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Effect of meteorological factors on the development of lentil stemphylium blight at different sowing dates in rampur, chitwan, Nepal

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ABSTRACT

Stemphylium species are pathogenic to a number of crops under broad geography and diverse environments. Stemphylium blight of lentil (*Lens culinaris* Medik) caused by *Stemphylium botryosum* Walr is becoming a serious emerging threat to lentil cultivation and become widespread throughout major legume growing areas in Nepal. Lentil was sown in different dates to observed incidence and severity of stemphylium blight in Rampur, Chitwan during two consecutive years 2012-2014. Lentil seeds sown up to middle of November escaped the disease severity and also resulted higher yield compared to other dates. Disease severity increased with the advancement of sowing date from November 1 to December 21 with decreased yields. The trends of disease development were similar in both years. The maximum and minimum temperatures, total rainfall and sunshine hour ranging from 22.42-24.23°C (mean 23.32°C), 4.12-13.00°C(mean 8.56°C), 9.6-30.5mm (mean 24.85mm) and 200.05-309.85 hour (mean 254.95 hour) respectively were favorable for disease development. A multiple linear regression model with temperature, rainfall and sunshine hours was developed to predict stemphylium blight disease severity on lentil plants.

INTRODUCTION

Stemphylium blight caused by *Stemphylium botryosum* Walr is the most important disease of lentil in Nepal (Joshi 2006; Gharti et al. 2008). It was first reported during 1993 in Nepal. The disease has become widespread throughout major lentil growing areas of the country (Bayaa et al. 1998). *Stemphylium botryosum* causes leaf blight on lentil that can result in large scale defoliation of plants. Preliminary studies in Bangladesh and India estimated yield losses of 62% and total crop failure have been reported in some cases where the disease defoliated the crop in the early pod setting stage (Bakr 1991; Erskine and Sarker 1997). In recent years, *Stemphylium* has been observed increasing in lentil fields in Banke, Bardia, Rupandehi, Chitwan, Nepalgunj, Makwanpur, Bara, Parsa and Rautahat districts (Joshi 2006). The initiation and development of plant disease is affected by environmental factors through their influence on host susceptibility, pathogen infectivity and the host-pathogen interaction (Agrios 2005; Campbell and Madden 1990). Lentil stemphylium blight incidence and development both is influenced by meteorological factors like temperature, humidity, rainfall and no. of cloudy days etc. (Bakr and Ahmed 1992). The precise effects of environmental factors on lentil stemphylium blight severity in the tropical and subtropical climate of Nepal has still to be explored, hence the present study was designed to study the epidemiology along with forecasting of disease severity at different sowing dates. Data obtained from this experiment were utilized to predict stemphylium blight development under diverse environments.

MATERIALS AND METHODS

The experiment was conducted in field following randomized complete block design with four replications during two winter seasons of 2012-2013 and 2013-2014. During lentil season of 2012-2013, a susceptible variety Shital was sown on 5 different dates, viz. November 6, 16, 26, December 6 and 16 in a unit plot size of 4m x 0.5m with 25cm

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row to row spacing. All procedures were similar except sowing dates, viz., November 1, 11, 21, December 1, 11 and 21 in a unit plot size of 4m x 2m during 2013-2014. After completion of the sowing, the experiment was kept under constant watch from sowing up to harvest. Agronomic practices were followed as recommended. Fertilizers @ 20:40:20 kg ha^{-1} (N:P:K) were applied as basal dose before sowing. The data on meteorological factors, such as atmospheric temperature, rainfall and sunshine hour with corresponding sowing dates were recorded from the meteorological station held at National Maize Research Program, Rampur, Chitwan in Nepal.

The disease data were recorded from 25 randomly tagged plants/plot on the basis of 1-9 scoring scale (Morrall and Mckenzie 1974).

1= No lesion visible (Highly resistant)
3= Few scattered lesions, usually visible after careful searching (Resistant)
5= Lesions common on plants and easily observed but defoliation and/ or damage not great, or in only one or two patches in plot (Moderately resistant)
7= Lesions very common and damaging (Susceptible)
9= Lesions extensive on all plants, defoliation and drying branches, and killing of some plants (Highly susceptible)

Percent Disease Index (PDI) was computed on the basis of recorded data according to the following formula (Wheeler 1969):

$$\mathrm{PDI} = \frac{\textbf{Sum of numerical values}}{\textbf{No of plant parts observed}} \times \frac{\textbf{100}}{\textbf{Maximum diseases rating}}$$

Data were recorded on yield and yield attributes.

All data were analyzed statistically using Microsoft Excel and MSTAT-C computer package program. Treatment means were compared using Least Significance Difference (LSD) and Duncan's Multiple Range Test (DMRT) at 5% significance level. Multiple linear regressions simplify the prediction methodology to allow for multiple predictor variables.The weather factors average maximum and minimum temperature in °C along with total rainfall (mm) and sunshine hours (hour) starting from two week prior to lentil flower initiation to two week post the days to more than 50% flowering were calculated and regressed against percent disease index (PDI). The multiple linear regression model used as follows;

$$y=\beta_0+\beta_1 w_1+\beta_2 w_2+\beta_3 w_3+\beta_4 w_4$$

Where y = *Response or dependant variable i.e. percent disease index (PDI)*
β_0=*Constant*
$\beta_{(1\text{-}4)}$ = Un-standardized coefficient for each predictor variables
w_1= Average maximum temperature in °C (2 weeks before and after flowering)
w_2 = Average minimum temperature in °C (2 weeks before and after flowering)
w_3 = Total rainfall in mm (2 weeks before and after flowering)
w_4 = Total sunshine hours (2 weeks before and after flowering)

RESULTS AND DISCUSSION

Disease development with relation to meteorological factors and different sowing dates

Percent Disease Index (PDI) and Yield both were significantly varied among the sowing dates at Rampur Chitwan condition during lentil season of 2012-2013. The lower PDI (40.65%) was recorded in the lentil plants sown on November 6 and the severity increased with the advancement of sowing dates, i.e. higher (65.77%) in lentil plots sown on December 16. The experimental plot sown on November 1 had higher yield (2025 kg ha^{-1}) followed by the plot sown on November 16. The lower yield (950 kg ha^{-1}) was obtained from the plot sown on December 16 (Table 1).

During the research period (2013-2014) also,

Table 1. Effect of sowing date and meteorological factors on Stemphylium blight severity and yield performance of lentil at Rampur, Chitwan during 2012/013

Sowing date	Meteorological observations (2 weeks prior and after the flowering)				PDI	Yield (kg ha^{-1})
	Avg. Max Temp (°C)	Avg. Min Temp (°C)	Total RF (mm)	Total SH hour		
6- Nov (2012)	22.30	3.51	9.60	241.50	40.65 ^{d†}	2025.00 ^{a†}
16- Nov (2012)	22.42	4.12	9.60	247.60	47.75 ^{c}	1213.00 ^{b}
26- Nov (2012)	24.38	5.72	9.60	309.85	50.22 ^{bc}	1188.00 ^{bc}
6 - Dec (2012)	24.23	5.36	9.60	226.05	54.25 ^{b}	1156.00 ^{bc}
16 - Dec (2012)	24.90	6.05	0.00	216.55	65.77 ^{a}	950.00 ^{c}
F-Test					**	**
LSD (≤0.05)					5.39	238.11
CV%					6.77	11.83
Cor. Coef. (r) with PDI	0.84	0.86	-0.85	-0.38		

† Means of 4 replication. Means in column with same superscript is not significantly different by LSD (P<0.05). Nov- November, Dec- December, Avg- Average, Max- Maximum, Min- Minimum, Temp- Temperature, RF- rainfall, SH- Sunshine Hour, PDI- Percent Disease Index, YIELD- Grain yield, Cor.- Correlation, Coef- Coefficient **- Highly Significant

Table 2. Influence of sowing date and meteorological factors on Stemphylium blight severity and yield performance of lentil at Rampur, Chitwan during 2013/014

Sowing date	Meteorological observations (2 weeks prior and after the flowering)				PDI	Yield (kg ha^{-1})
	Avg. Max Temp (°C)	Avg. Min Temp (°C)	Total RF (mm)	Total SH hour		
1-Nov (2013)	21.79	11.47	9.20	200.05	47.08 ^{d†}	962.50 ^{a†}
11 - Nov (2013)	21.89	11.57	28.30	212.50	50.72 ^{c}	837.50 ^{b}
21 - Nov (2013)	22.14	11.75	28.30	222.90	53.40 ^{c}	737.75 ^{c}
1-Dec (2013)	22.59	12.29	29.90	225.65	65.45 ^{b}	607.50 ^{d}
11 -Dec (2013)	22.99	12.64	30.50	214.80	66.92 ^{ab}	557.50 ^{e}
21 - Dec (2013)	23.36	13.00	21.30	229.00	69.10 ^{a}	318.75 ^{f}
F-Test					**	**
LSD (≤0.05)					2.86	44.18
CV%					3.23	4.36
Cor. Coef. (r) with PDI	0.96**	0.97**	0.46	0.73		

† Means of 4 replication. Means in column with same superscript is not significantly different by DMRT $_{(P<0.05)}$. Nov-November, Dec- December, Avg- Average, Max- Maximum, Min- Minimum, Temp- Temperature, RF- rainfall, SH-Sunshine Hour, PDI- Percent Disease Index, YIELD- Grain yield, Cor. Cor- Correlation, Coef- Coefficient **- Highly Significant

both the trends of disease development and yield were similar. The higher Percent Disease Index (PDI) was recorded on crops sown on December 21 (69.10%). The crop sown on November 1 had lower PDI (47.08%) followed by November 11. Yield was recorded higher in the plot sown on November 1, i.e. 962.50 kg ha^{-1}followed by November 11. The lower yield was found from the late sown plot December 21 (318.75 kg ha^{-1}) (Table 2).

The trends of disease incidence and its effect on yield were almost similar during the research period. Gradual increase in disease severity along with the advancement of sowing dates resulted in yield reduction. From the observations of two years study, it is clear that PDI was less in early sowing compared to that of late sowing. Sowing up to middle of November, lentil could escape the infection of stemphylium blight significantly and result in to increase in yield. The findings of the present study is in close agreement with the findings of Huq and Khan(2007), who reported that in the sowing of November 1, 10 and 20, lentil could escape the infection of Stemphylium blight and yield was also maximum in early sown crops. Time of sowing for any crop is a very important factor for growth and reproduction of plant pathogens. Lentil as winter crop is highly sensitive to variation of climatic conditions (Jain et al. 1987). This is one of the predisposing factors for building up of different diseases of a crop. Sowing time has marked effect upon the level of disease incidence where with the manipulation of sowing dates incidence of disease may be avoided (Hedge and Anahusor 1994). It is evident from the study that the incidence of Stemphylium blight (SB) could be avoided when lentil is sown early, i.e. within second week of November. This observation was in close agreement with that of (Gupta 1985), who reported that early sown crop suffered less whereas late sown crop suffered maximum because of inoculums pressure in the atmosphere. In mustard crop, progressive increase in infection rate and decrease in yield was found in delay sowing (Howlider et al. 1989), which is in close agreement of the present findings. Delayed sowing greatly increased the incidence of anthracnose of French beans (Sindhan and Bose 1981).

The average maximum and minimum temperature both were positively correlated (r = 0.84 & r = 0.86 respectively) and non-significant with the SB severity (PDI) at different sowing dates during crop season of 2012-2013. Similarly, the total rainfall and sunshine hours both were negatively correlated (r = - 0.85 & r = - 0.38 respectively) and non-significant with the SB disease development (PDI) recorded from different sowing dates during the crop season of 2012-2013 (Table 1).The development of stemphylium blight was low in early sowing crops (up to middle of November) and severity was increased with the advancement of sowing dates. The meteorological

Table 3. Parameters of PDI of lentil Stemphylium blight as affected by average atmospheric temperature (max & min °C), total rainfall (mm) and total sunshine hours

Parameter	Coefficients	SE	t -Stat	P-value	Lower 95% CI	Upper 95% CI
Intercept	-122.58	41.39	-2.96	0.03*	-223.86	-21.30
Avg. Max T (°C)	8.02	1.85	4.33	0.00**	3.48	12.55
Avg. Min T (°C)	1.18	0.79	1.49	0.19	-0.76	3.12
Total Rainfall (mm)	0.31	0.27	1.16	0.29	-0.35	0.97
Total sunshine hour	-0.09	0.07	-1.34	0.23	-0.27	0.08

Note: SE- Standard error, CI- Confidence interval, Avg.-Average, Max-Maximum, Min-Minimum, T- Temperature, (°C) – degree centigrade, mm- Millimeter, *- Significant, **- Highly significant

Table 4. Residual output of the PDI model

Sowing dates	Observed PDI	Predicted PDI	Residuals	Standard Residuals
6- Nov (2012)	40.65	40.41	0.24	0.06
16- Nov (2012)	47.75	41.52	6.23	1.58
26- Nov (2012)	50.22	53.21	-2.99	-0.76
6 - Dec (2012)	54.25	59.53	-5.28	-1.34
16 - Dec (2012)	65.77	63.61	2.16	0.55
1-Nov (2013)	47.08	49.53	-2.45	-0.62
11 - Nov (2013)	50.72	55.26	-4.54	-1.15
21 - Nov (2013)	53.40	56.49	-3.09	-0.78
1-Dec (2013)	65.45	60.97	4.48	1.14
11 -Dec (2013)	66.92	65.81	1.11	0.28
21 - Dec (2013)	69.10	64.97	4.13	1.05

Note: PDI- Percent Disease Index

factors average maximum temperature ranging from (24.38 – 24.90°C), average minimum temperature (5.72-6.05°C), total rainfall (9.6 mm) and total sunshine hour (216.55-309.85 hour) recorded during two weeks prior and after the flowering period of 2012/13 were favorable for the disease development (Table 1).

During the crop season 2013-2014 also, the average maximum and minimum temperature both were positively correlated ($r = 0.96$ & $r = 0.97$ respectively) and highly significant with the SB severity (PDI) at different sowing dates. Similarly, the total rainfall and sunshine hour both were also positively correlated ($r = 046$ & $r = 0.73$ respectively) and non-significant with the SB disease development (PDI) recorded from different sowing dates (Table 2). The meteorological factors average maximum temperature ranging from (21.89 – 23.36 °C), average minimum temperature (11.57-13.00 °C), total rainfall (9.2-30.50 mm) and total sunshine hour (212.50-229.00 hour) recorded during two weeks prior and after the flowering period of 2013-2014 were favorable for the disease development (Table 2).

The result from present study is in accordance with the observations from north-eastern India showed that 18 ± 2°C temperature, 85 to 90% relative humidity (RH) in the morning and more than 50% RH in the afternoon as well as less than 7.7 hour of sunshine per day were considered favorable for stemphylium blight development in winter growing lentil (Sinha and Singh 1993). Similar experiments from Bangladesh also indicated that prevailing higher relative humidity because of periodic rainfall and ambient temperature during crop season (November 01-December 30) were responsible for appearance and development of stemphylium blight of lentil (Huq and Khan 2008)

Percent disease index (PDI) model

The multiple linear regression based PDI model for forecasting of lentil stemphylium blight outbreaks in low lying, humid and subtropical climate of Chitwan, Nepal was as follows;

PDI = -122.58 + 8.02 Avg. Max. T (°C) + 1.17 Avg. Min. T (°C) + 0.31 Total Rainfall (mm) - 0.09 Total Sunshine hours

This forecasting model relies on temperature, rainfall and sunshine hours to assign PDI value. This model has an adjusted R^2 value of 0.72, root mean square error (RMSE) value is 3.73 and residual standard error is 5.08 (n=11). The P-value for the full model is 0.02 which is small enough at 5% level of significance to suggest that at least one of the predictor variables may be useful for the prediction. The adjusted R^2 is 0.72 which indicates that the predictor variables explain 72% of the variance in the response variable (Figure 1).

The model summary, regression coefficients and residual outputs are shown in table 3 and table 4. The meteorological parameters recorded and correlated with disease development, in two years indicated that the average maximum and minimum temperatures, total rainfall and sunshine hour ranging from 22.42-24.23°C (mean 23.32°C), 4.12-13.00°C (mean 8.56°C), 9.6-30.5mm (mean 24.85mm) and 200.05-309.85 hour (mean 254.95 hour) respectively were favorable for disease development.

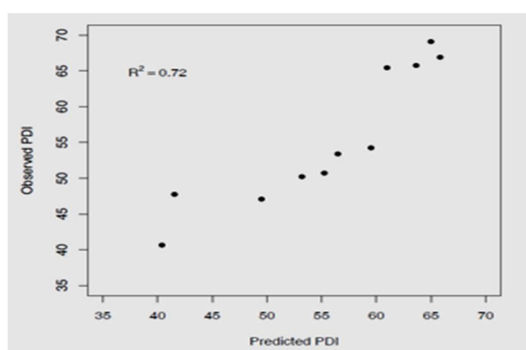

Figure 1. Observed versus Predicted PDI of lentil Stemphylium blight as affected by meteorological factors at different sowing dates in Rampur, Chitwan, Nepal 2012/14.

The goal of multiple linear regressions may be accurate prediction or the regression coefficients may also be of direct interest themselves (Maindonald and Braun 2003). In agricultural sciences, several models were developed for plant disease forecasting. However, forecasting models for lentil stemphylium blight are very few. In the present study, meteorological parameters were correlated with lentil stemphylium blight severity (PDI) and a multiple linear regression model was developed and validated with available data. We can use this model to predict the seasonal risk of SB disease on lentil by using meteorological factors. The model helped to find out the SB disease severity in different sowing dates on lentil at tropical and subtropical climatic conditions. Studies of other predictive models for *Stemphylium* spp. have demonstrated similar results to the findings in the present work. The predictive models such as BSPCast (Llorente et al. 2000), FAST (Montesinos and Vilardell 1992) and TOMCast (Meyer et al. 2000) recognized the importance of temperature and leaf wetness duration on disease severity and have been used successfully in timely scheduling of fungicide applications. This model simulates the severity of SB disease in lentil crop based on sowing date, flowering period and daily weather and useful to understand the disease importance on yield loss of crop.

CONCLUSION

The findings of two consecutive years (2012-2014) showed almost similar trends regarding yield and disease severity. It was noted that yield was decreased with increase in PDI. From this study, it is clear that PDI was less in early sowing compared to that of late sowing of lentil. In the sowing up to second week of November, lentil could escape the infection of Stemphylium blight significantly and resulted in to increase in yield. The severity increased with the advancement of sowing date from November 1 to December 21. The lentil yield was decreased with the progression of sowing dates. Lentil seed sown up to middle of November escaped the chances of attack of SB with higher yield. Thus, it is recommended that lentil should be sown as early as possible in November for maximum yield with the reduction of disease severity significantly. This study is also useful for the prediction of lentil stemphylium blight disease severity in different sowing dates of low lying, humid and subtropical climate of Nepal.

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