SimCanker: a simulation model for containing phoma stem canker of oilseed rape through cultural practices

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Abstract

Phoma stem canker is a major world-wide disease of oilseed rape. Genetic and chemical control methods have not succeeded in completely containing the disease. However, the combination of cultural with genetic and chemical controls may provide a efficient method to contain the disease. To define integrated strategies, a simulation model is needed due to the numerous interactions between cultural practices, the pathosystem and the environment. This paper presents the process chart of SimCanker, a **Sim**ulator of Crown **Canker** development. The aim of this model, which is still being developed, is to simulate the effects of cultural practices on crown canker development and yield loss to help in defining integrated cultural practices to control the disease. The cultural practices taken into account are the sowing date, crop density, the application of a fungicide at autumn, the susceptibility of the cultivar, and nitrogen management within the cropping system. The model works at the field scale during the whole cultural cycle. The parameterisation and the evaluation of two sub-models are presented. SimCanker will be used in the definition of Integrated Pest Management strategies for oilseed rape crops, in association to a crop model and other sub-models representing the effects of cultural practices on the development of other pests.

Media summary

This paper presents SimCanker, a Simulator of Crown Canker development to help in defining integrated cultural practices to contain phoma stem canker of oilseed rape.

Key Words

Blackleg – *Leptosphaeria maculans* - cultural control - Integrated Pest Management

Introduction

Phoma stem canker, caused by *Phoma lingam* (*Leptosphaeria maculans*) is one of the major world-wide oilseed rape diseases (West *et al*. 2001). Epidemics are initiated during autumn by air-borne ascospores released from infected stubbles of previous crops. Once in contact with plants, these ascospores germinate and produce leaf lesions. The fungus then grows systemically from the leaf lesions to the stem where it produces cankers which can result in major yield loss. Genetic control does not completely contain the disease and resistance can breakdown (Rouxel *et al* 2003). Chemical control is effective only if fungicides are applied during the phoma leaf spot stage. Since the fungicides are effective for only limited periods of time — generally for two to three weeks — total control of the disease using fungicides is not possible. It is therefore necessary to develop alternative methods for controlling the pathogen. The adaptation of cultural practices appears to be promising. Because of numerous interactions between cultural practices, the pathosystem and the environment, a simulation model would be helpful to define an integrated control strategy. This paper presents the process chart of SimCanker, a **Sim**ulator of Crown **Canker** development. The model, which is still being developed, will simulate the effects of cultural practices on crown canker development and yield loss to help in defining integrated cultural practices to control the disease. The model consists of linking three sub-models: the first one predicts yield loss as a function of the severity of crown cankers, the second predicts the severity of crown canker as a function of leaf lesions observed at autumn, climate and crop development during the vegetative stages, and the third one predicts leaf infections as a function of climate, ascospore concentration changes over time and crop development during the vegetative stages. The parameterisation and the evaluation of the first two sub-models are presented in this paper.

Methods

Process chart of SimCanker

The output variables predicted by SimCanker are the severity of crown cankers at crop maturity and yield loss. The input variables can be gathered in three groups: a variable describing the primary inoculum (*i.e.* atmospheric concentration in ascospores), climate (mean daily temperature and rainfall) and cultural practices: sowing date, crop density, nitrogen management in the cropping system, cultivar susceptibility and application of fungicides. The deposit of ascospores depends on their concentration in the atmosphere and on the leaf area. Because the atmospheric ascospore concentration not only depends on climate, but also on the spatial distribution of infected stubble (Salam *et al*. 2003), this variable is difficult to predict and is therefore taken as an input variable. Climate and some cultural practices affect crop development and therefore affect the leaf area likely to receive ascospores. Spores germination and subsequent infection of the leaf are influenced by temperature and humidity, the phenological stage of the plant, cultivar susceptibility and the effectiveness of the fungicide if applied. Infection leads to a secondary cycle via pycnidiospores and to the development of a crown canker which depends on the cultivar susceptibility and on the phenological stage at which infection occurred (MacGee and Petrie 1979; Hammond and Lewis 1987). At present, the secondary cycle is not explicitly described in the model, but its effects are embedded in an intermediate variable that describes leaf infections. Yield loss is simulated by a function that links the severity of crown cankers and the relative yield loss.

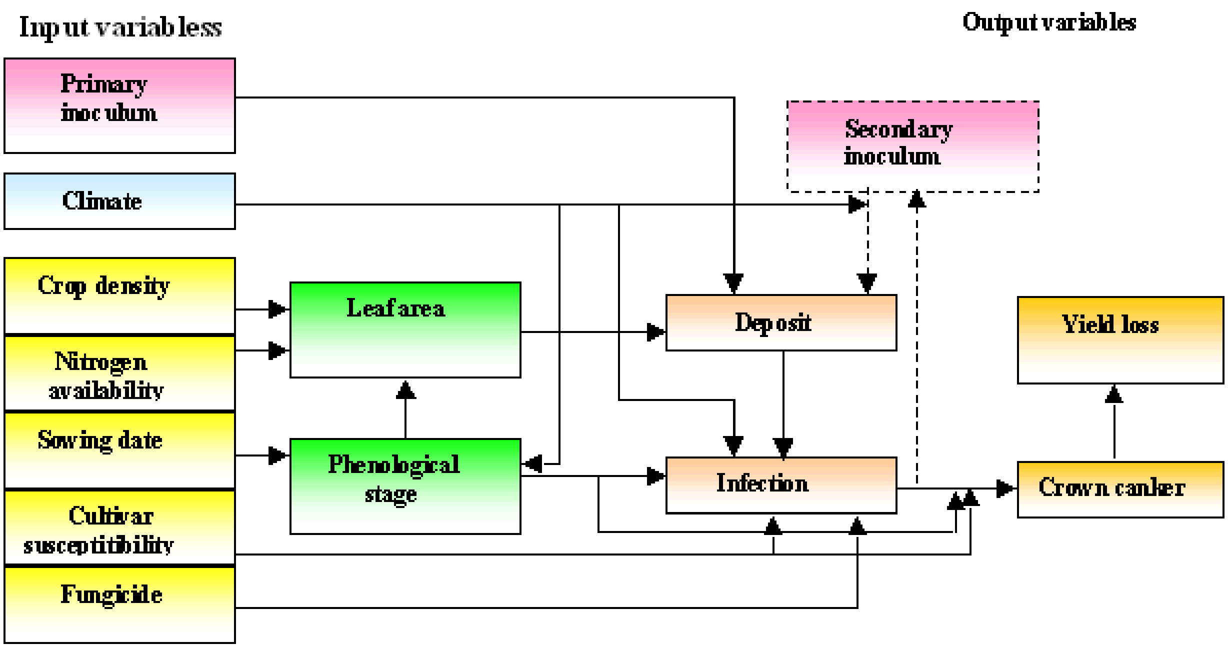

Figure 1. Process chart of the simulation model SimCanker.

Parameterisation and evaluation of two sub-models of Simcanker

Two data sets were used for the construction and the evaluation of two sub-models. (i) The first sub-model links the crown canker severity and relative yield loss and (ii) the second links phoma leaf spots during the vegetative stages and crown canker severity. The first data set consisted of six fungicide trials spread over 4 regions of France: Bourgogne (1998); Centre (1994); Ile-de-France (1994 and 1998);

Poitou-Charentes (1994 and 1998). Each trial consisted in a comparison of several fungicide treatments in a completely randomised block design with 3 to 4 replications (Le Page *et al*. 1994; Penaud *et al*. 1998). Yield and severity of crown cankers were measured in each elementary plot. A disease index ranging from 0 to 9 was used to summarise the observations of the severity of crown cankers (Aubertot *et al*. 2004). The mean disease severity indexes of the different treatments were used to predict the relative yield loss of the treatment with a multinomial regression. The relative loss was calculated in relation to the mean yield of the treatment with the lowest mean disease index within the considered trial (always lower than 3 for the 6 trials). The obtained model was evaluated by a cross-validation over the six trials. The Root Mean Square Error of Prediction (RMSEP) was used to characterise the quality of prediction of the model. The second data set consisted of four agronomic trials spread over 2 regions of France: Ile-de-France (2001 and 2002) and Centre (2002 and 2003). Each trial consisted in a comparison of different sowing dates and nitrogen availability during autumn for different cultivars on phoma stem canker development (Aubertot *et al*. 2004). The dynamic of phoma leaf spots was observed during the vegetative stage by measuring disease incidence and the mean number of phoma leaf spots per plant. The severity of crown cankers was characterised using the same Disease Index as described above at crop maturity. Crop density, biomass, leaf area index were measured on a regular basis during the whole cultural cycle. Climatic data such as cumulated thermal time or cumulated rainfall over three consecutive months were recorded. A stepwise selection was used to build a multiple linear regression model to predict the Disease Index using the proc REG of SAS (SAS Institute Inc., 1989). The obtained model was evaluated by a cross-validation over the four trials. The Root Mean Square Error of Prediction was used to characterise its quality of prediction.

Results

The quality of prediction of the polynomial model that simulates the relative yield loss as a function of the Disease Index is fair (Figure 2b). The RMSEP associated to Figure 2b is 0.08. The model underestimates the relative yield loss when it is high, as in the 1994 trial in Ile-de-France.

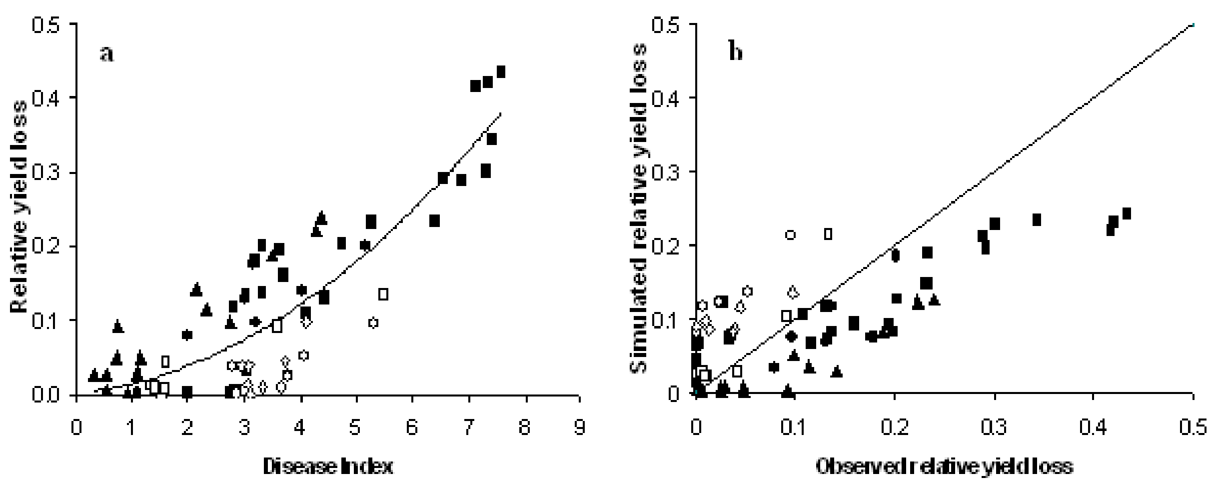

Figure 2. Relationship between the relative yield loss and the disease index (a). The line is a polynomial model: r?=?aDI^2+bDI where r is the relative yield loss, and DI the disease index (*a*?=?5.6 10^{-3},
***b*?=?7.7 10^{-3}, R^2?=?0.73). Cross-validation of this model over six sites-years (b). The strait line is the 1?:?1 line. Centre (1994); Ile-de-France (1994); l Poitou-Charentes (1994); ??Bourgogne (1998); ? Ile-de-France (1998); ? Poitou-Charentes (1998).**

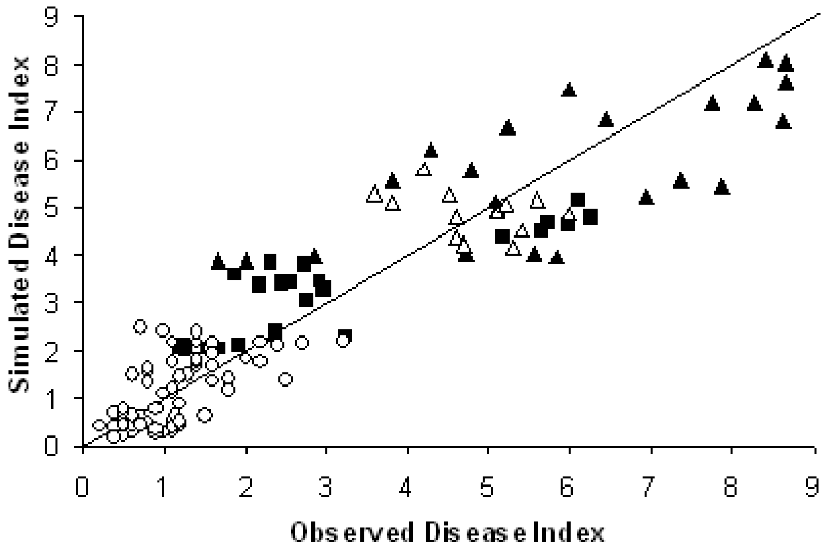

Figure 3. Cross-validation over four sites-years of a multiple linear regression model predicting the Disease Index. The strait line is the 1?:?1 line. ? Ile-de-France (2001); p Ile-de-France (2002); r?Centre (2002); ? Centre (2003).

The stepwise selection led to a mutiple linear regression model with four variables: the maximum number of phoma leaf spots per plant observed during the vegetative stages; the cumulated thermal time (0?C basis) from January to March; the cumulated rainfall from January to March; and the aerial biomass per surface unit at early winter (R^2?=?0.87). The quality of prediction of this sub-model is reasonable (Figure 3). The associated RMSEP is 0.90.

Discussion

SimCanker still requires some developments. The sub-model that predicts the dynamic of phoma leaf spots is currently being developed. The relationship between the Disease Index and the relative yield loss needs to be analysed more thoroughly, especially for situations with high disease pressure. The variables entered in the multiple linear regression model by a stepwise selection appear to be reasonable: the severity of crown cankers increases with the maximum number of leaf spots per plant during the vegetative stages and with the temperature and the rainfall during winter. High biomass per surface unit was also positively correlated to the severity of the disease. This point still requires further attention since the underlying processes are not clearly identified. The originality of the general approach is to take into account the cultural practices as input variables at the beginning of the modelling process. Those techniques influence the dynamic of phoma leaf spots (Aubertot *et al.* 2004) and therefore strongly affect the development of phoma stem canker.

Even if phoma stem canker is a major problem for cropping oilseed rape in many places world-wide, technical decisions cannot be taken just to control this disease. It is therefore important to integrate other processes in a more general model that will permit to achieve several objectives such as the control of other pests (*e.g.* weeds), as well as economic and environmental objectives. SimCanker will therefore be linked to a crop model that is susceptible to the above mentioned cultural practices and that integrates other sub-models representing the effects of cultural practices on the development of other important pests of oilseed rape. Once completed and evaluated, SimCanker will contribute toward defining integrated cultural strategies for oilseed rape crops.

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References

Aubertot JN, Schott JJ, Penaud A, Brun H, Dor? T (2004). Methods for sampling and assessment in relation to the spatial pattern of phoma stem canker (*Leptosphaeria maculans*) in oilseed rape. European Journal of Plant Pathology. 110: 183-192.

Aubertot JN, Pinochet X, Dor? T (2004). The effects of sowing date and nitrogen availability during vegetative stages on *Leptosphaeria maculans* development on winter oilseed rape. Crop Protection, in press.

Hammond KE, Lewis BG (1987). The establishment of systemic infection in leaves of oilseed rape by *Leptosphaeria maculans.* Plant Pathology. 36, 135-147.

Le Page R, Penaud A, Regnault Y, P?r?s A, Pinochet X (1995). Bilan des exp?rimentations du CETIOM de 1989 ? 1995. Num?ro sp?cial Ol?oscope n?18, 34 p.

MacGee DC, Petrie GA (1979). Seasonal patterns of ascospore discharge by *Leptosphaeria maculans* in relation to blackleg of oilseed rape. Phytopathology. 69, 586-589.

Penaud A, Poisson B, Fauvin P, Lamidieu JL (1998). Phoma du colza?: r?sultats. Dossier technique CETIOM.

Rouxel T, Penaud A, Pinochet X, Brun H, Gout L, Delourme R, Schmit J, Balesdent MH (2003). A ten-year survey of populations of *Leptosphaeria maculans* in France indicates a rapid adaptation towards the *Rlm1* resistance gene of oilseed rape. European Journal of Plant Pathology. 109, 871-881.

Salam M, Khangura RK, Diggle AJ, Barbetti MJ (2003). Blackleg Sporacle: a model for predicting onset of pseudothecia maturity and seasonal ascospore showers in relation to blackleg of canola. Phytopathology. 93, 1073-1081.

SAS Institute (1989). SAS/STAT User’s Guide. Version 6. SAS Institute, Cary, NC.

West JS, Kharbanda PD, Barbetti MJ and Fitt BDL (2001). Epidemiology and management of *Leptosphaeria maculans* (phoma stem canker) on oilseed rape in Australia, Canada and Europe. Plant Pathology. 50, 10-27.