METAPROGRAMME
SMaCH
Sustainable Management
of Crop Health

INRA
SCIENCE & IMPACT

Analysis and evaluation of crop losses
caused by pests and diseases

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A comprehensive and multidisciplinary approach to crop losses

How can we reconcile the pressing need for agricultural productivity with sustainable crop management? The analysis and evaluation of crop losses provide answers while opening up new approaches: this is what emerged from the SMaCH seminar held in Paris on September 1, 2015, where three projects and several evaluation models were discussed.

One of the main objectives of a metaprogramme such as SMaCH* is to obtain, simultaneously, the views of several disciplines on the same issue. This multidisciplinary approach is at work in the collaboration between different INRA teams and other organisations such as CIRAD. It promotes a more holistic view of plant production and the environment, taking into account the diversity of pests (pathogens and insects) and agricultural practices.

As part of DAMAGE - one of the SMaCH actions focused on the damage caused by diseases and insect pests - three projects were launched in 2013: ModQual, CoLosses and Grapevine Yield Loss (QMPV). These projects were presented at INRA Paris during the morning of the SMaCH seminar on September 1, 2015, which was concluded with a discussion of RAW, an international network for prospective analysis on wheat.

- The **ModQual** project is modelling the impact of pests in temperate and tropical perennial crops, incorporating the effects of agricultural practices such as fertilisation, irrigation and harvest date etc.
- The **CoLosses** project is modelling crop losses caused by diseases in coffee, making it possible to compare different agroecological approaches to crop management.
- The **Grapevine Yield Loss** project is focusing on another perennial crop - vines - and is analysing and modelling crop losses due to pests and diseases.
- **RAW** is focused on wheat - a significant crop in France used as a reference for annual production - including an analysis of long-term health based on biological, agronomic and climatic parameters.

The afternoon of the seminar was specifically dedicated to the economic, political and climatic dimensions of research, and to debate.

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The complementarity between field observations and modelling

The production of many crops is dependent on the use of cheap, easy to apply and generally effective pesticides. However, this approach to managing plant health is not sustainable and has harmful effects on the environment and human health. New management strategies are required, which, in order to be sustainable, combine multiple components for pest control. Analysing and modelling crop losses can identify appropriate combinations.

Christian Lannou

Director, SMaCH metaprogramme

« Given the complexity of health problems in crops, multidisciplinarity is a necessity. Our objective remains the sustainability of agricultural systems, with a long-term vision »

From 2012 to 2015, three research projects have been conducted on temperate and tropical perennial crops, assessing crop losses due to diseases and insects (grouped together as 'pests'), analysing the parameters and modelling them. These are the Grapevine Yield Loss, ModQual and CoLosses projects. In a fourth project - the RAW network - researchers have conducted a long-term health analysis on wheat as a prime example of an annual crop.

Evaluation and modelling

The evaluation of crop losses is conducted through the collection of data on plants and yields in experimental plots. The impact of pests may be seen immediately, in other words during the course of the season that is affected (primary losses), but can also manifest itself in the vegetation of the following season (secondary losses).

This dynamic is reflected in the development of models. Reduced yields can be observed during harvesting when pests have attacked fruits, but if leaves and other vegetative parts have been attacked (for example, in the case of green peach aphid attacks), yields will also be affected, including in subsequent years. A very early attack on fruit bodies may, however, have only a small effect: by limiting flowering through trimming or thinning, Nathalie Smits and her team (Grapevine Yield Loss project) observed that vines could partly offset these early losses.

Researchers model the effects of a set of varietal characteristics and agricultural practices

Regarding qualitative factors, researchers model the effects of a set of varietal characteristics and agricultural practices, including, for example, pruning, irrigation, thinning, and the frequency and earliness of harvesting. Significant effects can be seen in fruit size and sugar content, as well as the sensitivity of fruit to pests which cause crop losses.

Synergies between projects

The ModQual and CoLosses projects are collaborations between INRA and CIRAD. One of the benefits of this synergy comes from the specificities of the tropics, as Clementine Alline (CoLosses) explains: *"In Costa Rica, coffee is cultivated in agro-ecosystems of great biodiversity, where we can analyse many interactions. It is much more difficult to highlight this in the mono-specific systems which predominate in France.*

"In Costa Rica there is a payment programme for reforestation. In order to be able to introduce a compensation system for harvest losses for Costa Rican farmers practicing sustainable agriculture, we need to quantify the value of these losses. Paying bonuses would compensate for reduced earnings and encourage agricultural systems which provide ecosystem services (soil maintenance, carbon sequestration, reductions in pesticide use)." Evaluation and modelling of crop losses would therefore become major factors in agricultural policy.

Synergies between the three projects have become clearer, bringing tropical and temperate crops closer together.

Synergies between the three projects have become clearer, bringing tropical and temperate crops closer together. *"We expect, with Clémentine Allinne, rapprochements in our questions and modelling, for example by taking into account the influence of the conditions in year n on year n+1 and the reserves accumulated in the older parts of plants,"* explains Nathalie Smits.

Michel Génard

Interview

Michel Génard, joint scientific head with Isabelle Grechi of the ModQual project (Modelling quality loss due to pests in perennial crops).

You have analysed the opposite effects of green aphids and nitrogen fertilisation in peach production. Is there any interaction between the two?

In our model, aphids and nitrogen fertilisation affect both the yield and the quality of crops, but there is no statistical interaction. Our simulation over 10 years indicates that the increase in yield with nitrogen fertilisation is of the same order regardless of the initial level of green aphid infestation. Under simulation conditions, in other words with a constant number of fruits per metre of branch, nitrogen fertilisation increases the average mass of the fruit, which is a criterion in commercial quality. However, the increase in the sugar indicator is very modest.

The sensitivity of peach varietal ideotypes to brown rot was simulated under different cropping conditions, which ones?

Irrigation and load, in other words the number of fruits per branch. According to our experimental results, with traditional peach varieties, the higher the number of fruits per branch, the smaller they are and the less sensitive they are to brown rot. Similarly, the greater the water stress (low irrigation), the smaller the fruits are and the lower the susceptibility is. Conversely, with a small load and good irrigation, the fruits are large and sensitive to brown rot.

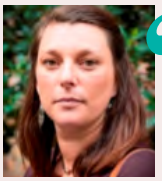
Reduced quality for a better yield?

Actually, medium and low-mass peaches do not meet certain quality criteria, but our results indicate that these fruits are less susceptible to brown rot, which means lower crop losses. Given the context of sustainable agriculture, such compromises in yield-quality have to be taken into account. With a model describing the sensitivity of plants to a particular pest, it is possible to study the effect on yields of agricultural practices which offer an alternative to the spraying of pesticides.

Isabelle Grechi

Joint scientific head with Michel Génard of the ModQual project

"We are seeking a compromise between quality and yield. So, mangoes whose maturation has been slowed by 'stressful' growing conditions certainly have lower quality (they are smaller and less sweet), but they are also less infested with fruit flies. Early harvesting and more frequent picking also reduce mango infestation: 5.4% losses for an early harvest against 20% for more mature fruits."



Clémentine Allinne

Interview

Clémentine Allinne, joint scientific head of the CoLosses project (Coffee yield losses, Evaluating primary and secondary losses due to diseases and insect pests in coffee harvests).

Why choose coffee?

Coffee is not only grown intensively, but also in diversified and less productive systems, on which many small producers depend. Crop losses caused by diseases and pests (including the coffee leaf rust epidemic since 2013) are the main limiting factors on production. To increase production without using more pesticides, or to reduce their use in intensive systems, the first step is to quantify yield losses and their economic cost. Before CoLosses, there was no specific study.

Modelling has an important place in your project.

The state of a plant at the time 't' depends largely on its past. If it has been treated the previous year, losses may be greater than those of a plant that has not been treated, simply because it has produced more fruit. Repeated use of pesticides has a phytotonic effect (the plants are stronger), which may bias the results. This illustrates the difficulty of an experimental approach and the importance of modelling to support and evaluate our results.

What are the next steps?

We have managed to produce a model which can, from simple measures, determine a posteriori yield losses. The initial results allow us to assess the primary losses at 43% and secondary losses at 37%. What we want now is to be able to offer predictions, based on climate and soil conditions, the type of system and the cultural practices associated with it. We are therefore trying to develop a predictive model.

RAW *(Risk Analysis in Wheat)*

An international prospective analysis project, RAW was launched in 2013, in parallel with the other works presented here. RAW is a research network in which the team of Serge Savary and other INRA laboratories cooperate with researchers from across Europe, Asia and America. They are modelling the evolution of long-term risks in wheat.

Nathalie Smits

Interview

Joint scientific head with Marc Fermand and Lionel Delbac of the Grapevine Yield Loss project (or QMPV) - Quantitative approach to modelling crop losses due to pests and diseases in grapevine.

Can your evaluations take into account the diversity of vineyards?

Grapevines are a very large consumer of pesticides and, indeed, subject to a great diversity of cultural practices. We built a conceptual model of grapevine and some of its main pests and diseases in order to compare the effects of different viticultural systems on crop losses.
Some of the methods and results have been shared at the European scale, in particular with Italian researchers.

How did you acquire the necessary data?

Little data was available on crop losses. Therefore we made use of experimental plots, collecting prior health data from such plots in the Bordeaux region, and we have been experimenting in other plots in Montpellier since 2013.

What are the next steps?

One of the objectives of the model was to produce a hierarchy of the risks linked to different grapevine pests, according to the production situation. We still have to integrate the specific parameters for each pest. The following steps could involve consideration of the economic consequences of pest attacks and their dynamics over two or more years. Our modelling should be enriched as a consequence of becoming closer to the other projects present at the seminar.

Sharing methodologies has allowed us to progress more than we expected!

« The increase in average temperatures is generally favourable to pathogens, but it can also prove unfavourable. By reducing the duration of wetness, for example, it can make some fungi less contaminant. However, given the complexity of the problems, it is necessary to promote networks for sharing phytosanitary information. »

Laurent Huber

Collaborates in the ACCAF-CLIF project - *CLimate change Impact on Fungal pathogens*

Serge Savary

Interview

Co-director of the POLiRiSK project and coordinator of the RAW network for prospective analysis on wheat health.

POLiRiSK is a tool for evaluating public policies on diseases and crop losses in wheat. What are its components?

The tool includes several facets. First, there is an interface between the biophysical and economic sciences: epidemiology and crop losses caused by wheat diseases on the one hand, and the agricultural economic strategy and public policy choices on the other. Then there several time frames: by day for biological processes, the duration of the growing season at the farm scale, and a succession of years for public policy.

Finally, there is the sequence of models: an epidemiological model (EPIWHEAT), another agro-physiological model for yield losses (WHEATPEST), a decision model at the farm scale and a model for the implementation and evaluation of policies.

We are in the process of writing a white paper on wheat health.

How do you sum up the contribution of POLiRiSK to public policy?

We hope that POLiRiSK will highlight the costs and benefits of different public policies on plant health. In particular, this means policies associated with greater or fewer restrictions on pesticide use, as well as strategies based on varietal resistance. Taking into account the dynamics of pest populations and diseases is another avenue for development.

There are examples of successful public management of diseases over several growing seasons. In Brazil, for example, fallow periods were introduced to break the development dynamics of soybean rust.

Pascal Leroy

P. Leroy is collaborating on a bio-economic model to evaluate and compare different protection strategies against mildew and powdery mildew in grapevine.

The risk of an economic shortfall linked to crop losses is a key factor. Pascal Leroy seeks to encourage farmers to reduce their use of pesticides.
"Our bio-economic model was designed to assess the risk to the vine. At the plot scale, it takes into account the agronomic context, climate scenarios and initial pest pressure, and data on the economic context. It makes it possible to compare different phytosanitary treatment strategies: standard, with fixed frequencies for re-application, and Mildium, with applications made according to health conditions. The latter strategy, which is more economical in treatment terms, could be accompanied by economic measures such as a slight increase in grape prices.

Certainly, we must be humble in modelling! The processes are complex and our choices can be challenged, but we have a duty to provide methods and to participate in changing producers' practices. "

*The SMaCH metaprogramme (Sustainable Management of Crop Health), established by INRA for the decade 2010-2020, represents a new way of managing multidisciplinary programmes on plant health, making it possible to co-construct in a coherent manner agricultural systems which are productive yet less sensitive to diseases and insect pests, and meeting the three pillars of sustainable development: economic performance, social performance and environmental performance
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