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# FORECASTING MODELS OF YIELD LOSS AND ALTERNARIA BLIGHT SEVERITY FOR INDIAN MUSTARD

KARUNA FAUJDAR and ANIL PRASAD MATHUR
Department of Botany, M.S.J Govt. P.G. College, Bhratpur-321001, Rajathan, India.

Indian mustard, an important oilseed crop of India, is ravaged by a number of diseases, Alternaria blight being one of them. The Alternaria blight caused by *Alternaria brassicae* and *A. brassicicola* has been reported from almost every continent of the world on oilseeds Brassica. Alternaria blight might be responsible for 10-70 per cent average yield losses in rapeseed - mustard depending upon prevailing weather and disease situation. Experiments laid out at location Bharatpur. Yield loss and severity of disease on leaf and pod at crop age were forecasted for variety cv. Varuna and Rohini by stepwise regression method. On pod, data revealed that for this location and variety age at first appearance of disease severity remained 90-120 days after sowing (d.a.s) and due to age at peak disease severity yield losses remained 21-53%. Peak disease severity remained 98-120 d.a.s. and on pod disease severity appeared 115-130 d.a.s. Due to appearance of disease in its peak form 115-130 d.a.s. yield losses remained 22-50%. Highest disease severity percentage forecasted was 1.4-45% on leaf and pod yield loss remained 5-60%. It was possible to provide the forecast in public interest at least one week prior to first appearance of disease, which allows farmers to either avoid fungicidal spray or make timely and effective prophylactic sprays. This could thereby reduce unwanted fungicidal load on the crop.

**Keyword :** Chlorotic lesion; Epidemic; Forcasting; Meterological observatory; Severity.

## Introduction

Rapeseed-Mustard are members of Cruciferae family that have been cultivated since 5000 BC in South and East Asia. It is now widely used as edible oil in human consumption and as an important source of protein for animal feed. Rapeseed-Mustard is among the major oilseed crops cultivated in India and around the world. Alternaria blight disease caused by *Alternaria brassicae* (Berk.) Sacc., damages arial plant part with visible symptoms of infection such as chlorotic and necrotic lesion on the leaf, petiole, stem, inflorescence, silique and seed[1]. In India Alternaria blight is reported to be responsible for 10-70 percent losses, depending upon weather condition during later part of crop growth[2]. In addition to direct losses, Alternaria blight can lower seed quality by reducing seed size causing discoloration and reduction in yield content[3]. Total reduction in crop due to disease is 5-15% and reaches up to 47%[4]. Fungicides remain the only effective means to manage the disease[5]. Despite high consumption of fungicides on rapeseed-mustard crops in India[6], timing their application has not been optimal. Crops requiring treatment have been left unsprayed and others sprayed unnecessarily.

Efficient, economical and environment friendly control of the blight may be obtained through knowledge of its timing of attack in relation to weather factors, which may enable prediction of its occurrence so as to allow growers to take timely action in an efficient manner for disease management. Weather is an exceptionally important factor in the severity of Alternaria blight of oilseed *Brassica juncea* and *Brassica rapa*[7-10]. Correlation study of the data revealed that Alternaria blight severity on leaves and pods of the plant was positively correlated with maximum daily temperature and morning Rh[11]. Accurate forecast of the crop age at first appearance of the disease and the risk of a blight epidemic would enable farmers to decide on optimum timing of fungicide sprays and to avoid unnecessary pesticide application. Hence, the present study was undertaken to develop forecasts for crop age at time of first appearance of Alternaria blight, for crop age when blight severity is maximum and for highest severity of the blight on the crop in the season.

## Material and Method

All field experiments and data analysis were conducted in Plant Pathology Laboratory of the Directorate of Rapeseed-Mustard Research (DRMR), erstwhile National Research Centre on Rapeseed Mustard (NRCRM), ICAR, Sewar, Bharatpur (Rajasthan) to study forecasting of Alternaria blight and yield loss assessment *vis-a-vis* yield in rapeseed-mustard. Weather data [maximum temperature, minimum temperature, relative humidity (Rh) morning, afternoon] and Alternaria blight disease severity (on leaf, pod) were taken from the reports of All India Co-ordinated Research Project on Rapeseed-Mustard (AICRP-RM) and Sub - project Mission Mode III-17 of National Agricultural Technology Project for locations Bharatpur on *Brassica juncea* (cv. Varuna, Rohini). Bharatpur is located at 27°15'N latitude and 77°30' E longitude. Temperature and relative humidity were recorded from standard meteorological observatory at location DRMR Sewar, Bharatpur.

*Year and varieties*-Five-year data (disease and weather) from-2001-02, 02-03, 03-04, 04-05, 05-06) were used for model development and last two year data 2006-07, 07-08 were used in validation of developed model.

*Data used in mdoel development-*

1. Weather data-maximum temperature, minimum temperature, relative humidity (Rh) morning, afternoon.
2. Yield data.
3. Alternaria blight severity (leaf, pod).

**Observation**

Initial date of Alternaria blight appearance in each plot and disease progress recorded from 10-tagged plants. Disease progress recorded randomly in experimental plot for percent disease severity (PDS) twice a week (Tuesday, Friday) till harvest on leaves, pods following scale of Conn *et al.*[12].

*Software used for development of model for disease severity and yield loss*-Weather and disease data were analyzed statistically for development of forecasting models (disease severity and yield loss assessment) by using statistical software .

Weather data (maximum temperature, minimum temperature, and Rh morning, Rh afternoon) was taken from 40th Sandard Meterological Week (SMW) from sowing to week when disease severity reached its peak.

The weekly average of disease data were calculated from 40th SMW (from sowing) to week when disease severity reached its peak for development of models.

SPSS Version 15 and 17 available at DRMR, Bharatpur. Stepwise regression method was used for development of forcasting model for disease severity and yield loss.

*Stepwise regression method-* In regression method to identify the boundary and optimum condition that affect the dependent variable (disease severity) on leaf and pod, different range of weather variables (one week preceding the assessment date) were used as independent variables. By regression method correlation of independent variable (weather parameter) and dependent variable (disease severity) for forecasting age at first appearance, age at peak disease severity and highest severity percentage on leaf and pod were studied. Linear prediction model based on weather parameter (independent variables) forecasted the dependent variables, *viz.*, the crop age at first appearance of disease (leaves and pod), crop age at highest severity of disease (on leaves and pods) in the season and highest disease severity in the season. These independent variables and dependent variable were fitted by multiple stepwise regressions using data of initial 5 years.

Based on correlation coefficient between dependent variable under study with the respective weather parameter (i) for different weeks, a composite weather variable ($z_i$) was developed as the weighted sum of the weather variable for different weeks starting from pre-sowing week up to the week of prediction. Similarly interaction term ($z_{ij}$) were developed as weighted sums of the product between two weather variables, weights being correlation coefficient of the dependent variable under study with the product of weather variables in respective weeks.

Model were developed in the following format-

$$Y = a_0 + \sum_{i=1}^{p} a_i z_i + \sum_{i \# j}^{p} b_{ij} z_{ij} + e$$

$$= a_0 + a_1 z_1 + a_2 z_2 + a_6 z_6 + b_{12} z_{12} + \ldots + b_{56} z_{56} + e$$

where,

$$Z_i = \sum_{W=1}^{f} r_{iw} x_{iw}$$

$$Z_{ij} = \sum_{W=1}^{f} r_{ijw} x_{iw} x_{jw}$$

with y depicting highest percent disease severity, $x_{iw}$ is value of i-th weather parameter in w-th week, $r_{iw}$ is value of correlation coefficient between yield and i-th weather parameter in w-th week, $r_{ijw}$ is correlation coefficient between y and product of $x_i$ and $x_j$ in w-th week, p is number of weather variable, f is week of prediction and e is error term.

For this location initial 5 year data was processed by regression method to forecast the targeted parameters *viz.*, crop age at first appearance of the disease, crop age at peak severity and highest disease severity on crop leaves and pods in the crop season. Set of last two-year data of independent variable (weather parameter) were used to test the performance of the model.

Chi square test was done to assess the models. $R^2$ values of all the models (if above 0.50) proved fitness of the models. Correlation pattern of highest PDS (percent disease severity) with weather variables was studied.

*Data analysis*-Disease severity on leaf was comparatively more affected by temperature (maximum and minimum) than relative humidity (morning and afternoon). Maximum temperature played greater role in disease development than minimum temperature. Rh morning seemed to have a greater role in disease development compared to Rh afternoon. Dual interaction of Rh morning and maximum temperature seemed to have a greater role in disease development compared to Rh afternoon and minimum temperature.

*Stepwise regression method for yield loss assessment*-For development of yield loss assessment model highest severity (on leaf and pod) was used as independent variable and yield data was used as dependent variable for the location and variety of *Brassica juncea.* Regression model (yield loss) was based on correlation coefficients i (disease severity) and j (yield data). Using i (disease severity) for different weeks a composite disease variable ($z_i$) was developed as weighted sum of the disease severity (highest severity) in different weeks starting from first appearance of disease to the week of peak appearance of the disease on crop (leaf and pod).

By using i and j parameters interaction terms ($z_{ij}$) were developed. $Z_{ij}$ is weighted sum of product of disease variables and dependent variable (yield). The interaction of disease severity with yield was found to be significant. The model was developed in the following format:

$$Y = a_0 + \sum_{i=1}^{p} a_i z_i + \sum_{i \# j}^{p} b_{ij} z_{ij} + e$$

$$= a_0 + a_1 z_1 + a_2 z_2 + a_6 z_6 + b_{12} z_{12} + \ldots + b_{56} z_{56} + e$$

where

$$Z_i = \sum_{W=1}^{f} r_{iw} x_{iw}$$

$$Z_{ij} = \sum_{W=1}^{f} r_{ijw} x_{iw} x_{jw}$$

Y = dependent variable

$r_{iw}$ = value of severity at its peak

$X_{iw}$ = the value of coordination coefficient between y and ith severity data in wth week.

$r_{iyw}$ the coordination coefficient between y and product at $x_i$ and $x_y$ with in week p=the number of weather variable

$a_0$ = intercept

a and b regression coefficient

e = error

The models have been tested keeping in view the normal date of sowing in the farmers' field for the location Bharatpur (22 Oct). Effect of disease severity (on leaf and pod) on crop yield was studied by this method. Correlation patterns of highest PDS (percent disease severity) with yield were studied. Yield loss was calculated comparing the predicted yield value with the normal value of yield.

*Results from Regression model for Alternaria blight disease severity forecasting and yield loss assessment (due to Alternaria blight)*- Incidence of disease and appearance of disease (on leaf and pod) was forecasted one week prior from first appearance of disease on crop. The forecast value of age at first appearance, age at peak severity, the highest severity percentage and yield loss was provided by this model. This could help growers to do timely disease management, avoid unwanted spray of fungicide and save their money. The models so developed were able to provide yield loss percent due to incidence of disease severity in each crop season.

**Regression model for forecasting of Alternaria blight disease severity (on leaf) (Table 1)**

*Observed and forecasted values of crop age at first appearance of Alternaria blight disease*-At Bharatpur for variety Varuna it was observed that first appearance of disease occurred at 67 d.a.s. and predicted value of first appearance of disease severity remained 78 d.a.s. $R^2$ value was 0.92 and difference between observed and predicted values was not significant. For Rohini it was observed that first appearance of disease occurred 75 d.a.s and predicted value of first appearance of disease severity remained 74 d.a.s.on leaves. $R^2$ value was 0.80 and difference between observed and predicted values was not significant (Table 1).

*Observed and forecasted values of crop age at peak appearance of* Alternaria blight *disease severity.*-At Bharatpur for variety Varuna it was observed that age at peak disease severity of occurred 120 d.a.s. and predicted value of age at peak disease severity remained 98 d.a.s. $R^2$ value was 0.88 and difference between observed and predicted values was not significant. For Rohini it was observed that age at peak disease severity occurred 121 d.a.s. and predicted value of age at peak disease severity remained 98 d.a.s on leaf. $R^2$ value was 0.88 and difference between observed and predicted values was not significant.

*Observed and forecasted values of highest disease severity percentage of Alternaria blight disease severity* -At location Bharatpur for variety Varuna, it was observed that highest disease severity percentage occurred 20.4% and predicted value of highest disease severity percentage remained 11%. $R^2$ value was 0.38 and difference between

**Table 1. Models to forescast age of crop at first appearance of Alternaria blight (AB) on leaf, age of crop at highest Alternaria blight severity on leaf and highest Alternaria blight severity on leaf in season at Bharatpur and their validation.**

| Parameters predicted | Cultivars | Crop age (week) of prediction | Model | $R^2$ | Test of models P | Test of models O (ANN) | Test of models O |
|---|---|---|---|---|---|---|---|
| Age of crop first appearance | Varuna | 12 | $Y = -222.9 + 4.43Z_{\text{min temp} \times \text{max temp u}} - 0.14Z_{\text{max temp u}} + 3.61Z_{\text{max temp w}} + 2.38Z_{\text{Rh mor w}}$ | 0.63 | 126 | | 116 |
| | Rohini | 9 | $Y = 152.03 + 6.34Z_{\text{max temp} \times \text{min temp w}} + 0.35Z_{\text{max temp w}} + 0.59Z_{\text{Rh mor w}}$ | 0.22 | 89 | 99 | 106 |
| Age of crop at highest severity of | Varuna | 14 | $Y = 362.9 - 0.58Z_{\text{RH mor u}} - 0.02Z_{\text{max temp} \times \text{Rh mor u}} - 2.15Z_{\text{max temp w}} + 0.08Z_{\text{max temp} \times \text{Rh mor w}}$ | 0.76 | 133 | 142 | 143 |
| | Rohini | 13 | $Y = 87.1 - 0.01Z_{\text{min temp} \times \text{Rh aft u}} + 0.01Z_{\text{min temp} \times \text{Rh mor w}} + 0.84Z_{\text{min temp} \times \text{Rh aft w}}$ | 0.40 | 118 | 129 | 133 |
| Highest AB severity | Varuna | 14 | $Y = 36.11 + 0.08Z_{\text{Rh mor w}}$ | 0.60 | 1.4 | 4.4 | 7.1 |
| | Rohini | 13 | $Y = 26.94 + 0.06Z_{\text{Rh mor w}} + 0.001Z_{\text{min temp} \times \text{Rh aft w}}$ | 0.63 | 2.6 | 3.5 | 7.2 |

**Table 2. Models to forescast age of crop at first appearance of Alternaria blight on pod, age of crop at highest Alternaria blight severity on pod and highest Alternaria blight severity on pod in season at Bharatpur and their validation.**

| Parameters predicted | Cultivars | Crop age (week) of prediction | Model | $R^2$ | Test of models P | Test of models O (ANN) | Test of models O |
|---|---|---|---|---|---|---|---|
| Age of crop first appearance of AB | Varuna | 7 | $Y = 87.51 + 0.06Z_{\text{max temp} \times \text{min temp w}} + 0.007Z_{\text{Rh mor} \times \text{Rh aft w}} + 0.003Z_{\text{Rh mor} \times \text{Rh aft u}} - 2.23Z_{\text{min temp w}}$ | 0.92 | 77 | 78 | 67 |
| | Rohini | 7 | $Y = 154.32 - 0.41Z_{\text{max temp u}} - 2.008Z_{\text{min temp u}} + 0.002Z_{\text{Rh mor} \times \text{Rh aft u}} + 0.08Z_{\text{max temp} \times \text{min temp w}} + 0.005Z_{\text{Rh mor} \times \text{Rh aft w}}$ | 0.80 | 77 | 81 | 74 |
| Age of crop at highest severity of AB | Varuna | 10 | $Y = 7.83 + 0.54Z_{\text{max temp w}} + 0.005Z_{\text{min temp} \times \text{Rh mor w}}$ | 0.88 | 98 | 125 | 120 |
| | Rohini | 9 | $Y = -46.12 + 0.001Z_{\text{Rh mor} \times \text{Rh aft u}} + 1.04Z_{\text{max temp w}} + 0.03Z_{\text{max temp} \times \text{Rh aft w}}$ | 0.88 | 98 | 95 | 121 |
| Highest AB severity | Varuna | 10 | $Y = -4.68 + 0.34Z_{\text{max temp w}}$ | 0.38 | 11 | 12.6 | 20.4 |
| | Rohini | 9 | $Y = 7.59 + 0.005Z_{\text{min temp} \times \text{Rh mor w}}$ | 0.20 | 12 | 17 | 18.6 |

Table3. Regression Model to forecast yield loss due to highest severity percentage (predicted) at Berhampur and Dholi on pod

| Locaton | Cultivars | Highest severity | | Crop age (weak) of prediction | Model | $R^2$ | Yeild | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | O | P | | | | O | P | s.v.y. | y.l.p. |
| Bharatpur | Varuna | 7.1 | 1.4 | 12 | Y=2052.6 -32.3*S | 0.39 | 1883 | 1853 | 2100 | 11 |
| | | 0 | 1.2 | 11 | | | 1826 | 1813 | 2100 | 13 |
| | Rohini | 7.2 | 2.6 | 12 | Y = 1886 -4.4*S | 0.42 | 1989 | 2345 | 2500 | 10 |
| | | | | 12 | | | 1826 | 1773 | 2500 | 29 |

S = Severity; O = observed; P= Predicted ; s.v.y = standard value of yield (kg/ha); y.l.p. = yield loss percentage.

observed and predicted values was significant. For variety Rohini it was observed that highest disease severity percentage occurred was 18.6% and predicted value of highest disease severity percentage remained 12% on leaf. $R^2$ value was 0.20 and difference between observed and predicted values was significant.

*Regression model for forecasting of Alternaria blight disease severity (on pod)-* It is concluded that disease severity and yield are positively correlated. Dual interaction among minimum temperature and morning Rh up to 9th week after sowing increased PDS. Occurrence of disease in crop on pod at earlier stage influenced the yield.

*Observed and forecasted values of crop age at first appearance of Alternaria blight disease severity-*At location Bharatpur for variety Varuna it was observed that first appearance of disease severity was 116 d.a.s. and predicted value of first appearance of disease severity remained 126 d.a.s. $R^2$ value was 0.63 and difference between observed and predicted values was not significant. In cv. Rohini it was observed that first appearance of disease severity was 106 d.a.s. and predicted value of first appearance of disease severity remained 89 d.a.s. $R^2$ value was 0.22 and difference between observed and predicted values was significant (Table 2)..

*Observed and forecasted values of crop age at peak appearance of Alternaria blight severity (on pod)-*At location Bharatpur, for variety Rohini, it was observed that peak appearance of disease severity was 133 d.a.s. and it was predicted that disease reached its peak form 118 d.a.s. $R^2$ value was 0.40 and difference between observed and predicted values was significant. In variety Varuna it was observed that peak appearance of disease severity occurred 143 d.a.s. and it was predicted that disease reached its peak form 133 d.a.s. $R^2$ value was 0.76 and difference between observed and predicted values was not significant.

*Observed and forecasted values of highest severity percentage of Alternaria blight on pod-*At location Bharatpur for variety Varuna it was observed that highest disease severity percentage of disease occurred 7.1% and it was forecasted that highest disease severity percentage remained 1.4%. $R^2$ value was 0.60 and difference between observed and predicted values was significant. In variety Rohini at Bharatpur it was observed that highest disease severity percentage of disease was 7.2% and it was forecasted that highest disease severity percentage remained 2.6%. $R^2$ value was 0.63 and difference between observed and predicted values was not significant. Chi square value for both Varuna and Rohini was above 0.50, which is significant.

*Yield loss prediction model and Yield loss assumption by predicted value of highest severity of Alternaria blight on pod-*At location Bharatpur for variety Varuna it was observed that highest disease severity percentage was 7.1% and yield was 1883 kg/ha and predicted value of highest disease severity percentage was 1.4% and due to this yield forecasted was 1853 kg/ha. Yield loss remained 11%. $R^2$ value was 0.39 and difference between observed and predicted values was significant. In variety Rohini, at Bharatpur, it was observed that highest disease severity percentage was 7.2% and yield was 1989 kg/ha and predicted value of highest disease severity percentage remained 2.6% and due to this yield forecasted was 2345 kg/ha. Yield loss forecasted was 10%. $R^2$ value was 0.42 and difference between observed and predicted values was significant. Chi square value for both Varuna and Rohini was below 0.50, which is significant (Table 3).

**Discusion**

Susceptibility of Alternaria blight severity increases with the age of the plant and disease become more severe in the later stage of crop growth and disease appear in its severe form in 10th week after sowing. Our results from regression model were similar with findings of Chahal and Kang[13] and Sarkar and Sengupta[14], that high temperature and Rh appear more important factor for spread of Alternaria blight infection on pods and disease appeared in severe form after mid of January.

The regression model revealed that disease appears mostly 3 week after the sowing of the crop and reach its peak in s10 week after sowing and results revealed that in variety Varuna disease appear much earlier than Rohini. Disease appeared in peak form when maximum temprature was about 15-20$^0$C and Rh was 85-90% and disease severity progress declined in February. Results from regression model revealed that disease severity appeared mostly during Ist week of December to 2nd week of February and peak severity of disease appeared mostly in 2nd week of January to 3rd week of January depending on variety and location. Present investigations from regression model match with findings of Meena *et al.*[15] and Sinha *et al.*[16], that on leaf for this location and variety first appearance of disease occurred 70-80 d.a.s. Fungicidal spray should be sprinkled according to forecasted value of first appearance of disease (70 d.a.s), so that yield losses remain minimum. The results from regression model matched with earlier findings and assumed that spray and other control devices could be used at 45, 60, 90, 120 d.a.s. so that disease did not reach at its peak form and yield loss remain minimum.

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