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Correlation between weather variables and ascochyta blight disease of chickpea

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ABSTRACT

Relationship of weather variables and chickpea ascochyta blight disease was studied using 24 years (1985-2008) data collected at Ludhiana, Punjab. Coefficients of correlation of ascochyta blight disease index (DI) were worked out with meteorological variables at weekly intervals starting from 5th SMW (standard meteorological weeks) to 17th SMW and utilized to develop regression model in disease forecasting. Minimum temperature (Tmin), morning relative humidity (RHmax), rainy days exhibited positive correlation with DI, however, (maximum temperature (Tmax) and the sunshine hours showed negative correlation. The relationship between DI and Tmin appeared to be exponential; DI sunshine hrs; DI rainfall appeared to be polynomial and regression lines explained 26%, 49% and 22% variation in disease respectively. The relationship between DI and afternoon relative humidity (RHmin); DI and humidity thermal ratio (HTR) appeared to be power function and regression line explained 34% and 35% variation in disease respectively. The favourable range of Tmin and weekly mean RHmin values were 12.5-14.5^{o}C and 45-60%, these two variables were combined as HTR, the values of which ranged from 0.4-0.5 for disease occurrence in central plain region of Punjab. The study concluded for maximum probability of disease from 7th-10th SMW which is also the beginning of reproductive phase of chickpea.

Key words: Chickpea, Ascochyta blight, weather variables, disease index

Chickpea (*Cicer arietinum* L.) is grown in diverse ecological regions, hence influenced by range of temperature-moisture regimes. The weather has profound influence on the crop growth, its productivity in relation to the disease/ pest attack. *Ascochyta rabiei* (Pass.) Labrousse, the cause of Ascochyta blight disease of chickpea is serious in many region of the world with cool moist climate. Interestingly, two third of world chickpea producing area is vulnerable to this disease (Nene and Reddy, 1987). A measure to overcome the disease is partially through shift in area and/or sowing time.

In India, the disease is favoured by climatic conditions prevalent in north zone (29^{o}-45^{o}N) during the crop season (Jhorar *et al.*, 1997), consequence to this major chickpea area shifted to central and south zone. The host resistance considered as finest strategy for disease management, however, gives way to pathogen pressure under vulnerable weather conditions due to lack of desired level of host resistance in chickpea. Despite this, workable approach considered for good crop harvest is integrating the resistant variety and fungicidal disease management. Weather is known to exercise an important role in disease occurrence and epidemic, in-depth understanding of their relationship can facilitate disease management. Dickmann (1992) integrated daily mean temperature, precipitation and number of rainy days to the occurrence of ascochyta disease. Jhorar *et al.* (1997) identified ratio of temperature maximum and afternoon relative humidity with disease prediction. However, such studies need long term yearly data sets of disease severity and weather variables to derive at accurate interrelationship and several such attempts are required to accurately forecast the disease. Thus associating the historical weather data and disease index, the aim was to generate a working model for disease prediction for prophylactic disease management and suggest new niches for crop cultivation.

MATERIAL AND METHODS

The germplasm lines and advance breeding lines in All India Chickpea Improvement Project were planted for normal growth in first fortnight of November every year in Research area, Department of Plant Breeding and Genetics, PAU, Ludhiana. The material was given formal dose of inoculum by spray of conidial suspension $4X10^{4\text{-ml-1}}$in first week of Feb (ie. 5th SMW) to boost primary inoculum. The disease was promoted by misting of water from 1st to 3rd week of February every year. In a normal course, reproductive period of the crop falls around 5-17 standard meteorological weeks (SMW) (February to April) in Ludhiana. Therefore, relationships of the meteorological variables with disease were considered from 5th SMW (beginning from first week of February) to 17th SMW (ending in April 29). Weather data over 24 years period (1985-2008) were obtained from Meteorological Observatory situated at 30^{o}54'N, 75^{o}48'E, 247 m above sea level, Department of Agricultural Meteorology, of the University. The meteorological variables included maximum (Tmax) and minimum (Tmin) temperature, representing day and night temperature, relative humidity maximum (RHmax) (morning) and minimum (RHmin) (evening), sun shine duration (an indirect measure of cloudiness), total rainfall and number of rainy days. The weekly data on all the meteorological variables were calculated corresponding to standard meteorological weeks (SMW). The observations on disease were taken from disease initiation (February) till full epidemic (March) for the same 24 years on 1-9 rating scale. The disease ratings were converted in to disease index.

$$DI = \frac{\text{Sum of numerical rating of all entries}}{\text{Total number of entries x maximum rating (9)}}$$

Coefficients of correlation of disease were worked out with all the meteorological variables separately for every week starting from 5th SMW to 17th SMW. The model was developed based on the statistical technique of correlation and regression. By analyzing the correlation coefficients for statistical and phenological significance, the critical periods when weather variables exert significant influence on disease were located. These were then used to calculate the multiple correlations with the disease. Multiple correlations of all the combinations were calculated and those parameters which were statistically significant at the mandatory levels were used in the final equation. These parameters were subsequently used to develop a regression model for utility in forecasting disease.

RESULT AND DISCUSSIONS

Correlations with weather parameters

Separate **c**orrelation analysis was done between weekly weather parameters and disease index for each SMW from 5-17. These identified time period within the growing season when there were significant correlations (over the 24 year period) between individual weather variable and disease (Table 1).

Maximum temperature (Tmax) had non significant correlation with disease index (DI) and minimum temperature (Tmin) had significant positively correlation with DI during 9 and 14 SMW. The Tmin during February and March (SMW 7-12) was 7.5 and 11.5°C which allowed infection to progress for disease establishment. The incubation period of the disease is 11-12 days (6-7 SMW) of inoculation and attains full magnitude after 20-40 days (SMW 8-11). Trapero Casas and Kaiser (1992**)** reported incubation period of 11 days and Tmax of 20ºC optimum for disease development. The observed mean maximum temperature for the 24 years was 21^{o}C which was close to the optimum temperature.

The morning relative humidity (RHmax) was significantly positively correlated with DI in 11 SMW. and afternon relative humidity minimum (RHmin) was significantly positively correlated with DI in 5-13 SMW and negatively correlated in 14-17 SMW. RHmin had high correlation than RHmax depicting that the afternoon RH is a better indicator for disease. The disease is considered to flourish in wet humid conditions and is desirable for primary and secondary infection.

The number of rainy days was significant positively correlated in 9 SMW 15 SMW. This indicated that frequent rains at on set of disease initiation promote the disease.

Significant negative co-efficient of correlations were observed in 7 and 9 SMW, indicating, less sun shine hours or cloudiness during this period is desirable for disease development. While total rainfall had significant positively correlation with DI in the period Gamliet-Atinsky *et al* (2005) pointed that spore dispersal was dependent upon successive rain and dry periods.

Humid thermal ratio (HTR)

On the basis of significant co-relations identified for two weather variables the Tmax and RHmin, humid thermal ratio (HTR) was calculated. Correlation coefficients showed HTR was highly negatively correlated with DI during SMW 5-10 and positively correlated during SMW 14-16.

The temperature and moisture are two important key weather parameters which determine the disease epidemic. Significant negative correlations from 5-10 SMW depict that Tmax and RHmin ratio ie. HTR is critical in disease epidemic. Any higher temperature during these weeks will seek for higher RHmin for disease occurrence. Under optimal temperature of 20^{o}C and leaf wetness 7.6 h to 17 h maximum disease can occur and any variation in temperature higher or lower, longer period of leaf wetness was required for good disease development (Trapero Casas and Kaiser, 1992).

Agro-meteorological models

The significant correlations of weather parameters and DI in the present study have been identified from 5-10 SMW. The period between these weeks can be marked as epidemic window. The crop canopy during these weeks has a cumulative effect in maintaining the RH, permitting long periods of leaf wetness. The most culminating factors for disease development are RH and temperature. When there is suitable temperature and RH during 5-10 SMW then there is risk of disease. Thus there is a need to keep these two parameters critically during SMW 5-10 to take precautionary management steps.

Disease forecasting models based on stepwise regression analysis between DI and different weather variables were developed. The results from basic models i.e.

Table 1: Correlation coefficient between meteorological variables and Ascochyta blight of chickpea over a period of 24

SMW	Temperature		Relative Humidity		Sun shine hrs	Total rain (mm)	No. of rainy days	HTR
	T min	T max	RHmin	RHmax				
5	0.12	-0.22	0.42	0.34	-0.25	0.07	0.22	-0.44*
6	0.12	-0.23	0.18	0.12	-0.29	0.00	0.03	-0.30
7	0.29	-0.15	0.32	0.08	-0.43*	0.40*	0.38	-0.36
8	0.37	0.04	0.38	0.18	-0.35	0.21	0.20	-0.27
9	0.45*	-0.34	0.44*	0.18	-0.60*	0.45*	0.47*	-0.48*
10	0.11	-0.38	0.38	0.04	-0.21	0.12	0.23	-0.55*
11	0.18	0.22	0.11	0.49*	0.27	-0.28	-0.35	-0.07
12	0.35	0.19	0.25	-0.14	-0.03	0.03	0.19	-0.11
13	0.19	0.28	0.02	0.03	0.11	0.00	-0.22	0.08
14	0.50*	0.30	-0.13	-0.22	-0.12	0.09	0.02	0.16
15	0.02	0.34	-0.47*	0.02	0.10	-0.22	-0.41*	0.46*
16	0.34	0.34	-0.31	-0.36	-0.05	0.17	0.15	0.35
17	0.22	0.09	0.09	-0.20	-0.23	-0.29	-0.16	-0.05

DI- Disease infection
SMW - Standard meteorological week
T Min- Temperature minimum (morning, night)
T Max- Temperature maximum (afternoon, day)
RH Min - Relative humidity minimum (afternoon, day)
RH Max - Relative humidity maximum (morning, night)
HTR - Humid thermal ratio

Table 2: Agro meteorological model to forecast Ascochyta blight of chick pea

Model	Data series	Multiple regression equation	*MCC	F-Ratio
Multiple Linear Regression (12 parameters)	1985 - 2008	$Y = -0.26 - 0.0027 X_1 + 0.0006 X_2 + 0.006 X_3 - 0.002 X_4 + 0.015 X_5 + 0.0345 X_6 + 0.02 X_7 - 0.0017 X_8 - 0.34 X_9 + 0.0006 X_{10} - 0.03 X_{11} - 0.348 X_{12}$	0.88	6.17
Multiple Linear Regression (7 parameters)	1985 - 2008	$Y = 0.64 - 0.002 X_1 + 0.014 X_2 + 0.21 X_3 - 0.016 X_4 + 0.002 X_5 - 0.042 X_6 - 0.43 X_7$	0.74	6.25

*MCC = Multiple correlation coefficient

Equation 1
X_1 = Min RH (SMW 8,9,10)
X_2 = Min RH (SMW 14,16)
X_3 = Max RH (SMW 14,17)
X_4 = Max T (SMW 9, 10)
X_5 = Max T (SMW 14, 15, 16)
X_6 = Min T (SMW 8,9)
X_7 = Min T (SMW 12,14)
X_8 = Min T (SMW 16, 17)
X_9 = Sunshine hours (SMW 5 -10)
X_{10}= Rainfall (SMW 7-9)
X_{11} = NORD (SMW 7-10)
X_{12}= HTR (SMW 5-10)

Equation 2
X_1= Max T (9,10)
X_2= Min T (8,9)
X_3= Min T (12,14)
X_4= SSH (5-10)
X_5= Rainfall (7-9)
X_6= NORD (7-10)
X_7= HTR (SMW 5-10)

multiple linear regression, Exponential regression and Power regression were obtained from a data series of 24 years (1985 to 2008) but only Multiple linear regression presented best relationship as shown in Table 2.

The multiple linear models successfully accounted for 88 percent of total variation in ascochyta blight of chick pea with twelve weather parameters. Where as, with the removal of five parameters of the total twelve, the model showed 74 percent of variation in the disease. The analysis of variance proved that the models were highly significant at 1% level when its computed F-value of 6.17 and 6.25 (linear

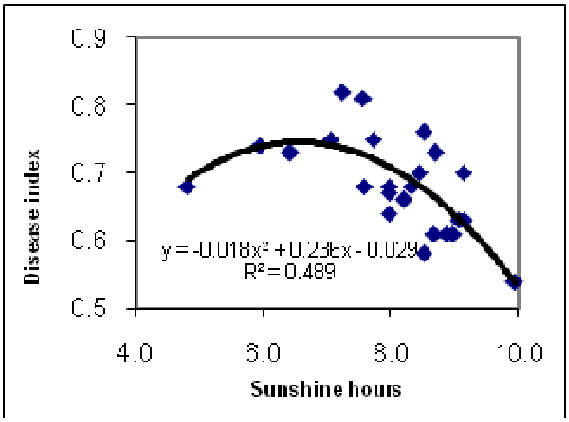

Fig. 1: Relationship between sunshine hours (SMW 5-10) and DI

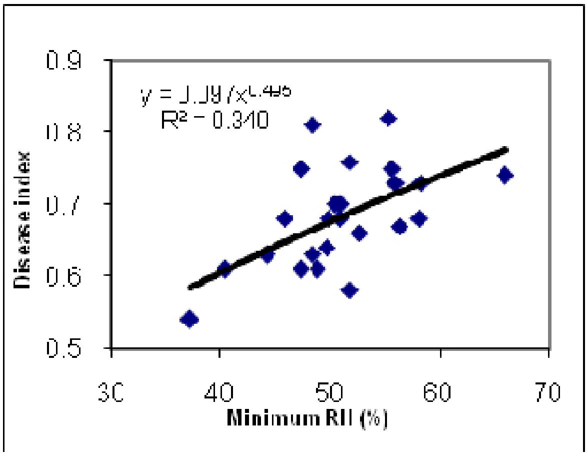

Fig. 2: Relationship between RHmin (SMW 7-9) and DI

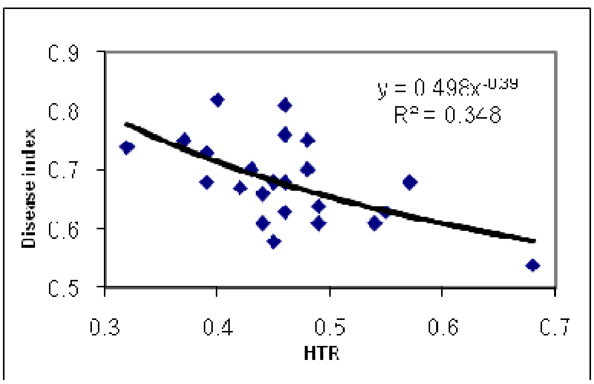

Fig. 3: Relationship between HTR (SMW 5-10) and disease index

regression) which was greater than the table value at 12 and 7 degrees of freedom, respectively.

The stepwise multiple regression relationship indicated that the best-fit model for disease prediction is equation number 1 with R^2 value of 0.88, which includes twelve parameters but equation number 2 with R^2 value 0.79 can also be used for disease prediction as it includes only seven parameters and simple to use. The curvilinear relation of disease index with sunshine hours, RHmin and HTR are presented un Fig. 1-3.

The epidemic window

During the maximum branching and beginning of reproductive phase the most highly correlated parameters in the longest window ie from 7th SMW to 10th SMW were selected for further processing. The period showed consistent correlations for the temperature afternoon (Tmax) and afternoon RH (RHmin), total rain fall and number of rainy days. Hence these parameters were considered for process for identification of epidemic window. In each year the averages of these four parameters were calculated between the 7th and 10th SMW, and the average values were correlated with DI to obtain aggregated coefficients for the whole window.

It was observed that Tmax was not contributing much individually in epidemic window. But when both afternoon parameters ie RHmin and Tmax were combined, these were found significantly correlated with DI. Hence, a ratio of these two parameters obtained as a single parameter referred to as humid thermal ratio (HTR) was calculated and the correlation coefficient between determined DI and HTR (Table 1).

The coefficient of variation between DI and minimum temperature (averaged from the 7th to 10th SMW) was –0.27, between DI and afternoon RH it was 0.28, between DI and rainfall was 0.23 and DI and rainy days was 0.24. Sunshine hours and HTR not shown in epidemic window but comes in the same period 5-10 SMW.

These results indicated maximum probability of disease in 7th-10th SMW when the crop was in the beginning of reproductive phase. For the timely disease management the first fungicidal spray could be given in 6th SMW, a week in advance to probability of disease occurrence and subsequent need based till 10th SMW covering the period 1st February to first fortnight of March. This will suppress disease out break if the conditions become suitable for disease in coming weeks.

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