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Review Article

Plant Disease Forecasting Models

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ABSTRACT

Plant Disease forecasting means predicting the occurrence of a particular disease in a specified area ahead of time, so that suitable control measures can be undertaken in advance to avoid losses below economic threshold level. Prediction of a disease outbreak is based on assumptions about the pathogen's interactions with the host and environment - the disease triangle. The objective is to accurately predict when the three factors – host, environment and pathogen – all interact in such a manner that disease can occur and cause economic losses. Disease forecasting systems are different for Monocyclic and Polycyclic diseases and is based on amount of initial inoculums, weather condition between the cropping seasons.Various forecasting models have been developed and utilized over the years for predicting various diseases across the globe. In 1978, a computerized forecasting system called FAST was developed for Alternaria solani, a fungus that infects tomato, when environmental conditions are favorable for early blight development.. BLITECAST, JHULSACAST etc are computerized forecast model for potato late blight. Predictions of disease outbreaks and the need for spraying have to be communicated rapidly to farmers.

Keywords: *Forecasting, plant disease, BLITECAST, JHULSACAST*

INTRODUCTION

Plant diseases cause significant loss of valuable food crops throughout the world. Diseases account for at least 10% of crop losses globally and are responsible for the lack of adequate food (Strange & Scott, 2005). Crop yields are reduced depending on the disease involved, crop species grown, management practices followed and prevailing environmental factors. An integrated disease-control program is based on the complete knowledge of pathogen biology and the predisposing factors like the prevailing environmental factors on an area or a particular time, the crop species grown and also the most effective and available means to manage the disease below Economic threshold level. Forecasting of plant disease means, predicting the occurrence of disease in a specified area and time, so that suitable control measures can be taken in advance to reduce crop losses.

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Forecasting involves all the activities in ascertaining and notifying the growers that conditions are sufficiently favorable for certain diseases that application of control measures will result in economic gain or on the other hand and just as important that the amount expected is unlikely to be enough to justify the expenditure of time, energy and money for control (Miller & O'Brien, 1952). Disease forecasts are predictions of probable outbreaks or increase in intensity of disease. It involves well organized team work and expenditure of time, energy and money. Disease forecasting models differ depending on the pathogen cycle (monocyclic & Polycyclic). Disease forecasting has become an established component of quantitative epidemiology. The presumption of a disease forecast model is that it makes future projections of major events in disease development – and most present forecast models do not (Seem, 2001). Prediction of an outbreak of disease also called disease forecasting or disease warning**,** generally based on completed infection events. A good disease forecasting system must be simple, reliable, cost effective and can be applicable to many diseases.

BACK GROUND

In 1911 one of the first attempts at predicting potato diseases was made by Lutmen who concluded that epidemics were favored in wet and cold conditions. In 1926, Van Everdingen in Holland proposed the first model based on four climatic conditions necessary for late blight development. In 1933 Beaumont and Stanilund of England emphasized the importance of humidity for late blight occurrence. In 1978, a computerized forecasting system called FAST was developed for *Alternaria solani*, a fungus that infects tomato, to identify periods when environmental conditions are favorable for early blight development (Madden, et al, 1978). It is based on the following daily environmental parameters: maximum and minimum air temperature, hours of leaf wetness, maximum and minimum temperature during the wetness periods, hours of relative humidity greater than 90%, and rainfall. The FAST system requires fewer fungicide applications compared with weekly spray schedules to obtain the same level of disease control.

In 1985, a modified FAST program called Tom- Cast was developed to aid in the management of anthracnose, Septoria leaf spot and early blight on tomatoes (Pitblado, 1992). Tom-Cast does not include the rain model of FAST, but includes the duration of leaf wetness and average air temperature during the wetness periods to calculate a daily disease severity value (DSV) of 0 to 4, corresponding to conditions unfavorable to highly favorable for spore formation of *A. solani*. In tomato, the number of fungicide sprays may be reduced by as much as 50% without compromising fruit quality or yield by using Tom-Cast.

Current examples of plant disease forecasting providing daily information on-line are available for two important plant diseases: Fusarium head blight of wheat (www.wheatscab.psu.edu) and Asian soybean rust (www.sbrusa.net).

Importance of disease forecasting:

a. Forewarning / assessment of disease important for crop production management for timely plant protection measures

b. Information whether the disease status is expected to be below or above the threshold level is enough, models based on qualitative data can be used – qualitative models and

c .Loss assessment forewarning actual intensity is required - quantitative model.

Information's needed for disease forecasting

Knowledge of epidemiology is necessary for accurate forecasting. The information required for forecasting are:

1. Host Factors

a. Prevalence of susceptible varieties in the given locality

b. Response of host at different stages of the growth to the activity of pathogen

c. Density and distribution of the host in a given locality.

2. Pathogen factors

Amount of primary (initial) inoculum in the air, soil or planting material, Dispersal of inoculums, Spore germination, Infection, Incubation period, Sporulation on the infected host, Re-dispersal / Dissemination of spores, Perennating stages and Inoculum potential and density in the seed, soil and air.

3. Environmental factors like Temperature, Humidity, Light intensity and Wind velocity etc.

Pre-requisites for disease forecasting or developing a forecasting system

1. The disease must have potential to cause losses (yield losses) which is economically significant.
2. The crop must be a cash crop or economically valuable.
3. Control measures must be available at an economically acceptable cost.
4. The disease must vary each season in the timing of the first infections and its subsequent rate of progress i.e. the disease should not be regular.
5. The criteria or model used in making a prediction must be based on sound investigational work carried out in the laboratory and in the field and tested over a number of years to establish its accuracy and applicability in all the locations where its use is envisaged.
6. Growers must have sufficient man power and equipments to follow the management measures when disease warning is given.
7. Long-term warnings or predictions are more useful than short-term warning or predictions.

Models for disease prediction:

1. **Empirical models-** based on experience of growers, the scientist or both
2. **Simulation models-** based on theoretical relationships
3. **General circulation models** –based on fixed changes in temperature or precipitation that has been used to predict the expansion range of some diseases. This type of models are not successful

4 Stages of a Model

1. Purpose of Disease Model -Specific disease, crop, climate, & region

2. Model Development -Assumptions & monitoring variables

3. Model Validation -Testing the assumptions

4. Model Implementation -Going public or private

Purpose of disease forecasting:

i. Models typically are developed in specific climates for specific diseases -Early blight model for Midwest tomatoes

ii. Models may contain assumptions about site specific conditions that might not apply for all areas -Early blight in Midwest, but what about the west coast, the desert?

iii. Variables such as timing of model initiation, host phenology, and host range may affect predictions

iv. Host plant resistance; variety & fungicide selection

Basis of disease forecasting

Forecasts based on amount of initial inoculum

- Heald (1921)- Number of spores on infected grains of wheat
- Wilhelm (1950)- spores of *V. alboatrum* in soil
- No. of sclerotia and nematodes cysts in soil

Forecasts based on weather conditions (late blight of potato)

Dutch rules (In Holland)

-Night temperature below dew points for at least 4 hours (dew), Minimum temperature of 10°C or above , Mean cloudiness on the next day of at least 0.8 and 0.1 mm of rainfall during the next 24 hours .

In England (only two)

-Minimum temperature of 10°C and RH not falling below 75% for at least 2 days

Forecasts based on amount of initial inoculum and weather conditons e.g. apple scab

Leaf wetness at 6-28°C (9 hrs at 18-24°C) , Length of leaf wetness, Temperature, Amount of initial inoculums, Data on temperature leaf wetness and duration of wetness can be used to predict the , infection periods, Level of disease

Methods of disease forecasting:

Disease forecasting requires field observations on the pathogen characters, collection of weather data, variety of the crop and certain investigations and their correlations. Usually the following methods are employed in disease forecasting.

1. Forecasting based on primary inoculums

Presence of primary inoculum, its density and viability are determined in the air, soil or planting material. Occurrence of viable spores or propagules in the air can be assessed by using different air trapping devices (spore traps). In the case of soil-borne diseases the primary inoculum in the soil can be determined by monoculture method. Presence of loose smut of wheat, ergot of pearl millet and viral diseases of potato can be detected in the seed lots at random by different seed testing methods. The extent of many virus diseases is dependent on the severity of the preceding winter which affects the size of vector population in the growing season. e.g., Sugar beet yellows virus.

2. Forecasting based on weather conditions

Weather conditions *viz*., temperature, relative humidity, rainfall, light, wind velocity etc., during the crop season and during the intercrop season are measured. Weather conditions above the crop and at the soil surface are also recorded.

3. Forecasting based on correlative information

Weather data of several years are collected and correlated with the intensity of the diseases. The data are compared and then the forecasting of the disease is done. Forecasting criteria developed from comparisons of disease observation with standard meteorological data have been provided for diseases like *Septoria* leaf blotch of wheat, fire blight of apple and barley powdery mildew.

4. Use of computer for disease forecasting

In some advanced countries forecasting of disease is made by the use of computers. This system gives the results quickly. One such computer based programmes in the USA is known as 'Blitecast' for potato late blight. It is perhaps the best known Prediction model. It is a combinations of two prediction models on Late blight.

Some Disease Forecasting Models –

SIMCAST- It is derived from a simulation model describing the effect of climate, fungicide and host resistance on *Phytophora infestance* development.

EPIDEM- *Alternaria solani* on tomatoes & potatoes

FAST - Forecasting *Alternaria solani* on tomatoes

TOMCAST-*Alternaria, (Septoria*, anthracnose)

WISDOM (BLITECAST)- Late blight on tomatoes & potatoes

MELCAST- Watermelons (Anthracnose, gummy stem blight), Muskmelons (*Alternaria*)

Mary blight- Fire blight on apples

EPIVEN- Apple scab on apples

EPICORN- Southern corn leaf blight

EPIPRE- diseases of winter wheat especially yellow rust

North American Blue Mold warning system- Tobacco

Climate factors play a major role in determining the impact of several pests and diseases on crop yields. Based on this, use of existing weather data as input to a computerised system for development of plant pest and disease forecasting models.

Forecasting models for potato late blight management:

Late blight of potato caused by *Phytophthora infestans* (Mont.) de Bary, is one of the most serious and devastating disease of potato world over, including India and is an important limiting factor for yield reduction in India. The great Irish famine in 1845, due to late blight is one of the most dramatic episodes caused by a plant pathogen in human history. For effective management of disease, efforts should make to reduce initial inoculum (in temperate conditions) but main emphasis should be to slow down progress of disease. Hence, there is urgent need to develop some kind of disease forecast/warning service for predicting the time of appearance of disease and optimizing use of fungicides without risking the crop and human health. Three attributes of late blight that justify the use of forecasting are its potential for severe damage through tuber infection or defoliation, its dependence on weather condition which makes late blight occurrence irregular and sometime explosive and availability of management practices for disease suppression. The implementation of forecasting model for late blight of potato depends upon area specific climatic conditions.

Forecasting assists the growers for spray schedule and reduces the costs involved by eliminating the unnecessary sprays and labour cost without increasing the risk of loosing the crop**.** The congenial conditions for appearance and build up of disease are 10-22°C temperature, humidity above 75%, cloudy or foggy weather (Bhattacharyya et al., 1983; Deweille, 1964). The role of environment in the development of late blight has been well documented (Harrison, 1992; Rotem et al., 1971; Wallin, 1953). Disease development is also depending on the presence of free water on the surface of foliage. Photoperiod, light intensity etc has direct impact on pathogen development and host susceptibility. Generally potato plants growing under short day condition are more susceptible to late blight disease.

Potato late blight forecasting models:

Various forecasting models have been developed and utilized over the years for predicting late blight of potato across the globe. These models are given below:

Fundamental Models

Dutch Rules (1926), BLIGHTCAST (1975), Beaumont's Rules (1947), Cook's System (1947, 49), Fry and Apple (1983), Bourke's System (1953), Hyre's System (1954), Hyre and Bonds's System (1955), Smith's Sytem (1956), Wallin's system (1962) etc.

JHULSACAST (2000)

Cook (1947, 49) used system (Cook's System) based on seven days moving graph and studied relationship of rainfall and temperature charts. He observed critical point for blight development started on 8th May and temperature 75°F. Bourke (1953) developed model known as the Irish rules which currently used in Ireland. For germination and infection, sporangia of *Phytophthora infestans* requires a wetness period of at least 12 hrs, air temperature not below 10°C and relative humidity at least 90%. Finally potato growers are warned that weather conditions are conducive for late blight spread and are favourable for spraying.

According to Smith (1956), two consecutive days with minimum temperature of 10°C and at least 11 hr of relative humidity 90% or greater than 90% are favourable for disease. Wallin (1962) developed a forecasting system (Wallin's system) for predicting the initial occurrence and subsequent spread of late blight based on relative humidity (RH) and temperature**.** This system is based on the seasonal accumulation of 'severity values'. Severity values are numbers arbitrarily assigned to specific relationship between duration of RH periods > 90% and the average temperature during those periods. The first occurrence late blight is predicted 7-14 days after 18-20 severity values have been accumulated from the time of plant emergence.

Sharma (2000) concluded that late blight development in the North-Western region especially in Jalandhar region was positively correlated with maximum relative humidity, rainfall, dew and cloudy days while negatively correlated with minimum temperature**.**

BLITECAST is a computerized forecast model for potato late blight developed by Krause and colleagues at Pennsylvania State University. BLITECAST combined by using two late blight forecasting techniques- Hyre's (1947) concept of blight favourable days and Wallin's (1962) severity values for potato late blight forecasting. The growers could send the weather data recorded in potato fields to a computer through a telephone at forecasting centre and get the recommendations. The recommendations to the growers were main attraction of this centralized disease forecasting system.

Potato late blight forecasting model in India:

Development of late blight mainly depends on moisture, temperature and cloudiness. In India, the rains are heavy and the weather is cool and cloudy during summer in hills but in the plains the weather is generally clear with scanty rains. Therefore the disease epidemic is not a regular feature. There are several models for late blight forecasting developed in India by various Scientists but the most successful models are:

JHULSACAST: Singh et al. (2000) developed JHULSACAST, a computerized forecast of potato late blight in Western Uttar Pradesh for rainy and non rainy year. The main menu of the programme is late blight forecasting model(s), data entry, modification and model execution. The weather parameters used in this programme are daily rainfall in millimeter, hourly temperature and relative humidity.

Forecasting late blight of potato in Punjab using JHULSACAST model:

Arora et al. (2012) modified JHULSACAST and developed a modified model for late blight forecasting at Punjab. Weather data collected in Punjab for 15 years (1997- 2012) was analyzed to calibrate 'JHULSACAST' - to make it suitable to forecast appearance of late blight in Punjab. The model specifies that 7 day moving sum of RH > 85% for at least 90 hr coupled with a 7 day moving sum of temperature between 7.2 to 26.6°C for at least 115 hr would predict appearance of late blight within 10 days of satisfying the conditions. The modified model was found suitable to predict appearance of late blight under Punjab conditions.

Late blight trap nurseries were raised with highly susceptible potato variety Kufri Chandramukhi at Central Potato Research Station, Jalandhar each year from 1997-98 to 2011 -12. Untreated seed tubers were planted. The crop was not sprayed with any fungicides to allow appearance of the disease. Plants were critically examined for appearance of late blight starting from complete emergence till maturity of the crop. Appearance of late blight was also monitored in potato fields in different localities around the experimental farm. Temperature and relative humidity data were recorded using daily thermo hygrograph charts mounted on thermo hygrograph machines housed in Steevenson screen placed within crop canopy. Other weather parameters *viz.* rainfall, sunshine hours, wind velocity and speed were recorded in adjacent observatory. Temperature and RH data was computed on hourly basis where as rainfall and sunshine hours were computed on daily basis. The data was converted into digital form and interpolated with the actual date of disease appearance using computer programme developed in Visual Basic. Model JHULSACAST was used as a standard and different combination of temperature and relative humidity recorded in the trap nurseries were evaluated for their fitness to predict late blight using computer programme developed for this purpose.

Weather conditions such as 5 and 7 day moving sum of RH >85% for different number of hours in a blight congenial temperature of 7.2 to 26.6°C were found suitable for development of a late blight forecasting model. The results of this JHULSACAST model revealed that the forecasting of late blight appearance worked in 5 years out of 15 years viz. 1999-2000, 2002-03, 2005-06, 2006-07 and 2007-08 when the disease appeared 2 to 10 days in advance of the predicted date. But disease appearance got delayed from 17 to 50 days from the stipulated date during the remaining10 years *i.e.*1997-98, 1998-99, 2000- 01, 2001-02, 2003-04, 2004-05, 2008-09, 2009- 10, 2010-11 and 2011-12.

Forecasting of rice blast in Kangra district of Himachal Pradesh

The favourable weather for rice leaf blast occurs from the second fortnight of August to first fortnight of September. The comparison of thirteen years (1984-1996 from 25th July to

7th September) meteorological data revealed that number of rainy days in a week , less sun shine hours (SSH) and days with RH > 90% were the probable critical factors in the development of rice blast epidemics during 1984 and 1992. Mean max., min. temperatures (26-27° C and 19-20°C,. respectively) and high humidity (RH >87 %) or high rainfall (2766 mm) during blast years favoured rapid blast development (Table1). In general, most of the years, temperature, RH, rainfall and wind velocity were more or less favourable for rice blast disease but not adequate for epidemic development. (Kapoor et al., 2004).

Communication of predictions and warnings to farmers:

Predictions of disease outbreaks and the need for spraying have to be communicated rapidly to farmers. Commonly, general warnings have been broadcast on the radio. More specific warnings can be transmitted to a group of farmers by telephone or, more recently, by modem from a central computer. A recent advance is the development of monitoring and predictive systems for all the major pests and diseases of a particular crop. A system called 'EPIPRE', based on monitoring by farmers of their local site, crop and disease factors, has been developed for six fungal diseases and all aphid pests of wheat in Europe.

CONCLUSION

A large number of forecasting models exist and are currently used in many areas throughout the world and gives satisfactory information. The success of a Forecasting system depends on factors like accuracy of the prediction of epidemic risk, ability to timely deliver the control measures (fungicidal application etc) and the economic impact of the prediction System. The implementation of forecasting model reduces the frequency of fungicides application up to 50 % as compared with conventional, calendar based schedule. Although the approach used to predict the onset of disease development is diverse but most of them have been demonstrated to adequately forecast the initial appearance of the disease as well as timely fungicide application.

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