Forecasting of Potato Early Blight Disease Using Different Sets of Meteorological Data

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Abstract

Early blight is a very common disease of potato in Iran. It causes leaf spots and tuber blight on potato. The disease can occur over a wide range of climatic conditions and can be very destructive if left uncontrolled, often resulting in complete defoliation of plants. In contrast to the name, it rarely develops early, but usually appears on mature foliage. This study was performed to forecast potato early blight in Kermanshah province, west of Iran. Hourly meteorological data were recorded by an iMETOS automatic weather station installed in the field and were compared with regional station. The primary symptom occurrence of early blight lesions was predicted by Phenological day (PD) and degree day (DD) models during 2013 and 2014 growing seasons. By application of both models using two data sets, the time of symptoms appearances was predicted between 1 to 3 days in advance. Results showed that early symptoms of disease can be observed after 300PD and 625DD in the vision. The results suggested that in case of unavailability of on-site meteorological parameters, the data obtained from a close weather station (with less than 10 kilometers distance) can be used for disease epidemic forecast. Further studies in other climates are suggested for more scrutiny.

1. Introduction

Potato (Solanum tuberosum L.) is one of the strategic crops and early blight of potato, caused by Alternaria solani Sorauer, is a pathogen which has economic significance in Iran. Management of early blight and its effects on potato is achieved largely through fungicide applications. This disease is one of the most important diseases of potato worldwide, receiving more than 4 fungicide applications in every cropping period. Growers adoption of forecast models that predict the onset of early blight with enough lead time to allow implementation of effective control can help to reduce crop inputs and increase profitability. By accurate disease forecasting and spray scheduling, unnecessary early-season applications can be reduced or eliminated that is the main goal of
integrated pest management (IPM) strategy with direct benefits to the public, the environment, and producers. Plant disease studies demonstrated that primary fungicide applications for early blight should be simultaneous with the first appearance of airborne spores. Fungicide applications before this time do not affect the disease and would essentially waste money and pollute the environment. Fungicide application when the symptoms are obvious, often result in diminished disease control and potential yield losses. Franc et al. [4] developed a growing degree-day (GDD) model to determine time for starting spraying programs in Colorado. A growing degree-day is determined as follows:

\[ DD = \frac{(T_{\text{max}} - T_{\text{min}})}{2} - 7.2°C \]  \[ (1) \]

Calculated from date of sowing. Using this model Growers could save three to four sprays without significant loss crop production. They reported that the first lesions developed at 361 GDD in the San Luis Valley and 625 GDD in northeastern Colorado. The model can be modified for use in other regions, crops, or cultivars. Pscheidt and Stevenson [12] suggested that Phenological Days (P-Days) approach, developed by Sands et al. [16] for prediction of potato yield, may be used to predict potato development and early blight appearance similar to GDD model, discussed earlier. Sands et al. [16] noted that the P-Days model accurately predicts phonological stages in different climates. P-Days are calculated using equation 2.

\[
P\text{-Days} = \left\{ \begin{array}{ll}
\frac{1}{24} & \left[ 5P(T_{\text{min}}) + 8P\left( \frac{2T_{\text{min}}}{3} + \frac{T_{\text{max}}}{3} \right) + 8P\left( \frac{2T_{\text{max}}}{3} + \frac{T_{\text{min}}}{3} \right) + 3P(T_{\text{max}}) \right] \\
\end{array} \right\} \]  \[ (2) \]

where;

\[
P(T) = 0 \quad \text{if} \quad T < 7°C \]  \[ (3) \]

\[
P(T) = 10 \left[ 1 - \left( \frac{T - 21}{21 - 7} \right)^2 \right] \quad \text{if} \quad 7°C < T < 21°C \]  \[ (4) \]

\[
P(T) = 10 \left[ 1 - \left( \frac{T - 21}{30 - 21} \right)^2 \right] \quad \text{if} \quad 21°C < T < 30°C \]  \[ (5) \]

Starting at emergence.

In this model, minimum, optimum, and maximum temperatures for potato development are 7°C, 21°C, and 30°C respectively. Pscheidt and Stevenson [13] reported that early blight is not a threat until reaching 300 P-Day threshold, starting from emergence for late maturing cultivars in Wisconsin, USA. A natural limitation of these forecast systems is the need for in-situ weather observations [1]. Farmers acceptance and adoption of disease forecast systems could be improved if regional climatic data are recorded and provided in regular basis from automatic weather stations.
This require installation of these stations within the field and capacity building for training and operation the system. which sometimes is not practical or economically feasible and hence limits the adoption of early warning disease systems [10]. If the empirical relationship between in-field and regional observations is determined, disease forecasts could be effectively generated for an extensive production area without need for in-field weather stations [1]. Bourke [1] asserts that there is no practical alternative to using standard regional observations in disease forecasting, but the quality of disease prediction using off-site weather stations degrades with increasing distance from the field. The purpose of this research was to validate and to compare the 300 P-Day forecast system for Kermanshah (west of Iran) potato production areas with the 625 GDD potato early blight forecast system.

2. Materials and methods

2.1. Experimental site

Kermanshah province is located in west Iran. (Figure 1). Its geographical coordinates are between 33 degrees and 36 minutes and 35 degrees 15 minutes north and 45 degrees 24 minutes and 48 degrees 30 minutes east. It has semi arid climate, according to De Martone climatic classification. Field plots were prepared in late March and seeds were cultivated according to local recommendations. All plots were planted on 0.76 meter centers with seed pieces weighing approximately 50 to 80 grams planted 0.15 meter deep, spaced 0.3 meter apart in the soil ridge.

![Figure 1. Geographical situation of Kermanshah province](image)

All plots were irrigated by surface furrow system. Scouting intervals were daily as model thresholds were approached. The specific emergence date for the field was 21 April. The experimental field was approximately 6 kilometers from the nearest regional weather station.

(Kermanshah airport). Characteristic early blight lesions were confirmed to be *A. solani* by microscopic examination of conidial and conidiophores morphology.

### 2.2. Weather monitoring

An iMETOS electronic weather station used to collect Weather data from experimental field. Data are transmitted daily by a cellular phone into a mainframe computer at the web server and are made available on the Internet. Meteorological data from potato crop planting (March) to harvest (September) were used directly in this study (Table 1). All sensors were positioned in 2 meter height except leaf wet duration sensor that was connected to potato leaf. Temperature and relative humidity were controlled with a sheltered thermo-hygrograph within the potato canopy. In the same period meteorological data received from Kermanshah airport regional station. Although the height of temperature observation within or above a crop canopy can have significant effects on microclimatic observations, meteorological data were collected and evaluated the various sources of microclimatic and regional for early blight forecasting..

#### Table 1. Monthly meteorological factors during the 2-year study period. Tmean; mean daily temperature, Tmax; maximum daily temperature, Tmin; minimum daily temperature, H; mean relative humidity and P is rainfall.

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>May</td>
<td>June</td>
</tr>
<tr>
<td>Tmean (°C)</td>
<td>17.7</td>
<td>22.3</td>
</tr>
<tr>
<td>Tmax (°C)</td>
<td>25.3</td>
<td>31.7</td>
</tr>
<tr>
<td>Tmin (°C)</td>
<td>10.1</td>
<td>12.9</td>
</tr>
<tr>
<td>H (%)</td>
<td>38</td>
<td>26</td>
</tr>
<tr>
<td>P (mm)</td>
<td>48.6</td>
<td>4.8</td>
</tr>
</tbody>
</table>

### 3. Results

#### 3.1. Comparison of P-Days and GDD for disease forecasting

Field surveys were conducted in experimental potato fields during 2013 and 2014 seasons to identify the initial appearance of early blight in the region. Surveys were conducted on a weekly basis beginning 3 weeks after emergence (approximately 15 May) and continued until vine kill (approximately September 20), but the observation interval was reduced to every 3 to 5 days as the 300 P-Day and 625 GDD thresholds were approaching. Early blight symptoms were consistently found in experimental field in two years. The first lesion appeared in field in 4 June and 6 June in 2013 and 2014 respectively, and after the accumulation of 300 P-Days in two years, according to the nearest regional station and in-field meteorological data (Table 2).
Primary early blight lesion appearance at ranged from 326 accumulated P-Days (as calculated by the regional station), which provided 3 days of lead time. Lead time was defined in this study as the time between forecasted disease and actual disease appearance dates, where a positive value indicates disease was observed after the forecasted date was reached. Forecasts were generated from 1 to 3 days before the initial disease appearance, but the lesions were not detected before 300 P-Days (Table 2). Primary lesions did not develop before the model threshold was crossed throughout the duration of this study in experimental plots and model predicted disease 1 and 2 days before the first observed lesion (Table 2).

Table 2. The relationship between first appearance of potato early blight lesions and accumulated Phenological days (P-Days) and growing degree-days (GDD) as measured by iMETOS infield weather station and Kermanshah airport regional station in 2013 and 2014

<table>
<thead>
<tr>
<th>Year</th>
<th>Station</th>
<th>First lesion date</th>
<th>Accrued P-day</th>
<th>300P-day date</th>
<th>Forecast lead time (days)</th>
<th>Accrued GDD</th>
<th>625GDD date</th>
<th>Forecast lead time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>Infield</td>
<td>4 June</td>
<td>320</td>
<td>3 June</td>
<td>1</td>
<td>649</td>
<td>2 June</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Synoptic</td>
<td></td>
<td>328</td>
<td>2 June</td>
<td>2</td>
<td>652</td>
<td>3 June</td>
<td>1</td>
</tr>
<tr>
<td>2014</td>
<td>Infield</td>
<td>6 June</td>
<td>315</td>
<td>4 June</td>
<td>2</td>
<td>642</td>
<td>5 June</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Synoptic</td>
<td></td>
<td>326</td>
<td>3 June</td>
<td>3</td>
<td>654</td>
<td>4 June</td>
<td>2</td>
</tr>
</tbody>
</table>

3.2. Regional and in-situ weather data

P-Day threshold dates calculated using observations from Kermanshah airport regional station were coincides with those obtained by using in situ automatic weather station. Observations generated by the Kermanshah regional station provided an early estimation of lead time comparing to predicted date by filed weather data, but improvements across all locations and years were 3 days or less (Table 2). Accumulative values of GDD & P-days calculated with in-field weather data in 2014 are shown in Figure 2.

![Figure 2. Accumulative values of GDD & P-days calculated with infield weather data in 2014](image-url)
4. Discussion

The 300 P-Day forecast model predicted early blight lesion appearance in the experimental field, using either in-situ or data observed in nearby regional weather station. The disease was accurately predicted in both study years. P-Days are essentially a measure. This require installation of these stations within the field and capacity building for training and operation the system of potato development and predict early blight onset well, due to close relation of disease appearance and plant development. The P-Day and GDD models generated timely forecast in this study, and may be a better predictor of crop development and thus susceptible to infection by A. solani. Although Pscheidt and Stevenson [12] reported that delaying sprays until 300 P-Days increased disease severity, but in current study, the disease symptoms were not observed before accumulated value 300 P-Days in the field. Pscheidt and Stevenson [13] also noted that the field used in their study cropped by potatoes in previous season and therefore the model threshold might be lowered for such higher-risk disease situations. Similarly, in New York, Shtienberg and Fry [17] reported that initial early blight lesions appeared 6 to 8 days earlier when the preceding crop was tomato or potato. Even though the 300 P-Day threshold accurately predicted host susceptibility in this study, the presence of the pathogen and favorable environmental conditions for infection and disease development are not considered in this model. Pscheidt and Stevenson [13] noted that while early blight lesions were observed after 300 P-Days, airborne spores, favorable weather for dispersal and infection, and host susceptibility did not simultaneously occur until 400 P-Days. Madden et.al. [10] suggested initiating sprays at 400 P-Days and then spraying as needed according to cumulative severity values, which are based upon hours of leaf wetness and temperature, as recommended for A. solani by the tomato (FAST) forecast system. Harrison et al. [7] reported that under sprinkler irrigation with highly susceptible cultivars, however, delaying initial fungicide applications 10 to 14 days after primary lesion appearance results in significantly less disease suppression. Despite of differences between temperature values recorded in regional station and the field, the source of meteorological data had little impact on early blight forecast accuracy. Calculating potato Phenological days requires only daily maximum and minimum temperatures. When the ambient air temperature is in its suitable range for crop development (7 to 30°C), the P-Days are calculated daily. Daily maximum and minimum temperatures were highly correlated to all meteorological parameters evaluated. The spore trapping showed that Alternaria spores do exist in the air during the study period; but the highest concentrations were observed during to the final stages of plant development. Similar observations have been reported in other studies [6, 8, 9]. Concentrations of spores in the air were very low on germination stage. Expansion of the aerial parts of the potato plant, provided the conditions for the gradual accumulation of inoculum. Because of the young
shoots are more resistant to the early blight; need more time to spread the fungus in the plants. Spores are produced mainly on older or dead leaves [14]. So when the leaves are in the last stages, the highest concentration of spores is visible [15, 18]. The spores in the air depend on the weather conditions. The models which are suggested for the first time spraying, should be evaluated for other geographic areas [3, 17]. This is true about degree-day model, which first presented to Colorado, USA [5]. In the degree-day model, disease symptoms have been observed after passing through the cumulative calculated value of index of 600 in different regions [4]. It was similar to the cumulative value obtained in this study (GDD = 642). In the phenological days model, In the Wisconsin State of America, the first symptoms of early blight were observed after passing through the cumulative calculated values of the index from 300 [12]. In this study, also in use of phenological days, disease symptoms was achieved after the passing through of models from this number on the farm (P-days = 315).

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References


