SISALERT - A generic web-based plant disease forecasting system

José Maurício Cunha Fernandes[1], Willingthon Pavan[2] and Rosa Maria Sanhueza[3]

[1]Embrapa Trigo, Passo Fundo, RS, 99001-970,Brazil, e-mail: mauricio@cnpt.embrapa.br
[2]ICEG, Univ. de Passo Fundo, Passo Fundo, RS, 99001-970, Brazil, e-mail:pavan@upf.br
[3]Proterra, Vacaria, RS, 95200-000, Brazil, e-mail: rosamaria@m2net.com.br

Abstract. Plant diseases cause significant crop loss throughout the world. Impact on yield depends on the disease involved, the crop species grown, the management practices followed, and various environmental factors. Integrate plant disease management advocates the use of multiple control measures, including, if possible, a rational system for predicting the risk of disease outbreaks. Presently, web-based technologies have led to great strides in the development and employment of decision support systems. The present work illustrates an approach towards that direction by the use of novel programming languages and technology for the development of a web-based system for model implementation and delivery. The objective of this work was 1) To use generic and modular simulation models for predicting diseases establishment based on weather data and 2) To implement a disease warning system using simulation models and the near real-time weather data acquisition system plus local specific weather forecast.

Keywords: simulation models, weather-driven, disease epidemics, warning system.

1 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, in part, responsible for the lack adequate food (Strange and Scott, 2005). Plant diseases may reduce crop yields depending on the diseases involved, the crop species grown, the management practices followed, and various environmental factors. An integrated disease-control program, based on knowledge of pathogen biology and which diseases are most likely to occur in an area, is the most effective and efficient means of controlling diseases in the long run. The integrated disease management is a system that, in the context of the associated environment and the population dynamics of the pathogen species, utilizes all suitable techniques and methods in a manner as compatible as

In: M. Salampasis, A. Matopoulos (eds.): Proceedings of the International Conference on Information and Communication Technologies
for Sustainable Agri-production and Environment (HAICTA 2011), Skiathos, 8-11 September, 2011.

possible and maintains the pathogen population at levels below those causing economic injury. Moreover, integrate plant disease management advocates the use of multiple control measures, including, if possible, a rational system for predicting the risk of disease outbreaks. Therefore, a support system for decision-making can be a valuable tool for farmers and crop advisers aiming for integrated disease management.

Disease forecasting has become an established component of quantitative epidemiology. The mathematics of disease development has matured to the point where it is a powerful and respected component of disease forecasting and management. However, many plant disease forecast models have not lived up to the expectations that they would play a major role in better disease management. Amongst the reasons, 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). An exciting development in this area is the possibility to use weather forecasts as input into disease models and consequently output "true disease forecasts". As weather forecasts improve together with more accurate estimations of environmental variables useful for plant disease models, as such precipitation and leaf wetness duration, it will be possible to provide seasonal estimates of disease likelihood and forecast outbreaks. This is especially interesting for crop management for the reason that unnecessary sprays has a significant impact on production costs, and no timely applications may result in inadequate control.

Computer modeling has provided a tool for using weather data to predict disease outbreaks. Traditional plant disease models have used accumulated hours of wetness duration combined with temperature requirements to predict the infection process and identify times of high disease risk. These types of models use recorded weather data to track when enough favorable disease hours have occurred to warrant management action. These models have been part of integrated pest management control measures.

The revolution in web-based technologies has led to great strides in the development and employment of decision support systems for growers and pest management specialists. The present work illustrates an approach towards that direction by the use of novel programming languages and technology for the development of a web-based system for model implementation and delivery. SISALERT is a multi-model platform that unleashes the power of hourly weather station data and hour-by-hour weather forecast information using sophisticated disease risk assessment models. These models interpret weather data giving information on past or recent disease behavior as well as predicted disease risk. The uniqueness of SISALERT format is the modularity that allows coupling crop and disease models depending on which model is under run.

The objective of this work was 1) To use generic and modular simulation models for predicting diseases establishment based on weather data and 2) To implement a disease warning system using simulation models and the near real-time weather data acquisition system plus local specific weather forecast.

2 Material and Methods

The software architecture was based on the MVC design pattern (Model-View-Controller), an application development model that uses layers during the programming. It was divided into three layers or functional areas: Model, View and Controller (Veit and Herrmann, 2003). The Model part represented the "business logic", the state and behavior of components, managing and leading all transformations. The View provided the data produced by the model, managing what could be seen in his state, presenting them in shape images, graphs or tabular data through web pages or mobile devices. The Controller determined the flow of the application, managing the user interaction/system with the Model (Figure 1).

Servers were designed to process requests and ensure the execution. They were divided into five servers: weather data management server (WDMS), database server (DBS), disease forecasting model server (DFMS), web server (WS), and crop model server (CMS). The WDMS consisted in a recovery data module to retrieve weather data from remote sites, updating the data into the DBS. The data retrieval module, which was executed every hour by the “crontab” Linux command, searches for a station file in the script directory to access an automated weather station via Internet. In the station file, the station name, IP address, and the last data retrieval were specified to telecommunicate with an automated weather station, provided by INMET (National Institute of Meteorology).

To facilitate the access to station’s data, specific software was design to be deployed on remote computers, allowing to receive data from a particular station network. This software was developed in a generic and configurable way, allowing the use in a variety of operating systems and weather stations configuration, filtering, validating and preparing the data for transferring and storing.

In addition, numerical weather forecast data, provided by INPE (National Institute for Space Research) was retrieved by FTP protocol. PostgreSQL was the core of DBS and stores weather data, as well the identifiers for weather station and run-time parameters as cultivar, planting date, previous crop, and others used by the CMS.

The collected meteorological data are considered adequate to generate warnings of epidemics in extensive crops such as grains (wheat, soybeans, rice, etc.), but cannot provide the desired quality for diseases alerts in crops with high commercial value, where any damage may result in substantial marketing penalties. In a vineyard, for example, the values for meteorological variables within plant canopy may differ from those collected in a nearby weather station. Therefore, onsite data was also obtained by means of a low-cost temperature and relative humidity logging sensors that can be deployed in a spatially dense network.

DBS was interfaced with WDMS and DFMS using a Java API, and with WS using an SQL module in a JSP script engine. WS retrieved information from DBS upon request by users through a client-side interface (web-browser, desktop and Smartphone applications).

Model outputs are displayed either in textual or graphical formats by using a server-side plotting script. Besides the option of defining a weather station in the database, the system allowed users to input their own weather data, such as precipitation, temperature, relative humidity, etc., customizing the results for site-specific conditions.

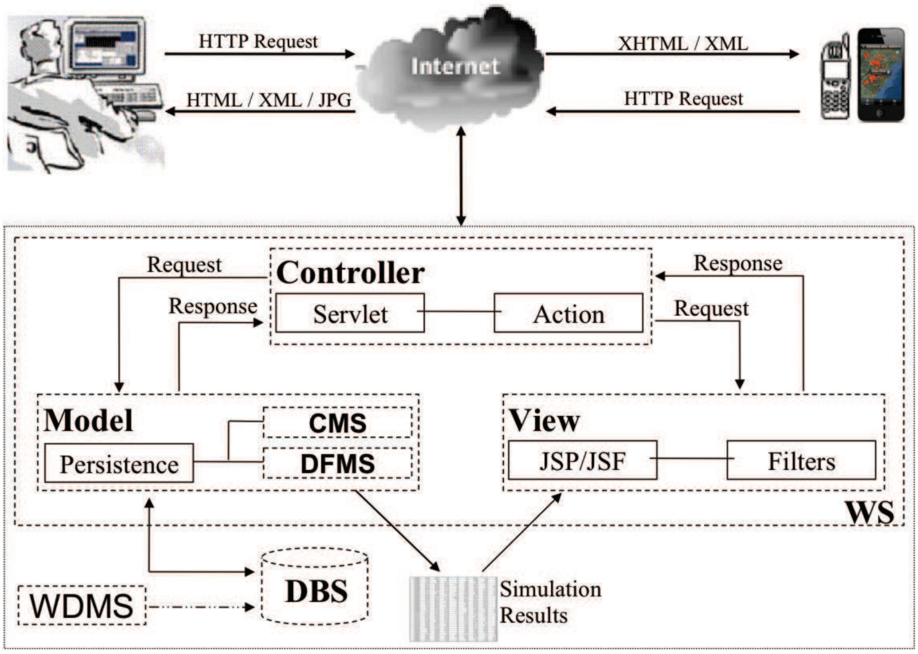

Fig. 1. Architecture designed for gathering and storing actual and forecast weather data to run a disease simulation to forecast a risk. The server programs are: weather data management server (WDMS), database server (DBS), disease forecasting model server (DFMS), crop model server (CMS), and web server (WS).

The system used either hourly or daily weather data from DBS, and DFMS produces daily risk infection index by using near real-time and anticipated risks by combining historical with 7-day numerical weather forecast. During the simulation process, each sub-model uses data from WDMS. The daily output is a risk infection index calculated based on daily outputs from each sub-model.

3 Results

By incorporating the automated weather monitoring system, the disease forecasting models, and the Internet, the information delivery system denominated SISALERT described in this paper has many advantages. These includes (1) increased accuracy and site-specificity of the forecasting information, (2) real-time delivery of the forecasting information, (3) effectiveness in sharing information on the Internet by multiple users, and (4) cost efficiency in the system implementation by using public domain software and programming tools. In addition, Information stored in the database is presented to users through a series of interactive web pages which are dynamically generated through a combination of scripts which interface between the website and relational database. To illustrate some of the functionalities of the system examples of punctual advisories and regional forecasts are presented bellow.

3.1 Local specific risk of infection warnings

In North of Rio Grande do Sul, Brazil, losses due to Apple Scab, caused by the fungus *Venturia ineaqualis*, are of great concern (Santos et al., 2005). Up to 12 fungicide applications per season are necessary to maintain a healthy crop in years highly favorable for disease development. Improved prediction of epidemic onset and identification of periods when fungicides are not required would increase control efficiency and reduce production costs. An Apple Scab model, adapted from the classic Mill's table, has proven to be useful to described the relationships between environmental variables and disease increase. Therefore, disease advisories based on algorithms of weather thresholds are available for apple growers in the area. Apple Scab advisory is based on an algorithm that accounts for rainfall, air temperature, and leaf wetness duration. First trapped ascospores start on the advisory system. Fungicide use based on these algorithms provided control comparable to, and in some cases better than, which obtained by the conventional method. To make the information system user-friendly, the weather and disease forecast data are provided in graphs, and text forms. In the figure 2, it is shown the information that local user can retrieve upon request. In addition, short messages indicating eminent infection risk are automatically delivered to mobile phones or/and e-mail addresses of registered users.

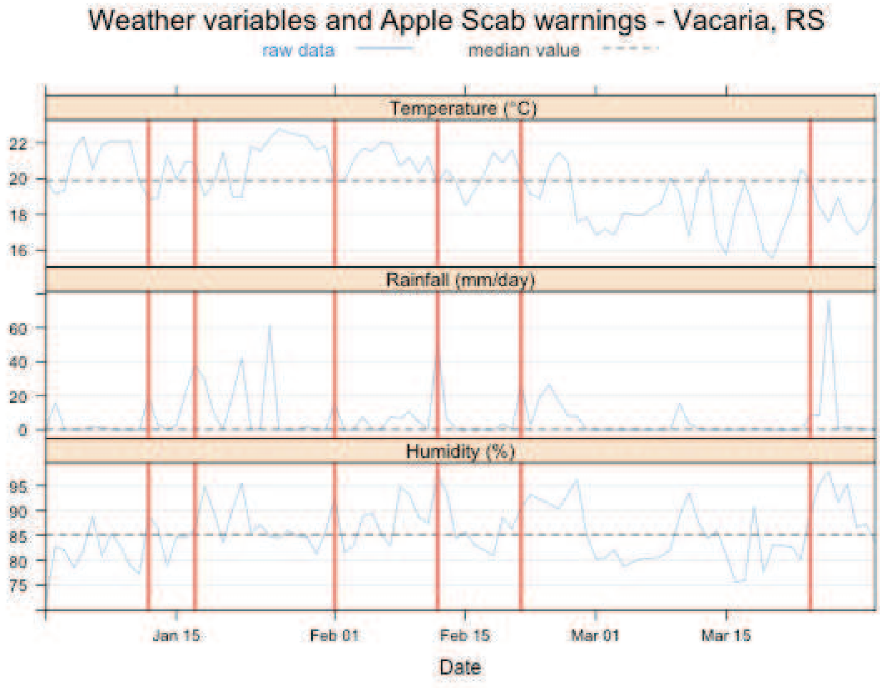

Fig. 2. Daily temperature, precipitation, and relative humidity observed in the municipality of Vacaria in the north of state of Rio Grande do Sul, Brazil, during the summer of 2011 and associated Apple Scab warnings indicated by vertical the line.

3.2 Risk Mapping to Support Decision Making on Plant Disease Management

Fusarium head blight (FHB) outbreaks increased considerably in many countries in the last two decades. In Brazil, FHB epidemics have become more frequent and often resulting in significant yield losses. The main causal agent of the disease in Brazil is the fungus *Gibberella zeae* that survives in host debris. FHB is best known as a disease of flowering stage but evidences suggest that wheat may be susceptible at later stages of kernel development. Economic losses result from decreased grain yield and quality because of contamination by toxins produced by the fungus, mainly deoxynivalenol (DON). A FHB infection-risk simulation model was developed and model details have been reported (Del Ponte et al., 2005). The FHB infection-risk model has a component for the disease cycle and component for growth and development of wheat spikes. The disease cycle, simulates the development of all cohorts of *G. zea ascospores*, from density in the air to infection. While spike susceptibility from emergence to late kernel development is given by the host component. In brief, a successful infection on a particular day depends on host tissue susceptible factor, inoculum density, temperature, daily precipitation and mean relative humidity in a 24-hour window. The risk index is the sum of daily successful infections. The goal of this predictive system is to help growers assess the risk of Fusarium head blight in their region. Users are asked to identify the flowering date for their fields. To make the information system more intuitive, the weather and infection risk data are provided in graphs and maps forms. FHB risk maps are computer-generated images depicting infection risk using special interpolation techniques for point estimations of the risks by site-specific weather stations and forecasted weather within a wheat growing area. The final risk maps are made by color transparency layers which overlays a geographic map delivered on the web. Therefore, it is important for growers to monitor conditions carefully in their area to evaluate the potential need for fungicide applications. In addition, maps may be useful for the fine-tuning of wheat zoning and for the identification of pos-harvest areas with lower or higher risk of mycotoxin contamination. In the figure 3, are presented post-harvested weather patterns and FHB risk maps for the years of 2009 and 2010, in the state of Rio Grande do Sul, Brazil.

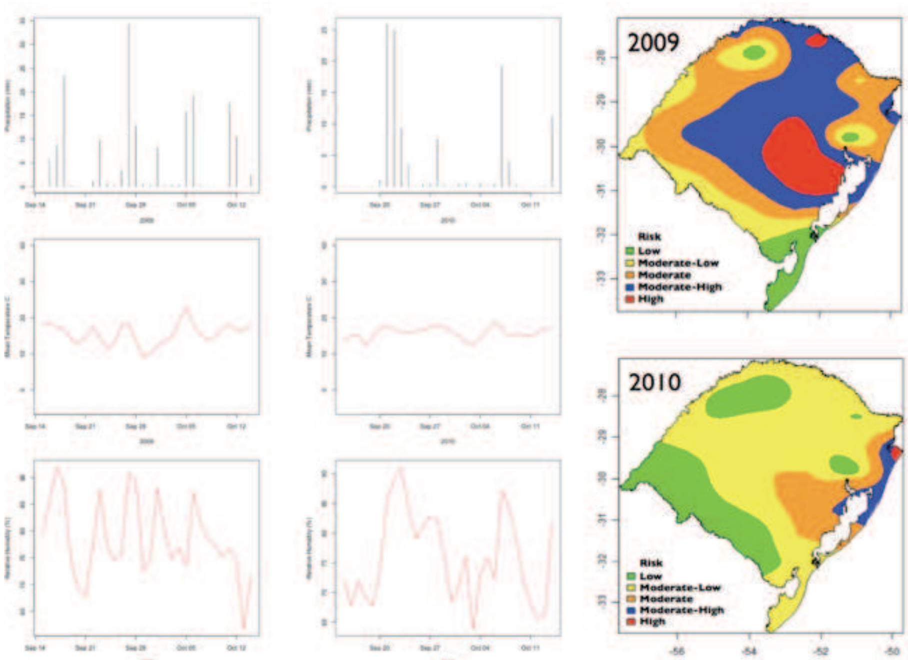

Fig. 3. Average of daily precipitation, temperature, and relative humidity observed in the state of Rio Grande do Sul, Brazil, during head stage of wheat (2009 and 2010) and associated FHB risk infection maps.

Up to this far, SISALERT is operational to predict risk of infection of two wheat diseases and five apple diseases. Epidemiological models for strawberry (Pavan et al., 2011), and grape diseases are under final evaluation. Disease cycle models for extensive crops such as wheat, rice, soybean and dry beans are under development (Fernandes et al., 2007).

A major obstacle in disease forecasting is the validity of the disease forecasting models. Although accuracy weather information could be improved by using on site weather data associated to weather forecast data, the model itself may cause inaccurate forecasting due to its limitation of validity. There is a need for continuous and systematic effort to develop better models. Its is, therefore, imperative that attempts should be made to establish a network for testing and model comparison.

The information delivery system in this study can be applied to forecast other diseases and insects pests just by changing forecasting models in the program server. Also, if mesh climatic data are available at a fine scale in the future, the system can produce the disease forecasting information at the same scale without automated weather stations at every site. In conjunction with geographical information systems, this system can be used to generate maps to illustrate disease development over the country.

4. Final Remarks

In the apple production area, the current advisory has enabled growers to manage fungicide use, time, and resources much more efficiently and profitably. Improvements to this system could only increase profit and efficiency, and reduce unnecessary dependency on fungicides.

Besides extending risk information for a large geographical region the use of intuitive images representing epidemic risks may facilitate dissemination and understanding of risks to guide decision-making on plant disease management. In addition, maps may be useful for the fine tuning of crop zoning and for the identification of quality aspects in post-harvested areas. Further work is under way to expand this framework to other pests, agronomic risks and crops.

Acknowledgments. This work was funded by the National Council of Research and Development (CNPq) under project number 578421/2008-9.

References

1. Del Ponte, E. M., Fernandes, J. M. C. and PAVAN, Willingthon. (2005). A risk infection simulation model for fusarium head blight of wheat. Fitopatol. bras. 30: 634-642.
2. Santos, M. C., Furtado, E. L., Sanhueza, R. V. (2005). Controle da sarna da maceira com utilização da Tabela de Mills, na região de Vacaria - RS. Summa Phytopathologica, 31: 254-260.
3. Strange, R. N. and Scott, P. R. (2005). Plant Disease: A Threat to Global Food Security. Ann. Rev. Phytopathol. 43:83-116
4. Seem, R. (2001). Plant disease forecasting in the era of information technology. In: Plant Disease Forecast: Information Technology in Plant Pathology. Kyongju, Republic of Korea: [s.n.].
5. Veit, M. and Herrmann, S. (2003). Model-view-controller and object teams: a perfect match of paradigms AOSD '03: Proceedings of the 2nd international conference on Aspect-oriented software development, ACM Press, 140-149
6. Pavan, W., Fraisse, C. W. and Peres, N. A. (2011). Development of a web-based disease forecasting system for strawberries. Computers and Electronics in Agriculture, 75:169-175.
7. Fernandes, J. M., Ponte, E. Del, Pavan, W. and Cunha, G. R. da (2007). Web-based system to true forecast disease epidemics-Case study for Fusarium Head Blight of wheat.. In: Mannava V. K. Sivakumar; James Hansen. (Org.). Climate prediction in agriculture: Advances and challenges. Berlin: Springer-Verlag, p. 265-271.