SMaCH
METAPROGRAMME
Sustainable Management
of Crop Health

INRA
SCIENCE & IMPACT

DURABLE MANAGEMENT OF PLANT PEST RESISTANCE

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From 'durable resistance' to 'durable resistance management'

How do we successfully deploy plants which are resistant to pests in the field and how do we do this durably? The preliminary results from five INRA projects in the SMaCH metaprogramme's Presume key action provided some of the answers at a seminar organised in Paris on November 12, 2014.

Using plant varieties which are resistant to pests is one of the best ways of reducing pesticide use while maintaining a good level of protection in intensive farming systems. This means that strategies for breeding and using these plants must be effective, durable and applicable in the field.

INRA is mobilising research on the subject, providing insight into future prospects. The Institute supports a multidisciplinary scientific community and partnerships with technical institutes and businesses on this theme. Research into the durability of pest-resistant varieties involves many disciplines, ranging from biology to ecology, and includes economic and social sciences. It also demands co-construction with farmers in order to take into account constraints in the field and to share good durability practices with producers. The seminar held in Paris on November 12, 2014, was part of these efforts. It provided the opportunity for 65 INRA researchers and numerous partners to learn about and discuss the preliminary results of five flagship projects initiated in 2012 and 2013 on the theme of the durable management of plant pest resistance. These five projects, called Aramis, Take Control, K-masstec, Gedunem and Panoramix, are part of Presume, one of 13 key actions in INRA's SMaCH metaprogramme*. They are contributing to the emergence of agroecology as a scientific discipline in its own right.

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COMBINING APPROACHES TO BOOST DURABILITY

Durable management of plant pest resistance demands the combination of the use of these resistances with carefully considered chemical treatments and appropriate agricultural practices. This is why the five projects in the Presume key action employ a very broad range of disciplines and partners. Geneticists, pathologists, agronomists, modellers, sociologists and farmers are working to co-construct durable strategies which producers regard as acceptable.

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Christian Lannou

coordinator, with Carole Caranta, of the Presume key action

“The durable management of plant pest resistance reflects a desire to limit pesticide use.”

Ten to 15 years are required to bring a resistant variety to market.

Why work on the durability of varieties which are resistant to pests? “To improve protection against diseases and pests, to reduce agriculture’s reliance on pesticides and to enhance the competitiveness of supply chains,” replies Christian Lannou, director, with Carole Caranta, of the Presume key action which brings together five research projects dedicated to this theme *(see interviews)*.

Significant research required

The challenge is not new as much knowledge has been gained in this area, but the need for research remains significant. “Known resistance genes which are easy to manipulate are still rare, so we need to identify new ones and understand the mechanisms involved,” says Christian Lannou. “However, parasites which overcome resistance emerge quickly. Characterising the adaptive capacity of these parasites to resistance genes is therefore essential. We also need to identify the organisational and economic constraints of stakeholders in order that we develop durable strategies and practices to support the deployment of resistant varieties in the field. The design of innovative cropping systems, possibly marking a break with conventional systems, is only useful if stakeholders can easily appropriate them. Finally, research must develop epidemiological surveillance and diagnostic tools in order to better understand protection needs and the appearance of resistance.”

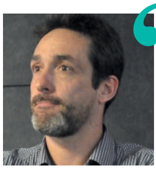
In terms of durability, a universal solution suitable for all systems does not exist.

Multidisciplinary approach essential

The concept of durability or sustainability now encompasses all stages, from the gene through to the agro-ecosystem. This is in order to take advantage of all possible levers at these different levels. There is a lot at stake because some 10 to 15 years are required to bring a resistant variety to market.

“Experience has shown us that varieties including only one resistance gene were very quickly overcome,” notes Xavier Reboud, director of the SMaCH metaprogramme. “To improve sustainability we therefore need to put every possible barrier in place against pathogens’ overcoming of resistance. Similar to the triple combination therapy used against the AIDS virus, the agricultural sector has to work at three levels: genetic, even if the resistance is partial, the rational use of pesticides and the full range of agricultural practices. This is all the more necessary because the crops we currently cultivate have improved in terms of yields but have reduced resistance to pathogens.”

The input of geneticists, pathologists, agronomists, modellers and sociologists is therefore required, as are partnerships with agricultural stakeholders. Equally, once a resistant variety has been registered, there are no regulations to restrict its use over time and space. To maintain this resistance, the management of its use across a given territory should therefore be organised with the agricultural sector. Xavier Reboud advocates the collective benefit and the long term. “All paths are to be explored collectively,” he concludes. “In terms of durability, a universal solution suitable for all systems does not exist.”



François Delmotte

Interview

François Delmotte, scientific co-manager, with François Hochereau, of the Panoramix project - Design and development of sustainable vine systems combining disease-resistant varieties and complementary protection methods.

Is reducing pesticide use in viticulture an important issue?

Yes. Vines occupy 3.8% of France's Utilised Agricultural Land yet consume 20% of pesticides. The explanation for the high level of pesticide use is simple: the diseases which the grape varieties currently grown in Europe have to cope with were introduced from North America in the 19th century and the vines do not, spontaneously, have the capacity to defend themselves.

Reduced pesticide use can lead to the re-emergence of some vine diseases, such as black rot.

Does this mean the use of resistant varieties is THE solution?

There is probably no single solution for reducing pesticide use in vine systems. However, among the possible innovations, those which seek to introduce varietal resistance are certainly one of the most promising. But these varieties must also possess agronomic and oenological characteristics which are in line with the quality standards demanded by the industry. INRA geneticists are working on it. Varieties resistant to powdery and downy mildew will be included in the catalogue in 2016. One of the major challenges for the deployment of these new varieties is to ensure resistance durability.

How can we durably manage vine resistance?

To prevent the rapid overcoming of resistance, INRA has decided, in agreement with the French Institute of Vine and Wine, to market only those varieties with multigenic resistance. Meanwhile, molecular biologists and pathologists are seeking to understand how pathogens adapt to resistant varieties in order to offer the best strategies for the deployment of these varieties. They have shown that partial resistance leads to increased aggressiveness in pathogens. For their part, agronomists are acquiring knowledge on the best crop management plan to maintain the sustainability of the system.

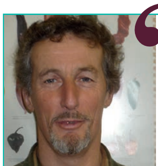
Can growers easily adopt these new varieties?

This is one of the challenges for the Panoramix project. Sociologists are working on the accompanying measures that are required and the promotion of varieties which require fewer pesticides but don't have the same name as those currently grown. In 2015, many partners will be involved in this sociological study and participatory workshops will be held with wine growers.

Thierry Coulon

scientific and technical director for vine and terroir at the French Institute of Vine and Wine (IFV)

"INRA's research is conducted in close consultation with IFV. Therefore INRA can better take into account wine growers' constraints. A shared concern of both INRA and IFV is to clarify, and show on the ground, the cultivation practices necessary to ensure thedurability of varietal resistance."



Alain Palloix

Interview

Alain Palloix, scientific co-manager, with Frédéric Fabre and Benoît Moury, of the Take Control project – Controlling pest evolution through the deployment of quantitative resistance.

Why the interest in partial resistance?

We don't have monogenic resistance for all pathogens nor for all crops. This type of resistance has the advantage of being totally effective but the downside is that it is quickly broken down by parasites. This is less so in the case of partial resistance, called quantitative resistance, against which adaptation is slower and more difficult. Partial resistance, determined by different parts of the genome, called QTL, can act through different and complementary mechanisms. The objective of the Take Control project is to understand these mechanisms and exploit the QTLs in question in order to take control of virus evolution. This work is conducted in the laboratory, studying quantitative resistance to PVY potato virus in pepper. Pepper and this virus are an ideal system because we can see very rapidly if the virus overcomes or fails to overcome resistance.

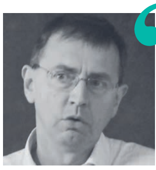
How does the plant take control of virus evolution?

By reducing the size of viral populations in plants, these QTLs directly affect the evolution of the virus and slow the appearance of forms which can overcome resistance. These mechanisms are complex and understanding the system requires the use of sophisticated models. Ultimately, the aim is to breed plants possessing these QTLs to protect a major resistance gene, which would then be more durable. Thus, new varieties will be bred not just for their resistance, but also for their ability to control pest evolution in the long term. We will also work on the combination of these varieties in the agricultural landscape.

“Nursery owners, who are co-breeders of apple tree varieties, work in close collaboration with INRA. Communication relating to resistance durability, which is disseminated when new genetic material is marketed, is validated together.”

Christelle Pitiot

technical and development manager at CEP Innovation and Novadi



Charles-Éric Durel

Interview

Charles-Éric Durel, scientific manager for the Aramis project – Evaluating the durability of partial resistance to apple scab through the analysis of metabolic pathways in apple trees and fungus adaptation.

Why is durable varietal resistance in apple trees particularly important?
Apple trees are a perennial species and producers only replant them every 15 to 25 years. Like the majority of tree crops, they receive a large number of treatments, notably to control apple scab, which is the principal disease. Finding varieties which have resistance that remains durable over time is a major issue, especially as the fungus develops resistance to fungicides.

How are you tackling your work on resistance durability?
The Aramis project is seeking to understand how, on the one hand, certain resistance genes function and, on the other, how the fungus adapts to these different resistance mechanisms. The objective is to eventually provide varieties with combinations of resistance genes that limit the adaptation of the fungus. Among other things, we are seeking to validate the hypothesis that the accumulation of different modes of action of partial resistance makes the overall resistance harder to overcome. This work is conducted by following the evolution of fungal strains collected from various experimental apple trees. Modelling also allows us to simulate the evolution over several generations in order to better explain and predict the process.

Interview

Caroline Djian-Caporalino

Caroline Djian-Caporalino, scientific manager of the Gedunem project – Technical and varietal innovations for durable management of root-knot nematodes.

Why work on the problem of root-knot nematodes?
A survey was conducted between 2007 and 2010 with 30 partners, bringing together all the stakeholders concerned, and it showed that root-knot nematodes were the major problem for Mediterranean vegetable producers: more than 40% of farms are affected and the few chemicals which remain authorised lack efficacy. Many control solutions are being tested: solarisation, cover crop management with 'nematicide' green manures, rotation with non-host plants. But none of them, taken individually, prove satisfactory.

What is the objective of the Gedunem project?
The Gedunem project is aiming to find greenhouse vegetable production systems which combine resistant varieties and several alternative techniques in order to increase the efficacy of parasite control, while preserving the few long-term resistance genes we have available. The project, which started in 2012 and will last for four years, includes experiments at four French sites and one in Morocco. In parallel with this, modelling work is being conducted to study the proposed systems in the long term.

Are producers stakeholders in the project?
Of course we are working with producers. These cropping systems must be acceptable to producers in terms of yields, work involved, the cost, the risk ... Therefore, alongside nematologists, geneticists, agronomists, soil ecologists, pathologists and experimental staff, agronomists are conducting investigations with vegetable growers in order to identify obstacles to the acceptability of the proposed multi-year systems. These obstacles are then analysed and solutions found. For example, we are seeking to reduce the length of fallow periods, which are deemed too long by some producers.

Marie-Hélène Balesdent

Interview

Marie-Hélène Balesdent, scientific manager for the K-Masstec project – Study of strategies for the management of resistance genes specific to phoma in oilseed rape.

Can a resistance gene that has been overcome still be useful?
Yes, we discovered this during a study on strains of phoma populations conducted in the field with seed producers and CETIOM (France's technical centre for the oilseed sector).
Some 10 years ago nearly 30% of rape varieties had the specific phoma resistance gene Rlm3 and pathogen populations seemed to have overcome this resistance, so it seemed to us that it was no longer useful. But Rlm3 became interesting again when varieties with another specific resistance gene, Rlm7, were deployed and the pathogen overcame this new resistance, because phoma strains which are virulent to Rlm7 prove incapable of attacking Rlm3 varieties.

What does the K-Masstec project involve?
We are comparing two strategies for the use of specific resistance genes Rlm3 and Rlm7. Is it better, in terms of resistance durability, to integrate a variety every two years, a technique called pyramiding, or to use them alternately, every other year? We are also seeking to understand at the molecular level the mechanisms involved in the resurgence of avirulent strains on Rlm3 and to establish how long it will take for strains capable of overcoming the two resistance genes to appear. To achieve this, we are conducting field trials to provide biological data for use in modelling the system, allowing us to make long-term predictions.

* 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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