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Stochastic Models of Yield Loss and Alternaria Blight Severity for Indian Mustard

Abstract

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 stochastic method. On leaf, data revealed that for this location and variety age at first appearance of disease severity remained 55-70 days after sowing (d.a.s.) and due to age at first disease severity yield losses remained 2.5-4%. On pod disease severity appeared 85-100 d.a.s. Due to appearance of disease in its peak from 110-120 d.a.s. yield losses remained 18-40%. 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.

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Introduction

Rapeseed-Mustard are members of Cruciferae family that have been cultivated since 500 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, clique and seed (Verma *et al.* (1994) . In India Alternaria blight is reported to be responsible for 10-70 percent losses, depending upon weather condition during later part of crop growth (Kolte (1995). In addition to direct losses Alternaria blight can lower seed quality by reducing seed size causing discoloration and reduction in yield content (Kaushik *et al.* (1984). Total reduction in crop due to disease is 5-15% and reaches up to 47% (Kolte et al. (1987). Fungicides remain the only effective means to manage the disease (Chattopadhyay *et al.* (1984). Despite high consumption of fungicides on rapeseed-mustard crops in India (IASRI (2002), timing their application has not been optimal. Crops requiring treatment have been left unsprayed and other 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 Alternanria blight of oilseed Brassica juncea and Brassica rapa [Saharan *et al*. (1984), Sinha *et al*. (1992), Awasthi et al. (1994), Dang et al. (1995)]. 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 (Chattopadhyaya (2005). 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.

Aim of the Study

Hence, the present study was done for development of forecast model for crop age at time of first appearance of Alternaria blight on leaf and pod to decide the actual time of spray of fungicide on crop.

Review of the Literature

Effect of initial epidermis conditions, sporulation rate, and spore dispersal gradient on the spatio-temporal dynamics of plant disease epidemics were used for model development in downy mildew of radish (Fink and Kofoet, 2005). Data can be used in stochastic models to predict maize potential productivity under different dates of sowing. The daily average value of temperature (from 1917 to 2002) and global solar radiation (from 1978 to 2002) were used. Statistical performance index was used to compare observed and simulated data. Nonlinear stochastic model for population growth proposes a novel nonlinear deterministic model for aphid abundance (James et al., 2005).

Development, progress and correlation of Alternaria leaf blight with environmental conditions were studied on different rapeseed-mustard cultivars during the 1988, 1989 and 1990 crop seasons at Hissar. The results revealed that cumulative increase was significant among the years, cultivars and observation intervals.The maximum increase in Alternaria blight was recorded on yellow sarson (YSPb-24) and brown sarson (BSH-1), however, the progress was least on mustard cv. RH-8113. Higher R^2 values showed that variation can be explained up to 58-69% with combined effect of temperature and wind velocity. A forecasting scheme for dark pod spot would also need to incorporate factors for inoculums concentration (Humpherson – Jones and Phelps, 1989) and pod growth stage which are both likely to effect disease development (Hong and Fitt, 1996). Temperature and wetness period greatly affected the development of dark leaf and pod spot on oilseed rape (Mirdha and Wheeler, 1993). The entire growing period of Indian mustard was divided into 4 phases. Linear models were developed for each phase. Forecasting of yield using these models could be done in every phase (Amrender Kumar and Bhar, 2005).

Fungicides are reported to be able to control the disease. (Chattopadhyaya and Bagchi, 1994). Foliar application at the two critical plant growth stages identified 45 and 75 d.a.s. seemed to be the best option for mustard. (Meena et al. 2004). Spraying from 30 Dec. to 15 January continued up to 15 February gave a very low intensity of the disease and highest seed yield per plot (Munde and Bhowmik, 1984). Critical period for disease development in the foliage was from 2nd week of December to 3rd week of January. During this period disease appeared in severe form in the both leaf and pod causing heavy damage.(Mirdha and Wheeler 1993, Hong and fit 1995, Ansari et al., 1989). After the 2nd week of February there was no increase in the disease severity this may have been due to gradual decline in relative humidity and rise in temperature (Humpherson Jones and Phelps 1989, Mirdha and Wheeler 1993).

Concepts and Hypothesis (Method Stochastic Model)

By stochastic model age at first appearance was forecasted using weather and disease severity data on leaf and pod. Before model development these weather and disease data were modified for sowing date 22 Oct. (Bharatpur).

Weekly average of daily weather data (Maximum temperature, Minimum temperature, morning relative humidity, and afternoon relative humidity) was calculated. This weekly average of weather data was used in model development. Average of disease data was also done on leaf and pod (reported two times in s week). Different range of weather variable of one week preceding the assessment date were used as independent variable to identify the boundary and favourable conditions that positively influence the dependent variables or disease severity (age at first appearance) on leaf and pod through stochastic analysis. Weather parameter (weekly average) was used as independent variable and age at first appearance data were used as dependent variable.Output of R^2 value gives the model fitness. Actual time of spray (in the format of t value) was obtained from the model. The response of the developed model can be experience or reported in the form of value of a, b, d (parameters estimated). Similarity of value of a, b,d parameters with each other for different year prove the fitness of model.

The Alternaria blight severity on crop of mustard at a time to be noted by N (t).The severity of Alternaria blight on crop increases dramatically subsequently. The reason for this is that Alternaria blight on mustard causes heavy losses in yield/ha.

Nonliner dependence between weather parameter and Alternaria blight appearance on mustard crop is assumed.

This can be pressed as

$N(t) = ae^{-bt}(1+de^{-bt})^{-2}+e$

Or

$N(t) = ae^{(bt+dtxt)}+e$

This model was found suitable for forecasting of first appearance of Alternaria blight severity on mustard crop.

Hence, it may be concluded that the model provided a good fit to all the data sets for locations (Bharatpur) varieties of Brassica juncea (cv. Varuna, Rohini.

As an application of the model, optimum time for fungicidal spray can be determined. Evidently fungicides should be sprayed when the rate of severity of the disease i.e. dn/dt is maximum. It may be noticed that, for all the data set, the estimates of the parameters d are very large as compared to that of b. Therefore, for the present data set, an approximation to the optimum time of fungicidal spray can be taken as

$T=b^{-1}$ 1nd

So by the help of stochastic model we can assume age of first appearance of disease on crop and actual time of spray of fungicide on mustard crop is obtained in the form of t value).

Fitting the Model to Data

Weather parameter, disease data of age at first appearance from 4-7 years were used for development of stochastic model. Weather parameter were used as independent variable and disease data as dependent variable :

$yt = ae^{(bt+dt \times t)} + e$

This equation represents a non-linear stochastic model, which was used for forecasting age at first appearance of Alternaria blight on crop.

Age of first appearance of disease severity on leaf and pod was predicted for different years and compared with observed value of age of first appearance of disease severity on leaf and pod. Close similarity of observed and predicted value and chi square test value conclude that the model has a goodness of fit. The output value of a, b, d parameter for each year (which were used) were used for fitness of model for location Bharatpur. Values of a, b, d parameter totalized and comprised for each year. Similarity of values of a, b, d parameters with each year prove the model fitness. Actual time of spray was calculated in the form –

Obtaining b and d value for each year separately from the value obtained by using stochastic model on the disease and weather data, t value or actual time of fungicidal spray on crop is calculated, which allow growers to make timely disease management and avoid unnecessary spray on the crop so that it is ecofriendly to farmers.

Research Design

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-à-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-Mustarc (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 $27^0$15'N latitude and $77^0$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, 07-80 were used in validation of developed model.

Data used in Model 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 progress recorded from 10-tagged plants. I 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. (1990).

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 40^{th} Standard Meteorological Week (SMW) from sowing to week when disease severity reached its peak.

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

SPSS Version 15 and 17 available at DRMR, Bharatpur.

Observed and Forecasted Values of Crop Age at First Appearance of Disease Severity at Bharatpur for Variety Varuna on Leaf

Table-1

Observed and Predicted age at First Appearance of Disease on Leaves is Given

Year	2001-02	02-03	03-04	04-05	05-06	06-07	07-08
Observed	84	76	55	55	59	77	69
Predicted	75	78	65	69	76	70	72

By the examination of predicated and observed value from the table we noted that observed and predicted value was closely similar at Bharatpur for Varuna. Disease severities remained 2.5-4%, 55-70 d.a.s. (forecasted in the form of t value). The value of t for all years indicates the actual time of appearance of disease (Table-1).

Table-2

Stochastic Model Values of Values of A, B, D Parameter and Crop Age at First Appearance / Actual Time of Spray In the form of T Value at Location Bharatpur for Varuna on Leaf

t	year	a	b	d	R^2
75	2001-02	2.87	0.111	-.002	.69
78	2002-03	.363	.216	-.003	.95
65	2003-04	.312	.242	-.003	.98
69	2004-05	.456	.202	-.003	.98
76	2005-06	.342	.198	-.002	.97

70	2006-07	.434	.240	-.003	.96
72	2007-08	.550	.210	-.003	.98

T= Actual Time of Spray

Observed and Forecasted Values of Crop Age At First Appearance of Disease Severity At Bharatpur for Variety Rohini on Leaf

For variety Rohini actual time of spray forecasted 65 d.a.s. because diseases firstly appear 65-70 d.a.s. (Table 3).

Table-3

Observed and Predicted Age at Peak Disease Severity on Leaves is Given

Year	2001-02	02-03	03-04	04-05	05-06	06-07	07-08
Observed	75	62	62	55	56	70	59
Predicted	65	68	70	70	71	65	64

From the table it was resulted that observed and predicted values are nearly similar and disease appear 60-70 d.a.s. and disease incidence remained 1.5-5.1%.

Table-4

Stochastic Model Values of Values of A, B, D Parameter and Crop Age at First Appearance / Actual Time of Spray in the Form of T Value At Location Bharatpur for Rohini on Leaf

t	year	a	b	d	R^2
65	2001-02	.90	.192	-.002	.99
68	2002-03	.87	.394	-.005	.98
70	2003-04	.75	.131	-.002	.99
70	2004-05	.81	.142	-.003	.98
71	2005-06	.86	.172	-.002	.93
65	2006-07	.54	.253	-.001	.92
64	2007-08	0	0	0	0

T= Actual Time of Spray

Observed and Forecasted Values of Crop Age at First Appearance of Disease Severity at Bharatpur for Variety Varuna on Pod

The predicted value for first appearance of disease on pod of cv. Varuna in Bharatpur remains 90-100 d.a.s. for all years. Observed and predicated value were also nearly similar. In variety Varuna on pod the predicted age at first appearance of disease on crop was 85-100 d.a.s. and spraying should be done 85 d.a.s. so that yield loss can be maintained properly.

Table-5

Observed and Predicted Values are Nearly Similar, Which Indicate the Fitness of Model

Year	2001-02	02-03	03-04	04-05	05-06	06-07	07-08
Observed	98	105	110	81	0	98	84
Predicted	98	105	90	88	91	90	87

Table-6

Stochastic Model Values of Values of A, B, D Parameter and Crop Age at First Appearance / Actual Time of Spray in the Form of T Value at Location Bharatpur for Varuna on Pod

t	year	a	b	d	R^2
85	2001-02	1.9	.273	-.001	.87
90	2002-03	.97	.286	-.003	.95
88	2004-05	.87	.338	-.004	.94
91	2005-06	1.1	.279	-.003	.92
90	2006-07	1.9	.75	-.001	.89
87	2007-08	0	0	0	0

T= Actual Time of Spray

Observed and Forecasted Values of Crop Age at First Appearance of Disease Severity at Bhagalpur for Varieity Rohini on Pod

Table-7

Observed and Predicted Values Indicate that Disease Appeared in Rohini 115-120 D.A.S. for All Year

Year	2001-02	02-03	03-04	04-05	05-06	06-07	07-08
Observed	111	111	112	111	0	113	119
Predicted	115	120	117	119	120	125	120

Calculation of actual times of spraying (calculated by t value) from model indicate that spraying should be done 110-120 d.a.s. The value of predicted age of first appearance of Alternaria blight on pod and t value (actual time of spray) were similar that indicate the fitness of model (Table-)

Table-7
Stochastic Model Values of Values of A, B, D Parameter and Crop Age at First Appearance / Actual
Time of Spray in the form of T Value at Location Bharatpur for Rohini on Pod

t	year	a	b	d	R^2
115	2001-02	.57	.204	-.003	.93
120	2002-03	.65	.273	-.003	.98
117	2003-04	.72	.371	-.001	.95
119	2004-05	.85	.247	-.001	.89
120	2005-06	.29	.330	-.004	.97
125	2006-07	.63	.287	-.001	.89
120	2007-08	0	0	0	0

T= Actual Time of Spray

Conclusion

There is no literature available about actual time of appearance of disease on crop while our study done by stochastic model gave proper emphasis on actual time appearance of disease on crop. Our results from stochastic model also gave us real-time prediction of disease appearance and stochastic model suggested actual time of spray on the crop so that farmer can do proper management of their crop. Our forecasting by stochastic model for all locations and varieties gave as forecast value of appearance of disease severity bothy on leaf and pod one week prior to appearance of disease on mustard crop. Our results from stochastic model suggested that for all locations and varieties spray should be done 45-75 d.a.s. and 90-120 d.a.s.

Earlier literature gave common spraying schedule for all locations and varieties while our study was able to give separate spraying schedule for each location and variety. So our models are location-specific. At Bharatpur on leaf disease appeared very early so that farmer could spray on crop when it is of 5-6 week.

Earlier reports did not indicate about proper time of first spraying. Earlier reports only provide first appearance of disease rather than, first spraying time by which farmer can property manage their crop. Our study also forecast incidence of disease (in the form of highest severity percent) due to prevailing weather parameter. Due to disease severity percent we can set our spraying schedule and it remained higher spraying done 2-5 time or it remains lower in percent spraying done 2-3 time.

Spraying schedule from our result for all locations and varieties is more accurate than other findings. Our assumption gave proper emphasis on spraying schedule for prevention of higher disease severity by proper time investigation or forecast of first appearance on leaf and pod (regression and logistic model). We could be able to tell the farmer the proper time of spraying of fungicide on mustard crop. Result from stochastic model gave us actual time of spraying in the form of t value.

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