Is the efficiency of biological control against insect pests likely to be more durable than that of chemical pesticides?

Lessons learned using CpGV to protect apple orchards from codling moth

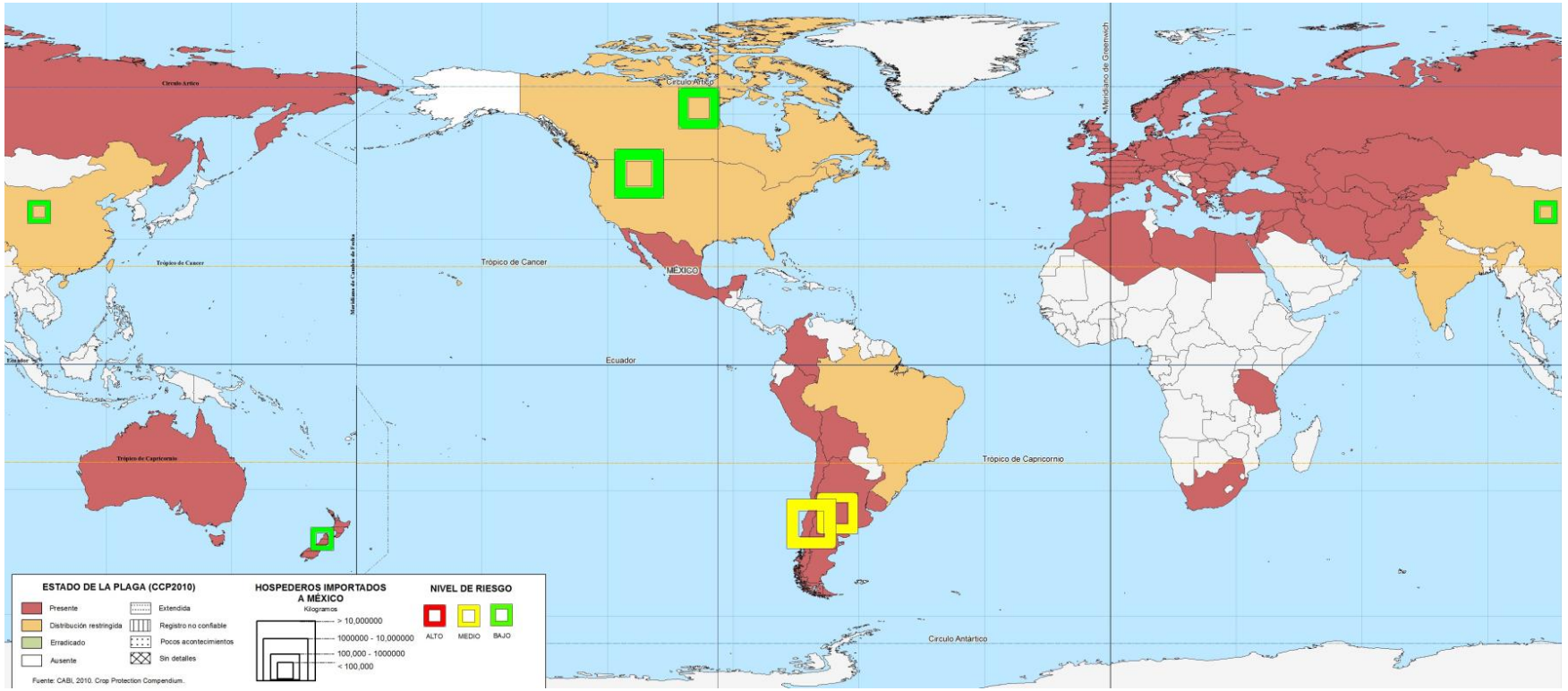
B. GRAILLOT
S. BESSE

M. LOPEZ-FERBER
C. BLACHERE-LOPEZ

M. SIEGWART
M. BARDIN
P. NICOT

Codling moth importance

- Worldwide distribution of codling moth (*Cydia pomonella*)
- Linked to presence of apple and pear orchards
- Main pest on pome fruits



http://portal.sinavef.gob.mx/MapasInternacionales.html

Orchard protection against codling moth

- Many resistances developed towards chemical insecticides
- Alternative = CpGV (*Cydia pomonella* Granulovirus) ➔ > 100 000 ha treated in Europe with only one isolate: Mexican isolate (CpGV-M)
- Natural Plant Protection manufactures Carpovirusine™, CpGV-M based-biocontrol product, registered in 20 countries over the world
- In 2004: first record of codling moth populations resistant to CpGV-M after 20 years of use ➔ Protection failures

First development of virus resistance in field

Need to study this phenomenon and to find new alternative virus isolates to overcome the resistance in orchards

R&D projects

Context and previous work

- European CRAFT project « Sustain CpGV » (2005-2008)
- German BÖL project 05OE023 (2006-2009)
- French ANR project « CARPORES » (2006-2010)
  Analysis of *Cydia pomonella* Granulovirus (CpGV) evolution under selection against non permissive host

4 partners:

NATURAL PLANT PROTECTION

MINES Alès

INRA SCIENCE & IMPACT

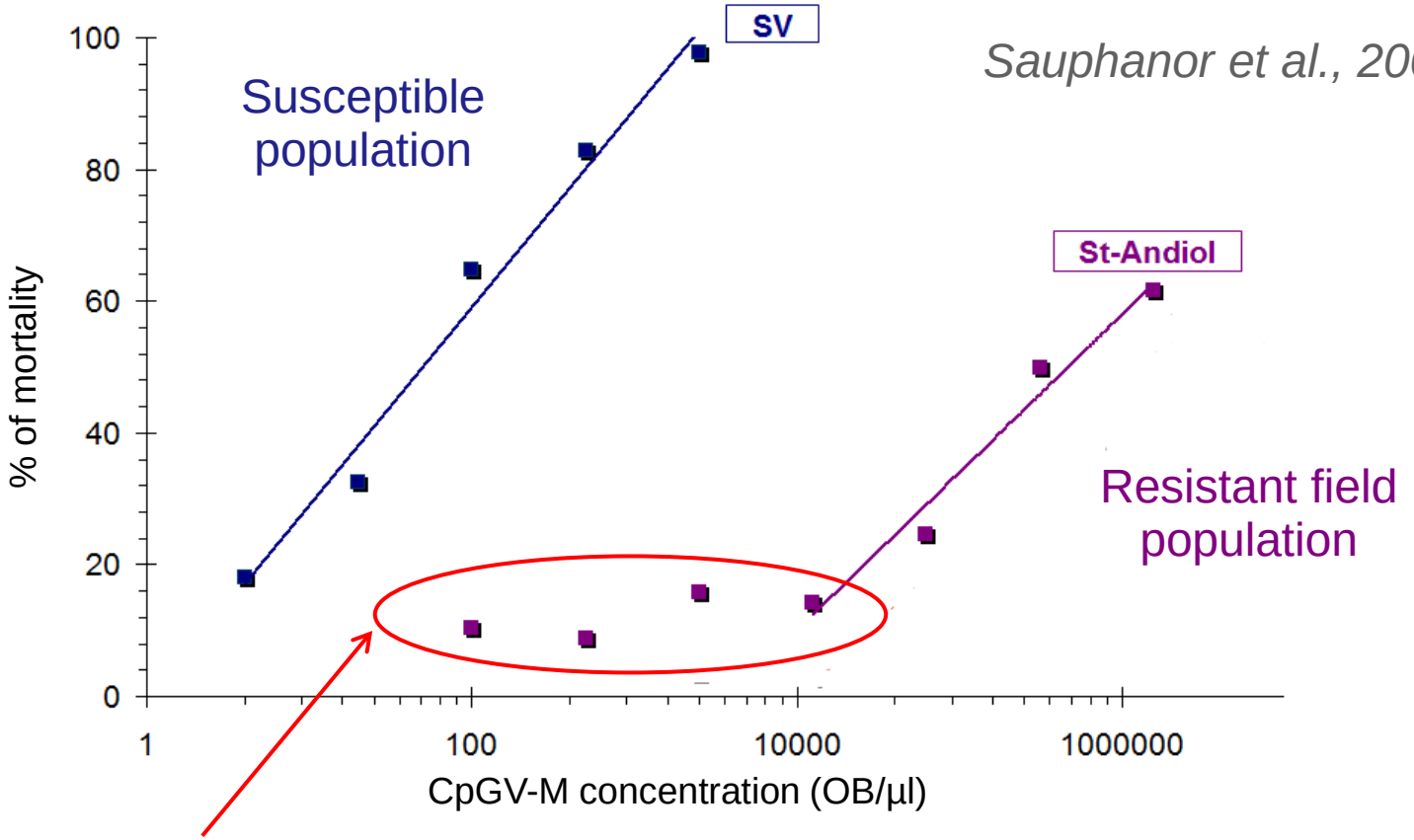
GRAB Groupe de Recherche en Agriculture Biologique

Objectives:

- Analyze the blocking points for the virus replication
- Select a variant by screening of CpGV existing populations
- Relation host/virus: co-evolution and adaptation
- Make this approach sustainable

Codling moth resistance to CpGV-M

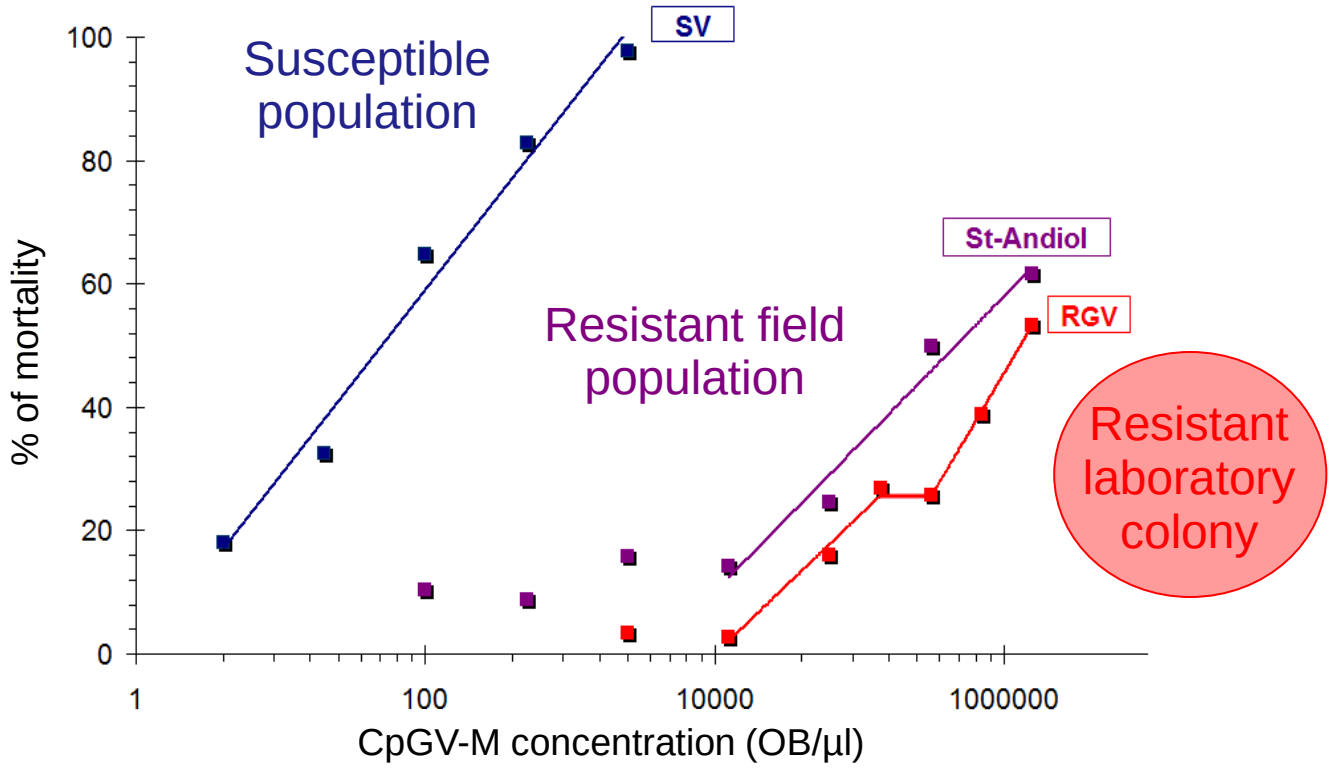
The first French resistant field population was identified near Avignon (South East of France, Rhône Valley)



St Andiol population ➔ mixture of susceptible and resistant individuals ➔ plateau at 20% mortality

Codling moth resistance to CpGV-M

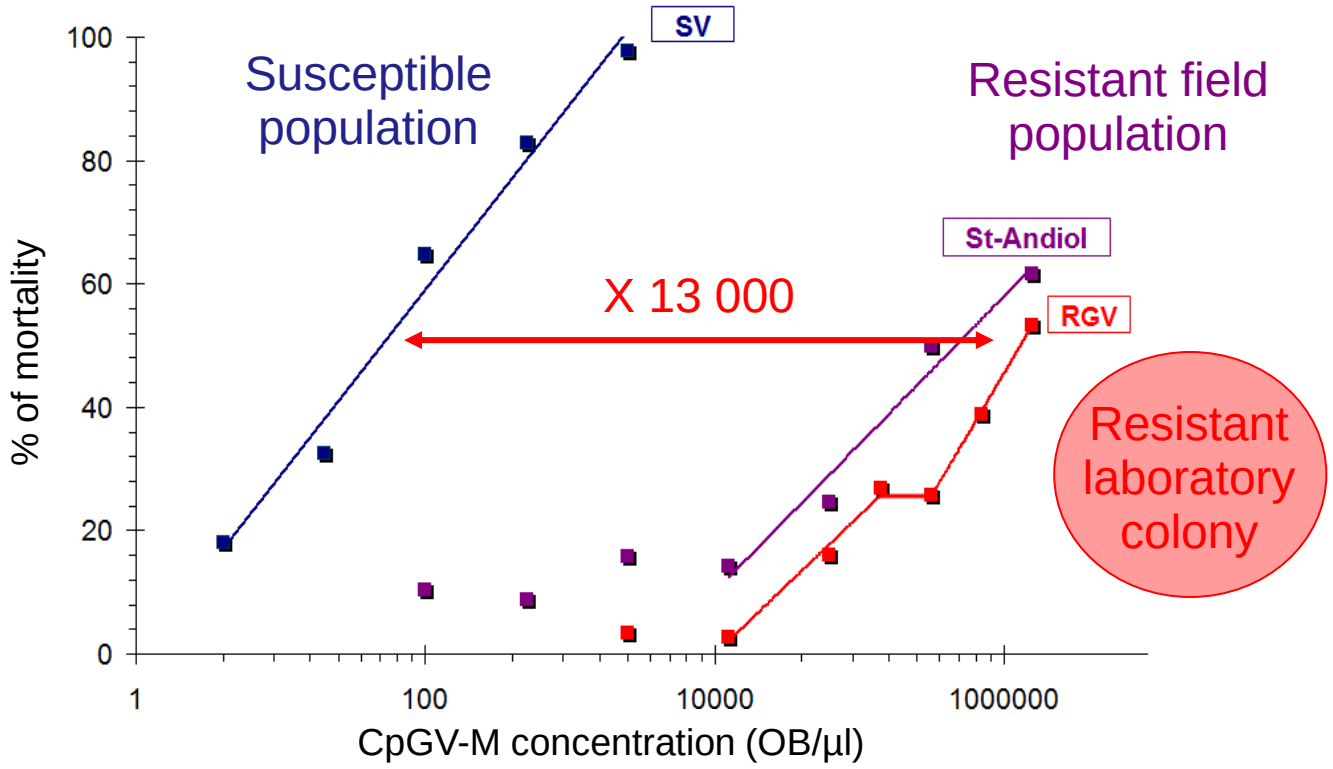
- The RGV colony was obtained from this population by crossings and selection.
- It is a fully resistant and genetically homogeneous colony



Berling, M. 2009.

Codling moth resistance to CpGV-M

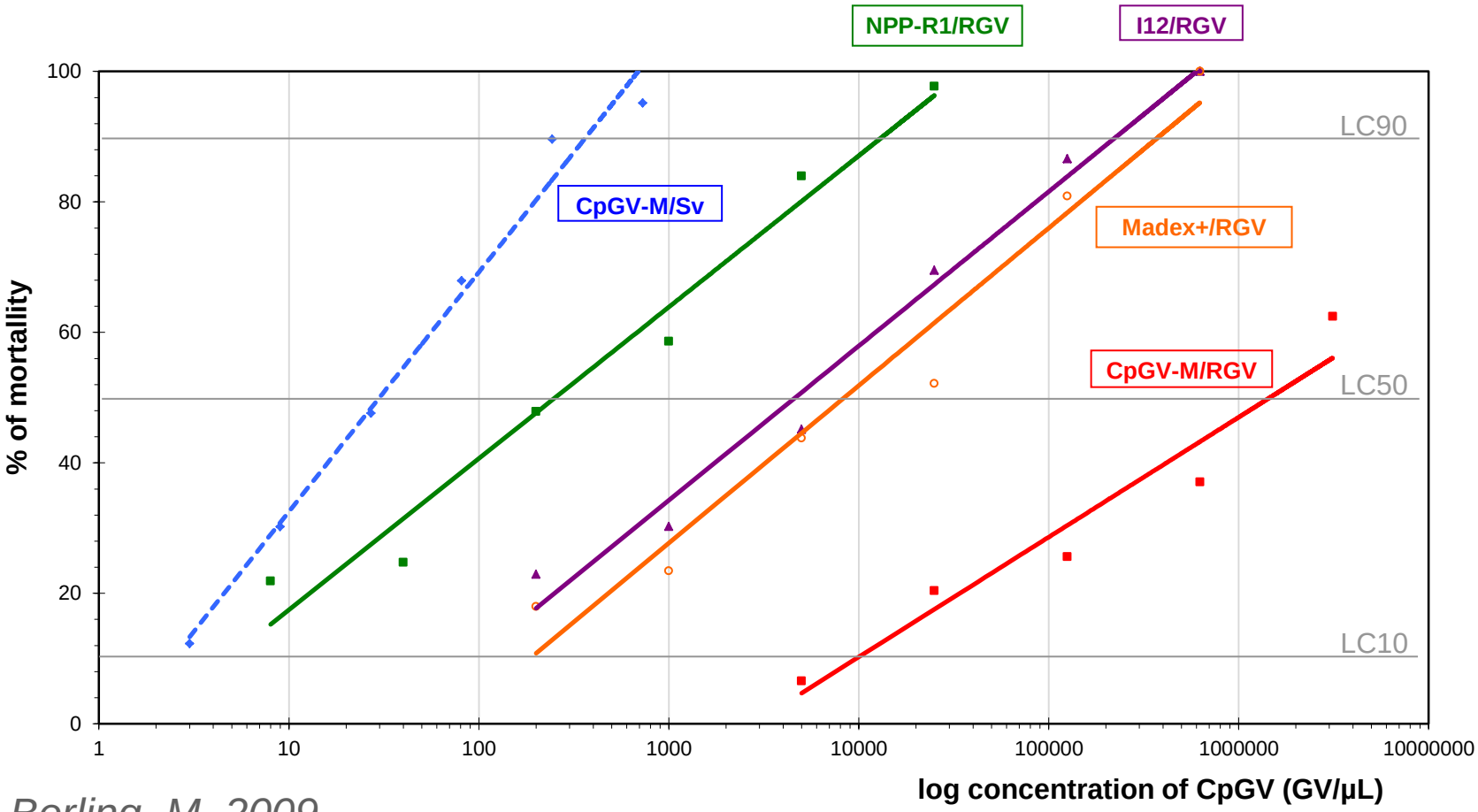
- The final resistance factor of RGV is about 13000.
- The resistance is monogenic, dominant and sex linked.



Berling, M. 2009.

New CpGV isolates to overcome resistance

- Other tested isolates partially overcome the resistance ➔ NPP-R1 isolate pathogenicity is not high enough to be used in orchards.
- LC_{50} on RGV = 250 OB/µL compared to 25 OB/µL for CpGV-M on Sv.



Berling, M. 2009.

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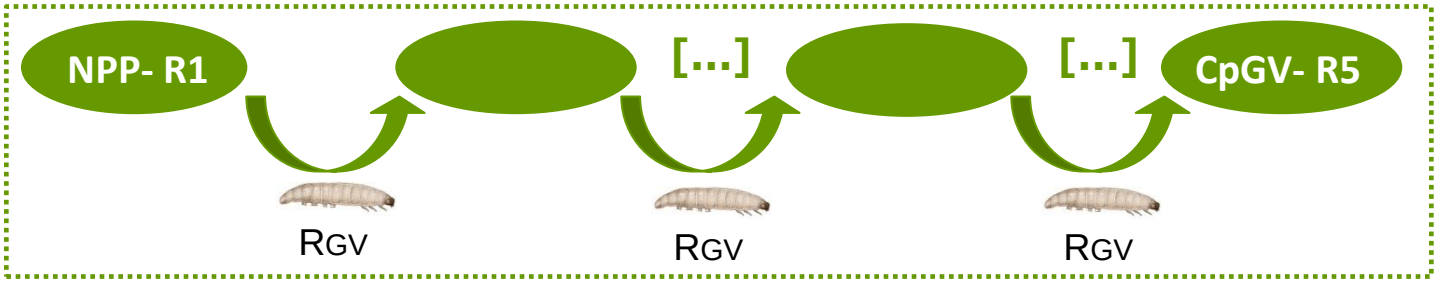
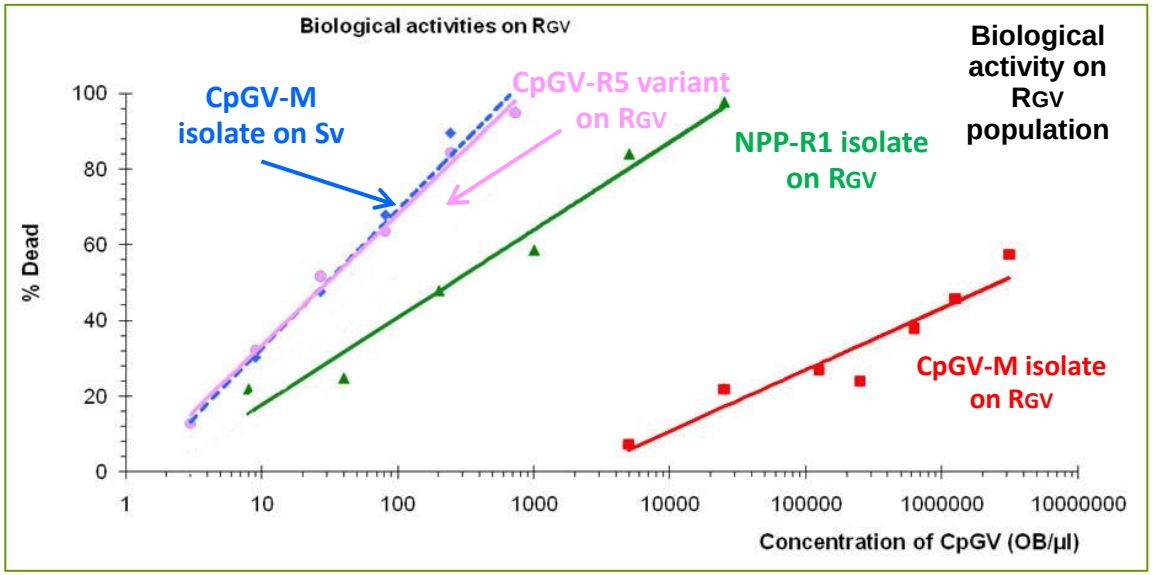
Selection of a new CpGV variant

- Improvement of the pathogenic character of NPP-R1 by co-evolution ➔ interesting mortality on RGV codling moth population + replication capacity on Sv population kept
- Use of RGV codling moth population as a support for the virus evolution ➔ successive passages up to obtain the best variant (called CpGV-R5)



Efficacy of CpGV-R5 isolate on RGV and on Sv is comparable to CpGV-M on Sv



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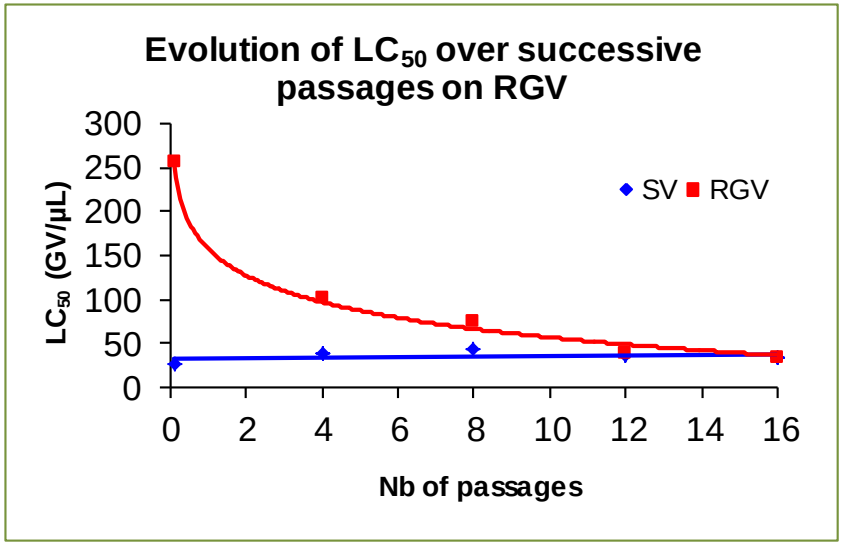
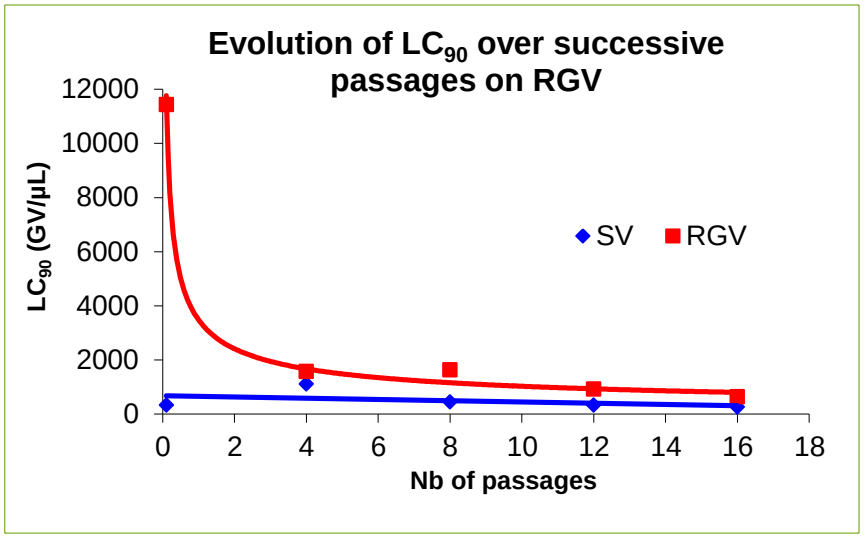
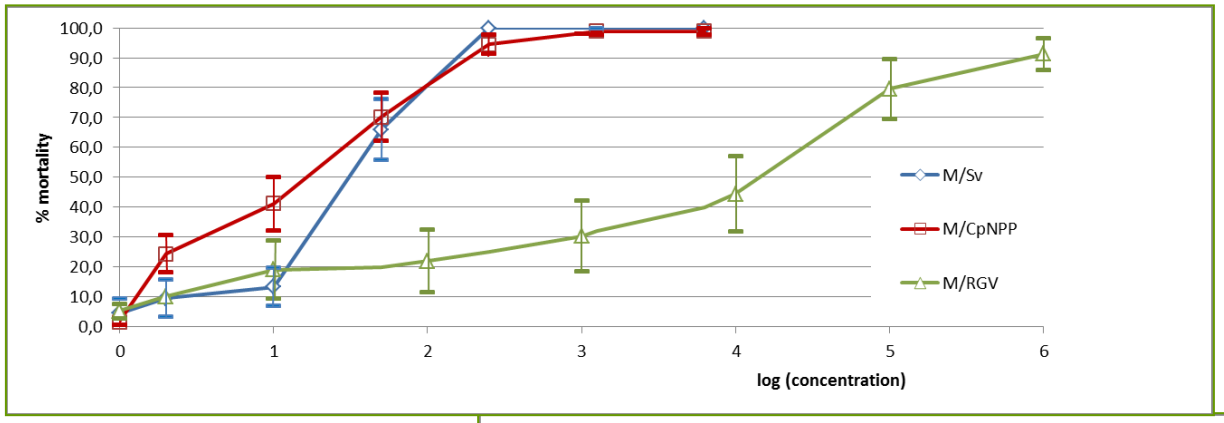
Improvement of CpGV isolates by selection





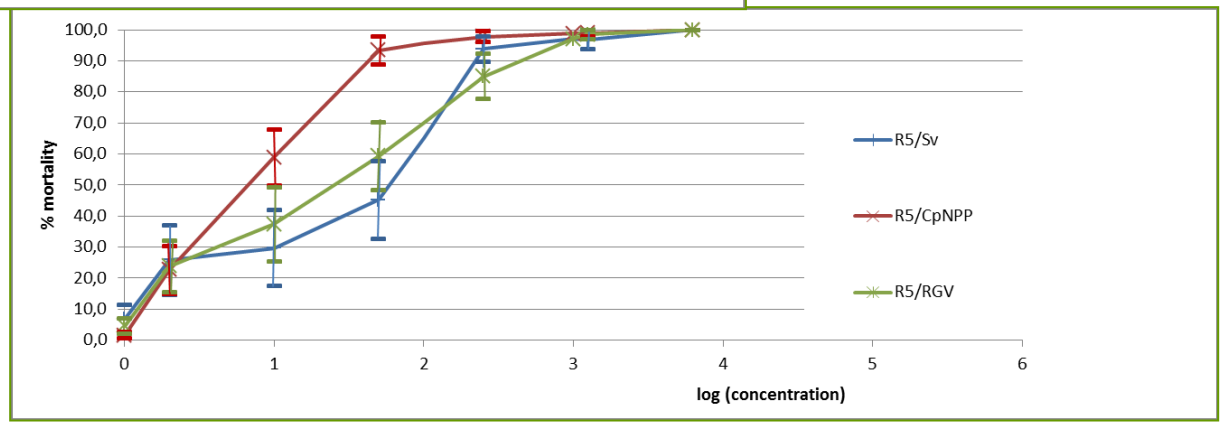
- Both LC_{50} and LC_{90} are reduced over passages on RGV larvae of the original NPP-R1 isolate.
- After 16 passages on CpGV-M resistant larvae, the CpGV-R5 isolate is able to control resistant as well as susceptible larvae was obtained
- This isolate is commercialized under trademark Carpovirusine™ Evo2

Variability in the susceptibility of codling moth populations



With CpGV-M, the mode of action and intensity of infection appear different on Sv and CpNPP

With CpGV-R5, the mode of action seems similar but the intensity differs



- CpNPP insect colony “fully susceptible” to both CpGV virus isolates
- SV colony and its resistant derivate, RGV have a lower susceptibility level
- At low multiplicity of infection, the insect colony CpNPP is more susceptible than SV to both virus isolates

Cost for codling moth to become resistant to CpGV-M

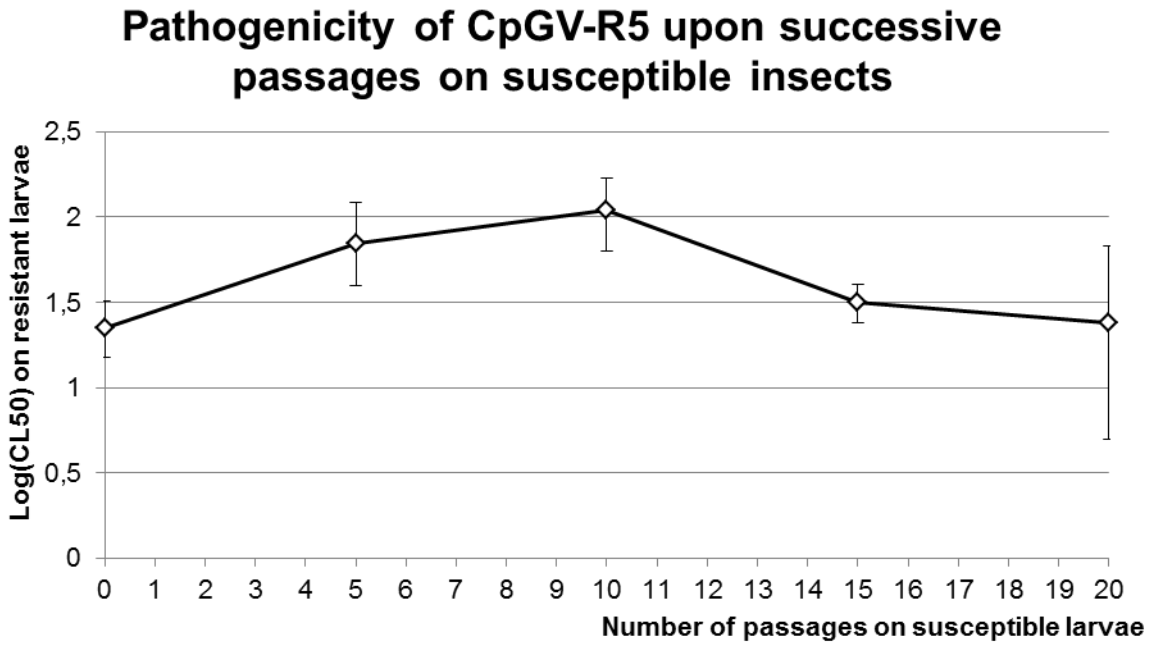
- No apparent cost for codling moth to become resistant (Asser-Kaiser et al., 2011)

- Heterogeneous population (mix of SV and RGV) do not change its resistance level (= allele frequency) over 10 generations without selection pressure in laboratory conditions

No apparent cost for codling moth to become resistant to CpGV

Cost for CpGV to overcome the resistance

- CpGV-R5 was amplified on fully susceptible CpNPP larvae and the produced virus was tested both on susceptible and resistant larvae ➔ No loss on efficacy observed.
- Successive passages on susceptible larvae do not lead to a reduction of pathogenicity on RGV larvae



No apparent cost for the virus to overcome the resistance

Increasing genetic diversity of CpGV

- Experimental virus populations were constructed by mixing CpGV-M and CpGV-R5 in various proportions.

  ➔ Synergy is observed when both genotypes are present.

- Mix of CpGV-M and CpGV-R5 in various proportions increases the pathogenicity both on susceptible and on resistant insects (submitted for publication).

Conclusions

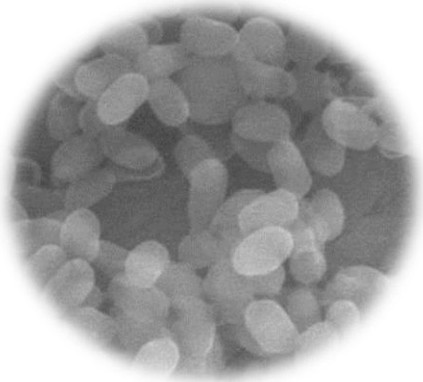
- During several research projects, both fundamental knowledge and commercial products have been obtained to overcome CpGV-M isolate resistance.

- Not all resistances imply an « arms race ».

  ⇒ The virus is able to adapt to new environment (host genetic background).

- A continuous adaptation of the virus is required to guaranty efficacy over time (sustainability)

Thank you for your attention!



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