FORECASTING LATE BLIGHT OF POTATO IN PLAINS OF WEST BENGAL USING JHULSACAST MODEL

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ABSTRACT: Late blight is the single most important impediment in potato cultivation throughout the world. The management of this devastating disease depends on regular application of fungicides at short intervals throughout the growing season resulting in health and environment hazards. However, timely forecasting of the disease may result in lesser application of fungicides with effective management of the disease. Out of fourteen forecasting models tested for predicting late blight in plains of West Bengal, none of the model (except Wallin, Bhattacharyya’s II forecast and Dutch rules) could predict late blight. JHULSACAST model was fine-tuned by making modifications in input parameters (relative humidity, temperature duration and amount of rainfall) by utilising weather data for 7 years collected at Bidhan Chandra Krishi Vishvavidyalaya, Kalyani, West Bengal, India. The modified JHULSACAST model could predict late blight within 14 days with an accuracy of 100% if 7-day moving relative humidity ($\geq$ 90%) period for $\geq$ 105 hours coupled with 7-day moving congenial temperature (7.2 to 26.6°C) for $\geq$ 150 hours prevail for 7-consecutive days or if 5-day moving relative humidity ($\geq$ 90%) period for $\geq$ 65 hours, 5-day moving congenial temperature (7.2 to 26.6°C) for $\geq$ 105 hours for 5 consecutive days and sum of two consecutive days rainfall ($\geq$ 2.5 mm) prevail. These models were validated and predicted late blight successfully for two years.

KEYWORDS: Late blight, Phytophthora infestans, prediction

INTRODUCTION

Late blight caused by the fungus like organism Phytophthora infestans (Mont.) de Bary is one of the most destructive diseases of potato crop world over, including India. Due to differences in prevailing weather conditions, its severity varies from region to region. Forecasting of the disease can greatly help in managing this disease thereby lowering crop losses. Van Everdingen (1926) for the first time developed decision rules for predicting late blight in Holland. Since then these rules have been modified by various workers (Beaumont and Stanilund, 1934; 1938; Bourke, 1953; Johannes, 1953; Wallin and Hoyman, 1954) to suit to their conditions. In India, Singh et al. (2000) developed a computerized forecast model (JHULSACAST) for western Uttar Pradesh using hourly temperature, relative humidity (%) and daily precipitation (mm) as input parameters. However, this model is location specific and needs to be calibrated for different agro-climatic conditions. Since then the model has been calibrated for predicting late blight appearance in Punjab (Arora et al., 2012) and Tarai region of Uttarakhand (Pundhir et al., 2014). In present study, the JHULSACAST model was modified for predicting late blight in plains of West Bengal.

MATERIALS AND METHODS

Field experiments

Ten plots, consisting of 50 plants each of susceptible potato cultivars Kufri Chandramukhi and Kufri Jyoti, were raised...
as trap nurseries at Bidhan Chandra Krishi Vishavidhyalaya, Kalyani, West Bengal experimental farm (22°59’ N Latitude, 88° 29’ E Longitude and 11 m amsl) during the years 2006-07 to 2012-13. Late blight infected tubers (artificially inoculated) were planted in the centre of each plot of the nursery for ensuring the availability of the inoculum. Planting of trap nurseries was done between 15 and 20 November each year near the observatory. Temperature, relative humidity and rainfall were recorded using the automatic weather station from 15 November till appearance of first late blight symptom in the trap nursery and, in other fields at the farm or adjoining farmers’ fields. The temperature and relative humidity data were computed on hourly basis whereas rainfall was computed on daily basis and these parameters were interpolated with the actual date of disease appearance using computer programmes developed in Visual Basic, MS Excel work sheet, FoxPro, Castor-2.0 and JHULSACAST software. The forecasting systems based on temperature and precipitation viz. Dutch rules (Van Everdingen, 1926), Beaumont rules (Beaumont and Staniland, 1934), Cook’s rules (Cook, 1947), and Hyre’s rules (Hyre and Bonde, 1955); based on temperature and relative humidity viz. Smith’s (Smith, 1956), Ullrich and Schroder’s method (Ullrich and Schroder, 1966), Wallin’s (Wallin, 1962; Wallin and Hoyman, 1954), and Winstel’s (Winstel, 1993) models; based on temperature, relative humidity and precipitation viz. Forsund’s (Forsund, 1983), Hyre’s (Hyre and Bonde, 1955; Hyre, 1954, 1955), BLITECAST (Krause et al., 1975), SIMCAST (Fry and Doster, 1991; Grunwald et al., 2000), NEGFRY (Hansen et al., 1995), Bhattacharyya’s et al. II forecast (Bhattacharyya et al., 1982), and JHULSACAST (Singh et al., 2000) models were tested using the weather parameters. Besides, several other new combinations of relative humidity, temperature and/or rainfall were evaluated for their fitness to predict late blight by using computer programmes developed for this purpose.

Data acquisition

Weather parameters (temperature, relative humidity and rainfall) were collected from the automatic weather station installed at Bidhan Chandra Krishi Vishavidhyalaya, Kalyani, West Bengal and converted into the required format of Castor-2.0 software developed by Juarez et al. (2002). Software was run for testing the late blight forecasting of all the 14 methods as well as other combinations of relative humidity, temperature and rainfall and the accuracy of each model was calculated. The modified version of JHULSACAST was developed in MS Visual Basic and MS Access database and the main MENU of the programme were: i) late blight forecasting model(s) ii) data entry and modification, and iii) model execution to see the status of late blight appearance. The weather data can be updated daily by entering it manually and the models are executed for knowing the status of late blight. Depending on the weather conditions, late blight status is displayed and a warning is flashed stating, “The late blight is expected to appear within seven to fourteen days”. The model was validated using the weather parameters for two consecutive years viz. 2011-12 and 2012-13 using computer software developed for the purpose.

RESULTS AND DISCUSSION

The efficiency of the forecasting models tested under plains of West Bengal is presented in Tables 1a and 1b. Out of 14 models tested, none of the model had accuracy more than 20%. The accuracy of eleven models
Table 1a. Potato late blight appearance and prediction by different models using Castor-2.0 software at Kalyani, West Bengal.

<table>
<thead>
<tr>
<th>Year</th>
<th>Forsund</th>
<th>Smith</th>
<th>Ullrich &amp; Schroeter</th>
<th>BLITECAST</th>
<th>SIMCAST</th>
<th>NEGFRY</th>
<th>Winstel</th>
<th>JHULSACAST</th>
<th>Beaumont rules</th>
<th>Cook rules</th>
<th>Wallin</th>
<th>Bhattcharyya’s II forecast</th>
<th>Dutch rules</th>
<th>Accuracy</th>
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<tbody>
<tr>
<td>2006-07</td>
<td>PD</td>
<td>PS</td>
<td>PD</td>
<td>PD</td>
<td>PD</td>
<td>PD</td>
<td>PD</td>
<td>PS</td>
<td>PD</td>
<td>PS</td>
<td>PD</td>
<td>PD</td>
<td>PD</td>
<td>0%</td>
</tr>
<tr>
<td>2007-08</td>
<td>F</td>
<td>D</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>D</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>0%</td>
</tr>
<tr>
<td>2008-09</td>
<td>F</td>
<td>D</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>D</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>0%</td>
</tr>
<tr>
<td>2009-10</td>
<td>F</td>
<td>D</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>D</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>0%</td>
</tr>
<tr>
<td>2010-11</td>
<td>F</td>
<td>D</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>D</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>0%</td>
</tr>
</tbody>
</table>

Note: PD: Prediction date, *Year 1st April to 31st March, PS: Prediction status, (-) means no prediction of late blight appearance, ** days by which late blight delayed/earlier appeared as per rules of the specific model and OK indicate this model well predicted LB appearance. Accuracy: 0%.

viz., Forsund method, Hyre method, Smith method, BLITECAST, SIMCAST, NEGFRY, Ullrich & Schroeter, Winstel, JHULSACAST, Beaumont rules, and Cook rules was 0%, while that of Wallin, Bhattcharyya’s II forecast and Dutch rules was 20% only. Since none of the model could forecast late blight accurately in the plains of West Bengal, the weather and disease appearance data were interpolated for identifying weather conditions which are essential for the initial appearance of the disease in this region. The parameters tried were (i) minimum and maximum temperatures, (ii) minimum and maximum relative humidity, (iii) 7-day moving ≥75% relative humidity and congenial temperature (7.2-26.6°C) periods, (iv) 5-day moving ≥75% relative humidity and congenial temperature (7.2-26.6°C) periods, (v) 7-day moving ≥80% relative humidity and congenial temperature (7.2-26.6°C) periods, (vi) 5-day moving ≥80% relative humidity and congenial temperature (7.2-26.6°C) periods, (vii) 7-day moving ≥85% relative humidity and congenial temperature (7.2-26.6°C) periods, (viii) 5-day moving ≥85% relative humidity and congenial temperature (7.2-26.6°C) periods, (ix) 7-days moving ≥90% relative humidity and congenial temperature (7.2-26.6°C) periods, (x) 5-days moving ≥90% relative humidity and congenial temperature (7.2-26.6°C) periods, and (xi) rainfall (≥2.5 mm) for two consecutive days. No correlations were observed between minimum temperature, maximum temperature, minimum relative humidity, maximum relative humidity, rainfall and the disease appearance and therefore, were discarded. Data on 7-day and 5-day moving relative humidity (75-90%), congenial temperature (7.2-26.6°C) periods and rainfall (≥2.5 mm) for two consecutive days revealed that their efficacy varied with relative humidity regimes.
Forecasting late blight of potato using JHULSACAST

Table 1b. Potato late blight appearance and prediction by different models at Kalyani, West Bengal.

<table>
<thead>
<tr>
<th>Year</th>
<th>JHULSACAST forecast</th>
<th>Bhattacharyya II forecast</th>
<th>Beaumont Rules</th>
<th>Dutch Rules</th>
<th>Cook Rules</th>
<th>Actual date of late blight appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD*</td>
<td>PS**</td>
<td>PD</td>
<td>PS</td>
<td>PD</td>
<td>PS</td>
<td>PD</td>
</tr>
<tr>
<td>2006-07</td>
<td>02 Jan</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>09 Jan</td>
</tr>
<tr>
<td>2007-08</td>
<td>08 Dec</td>
<td>27</td>
<td>25 Jan</td>
<td>11</td>
<td>25 Jan</td>
<td>11</td>
</tr>
<tr>
<td>2008-09</td>
<td>10 Dec</td>
<td>18</td>
<td>-</td>
<td>-</td>
<td>15 Dec</td>
<td>23</td>
</tr>
<tr>
<td>2009-10</td>
<td>13 Dec</td>
<td>49</td>
<td>19 Jan</td>
<td>12</td>
<td>-</td>
<td>11 Dec</td>
</tr>
<tr>
<td>2010-11</td>
<td>05 Dec</td>
<td>No late blight</td>
<td>OK</td>
<td>09 Dec</td>
<td>No late blight</td>
<td>07 Dec</td>
</tr>
</tbody>
</table>

Accuracy 0% 20% 0% 20% 0%

Note: PD: Prediction date, *Year 1st April to 31st March, PS: Prediction status, (-) means no prediction of late blight appearance, ** days by which late blight delayed/earlier as per rules of the specific model and OK indicate this model well predicted LB appearance.

Congenial temperature hours and \( \geq 75\% \text{ RH} \) for 7-day OR congenial temperature hours and \( \geq 75\% \text{ RH} \) for 5-day and rain \( \geq 2.5 \text{ mm} \) for two consecutive days

Accumulation of congenial temperature hours and \( \geq 75\% \text{ RH} \) were compared for their efficacy in predicting late blight. The combination of two conditions (i) accumulation of 7-day \( \geq 120 \text{ hrs} \) of \( \geq 75\% \text{ RH} \) and \( \geq 150 \text{ hrs} \) of congenial temperature \((7.2 - 26.6^\circ C)\) OR (ii) accumulation of 5-day \( \geq 90 \text{ hrs} \) of \( \geq 75\% \text{ RH} \), \( \geq 105 \text{ hrs} \) of congenial temperature \((7.2 - 26.6^\circ C)\) and \( \geq 2.5 \text{ mm} \) rainfall for two consecutive days predicted late blight appearance accurately only in one year (2008-09) out of five. In two years (2006-07 and 2009-10) late blight was not predicted at all although the disease appeared in these years, while during 2007-08 the disease appeared well before the predicted date. During the year 2010-11 though late blight was predicted (12-12-2010), but it did not appear throughout the crop season. The accuracy of this model was 20% only, hence discarded (Fig. 1b).

Congenial temperature hours and \( \geq 80\% \text{ RH} \) for 7-day OR congenial temperature hours and \( \geq 80\% \text{ RH} \) for 5-day and rain \( \geq 2.5 \text{ mm} \) for two consecutive days

When accumulation of congenial temperature hours and \( \geq 80\% \text{ RH} \) were compared for their efficacy in predicting late blight, the combination of (i) accumulation of 7-day \( \geq 120 \text{ hrs} \) of \( \geq 80\% \text{ RH} \) and \( \geq 150 \text{ hrs} \) of congenial temperature \((7.2 - 26.6^\circ C)\) OR (ii) accumulation of 5-day \( \geq 85 \text{ hrs} \) of \( \geq 80\% \text{ RH} \), \( \geq 105 \text{ hrs} \) of congenial temperature \((7.2 - 26.6^\circ C)\) and \( \geq 2.5 \text{ mm} \) rainfall for two consecutive days predicted late blight appearance accurately in one year (2008-09) out of five. In two years (2006-07 and 2009-10) late blight was not predicted at all although the disease appeared in these years, while during 2007-08 the disease appeared well before the predicted date. During the year 2010-11 though late blight was predicted (12-12-2010), but it did not appear throughout the crop season. The accuracy of this model was 20% only, hence discarded (Fig. 1a).

Congenial temperature hours and \( \geq 85\% \text{ RH} \) for 7-day OR congenial temperature hours and \( \geq 85\% \text{ RH} \) for 5-day and rain \( \geq 2.5 \text{ mm} \) for two consecutive days

The combination of (i) accumulation of 7-day \( \geq 110 \text{ hrs} \) of \( \geq 85\% \text{ RH} \) and \( \geq 150 \text{ hrs} \) of congenial temperature \((7.2 - 26.6^\circ C)\) OR (ii) accumulation of 5-day \( \geq 85 \text{ hrs} \) of \( \geq 85\% \text{ RH} \), \( \geq 105 \text{ hrs} \) of congenial temperature \((7.2 - 26.6^\circ C)\)
and ≥2.5 mm rainfall for two consecutive days predicted late blight appearance accurately in one year (2008-09) only while in two years (2006-07 and 2009-10) it couldn’t predict, although the disease appeared in all these years. During the year 2007-08 blight appeared well before the predicted date, while during 2010-11 though blight was predicted, but it did not appear throughout the crop season. The accuracy of this model was also low (20%), hence discarded (Fig. 1c).

Congenial temperature hours and ≥90% RH for 7-day OR congenial temperature hours and ≥90% RH for 5-day and rain ≥2.5 mm for two consecutive days

When combination of (i) accumulation of 7-day ≥105 hrs of ≥90% RH and ≥150 hrs of congenial temperature (7.2-26.6°C) OR (ii) accumulation of 5-day ≥65 hrs of ≥90% RH, ≥105 hrs of congenial temperature (7.2-26.6°C) and ≥2.5 mm precipitation for two consecutive days were compared, it could predict late blight appearance accurately in four year (2006-07, 2007-08, 2008-09 and 2010-11) out of five while in one year (2009-10), its appearance was delayed by 19 days. Overall the results revealed that this combination is the best fit for the prediction of late blight in the plains of West Bengal (Fig. 1d).

Validation of model

The best model viz. accumulation of (i) 7-day ≥105 hrs of ≥90% RH and ≥150 hrs of congenial temperature (7.2-26.6°C) periods, OR (ii) 5-day ≥65 hrs of ≥90% RH, ≥105 hrs of congenial temperature (7.2-26.6°C) periods and ≥2.5 mm precipitation for two consecutive days was successfully validated for two consecutive years viz. 2011-12 and 2012-13 using computer software developed for the model indicating suitability of this model as well as of the software for predicting late blight in the plain region of West Bengal (Table 2).

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**Fig. 1. Testing the accuracy of model in predicting potato late blight in plains of West Bengal**
Most of the late blight forecast models are location specific and these need to be fine tuned for predicting the disease in a new geographical area (Singh and Sharma, 2013; Arora et al., 2014). Bhattacharyya et al. (1990) developed 1st and 2nd forecast for predicting late blight in hilly regions but these failed to predict late blight in Indian plains (Singh et al., 2000). Consequently, Singh et al. (2000) developed JHULSACAST for Western Uttar Pradesh which is forecasting potato late blight successfully in the region. Luck et al. (2010) also studied the efficacy of nine models in Castor-2.0 software and JHULSACAST model in the plains of West Bengal but none of the models was found suitable for this region. Present studies were aimed at developing suitable late blight prediction system for the plains of West Bengal which is one of the most important potato growing regions of the country. Evaluation of fourteen well established models revealed that none of these models worked under plains of West Bengal. Only three models viz. Wallin, Bhattacharyya’s 2nd forecast and Dutch rules could forecast the disease but even their accuracy was only 20%. Therefore, different temperature and relative humidity regimes along with the accumulation of congenial temperature and, RH hours and rainfall were correlated with appearance of late blight. Among all the combinations tried, the combination comprising of accumulation of (i) 7-day ≥105 hrs of ≥90% RH and ≥150 hrs of congenial temperature (7.2-26.6°C) periods, OR (ii) 5-day ≥65 hrs of ≥90% RH, ≥150 hrs of congenial temperature (7.2-26.6°C) periods and rain ≥2.5 mm for two consecutive days predicted late blight in four out of five years with an accuracy of 80%. Hence, based on comparative accuracy of all the combinations of temperature, RH and rainfall above decision rules are recommended for predicting late blight in the plains of West Bengal. These conditions were able to forecast late blight within 14 days of their occurrence. The software developed can be utilized by the scientists as well as by the farmers’ associations for predicting late blight in this region.

CONCLUSIONS

JHULSACAST model was calibrated to forecast late blight under plains of West Bengal. The modified model specifies that a 7-day moving sum of RH ≥90% for at least 105 hrs coupled with congenial temperature (7.2 to 26.6°C) period for at least 150 hrs or (ii) 5-day moving sum of ≥90% RH for at least 65 hrs coupled with congenial temperature (7.2-26.6°C) period for at least 105 hrs and cumulative rainfall of ≥2.5 mm for two consecutive days could forecast appearance of late blight within 14 days of meeting these conditions in the plains of West Bengal.

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LITERATURE CITED


Cook HT (1947) Forecasting tomato late blight. *Food Packer* April, 1947: 69-70

Cook HT (1947) Results-late blight forecasting. *Food Packer* December 1947: 63-64


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