Late Blight Forecasting Models and the Castor 2.0 Software

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Abstract

Timing of fungicide applications against potato late blight is complicated because the disease is strongly dependent on the weather, which is highly variable in time and space. Weather-dependent late blight forecasting models have been developed to guide fungicide use. In this paper we review existing forecasting models and discuss the CASTOR software that implements the Hyre, Smith, Wallin, Ullrich y Schrodter, BLITECAST, SIMCAST, Forsund, Winstel, and NegFry models. Four automatic weather stations that can generate input data for the models are described: the “Hobo”, “Watchdog”, “GroWeather” and “Vantage Pro”. The utility of the forecasting models is discussed. For use in the Andean region they first need to be validated. Then they can be used for zonification, and to guide the development of decision rules that can be used by farmers (without the need for a computer).

Resumen

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La toma de decisiones de cuando aplicar fungicidas para controlar el tizón tardío es complicada debido a que la enfermedad depende del clima, lo cual es muy variable en el tiempo y en el espacio. Varios modelos que predicen la ocurrencia del tizón tardío en base a datos climáticos han sido desarrollados para guiar el uso de fungicidas. En el presente artículo se hace una revisión de los modelos de predicción desarrollados al presente y se describe el programa CASTOR que implementa los modelos de Hyre, Smith, Wallin, Ullrich y Schrodter, BLITECAST, SIMCAST, Forsund, Winstel, y NEGFRY. Se describe cuatro estaciones meteorológicas automáticas que pueden generar los datos de entrada para estos modelos: “Hobo”, “Watchdog”, “GroWeather” y “Vantage Pro”. Se comenta sobre la utilidad de los modelos de predicción. Para el uso en la región Andina, se necesita primero que estén validados. Luego se pueden usar para la zonificación, y para desarrollar sistemas de toma de decisiones que puedan ser usados por los agricultores (sin necesidad de computadoras).

Introduction

Many potato producers apply fungicides to prevent yield losses due to late blight (LB). Decisions concerning fungicide use are complex due to various factors and interactions, such as climatic conditions, dosage and type of fungicide, cultivar resistance, and pathogen genotype. Weather conditions are important because humidity and cold conditions favor LB development, but these conditions vary greatly in space and time. Since LB is dependent on weather conditions, which are highly variable, meteorological data has long been used to guide decisions concerning fungicide applications. Several models for forecasting LB are available today and are being used in different zones of potato production throughout the world.

In this article we present a short review of the forecasting models that have been developed; for a more complete review, see Miller and O’Brien (1957) or Fry and Doster (1991). We then go on to describe the CASTOR program, which involves nine of these prediction models. We describe the use of automatic weather stations that can generate input data for these models, and finally we discuss the utility of these prediction models.

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History of forecasting systems

One of the first attempts at predicting LB was made by Lutman (1911) 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 LB development: night temperatures below dew point for at least four hours; minimum temperature no lower than 10°C, cloud cover the following day of at least 0.8, and rainfall in excess of 0.1 mm. These four conditions were confirmed by Van Poeteren in 1928 and were used for a LB warning service in Holland the same year.

In England, Beaumont and Stanilund (1933) also emphasized the importance of humidity for late blight occurrence. They considered a day humid when the relative humidity at 3:00pm was higher than 75%. Conditions were even more favorable for LB development with two consecutive humid days and when the minimum temperature was not lower than 10°C. A year later, Beaumont and Stanilund (1934) proposed five conditions defining a favorable day, and in 1937 these conditions were reduced to two: minimum temperature no lower than 10°C and two consecutive humid days (Beaumont and Stanilund, 1937).

Various prediction models were developed after this, among these the 'Irish rules' described by Burke (1953) (minimum temperature no less than 10°C and relative humidity no lower than 90% for 12 hours); and the Smith period (1956) (two consecutive days with minimum temperatures above 10°C and at least 10 hours with relative humidity above 90%).

BLITECAST (Krause et al., 1975), perhaps the best-known prediction model, is a combination of two LB prediction models. The first part of the model forecasts the occurrence of LB at 7–14 days after an accumulated total of 10 favorable rainy days according to the model of Hyre (1954, 1955), or the accumulation of 18 severity units according to the model of Wallin (1962). The second part of the model recommends fungicide application based on the number of favorable rainy days and the severity values accumulated over the 7 previous days. The rainy days are based on accumulated precipitation. Severity ratings relate the duration of RH above 90% and the average temperature during these periods of high humidity.

Another method combining two forecasting models is NegFry (Hansen et al., 1995). Phytoprog (Schrodter and Ulrich, 1966) predicts the risk of blight using 'negative prognosis' or 'LB-free days'; and SimCast (Fry et al., 1983; Grünwald et al., 2000) recommends the subsequent fungicide treatment. SimCast is derived from a simulation model describing the effects of climate, fungicide and host resistance on *Phytophthora infestans* development.

The latest generation of forecast systems includes more factors and interactions for predicting LB (such as the pathogen life cycle, weather conditions, fungicides and host resistance). Among this type of model are: PROGEB (Gutsche, 1993), PhytoPRE (Forrer et al., 1993), Negfry (Hansen et al., 1995), Prophy (Schepers, 1995), and SIMPHYT (Gutsche and Kluge, 1996).

The Castor 2.0 program

CASTOR is a program for handling weather data and forecasting potato LB (Juárez et al., 2002) (Figure 1). It is a compilation of several forecasting models for LB, which are used and compared among each other. It can be accessed freely at http://www.cipotato.org.

CASTOR enables weather data to be imported directly in text form (ASCII), which, typically, has been recorded by automatic weather stations. These records are generally extensive and hard to manage when they are collected at intervals of one hour or less. CASTOR is able to import this data, combine several data sets from the same station, and calculate the length of time that RH is above 90%. CASTOR stocks the records in a standard form and generates hourly, daily, ten-day and monthly climate data. These reports can be used by other program such as spreadsheets or database management systems.

CASTOR includes several forecast models: Hyre, 1954; Smith, 1956; Wallin, 1962; Ullrich and Schrodter, 1966; BLITECAST (Krause et al., 1975); SimCast (Fry et al., 1983; Grünwald et al., 2000); Forsund, 1983; Winstel, 1993; NegFry (Hansen et al., 1995). The models currently being implemented in CASTOR are based on the compilation made by Broome et al. (1995) of U.C. Davis, California, Statewide IPM, http://axp.ipm.ucdavis.edu/DISEASE/DATABASE/potatolateblight.html

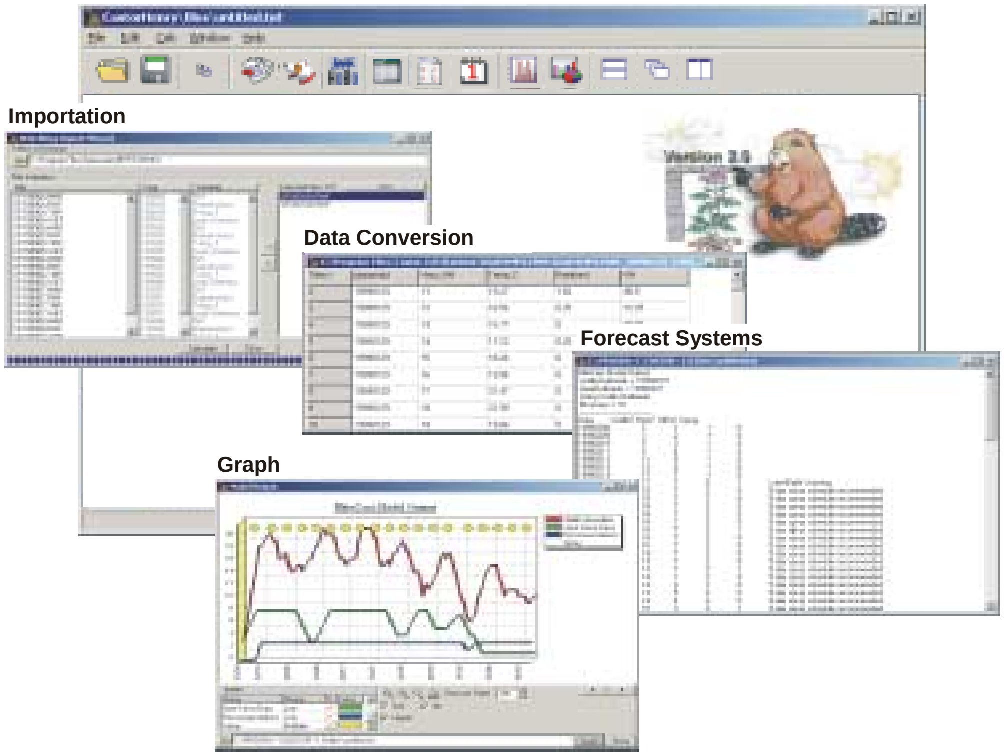

Figure 1. Version 2.0 of the CASTOR program for handling hourly weather data and potato LB forecast systems.

The forecast systems in CASTOR use hourly and daily weather data for predicting the risk of a LB outbreak, when fungicide treatments should start and the frequency of fungicide application (Table 1). To validate the prediction models in a given locality, field trials should be set up and weather data should be recorded over several seasons, to test whether any of them are valid in these specific environmental conditions.

Table 1. General characteristics of few potato late blight forecasting models.

		Atmospheric Variables							
		Hourly Records			Daily Records		Forecast		
Model		T [1]	RH [2]	Rainfall [3]	T [1]	Rainfall [3]	Risk/start of epidemic	First application	Subsequent applications
Hyre	1954				x	X	x		
Smith	1956		x		x			X	
Wallin	1962	x	x				x		x
Ullrich y Schrodter	1966	x	x	x				X	
BLITECAST	1975	x	x			X		x	x
Forsund	1983		X [4]		x	x	x		
SimCast	1983	x	x			x			x
Winstel	1993	x	x					x	
NegFry	1995	x	x	x				x	x

[1] Temperature (ºC)
[2] Relative humidity > 90%
[3] Rainfall (mm)
[4] Relative humidity > 75% (night-time)

Weather data

Three variables are generally required in the forecast models: relative humidity (RH), temperature and precipitation, although some models do not require rainfall. Hourly RH information is needed for calculating the duration of leaf wetness (RH greater than 90%).

It is most practical to use automatic weather stations. Several models exist. Professional models such as those produced by Campbell Scientific (www.campbellsci.com) are a good option, but expensive. In Table 2 four of the less expensive weather stations are compared. "Hobo" produced by Onset Computer Corporation (www.onsetcomp.com), "Watchdog" from Spectrum Technologies (www.specmeters.com), and "GroWeather" and "Vantage Pro" from Davis Instruments (www.davisnet.com).

Table 2. Comparison of automatic weather stations.

	Hobo	Hobo	WatchDog[3]	GroWeather	Vantage
Model	H8 Pro RH/T	Event	450	Industriale[5]	Vantage Pro[5]
Price[1] (US$)	159	85	299	1400	595
Temperature	++	-	++	++	++
Relative humidity	++	-	++	++	++
Precipitation	-	+ (75-100 US$)	+ (99 US$)	++	++
Solar radiation	-	-	+ (249 US$)[4]	++	+(160 US$)
Leaf wetness	-	-	+ (75 US$)	++	-
Wind speed	-	-	-	++	++
Protective case	65 US$	Not applicable	44 US$	Included	Included
Data offloading facility	Yes (159 US$)	Yes (159 US$)	Yes (240 US$)	No	No
Storage capacity[2]	350	350	156	37	

++ Includes sensors
+ Optional external sensors bought separately (prices in brackets)
[1] March 2002 prices. Other prices indicated in the table are extra.
[2] Number of days during which hourly readings are stored.
[3] RH and T are internal sensors. Two extra external sensors may be used with the data logger.
[4] The data logger stocks spot PAR readings but does not integrate the readings over time.
[5] Includes a solar panel.

Hobo is the simplest of these weather stations. Hobo Pro is a data logger (electronic instrument that stores measurements from the sensors over time) with internal sensors for temperature and RH. An additional rain gauge and a rainfall logger are necessary (Hobo Event). There are different models of the WatchDog, the most complete is the 450 model, which has two internal sensors (temperature and RH) and can be connected to two external sensors (rainfall, solar radiation or leaf wetness for example). The Groweather and Vantage Pro stations are substantially more complete weather stations.

Hobo and WatchDog have peripheral systems for offloading data directly from the logger in the field. Groweather and Vantage Pro weather stations need to be connected to a laptop computer or taken into the office to offload information. To offload the collected data, Hobo requires the BoxCarPro software from Onset, or SpecWare from Spectrum Technologies of WatchDog. GroWeather and Vantage Pro have their own inbuilt software.

Discussion

Forecast models are a simplification of nature, but despite their relative simplicity, they can help in making decisions about when to apply fungicides in different regions of potato production throughout the world. Even so, these models are not extensively used. The success of BLITECAST for example, was not because it enabled the number of fungicide treatments against LB to be reduced, but rather because it brought about new horizons in plant epidemiology and integrated pest management (MacKenzie, 1984).

Many farmers in developed countries have adopted calendar-scheduled treatments due to the high risk of LB and the low cost of fungicides relative to the value of the crop. However, pressure from society to reduce pesticide use is becoming steadily stronger. Models can be used for this purpose in developed countries because computers and the Internet are in common use. In the near future, forecasting models can play an important role in decision-making concerning fungicide use and disease control in these countries.

In the Andean region, farmers usually cannot afford to buy enough fungicide to control the disease; losses can be very high and even lead to crop abandonment (Ortiz et al., 1999; Thiele et al., 1998). The optimization of fungicide use is therefore of utmost importance in the Andes.

Forecast models can be used for optimizing fungicide use, but their effectiveness in the Andean region must first be verified. Most of these models were developed in temperate zones (USA and Europe) and little is known about how useful they are outside the areas where they were developed. At present, coordinated efforts are being made to test how applicable these forecasting models are and to adjust them to Andean conditions.

In the first place, the calibrated forecasting models could be useful for identifying LB zones and for providing general guidelines on fungicide treatments to extension workers and farmers. They could also be used to develop systems for making decisions on fungicide use that are simple to apply for Andean farmers, the majority of whom have neither computers nor automatic weather stations.

In these decision support systems (DSS), the rules for deciding whether or not to apply fungicides could be listed on a sheet of paper. The DDS could require simple assessments made in the field. For example, the number of 'wet days' could be estimated by using the presence of dew at a specified time of day, or by using soft drink bottles as 'home rain gauges' (Forbes, personal communication). Moreover, information such as the stage of crop development and infection hot spots could be taken into account.

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