SUSTAINABLE MANAGEMENT OF VARIETAL RESISTANCE TO BLACKLEG IN RAPESEED: ADAPTING ADVICE TO FARM

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Biography of the presenter:
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Abstract

Blackleg, a major disease in rapeseed, can be managed using varietal resistance. However, to minimize resistance breakdown, other management techniques must also be used. We studied current agricultural systems used to manage rapeseed and blackleg on farms by means of a survey in two French regions. The data obtained were summarized and eight main systems were identified with an associated risk level of resistance breakdown. Rapeseed return time and varietal diversity were not the only techniques used by farmers to manage blackleg. Each system was also characterised for its capability of integrating current agronomic advice. Risky types were not always found in areas where blackleg was relatively rare. Less risky types would be able to improve their management whereas risky types may not have any leeway to include agronomic advice in their system. These data are now used to develop farming systems integrating agronomic advice and farmer's objectives and resources.

Introduction

Blackleg (*Leptosphaeria maculans*) is one of the major diseases in rapeseed worldwide (Gladders et al., 2006; Aubertot et al., 2006). It can result in major yield losses (50% losses have been observed in Australia and 5-20% in France) and is the major disease of rapeseed in the UK (West *et al.*, 2001; Fitt *et al.*, 2006). It is widespread, occurs on all continents and is on the increase.

The pathogen is airborne. It occurs in a seasonal pattern (Petrie, 1995) and can spread over several kilometres (Bokor *et al.*, 1975) but the greatest risk is within 500m of the inoculum source (Barbetti and Khangura, 2000). It can survive for at least 3-5 years on crop residues (Naseri, 2006). Infected seeds, feral rapeseed plants and other Brassicacae can host and disseminate it. Agricultural practices can spread it via soil and spore transport on tools but they can also limit pathogen dispersion. In general, cultural control of the pathogen is mainly a lengthening of the period between two rapeseed crops and the destruction and ploughing in of crop residues. Neither of these actions may be very popular in view of the increase in rapeseed area and conservation agriculture.

In rapeseed, the most commonly used defence against blackleg is varietal resistance. Varietal selection aims for genetic resistance to the pathogen, mainly through specific resistance, which may cause high selective pressure on the pathogen and adaptive response, as happened in France and in Australia (Sprague *et al.*, 2006; Rouxel *et al.*, 2003). Monogenic resistance is easily broken down, sometimes in only 2 years, for this pathogen combines sexual and asexual reproduction (Aubertot *et al.*, 2006). Pathogen adaptation is even faster when the primary inoculum is important for recombination events intensify (Marcroft *et al.*, 2004; Sprague *et al.*, 2006). Quantitative resistance would seem to be a more sustainable solution for pathogen management as the multiplicity of genes involved limits the possibility of selective pressure. However it is less effective and yield loss may result. The solution is the combination of quantitative and specific resistance to retain an acceptable yield (Sivasithamparam *et al.*, 2005) associated with suitable agricultural practices to preserve their sustainability (West *et al.*, 2001; Mestries, 2005).

Means of sustainable management of plant resistance can be defined on 3 scales: the plot, the farm and the small region. Sowing a mixture of cultivars is one way. It is done during sowing or before by seed producers and will not be studied here. We have seen that blackleg can disperse at least 500m and survive for at least 5 years in the soil. For all these reasons, pathogen management must be considered at the farm level. Management can also be done at the regional level since pathogens do not respect farm boundaries.

Our main hypotheses are that: i) sustainable management of pathogens needs to include limitation of primary inoculum to diminish selective pressure (Aubertot *et al.*, 2004); ii) management of phoma pressure must be done on a wider scale than the field, pathogen dissemination distance being several kilometres (Schneider *et al.*, 2006); iii) current crop management does not allow sustainability of varietal resistance, but leeway exists.

Our objective in this study is mainly to find which farms already apply these recommended cropping techniques, or easily could, and are thus more adapted to these sustainability objectives. Technical advice must then help farmers develop more sustainable systems according to their constraints and leeways using these recommended cropping techniques or others. As stated by Coleno *et al.* (2005), it is necessary to know farmers' objectives for managing the system in a particular way in order to enhance its capacity to adopt new technologies or organisation (Thornton and Herrero, 2001).

The objectives of this study can be defined as i) identifying cropping system management within the farm, focusing on rapeseed; ii) identifying the possibilities of adopting agronomic advice to reduce blackleg adaptation, taking into account the strategies we identified.

Methodology

1. Regions studied

To study the maximum diversity, two French regions were chosen (Centre and Vendée) differing in rapeseed crop importance, blackleg pressure and production contexts (presence or otherwise of cattle, importance of cereal crops, intensification or extensification). Within each region a diversity of farms was surveyed. In Centre and the immediate surroundings, 22 farms were surveyed in 5 departments (Eure, Eure et Loir, Loiret, Orne and Essonne). In Vendée, 10 farms were surveyed.

The two regions studied also differ in their production practices, blackleg pressure (which is high in the Centre and low in Vendée) and proportion of rapeseed, which is also low in Vendée. Soil and climatic characteristics also differ and vary within a region. We thus subdivided these two regions into seven areas or small agricultural regions.

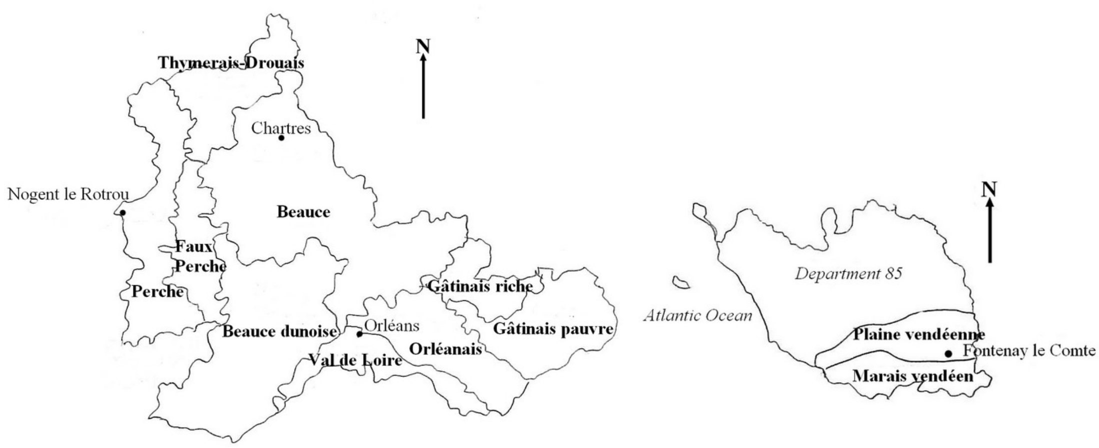

Figure 1. Small agricultural regions distinguished in the study in the Centre (left) and Vendée (right) region.

Zone	Main crops	Field pattern and soil characteristics
Beauce chartraine Beauce	Cereal, oilseed and protein (cop) Cop, onion, potato, sugar beet	Large fields, mainly cop, silt soil 1-13m
Beauce dunoise	All crops	Mainly large fields, heterogeneous

Val de Loire-Orléanais	Cop, vegetables, asparagus, corn	soils Mainly large fields, sandy soils
Thymerais – Drouais	Cop, cattle in valleys	Stones in mainly large fields
Perche – Faux Perche	Cop, meadows, cattle	Many valleys, heterogeneous soils, hedges and crooked fields
Gâtinais	Cop, sugar beet, potato	Heterogeneous soils, clustered fields, contrasted zones of forest and crops
Marais vendéen	Corn, durum wheat, some goats	Drained or not soils, clay >1m, big farms
Plaine vendéenne	Cop, irrigation	2 kinds of soils: silt 1-1,2m and carbonate-clayey 10-80cm, drought

Table 1. Description of the small agricultural regions studied

2. Method used

In this study, we used the same method as Girard (2004) and Girard *et al.* (2008) for stock farming in the South of France, which we adapted to the study of crop farming.

This method is not based on quantitative but on qualitative data on farming practices. It nevertheless takes technical and economic variables into account.

It can be broken down into four phases: i) precisely identifying the study outlines; ii) conducting semi-structured interviews with farmers; iii) synthesizing the data as practice cards and formalising the data obtained with the help of experts to identify diversity criteria; iv) using these criteria to identify prototypes.

In the second phase of our study we surveyed 32 farms using semi-structured interviews (Miles and Hubermen, 1994). A sample of farms maximizing diversity of total farm area (UAA), rapeseed area (5 to 45% of the UAA with a mean of 17%), management and production context (organic/conventional farming, vegetable/seed/cereal producers etc.) was surveyed. These criteria were determined by an expert panel involved in the study. A lot of data about the farm and its management was gathered, such as production resources (cropped area, equipment, labour), production strategies (yield, source of seed and harvest outlets), technical choices (cropping techniques, field pattern, varietal choice, varietal changes and crop succession) and disease management (including blackleg history, management techniques and reaction to potential field contamination) as well as leeway to adapt rapeseed management according to recommendations. The opinions of the farmer were also noted during the course of the interview.

In the third phase, data from the farms were synthesized as practice cards representing qualitative and quantitative information about the farmer's practices which are relevant to resistance sustainability. These practice cards and interview summaries were then used as a basis on which experts defined diversity criteria by comparing the farms and identifying attributes for which diversity existed and could have an effect on rapeseed crop resistance sustainability. For each diversity criterion, two extremely divergent practices were identified and intermediate practices were then characterised.

10 diversity criteria were selected by experts as relevant to resistance sustainability in this case. i) Adaptation of cropping techniques for maximum yield, ii) Adaptation of cultivar choice to investment and resources, iii) Choice of cultivars to maximize the use of plot localisation, iv) Diversification of cultivars in space and time, v) Use of the field pattern to diminish frequency of rapeseed in the rotation, vi) Adaptation of cropping techniques to limit damage on rapeseed crop, vii) Adaptation of rapeseed management for maximum economic return, viii) Adaptation of management to limit the use of environmentally unfriendly

products, ix) Use of innovative techniques to optimize rapeseed results and crop sustainability, x) The retrieval and use of information for planning cropping systems.

Each farm was thus represented by a combination of qualitative descriptors which could be compared between farms and were used to classify the farms. Poles are defined by their most typical practices and their rationale and not by their borders. In our study, farms were grouped using correspondence analysis (disjunctive treatment) followed by an agglomerative hierarchical clustering with XLStat®. Types were differentiated at the 5% level of significance.

Results

Description of farm prototypes

Eight cropping system prototypes were defined (*Figure 2*) and farms were brought closer to the prototypes they most resembled. For each prototype, experts determined the risk level for sustainability of rapeseed varietal resistance in this system. These prototypes are described by a sentence expressing their strategy (*Table 2)*.

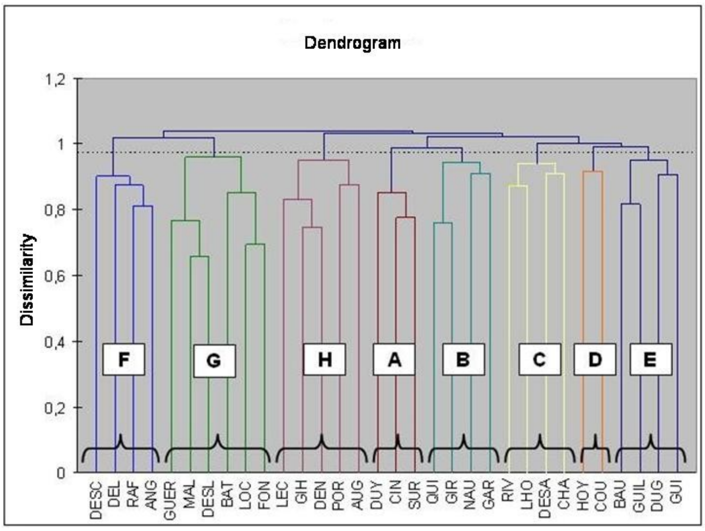

Figure 2. Dendrogram establishing the farm typology

Type and strategy	Typical practices	Risk Level
A: *Simplification of work and system*	1 variety, high inputs (weeds, nitrogen…), plough, small number of runs	5
B: *Simplification because of another main activity*	Simplification of varieties, not all work done by farmers, low interest in innovations and information, low inputs and no ploughing, return time 3-4 years	4
C: *Complex system with a well-defined role for rapeseed*	Rapeseed to absorb nitrogen for succeeding crops, to diversify on small area, long return time, low inputs, often 1 variety, high yield objective	1
D: *Securing with field plan management*	Complex varietal choice combined with field pattern, return time around 4 years, high yield objective, mean input level, good knowledge of rapeseed, defined rapeseed outlets	2
E: *Securing with cropping techniques*	1-2 “sure-fire” varieties, high inputs (weeds, pests, high yield), 2-3 years return time, low innovation, low workload, limiting factors (climate, soil, equipment)	5
F: *Technical but risky techniques for a high productivity*	Specific management according to field pattern, complex varietal choice (tests every year), intensive farming (numerous runs but lowering inputs), return times 3 years or	4

	less (volunteers), defined rapeseed outlets	
G: *Technical and adaptation to high constraints*	Combined varieties x field pattern management (limiting factor = robust variety…), low renewal of varieties, high yield objective (try for the potential), high inputs, low return time	3
H: *Technical for sustainability with limited objectives*	Combined varieties x field pattern management but small choice in varieties, long return time, low or no chemical inputs, low environmental impact techniques, frequent soil tillage, high workload	2

Table 2. Types defined by the diversity criteria and their associated typical practices and risk level.

Connections between types

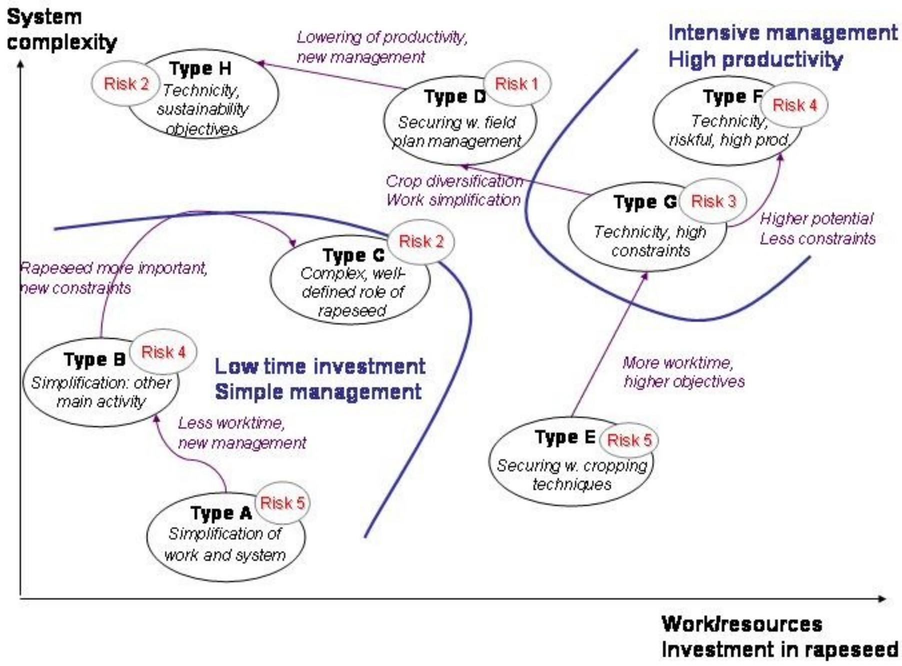

Figure 3. Interaction between types and risk level

The main differences between types and their connections are shown in *Figure 3*. The 8 types obtained can be segregated along two axes - farming system complexity and investment in work and resources for rapeseed crops - to describe the types found. Common or similar elements join these types. For example, types B and C are similar but in the former, rapeseed is really secondary whereas in the latter it is integrated in the farming system, involving different management practices and greater investment. Individual farms surveyed are in fact positioned in the spaces between these farms and can be related to a main type and a secondary one.

The risk levels associated with the types show that similar types have similar risk levels but that the two axes chosen do not discriminate risk levels.

Diversity between and within types

	Rapeseed cropping area		
UAA	0-10 ha	11-30 ha	>30 ha
0-100 ha	A B C H	DD E H G	-

101-200 ha	A E H	B E CC	A B E GGGG H
>200 ha	-	C H	B FFFF G

Table 3. Types found during the survey according to their AUA and rapeseed area.

A diversity of farms can be found in each type for their AUA and rapeseed area (*Table 3*) except for type F, which can be found only in farms of more than 200 ha with more than 30 ha in rapeseed (short return time and high risk level) and type D, in which farms have less than 100 ha and 11-30 ha rapeseed (return time of 4-10 years, complex varietal choice and low risk level).

Types A, B, C, D and G are found only in areas where the main crops are cereals and some oilseed/proteinaceous crops. As for type E, they are found in two areas (Marais vendéen and Perche), which are not alike. Type F and H are found in more diverse circumstances. Types A, B and F are only found in the Centre of France where there is a higher phoma pressure. The 5 other types are found with high and low phoma pressure.

	Types found in the survey							
Production system	A	B	C	D	E	F	G	H
Organic farming								4
Mixed organic/conventional farming			1					
Farmers using on-farm produced seeds			1				1	2
Vegetable growers	1				1			
Oilseed rape seed producing farmers			2					
Crop and cattle producers		3	3		1	1		
Conventional cereal producers	2	1		2	2	3	6	1

Table 4. Correspondence between farm type and production system. The same farm can be found both in the category "on-farm produced seeds" and in another.

The production system seems to influence farm type (*Table 4*). This can be explained for types D and G by the specific associated practices, which restrict these types to cereal producers. Type H concerns organic farms, which may or may not produce their own seed, and one conventional farmer who produces his own seeds and has a high level of constraints. Only types C an E seem to be less specific.

Variables explaining risk level differences

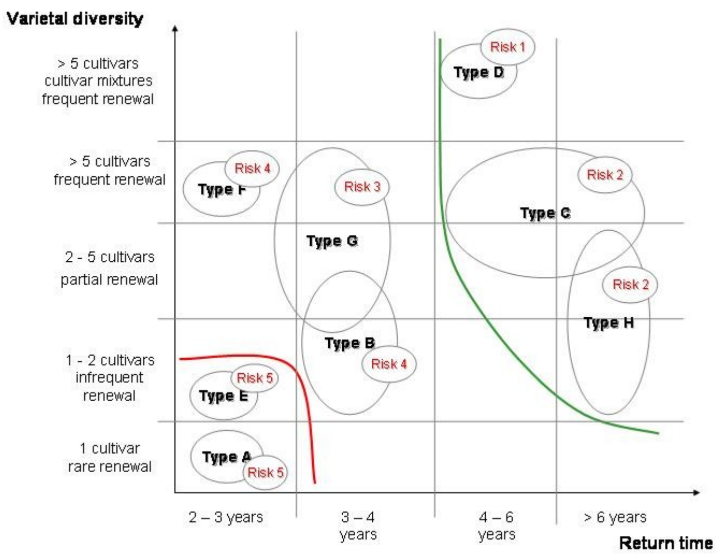

Figure 4. Distribution of types and risk level according to varietal diversity found on the farms and return times.

The usual indicators of risk level for sustainability of varietal resistance to blackleg are return time for rapeseed and varietal diversity. *Figure 4* shows that these two criteria do indeed discriminate types according to their risk level but also that other criteria seem to be able to compensate. Indeed, the types are spread over a rather wide range for these two criteria. For example, B and G types do not have the same risk level but overlap in the figure. G type farms are more technical and in them, risk is also managed using techniques like crop residue management, whereas B type farms tend to simplify cropping techniques. Three groups in terms of erosion of varietal resistance to blackleg can be identified:

- those with a low level of risk: type D has a very low level of risk since it combines a field pattern management and management practices to limit the adaptive response of blackleg. C and H types reduce the risk by lengthening the return time but their varietal diversity is less and their risk level is higher.

- those with a mean level of risk: G type farms have a mean level of risk because their return time for rapeseed is short; they use a limited number of varieties and have changing management practices to adapt the crop to the environmental constraints rather than to pathogen constraints. F type farms are similar to these but their return time is even shorter. Type B includes only farmers investing little time in rapeseed and using no mitigating practices.

- those with a high level of risk : Types A and E show low levels of varietal diversity and short return times, the same variety coming back on a given plot quite soon, which maximizes the adaptive response of the pathogen.

Another result of our study is the capacity of each type of farm to adapt its management practices to increase sustainability of varietal resistance in the case of blackleg resurgence. Some types, such as B, could adapt, with changes in management being made if rapeseed became more profitable. In type C farms there is a low workload for rapeseed and there is some leeway left to change management if need be. Type H farms also show little interest in rapeseed diseases but farmers are well-informed and innovative and if blackleg became important in their region they could adapt their management practices since there is flexibility. Type D is also a flexible system but due to a high workload, management of rapeseed cannot easily be changed.

As for the four other types (A, E, F and G), changing rapeseed management would not be easy. In the case of A farms, other activities are more important and there is little scope to change rapeseed cropping. E type farms have high organisational constraints and G type farms have high field pattern constraints, which leave them little room to adapt rapeseed management. As for F type farms, they are well-informed and innovative but their farming systems are already optimized and they are not ready to adapt their management practices.

Discussion

An "easily" adapted method

This method was adapted from a tool to analyse stock farming practices. The sampling method is directive and pre-selects the farm structures surveyed to maximize diversity instead of being representative to ensure the generality of the system. The semi-directive interviews are also re-centred on rapeseed cropping, which was sometimes difficult for farms where rapeseed is only a small fraction of the crops. However, open questions at the end of the interviews enabled us to learn about the determinants and constraints of the system. The interview guidelines were modified after the first interviews. Data synthesis was done as in Girard (2001) and seems to be suited to crop farming as well as stock farming. A difficult phase is the conversion of qualitative data into quantitative data (construction and notation on the 10 diversity criteria). This was one of the reasons for introducing expert advice in this phase to limit the bias. Our diversity criteria were more complex than in Girard (2001) since we had to represent a combination of practices at different levels (plot, farm).

Our method of a “snapshot” of farmers’ practices via a farm typology coupled with knowledge about the blackleg disease system enabled us to deduce the risk level for resistance breakdown

Adapting advice to farms

We have found five farm types which don’t use rapeseed management practices that increase varietal resistance sustainability. These risky types all have high constraints and there is only one type, B, where there is enough leeway to adapt rapeseed management practices. However farmers in this type would be interested in change only if this crop became more profitable. This explains why, even though CETIOM (advisory service for oilseed crops in France) tries to change rapeseed management on French farms, few farmers in these five types adopt its advice. What is more surprising is that less risky types have more leeway and could improve their rapeseed management practices, for example by introducing inter-farms collaboration to diversify rapeseed varieties spatially. They would find this advantageous, especially in regions where blackleg often decreases yield.

Some types are regionalized but not all

Two types have the maximum risk level: types A and E. Type E is only found in 2 regions (Marais Vendéen and Perche) where blackleg is not often found. However, type A is found where blackleg is a real risk. The fact that farmers of this type do not change their management is explained by the low importance of rapeseed in the farm income and the balance between the blackleg risk and the time available.

Several criteria explain resistance sustainability at the farm level

Our results show that both return time and varietal diversity have a big influence on resistance breakdown, as has been shown by Rouxel et al. (2003), but that other criteria either are able to compensate (like crop residue management) or can increase resistance breakdown risk, like simplified cropping techniques. The presence or otherwise of CETIOM advisors was also found to have an impact on management practices. As seen by Weber (1999) and Maton et al (2005) similar behaviour is found in farmers who have been advised by the same data source and share part of their network.

Considering farmers’ strategies is important at the landscape level

Pathologists usually work at the pathogen level: plant, plot or even landscape, but in the case of landscape scale studies, the landscape is considered to be uniform (West *et al.*, 2001) or broken down into different kinds of areas: survival on host, survival on residue, or inhospitable (West and Fitt, 2005). However, farmers and their management do not appear in these studies and it is their decisions that shape the landscape so far as a pathogen is concerned. Agronomists, for their part, work on cropping techniques, usually on a plot scale (Aubertot, 2004; Schneider *et al.*, 2006) and rarely on a landscape scale (Lo-Pelzer, 2008). To upscale their model from the plot to the landscape, aggregation is not enough. Hansen and Jones (2000) have shown that when aggregating, the validity of the model prediction depends on the quality of the representation of the spatial variability of the input data. Our results show that farmers’ management and decisions must be taken into account and that this management is dependent upon the other crops and constraints found on the farm. We have shown in our study that there is neither a uniform nor a random distribution of farms in the landscape.

Conclusion

Cropping System Prototypes were constructed as a combination of resources, techniques and objectives, the relation with which was measured for the surveyed farms.

This study is based on an adaptation to the rapeseed crop of the methodology developed by Girard (2001) for sheep farms. It distinguishes farms based on their strategies without rigid limits between types. It could as well be used on other crop issues, like other pathogen-crop relations.

Lô-Pelzer (2008) developed a model, SIPPOM-WOSR, to test the effects of cropping systems on crop yield, disease severity and genetic structure of the blackleg population on a small landscape scale. Our farm typology could be used as a basis for a new module dealing with combinations of cropping techniques to simulate diversity and operation of farms and their effect on resistance breakdown on a landscape scale.

Our results combine knowledge about management techniques limiting the risk of resistance breakdown and an analysis of farmer's decision rules and are being used by the agricultural advisors of the CETIOM to help them adapt their advice to farmers.

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