A PHENOLOGY-BASED PREDICTIVE MODEL FOR FUSARIUM HEAD BLIGHT OF WHEAT

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ABSTRACT

Our goal was to establish a model to account for anther extrusion period that could be used to calculate probabilities of Fusarium head blight incidence as the window of opportunity for infection advances from beginning of anther extrusion to complete anther fall. The model combines several elements of meteorology, biology of G. zeae and wheat phenology.

KEYWORDS: Wheat, Fusarium Model, Simulation Model

MODELO PREDITIVO DE GIREBELA BASEADO NA FENOLOGIA

RESUMO

O objetivo deste trabalho foi desenvolver um modelo que considerasse o número e o período de extrusão de anteras no trigo para ser usado no calculo probabilístico de incidência de Giberela à medida que a janela de oportunidade para infecção avança do inicio da extrusão de anteras até que seja completo o processo da floração. O modelo combina vários elementos de meteorologia, biologia de *G. zeae* e a fenologia do trigo.

PALAVRAS-CHAVE: Trigo, Modelo de Giberela, Modelos de Simulação

1. INTRODUCTION

Fusarium head blight (FHB), incited by a fungus (Gibberella zeae (Schwein.) Petch), is an important disease affecting wheat. Fusarium head blight fungus survives in crop debris and windborne or splashed spores infects the heads during flowering. Humid weather and moderate temperatures are favorable for infection (Sutton, 1982). Fusarium head blight can be devastating to yields if a large proportion of plants are infected. The fungus also can produce harmful mycotoxins which depreciate grain value (McMullen et al., 1997).

Despite the absence of reliable data for comparing FHB intensity amongst different years in southern Brazil, it is generally accepted that the disease has been more severe in the last decade. It is believed that a combination of 'El Niño' years and of abundant sources of inoculum are the cause for such high intensity of FHB in the wheat fields in southern part of Brazil (Fernandes, 1997).

The relative narrow susceptible phase of wheat and the strong dependence on climatic requirements for infection success makes the pathosystem suitable for modeling. A realistic approach should account for availability of susceptible tissue besides weather driven pathogen dynamics.

Process-based models of crop growth and development are exciting tools emerging from the on-going information technology. Models can improve our understanding of the complex pro-cesses underlying wheat production including Fusarium head blight management. Their analytical power can help deal with difficult tasks such as predicting the incidence of Fusarium head blight on wheat.

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2. MATERIAL AND METHODS

Brief Model Description

Model Framework. To develop a wheat simulation model into an Object Oriented environment we started with a small generic crop model. This model is available at www.icasanet.org/ modular. The model contains three main modules: Soil, Plant and Weather (Jones, et al., 2001). The model originally written in FORTRAN was converted to JAVA and followed the principles of Object Oriented approach. The modular structure was used to depict classes and provide them with the right data behavior. One of key features of a modular approach is that models should relate to the real world components or processes.

Wheat Simulation Model. Wheat simulation, a process oriented model which is based on daily time-steps considers 1 m 2 area of wheat crop. It simulates the dynamics of wheat biomass through inputs of historical records of weather data, cultivar coefficients, and soil properties. The wheat simulation model includes growth, phenology and water balance routines.

The plant growth module computes crop growth and development based on daily values of maximum and minimum temperatures, radiation and the daily value of two soil water stress factors, deficit and surplus. This module also simulates leaf area index (LAI), which is used in the soil water module to compute evapotranspiration.

Crop development is simulated based on thermal time required to reach specific growth stages. The model also accounts for simulating the dynamics of heading emergence including extrusion of anthers (flowering). State variables and simulated processes allow accounting for incidence of Fusarium head blight.

The water budget in the model includes precipitation, irrigation, runoff, water infiltration in the soil profile, crop transpiration, and evaporation. Crop evapotranspiration is determined from leaf area index.

Fusarium head blight Simulation Model. A module was developed to simulate head infection through inputs of local weather data. The first anthers were empirically set to be extruded on day five after heading emergence. Flowering dynamics was handled as a cohort of heads exhibiting anthers resulting from simulation and assumed to be a potential infection site.

Predictive modeling tries to match the rules (models) for guessing (predicting) the Fusarium head blight incidence from weather variables. Stepwise multiple regression procedures were used to determine the prediction rules. The weather variables examined were solar radiation, maximum temperature, minimum temperature and precipitation.

Model Inputs

Input data such as location, soil, crop and management files are required to run the model. An advanced user-friendly interface allows users to easily manipulate input files, create simulations, execute single and batch run simulations and produce text and graphical reports. The data base was implemented using PostgreSql and Interbase for remote and local access, respectively.

3. RESULTS AND DISCUSSION

The model predicted reasonable well the phenological stages of the wheat cultivar BR23, especially at the flowering stage, except at very early or very late sowing dates. In general, the date for heading stage (50 % heads emerged) was predicted within an interval of two-three days around the observed date.

Findings from field experiments revealed that daily number of anthers per head varied significantly. In general, in a single head flowering lasts from five to eight days. As a contrast, in a group of heads the course of anther extrusion last from 14 to 18 days. The peak of number of extruded anthers was observed at six to eight days after the beginning of flowering.

Growth chamber experiments showed that anther extrusion was responsive to temperature. Rate of extrusion increased proportionally to temperature increments (Vargas et al., 2001). This conceptual model was translated to the predictive model.

The model attempts to predict the probability of Fusarium head blight based on the weather variables occurring around flowering. The weather variables inserted in the model are rain greater than 1mm and maximum temperature. An ascospore cloud is formed every day rain is greater than 1 mm. The ascospore maturation rate is reduced at temperatures lower than 20 °C. Daily ascospore cloud values are summed in simple 4-day moving periods.

If anthers are present infection occurs during a rain event greater than 1 mm. The proportion of infected heads depends on the time course of anther extrusion and the size of the ascospore cloud.

In the field, the level of Fusarium head blight varied among experiments. The disease intensity was dependent on weather conditions during the flowering stage. Sowing date could alter flowering date of a cultivar in a particular year causing great differences in disease levels. As a consequence, fields with distinct sowing date can have a different level of disease (Figure 1). Thus, to predict Fusarium head blight incidence the simulator first needs to be very accurate in predicting growth stages of wheat. Any slight deviation from the target (susceptibility window) may cause a considerable error in predicting Fusarium head blight incidence. Further studies on wheat phenology are being planned. Hopefully, as more data becomes available it will be possible to improve the model performance.

The Fusarium head blight predictive model predicts the probability of disease occurrence; it does not predict level of disease severity. The predictive Fusarium head blight model predicted moderate to high levels of incidence for a majority of simulated wheat fields with sowing dates in the period of 1998 to 2002, at Passo Fundo, RS, Brazil. This moderate to high incidence was probably due to the high frequency of rainy days during the flowering stage of wheat.

In the year 2002, for example, a "El Niño" event occurred. In southern Brazil a "El Niño" year means precipitation above normal at spring time coinciding with heading stage of wheat. Thus, diseases such as tan spot, glume blotch and Fusarium head blight are usually severe in "El Niño" years. As a consequence during such years wheat yields are degraded (Cunha, et al., 2001). Besides, rainfall around harvest time may contribute to a lower test weight of wheat which penalizes profits.

Plans for the future

"As is" the predictive model is a convenient tool for researchers, teachers and students to use in the study of wheat development and incidence of Fusarium head blight. The model was developed using up to date technology for Web deployment. Therefore, it can be shared over the Web with a wide variety of potential users.

So far, this predictive Fusarium head blight model has been developed and tested using the Brazilian wheat cultivar BR23 and historic weather data from Passo Fundo, RS, Brazil. Thus, model outputs should be interpreted cautiously avoiding extrapolation to other cultivars and regions before further testing and validation. Nevertheless, the model is suitable for general research and educational purposes. Hopefully, as more data becomes available, it can be easily modified to accommodate different cultivars and regions.

In the meantime, aiming to reduce the error in estimating the "window of susceptibility" model is being modified so that the user can enter the date(s) for any growth stage(s) before flowering. Finally, the modular structure adopted in the model construction should facilitate adding new components, as they become available, to expand model capability.

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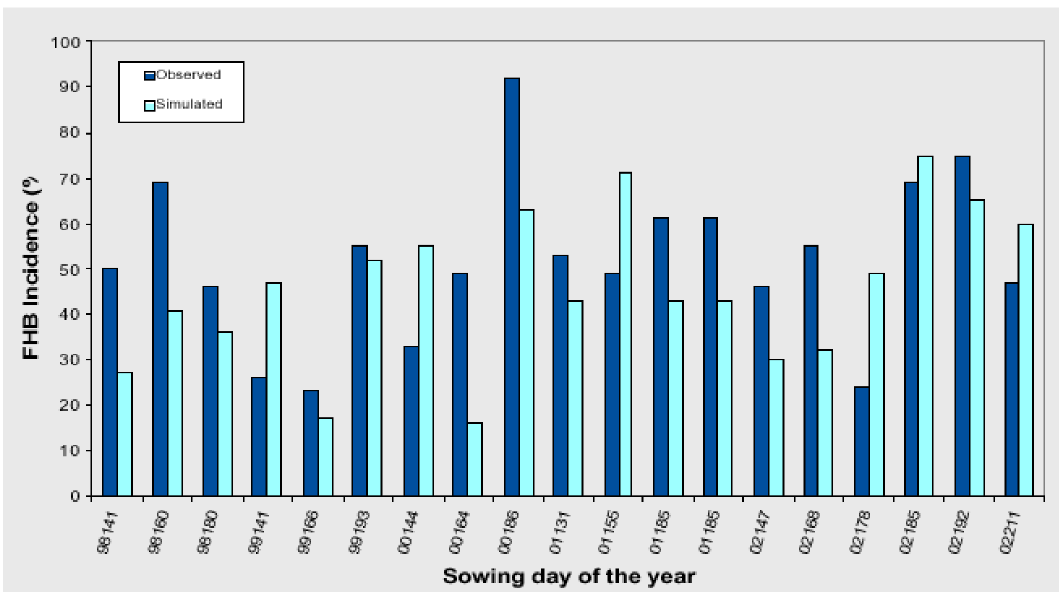

FIGURE 1: Simulated and observed FHB incidence for the wheat cultivar BR23 at Passo Fundo, RS, Brazil.