjab. Maximum temperature during March in range of 25-31°C, minimum temperature of February (8.5-11.0°C), morning and evening relative humidity of March in range of 85-95 and 40-60 per cent respectively, rainfall more than 25 mm with sunshine hours 5.5-9.0 hrs/day during mid-February to mid-March favour Karnal bunt in wheat crop. Maximum temperature of March showed significant negative correlation with incidence of Karnal bunt whereas minimum temperature of February showed significant positive correlation with disease incidence at both locations. Morning and evening relative humidity showed significant positive correlation with disease incidence. Rain amount and rainy days during mid-February to mid-March significantly influenced disease incidence. Sunshine hours had negative correlation with disease incidence. Backward multiple linear regression (BMLR) analysis indicated maximum temperature, rainfall and sunshine hours play significant role in Karnal bunt incidence at Ludhiana. However, at Bathinda, maximum temperature, evening time relative humidity, rain amount and rainy days played significant role.

Key words: Karnal bunt, wheat, critical ranges, backward multiple linear regression

Wheat is the second most important cereal crop of India after rice and also a major crop during *rabi* season in north western states like Punjab, Haryana etc. In Punjab, during 2019-20, it was grown on 35.20 lakh hectares with production of 176.20 lac tonnes with grain yield of 50.04 q/ha (Anon., 2021). Wheat is the cool season crop, high temperature at the time of sowing as well as during reproductive stage leads to poor tillering, early heading and reduction in grain weight, respectively which ultimately reduces its yield. Life cycle of plant depend upon on the weather conditions during cropping season. Similarly, activity of the pathogens depends upon the meteorological parameters. Karnal bunt is becoming a major disease of wheat from minor one, especially in north-western India. Karnal bunt caused by fungus *Tilletia indica*, was first reported by Mitra at Karnal in 1931. It is also known as new bunt or partial bunt. Flowering stage of wheat is vulnerable to attack by *Tilletia indica* and when the grains have developed, the disease become apparent. Wheat grain is incompletely or wholly converted into black powdery masses enclosed by the pericarp. It does not affect all the ear heads of the plant and not all grains are bunted in an ear. Only under severe cases embryo of the seed gets infected

and endosperm remain uninfected (Mansoori, 2015). Karnal bunt of wheat is seed, soil and air borne disease, but it is not systemic in nature. When the host is at the flowering stage, the soil and seed borne teliospores germinates. They germinate from mid-February to mid-March, when suitable soil moisture and temperature are available. At flowering time, high humidity and low temperature lead to conditions conducive to infection. Initially it was a minor disease but became epidemic in 1976, 1979, 1981-83 and 1986 (Bala and Kaur, 2020). The variation in disease development was due to varietal susceptibility and environment conditions (Sharma *et al.*, 2004). In Punjab, the disease reported to be rigorous, when temperature from February onward was 18°C to 22°C with above 70 per cent relative humidity. The moisture on the soil surface, for teliospore germination as well as for infection on the spike by secondary *sporidia*, is the most important factor (Rai, 2009). Weather parameters *viz.* rainfall, maximum temperature, evening relative humidity, sunshine hours and number of rainy days are important for outbreak and spread of the disease (Singh *et al.*, 2010). In the present era of climate change and variability, Karnal bunt is a disease with a high potential of re-emergence in the areas where

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it is already endemic as well as its diffusion to new areas (Bishnoi *et al.*, 2020). So keeping in view the importance of meteorological parameters in development of incidence of Karnal bunt, an analysis was conducted using long term data and critical ranges of various meteorological parameters conducive for Karnal bunt incidence in Ludhiana and Bathinda districts of Punjab.

MATERIALS AND METHODS

Karnal bunt incidence data

The data of Karnal bunt incidence of 12 seasons i.e. from 2009-10 to 2020-21 of Ludhiana district and of 9 seasons i.e. from 2010-11 to 2018-19 of Bathinda district were obtained from the Wheat Section, Department of Plant Breeding and Genetics, PAU, Ludhiana. The wheat grain samples were collected from the various grain markets in both the districts. Every year grain markets were surveyed and 15-30 samples were taken from each grain market. Samples of 500 g to 1000 g of grains from different heaps of wheat were collected randomly in paper bags. And the Karnal bunt incidence was calculated by using following formula:

$$\text{Disease incidence (\%)} = \frac{\text{No. of infected grains}}{\text{Total no. of grains examined}} \times 100$$

Meteorological data

The meteorological data of the respective districts were obtained from Department of Climate Change and Agricultural Meteorology, PAU, Ludhiana. The meteorological data of different parameters were used for three critical time periods *viz.*, February (I period), 15 Feb-15 March (II period) and March (III period) because during this period wheat is at anthesis and ear formation stages which are most vulnerable stages to Karnal bunt development under Punjab environmental conditions.

Statistical analysis

Correlation coefficients were calculated between data of Karnal bunt disease incidence and different meteorological parameters *viz.*, temperature, relative humidity, sunshine hours (for Ludhiana), rain amount and rainy days occurred during different critical periods assigned. For the analysis of disease data, the multiple linear regression (MLR) technique happens to be most flexible where disease incidence is being taken as dependent variable (Y) and different meteorological parameters as independent variables. This statistical technique uses several explanatory variables to predict the outcome of a response variable i.e. dependent variable. The generalized formula for MLR is as follows:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p + \epsilon$$

Where, $i = n$ observation; $Y =$ dependent variable; $\beta_0 =$ intercept (constant term); $x_i =$ explanatory variables; $\beta_p =$ slope coefficients for each explanatory variable; $\epsilon =$ the model's error term (also known as the residuals)

Multiple linear regression equations were developed using most favorable meteorological parameters during different critical periods. It can be observed from MLR technique that number of parameters have been taken as independent

variables to predict the dependent variable. But, because of collinearity between these independent variables because of the results may not be significant. To determine multi-collinearity among variables, variance inflation factors (VIF) for each independent variable using statistical analysis software R (ver. 4.1.1, car library) was calculated. To remove the non-impressive parameters step by step, backward multiple linear regression (BMLR) method based on Akaike Information Criterion (AIC) was applied to get the best fit model. The model with the minimum value of the AIC is often the best model for prediction. The last equation developed from this analysis has parsimonious parameters with acceptable accuracy. This BMLR analysis was conducted using statistical analysis software R (ver. 4.1.1, MASS package).

RESULTS AND DISCUSSION

Karnal bunt incidence

The respective disease incidence data of Karnal bunt in Ludhiana and Bathinda districts have been presented in Table 1. Maximum infected samples (98.4%) were recorded in the crop season of 2014-15 and minimum (1.59%) in the crop season of 2016-17 at Ludhiana. The maximum infected samples in Bathinda district were recorded in crop season of 2010-11 and minimum in the crop season of 2016-17. During year 2010-11, 92 per cent infected samples were recorded, whereas during 2016-17 only 6.05 per cent collected samples were infected. Weather conditions played an important role in year to year variations in infected samples and average disease infection. Bala *et al.*, (2013) too concluded that in Punjab, year to year variations have occurred in the incidence of Karnal Bunt. A total of 10593 grain samples collected during 2005-2012 and of 3677 (34.71%) samples were infected with Karnal bunt disease.

Correlation analysis

The correlation coefficients between the meteorological parameters and incidence of Karnal bunt were worked out and have been presented in Table 2 for Ludhiana and Bathinda. The data of weather parameters was included for three critical periods *viz.* period I i.e. February month weather data and period II i.e. weather parameters for mid-February to mid-March period and period III i.e. March month. Correlation analysis for Ludhiana indicated that in case of first critical period, minimum temperature, evening relative humidity and sunshine hours showed significant correlation whereas maximum temperature, morning relative humidity and rainfall were not significantly correlated. During second critical period, evening relative humidity, rainfall, rainy days and sunshine hours showed significant correlation with disease incidence. During third critical period maximum temperature, morning and evening relative humidity, rainfall and rainy days showed significant correlation. In corroboration with this study, Kaur (2001) also reported positive correlation between morning relative humidity and teliospores germination and maximum teliospores germinated at mean relative humidity of more than 75 per cent. For Bathinda, minimum temperature along with morning and evening relative humidity significantly influenced disease incidence. Maximum temperature, relative humidity and rainfall were significantly correlated with Karnal bunt incidence. Morning relative humidity of March showed

Table 1: Karnal bunt incidence (%) at Ludhiana and Bathinda districts of Punjab

Year	Ludhiana	Bathinda
2009-10	10.00	--
2010-11	30.30	92.00
2011-12	3.36	6.40
2012-13	35.96	8.24
2013-14	39.56	8.24
2014-15	98.40	87.50
2015-16	23.64	19.53
2016-17	1.59	6.05
2017-18	28.57	17.58
2018-19	33.24	32.37
2019-20	54.00	--
2020-21	30.00	--

higher r-value. Mavi *et al.*, (1992) also reported that evening relative humidity during 9th to 11th standard meteorological week had positive correlation with disease intensity. Kaur *et al.*, (2007) also developed the correlation coefficients of weather parameters with Karnal bunt incidence in Punjab and found that maximum temperature and morning relative humidity had non-significant correlation whereas minimum temperature had significant positive correlation.

Meteorological parameters and disease incidence

Quantification of most favourable meteorological parameters on the basis of correlation analysis for incidence of Karnal bunt was done to identify the critical values of different meteorological parameters has been presented in Table 3. From first critical period i.e. in February month, minimum temperature in the range of 8.5-11°C was most vulnerable for disease incidence. Maximum temperature, morning and evening relative humidity

Table 2 : Correlation coefficient between Karnal bunt incidence and different weather parameters

Period/ Parameters	Tmax (°C)		Tmin (°C)		RHm (%)		RHe (%)		RF (mm)		RD (No.)		BSS (hr/day)
	LDH	BTH	LDH	BTH	LDH	BTH	LDH	BTH	LDH	BTH	LDH	BTH	LDH
February (I-period)	-0.03	0.04	0.63*	0.57*	0.23	0.64*	0.63*	0.55*	0.34	0.30	0.45	0.17	-0.55*
Mid Feb-Mid March (II-period)	-0.31	-0.50*	0.40	0.12	0.39	0.66*	0.78**	0.64*	0.72*	0.56*	0.76**	0.50*	-0.83**
March (III-period)	-0.49*	-0.33	0.07	-0.01	0.50*	0.67*	0.84**	0.45*	0.70*	0.46	0.72*	0.30	-0.44

LDH- Ludhiana, BTH – Bathinda;

Tmax – Max Temp; Tmin – Min Temp; RHm – Morning RH; RHe- Evening RH; RF – Rainfall; RD – Rainy Day; BSS-Bright Sun Shine

*Significant at 5% level of significance, ** significant at 1% level of significance

#Bold values used for development of regression models

Table 3: Critical values of different meteorological parameters favourable for incidence of Karnal bunt in wheat

Meteorological Parameter	Critical Range/ Value
Tmax (III-period)	25-31 °C
Tmin (I-period)	8.5-11.0 °C
RHm (III-period)	85-95%
RHe (III-period)	40-60%
RF (II-period)	>25 mm
RD (II-period)	> 3 days
SSH (II-period)	5.5-9.0 hrs/day

during March period in the range of 25-31°C, 85-95 and 40-60 per cent respectively, were most favourable for disease incidence at both the locations. Rainfall (>25 mm) and rainy days (>3.0) during mid-February-mid March period were most favourable for disease incidence. For Ludhiana, sunshine hours during mid-February-mid March period in the range of 5.5-9.0 hrs/day were congenial. Biswas *et al.*, (2013) also concluded that Karnal bunt of wheat was influenced by meteorological parameters. Day temperature values between 25-30°C and night time temperature values between 10-15°C showed higher probability density asserting good association with sporidial showering. However, individually, relative humidity at morning or evening time did not show such association. Though, the diurnal range of RH was important as RHm >90 per cent and RHe between 40 and 60 per cent gave the maximum combined probability density

Table 4: Variance inflation factors (VIF) of individual predictive variables

Parameters	Ludhiana	Bathinda
Tmax	8.50	1.41
Tmin	5.43	1.88
RHm	4.54	4.81
RHe	9.22	5.00
Rainfall (RF)	24.9	18.70
Rainy days (RD)	27.9	5.89
Sunshine hours (SSH)	11.6	NA

with daily sporidial showering. Further to make out distribution of different meteorological parameters during incidence and development of disease box plots were plotted using pooled data at both locations and has been depicted in Fig.1. These plots helped to recognize significant meteorological parameters in quantitative terms. The temperature around 27°C (max) and 9.5°C (min) were found to be deciding factor for the development of Karnal bunt after its establishment in the crop field. Higher RHm (>89%) as well as RHe (>45%) during most of the season facilitate the development of Karnal bunt. Rainfall around 38 mm along with 3 rainy days favoured disease incidence. Sunshine hours of nearly 7.5 hrs/day during the season favoured disease incidence at Ludhiana. Chahal (2001) reported too, that environmental factors played major role in occurrence of disease in epidemic form. Moderate temperature

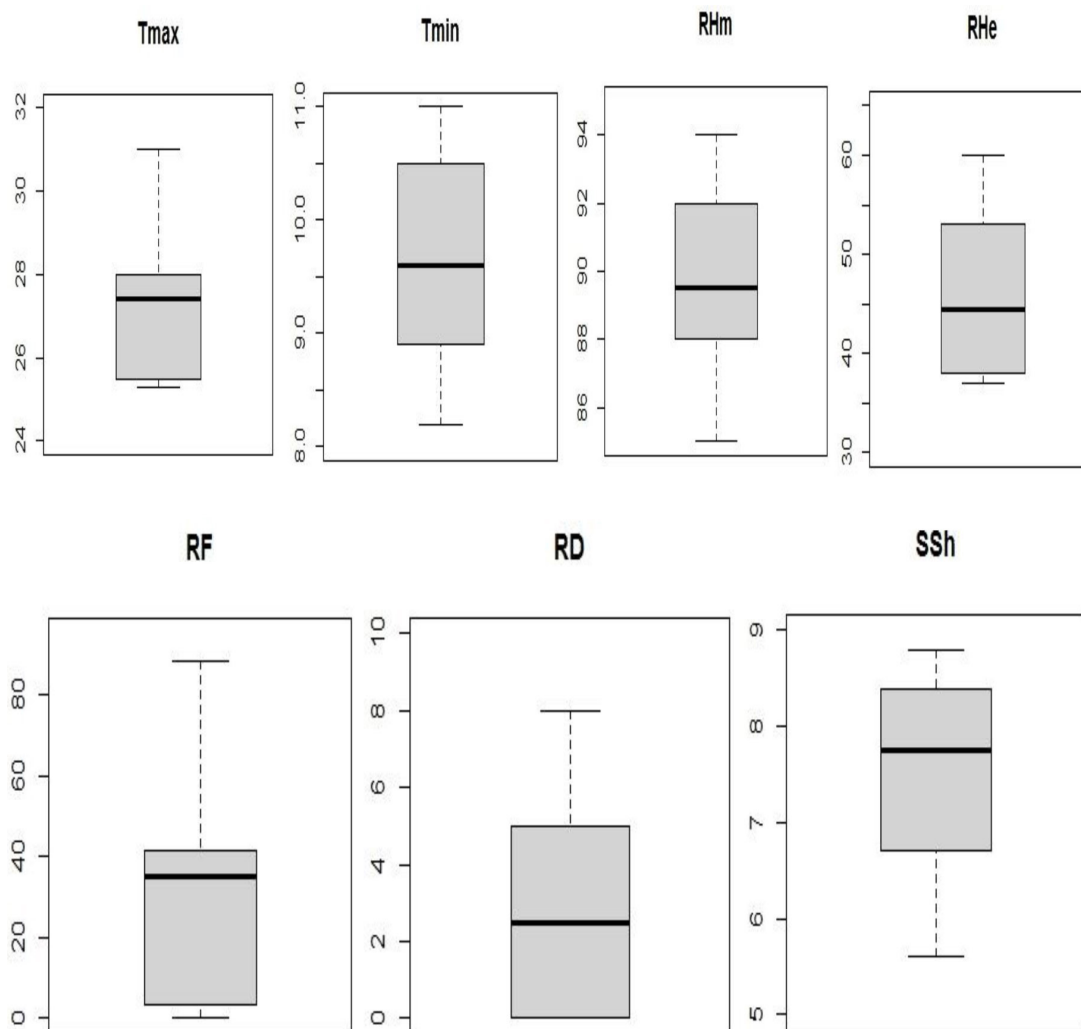


Fig.1: Distribution of different meteorological parameters during Karnal bunt incidence years

between 19-20°C, RH >70 per cent, cloudiness and light rains during anthesis favored the development of Karnal bunt. With day time temp of $22\pm 2^\circ\text{C}$, RHe > 48 per cent, partly cloudy (3.5 hour per day cloudiness) and >3 rainy day in last week of February and first week of March at boot to spike emergence stage, outbreak of Karnal bunt supposed to occur. Number of rainy days at boot leaf stage found to be more important for disease development. Khan *et al.*, (2010) also concluded that if the average minimum temperature range between 11 to 16°C and maximum temperature 27.5 to 31.1°C in month of February and March in Pakistan, then the incidence chances of Karnal bunt will be more. They further reported that high rainfall of 1.1 mm, relative humidity of 49 per cent, low minimum temperature of 14.8°C and low maximum temperature of 27.8°C during the year 2007 caused more disease incidence when compared with season of 2006. Jakhar *et al.*, (2019) also reported that reason behind the high occurrence of Karnal bunt in Karnal was due to favorable temperature, high RH, cloudy and wet weather.

Variance inflation factors (VIF) of seven predictive variables concluded several variables that were highly inter-correlated (i.e. condition of multi co-linearity). High VIF values were obtained in some meteorological parameters *viz.*, rain amount

and rainy days for Ludhiana as presented in Table 4. High VIF signified strong association among these weather variables.

Development of exploratory model

Development of exploratory model was attempted using meteorological and disease data for both the locations. Multiple linear regression (MLR) was developed using the most significant weather parameters which were perceived by correlation analysis. In MLR, disease incidence (Y) was response variable and all meteorological parameters were taken as continuous predictors. For Ludhiana, the MLR was developed by including meteorological parameters *viz.* minimum temperature (I-Period), rainfall, rainy days and sunshine hours from second period (mid-February to mid-March) and maximum temperature, morning and evening relative humidity from third period (March). From VIF analysis, it was evident that there was co-linearity between different independent variables so backward multiple linear regression (BMLR) analysis was done using Akaike information criterion (AIC) as presented in Table 4. The final output was a parsimonious model with lowest AIC value (57.6) using maximum temperature, rainfall and sunshine hours with significant R^2 value (0.78). According to the final model,

Table 5 : BMLR based regression analysis to select appropriate exploratory model for Ludhiana and Bathinda

I-Regression Equation at Ludhiana	AIC	R²
DI= 191.6+8.6X ₁ -5.44X ₂ -3.34X ₃ +1.87X ₄ +0.54X ₅ -0.97X ₆ -19.9X ₇	93.0	0.84
DI= 198.1+8.50X ₁ -5.21X ₂ -3.92X ₃ +2.31X ₄ +0.51X ₅ -16.91X ₇	60.6	0.84
DI= 142.8+5.61X ₁ -2.96X ₃ +2.03X ₄ +0.32X ₅ -13.80X ₇	59.1	0.84
DI= -0.45+3.25X ₁ +0.98X ₄ +0.26X ₅ -14.82X ₇	58.8	0.80
DI= 73.16+3.72X ₁ +0.34X ₅ -20.66X ₇	57.6	0.78
II- Regression Equation at Bathinda	AIC	R²
DI= -223.2-9.41X ₁ -0.81X ₂ -3.47X ₃ +4.70X ₄ -1.06X ₅ -8.64X ₆	51.0	0.94
DI= -215.3-9.44X ₁ +3.39X ₃ +4.55X ₄ -1.03X ₅ -8.11X ₆	49.9	0.94
DI= 85.34-9.85X ₁ +4.06X ₄ +0.50X ₅ -16.97X ₆	49.2	0.87

Where, X₁ – Max Temp (°C); X₂ – Min Temp (°C); X₃ – Morning RH (%)

X₄ – Evening RH (%); X₅ – Rainfall (mm); X₆ – Rainy days (No.); X₇ – Sunshine Hours (hr/day)

maximum temperature of March month, rainfall and sunshine hours of mid-February to mid-March period exhibited strong effect on Karnal bunt incidence at Ludhiana (Table 5). Similarly, Khan *et al.*, (2010) conducted regression analysis between Karnal bunt incidence and various meteorological parameters and found that air temperature, rainfall, wind speed and relative humidity explained upto 84 per cent variability in disease development. The exploratory model using BMLR analysis was developed for Bathinda and predictive models has been presented in Table 5. The MLR was developed by including meteorological parameters *viz.* minimum temperature (I-Period), maximum temperature, evening relative humidity, rainfall and rainy days from second period (mid-February-mid March) and morning relative humidity from third period (March). Number of meteorological parameters were omitted by the software to get the best model. The final model included maximum temperature, evening relative humidity, rainfall and rainy days with AIC value of 49.2 and these meteorological variables explained upto 87 per cent variations in disease incidence at Bathinda. Singh *et al.*, (2018) also reported that average infection of Karnal bunt was regulated by maximum and minimum temperature, morning and evening time relative humidity, rainfall and rainy days with R² values between 0.68 to 0.92 in different districts of Haryana state.

CONCLUSION

Among different meteorological parameters minimum temperature (8.5-11.0°C) of February month, maximum temperature (25-31°C) of March month, rainfall (>25 mm) and rainy days (>3 days) of mid-February-mid March period can act as key indicators for disease incidence. On the basis of developed regression models, location specific forewarning of Karnal bunt incidence can be done for timely and effective management of disease to avoid any further epidemic conditions in the region.

Conflict of Interest Statement: The author(s) declare(s) that there is no conflict of interest.

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