Designing sustainable cropping systems scenarios to control blackleg of winter oilseed rape from a combination of participative design and model simulations

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Introduction

Phoma stem canker, also called blackleg, is a worldwide disease resulting in major oilseed rape yield losses and subsequent economic losses. To prevent this disease, three levers can be used: genetic, chemical and cultural control methods, which exhibits different efficiencies and durability. Indeed, genetic control is the most efficient method, but its durability can be very low, as qualitative resistance can be quickly overcome (Rouxel et al., 2003), depending on pathogen population pressure and cultivar genetic background. Then, chemical control method is hardly efficient since the time-windows for fungicides application is very short. Finally, cultural methods (e.g. tillage practice, sowing date) can help disease prevention, through decreasing pathogen population size.

Managing population pressure and evolution is thus the corner stone of durable blackleg control. It can be achieved by combining genetic and cultural control methods in time and space. Blackleg management can then be efficiently achieved by modifying cropping system (CS) spatial management at the territory scale: coordination between local stakeholders is thus decisive. Scenario design with local stakeholders impacting WOSR management can therefore help finding CS spatial management ensuring resistance durability and accounting for stakeholders' constraints, opportunities and strategies. The spatially explicit model SIPPOM-WOSR (Lô-Pelzer et al., 2010), designed to simulate effects of spatio-temporal location of CS on resistance durability and disease control of blackleg of winter oilseed rape (WOSR), can help in this design. This study aims at (1) designing with stakeholders scenarios of CS spatial management for durable control of blackleg; (2) evaluating these scenarios with SIPPOM-WOSR to identify the scenarios of spatial localization of cropping systems controlling blackleg and preserving resistance efficacy.

Materiel and method

The case study is a small region (16 km^2) located in the Centre region of France. Actual CS are composed with about 31% of oilseed rape per year throughout the landscape and mean field size is 13.5 ha, in accordance with Centre regional characteristics. Phoma stem canker is a historical major disease in the region, with disastrous epidemics until 2002. Since then, a very low level of disease has been observed in the region, since cultivars with a new qualitative resistance (which has not yet been overcome) are largely used.

The approach involves five steps:

(1) Identification of the relevant stakeholders' types to be involved in the study (based on previous studies and expert knowledge: national Specialist Technical Organization (Cetiom, the french Technical Center for oleaginous plants) and survey of the most relevant stakeholders, to get inside into regional agricultural systems and stakeholders organization for oilseed rape production/collect and implication for blackleg management;

(2) Building with stakeholders a scheme of their shared vision of blackleg, taking inspiration from the ARDI (Actors, Resources, Dynamics and Interactions) method (Etienne et al., 2006): which techniques impact the disease? Who is acting, directly or indirectly, on these techniques? Is this framework in agreement with SIPPOM-WOSR structure?;

(3) Building scenarios of possible future of CS and their spatial management with stakeholders, accounting for cultural practices, and taking account of stakeholders' strategies;

(4) Evaluating, by simulations, these scenarios to quantify their efficiency for disease control (i.e. resistance durability) and environmental and economic impacts (at field*year scale for oilseed rape and field rotation scale);

(5) Discussing with stakeholders the scenarios' evaluations and eventually designing new CS spatial management scenarios (evaluated with SIPPOM-WOSR model).

As scenarios will be simulated with the model SIPPOM-WOSR (Lô-Pelzer et al., 2010), they need to be spatially described with characteristics corresponding to model inputs. These characteristics concern spatially distributed (i.e. for each field of the simulated region) CS characteristics, i.e. crop sequence (occurrence(s) and rank(s) of WOSR within rotations), and crop management for WOSR, i.e. cultivar, sowing date and rate, autumnal organic application (type, date and rate), fungicide(s) use (type and date) and stubble management (type of tillage technique after WOSR harvest: e.g. chisel plough, rotatory harrowing, mouldboard ploughing). These techniques are essential for phoma stem canker management (Aubertot et al., 2004).

First results

(1) Surveys have been realized with relevant stakeholders having a regional knowledge of oilseed rape cultivation context in the regional area. Three stakeholders have been interviewed: the main cooperative (representing 65% of oilseed rape collect of the area), the local Specialist Technical Organization (Cetiom) and the local Chamber of Agriculture.

Their visions of topical agricultural systems and crop management strategies for WOSR were largely in agreement. Their global visions of stakeholders' organization for oilseed rape production/collect and implication towards blackleg management (figure 1) were also consistent: the three interviewed stakeholders considered that (i) policy makers have a medium impact on courses of action and are not concerned by blackleg management; (ii) extension and advisory services are highly concerned and have low to medium courses of action; (iii) cooperatives and retailers are highly concerned and have high courses of actions; (iv) breeders have the highest concern about blackleg management and higher courses of action. According to the interviewed stakeholders, farmers behavior is less homogeneous: their courses of action differ between farmers, even though they remind high; they have low to medium concern about blackleg management, depending on their historical background. Only the Specialist Technical Organization (Cetiom: Technical Center for oleaginous plants) presents differences in its level of courses of action, considered from low by this organization itself (due to only indirect communication) to high by the Chamber of Agriculture.

These stakeholders impact directly or indirectly WOSR management in different ways:

- Farmers are the final decision makers for oilseed rape cultivar choice and practices. They can be advised/influenced by the extension and advisory services and by cooperatives/retailers. Their practices can be constrained by policy, e.g. on dates for tillage practices.
- Crop collectors (cooperatives and retailers) impact crop management by two ways: (i) the choice of products they sell, e.g. fungicides and seeds, and can thus restrain fungicide choice and cultivar choice (and associated genetic characteristics, i.e. resistance); (ii) their advices concerning products farmer should buy especially on cultivar choice, according to objective criteria (field observation and in-site experiments), e.g. soil types, cultivar phenological; and strategy/business-dependent criteria.
- Breeders impact cultivar characteristics, e.g. phenological characteristics, potential yield, sensibility to disease (resistance type – qualitative and/or quantitative and quantitative resistance level) and thus their potential availability for cooperatives/retailers.
- Local Specialist Technical Organization (Cetiom) act through their potential influence on breeders and their experiments, communicated to crop collectors/retailers and extension and advisory services.

- Extension services and advisory services (Chamber of Agriculture, associations managed by farmers for agricultural technical studies and development) communicate to farmers and between advisory services experiment results on WOSR crop management strategies.
- Policy makers, through policy oriented toward a single objective (e.g. limitation of nitrates loss) can constraints cultivation practices (type or time).

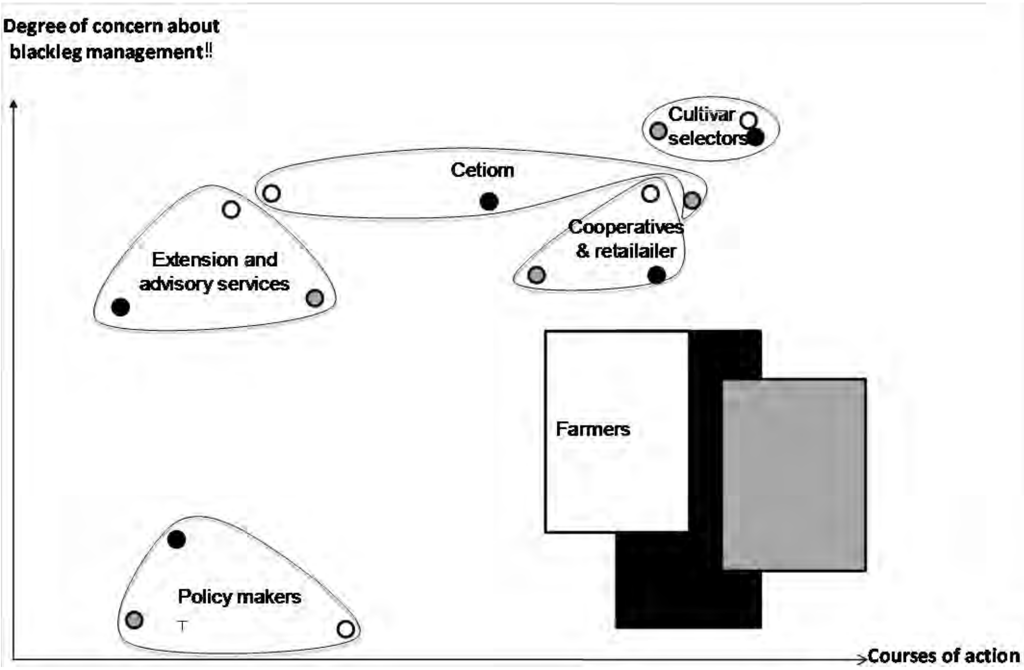

Figure 1. Stakeholders' implication toward phoma stem canker of oilseed rape management: visions of the main stakeholders on stakeholders' concern and courses of action (empty symbol: vision of the main cooperative; grey symbol: vision of the Chamber of Agriculture; black symbol: vision of the Specialist Technical Organization, i.e. Cetiom)

Their degree of implication/concern about WOSR crop management towards phoma stem canker depends on the potential consequences the disease return would have (potential yield loss for farmers (and indirectly for advisory services), cooperatives and Cetiom; need for innovation for Cultivar selectors; very low direct impact for policy makers).

(2) During a four-hours working session, participants have been invited to present their visions of the functioning of the disease, the practices impacting it, the impacts of all stakeholders on practices and relationships between stakeholders. It resulted into two schemes presenting (a) resources dynamics (resources: cultivation techniques, stubbles, ascospores, etc) impacting phoma stem canker and type of relationships between the resources; (b) stakeholders impacts on cultivation practices (e.g. testing, regulation) and type of relationships between stakeholder (e.g. communication, choice) (data not shown).

These schemes exhibit that main relevant stakeholders were fortunately involved in the study, and that the model structure were in accordance with stakeholders' vision of the disease (although some factors may be absent in the model, e.g. working time, material availability).

(3) Scenarios of possible future CS and their spatial management have been designed during a second four-hours working session. After discussions on possible future (e.g. on future proportion of WOSR in the landscape? Cultivar evolutions? Policy evolutions?), a summary of these trends has been realized in order to get structured scenarios with all the details required for model input. Three main trends were identified, corresponding to different contexts (political, epidemiological). The first trend considers an increase of WOSR surfaces, which seems the more plausible to the different stakeholders, in accordance with the national trend and the development of biofuels. This global trend results in shorter crop sequences (e.g. WOSR-Wheat-Barley => WOSR-Wheat), which are associated with varieties containing quantitative and/or qualitative resistance; different possible surfaces with

mouldboard ploughing and an increase in autumnal nitrogen applications. The second trend considers a decrease of WOSR surfaces, which could occur if policy would change: e.g. if nitrate regulation constraints more the time window for tillage practices, working organization could lead to a necessity of diversifying crops to decrease working pressure at a certain time; or e.g. policies could be implemented to promote an increase of crop sequences for environmental reasons. This trend is associated with longer crop sequences, current varieties and cultivation practices, except for the increase in autumnal nitrogen applications. The third trend considers a significant increase of surfaces with moulboard ploughing after WOSR harvest, which would occur either if the current (not overcome) qualitative resistance would quickly be overcome and thus become inefficient, or if the herbicide glyphosate would be forbidden, in relation with current policy aiming at pesticide' use reduction. This trend is associated with cultivars with quantitative resistance, an increase in autumnal nitrogen applications and 10% WOSR-surfaces with fungicide applications.

Scenarios simulation and evaluation (stage 4) is currently under development and their evaluations with stakeholders (stage 5) will be realized in the next weeks.

Conclusion

Although the SIPPOM-WOSR modeling framework does not explicitly account for stakeholders, designing scenarios of CS (via model inputs: crop management and localization, cultivar choices) can account for their visions of the potential regional future of WOSR. Even though their strategies (e.g. cultivar commercialization, crop management promotion, regulation) are not explicit in the process of scenario construction, some elements reveal these strategies (e.g. the Chamber of Agriculture advise longer crop sequences, while cooperative would prefer to shorten them and focus on less cultures). Evaluation, with a complex model, of scenarios of spatialized CS designed with local stakeholders is an original approach, which provides information on levers and restraints for cropping systems design. This method will be applied on two other French regions, to study historical impact, stakeholders' strategies, initial cropping systems' characteristics and landscape structure impacts on scenarios.

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