O.43 - SIPPOM-WOSR: simulator for integrated pathogen population management for blackleg on canola

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Abstract

Resistant cultivars are an effective way to reduce the structural dependency of cropping systems to fungicides. However, specific resistances usually lack durability. A model was developed to help design control strategies that i) limit pathogen populations and ii) preserve the efficacy of specific resistances. In addition to the limitation of the selection pressure, the reduction of the size of pathogen populations by combining cultural, chemical, biological and physical control methods should also enhance specific resistance durability.

Due to its agronomic importance, the phoma stem canker/oilseed rape pathosystem was chosen as a case-study to develop SIPPOM, a ‘Simulator for Integrated Pathogen POpulation Management’. However, the structure of the model is generic in order to be easily applied to other pathosystems. SIPPOM is composed of 5 sub-models simulating primary inoculum production, ascospore dispersal, changes of the genetic structure of pathogen populations over time, infections and yield losses, and crop growth dynamics. Input variables describe the considered cropping systems and their spatial distribution, soil and climate, along with the initial size and genetic structure of pathogen populations. Output variables are disease severities, pathotype frequencies, actual yields, gross margins, Treatment Frequency Indexes, and cultural practice energy costs. After independent evaluations of the modules, and a sensitivity analysis, SIPPOM was used to rank strategies with regards to their agronomic, epidemiologic, economic and environmental performances. This type of integrative model, with large temporal and spatial scales, are useful to help design integrated crop management strategies.

Pest control in integrated crop management (ICM) systems relies on a combination of control methods satisfying economical, ecological and toxicological requirements. Two challenges are to find alternative control methods that limit excessive pesticide use, and preserve the efficiency of control methods over time. In the case of diseases, the high use, in a given area, of cultivars with the same specific resistance gene can lead to the total inefficiency of this resistance. Limiting the selection pressure exerted on pathogen populations implies considering the specific resistant gene distribution in space and over time. In addition, reducing the size of pathogen populations by combining cultural, chemical, biological and physical control methods should enhance the durability of specific resistances (Aubertot et al., 2006).

For airborne diseases, it is necessary to design combinations of control methods at the regional scale rather than at the field scale. Similarly, because of polyetical processes in epidemic cycles of diseases, it is necessary to design control strategies at the pluriannual scale. At these scales of time and space, field experiments are difficult to set up, and modelling is an advantageous approach.

Several models aiming at analysing the effect of pathogen population dynamics and their genetic structure changes over time on durability of specific resistances, simulate the impact of the proportion of resistant cultivar on durability, sometimes accounting for spatial pattern of resistance management.

However, most of these models only consider resistant cultivar deployment. On the other hand, existing models take into account cultural practices as well as soil and climate characteristics, usually at the annual and field scales. However, few simulate pest damages. Other models allow the optimisation of diseases by chemical treatments at the field scale or at the landscape scale, but they generally do not take into account other control methods. The output variables of a model aimed at establishing integrated control strategies of a disease should therefore characterise pathogen population, disease severity, crop production, as well as economic and environmental performances. To our knowledge, such a model did not exist yet.

The development of a model was carried out for the durable control of phoma stem canker on winter oilseed rape, caused by the species complex *Leptosphaeria maculans*/*L. biglobosa*, and that has a major economic impact on oilseed rape yield world-wide. Ascospores, the main primary inoculum, are released by matured pseudothecia located on infected stubble left in fields after harvest. They are wind-dispersed over several kilometres, and can infect seedlings.

If infection occurs, the first symptoms, leaf-spots, appear. Primary infections cause greater yield loss when they occur before the 6-leaves stage. The fungus then progresses from the leaves to the base of the stem, where the second symptom appears, the basal stem canker which is responsible for yield loss. The main efficient control method against phoma stem canker is genetic through the use of cultivars with specific or quantitative resistances, but specific resistances lack durability. Each spore landing on an oilseed rape field is able to infect a specific resistant cultivar only if it has lost the corresponding avirulence gene.

Quantitative resistances limit the systemic progression of the fungus and can therefore reduce canker severity. Fungicide treatments, if applied at the right time, allow the infection to be limited. Cultural practices, such as sowing date, sowing rate or nitrogen management at the cropping system level have an impact on the leaf area receiving ascospores, and thus on the risk and intensity of infection. Moreover, shifting the sowing date can prevent the coincidence between the release of ascospores and the most sensitive stage of oilseed rape to infection. After harvest, tillage can reduce the quantity of primary inoculum by burying infected stubble and preventing pseudothecial maturation. Disease control can be improved by reducing spore flow between fields, which requires considering the spatial distribution of oilseed rape fields.

SIPPOM-WOSR, a Simulator for Integrated Pathogen POpulation Management, has been created to simulate the effects of cropping systems and their spatial distribution on phoma stem canker epidemics over years, at a regional scale, along with the adaptation of *L. maculans* populations to oilseed rape specific resistances. This simulator aims at testing and ranking control strategies according to durability of specific resistance, yield, economic profits for farmers and environmental impacts. SIPPOM is composed of 5 sub-models simulating primary inoculum production, dispersion of ascospores, changes of the genetic structure of pathogen populations over time, infection and yield loss, and crop growth dynamic.

The first sub-model simulates the primary inoculum production of *L. maculans*: impact of tillage on vertical displacement of stubble in soil, subsequent potential density of pseudothecia on stubble present at soil surface, and effect of climate on pseudothecial maturation and release of ascospores. According to an experiment carried out by the authors, the quantity of inoculum also depends on the severity of the disease in the previous year (Lô-Pelzer et al., 2009), and this has been implemented in SIPPOM. The dispersion sub-model simulates the flow of ascospores in the region, and thus quantifies the number of ascospores that each WOSR field is likely to receive in the region (derived from Diggle et al., 2002). The model is spatially explicit. The dynamic crop growth (Jeuffroy et al., 2003) sub-model simulates the development stages and the growth of the crop from emergence to the end of winter and attainable yield. It takes into account the influence of cultural practices (pre-sowing organic nitrogen supply, sowing date and density) as well as soil and climate conditions. The genetic sub-model takes into account pathotype frequencies in each pathogen population and simulates the possibility for pathotypes to infect cultivars with specific resistances.

Evolutionary forces represented in SIPPOM are migration, selection, recombination between two or three avirulence genes, as well as the Allee effect. The infection sub-model simulates the severity of the disease as a function of the number of ascospores that can infect a cultivar (virulent ascospores), the crop status, fungicide treatments and the quantitative resistance of the cultivar. It also simulates the relative yield loss.

Pseudothecial maturation, ascospore release and dispersion, leaf infections, as well as crop growth are simulated on a daily basis. The model is adapted to winter oilseed rape, in northern Europe climatic conditions. The user of SIPPOM determines the number of years to be simulated, the spatial distribution of fields in the landscape, the crop sequence associated to each field and all the cultivation techniques: tillage (type of tool and date), organic nitrogen application before sowing (type, date and rate), sowing date and rate, cultivated species and oilseed rape cultivar (specific resistance genes, quantitative resistance level and potential yield), chemical treatments (type and date of application), nitrogen mineral fertilisation in spring (date and rate of application). Soil characteristics have to be described for each field, along with daily climatic data (rainfall, mean temperature, evapotranspiration, radiation, wind speed and direction). Output variables are epidemiologic, agronomic, economic, environmental and genetic. Epidemiologic outputs are disease severity index and the associated yield loss. The agronomic output is the actual yield. The economic output is a simplified gross margin (€/ha) that takes into account the cost of cultural practices and crop price. The environmental outputs are Treatment Frequency Indices (TFI) and energy cost of the cultural practices (MJ/ha). The genetic output is the pathogen population structure (one population corresponds to one field) described by the frequency of each pathotype.

Most sub-models have been evaluated independently. Data (cultural practices, disease severity, genetic sampling) collected in a small region in central France since 2006, where cultivars with a new specific resistant gene have been introduced, will be used to perform simulations, and output variables of the model will be compared with field observations. It will be a way to assess the general behaviour of SIPPOM. Because it is nearly impossible to evaluate the predictive quality *sensu stricto* of such a model, it is essential to emphasize that the model was created not to predict absolute values, but to rank control strategies. A sensitivity analysis has also been carried out in order to identify parameters which variation leads to a modification of the ranking of control strategies, and results show that classification of contrasted crop management situations is stable when parameters vary.

Examples of simulation with contrasted crop managements and cultivar deployments show the potential use of SIPPOM to test and rank integrated control strategies taking into account several control methods. SIPPOM-WOSR can display the impact of cultivar deployment in association with crop management on disease and pathogen population structure evolution. In particular, simulations demonstrated that it is possible to enhance the durability of a specific resistance gene only if cultivar management is adequately combined with other control methods: the efficiency of the specific resistance is maintained when the pathogen population size on the fields with the specific resistant cultivar is reduced. SIPPOM is the first spatially explicit model that takes into account genetic, cultural and chemical control methods together, and the spatial distribution of cropping systems to evaluate management strategies of specific resistances. One of its originalities is to link a crop model with an epidemiological model and a population model. SIPPOM can be used to rank integrated management strategies of a disease according to how well they maintain efficiency of specific resistances against phoma stem canker, and how well they limit environmental costs and enhance economical profits. SIPPOM-WOSR can also be used as a demonstrative tool for farmers and all stake-holders concerned by the evolution of practices on oilseed rape to durably control phoma stem canker.

References

Aubertot JN, West J, Bousset-Vaslin L, Salam M, Barbetti M, Diggle A. 2006. Improved Resistance Management for Durable Disease Control: A Case Study of Phoma Stem Canker of Oilseed Rape (Brassica napus). European Journal of Plant Pathology 114, 91-106.

Diggle AJ, Salam MU, Thomas GJ, Yang HA, O'Connell M, Sweetingham MW. 2002. AnthracnoseTracer: a spatiotemporal model for simulating the spread of anthracnose in a lupin field. Phytopathology 92, 1110-1121.

Jeuffroy MH, Valantin-Morison M, Saulas L, Champolivier L. 2003. Azodyn-Rape: a simple model for decision support in rapeseed nitrogen fertilisation. Proceeding of the 11th international rapeseed congress, Copenhagen, Danemark.

Lô-Pelzer E, Aubertot JN, David O, Jeuffroy MH, Bousset L 2009. Experimental evidence for a relationship between the severity of phoma stem canker (*Leptosphaeria maculans*/*L biglobosa* species complex) and subsequent primary inoculum production on oilseed rape stubble. Plant Pathology 58, 61-70